ECOLOGICAL STUDIES OF SOIL AND LITTER MICROARTHROPODS IN A FOREST ECOSYSTEM IN LAKHIMPUR DISTRICT, ASSAM

THESIS SUBMITTED TO NAGALAND UNIVERSITY IN PARTIAL FULFILMENT FOR THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY IN ZOOLOGY

By

MINATI BORAH

Ph. D. Registration No. 242/ 2006

DEPARTMENT OF ZOOLOGY
SCHOOL OF SCIENCES
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2013

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CERTIFICATE

This is to certify that, the thesis entitled "Ecological studies of Soil and Litter Microarthropods in a Forest Ecosystem in Lakhimpur District, Assam " incorporates the results of the original findings carried out by ***Mrs. Minati Borah*** *under my guidance and supervision. She is a registered research scholar (Regd. No. 242/2006) of the Department and has fulfilled all the requirements of Ph. D. regulations of Nagaland University for the submission of her thesis.*

The work is original and neither the thesis nor any part of it has been submitted elsewhere for the award of any degree or distinction. The thesis is therefore, forwarded for adjudication and consideration for the award of degree of Doctor of Philosophy in Zoology under Nagaland University.

Dated: May, 2013
Place: Lumami

Head
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Supervisor

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(Minati Borah)

DECLARATION

I hereby declare that the thesis entitled **"Ecological studies of soil and litter microarthropods in a forest ecosystem in Lakhimpur district, Assam"** submitted by me is entirely the research work of my own. The thesis or part thereof has not been submitted elsewhere for any research degree or distinction.

Date
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(Minati Borah)
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CONTENTS

Chapter – I
INTRODUCTION

Microarthropods represent one of the most complex groups of small arthropods that play significant role in detritus food chain and food web by regulating the rates of decomposition, nutrient cycling and energy flow in most terrestrial ecosystems. Ecological study of soil and litter microarthropods has been readily recognized as an area of particular concern because they are ubiquitous, abundant, and diverse ranging from natural to degraded ecosystem. The description and distribution pattern of microarthropods help in understanding their role in soil formation. The physico-chemical factors of soil are very important in determining the population distribution pattern and species composition of microarthropods. The abiotic factors affecting the soil, to which the soil microarthropods mainly adopt, include soil structure, soil moisture, pore volume and soil temperature. The various chemical factors such as pH, organic matter, nitrogen, phosphorus and potassium play important role on the life of soil microarthropods (Mukharji and Singh, 1970; Banerjee, 1974 a; Banerjee, 1976; Sharon and Warburg, 2001). Organic carbon content of the soil is an important factor in determining the composition of soil fauna (Loots and Ryke, 1967). The organic matter along with moisture content of the soil makes a condition highly favourable for the group of fungi which is the source of food of various soil microarthropod groups. The relationship between the different chemicals like pH, Na, K and N of soil and the abundance of soil microarthropod species indicates the level of soil quality (Hagvar, 1984).

The main source of organic detritus in terrestrial ecosystem particularly forest soil, are leaf litter which plays a major role in the transfer of energy and nutrients. Leaf litter as source of mineral nutrients varies from plant to plant and influences the qualitative and quantitative composition of edaphic microarthropods which physically disintegrate the plant tissue and increase the surface area for microbial activity and transform the plant residue into humic substances (Swift *et al.*, 1979). Even the nutrients of litter of same plant vary under different stages of decomposition and give shelter to different types of microarthropods which play a significant role in the decomposer subsystem. The role of micro arthropods in decomposition and mineralization processes has been reviewed by Seastedt (1984).

The microclimatic factors of soil have profound influence on soil and litter microarthropods. Seasonal changes in the population of soil microarthropods are influenced by the types of vegetation cover, climate, physico-chemical properties of soil, nature and depth of the litter and humus and variety of other environmental factors (Price, 1973). Reduction of vegetation cover and the consequent changes in microclimate has shown negative effects on survival and reproduction of soil microarthropods, however, abundance of soil microarthropods is ecologically important to maintain soil fertility status through decomposition and nutrient cycling for forest restoration (Seastedt, 1984; Badejo and Straalen, 1993; Wardle and Giller, 1996). A seasonal response to temperature changes was shown by soil fauna in their pattern of vertical distribution in the soil (Aitchison, 1979 a, b, c). Merrian *et al.* (1983) revealed that several variables including light intensity and relative humidity affected microarthropod activity in winter but concluded that soil surface temperature was likely the most important factor. During winter season microarthropods move from surface layers into the deeper layers and this condition is just reversed during summer.

Microarthropods in different terrestrial ecosystems constitute a major share of the biotic components of the soil showing variety of organisms both in the soil and litter. Among the soil microarthropods, Acarina and Collembola are the most abundant and dominant groups in soil-litter sub system and play an important role in sustaining forest ecosystem by maintaining the edaphic factors through decomposition and mineralization of leaf litter. Acarina, the very small, free-living soil and litter inhabiting group are divided into four sub orders *viz.* Cryptostigmata, Mesostigmata, Prostigmata and Astigmata. The Cryptostigmata (oribatid) are also called beetle mites for resembling small beetles. Adults have a sclerotized exoskeleton and are found in leaf litter, under bark and stones. The Mesostigmata (Gamasida) are generally flattened, tick like mites, and they are found as predaceous, scavengers or in parasitic form. They are mostly free living and are usually dominant mites in leaf litter, humus and soil. The Prostigmata (Actinedida) are delicate, white to colourless and subject to desiccation. Astigmata are free living and are commonly called cheese mites having no stigma or trachea. They are seen associated with highly organic, decomposing material such as manure. The Collembola or Springtails are wingless and are divided into three sub-groups: Entomobryomorpha, Poduromorpha, and Symphypleona. They possess unique structure called furculum, which enable them to jump when disturbed. Most of them feed on decaying vegetation, bacteria, fungi, algae, pollen and other forms of organic material. They are cosmopolitan in distribution and despite their small size of only 0.2-9 mm, their abundance makes them important soil organisms, playing a significant role in decomposition process (Christiansen and Bellinger, 1980). Collembola are largely detritus or fungal feeders and have well developed mouthparts capable of fragmenting plant material (Seastedt, 1984). The other microarthropod groups that make up a significant part of the belowground food web in most terrestrial ecosystems include Symphyla, Protura, Diplura, Pauropoda, Myriapoda, Isoptera, Dermaptera, Coleoptera, small centipedes and millipedes and small insects from several orders. The mites and Collembolan constitute 72-97% of the total arthropod fauna of Indian soil (Singh and Mukharji, 1973; Singh and Pillai, 1975; Roy *et al*, 1998).

An important aspect of ecological study of soil and litter microarthropods is describing and understanding the pattern of distribution in their habitat (Krebs, 1972). While participating significantly in the processes of soil formation, function and maintenance, they serve as sensitive indicators of the state of soils and of the impacts of environmental changes. While seasonal changes with vertical movement do occur in some cases, the centre of the population density of many species remains in particular horizons throughout the year (Anderson, 1971). The heterogeneity of organic profile and the diversity of microhabitats encourage a spatial separation of species population and reduce inter-specific competition and increase species diversity (Ananthakhrishnan *et al*, 1992). Further, vertical, diurnal and seasonal distribution of microarthropods are generally influenced by the abiotic factors particularly moisture and temperature in the soil and litter layer (Wallwork, 1959). Mites as a whole migrate to deeper soil layer during hot, dry and winter season. While Cryptostigmata are mostly surface dweller in litter, Prostigmata are found in deep layer of the soil. Large sized Collembolan species appear on the surface, while smaller sized are found to be in humus layers of the soil. This diversity is enhanced by the various organic horizons providing different ranges of substrate on which soil animals can feed and decrease in the particle size of the organic material with depth from the litter to the humus.

Population density of soil microarthropods is appreciably lower in the tropical forest than the temperate forest soil; however species diversity is probably greater in the tropical forest than temperate (Wallwork, 1976). Culik *et al.* (2002) observed that soil micro arthropods density were low in tropical-agricultural environment compared to temperate-nonagricultural environment. The difference is probably due to more varied nature of leaf litter and to more extensive pattern of vertical distribution in the tropical forest. Freshly fallen leaves that accumulate at the surface of the soil profile represent the initial stage in this sequence. With the decomposition variety of breakdown products accumulate in the organic horizons. Thus there is an increase in the variety of food material and this increases the species diversity of the soil fauna. Each organic horizon in the forest soil profile presents its own distinct complex of environmental features, with a particular association of animal species. As a consequence of this, the larger sized mites and Collembola tend to confine to the surface layers of the soil profile, while the smaller forms predominate at lower levels (Ananthakhrishnan *et al.*, 1993).

Gonzalez and Seastedt (2000) gave a comparative account on ecological interaction of soil micro arthropods between tropical and sub alpine forest. Studies on microarthropod diversity and density were reported from different soil vegetation systems of Indian subcontinent ranging from Himalayan grassland (Singh and Singh, 1975), Pine forest (Reddy, 1981), Semi arid savannah (Reddy and Venkataiah, 1990) to deciduous forest (Hazra, 1978; Narula *et al*, 1998). While quite a few comparative studies have been undertaken on abundance and distribution of soil and litter microarthropods in natural and degraded forest ecosystem under variable eco-climatic conditions of North Eastern region viz. Meghalaya (Reddy and Alfred, 1978 a, b; Vatsauliva and Alfred, 1980; Darlong and Alfred, 1982; Hattar and Alfred, 1986; Paul and Alfred, 1986; Alfred *et al*, 1991; Darlong *et al*, 2010), Tripura (Sarkar, 1991; Chakraborti and Bhattacharya, 1996), Manipur (Chitrawati, 2002; Waikhom *et al*, 2006; Devi and Singh, 2007, Devi *et al*, 2011), Nagaland (Doulo, 2007; Doulo and Kakati, 2009, 2010), Barak valley of Southern Assam (Gope and Ray, 2006, 2010, 2012; Ray and Gope, 2006; Gope *et al*, 2007; Ray *et al*, 2012) there has been no report in this aspect from the Brahmaputra Valley districts of Upper and Northern Assam climatic condition. Due to several anthropogenic reasons, including illegal felling of trees, and transformation of forest land to agricultural purpose, these areas of Assam are also facing continuous degradation of natural forest which are the most suitable habitats for soil microarthropods. Hence the present study was carried out in natural (undisturbed) and degraded (disturbed) forest ecosystem in Dulung reserve forest, Pathalipam, Lakhmpur district of Assam to fill up the gap for understanding in the abundance, distribution, density and species diversity of soil and litter microarthropods in relation to certain climatic and edaphic factors in this region.

Chapter – II
REVIEW OF LITERATURE

The present chapter deals with the review of literatures pertaining to ecological studies on soil and litter microarthropods at international level, in Indian subcontinent and from North Eastern region of India in particular.

Microarthropod studies in general

Berlese (1913) was perhaps the first to study the soil microarthropods particularly Oribatid fauna from Indonesia at the beginning of the 20^{th} century. Glasgow (1939) studied on the population of soil Collembola in subterranean soil and found that microarthropods tend to be aggregated in the soil. Dowdy (1944) studied the influence of temperature on vertical migration of soil fauna in different soil layers and reported that with drastic changes in temperature the soil organisms migrated to the deeper layer. Weis-Fogh (1948) recorded the maximum population of Collembolan at some period between late autumn and early spring. Drift (1951) noticed the presence of Astigmata in a very small number while studying the population dynamics of animal community in a beach forest floor of Netherlands. Kunelt (1955) recorded higher population density of soil animals in the upper layers of soil; however there was vertical distribution of mites and Collembola in relation to their food preference. Sheals (1957) observed higher population of Collembola in autumn and winter. Higher population density of Collembola in the upper soil layer than the lower depth was also recorded by Poole (1959). In a comparative quantitative study of the microarthropods in different types of pasture soil Loots and Ryke (1966, 1967) recorded peak population during late summer and minimum during winter and reported that the organic content of the soil was an important factor in determining the composition of soil fauna. Wood (1967) noted the greatest density of Acari and Collembola in the upper surface layer in Moorland soil in Yorkshire, England. Thomas (1968) reported that Acarina and Collembola were the dominant and the largest population among the litter fauna contributing to the maximum litter decomposition. Seasonal distribution of some forest soil Oribatids were studied by Reeves (1969). Usher (1969) studied on some properties of the aggregations of soil microarthropods (Collembola) occurring for various environmental factors. However, Gill (1969) demonstrated that physical factors in the environment were of major importance in determining the vertical distribution and abundance of soil microarthroods and were not limited by the nutritional properties of the litter. Joosse (1970) studied on the formation and biological significance of aggregation in the distributional patterns of Collembola. Fujikawa (1970) had studied the distribution of Oribatid in the forest of northern Hokkaiko Japan and observed that majority of Oribatid was collected from the top layer of soil. Block (1970) found abundance of microarthropods in temperate zones and suggested that it was due to changes in soil organic matter, mineral, moisture and temperature. Usher (1970) discussed vividly the vertical migration of Collembola as well as their population size. Wallwork (1970) studied the qualitative and quantitative composition of the soil fauna and their relation with the different soil factors in respect to their population size and distribution pattern. Tanaka (1970) did ecological studies on communities of soil Collembola in Mt. Sobo, Southwest Japan. Butcher *et al.* (1971) studied on bio-ecology of edaphic Collembola and Acarina. Wood (1971) observed decrease of population of microarthropods with the increase in seasonal and regional aridity. Metz (1971) studied on vertical movement of Acarina under moisture regime and found decreased in Oribatid numbers in lower soil layer. Nijima (1971) noticed the seasonal changes in Collembola population in a warm temperate forest of Japan and reported that low soil temperature resulted in the reduction of activity of soil microarthropods. In a Califormia pine forest soil, Price (1973) compared the population density of Acarina, Collembola and some insect groups and found that Acarina was the dominant group followed by Collembola among the soil fauna. Willard (1973) studied population and biomass of soil arthropods in Canada and reported that population of Collembola was more common in 0-10cm soil layers. Blackith and Blackith (1975) studied geographical and ecological determinants of Collembola distribution and observed that the vegetation and litter type did not always affect the community of soil organisms. Kaczmarek (1975) found maximum population of Collembola in the monsoon months when the moisture level reached its peak and minimum in summer months when the moisture content was significantly low. Usher (1975) revealed that temporal variation in microarthropods abundance was attributable to factors such as temperature, precipitation and litter fall. Anderson (1978) studied on inter and intra habitat relationship between woodland Cryptostigmata species diversity and diversity of soil and litter microhabitats. The relationship between microarthropod communities, soil and litter microhabitats was established by Curry (1978). Mitchel (1978) studied vertical and horizontal distribution of mites in an Aspen woodland soil. Usher *et al.* (1979) noticed that soil and litter communities usually contain more than 150 microarthropods species and the most abundant species among them was Collembola. Swift *et al.* (1979) demonstrated that Acari and Collembola are more prevalent in coniferous forest. Christiansen and Bellinger (1980) reported that Collembola, one of the major groups of soil microarthropods played a significant role in soil formation, nutrient cycling and decomposition on forest floor ecosystem by decaying vegetation. Petersen (1980) while investigating the vertical distribution of nine selected species in beach forest ecosystem in Denmark had observed that all the species confined to the litter and the upper most 6 cm of the mineral layer. Holt (1981) studied Acari and Collembola, in the litter and soil of three North Queensland rainforests, Australia. Hagvar (1982, 1983) recorded the higher population density of Collembola in the upper soil layers in Norwegian coniferous forest soils. Kevan (1982) reported that soil moisture content was a vital importance to the soil fauna. In a comparative analysis of soil fauna population and their role in decomposition processes Petersen and Luxton (1982) recorded very high abundance and diversity of mesofauna species particularly of Collembola and Oribatid mites. Hutson and Veitch (1983) worked on the Collembola and Acarina in soil and litter of three south Australian forests and recorded the highest mean percentage of the population inhabiting the upper soil layer and least in deeper soil layers. In pasture soil on Kaipakipeat (New Zealand) Luxton (1983) recorded maximum relative abundance of Cryptostigmata followed by Mesostigmata, Prostigmata and Astigmata. Kaneko (1985) made a comparative study on the Oribatid mite communities in two different soil types in a cool temperate forest in Japan. While studying on the Acari and Collembola in litter and soil of North Queensland rain forest, Holt (1985) recorded higher percentage of collembolan population in the upper soil layer at each site. Visser (1985) observed Collembola as fungivorous while working on the role of the soil invertebrates in determining the composition of soil microbial communities. Pozo *et al*. (1986) reported Collembolan population from several plant communities such as oak wood, beech wood and pinus and showed that the number of litter species practically steady in spring while increase in soil during summer. Crossley *et al.* (1989) revealed the importance of the faunal activities in agricultural soils in below ground herbivory, stimulation of plant growth and direct effects of fauna of soil structure. Whitford and Parkar (1990) studied the contribution of soil fauna to decomposition and mineralization processes in semi-arid and arid ecosystems. Norton

(1990) while studying on Acarina, found that Oribatids showed high diversity in forest soils and were among the most numerically dominant soil microarthropod groups. Crossley *et al.* (1992) studied on the biodiversity of microarthropods in agricultural soil. Tousignant and Coderre (1992) showed that micro-site factors such as soil temperature, soil moisture etc. and concentration of nutrients were important in explaining the variation in numbers and community composition of microarthropods. Badejo and Straalen (1993) observed negative effects of reduced vegetation cover and the consequent changes in microclimate on survival and reproduction of soil microarthropods. Salona, Iturrondobeitia (1993) made a comparative study of the soil mite communities (Acari) of wooded and unwooded areas in the Basque Country, Northern Spain. Gama *et al.* (1994) studied Collembolan population diversity between Portuguese autochnous and allochthonous forests. Noble *et al.* (1996) studied on Soil and litter microarthropod populations from two contrasting ecosystems in semi-arid eastern Australia. While studying the distribution of Collembola and Oribatid fauna, Dwyer *et al.* (1997) identified 14 genera and 36 species of Oribatida (Acari) in the commercial Balsam Fir forest of Western New foundland, Canada. Hopkin (1997) revealed that migration of Collembola to deeper layers was related to different climatic conditions of the areas. Straalen and Verhof (1997) developed a bio indicator system for soil acidity based on soil arthropod pH preferences by their tendencies to settle in a gradient of soil pH from 2 to 9. Hansen and Coleman (1998) studied that litter and its composition were the determinants on the diversity and species composition of Oribatid mites (Acari: Oribatida). In Galapagos Islands, Schatz (1998) recorded increase in diversity and abundance of oribatid mites from arid to moisture zones at higher elevation having their most preferential habitat at medium to higher elevations and identified 202 oribatid species belonging to 64 families including 81 new species.

Lamoncha and Crossley (1998) studied Oribatid mite diversity along an elevation gradient in southeastern Appalachian forest. Addington and Seastedt (1999) investigated on the activity of soil microarthropods beneath snow pack alpine tundra and sub alpine forest and observed that microarthropods activity were positively correlated with soil surface temperature. Ito and Aoki (1999) studied on species diversity of soil inhabiting Oribatid mites in Yanbaru, the northern part of Okinawa Honto. Heneghan *et al.* (1999) studied on soil microarthropods contribution to decomposition dynamics. Kay *et al.* (1999) found that mite numbers generally increased with decrease of grazing disturbances while studying on microarthropods as indicators of exposure to environmental stress in Chihuahuan desert rangelands. Kovac *et al.* (1999) reported that species richness of Gamasina varied between 11-26 species which were significantly correlated with content of organic carbon in two different arable soil types. O' Lear and Blair (1999) studied on the responses of soil microarthropods to changes in soil water availability in tall grass prairie. Badejo *et al.* (1999) studied on Oribatid mite fauna of soil under different vegetation cover in Ile-Ife, Nigeria. While studying the vertical distribution in deciduous forest under Mediterranean climate conditions, Detsis (2000) recorded majority of the animals in the zero to upper soil layer under adverse conditions in summer. Ponge (2000) studied on vertical distribution of Collembola and their food resources in organic horizon in beach forests. Luanga-Reyrel and Deconchat (1999) studied on the diversity within the Collembola community in fragmented coppice forests in South Western France and recorded 47 species having been dominated by *Folsomia quadriocuta* and *Isotoma notabilis*. A change within Oribatid mite communities associated with Scot pine regeneration was studied by Horwood and Butt (2000). Vassilis (2000) studied the vertical distribution of Collembola in deciduous forest under Mediterranean climatic conditions. Gonzalez and Seastedt (2000) studied on soil fauna and plant litter decomposition in tropical and sub-alpine forests and indicated that soil fauna have a disproportionately larger effect on litter decomposition in a tropical wet forest than in a tropical dry or a sub-alpine forest. Badejo and Adam (2000) studied abundance and diversity of soil mites of fragmented habitats in a biosphere reserve in southern, Nigeria. Doles *et al.* (2001) studied community structure and dynamics of soil microarthropods highlighting their richness and diversity of functional groups and families in Western Colorado, USA. While analyzing the effect of temperature and moisture fluctuation on an experimental soil microarthropod community, Huhta and Hanninen (2001) established a hypothesis that populations of some species benefited from fluctuating microclimate in varying conditions to permit more species to co-exist than uniform conditions. Ojala and Huhta (2001) described dispersal of microarthropods in forest soil of birch stands in Filand. In a comparative study of soil macro-fauna in two Oak wood forests, Sharon *et al.* (2001) observed that in similar forest types under similar climatic conditions, the soil composition and texture did not directly affect biodiversity and faunal richness. The role of Collembola in carbon and nitrogen cycling in soil was studied by Filser (2002) and found poor correlationship among them. Culik *et al.* (2002) reported that soil microarthropod density was low in tropical and agricultural environments (conventional tillage with no mulch) when compared to temperate and non-agricultural environment (no tillage with mulch). Stevens and Hogg (2002) studied on expanded distributional record of Collembola and Acari in Southern Victoria land, Antartica. Addison *et al.* (2003 a, b) studied on abundance, species diversity and community structure of Collembola in successional coastal temperate forests on Vancouver Island, Canada. Zhong and Qigno (2001) studied on organic carbon content in soil under different land uses in tropical and subtropical china and observed that for the various land uses in the region, the C density estimation was accompanied by relatively large variations. Kallimanis *et al.* (2002) analysed the two scale patterns of spatial distribution of Oribatid mites (Acari, Cryptostigmata) in a Greek mountain. Caballero *et al.* (2004) studied on the indirect biomass estimation in Collembola. A long-term change in Collembolan communities in grazed and non-grazed abandoned arable fields in Denmark was studied by Petersen *et al.* (2004). Sousa *et al.* (2004) studied on effect of land-use on Collembola diversity patterns in a Mediterranean landscape. Spatial distribution of Collembola in presence and absence of a predator was studied by Negri (2004). While studying the abundance of soil mites (Arachnida: Acari) in a natural soil of Central Argntina, Bedano *et al.*, (2005) opined that, natural soils situated near to cultivated soils could provide baseline information of bioindicators of soil quality. Matic *et al.* (2005) made an analysisof collembolan species abundance and distribution in beech and spruce forest habitats of Jastribac Mountain (Serbia). Culik *et al.* (2006) studied on Collembola communities in the soil Papaya Orchards in Espirito Santo, Brazil and found high population and diversity of Collembola in the study site. Iloba and Odon (2007) studied on the biodiversity of soil microarthropods and their responses to crude oil spills in Benin City, Nigeria.

Micro arthropod studies in India

Trehan (1945) initiated the first study on the ecological aspect of soil microarthropods in India. Choudhury (1961) showed the importance of soil moisture content in relation to the population of Collembola. Choudhuri and Roy (1967) observed the maximum population of Collembola during rainy season in uncultivated soil. Mukharji and Singh (1970) studied the soil microarthropods in relation to the different edaphic factors and soil ecosystem at Banaras Hindu University, U.P. Singh and Mukharji (1971) had studied the qualitative composition of soil arthropods in some field of Varanasi and also recorded nine species of Collembola from uncultivated fields, the most common species being *Folsomides parvulus, Isotomides sp*. and *Onychiurus armatus*. Choudhury and Roy (1972) observed only one peak population of collembolan during June-August in West Bengal. Singh and Mukharji (1973) reported that Acari and Collembola constituted 72% to 97% of the total arthropod fauna in Indian soil. Relationship between oribatid mites and organic carbon content of soil and impact of growth of vegetation on soil mites was studied by Banerjee (1974 b). Singh and Singh (1975) studied the population density of different groups of microarthropods during the rainy season on the forest floor of Varanasi (India) and found that Cryptostigmata constituted the highest percentage of the total population density of microarthropods in both soil and litter. Singh and Pillai (1975) while studying on soil microarthropod communities in the cropland soil of Varanasi reported that Prostigmata mites were the most dominant groups in all fields. Choudhuri and Banerjee (1975) studied the soil meso and microfauna of uncultivated plots of West Bengal and reported that Cryptostigmatid mites predominated during the monsoon months. In an ecological study of different groups of microarthropods in tropical deciduous forest of Varanasi, Singh and Singh (1975) observed maximum population density of microarthropods in both soil and litter during rainy season on the forest floor. Prabhoo (1976) recorded that deforestation and cultivation in Western ghat, Kerala, drastically change the microarthropod population, particularly of Acarina, Symphyla, Collembola, and Protura. Gupta and Mukharji (1976) have recorded 35 genera comprising 37 species of Acarina, 22 genera with 35 species of Collembola and 16 genera of other Taxonomic groups in crop plots at Varansi, however Choudhuri and Roy (1967) recorded only 12 genera of Collembola in addition to other soil arthropods from uncultivated fields of

West Bengal. While studying seasonal variation, Choudhuri and Banerjee (1977) reported that soil Oribatid were most abundant during July-August and minimum in April-May in alluvial and sandy loam soils. Joy and Bhattacharya (1977) surveyed a qualitative and quantitative study of soil inhabiting Cryptostigmatid mites in four different sites of West Bengal. Bhattacharya and Joy (1978) studied the habitat preference of different groups of soil microarthropods in Shatiniketan, West Bengal. Gupta and Mukherjee (1978) observed that excessive moisture affected soil fauna negatively. Hazra (1978) pointed out the existence of a strong positive correlation between soil moisture and Collembolan population and considered it as the principal factor of population fluctuation. Bhattacharya and Raychoudhuri (1979) noted that moisture content and temperature of soil, rainfall of the previous months showed significant positive correlation with the total soil microarthropods population. Choudhuri and Pande (1979) reported maximum relationship between soil factors and mites population in monsoon season at high altitude condition. Roy and Ghatak (1980) worked on soil microarthropod community of a forest ecosystem of West Bengal. Raina *et al.* (1979) studied the soil and litter mesofauna from Kashmir, Himalayas. Kurup and Probhoo (1980) described the vertical distribution of Collembola in an abandoned field in Trivandrum, Kerala. Bhattacharya *et al*. (1981) studied the structure of Cryptostigmata under different vegetation and observed 6236 nos m^{-2} population belonging to 38 species of Cryptostigmata. Takeda (1981) noticed that the population density of Collembola was significantly higher in the forest area than in the shifting cultivation area, however such variation was not observed in Acari and other soil mesofauna. Hazra and Choudhury (1981) recorded 11 genera and 17 species of Collembola from two different soil types and reported the highest numbers (65%) in alluvial soil and only 39.9% in lateritic soil. Sanyal and Bhanduri (1982) studied seasonal changes in density of soil Oribatid mites in relation to temperature and water contents soil at Sagar Island, West Bengal, India. Singh and Mahajan (1983) studied community structure and bioecology of soil microarthropods at Varanasi and found highest percentage composition of Acarina in the forest soil. Sanyal and Sarkar (1983) recorded maximum and minimum population density of Oribatid mites during pre-monsoon and monsoon months respectively. A comparative study on the Collembola density between the cultivated and uncultivated sites was reported by Hazra and Choudhuri (1983) and revealed that higher population density was found in the uncultivated site in comparison to the cultivated site. Banerjee (1984) reported the effect of micro-site physico-chemical factors of soil on variation and community composition of microarthropods. Chakraborty (1985) have studied some aspects of the ecology of soil arthropods particularly mites and Collembola of tropical forests and plantations in India. Mir (1986) studied the faunal composition and bio-ecology of soil microarthropods of coniferous forests ranges of Kashmir valley. Joy *et al.* (1986) investigated the phylogenic composition of litter and soil inhabiting microarthropods in an artificial forest at Santiniketan. A study on correlation between soil and its acarine fauna in Himalayan ecosystem of West Bengal was carried out by Maitra (1987) and reported that the population density reached maximum in the month of March. Bhattacharrya and Bhattacharrya (1987) observed on the changes in the abundance of soil microarthropods in two contrasting sites in the Durgapur Industrial area of India. While studying on the vertical distribution of different species of Collembola on crop field of eastern Orissa, Panda (1987) observed that the population of the species increased in the upper layer and decreased towards the bottom layers. Nielson (1987) investigated the vertical distribution of insect population in the free air space of beach woodland and found that 85% of specimen was recorded at ground level. Guru *et al.*

(1988) recorded 8 species of Collembola belonging to 5 families and reported a significant decrease in population density of Collembola from uppermost soil layer to lower layer. Sinha *et al.* (1988) studied the seasonal population fluctuation of Collembola and Acarina in a deciduous forest at Ranchi and observed that no single factor but a cumulative actions of a number of factors have been found responsible for seasonal changes of soil mesofauna. Prabhoo *et al.* (1988) while working on the ecology of soil fauna in a fire prone tropical forest noticed that burning adversely affected the population of soil fauna. Hazra and Sanyal (1989) studied the population fluctuation of some predominant species of Acarina and Collembola on the embankment of a drainage system at Eden garden, Calcutta and revealed that the drainage embankment affected directly in fluctuating the population peaks of Acarina and Collembola. Veeresh (1990) observed the role of soil fauna in the Organic matter turnover and nutrient cycling. Reddy and Venkataiah (1990) studied on the effect of tree plantation on seasonal community structure of soil microarthropods in tropical semi-arid Savanna. Hazra and Choudhury (1990) studied the effect of nitrate on Mesostigmata and Prostigmata mites and revealed that the population was always significantly correlated with the nitrate content of the soil. In his studies on ecology of soil Oribatid fauna in two contrasting environment of Calcutta, Sanyal (1991) found that number of mites always predominated the rest of the microarthropods. Hazra (1991) studied the effect of deforestation on the soil microarthropod fauna in two forest floor sites of West Bengal, India and observed decrease in population percentage of mites in the deforestated site as compared to reserved Forest site. Bisht *et al.* (1991) studied on population distribution of Collembola at three uncultivated sites of the Alaknanda river bank of Garhwal Himalayas. Guru and Das (1991) reported that total population of Collembola decreased significantly from the upper soil layer to deeper layer in some cultivated field of Bhubaneswar. While studying microarthropod community Sarkar (1991) found that Acari were the most dominant group followed by Collembola and other microarthropods. Banerjee and Sanyal (1991) investigated on Oribatid in soil with high organic matter. A comparative study on population ecology of microarthropods in relation to vegetation and rainfall between bamboo groove and shaded grass in Southern part of Kerela was carried out by Haq and Ramani (1991) found higher population density in bamboo groove A comparative study on soil microarthropods fauna in paddy field and control plot in West Bengal, India was carried out by Sengupta and Sanyal (1991) and revealed that Acarina dominated Collembola in terms of number and species in both the study plot. Sanyal and Sarkar (1993) studied on the soil Oribatid mites in three contrasting sites at Howrah, West Bengal, India. Bhandari and Somani (1994) and Haq (1994) studied the ecology and biology of soil organisms particularly oribatid mites at Udaipur. Thomas *et al.* (1995) studied on the abundance of mites, Collembolans at different elevations of soil in the Shola forest of Kodaikanal hills. Guru and Mohanty (1995) made an elaborate study on species composition, distribution and seasonal variationof Collembola in two agrecosystem of Bhubaneswar. Sanyal (1995) reviewed the ecological studies of soil mites (Acari) in India. Hazra and Sanyal (1996) studied the ecology of Collembola in a periodically inundated newly emerged alluvial island, West Bengal of India. Reddy and Reddy (1996) recorded the presence of more than 65% of Acarina and Collembola among the total arthropods in four types of leaf litter. Chakraborti and Bhattacharya (1996) studied on soil microarthropods in a rubber plantation and an adjacent wasteland exhibiting peaks in early monsoon and post monsoon. Soil arthropods inhabiting grassland and silvipastoral system in Jhansi, Uttar Pradesh, in central India studied by Roy *et al.* (1998) and reported higher species diversity in grassland. Narula *et al* (1998) studied Collembola and mites of deciduous forest stand in Kurukshetra and reported that soil moisture and temperature collectively regulated the population. Faisal and Ahmed (2005) observed changing collembolan diversity with agricultural landscapes in Thar Desert. Tripathi *et al.* (2005) discussed the importance of soil biodiversity including collembolan and impact of soil pollution on soil faunal resources. In five vegetational sites at Banaras Hindu University, Varanasi, Raghuraman *et al.* (2010) identified 1789 collembola belonging to 18 genera and recorded maximum and minimum mean relative abundance in floral garden and grassy field respectively. Lal *et al.* (2011) studied population dynamics of collembola and acari in wetlands and croplands in indo-gangetic plains of North Bihar. Rajagopal (2011) recorded 16 different species of mesostigmatid mite species in four altitudes of Western Ghats and found to be more abundant during monsoon months. Sanal Kumar *et al*. (2011) studied density and diversity of soil microarthropods,annelids and nematodes in relation to soil edaphic and chemical factors and observed that soil moisture, temperature, pH, nitrogen and phosphorous is affecting the distribution of micro arthropods.

Microarthropod studiy in NE India

Reddy and Alfred (1978 a) perhaps initiated the study on microarthropods in association with the decomposition process of needle litter of Meghalaya pine forest. A comparative seasonal population dynamics of dominant Collembola species in a pine forest and Jhum soils of Meghalaya was studied by Darlong and Alfred (1982, 1984). Paul and Alfred (1986) made comparative study of soil microarthropods in three disturbed habitats of Meghalaya, North-East India. The qualitative study of the soil arthropods in Jhum ecosystems of North Eastern of India studied by Vatsauliya and Alfred (1980). Population dynamics and community analysis of Collembola in pine forest soils of Meghalaya, North Eastern India was reported by Hattar and Alfred (1986). Reddy and Alfred (1989) studied on seasonal abundance of microarthropods of needle-litter during decomposition in a pine plantation in relation to litter mass-loss, moisture and temperature. Alfred *et al.* (1991) studied on the soil microarthropods and their conservation measures in certain part of North-Eastern India and reported lower population of soil microarthropods in plantation forest, cultivated lands, orchards and Jhum fallows as compared to natural forest stands. A comparative study on soil Acarina and Collembola in the pine forest and cultivated land of Khasi Hill, Meghalaya was made by Hattar *et al* (1992) and found higher number of species in pine forest. Darlong *et al.* (2010) reviewed the soil faunal studies in the rain forest of North East India and identified the knowledge gaps on the areas research priorities

Thingbaijam *et al.* (1986) studied on population density of soil arthropods in the subtropical forest ecosystems at Shiroy Hill, Manipur. Yadava and Singh (1988) observed maximum population density of soil microarthropods during rainy season and minimum during dry winter season in their study at Oak forest of Shiroy Hill, Manipur. Singh and Yadava (1998) studied on seasonal fluctuation of Oribatid mites in sub-tropical forest ecosystem of Manipur, India and reported maximum population during summer with declining trend towards the winter season. Chitrapati (2002) while studying in sub-tropical forest ecosystem at Khonghampat, Manipur, reported that high population density of microarthropods was due to higher soil moisture content and temperature. Devi *et al.* (2002) investigated the vertical and horizontal distributions of five microarthropod taxa in a subtropical forest ecosystem at Phayeng in Manipur. In a Dipterocarpus forest ecosystem of Manipur, Chitrapati *et al.* (2002) recorded the dominance of litter collembolan followed by Acarina among microarthropod groups during the month of July and found positive corelationship with temperature and moisture content of litter. Waikhom *et al.* (2006) studied on vertical distribution of Collembolan in a sub tropical forest floor of Manipur. In comparative ecological study in two subtropical forest ecosystem in Manipur, Chitrapati and Singh (2007) recorded maximum population density of soil micro arthropods during monsoon period and observed the decreasing trend of population density with increase in soil depth in both study sites. Devi and Singh (2007) studied the population fluctuation of soil mites in relation to some important abiotic factors in the Pine forest ecosystem of Manipur. Devi and Singh (2009) studied the leaf litter decomposition and established it relationship with abiotic factors and population of micro-arthropods in a sub-tropical forest ecosystem, Manipur. Devi *et al.* (2011) studied the monthly changes of collembolan population under the gradients of moisture, organic carbon and nitrogen contents in a sub-tropical forest soil, Manipur and found significant positive correlatioship with the abioticfactors.

Ao (1987) studied on the soil arthropods in Jhum agro-ecosystem, Nagaland, North Eastern Region. Doulo (2007) studied on population dynamics of soil microarthropods and effect of soil nutrients in natural and degraded forest eco-system at Lumami, Nagaland. In a comparative study between natural and degraded forest ecosystem in Lumami, Nagaland, Doulo and Kakati (2009) recorded higher population of soil micro arthropods in natural site exhibiting conspicuous vertical distribution and seasonal variation in both sites. Doulo and Kakati (2010) also highlighted on abundance and distribution of Collembola in two contrasting sites of a subtropical forest Ecosystem at Lumami, Nagaland.

Sarkar (1990) found minimal population of Oribatid during monsoon in some plots of undisturbed habitat of Tripura. Sarkar (1991) found that Acarina was the most dominant group followed by Collembola and other microarthropods and population fluctuation of Collembola and Oribatid exhibited similar trend. Chakraborti and Bhattacharya (1996) studied on fluctuations of soil microarthropods of rubber cultivation and an adjacent Wasteland, in Tripura district in North East India.

Ray and Gope (2006) studied the ecology and diversity of soil microarthropod in two vegetational types in Barrak valley of Assam. Gope *et al*. (2007) also reported about seasonal distribution and community structure of edaphic Collembolans in home garden and secondary successional soil in subtropical humid climate of Barak Valley, North Eastern, India. In an ecological study under banana (Musa sp.) plantation at Dorgakona village of Silchar, Assam, Gope and Ray (2006) recorded higher diversity and evenness stability of soil microarthropod community. Gope and Ray (2010) revealed that cryptostigmatid mite was predominant group among the soil microarthropod fauna from pig slurry, poultry litter and cow dung umping sites of Cachar district, Assam. Gope and Ray (2012) investigated on the population dynamics of *Isotomina thermophila* and its correlation with environmental as well as edaphic factors in a secondary succession and a homegarden in Cachar district of Assam. While studying the ecology and diversity of microarthropods in canopy and soil from tropical evergreen forest of Cachar district, Assam Ray *et al.* (2012) concluded that edaphic factors and climatic factors affect the dynamics of microarthropods.

Chapter - III
DESCRIPTION OF THE STUDY SIDES AND CLIMATE

LOCATION

The present investigation was carried out in two adjoining area of natural and degraded forest ecosystem in Dulung Reserve Forest of Lakhimpur district, Assam which lies at 26°48´- 27°53´ N latitude and 93°42´- 94°20´E longitude at an altitude of 101 m above mean sea level, covering an area of 9900.23 hectre **(plate no.1a. and 1b).** While the natural forest site comprises of rich vegetation, the vegetation in degraded forest site is comparatively thin vegetation due to human activities and occasional logging of forest tree **(plate no. 2a and 2b; 3a and 3b).**

VEGETATION

The vertical stratification in the natural forest stand was very distinct.The canopy layers have an average height of 20 meters. The small trees, shrubs and herbs compose the rest of the under canopy layer. The under layer was dense in some places. The first dominant trees species that form the canopy layer is ***Keyia assamica*** (30%). The second dominant trees are ***Mesua ferrea*** (15%), and other **trees** are *Boswellia serrata, Calatropis gigantea R.B., Dillenia indica, Azadirachto indica Adr. Juss, Bombusa mutans, Dendrocalamus hamiltonii Ness & Arn Ex Munro, Dendrocalamus hamiltonii Ness & Arn Ex Munro., Citrus grandis, Areca catechu, Musa paradisiaca L. ,Terminalia chebula Retz. & Willd., Ficus benghalensis, Machilus bombycina, Zyzyphus oenoplia, Zizyphus mauritiana Lam., Alstonia* scholaris (Devil tree) Bombusa tukla, Bombus balcooa. Bombusa muthplex**,**z**,** The smaller trees mostly belong to the families of *Lauraceae, Euphobiaceae, Araliaceae, Ficaseae and Rubiaceae.* The average height of these members was found to be 5 to 15m height. Other ***shrubs*** are

Alpinia allughas, Alpina pudica L. Calamus erectus (Climber), Calamus viminalis, Leucas lavandulaefolia Sm. Solanum indicum L., Clerodendrum viscosum Vent. Clerodendrum serratum (L), etc. Very small plants i.e., ***herbs*** *are Centella asiatica L., Mimosa pudica L., Coix lacrymal- jobi L. Job's tears), Polygonum orientale L., Polygonum chinense. Cyperus rotundus, Leea crispa L., aederia foctiola,* etc. The *ground flora (Herb)* was rich and also *epiphytes, climbers* and *lianas* were also found to be growing abundantly.

The degraded area was not well stratified as the natural stand however represented mostly by herbs and shrubs. The tree species present were the species that left uncut while clearing the forest and the stumps that survived forest fire. *Keyia assamica* (20%) was the major group of species in degraded forest ecosystem. Less quantity of trees, shrubs and herbs as natural site were found in degraded forest.

CLIMATE

The climate of the area is monsoonic with three distinct seasons i.e. summer, rainy and winter. The ombrothermic data based on twenty years (1987–2006) highlights the climatic condition of Lakhimpur district which reveals that June to September constitute rainy seasons while October to May comprise dry period **(Fig.1)**. The dry period can be further divided into moist summer (February to May) and cool dry (October to January) season. Thus there is distinct summer (February to May), rainy (June to September) and winter (October to January) seasons. While February constitute the transitional month between winter and summer, October is the transitional month between rainy and winter season.

Meteorological data during the study period

The meteorological data during the study period from October 2006 to September 2007 is shown in **(Fig.2).** The average minimum and maximum air temperature was recorded in the month December, 2007 (9.10˚C) and August, 2007 (34.03˚C) respectively. The maximum relative humidity was recorded in the month July, 2007 (96.73%) and the minimum was (26.03%) in the month June, 2007 at 8-30 hours. The highest record was of 91% in the month of July, 2007 and the lowest was recorded in the month of April, 2007 of (52.4 %) at 17-30 hours. The maximum annual rainfall during the study period was recorded in the month of June (853.8 mm) and minimum in the month of December and January (13.3 mm). The total annual rainfall was 3753 mm.

Description of study site and Climate

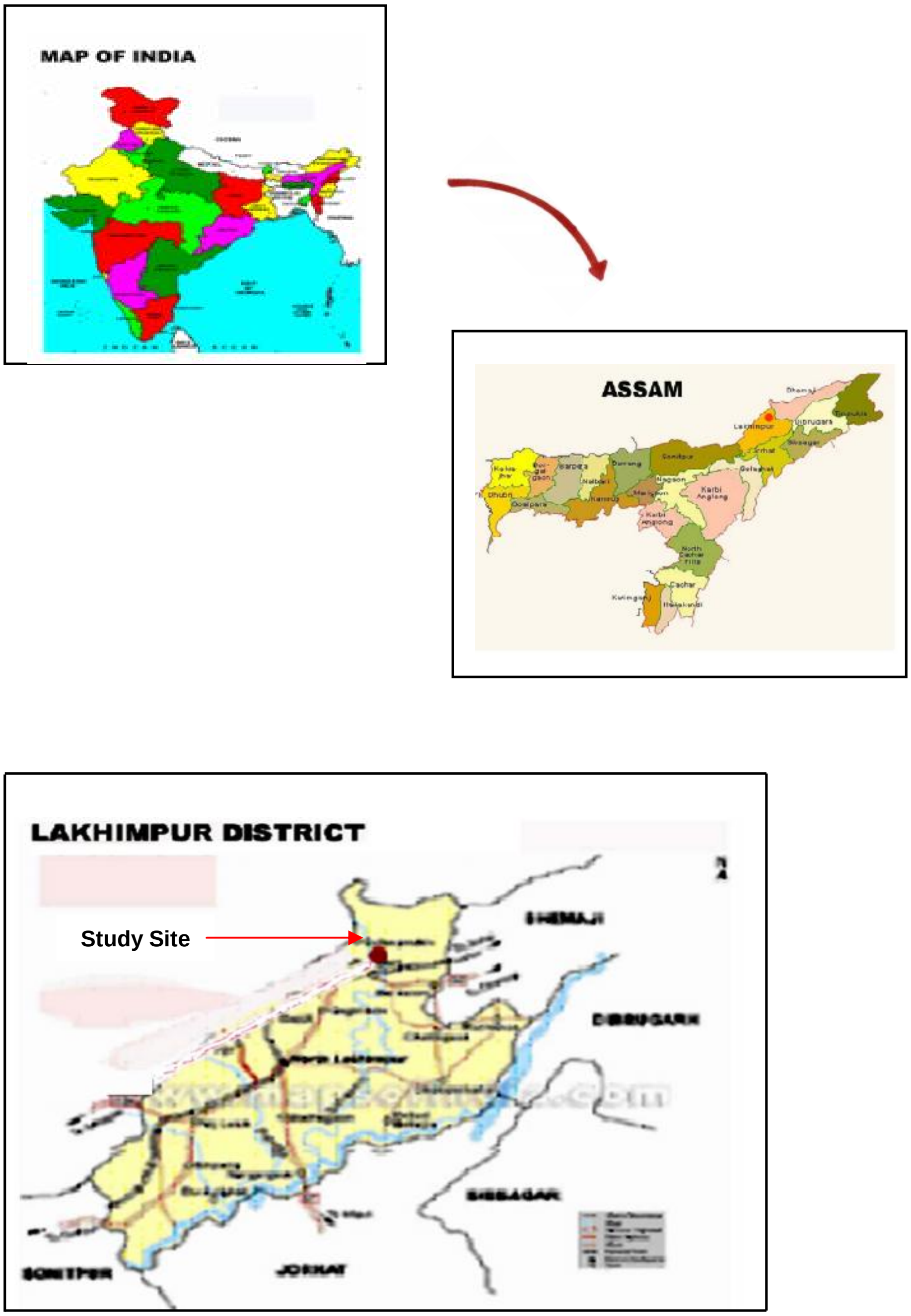


Plate No. 1a. Assam State and Lakhimpur District

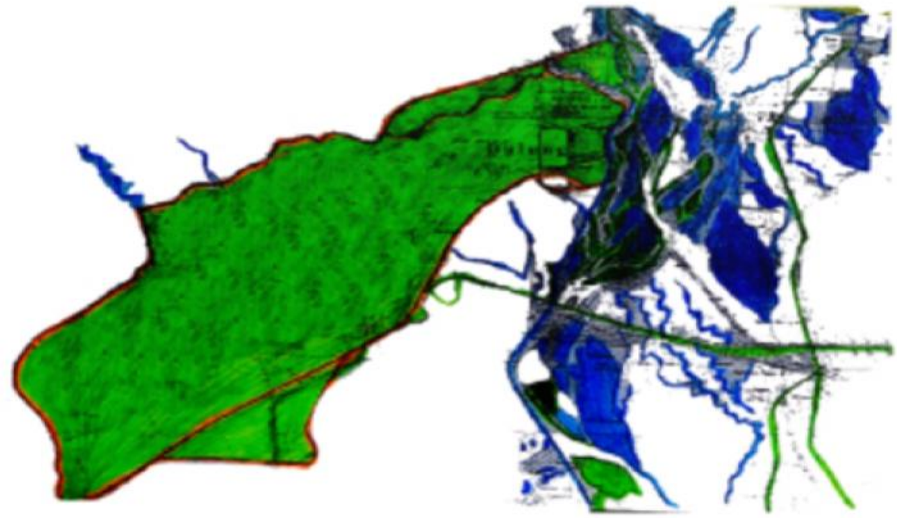


Plate no. 1b Study area- Dulung Reserve Forest

Natural and Degraded Forest

N a t u r a l

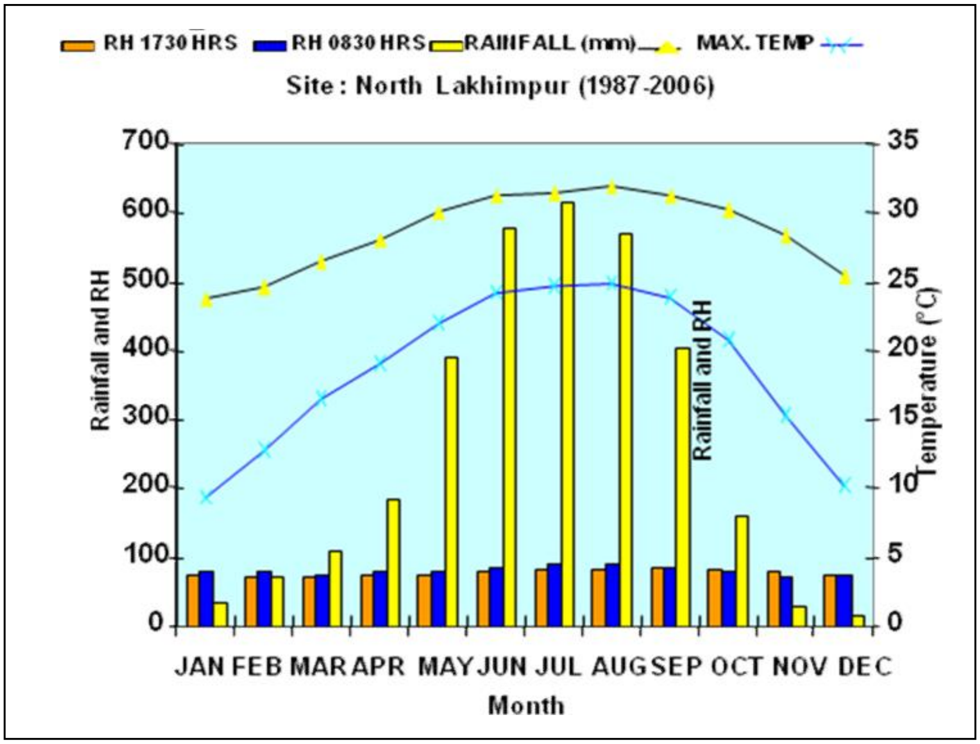
Plate No. 2a

Plate No. 2b

D e g r a d e d

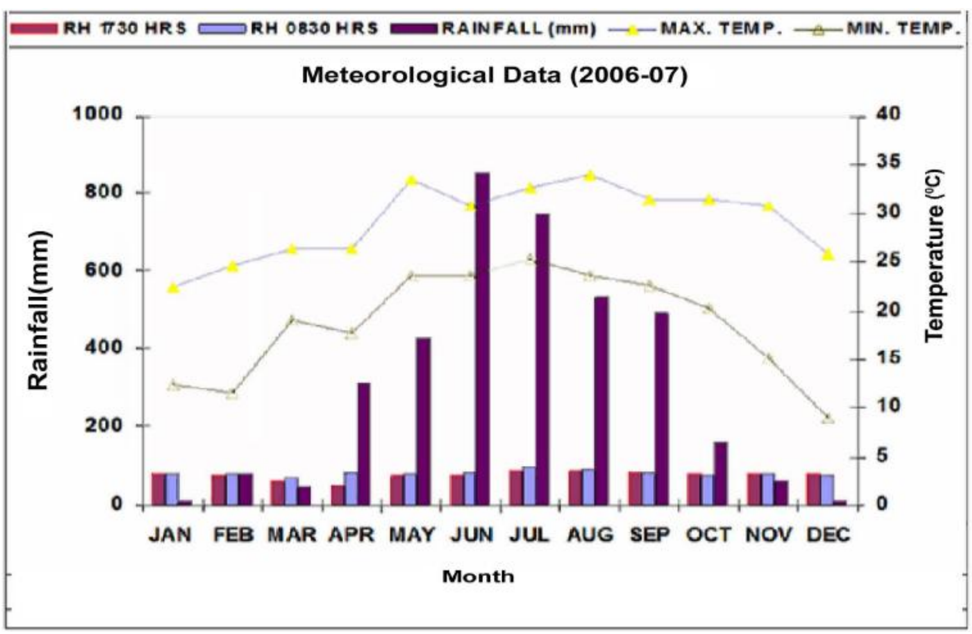
Plate No. 3a

Plate No. 3b



(a)

Figure 1: Ombrothermic diagram based on twenty years (1987–2006)



(b)

Figure 2: Climatic variation during study period (Oct/2006–Sep/2007)

Chapter – IV
MATERIALS AND METHODS

Sampling

In both the natural and degraded forest ecosystem, the sampling collection sites are divided into lower, middle and upper elevation site. Each site is further divided into three different plots having an area of 10m x 10m size which are approximately 25m to 30m apart from each other. Soil samples for microarthropods were collected from each area at different soil depths i.e. 0-10 cm, 10-20cm and 20-30cm by using soil corer with sampler size of 3.925 cm^2 (10 cm in height and 5cm in diameter). For analysis of physico-chemical characteristics, soil samples were also collected in similar manner from the adjacent sampling area of microarthropods. For litter microarthropods, leaf litter were sampled from nearby area laying quadrates of 30 x 30 cm in each study area. Sampling for soil and litter microarthropods was initiated in October, 2006 and continued till September, 2007 with an interval of one month. All the sampling was done in the morning between 9:00am and 11:00am in mid week of the each month. Three replicates one from each area was collected from upper, middle and lower elevation sites from both ecosystems. As such, 324 and 108 samples for soil and litter microarthropods were collected from each ecosystem for 12 months during study period.

All the soil and litter samples were kept in individual polythene bags, labelled and packed to avoid moisture loss and any kind of disturbance to microarthropods during its transit period and immediately brought to the laboratory for further analysis/ extraction within an average of one hour after the field collection.

(a)

(b)

Figure 3: Sample Collection from study site
(a-Natural Forest and b-Degraded Forest)

Methods of faunal extraction and identification

The extraction of soil and litter microarthropods was based on the modified Tullgren funnel as described by Crossley and Blair (1991). A 30-watt electric bulb was used as the source of heat and light. The period of the extraction was 6-7 days at constant temperature of 35±2 ^{O}C depending on the moisture contents of the soil samples. Both soil and litter microarthropods were extracted into collecting vial, containing 70% ethanol **(Plate no. 4b and 4c).** After the extraction, the vials containing the extracted microarthropods were removed from the funnel and transferred into a petridish and vials were washed several times with 70% ethanol. The soil microarthropods were preserved in 70% ethanol to which few drops of glycerine were added to prevent desiccation. Identification and counting was done under a binocular microscope.

During the present investigation both soil and litter microarthropds were divided into three major animal groups. They are-

I. Acarina

II. Collembola

III. Other microarthropods

Faunal Extraction

Plate No. 4 a: Extraction chamber

Plate No.4 b: Arrangement of funnels along with soil sample

Plate No. 4 c: Arrangement of funnels along with soil sample in light

Physico-chemical characteristic of soil

Physico-chemical characteristics of soil such as temperature, moisture, pH, organic carbon, total nitrogen, available phosphorus, and potassium were analysed during each sampling period in order to study the impact of these factors on the population changes of microarthropods

Soil analysis

i. Soil temperature was recorded on each sampling date with the help of soil thermometer from the adjacent collection area for each layer i.e. 0-10cm,10-20cm, and 20-30cm.

ii. Soil moisture content was determined for each layer i.e., 0-10cm, 10-20cm, and 20-30cm by gravimetric method (Misra, 1968 and Wilde *et al*,1985).

iii. Soil pH at different depth layers were determined by using a portable glass electrode pH meter (Anderson and Ingram, 1993). The soil samples were suspended in double distilled water in the ratio of 1:5 for determination of pH (Jackson, 1958).

iv. The soil organic carbon was determined by oxidation calorimetric method after modified Walkey and Black method (Anderson and Ingram, 1993).

v. Soil total nitrogen was determined by acid digestion Kjeldahl procedures (Anderson and Ingram, 1993).

vi. Soil available phosphorus was determined by ammonium molybdate stannous chloride method (Sparling *et al*, 1985)

vii. Soil potassium and sodium were determined by flame photometer (Steward, 1971)

Statistical and community analysis

The statistical analysis such as standard error, correlation and ANOVA (single factor) were done using SPSS software.

In community analysis, species diversity and community similarity were analysed for collembolan and acarina using the following formulae.

Margalef's Index

Species diversity (number of species) or species richness was calculated after Margalef (1968).

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

Where,

Da = Margalef's Index

S = Number of species

N = Total number of individuals

Shannon-Wiener diversity index

Measure of species diversity based on information theory or related to the concept of 'Uncertainty' was calculated after Shannon and Wiener (1949).

$$H' = -\sum_{i=1}^{s} Pi \text{ Log } Pi$$

Where H' = Measure of Shannon and Wiener diversity

S = Total number of species in a sample

P_i = Proportion of the total number of individuals occurring in species i.

H max'

The maximum possible diversity of H' or H max' was calculated using the following formula

H max' = Log_2S; Where, S = Number of species or category

Evenness

The evenness or equitability index (Pielou, 1969) of the individual, distribution among the species, designated by the quantity J' (also sometimes referred to as relative diversity) was calculated using the following formula.

$$J' = H / H\ max'$$

Where,H' = Shannon-Weiner function or Mac-Arthur index of diversity

(Mac. Arthur, 1955)

Average faunal resemblance

The average faunal resemblance between the natural and degraded forest ecosystem were calculated using the following formula.

$$\text{Average faunal resemblance} = \frac{C(S_1 + S_2)}{2 \times S_1 \times S_2} \times 100$$

Where, C = Number of species common to both the communities

S_1 = Total number of species in community 1 (natural forest)

S_2 = Total number of species in community 2 (degraded forest)

Chapter - V
STATUS OF SOIL PHYSICO-CHEMICAL FACTORS IN THE STUDY AREAS

The different physico-chemicals characteristics of soil viz. soil temperature, soil moisture, pH, organic carbon, total nitrogen, phosphorus, potassium sodium were determined in natural and degraded forest ecosystem during the study period.

Physical factors

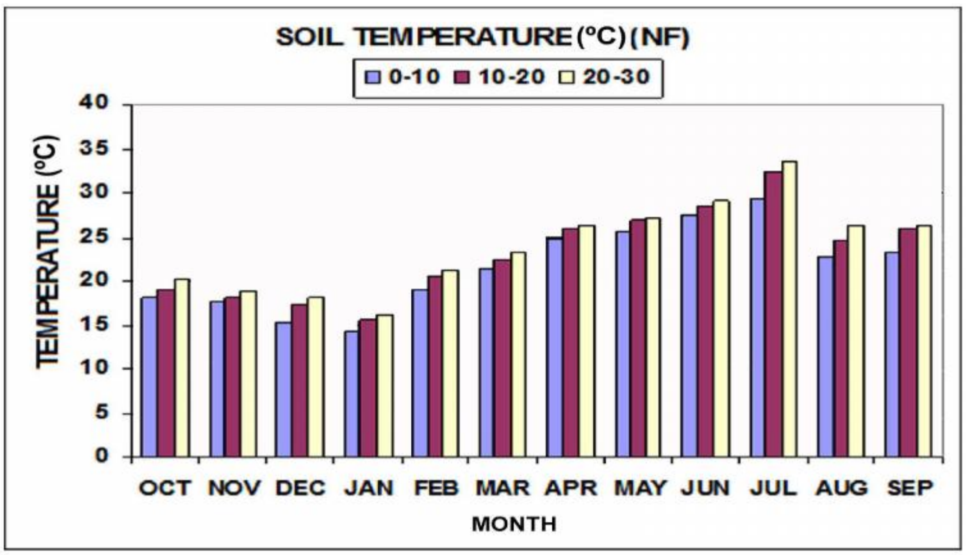
Soil temperature

The soil temperatures of both natural and degraded study sites are represented in (**fig. 3a and 3b**.) The average soil temperature is recorded higher in natural forest than degraded forest. Further, having shown a decreasing trend from October to January in both sites, temperature again increases to reach the peak in July and there after again decline. Soil temperature in natural forest exhibited an increasing trend along with the soil depth which may be due to close vegetation cover and rain that keep the surface cooler than lower region. The higher soil temperature in top layer in degraded forest except for rainy season may be due to exposure to sun light and low vegetation on the ground than natural forest area. The slight decrease in temperature in top layer than middle layer in rainy season is due to continuous rainfall that helps in raising temporary small vegetation cover that to keep the surface cool. Monthly variation of soil temperature followed the pattern of air temperature which is indicative of the fact the soil temperature is largely dependent on air temperature.

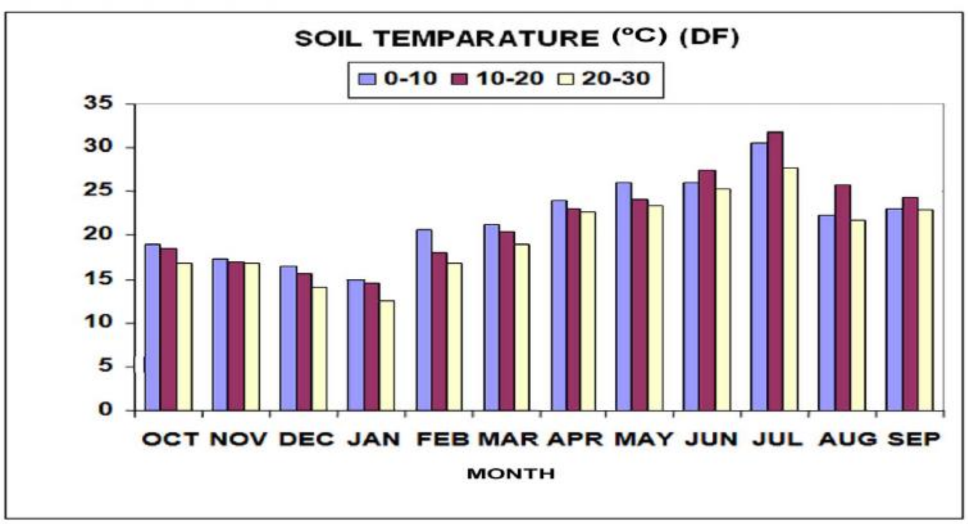
In natural forest, the soil temperature ranges from minimum 14.20 ºC (January) to maximum 29.30 ºC (July) in 0-10cm layer, from 15.40 ºC (January) to 32.40 ºC

(July) in 10-20cm layer and from 16.00 ºC (January) to 33.60 ºC (July) in 20-30cm layer.

In degraded forest also, minimum and maximum of soil temperature in different depth i.e. 0-10cm, 10-20cm and 20-30cm soil layer is recorded in the month January (15.00 ºC, 14.60 ºC, 12.60 ºC) and July (30.60 ºC, 31.70 ºC , and 27.60 ºC) respectively.



(a)



(b)

Figure 3: Monthly variation of soil temperature (ºc) at different soil layers (cm)

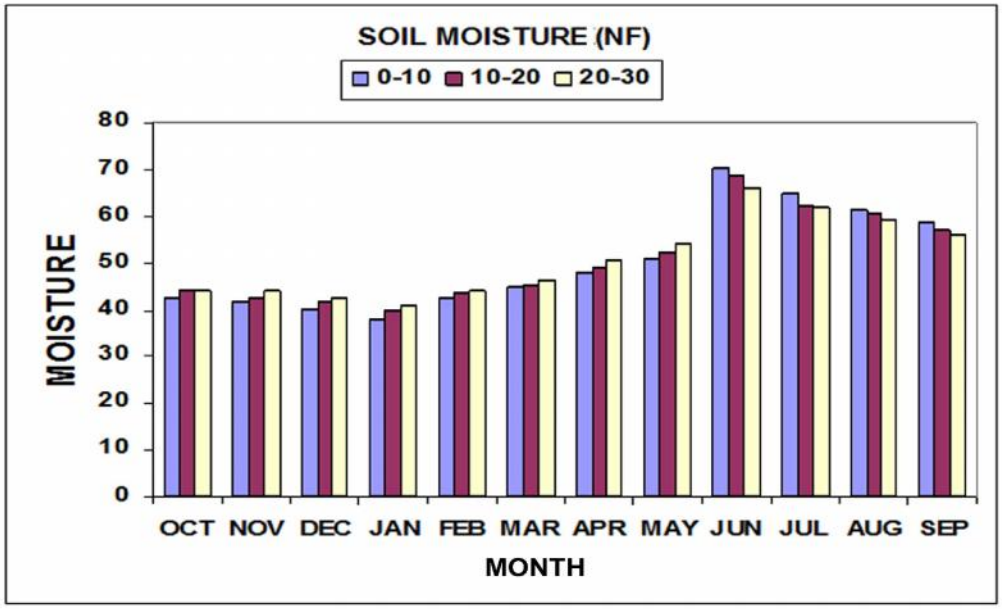
(a) Natural (b) degraded forest ecosystem.

Soil moisture

The total soil moisture content in natural forest area is recorded to be higher than disturb forest soils through out the study period (**fig. 4a and 4b**) which may be due to vegetation cover. Higher rainfall together with high relative humidity followed by vegetation growth leads to the increase of soil moisture content during rainy season. It is interesting to note while natural forest ecosystem exhibits decreasing trend in soil moisture content during rainy season, the middle layer (10-20 cm) in degrade site retains comparatively higher percentage of soil moisturw than the top layer (0-10 cm) having a trend middle layer> top layer > basal layer (20-30 cm). However the reverse trend has been observed during dry season (October to May) with increasing and decreasing trend in soil moisture content along with depyh in natural and degraded forest respectively.

In natural forest, the soil moisture ranges from 37.70 % (January) to 70.40 % (June) in 0-10cm layer, from 39.80 % (January) to 70.40 % (June), in 10-20cm layer and from 39.80 % (January) to 68.70 % (June) and from 41.00 % (January) to 66.20 % (June) in 20-30cm layer. In degraded forest, the soil moisture ranges from 38.80 % (February) to 57.70 % (June) in 0-10cm layer, from 38.10 % (December) to 58.90 % (June) in 10-20cm layer and from 37.00 % (December) to 55.90 % (June) in 20-30 cm layer.

Higher rainfall together with high relative humidity followed by vegetation growth leads to the increase of soil moisture content during rainy season. It is interesting to note that the top layer (0-10 cm) in both study sites retain comparatively less percentage of soil moisture than the middle layer (10-20cm) basal layer (20-30 cm) throughout the year except October.



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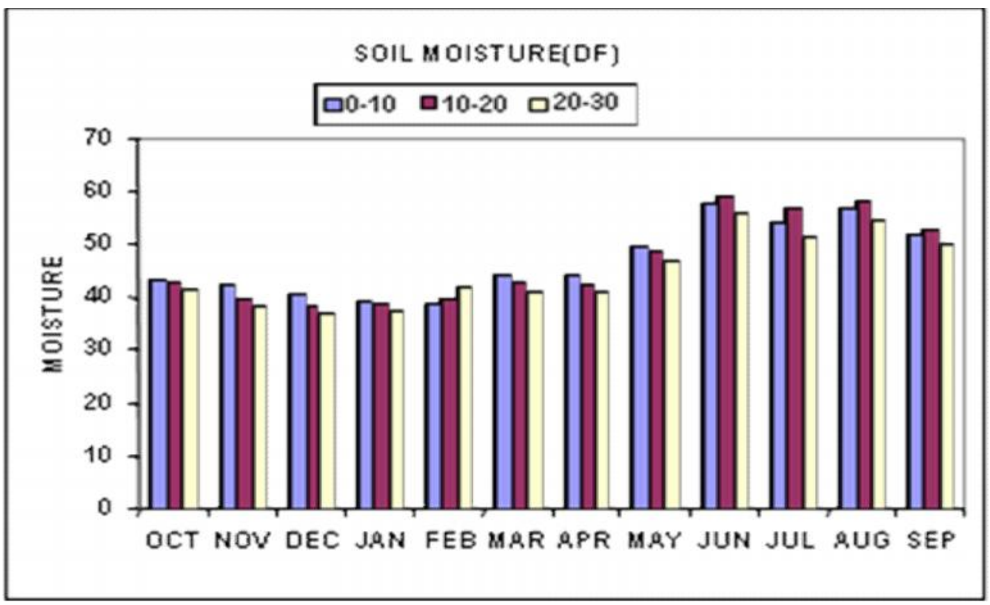


(b)

Figure 4: Monthly variation of soil moisture (%) at different soil Layers(cm). (a) Natural and (b) degraded forest ecosystem.

Chemical factors

Total Nitrogen

No appreciable monthly and seasonal variation was observed on concentration of soil nitrogen among the different soil layers between the two sites (**fig. 5a and 5 b**).

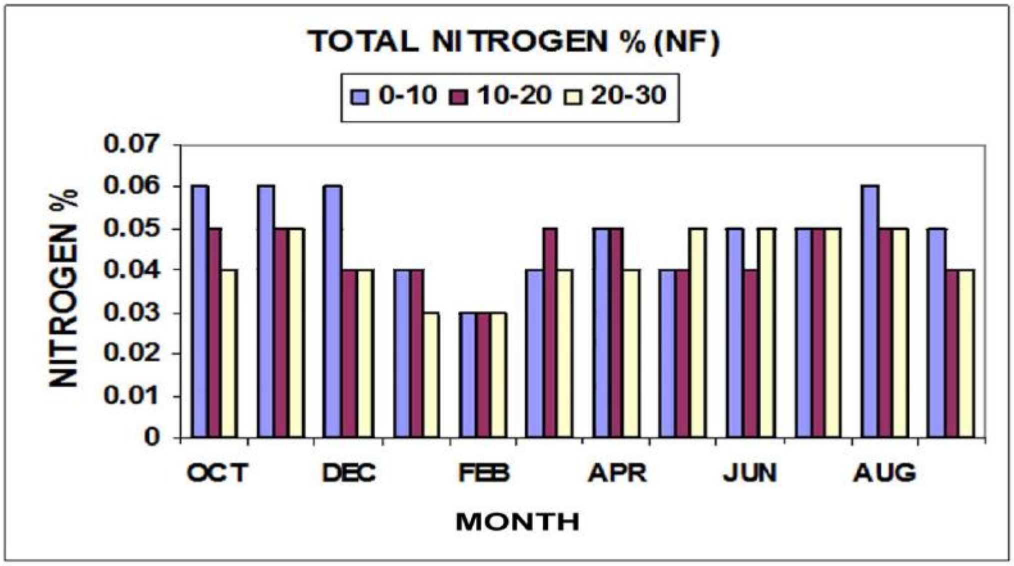
In natural forest, while February recorded minimum soil total nitrogen (0.03%) in all soil layers, maximum (0.06%) was recorded in top layer (0-10 cm) during August, October, November and December. However in other two layers it ranges between 0.04% and 0.05% in different months.

In degraded forest, also soil total nitrogen ranged from 0.03% (January) to 0.06% (October, November) in 0-10cm layer and exhibited fluctuating ranges from 0.04% and 0.05% lower layers in different months.

Soil pH

The soil pH in different soil layers was acidic in natural and disturb forest **(fig. 6a and 6b).** Minimum soil pH was recorded in winter season. It is interesting to note that there is an increase of pH value during winter season in the natural forest and degraded forest which may be due to low organic matter content and microbial activity which ultimately results in low organic acid productions in both sites. The acidic nature of soil pH may be due to the frequent and rainfall especially in winter season. Further with the increase of soil moisture content, the soil pH also has the tendency to shift towards acidic nature of the soil i.e. decrease in soil pH (Vatsauliya and Alfred (1980).

In both sites soil pH was recorded to be minimum in the month of November (3.9 to 4.0 in different soil layers) while maximum was recorded during January (7.1 to 7.3 in different soil depth) having shown fluctuation in different months.



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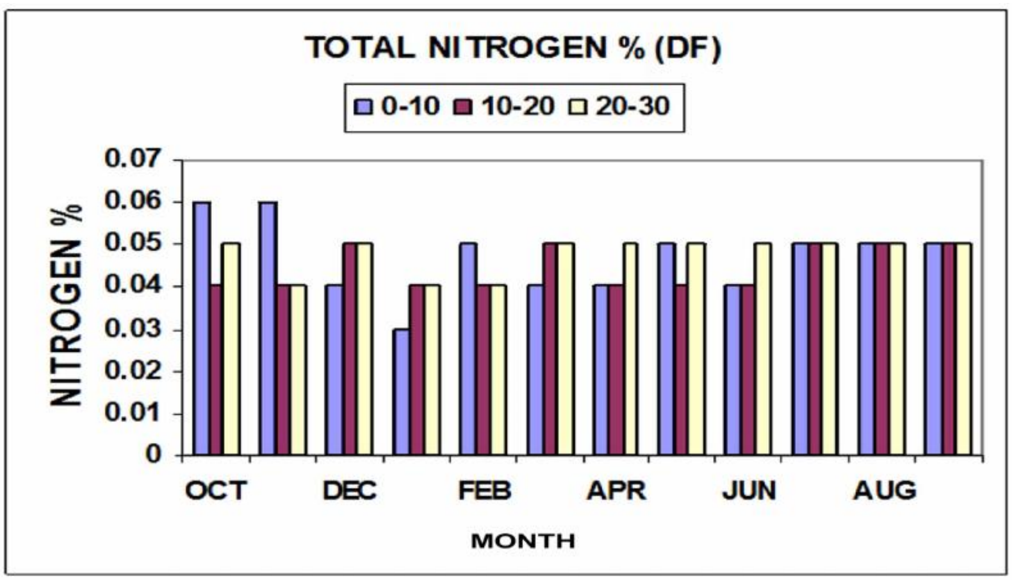

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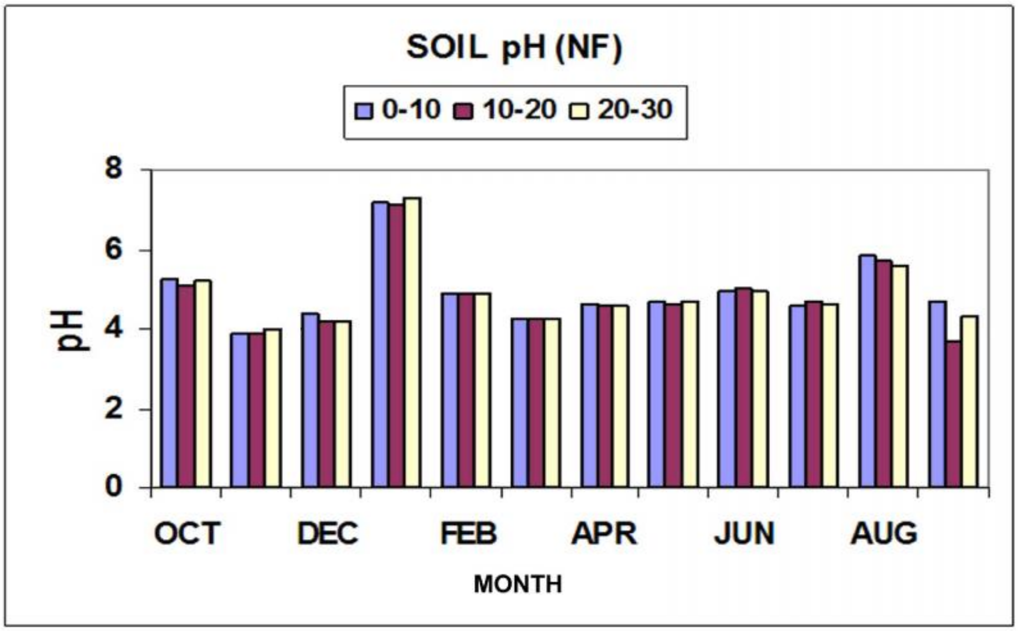
Figure 5 : Monthly variation of soil total nitrogen (%) at different soil layers (a) Natural (b) degraded forest ecosystem.



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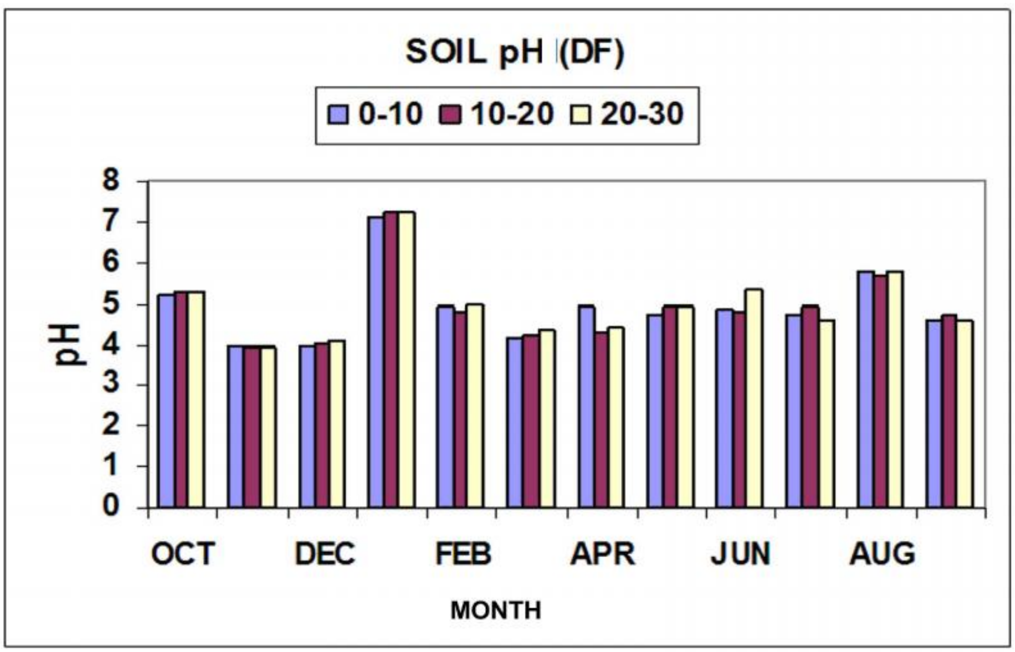


(b)

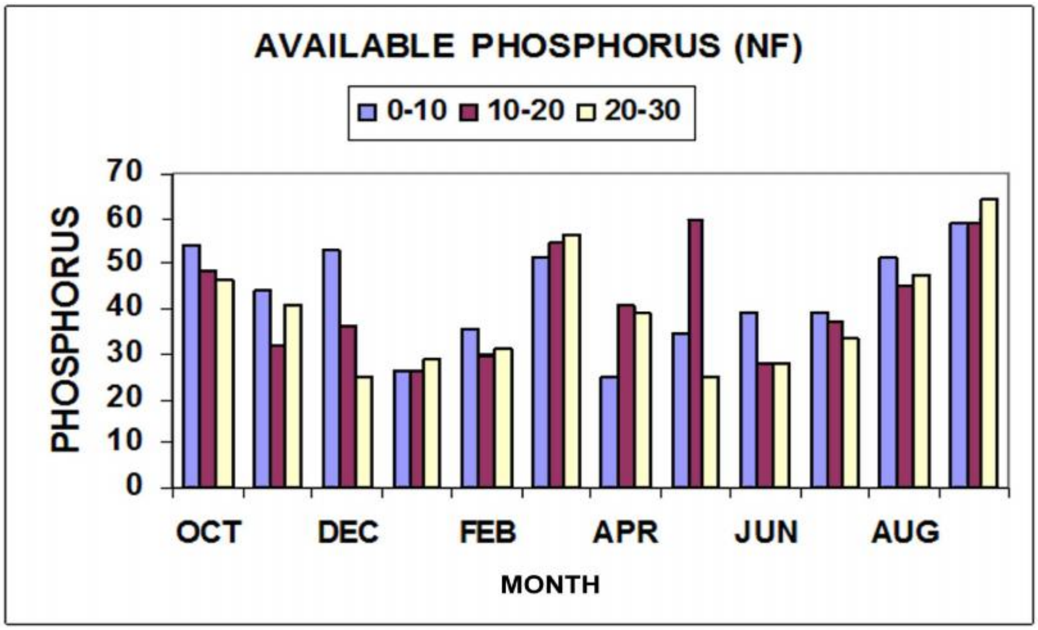
Figure 6 : Monthly variation in soil pH at different soil layer (a) Natural and (b) degraded forest ecosystem.

Available Phosphorus

While soil available phosphorus exhibited fluctuation in different months and soil depth in both study sites, it was found to be little more in degraded site than the natural forest (**fig. 7a and 7b**). Rainy season contributed maximum (44.2 kg/he) followed by summer (40.18 kg/he) and winter (38.35 kg/he) in natural forest, however in degraded forest it was summer season that recorded maximum (45.4 6kg/he **)** followed by rainy (40.45 kg/he) and winter season (38.67 kg/he).

In natural forest, the soil Phosphorous ranges from 24.60 kg/he (April) to 59.10 kg/he (September) in 0-10cm layer, from 26.20 (January) to 59.90 kg/he (September) in 10-20cm layer and from 24.70 and 25.00 (December & May) to 64.50 kg/he (September) in 20-30cm layer.

In degraded forest, the soil Phosphorus ranges from 29.40 (June) to 67.50 kg/he (March) in 0-10cm layer, from 30.50 (January) to 54.60 kg/he (March) in 10-20cm layer and from 26.10 (January) to 48.20 kg/he (March) in 20-30cm layer.



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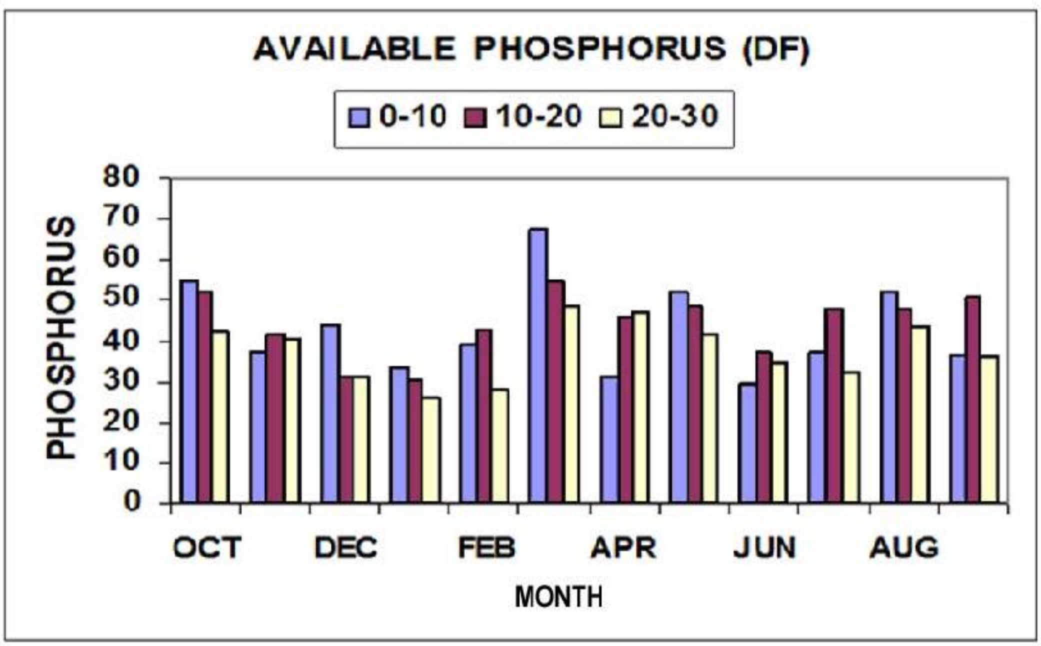

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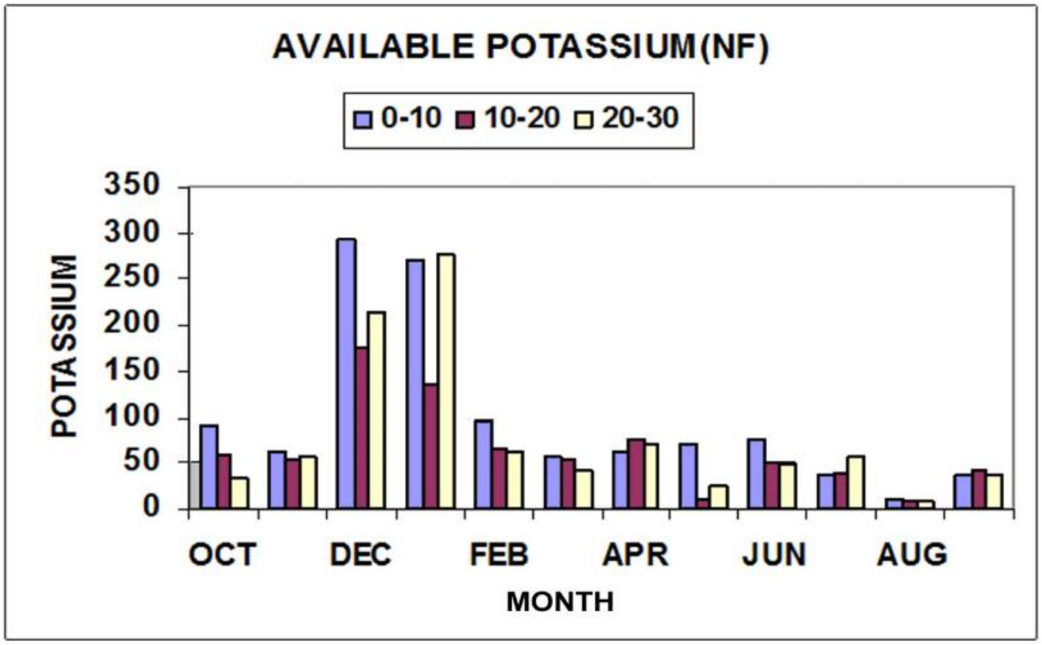
Figure 7: Monthly variation of soil available phosphorus (kg/ht) at different soil (a) natural (b) degraded forest ecosystem

Soil Potassium

Soil potassium content did not show any definite increasing ordecreasing trend in different soil layers in both sites **(fig. 8a and 8b).** However in both sites, December and January recorded higher content with the least in August in all layers. Winter season has recorded maximum potassium content followed by summer and rainy season in both sites. Potassium content is comparatively more in natural forest site than the degraded one. On seasonal basis, winter and rainy season recorded higher amount in natural forest than degraded forest, however the reverse has bee observed during summer season.

In natural forest, minimum of soil Potassium was recorded in the month of August as 11.20 kg/he in 0-10cm layer and 4.4 kg/he in 10-20cm and 20-30cm soil layer. However, maximum is recorded during December (294 kg and 175.6 kg/he in 0-10 cm and 10-20 cm soil layer respectively) and in January (277.4 kg/he in 20-30cm soil layer).

In degraded forest, also minimum of soil Potassium was recorded during August in different soil layers (7.5 kg, 7.6kg and 70 kg per hectare in 0-10cm, 10-20 cm and 20-30 cm respectively). The maximum value was recorded 297.4 kg/he (January), 219.8 kg/he (March) and 220.4 kg/he (January) in 0-10 cm, 10-20 cm and 20-30 cm respectively.



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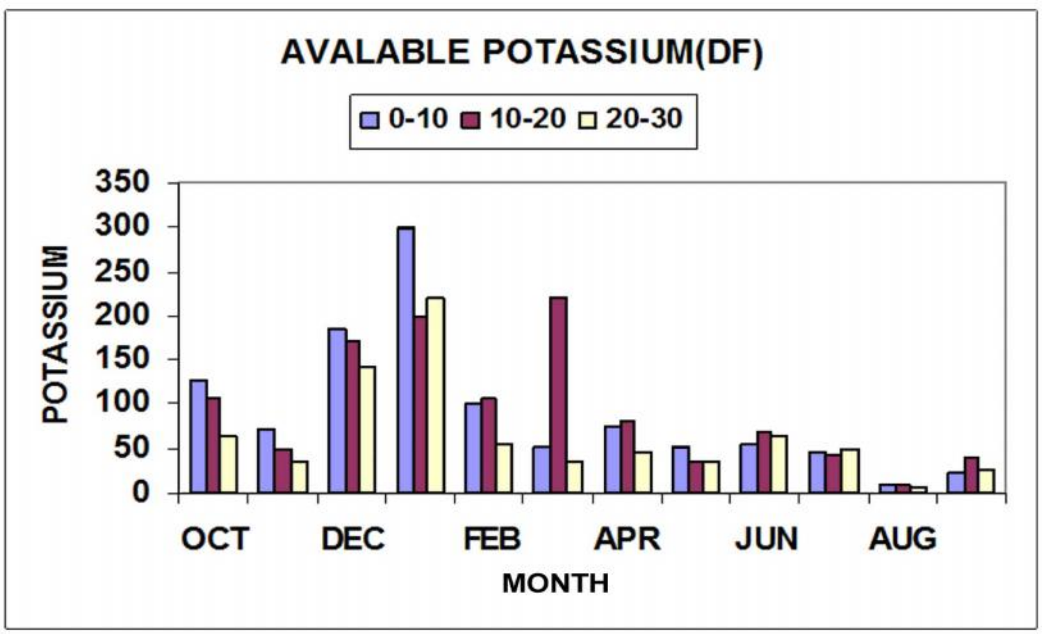


(b)

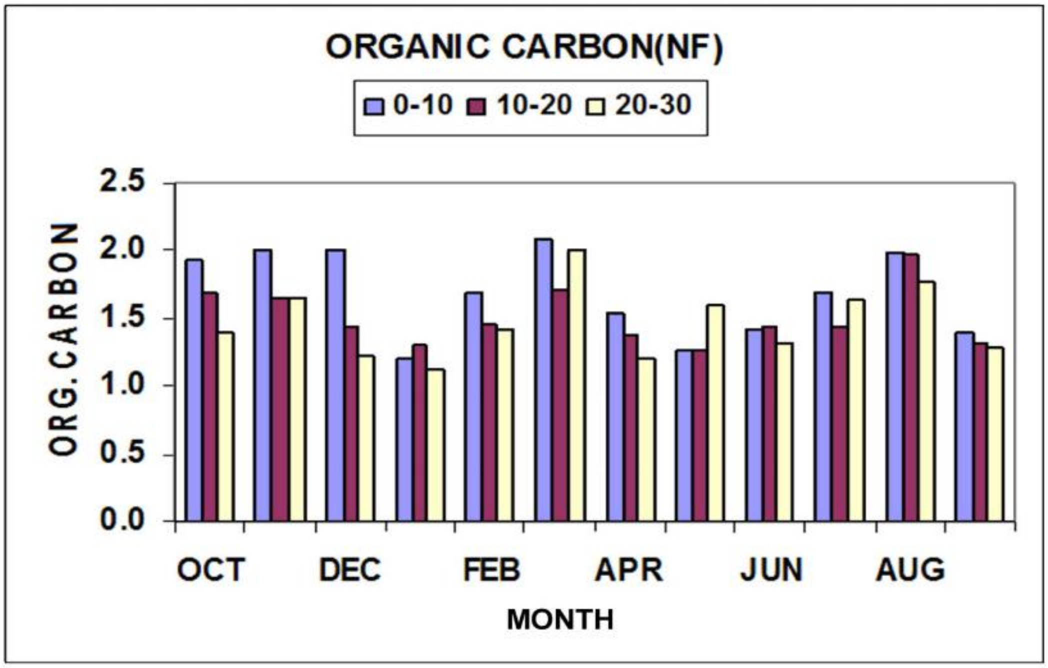
Figure 8: Monthly variation of soil Potassium at different soil layers (a) natural and (b) degraded forest ecosystem.

Soil Organic carbon

The soil organic carbon is comparatively more in natural forest site than the degraded one (**Fig. 9a and 9b**). It may be due to the higher accumulation of litter and higher decomposition rate of organic matter in the natual forest than the disturb forest where the ve very sparse. However, the three seasons have not shown appreciable difference in soil organic in both sites.

In natural forest, minimum of the soil organic carbon was recorded in the month of January (1.20%, 1.30% and 1.12% in 0-10 cm, 10-20 cm and 20-30 cm respectively) and March recorded maximum at 0-10 cm (2.08%) and 20-30 cm soil layer (1.96%) and August at 10-20 cm (1.96%).

In degraded forest, the soil organic carbon ranges from 1.07% (September) to 2.00% (October) in 0-10cm layer, from 1.30% (June) to 1.76% (August) in 10-20cm layer and from 0.69% (March) to 1.79% (April) in 20-30cm soil layer.



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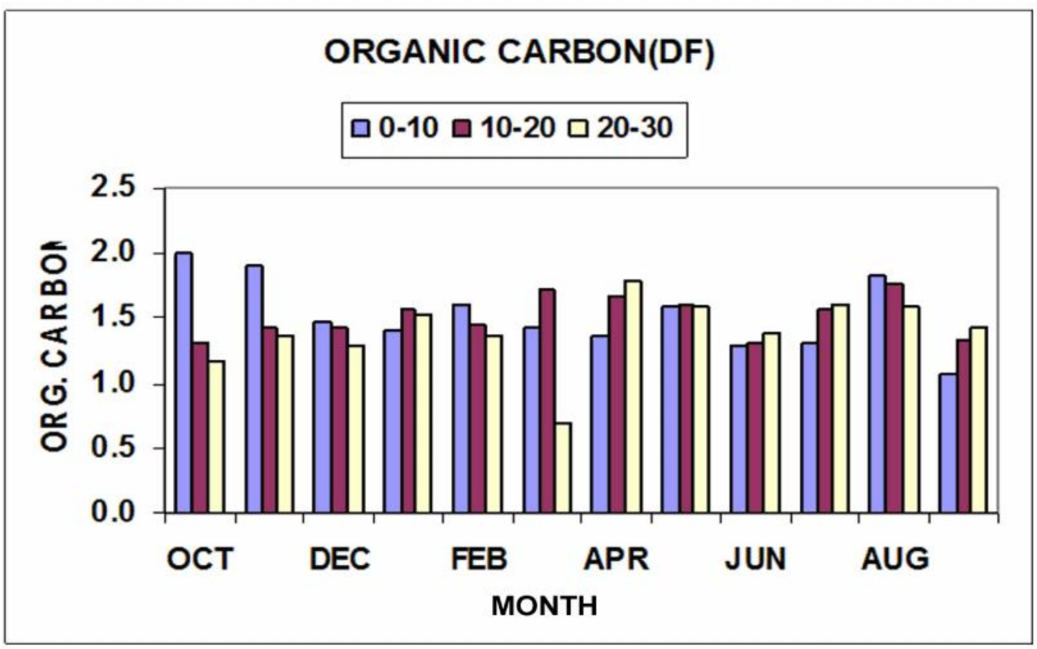


(b)

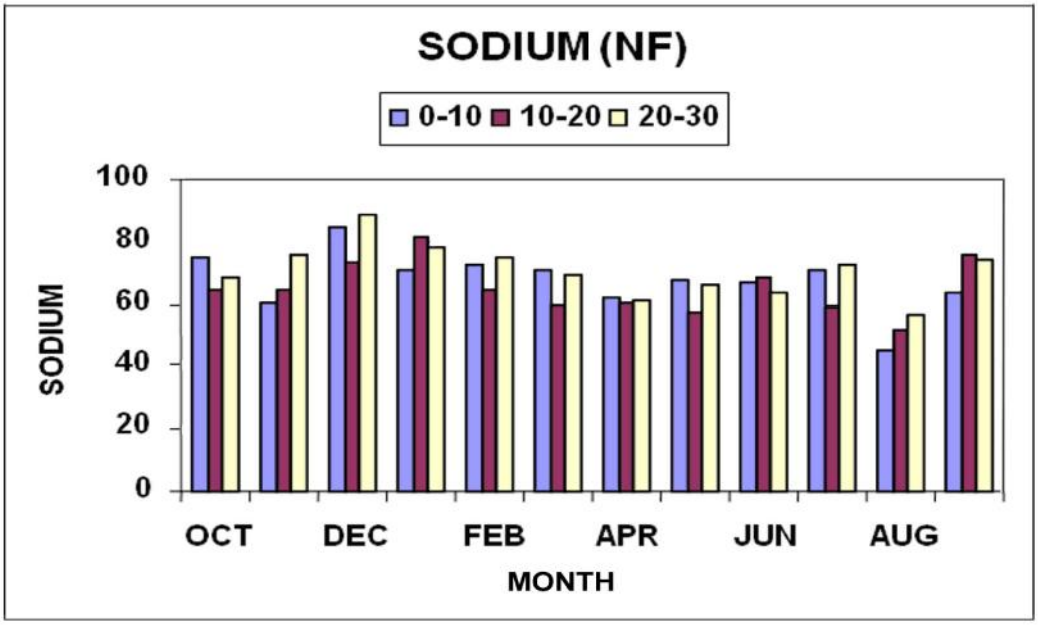
Figure 9: Monthly variation of soil organic carbon (%) at different soil layers (a) Natural and (b) degraded forest ecosystem.

Soil Sodium

While there is no consistency on monthly variation, soil sodium content is comparatively recorded higher in natural forest than the degraded site **(fig. 10a and 10b)** Further, on seasonal basis also natural forest exhibited higher content than degraded one in respective seasons havin recorded maximum during winter followed by summer and rainy season.

In natural forest, minimum soil Sodium was recorded during August in all soil depth layers (45.40, 52.00 and 56.80 kg/he in 0-10 cm, 10-20 cm and 20-30 cm soil layer respectively). Maximum was recorded during December (85.o8 and 88.4 kg/he in 0-10 cm and 20-30 cm layer respectively) and in January (81.2 kg/he in 10-20 cm soil layer).

In degraded forest, minimum of soil Sodium was recorded during January 39.80 and 44.80 kg/he in 0-20 cm layer) and in May (48.2 kg/he in 20-30 cm). However maximum was recorded during December in all soil depth layers (83.44, 84.60 and 77.0 kg/he ranges from 39.80 kg/he (August) to 83.44 kg/he (December) in 0-10cm layer, from 44.80 kg/he (August) to 84.60 kg/he (December) in 10-20cm layer and from 48.20 kg/he in 0-10, 10-20 and 20-30 cm layer respectively.



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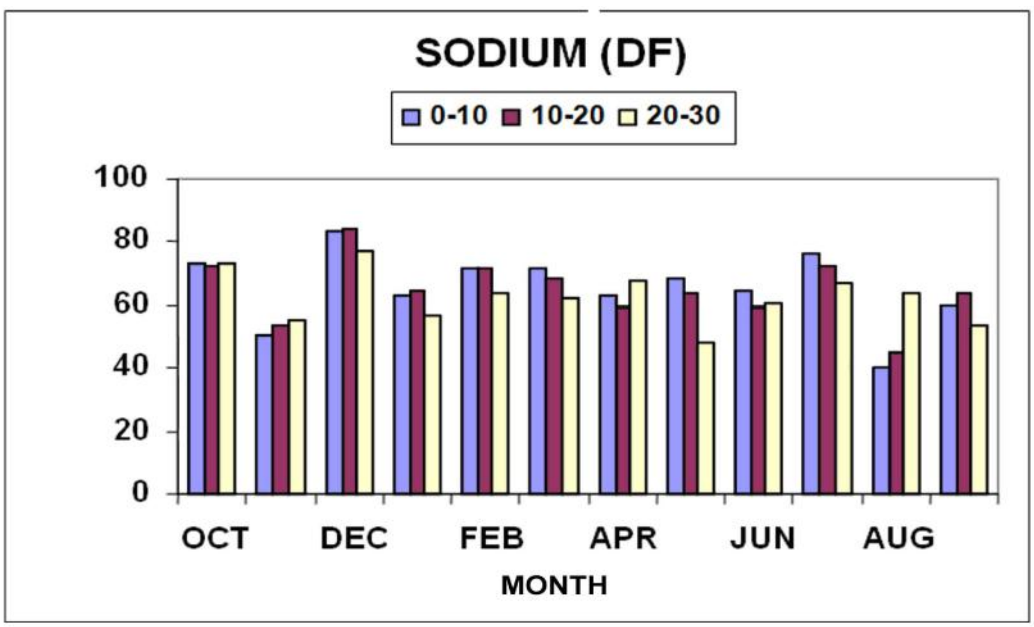


(b)

Figure 10: Monthly variation of soil sodium (%) at different soil layers (a) Natural and (b) degraded forest ecosystem.

Chapter - VI

POPULATION DYNAMICS OF SOIL AND LITTER MICROARTHROPODS IN NATURAL AND DEGRADED FOREST

The microarthropods recorded from the two study sites (natural and degraded forest ecosystem) are grouped into two components (A) soil microarthropod component which is further subdivided according to three soil sub layers viz. 0-10cm, 10-20cm and 20-30cm and (B) litter microarthropod component. On the basis of density, number and contribution to the total microarthropods, populations are classified into two main groups i.e. Acarina and Collembola. However, some others such as Protura, Diplura, Myriapoda, Hymenoptera, Pseudoscorpion, Homoptera, Coleoptera etc. which were also recorded, but exhibited very low contribution throughout the study period are placed under 'other soil microarthropods'. Accordingly different aspects of microarthropods are discussed with more emphasis to the groups given below:

1. Acarina
11. Collembola
111. Others

SOIL COMPONENT

Acarina (Mites)

Annual population density and vertical distribution

The total annual population density of Acarina and their distribution pattern in different soil layers is recorded higher in the natural forest than the degraded forest sites **(Table 1)**. The higher concentration of population density in natural forest may be attributed to close canopy with vegetation cover, availability of food, accumulation of litter and optimum physico-chemical factors that favour optimum growth of acarine population. On the other hand, disturbances and lack of canopy in degraded forest site may have a negative impact on soil microarthropods community.

In natural forest, the total annual population density of Acarina recorded was 396.94 x 10^2m^{-2}, which is 39.26% of the total soil microarthropods population. Population density of Acarina shows decreasing trend with increase in soil depth in different soil layers i.e. 188.80 x 10^2m^{-2} (47.56%) at 0-10cm, 13602 x 10^2m^{-2} (34.27%) at 10-20 cm and 72.12 x 10^2m^{-2} (18.19%) at 20-30cm. Percentage contribution of Acarina to total soil microarthropods in different depth layers also exhibited similar trend which is reflected as 40.91%, 40.47% and 33.81% in 0-10, 10-20, and 20-30 cm layers respectively.

In degraded forest, the total annual population density of Acarina recorded was 226.32 x 10^2m^{-2}, contributing 37.51% to the total soil microarthropod population. At different soil layers, population density of Acarina showed decreasing trend with increase in soil depth i.e. 150.69 x 10^2m^{-2} (66.58%) at 0-10 cm, 50.82 x 10^2m^{-2} (22.46%) at 10-20 cm and 24.81 x 10^2m^{-2} (10.96%) at 20-30 cm. Acarina constituted 44.03%, 31.21% and 25.23% at 0-10cm, 10-20cm and 20-30cm soil layers respectively to the total soil microarthropods.

The higher density of microarthropods in Acarina in upper layer of the soil (0-10cm) is characterized by favourable moisture condition, adequate living space aeration ratio and rich accumulation of organic debris (Peterson, 1980; Hagvar, 1983) had also observed higher density of microarthropod population in the upper layers of the soil. However steep decline in population density in lower layer (20-30 cm) in degraded forest in comparison to natural forest may be attributed to poor living space, insufficient food resources and inimical microclimatic condition which results in maximum migration to top layer.

Table 1: Total Numbers and percentage of Acarina

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)
(B= Percentage contribution to the total soil microarthropods in each layers respectively)
(Numbers ± S. E. x 10^2 m^{-2})

(a) Natural forest ecosystem

Soil layer (cm)	Number ± S.E.	A%	B%
0-10	188.60 ± 0.68	47.54	40.86
10-20	136.02 ± 0.48	34.28	40.47
20-30	72.12 ± 0.18	18.18	33.81
Total	396.74 ± 3.69	100.00	39.26

(b) Degraded forest ecosystem

Soil layer (cm)	Number ± S.E.	A%	B%
0-10	150.69 ± 0.26	66.58	44.03
10-20	50.82 ± 0.22	22.46	31.21
20-30	24.81 ± 0.13	10.96	25.23
Total	226.32 ±1.74	100.00	37.51

Seasonal variation of Acarina

The seasonal variation of Acarina for the natural and degraded ecosystem was shown in **(Table 2).**

Population density in natural forest ecosystem was found to be more abundant during rainy season (228.66 x 10^2m^{-2}), followed by summer (108.74 x 10^2m^{-2}) and winter season (59.34 x 10^2m^{-2}) respectively. The seasonal vertical distribution pattern of Acarina showed a decreasing trend with increase in soil depth in all seasons. Among the soil layers, the highest vertical population density was recorded in 0-10 cm during rainy season (101.39 x 10^2m^{-2}) and the lowest was recorded in 20-30cm during winter season (10.04 x 10^2m^{-2}).

In the degraded forest ecosystem, population density was found to be higher during the rainy season (121.16 x 10^2m^{-2}) and followed by summer (72.69 x 10^2m^{-2}) and winter season (32.47 x 10^2m^{-2}) respectively. The seasonal vertical distribution pattern also showed a decreasing trend with increase in soil depth in all the seasons like that of natural forest site. Among the soil layer, the maximum vertical population density was recorded in 0-10cm during rainy season with its value of 78.87 x 10^2m^{-2} and the minimum was recorded during winter in 20-30cm (4.02 x 10^2m^{-2}).

Higher population density during rainy season is attributed to congenial temperature and moisture that favour growth and development of acarina population. It indicates clearly that thick cover of litter in the natural forest form suitable substratum for accumulation and aggregation of a large number of individuals in the top layer at 0-10cm. Reduction in the abundance and aggregation of individuals in deeper layers may be due to the reduction of pore space, less available food sources and corresponding unfavourable microclimatic conditions. However, in degraded site, acarine population is comparatively less than the natural forest due to less vegetation and litter cover that makes the condition drier.

Table 2: Seasonal variation of Acarina (Numbers ± S. E. x $10^2 m^{-2}$)

(a) Natural forest ecosystem

Group of Soil micro-arthropods	Season	Soil layer (cm)			Total
		0-10cm	10-20cm	20-30cm	
Acarina	Winter	32.05±1.69	17.25 ± 1.04	10.04 ±1.16	59.34 ± 3.10
	Summer	55.16 ±3.07	35.17 ± 1.72	18.41 ± 1.28	108.74±2.21
	Rainy	101.39±3.52	83.60 ± 0.86	43.67 ± 1.43	228.66 ± 2.04
	Annual	188.60±1.33	136.02± 1.20	72.12 ± 0.69	396.74 ± 3.63

(b) **Degraded forest ecosystem**

Group of Soil micro-arthropods	Season	Soil layer (cm)			Total
		0-10cm	10-20cm	20-30cm	
Acarina	Winter	20.17 ± 1.12	8.28 ± 0.88	4.02 ± 0.11	32.47 ± 1.20
	Summer	51.65 ± 3.64	13.67 ± 2.15	7.37 ± 0.36	72.69 ± 1.27
	Rainy	78.87 ± 1.74	28.87 ± 0.42	13.42 ± 3.28	121.16 ± 4.06
	Annual	150.69 ±1.05	50.82 ± 3.78	24.81 ± 4.11	226.32 ± 3.27

Monthly variation of Acarina

Monthly variation of total population density of Acarina exhibited similar trend in both natural and degraded forest. With the initial record of 24.68 x 10^2m^{-2} and 15.27 x 10^2m^{-2} during October, the number decreases to minimum during January (5.90 x 10^2m^{-2} and 1.93 x 10^2m^{-2}) in natural and degraded forest respectively. Thereafter, with a sharp increase during February, population density exhibits a trend of steady and gradual increases in the following months in both natural and degraded forest reaching the peak during August (70.77 x 10^2m^{-2} and 40.08 x 10^2m^{-2} respectively) **(Fig.11).**

While Acarina population in natural forest ecosystem showed maximum density in the month of August for all soil depth layers (31.06 x 10^2m^{-2}, 26.10 x 10^2 m^{-2} and 13.61 x 10^2m^{-2} in 0-10, 10-20 and 20-30 cm layers respectively) the minimum was recorded during January i.e. 3.58 x 10^2m^{-2} at 0-10 cm, 0.79 x 10^2m^{-2} at 10-20 cm and 1.53 x 10^2m^{-2} at 20-30 cm **(Fig. 12 a).**

In degraded forest also, acarina population at all soil depth showed maximum in the month of August (26.45 x 10^2m^{-2} in 0-10cm, 9.38 x 10^2m^{-2} in 10-20 cm, 4.25 x 10^2m^{-2} in 20-30 cm) and minimum during January (1.42 x 10^2m^{-2}, 0.23 x 10^2m^{-2} and 0.28 x 10^2m^{-2} at 0-10,10-20 and 20-30 cm soil layers respectively) (**Fig. 12 b**).

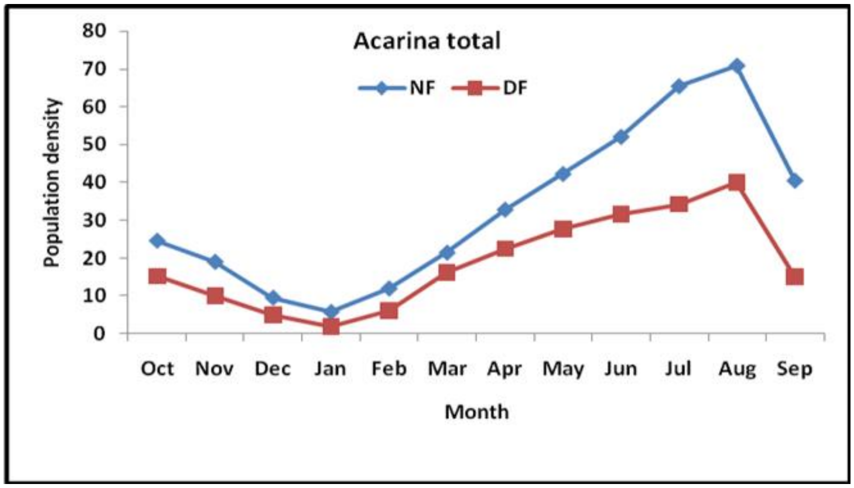
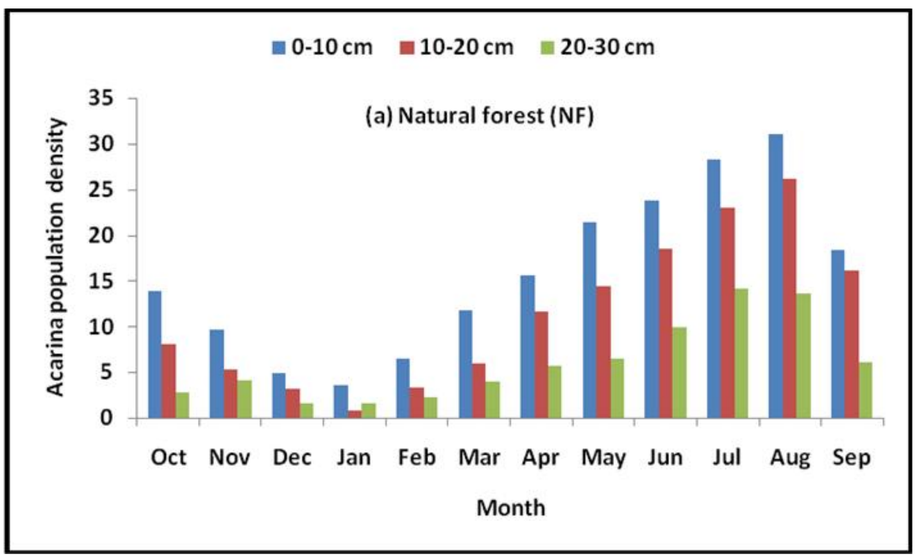


Figure11: Monthly fluctuation of total Acarina population density (Numbers x10²m⁻²) in natural (NF) and degraded (DF) forest ecosystem.



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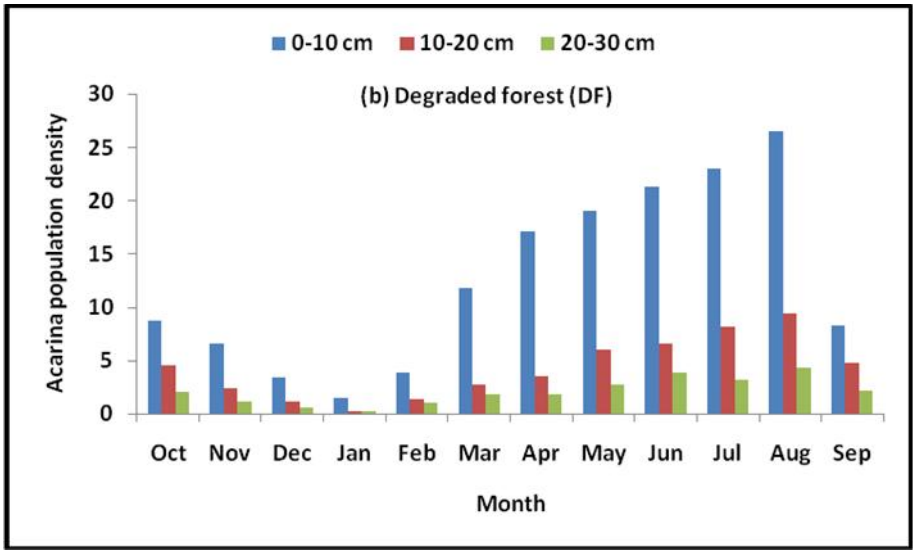


(b)

Figure 12: Monthly vertical distribution of total Acarina population density (Numbers x $10^2 m^{-2}$) in different soil layers of (a) natural (NF) and (b) degraded (DF) forest ecosystem

The analysis of variance (ANOVA) of Acarina population in the natural forest ecosystem showed highly significant difference in all seasons; winter season (F=36.310, p<0.001), summer season (F=12.861, p<0.001), rainy season (F= 3.639, p <0.037) and annual (F=5.783, p<0.007) at 0-10 cm. At 10-20 cm soil layer also highly significant difference was observed in all the seasons: winter season (F= 16.450, p<0.001), summer season (F=18.000,p<0.001), rainy season (F= 15.040,p<0.001) and annual (F= 6.496,p<0.004). However, having highly significant difference (F=13.026,p<0.001) only during winter season, difference was not significant in summer, rainy and annual population density at 20 there-30 cm soil layer (**Table 3 to 5**).

In degraded forest ecosystem at 0-10 cm soil layer, difference was highly significant and significant in winter (F = 10.530, p<0.001) and summer season (F= 4.096,p<0.026) respectively, however no significant difference was observed for rainy and annual total. At 10-20 cm soil layer, significant difference was observed in all the seasons i.e., winter season (F=17.947, p<0.001), summer (F = 4.378, p <0.02), rainy season (F=5.522, p<0.004) and annual (F = 8.195, p<0.02). At 20-30 cm soil layer difference was highly significant during winter season (F= 7.216. p<0.001) only (**Table 6 to 8**).

The total analysis of variance (ANOVA) of Acarina considering average population density in different months exhibited highly significant difference in both natural (F=20.051,p<0.001) and degraded (F=24.131,p<0.001) forest ecosystem (**Table 9 and 10**).

Table 3: Analysis of variance (ANOVA) of Acarina population in different months of natural forest ecosystem

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter					
	Between the months	3	23.718	7.906	36.310	P<0.001
	Within the months	16	.870	5.800		
	Total	19	24.588			
	Summer					
	Between the months	3	16.707	5.569	12.861	P<0.001

	Within the months	16	6.495	.433		
	Total	19	23.202			
(0-10)	**Rainy**					
	Between the months	3	24.093	8.031	3.639	P<0.037
	Within the months	16	33.100	2.207		
	Total	19	57.193			
	Annual					
	Between the months	11	4.949	1.650	5.783	P<0.007
	Within the months	48	4.564	.285		
	Total	59	9.513			

Table 4: Analysis of variance (ANOVA) of Acarina population in different months of natural forest ecosystem

Soil Layer (cm)	**Source of variation**	**df**	**SS**	**MS**	**F**	**P**
	Winter season					
	Between the months	3	5.721	1.907	16.450	P<0.001
	Within the months	16	1.855	.116		
	Total	19	7.576			
	Summer season					

	Between the months	3	.242	1.414	18.000	P<0.001
	Within the months	16	1.257	7.856		
	Total	19	5.499			
(10-20)	**Rainy season**					
	Between the months	3	9.475	3.158	15.040	P<0.001
	Within the months	16	3.360	.210		
	Total	19	12.835			
	Annual					
	Between the months	11	1.441	.480	6.496	P<0.004
	Within the months	48	1.183	7.395		
	Total	59	2.624			

Table 5: Analysis of variance (ANOVA) of Acarina population in different months of natural forest ecosystem

Soil Layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	2.118	.7 06	13.026	P<0.001
	Within the months	16	.867	5.419		
	Total	19	2.985			
	Summer season					
	Between the months	3	.721	.240	.494	P<0.691

	Within the months	16	7.785	.487		
	Total	19	8.506			
20-30	**Rainy season**					
	Between the months	3	1.605	.535	.779	P<0.523
	Within the months	16	10.980	.686		
	Total	19	12.585			
	Annual					
	Between the months	11	.194	.265	.244	P<0.885
	Within the months	48	4.242			
	Total	59	4.435			

Table 6: Analysis of variance (ANOVA) of Acarina population in different months in degraded forest ecosystem

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	.835	.945	10.530	P<0.0 01
	Within the months	16	1.436	8.976		
	Total	19	4.271			
	Summer season					
	Between the months	3	3.261	1.087	4.096	P<0.026
	Within the months	16	3.980	.265		

	Total	19	7.241			
0-10	**Rainy season**					
	Between the months	3	3.352	1.117	2.717	P<0.079
	Within the months	16	6.579	.411		
	Total	19	9.931			
	Annual					
	Between the months	11	.383	.128	1.146	P<0.361
	Within the months	48	1.782	.111		
	Total	59	2.165			

Table 7: Analysis of variance (ANOVA) of Acarina population in different months in degraded forest ecosystem

Soil Layer (cm)	Source of variation	df	SS	S	F	P
	Winter season					
	Between the months	3	4.370	1.457	17. 947	P<0.001
	Within the months	16	1.298	8.116		
	Total	19	5.668			
	Summer season					
	Between the months	3	3.628	1.209	4.378	P<0.020
	Within the months	16	4.420	.276		
	Total	19	8.048			

10-20	**Rainy season**					
	Between the months	3	5.338	1.779	5.522	P<0.004
	Within the months	16	10.311	.322		
	Total	19	15.649			
	Annual					
	Between the months	11	1.048	.349	8.195	P<0.002
	Within the months	48	.682	4.263		
	Total	59	1.730			

Table 8: Analysis of variance (ANOVA) of Acarina population in different months in degraded forest ecosystem

Soil Layer (cm)	Source of variation	df	SS	S	F	P
	Winter season					
	Between the months	3	2.705	.902	17.216	P<0.001
	Within the months	16	.838	5.238		
	Total	19	3.543			
	Summer season					
	Between the months	3	.115	3.827	.232	P<0.873
	Within the months	16	2.643	.165		
	Total	19	2.758			

(20-30)	R**ainy season**					
	Between the months	3	1.080	.360	1.635	P<0.221
	Within the months	16	3.523	.220		
	Total	19	4.602			
	Annual					
	Between the months	11	.271	9.028	2.304	P<0.116
	Within the months	48	.627	3.918		
	Total	50	.898			

Table 9: Analysis of variance (ANOVA) of Acarina population in all months of natural forest ecosystem.

Source of variation	**df**	**SS**	**MS**	**F**	**P**
Between the months	11	45.899	4.173	20.051	P<0.001
Within the months	48	9.989	.208		
Total	59	55.888			

Table 10: Analysis of variance (ANOVA) of Acarina population in all months of degraded forest ecosystem.

Sourceof variation	df	SS	MS	F	P
Between the months	11	17.094	1.554	24.131	P<0.0 01
Within the months	48	3.091	6.440		
Total	59	20.186			

Acarina was found to be dominant group comprising 39.26% and 37.51% of the total soil microarthropods in natural and degraded sites respectively. Higher abundance of Acarina among soil microarthropods were also reported in different forest ecosystem (Ryke and Loots, 1967; Mitchell, 1977; Wallwork, 1983; Sarkar, 1991; Norton, 1994; Behan-Pelletier and Walter, 2000). While studying in protected and degraded sites in Imphal valley, Chitrapati (2002) reported that Acarina comprised 66% and 63% of total soil microarthropods. Doulo (2007) also reported that Acarina comprised 42.4% and 40.8% of the total soil microarthropods in natural and degraded in forest sites respectfully in Lumami, Nagaland. The Acarina population was recorded to be 1.75 times higher in the natural forest (396.74 x $10^2 m^{-2}$) than the degraded site (226.32 x $10^2 m^{-2}$). Having been less disturbed and with more favourable microclimatic condition natural site possessed higher Acarina population than degraded site (Aoki, 1967). Hazra (1991) also reported a decrease in population percentage of mites in deforested site as compared to the reserve forest. Ito and Aoki (1999) reported that oribatid population of subtropical regions was smaller than those of temperate or subarctic regions due to accumulation of small amount of litter, thin humus rich layer and also due to high subtropical temperature as compared to the temperate climatic soil condition. Wood (1960) reported that organic matter together with the moisture present in the soil made a condition highly favourable for higher concentration of mites. Morris (1978) also recorded higher concentration of soil fauna in ungrazed site than grazed site.

In both study sites, maximum population growth during rainy season reached the peak in August and there after retreated in post monsoon and winter season with minimum record during January to highlight strong seasonality and effect of climatic condition during the study period. This may be due to favorable, physico-chemical factors i.e. optimum condition of moisture, organic carbon content etc during rainy season as the population buildup of soil microarthropods is influenced by a variety of factors viz., vegetation, soil, climate etc. and their interaction (Narula *et al*, 1998). Badejo *et al.* (1997) reported maximum population of Acarina when there was high moisture content. Loots and Ryke (1966) reported minimum population during winter season. Many workers have also reported higher population of soil microarthropods during rainy season and a sharp decline during summer months (Hazra and Sanyal 1996; Reddy and Venkataiah 1990). In tropical India single population peak of microarthropods and Acari, mostly during monsoon or post monsoon period, have been observed by Mukharji and Singh (1970), Banerjee (1973), Gupta and Mukharji (1976), and Sinha *et al.* (1988). Bhattacharya and Raychaudhuri (1979) and Sanyal (1982) have however, observed two peaks, one during post monsoon period and another during late summer or premonsoon period. In four different habitats of Western Ghat, Rajagopal (2011) also recorded seasonal fluctuation of Mesostigmatid mites (miminim from February to April and maximum from May to December) and observed that heavy rainfall as well as dry season reduced the population drastically.

The 1.3 to 2.9 times decrease in Acarina observed in different vertical soil layers in degraded site than the natural site in the present study was due to habitat differences influenced by the kind of substratum present. Although Acarina exhibited higher aggregation in the upper soil layer (0-10cm) in both the study sites, the distributional patterns in lower depths were not drastically reduced. This might be due to considerable population growth of Acarina at lower depths having similar microclimatic condition. Many earlier workers also reported greater abundance of Acarina in the upper soil layer than the lower depth (Wallwork, 1970; Niijima, 1971 and Alfred *et al.* 1991 and Chitrapati, 2002). The strong aggregation of Acarina in the upper soil layers was primarily found to be influenced by moisture content and secondarily by temperature conditions (Strong, 1967). In the present investigation also similar pattern was observed in the population density of Acarina representing maximum in the upper soil layer at 0-10cm. The seasonal variation of Acarina in both sites in the present investigation may be attributed to cumulative effect of all physico-chemical factors rather than a single factor influence. Petersen (1980) and Hagvar (1983) had also shown that the higher densities of micro-arthropods population occurred in the upper layers of the soil. Hattar *et al.* (1998) and Chitrapati (2002) also reported maximum population of Acarina during rainy season and observed decreasing trend with the on set of winter. However, Doulo (2007) recorded higher population density of Acarina during winter season and rainy season in natural and degraded forest ecosystem respectively.

Acarina has been further classified into four sub-orders: Cryptostigmata (Oribatida), Mesostigmata (Gamasida), Prostigmata (Actinedida) and Astigmata Acaridida).

Cryptostigmata (Oribatida)

The population density of Cryptostigmata in different soil layers and its percentage contribution to total Acarina and total soil microarthropods population in both the study sites is shown in (**Table 11a and 11b).**

In natural forest, the population density of Cryptostigmata recorded was 167.74 x $10^2 m^{-2}$, which contributed 42.28% and 16.59% to the total Acarina and total soil microarthropods population respectively. Upper soil layer i.e.,0-10 cm recorded highest concentration of population density of 71.10 x $10^2 m^{-2}$ (42.39 %) followed by 62.71 x $10^2 m^{-2}$ (37.38%) and 33.93 x $10^2 m^{-2}$ (20.23%) in 10-20 cm and 20-30 cm respectively.

The population density of cryptostigmata which was lower in degraded forest than the natural forest was 147.77 x $10^2 m^{-2}$, contributing 65.29% and 24.49% to the total Acarina and total soil microarthropods population respectively. Cryptostigmata showed maximum migration towards the upper soil layer i.e., 0-10cm recording highest population density of 82.22 x $10^2 m^{-2}$ (555.64%) with a decreasing trend of 40.74 x $10^2 m^{-2}$ (27.57%) and 24.81 x $10^2 m^{-2}$ (16.792%) in 10-20cm and 20-30cm soil layers respectively. Monthly population density of Cryptostigmata was recorded to be maximum in the month of August both in natural (29.71 x $10^2 m^{-2}$) and degraded (25.54 x $10^2 m^{-2}$) forest site (**Fig. 13**).

Vertical distribution of Cryptostigmata population in natural forest ecosystem exhibited maximum during month of August in 0-10 cm (12.85 x $10^2 m^{-2}$) and in 10-20 cm (10.82 x $10^2 m^{-2}$) and in the month of July in 20-30 cm layers (7.11 x $10^2 m^{-2}$), however minimum density for all soil depth layers was recorded in the month of January (0.89 x $10^2 m^{-2}$, 0.56 x $10^2 m^{-2}$ and 0.74 x $10^2 m^{-2}$ in 0-10, 10-20 and 20-30 cm layers respectively).

In degraded forest also, Cryptostigmata population at all soil depth showed maximum in the month of August (13.38 x $10^2 m^{-2}$ in 0-10cm, 7.91 x $10^2 m^{-2}$ in 10-20 cm, 4.25 x $10^2 m^{-2}$ in 20-30 cm) and minimum population density in the month of January (0.97 x $10^2 m^{-2}$ in 0-10 cm, 0.23 x $10^2 m^{-2}$ in 10-20 cm, 0.28 x $10^2 m^{-2}$ in 20-30 cm) (**Fig. 14a and 14b**).

Table 11: Total numbers and percentage of Cryptostigmata

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)

(B= Percentage contribution to the total Acarina in each layer respectively)

(C= Percentage contribution to the total soil microarthropods in each layer respectively)

(Numbers ± S.E) x $10^2 m^{-2}$.

(a) Natural forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	71.10 ± 1.03	42.39	37.70	15.40
10-20	62.71 ± 0.49	37.38	46.10	18.66
20-30	33.93 ± 0.31	20.23	47.05	15.90
Total	167.74 ± 1.98	100.00	42.28	16.59

(b) Degraded forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	82.22 ± 0.54	55.64	54.56	24.02
10-20	40.74 ± 0.72	27.57	80.17	25.02
20-30	24.81 ± 0.15	16.79	100.00	25.23
Total	147.77 ± 1.68	100.00	65.29	24.49

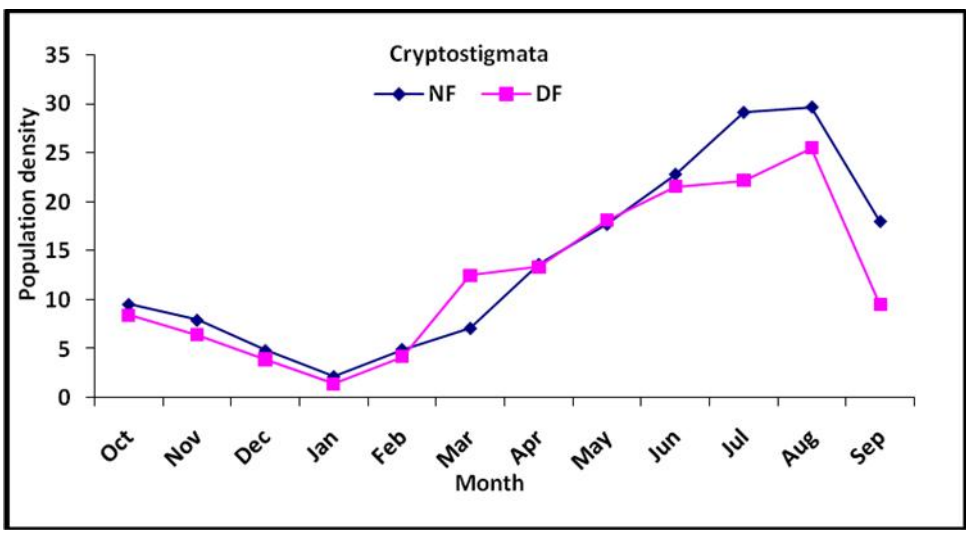
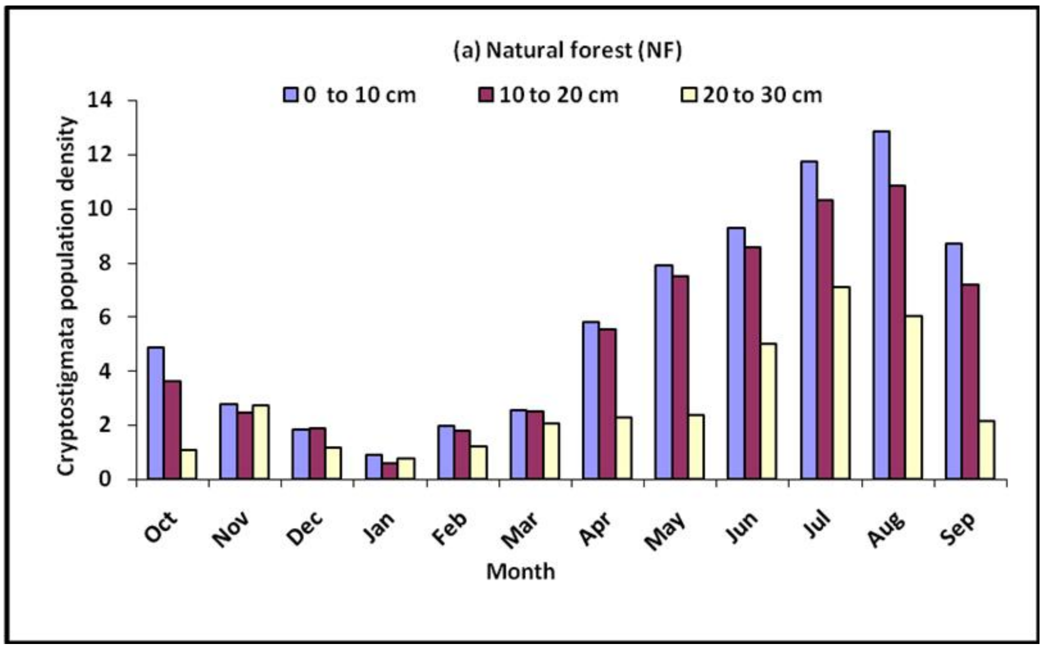


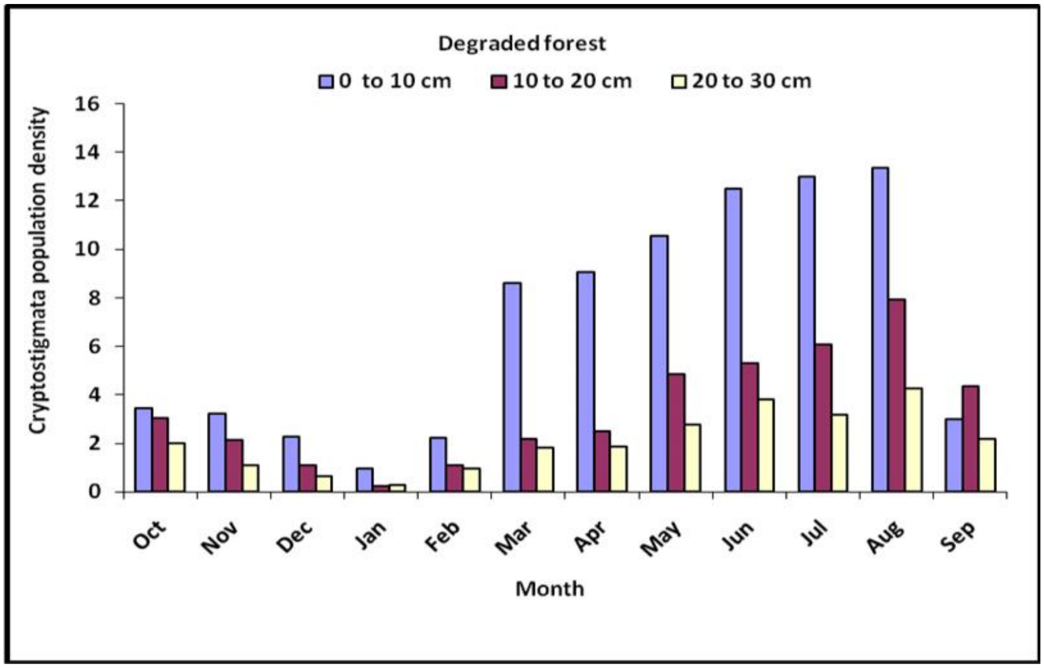
Figure 13: Monthly fluctuation of Cryptostigmata population density (Numbers x10^2m^{-2}) in natural (NF) and degraded (DF) forest

ecosystem.



(a) Natural forest (NF)
0 to 10 cm
10 to 20 cm
20 to 30 cm
Cryptostigmata population density
0
2
4
6
8
10
12
14
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month

(a)



(b)

Figure 14: Monthly vertical distribution of Cryptostigmata population density (Numbers x 10^2m^{-2}) in different soil layers of (a) natural (NF) and (b) degraded (DF) forest ecosystem.

Mesostigmata (Gamasida)

Population density of Mesostigmata and their dispersal pattern in different soil layers in relation to Acarina and to the total soil microarthropods in both the study site is shown in (**Table 12)**. In natural forest ecosystem, the total Mesostigmata density was recorded to be 145.27 x 10^2m^{-2} contributing 36.62% and 14.37% to the total Acarina and total soil microarthropod population respectively. Upper soil layer i.e., 0 – 10cm recorded highest concentration of population density of 66.92 x 10^2m^{-2} (46.06%) and followed by 52.99 x 10^2m^{-2} (36.48 %) and 25.36 x 10^2m^{-2} (17.46%) in 10-20 cm and 20-30 cm respectively.

In degraded forest ecosystem, the population density of Mesostigmata which was lower than that of the natural forest, was recorded to be 78.55 x

$10^2 m^{-2}$, contributing 34.71% and 13.02% to the total Acarina and total soil microarthropods population respectively. The top layer (0-10cm) recorded 87.17% (68.47 x $10^2 m^{-2}$) followed by 12.83% (10.08 x $10^2 m^{-2}$) having no record in 20-30 cm soil layer. Monthly peak density of Mesostigmata both in natural (26.47 x $10^2 m^{-2}$) and degraded (14.54 x $10^2 m^{-2}$) forest was also recorded in the month of August (**Fig. 15**).

In natural forest, population density of Mesostigmata at all soil depth was recorded maximum in the month of August (10.88 x $10^2 m^{-2}$ in 0-10cm, 10.52 x $10^2 m^{-2}$ in 10-20 cm, 5.07 x $10^2 m^{-2}$) in 20-30 cm). Minimum population density at 0-10 and 20-30 cm was recorded during December (0.96 x $10^2 m^{-2}$ and 0.42 x $10^2 m^{-2}$ respectively) and at 10-20 cm it was recorded in January (0.23 x $10^2 m^{-2}$) (**Fig. 16 a**).

In degraded forest Mesostigmata population at 0-10 cm soil depth showed maximum in the month of August (13.07 x $10^2 m^{-2}$) and minimum in the month of January (0.45 x $10^2 m^{-2}$). At 10-20 cm soil depth maximum was recorded in the month of July (2.09 x $10^2 m^{-2}$) and minimum in the month of November (0.29 x $10^2 m^{-2}$) with no individuals recorded in the month of December and January. No individual was recorded at 20-30 cm soil depth (**Fig. 16 b**).

Table 12: Total numbers and percentage of Mesostigmata

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)

(B= Percentage contribution to the total Acarina in each layer respectively)

(C= Percentage contribution to the total soil microarthropods in each layer respectively)

(Numbers ± S.E) x $10^2 m^{-2}$.

(a) Natural forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	66.92 ± 0.33	46.06	35.48	14.50
10-20	52.99 ± 0.19	36.48	38.96	15.76

20-30	25.36 ± 0.09	17.46	35.16	11.89
Total	145.27 ± 1.64	100.00	36.62	14.37

(b) Degraded forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	68.47 ± 0.63	87.17	45.44	20.01
10-20	10.08 ± 0.06	12.83	19.83	6.19
20-30	Nil	Nil	Nil	Nil
Total	78.55 ± 0.62	100.00	34.71	13.02

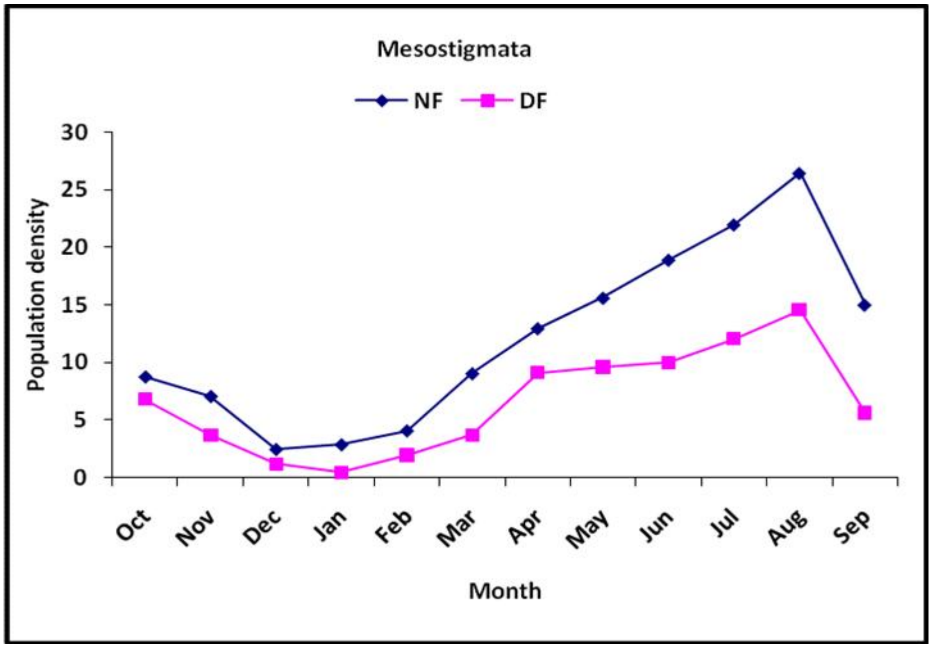
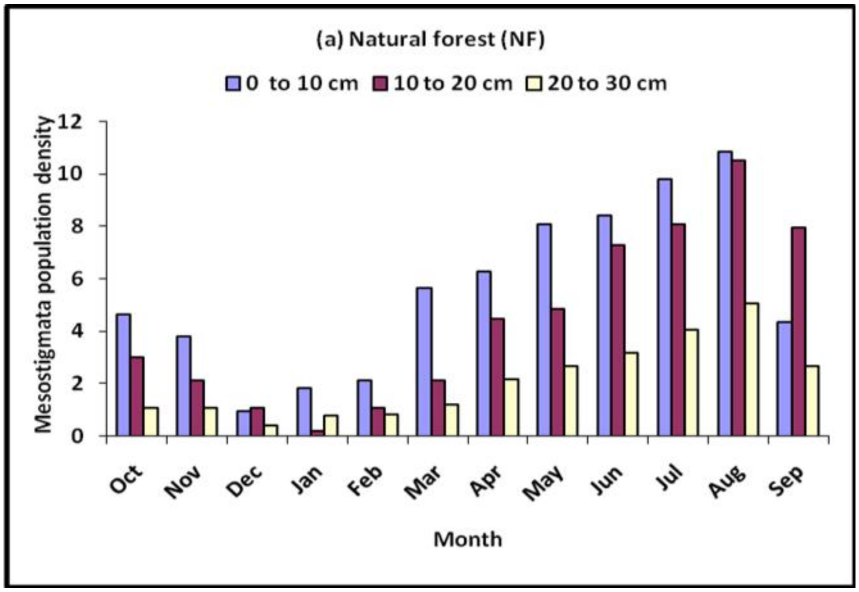
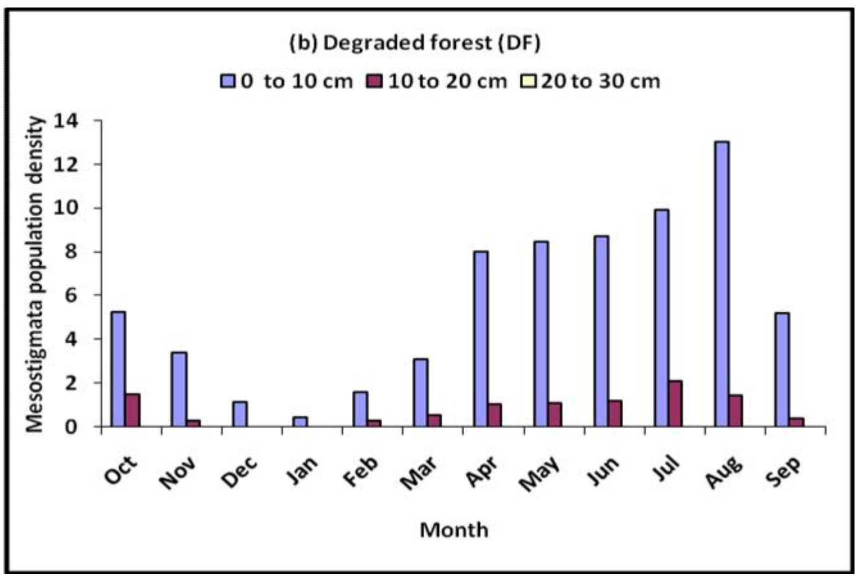


Figure 15: Monthly fluctuation of Mesostigmata population density (Number x10^2m^{-2}) in natural (NF) and degraded (DF) forest ecosystem.



(a)



(b)

Figure 16: Monthly vertical distribution of Mesostigmata population density (Numbers x $10^2 m^{-2}$) in different soil layers of (a) natural (NF) and (b) degraded forest (DF) ecosystem

Prostigmata (Actinedida)

Population of Prostigmata was recorded only in natural forest site having the total density of 45.94 x $10^2 m^{-2}$ contributing 11.58% and 4.54% to total Acarina and total soil microarthropod population respectively (**Table 13).** With the maximum concentration of 34.03 x $10^2 m^{-2}$ (74.08%) in 0-10 cm layer, the population density has been found to be decreased in 10-20 cm and 20-30 cm with the record of 8.45 x $10^2 m^{-2}$ (18.39%) and 3.46 x $10^2 m^{-2}$ (7.53%) respectively. Monthly population variation has exhibited single peak in the month of July (7.39 x $10^2 m^{-2}$) **(Fig. 17).** Among the sub-orders of Acarina, Prostigmata was third dominant having close range with Mesostigmata

In natural forest Prostigmata at 0-10 cm soil depth showed maximum in the month of August (4.49 x $10^2 m^{-2}$) and minimum in the month of January (0.84 x $10^2 m^{-2}$). At 10-20 cm soil depth, maximum was recorded in the month of July (2.07 x $10^2 m^{-2}$) and minimum the month of February (0.02 x $10^2 m^{-2}$). No individuals were recorded in the month of December and January. While at 20-30 cm soil depth, maximum was recorded in the month of July (1.00 x $10^2 m^{-2}$) and minimum in the month of November (0.04 x $10^2 m^{-2}$), no individual was recorded in the month of December, January and February **(Fig. 18).**

Table 13: Total numbers and percentage of Prostigmata

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)

(B= Percentage contribution to the total Acarina in each layer respectively)

(C= Percentage contribution to the total soil microarthropods in each layer respectively)

(Numbers ± S.E) x $10^2 m^{-2}$.

Natural forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	34.03 ± 0.16	74.08	18.04	7.37
10-20	8.45 ± 0.09	18.39	6.21	2.51
20-30	3.46 ± 0.10	7.53	4.80	1.62
Total	45.94 ± 0.26	100.00	11.58	4.54

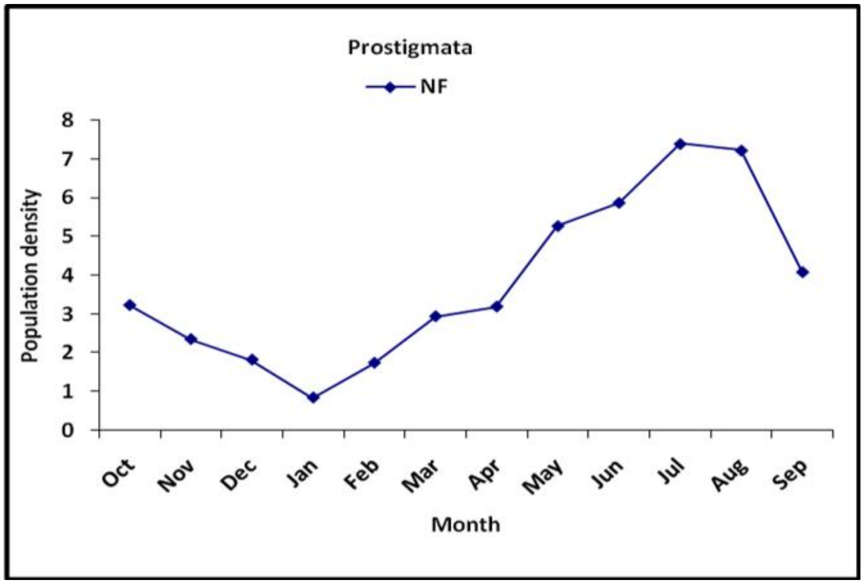


Figure 17: Monthly fluctuation of Prostigmata population density (Numbers x10^2m^{-2}) in natural forest ecosystem

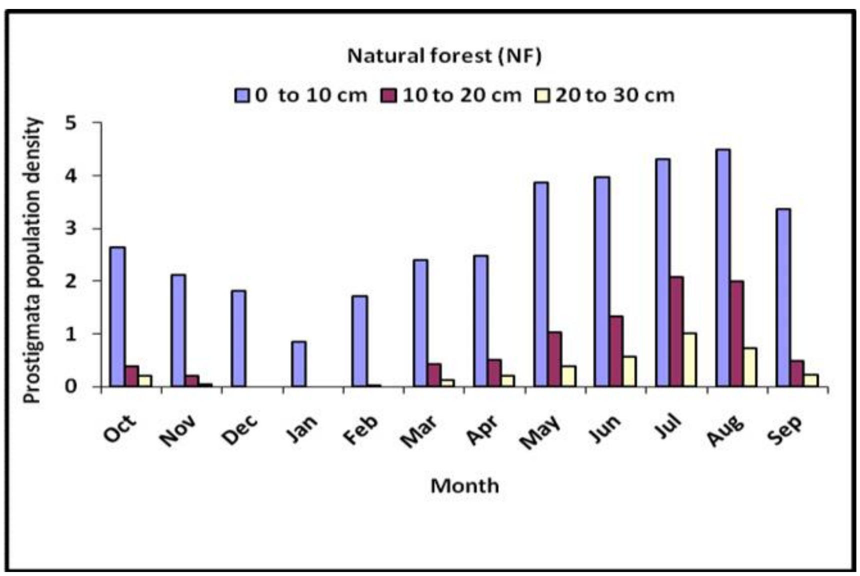


Figure 18: Monthly vertical distribution Prostigmata population density (Numbers x 10^2m^{-2}) in different soil layers of natural forest (NF) ecosystem.

Astigmata (Acaridida)

Population of Astigmata exhibited the lowest density among the four suborders of Acarina and was also recorded only in natural forest site having the total density of 37.79 x $10^2 m^{-2}$, contributing 9.53% and 3.74% to the total Acarina and total soil microarthropods population respectively. Top soil layer i.e., 0-10 cm recorded the maximum population density of 16.55 x $10^2 m^{-2}$ (43.80%) with a decreasing trend of 11.87 x $10^2 m^{-2}$ (31.41%) and 9.37 x $10^2 m^{-2}$ (24.79%) in 10-20 cm and 20-30 cm soil layers respectively (**Table 14)**. Monthly fluctuation of Astigmata showed minimum (0.52 x $10^2 m^{-2}$) and maximum (7.37 x $10^2 m^{-2}$) (**Fig. 19**) density in the month of December and August respectively having no record during the month of January.

At 0-10 cm and 10-20 cm soil depth, Astigmata population was recorded to be maximum in the month of August (2.84 x $10^2 m^{-2}$ and 2.76 x $10^2 m^{-2}$) and minimum in the month of December (0.31 x $10^2 m^{-2}$ and 0.21 x $10^2 m^{-2}$) having no record during January. At 20-30 cm soil depth, the maximum was recorded in the month of July (1.91 x $10^2 m^{-2}$) and minimum in the month of February (0.23 x $10^2 m^{-2}$) with no individual recorded in the months of December and January (**Fig. 20).** In degraded forest Astigmata population was not recorded.

Table 14: Total number and percentage of Astigmata

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)

(B= Percentage contribution to the total soil microarthropods in each layer respectively)

(C= Percentage contribution to the total soil microarthropods in each layer respectively)

(Numbers ±S.E.) x $^{2}10\ m^{-2}$

Natural forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	16.55 ± 0.08	43.80	8.78	3.59
10-20	11.87 ± 0.03	31.41	8.73	3.53
20-30	9.37 ± 0.12	24.79	12.99	4.39
Total	37.79 ± 0.18	100.00	9.53	3.74

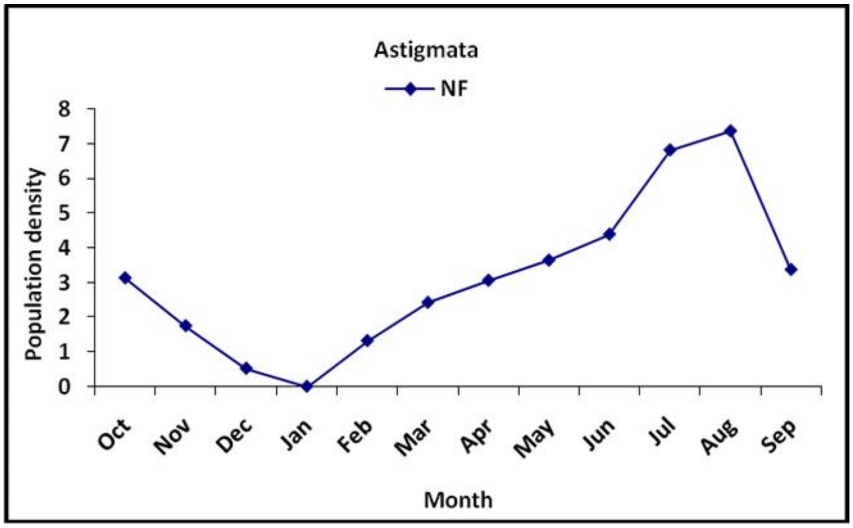


Figure 19: Monthly fluctuation of Astigmata population density (Numbers $x10^2m^{-2}$) in natural forest ecosystem.

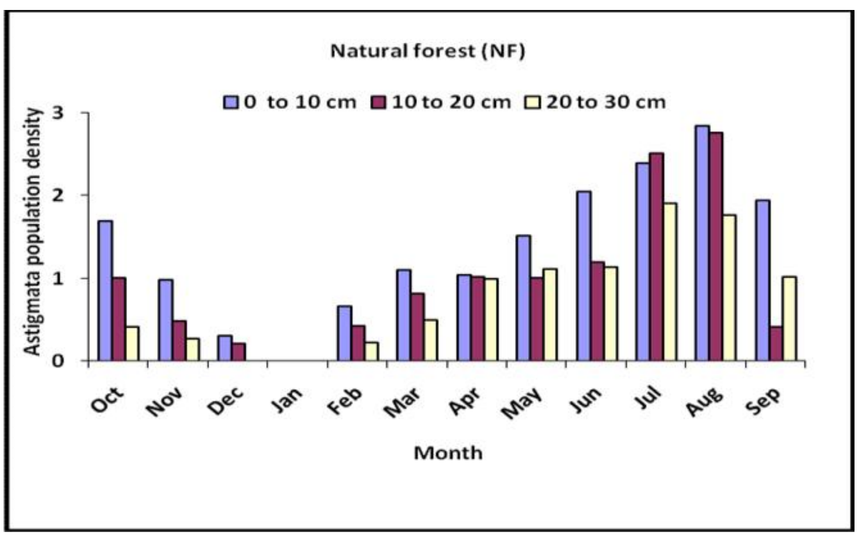


Figure 20: Monthly vertical distribution of Astigmata population density (Numbers x 10^2m^{-2}) in different soil layers of natural forest (NF) ecosystem.

Among the sub-orders of Acarina, Cryptostigmata (42.28%) was found to be the most dominant group followed by Mesostigmata (36.62%), Prostigmata (11.58%) and Astigmata (9.53%) in natural forest, while in degraded forest contribution to total Acarina population was shared by Cryptostigmata (65.29%) and Mesostigmata (34.71%,) having no record of the latter two groups. The undisturbed organic layer under trees has been found to be more preferable environment for oribatid mites (Bhaduri and Roychaudhuri, 1968). The relative density of different sub-orders of Acarina in the present study exhibited both similarity and contrast with the study as reported by others. In four different habitats in England, Madge (1965) recorded maximum contribution of Cryptostigmata (90%) followed by very less percentage of Mesostigmata (7%) and Prostigmata (3%) to total Acarina population. Block (1965) found the range of Prostigmata from 0.2 to 15% while the Cryptostigmata ranged from 62 to 94% in six habitats in England. Wallwork (1967) stated that the Cryptostigmata occurred in the greatest number in coniferous forest soils representing as much as 75% of the total Acarina population. However, Price (1973) reported Prostigmata as the most numerous among the Acarina, contributing 51.3% of the mites fauna, followed by Cryptostigmata (38.5%), Mesostigmata (10.2%) and without any record of Astigmata in pine forest ecosystem. Singh and Pillai (1981) reported that Cryptostimata accounted for 16.99 to 42.21% of the total Acari in different fields at Varanasi. Alfred *et al.* (1991), Narula *et al.* (1998) also reported the maximum density of Cryptostigmata among the Acari and usually Astigmata the least in abundance which was similar to the present finding. Chitrapati (2002) reported highest percentage of Cryptostigmata (48-52%), followed by Mesostigmata (27-29%), Prostigmata (18-29%) and Astigmata (3% only in degraded site) having similar vertical distribution in protected and degraded forest ecosystem at Imphal. Similarly, in the natural and degraded forest ecosystem in

Lumami, Nagaland, Cryptostigmata contributed 53.3 to 55.7%, Mesostigmata 25.3 to 31.7%, Prostigmata 13.2 to 14.8% and Astigmata contributed only 1.8 to 4.2% respectively to the total Acarina population (Doulo, 2007). The marked difference in the density among the different groups of Acarina in the present study and others as reported may be attributed to some physiological or behavioral adaptation as group and tolerant ability in different environmental factors (Karppinen, 1955; Ryke and Loots, 1967 and Price, 1973). Cryptostigmatid mites were very sensitive to temperature changes and responded at least in part to diurnal variations in temperature when undertaking their movement (Wallwork, 1961; Madge, 1965) The Oribatids mites acted as indices of specific microclimatic conditions and have conferred species status bioindicators to them (Bhandari and Somani, 1994). Zonal distribution of some species of Acari may be due to selectivity in their food choice (Luxton, 1966). Rajagopal (2011) recorded decrease of mesostigmatid mites during winter season. Sheals (1955) reported that the Mesostigmata and Prostigmata were both predatory and detritus feeders while the Cryptostigmata were primarily detritus feeders and Astigmata were not generally abundant in the soil, although they may occur in local concentrations, particularly in pasture and arable soils. The vertical distributional pattern of these suborders exhibited a decreasing trend with the increasing depth. The poor availability/absence of Prostigmata and Astigmata in lower vertical layers particularly 20-30 cm and total absence in degraded sites may be attributed to its less tolerance ability, poor adaptation and limited food habit. Chitrapati (2002) also reported the presence of Astigmata only in the upper most layer of the soil.

In present investigation Cryptostigmata constituted about 16.59% and 24.49% of the total soil microarthropods in natural and degraded sites respectively. Rykes and Loots (1967) reported 50% of the Cryptostigmata population of the Acari-Collembola total. Singh and Singh (1975) reported only 34% of Cryptostigmata of the total soil fauna. Chitrapati (2002) reported 32% of Cryptostigmata population of the total microarthropods. Doulo (2007) reported 24% and 22% of Cryptostigmata to the total microarthropod in natural and degraded ecosystem in Lumami, Nagaland. Seastedt (1984) reported that many Cryptostigmatid mites were mesophilus and flourish in the moist organic soils under woodland and forest. The other two groups of mites i.e. Mesostigmata and Prostigmata were also recorded higher in the natural than that of the degraded study site as these groups were also predatory and detritus feeders and more preferred in organic and high humus layers (Sheals, 1956). Ryke and Loots (1967) reported Prostigmata as the dominant form among the total Acarina population in the study of 11 different South African soils.

While comparing vertical dominancy of different sub orders of Acarina, Cryptostigmata was found to be dominant among all the other groups in all the soil layers in both natural and degraded sites which indicated wide range of tolerance ability and adaptation of Cryptostigmata to different climatic factors such as moisture content, organic carbon and possibly pH (Wallwork, 1970). It was reported that some species of Oribatid possess a close association with moist habitat (Hammer, 1944 and Haq and Ramani, 1991). Several others species exhibited negative correlation with moisture (Dhillon and Gibson, 1962; Davis, 1963) while others still respond positively to organic content of the soil (Loots and Ryke, 1967). Bhandari and Somani (1994) also reported that Oribatid mites could adapt to survive and replenish in altering environmental conditions by folding the fore part of the body against the hind part to become spherical thereby protecting themselves against desiccation or flooding of the soil as well against predators.

The least presence of Astigmata in different vertical layers and completely absent in degraded site may be attributed to its less tolerance ability, adaptation and limited food habit. Chitrapati (2002) also reported the presence of Astigmata only in upper most layer of the soil. Loots and Ryke (1966), Ryke and Loots (1967), Wood (1967) and Berg and Ryke (1968) mentioned that Astigmata were not important elements in the Acarina fauna of many soils and the roles of these mites in the soil community had been little studied.

Collembola

Annual population density and vertical distribution

The total annual population density of collembola and their distribution pattern in different soil layers was recorded higher in the natural than the degraded forest site **(Table 15).**

In natural forest ecosystem the total annual population density of Collembola was recorded 350.04 x$10^2 m^{-2}$ contributing 34.62% to the total soil microarthropod population. With 179.09 x $10^2 m^{-2}$ (51.16 %) in the top layer (0-10 cm) population density of Collembola gradually decreased to 115.13 x $10^2 m^{-2}$ (32.89%) in the middle layer (10-20 cm) and 55.82 x $10^2 m^{-2}$ (15.95%) in the 20-30 cm layer. Percentage contribution of Collembola to total soil microarthropods has been 38.80%, 34.25% and 26.17% in 0-10cm, 10-20 cm 20-30 cm respectively.

The annual population density of Collembola recorded in degraded forest was 155.32 x $10^2 m^{-2}$ which was 25.74% of the total soil microarthropods. Population density decreased along with the depth i.e. 96.94 x $10^2 m^{-2}$ (62.41%) at 0-10 cm, 42.13 x$10^2 m^{-2}$ (27.12%) at 10-20cm and 16.25 x $10^2 m^{-2}$ (10.46%) at 20-30 cm. Collembola constituted 28.32%, 25.88% and 16.53% to the total soil microarthropods at 0-10 cm, 10-20 cm and 20-30 cm soil layers respectively

Aggregation of Collembolan population in top layer (0-10cm) was found to be more in degraded (62.41%) than the natural site (51.16%).

Table 15: Total Numbers and percentage of Collembola

(A= *Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)*

(B= *Percentage contribution to the total soil microarthropods in each layers respectively)*

(Numbers ± S. E. x 10^2 m^{-2})

(a) Natural forest ecosystem

Soil layer (cm)	Number ± S.E.	A (%)	B (%)
0-10	179.09 ± 0. 43	51.16	38.80
10-20	115.13 ± 0. 59	32.89	34.25
20-30	55.82 ± 0. 40	15.95	26.17
Total	350.04 ± 2.49	100.00	34.62

(b) Degraded forest ecosystem

Soil layer (cm)	Number ± S.E.	A (%)	B (%)
0-10	96.94 ± 0.48	62.41	28.32
10-20	42.13 ± 0.18	27.12	25.88
20-30	16.25 ± 0.04	10.46	16.53
Total	155.32 ± 1.28	100.00	25.74

Seasonal variation of Collembola

The seasonal variation of Collembola for the natural and degraded ecosystem is given in **(Table 16).**

In the natural forest ecosystem, population density of Collembola was more abundant during rainy (189.57 x $10^2 m^{-2}$) followed by summer (101.55 x $10^2 m^{-2}$) and winter season (58.92 x$10^2 m^{-2}$) respectively exhibiting decreasing vertical distribution pattern with increase in soil depth, in all season. Among the soil layers, population density was found to be maximum in 0-10 cm during rainy season (90.64 x $10^2 m^{-2}$) and the minimum in 20-30 cm during winter (8.85 x $10^2 m^{-2}$).

In the degraded forest ecosystem also, population density of Collembola was maximum during the rainy (85.93x$10^2 m^{-2}$), followed by summer season(40.64 x $10^2 m^{-2}$) and winter season (28.75x$10^2 m^{-2}$).The seasonal bvertical distribution pattern of Collembola followed a decreasing trend with increase in soil layer, having a record of maximum population density in 0-10 cm (49.87 x $10^2 m^{-2}$) during rainy season and minimum in 20-30 cm (2.12 x $10^2 m^{-2}$) during winter season.

Table 16: Seasonal variation of Collembola ***(Numbers ± S.E) x*** $10^2 m^{-2}$**)**

(a) Natural forest ecosystem

Soil micro-arthropods group	Season	Soil layers			Total
		0-10cm	10-20cm	20-30cm	
Collembola	Winter	31.77 ± 1.29	18.30± 1.28	8.85 ±1.20	58.92±1.53
	Summer	56.68 ± 3.67	31.71±3.72	13.16± 3.72	101.55±2.92
	Rainy	90.64 ± 2.80	65.12± 1.10	33.81± 3.74	189.57± 4.41
	Annual	179.09 ± 2.12	115.13±2.04	55.82±4.02	350.04± 3.42

(b) Degraded forest ecosystem

Soil micro-arthropods group	Season	Soil layers			Total
		0-10cm	10-20cm	20-30cm	
Collembola	Winter	19.49 ± 0.79	7.14 ±1.33	2.12 ± 0.48	28.75 ±1.02
	Summer	27.58 ± 2.57	9.88 ±1.28	3.18 ± 0.31	40.64 ±1.35
	Rainy	49.87 ± 2.84	25.11±1.46	10.95 ± 0.77	85.93 ± 2.38
	Annual	96.94 ±0.43	42.13 ± 2.94	16.25 ± 0.94	155.32 ± 3.8

Monthly variation of Collembola

There was a monthly fluctuation of total collembola population both in natural and degraded forest exhibiting a single peak of 60.93 x 10^2m^{-2} and 28.00 x 10^2m^{-2} respectively during August (**Fig. 21**).

In natural forest, Collembolan population in all soil layers was maximum in the month of August i.e. 29.22 x 10^2m^{-2}, 19.55 x10^2m^{-2} and 12.16 x 10^2m^{-2} in 0-10, 10-20 and 20-30 cm respectively. However minimum at 0-10 cm (1.12 x 10^2m^{-2}) and 10-20 cm (0.46 x 10^2 m^{-2}) was recorded during January and at 20-30 cm (0.21 x 10^2m^{-2}) during December having no record in January.

In the degraded forest also, monthly fluctuation of population density ranged from 1.73x10^2m^{-2} (January) to 14.33x10^2m^{-2} (August) at 0-10 cm, 2.19x10^2m^{-2} (February) to 9.31x10^2m^{-2} (August) at 10-20 cm and 0.31 x10^2m^{-2} (December) to 3.76x10^2m^{-2} (August) at 20-30 cm soil layers. However collembolan population was not recorded during December and January at 10-20 cm and January at 20-30 cm soil layers. (**Fig. 22**).

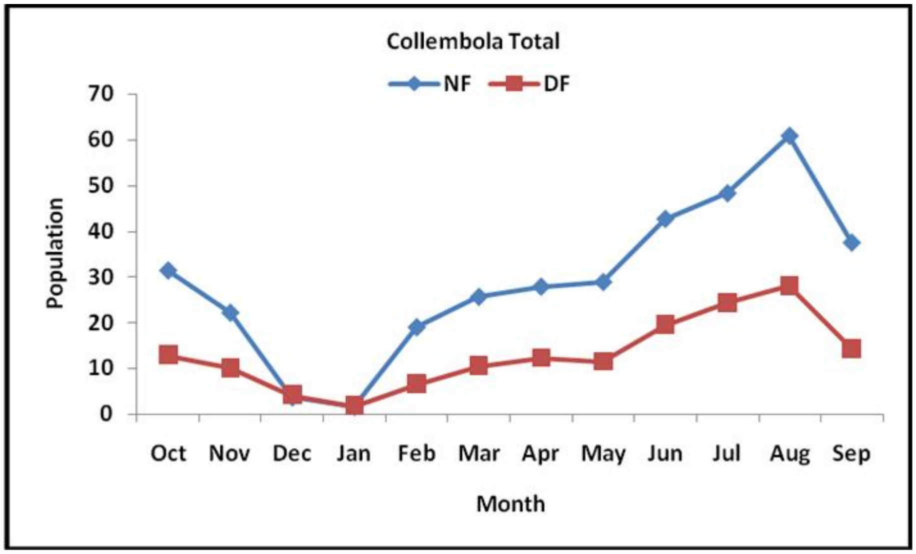
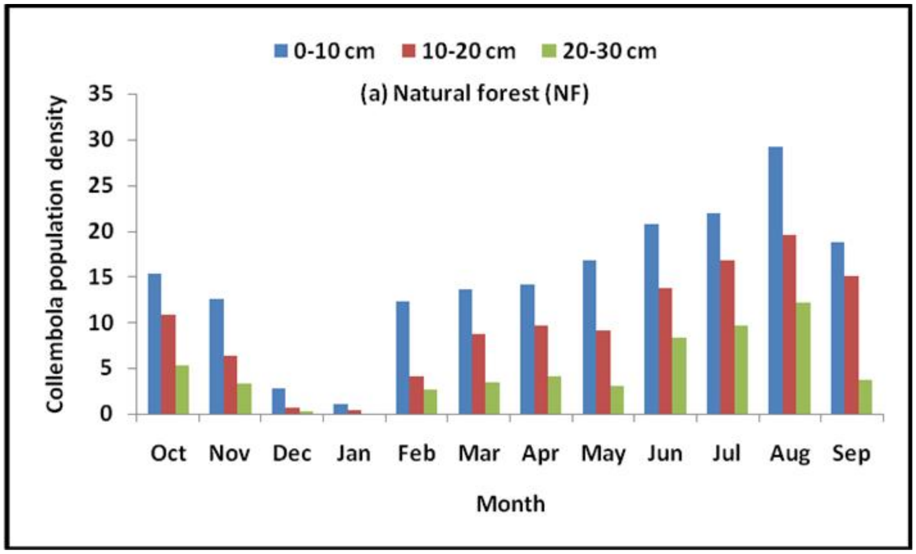
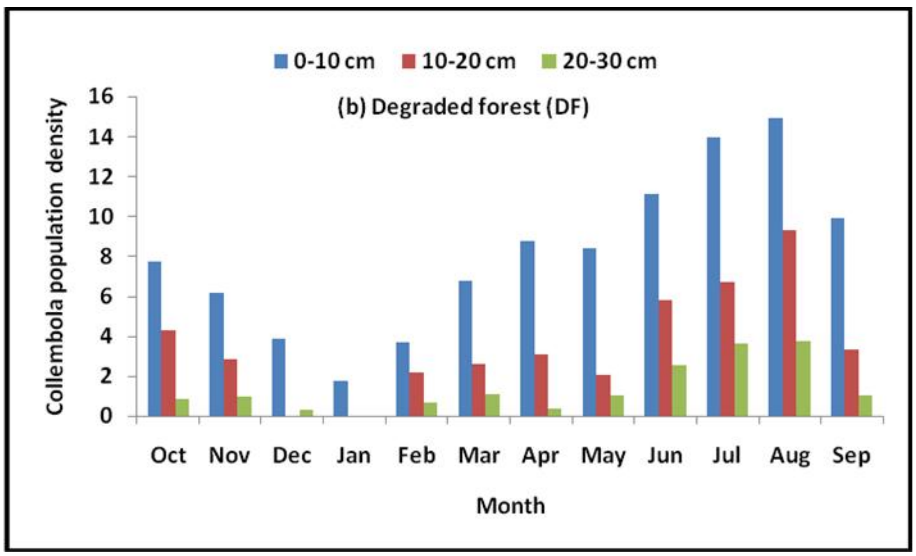


Figure 21: Monthly fluctuation of total Collembola population density (Numbers $x10^2m^{-2}$) in natural (NF) and degraded (DF) forest ecosystem



(a)



(b)

Figure 22: Monthly vertical distribution of Collembola population densit (Numbers x $10^2 m^{-2}$) in different soil layers of (a) natural (NF) and (b) degraded (DF) forest ecosystem.

The analysis of variance (ANOVA) of Collembola population in the natural forest ecosystem showed highly significant difference in winter (F=14.867,p< 0.001), rainy season (F= 3.425, p<0.043) and annual (F= 6.309, p<0.005), however it was not significant in summer season (F=.681,p<0.576) at 0-10 cm. At 10-20 cm soil layer highly significant difference was observed only during winter (F = 20.120, p<0.001) and summer season (F =5.378,p<0.009) while in rainy season and annual population difference was not significant. At 20-30 cm soil layer also ANOVA showed highly significant difference in winter season (F = 28.578,p<0.001) and summer season (F = 53.301,p<0.047), having no significant difference in rainy season and annual total (**Table 17 to 19**).

In degraded forest ecosystem at 0-10 cm layer, except for rainy season analysis of variance showed highly significant difference in winter (F=4.598,p<0.017), summer (F= 8.251, p<0.002), and total annual (F =1.328, p<0.030). At 10-20 cm soil layer significant difference was observed in rainy season (F=6.942,p<0.003), however no significant difference was observed during summer, winter and annual total. At 20-30 cm soil layer, highly significant difference was observed in winter season (F=9.275. p<0.001), summer season (F= 4.791, p<0.014), and annual total (F=9.794, p<0.001) except for rainy season (**Table 20 to 22**).

The total analysis of variance of Collembola considering average population density in different months exhibited highly significant difference in both natural (F=10.716, p<0.001) and degraded (F=25.722, p<0.001) forest ecosystem (**Table 23 and 24**).

Table 17: Analysis of variance (ANOVA) of Collembola in different months in natural forest ecosystem

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	7.399	2.466	14.867	P< 0.0 01
	Within the months	16	2.654	.166		
	Total	19	10.053			
	Summer season					
	Between the months	3	.284	9.467	.681	P< 0.576
	Within the months	16	2.224	.139		
	Total	19	2.508			
0-10	**Rainy season**					
	Between the months	3	2.020	.673	3.425	P< 0.043
	Within the months	16	3.145	.197		
	Total	19	5.165			
	Annual					
	Between the months	11	.835	.278	6.309	P<0.005
	Within the months	48	.706	4.410		
	Total	59	1.540			

Table 18: Analysis of variance (ANOVA) of Collembola in different months in natural forest ecosystem

Soil Layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	4.052	1.351	20.120	P<0.0 01
	Within the months	16	1.074	6.714		
	Total	19	5.127			
	Summer season					
	Between the months	3	2.902	.967	5.378	P<0.009
	Within the months	16	2.878	.180		
	Total	19	5.780			
10-20						
	Rainy season					
	Between the months	3	7.795	2.598	2.741	P< 0.077
	Within the months	16	1.390	.948		
	Total	19	8.840			
	Annual season					
	Between the months	11	1.028	4.633	2.853	P< 0.070
	Within the months	48	1.921	.306		
	Total	59	2.948			

Table 19 : Analysis of variance (ANOVA) of Collembola population in different months of natural forest ecosystem (20 – 30cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	7.449	2.483	28.578	P<0.001
	Within the months	16	1.390	.143		
	Total	19	8.840			
	Summer season					
	Between the months	3	1.599	.533	3.301	P<0.047
	Within the months	16	2.582	.161		
	Total	19	4.181			
20-30						
	Rainy season					
	Between the months	3	2.191	.730	1.499	P<0.253
	Within the months	16	7.797	.487		
	Total	19	9.988			
	Annual total					
	Between the months	11	.252	8.397	.943	P<0.443
	Within the months	48	1.425	8.906		
	Total	59	1.677			

Table 20 : Analysis of variance (ANOVA) of Collembola population in different months of degraded forest ecosystem (0 – 10cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	1.941	.647	4.598	P<0.0 17
	Within the months	16	2.251	.141		
	Total	19	4.192			
	Summer season					
	Between the months	3	6.277	2.092	8.251	P< 0.0 02
	Within the months	16	4.057	.254		
	Total	19	10.334			
0-10	**Rainy season**					
	Between the months	3	.623	.208	.804	P<0.510
	Within the months	16	4.133	.258		
	Total	19	4.755			
	Annual total					
	Between the months	11	.323	.108	1.328	P<0.0 30
	Within the months	48	2.929	8.103		
	Total	59	1.619			

Table 21: Analysis of variance (ANOVA) of Collembola population in different months of degraded forest ecosystem (10 – 20cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	3.391	1.130	1.966	P<0.160
	Within the months	16	9.199	.575		
	Total	19	12.590			
	Summer season					
	Between the months	3	.113	3.756	.124	P<0.945
	Within the months	16	4.844	.303		
	Total	19	4.957			
10-20						
	Rainy season					
	Between the months	3	2.200	.733	6.942	P<0.003
	Within the months	16	1.690	.106		
	Total	19	3.890			
	Annual total					
	Between the months	11	1.059	.353	2.650	P<0.084
	Within the months	48	2.131	.133		
	Total	59	3.191			

Table 22: Analysis of variance (ANOVA) of Collembola population in different months of degraded forest ecosystem (20 – 30cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	1.935	.645	9.275	P<0.0 01
	Within the months	16	1.113	6.956		
	Total	19	3.048			
	Summer season					
	Between the months	3	1.078	.359	4.791	P<0.014
	Within the months	16	1.200	7.500		
	Total	19	2.278			
20-30						
	Rainy season					
	Between the months	3	.518	.173	1.151	P<0.359
	Within the months	16	2.400	.150		
	Total	19	2.918			
	Annual season					
	Between the months	11	.575	.192	9.794	P<0.001
	Within the months	48	.847	1.957		
	Total	59	.975			

Table 23: Analysis of variance (ANOVA) of Collembola population in all months of natural forest ecosystem.

Source of variation	df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	9.949	.904	10.716	P<0.001
Within the months	48	4.051	8.441		
Total	59	14.001			

Table 24: Analysis of variance (ANOVA) of Collembola population in all months of degraded forest ecosystem.

Source of variation	df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	22.052	2.005	25.722	P<0.001
Within the months	48	3.741	7.794		
Total	59	25.794			

Collembola was the second dominant group of soil microarthropods in both study sites and constituted 34.62% and 25.74% of the total soil microarthropods in natural and degraded forest site respectively. Takeda (1981) reported 23% of Collembola to the total soil microarthropods in a forest plot. Hazra (1978) recorded about 11.8 % and 59% of Collembola among the total microarthropods. Bhattacharya and Bhattacharya (1987) recorded about 12% and 4% of Collembola in unpolluted and polluted sites in Durgapur industrial area. Chitrapati (2002) reported the contribution of 21% and 24% of Collembola to the total microarthropods in natural and degraded forest sites respectively at Imphal valley of Manipur. In five different sites of Banaras Hindu University, Varanasi, Raghuraman *et al.* (2010) recorded maximum abundance of collembolan in floral garden (23.90%) followed by Bamboo grooves (20.50%), teak plantation (20.28%), mango orchard (18.68%) and grassy field (16.55%). Doulo and Kakati (2009) recorded 24% and 28% contribution of Collembola to the total soil microarthropods in natural and degraded forest sites respectively from Nagaland.

The 2. 25 times higher population of Collembola in the natural ($350.04x10^2m^{-2}$) than the degraded forest ecosystem (155.32 $x10^2m^{-2}$) may due to the close canopy of forest area, optimum micro-climate and high organic carbon content in natural forest. The degraded site of the present investigation, with less vegetation cover and low litter accumulation had always a tendency of wide fluctuation in the microclimatic conditions of the soil profile. Thus, reduction of vegetation cover and the consequent changes in microclimate particularly low moisture form a critical period that has been considered vulnerable for Collembola population (Christiansen, 1964; Price, 1973) and had negative effects on survival and reproduction of soil microarthropods (Badejo and Straalen, 1993). Doulo and Kakati (2009) also recorded 1.3 times higher Collembolan population in the natural forest than the degraded site at

Lumami, Nagaland. Sharon *et al*. (2001) also reported that the forest floor microarthropods abundance was highly correlated with moisture and was affected mainly by the microclimate and less by soil texture.

In the present investigation 51.16% and 62.41% of the total Collembola population were confined to upper soil layer (0-10cm) in natural and degraded forest sites respectively. Comparatively low aggregation of collembolan at 0-10 cm in natural site may be due to high rainfall during summer and rainy season due to which collembolan population migrated to lower depth. The decreasing trend of population density of Collembola with the increase in the soil depth might be due to the fact that the prevailing microclimatic condition in this layer was not congenial for Collembolan activities. The 1.85 to 3.44 times increase in microarthropods in different vertical soil layers in natural site than the degraded site may be due to habitat differences influenced by the kind of substratum present. While discussing the vertical migration of Collembola, Usher (1970) inferred on the climatic influence on the vertical distribution of Collembola as well as their population size. Dhillon and Gibson (1962) and Choudhuri and Roy (1967) reported concentration of 85-95% Collemblans in the upper strata i.e., at the 0-10cm for favourable moisture and high organic matter of soil. Haq and Ramani (1991) reported that microarthropods population varied directly with the temperature and moisture conditions of the soil. Detsis (2000) recorded maximum Collembola in the upper soil layer and in the ‘O’ layer. Collembola fauna were richly represented in terms of number and species in the organic layer i.e. at the top layer (Drift, 1951; Wood, 1967; Price, 1973; Alfred *et al* 1991) as the fermentation layer (decomposition of organic material) offered the most suitable conditions for soil microarthropods due to presence of abundant food and favourable moisture contents (Haarlov, 1955; Wallwork, 1970). Petersen (1980) and Hagvar (1983) have also recorded the higher densities of Collembola occurred in the upper layers of the soil. Takeda (1978) recorded majority of Collembola in the upper 0-4 cm layer and opined that the concentration of individuals in this layer was mainly due to the soil structure and the springtail were limited to the soil organic layer. Hazra and Choudhuri (1983) also recorded about 59.15% of Collembola fauna in the upper most layer (0-30cm) at uncultivated site while the minimum percentage was recorded from lower most layer of the cultivated site (3.7%). Guru *et al*. (1988) reported over 58 % of total Collembola in top 0-5 cm layer in cultivated and uncultivated sites of Eastern Orissa. Wallwork (1970) had pointed out that Collembola were unable to burrow, so must utilize existing living space and decreased with depth because large sized Collembola could not migrate into deeper layers. Reddy and Vankataiah (1990) recorded Collembola only in top layer (0-5 cm) of grassland and higher population in tree planted area in tropical semi-arid savanna. Doulo and Kakati (2009) recorded 47% and 59% of the total Collembola population to upper soil layer (0-10cm) in natural and degraded forest sites respectively from Nagaland.

In the present investigation Collembola exhibited maximum population during rainy season in both sites coinciding congenial climatic condition favouring the decomposition rate which was reflected in the higher organic carbon content of the soil thereby bringing suitable condition for multiplication of Collembola. The lowest population density of Collembola in degraded site during winter season was probably due to the less rainfall and low moisture content of the soil. The different physico-chemical factors like soil moisture, soil temperature, organic carbon and total nitrogen determined the seasonal abundance and distribution of Collembola population. Kevan (1965), Butcher *et al.* (1971), Niijima, (1971) and Gupta and Mukharji (1978) also reported the importance of soil temperature on the fluctuation patterns of Collembola.

Nijima (1971), while studying seasonal changes of Collembola population in forest ecosystem in Japan also reported maximum Collembola density during high rainfall season due to the favourable environmental factors. Mitra *et al*. (1977) found the maximum population of Collembola during monsoon (July) and pre winter (October) months. Aggregation of Collembola under high soil moisture was also reported by Badejo *et al.* (1997). Lower population density of Collembola during dry winter months was also reported by Drift (1951), Wallwork (1967) and Niijima (1971). Reddy and Venkataiah (1990) recorded the highest number of Collembola during monsoon (July), less during post monsoon period, minimum in winter and absent in summer in a tropical semi – arid savanna. Mukharji and Singh (1970), while working on the seasonal variation of the soil microarthropods population in a rose garden at Varanasi, calculated the maximum number of Collembola population in the months of March, August and January. However Choudhury and Roy (1972) observed only one peak during June and August in the soils of West Bengal. Guru *et al* (1988) recorded two distinct peaks in the month of November and February in crop field and October and February in grassland located in Eastern Orissa. Loots and Ryke (1966) recorded a peak density during late summer period while working in the tropical Africa. Culic *et al.* (2002) found total collembolan density was greater during September than in December in Brazil. Matic *et al.* (2006) observed two peaks one in spring and other in autumn with a minimum in summerfrom beech and spruce forest habitatsin Jastribiac Mountain of Serbia. While working in natural and degraded forest ecosystem at Lumami, Nagaland, Doulu and Kakati (2009) recorded one peak during August in both study sites and reported lesser population density of Collembola during summer than winter season in natural forest which might indicate arrested growth in a condition of water saturation level due to excessive rainfall during that season.

Raghuraman *et al.* (2010) recorded two peaks of collembolan population during July to August and January in five study sites from Varanasi. Thus the present findings along with the reports from other workers emphasized that no single but a cumulative effects of all factors were responsible in the seasonal and vertical distribution of Collembola in both of the study sites.

In the present investigation Collembola has been further classified into three sub-orders i.e. Entomobryomorpha, Poduromorpha and Symphypleona

Entomobryomorpha

The population density of Entomobryomorha was recorded to be maximum in different soil layers among all the sub-orders The percentage contribution to Collembola and total soil microarthropods population in both the study sites is given in (**Table 25).**

Population density of Entomobryomorpha in natural forest ecosystem was recorded to be $202.33 x 10^2 m^{-2}$ contributing 57.80% and 20.01% to Collembola and total soil microarthropods population respectively. Upper soil layer i.e., 0-10 cm recorded the highest concentration of population i.e. $82.23 x 10^2 m^{-2}$ (40.64%) followed by $77.06 x 10^2 m^{-2}$ (38.09%) and $43.04 x 10^2 m^{-2}$ (21.27%) in 10-20 cm and 20-30 cm respectively.

In degraded forest ecosystem, population density of Entemobryomorpha was recorded to be $129.70 \pm 0.65 x 10^2 m^{-2}$ contributing 83.51% and 21.50% to Collembolan and total soil microarthropod population respectively. Maximum Entomobryomorpha population migrated towards upper most layer (0-10 cm) having population density of $71.32 x 10^2 m^{-2}$ (54.99%) and showed decreasing trend in subsequent layers of 10-20 cm and 20-30 cm with 42.13 x 10^2m^{-2} (32.48%) and 16.25 x 10^2m^{-2} (12.53%) respectively.

Monthly fluctuation of Entomobryomorpha showed single peak density during the month of August both in Natural (32.34 x 10^2m^{-2}) and degraded forest site (22.89 x10^2m^{-2}). (**Fig. 23).**

Table 25: Total numbers and percentage of Entomobryomorpha

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)
(B= Percentage contribution to the total Collembola in each layer respectively)
(C= Percentage contribution to the total soil microarthropods in each layer respectively)
(Numbers ±S.E) x 10^2m^{-2}.

(a) Natural forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	82.23 ± 0.73	40.64	45.92	17.82
10-20	77.06 ± 0.29	38.09	66.93	22.93
20-30	43.04 ± 1.02	21.27	77.10	20.18
Total	202.33 ± 1.37	100.00	57.80	20.01

(b) Degraded forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	71.32 ± 0.42	54.99	73.57	20.84
10-20	42.13 ± 0.71	32.48	100	25.88
20-30	16.25 ± 0.13	12.53	100	16.53
Total	129.70 ± 0.65	100.00	83.51	21.50

While Entomobryomorpha population in natural forest ecosystem showed maximum density in the month of August for all soil depth layers (9.70 x10^2m^{-2}, 13.24 x 10^2m^{-2} and 9.40 x10^2m^{-2} in 0-10, 10-20 and 20-30 cm layers respectively), minimum was recorded during January in 0-10 cm (1.12 x10^2m^{-2}) and 10-20 cm (0.46 x 10^2m^{-2}) and during May in 20-30 cm (2.03 x 10^2m^{-2}) with no record in the months of December and January **(Fig. 24 a).**

In degraded forest also, Entomobryomorha population at all soil depths showed maximum in the month of August (9.82 x 10^2m^{-2} in 0-10cm, 9.31 10^2m^{-2} in 10-20 cm, 3.76 x 10^2 m^{-2} in 20-30 cm). While minimum population density in 0-10 cm and 10-20 cm was recorded during January (1.52 x10^2m^{-2}) and May (2.03x 10^2m^{-2}) respectively, there was no record in the month of December and January at 10-20 cm soil layer. Further population in 20-30 cm was minimum during December (0.31 x 10^2m^{-2}) with no record in the month of January **(Fig. 24 b).**

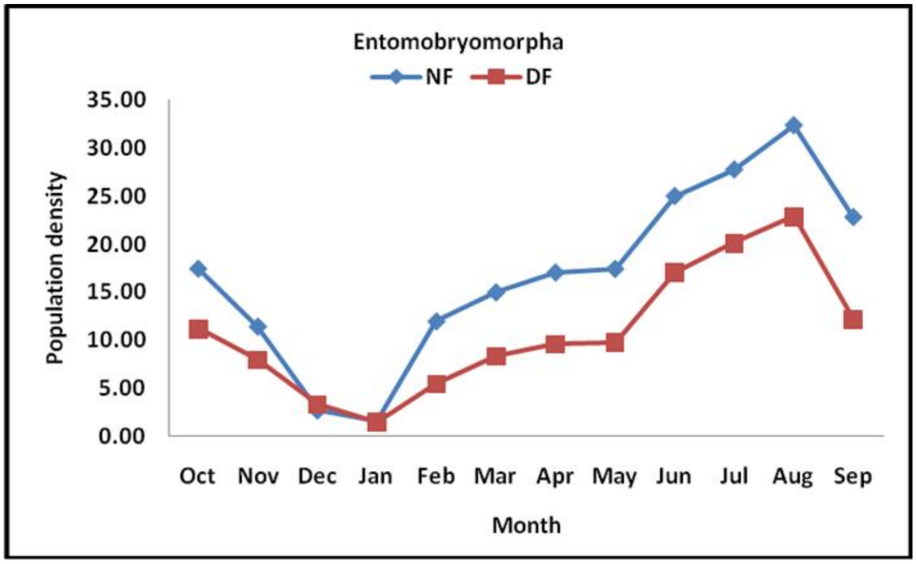
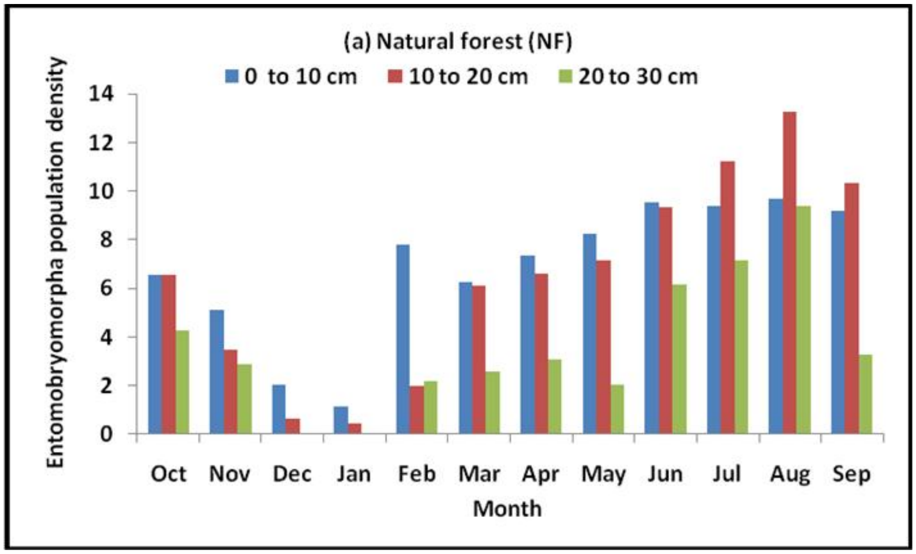
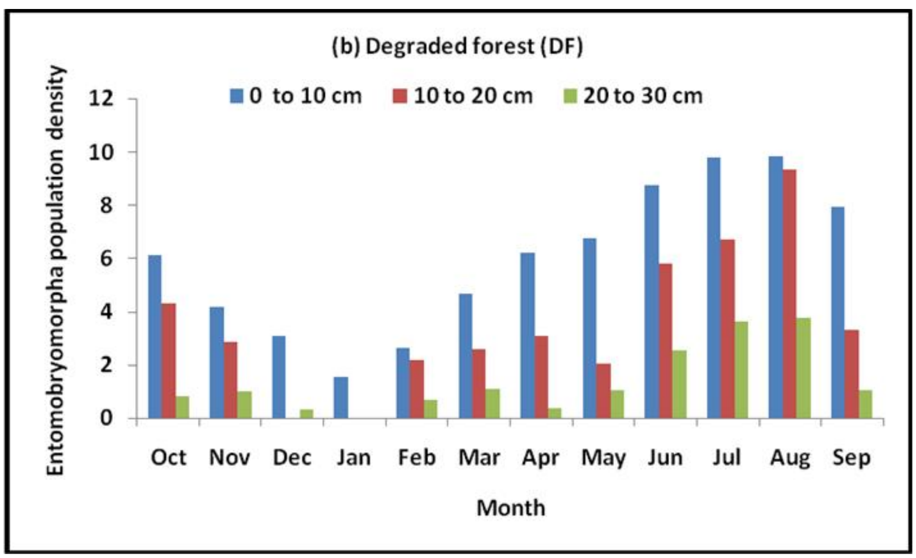


Figure 23: Monthly fluctuation of Entomobryomorpha population density (Numbers $x10^2m^{-2}$) in natural (NF) and degraded(DF) forest ecosystem



(a)



(b)

Figure 24: Monthly vertical distribution of Entomobryomorpha population density (Numbers x $10^2 m^{-2}$) in different soil layers of (a) natural and (b) degraded forest ecosystem

Poduromorpha

The population density of Poduromorha in different soil layers and its percentage contribution to Collembola and total soil microarthroods population in both the study sites is given in (**Table 26).**

In natural forest ecosystem, Poduromorpha population was recorded to be 107.06 x10^2m^{-2} contributing 30.59% and 10.59% to Collembola and total soil microarthropods population respectively. With 56.21 x10^2m^{-2} (52.50%) density in the upper most layer (0-10 cm), population density decreased to 38.07x 10^2m^{-2} (35.56%) in 10-20 cm layer and 12.78 x 10^2m^{-2} (11.94%) in 20-30 cm .

The population of Poduromorpha in degraded forest ecosystem was concentrated only in top layer i.e. 0-10 cm and recorded to be 25.62 x 10^2 m^{-2} ,contributing 16.49% and 4.25% to total Collembola and total soil microarthroods population respectively. No individual was recorded in the 10-20 cm and 20-30 cm soil layers.

Monthly fluctuation of Poduromorpha showed single peak density during the month of August both in Natural (18.69 x10^2m^{-2}) and degraded forest site (5.11x10^2m^{-2}). (**Fig. 25)**.

Table 26: Total numbers and percentage of Poduromorpha

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)

(B= Percentage contribution to the total Collembola in each layer respectively)

(C= Percentage contribution to the total soil microarthropods in each layer respectively)

(Numbers ± S.E) x $10^2 m^{-2}$.

(a) Natural forest ecosystem

Soil layer (cm)	Numbers±S.E.	A	B	C
0-10	56.21 ± 0.44	52.50	31.39	12.18
10-20	38.07 ± 0.21	35.56	33.07	11.33
20-30	12.78 ± 0.3	11.94	11.94	5.99
Total	107.06 ± 1.82	100.00	30.59	10.59

(b) Degraded forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	25.62 ± 0.27	100.00	26.43	7.49
10-20	0.00	0.00	0.00	0.00
20-30	0.00	0.00	0.00	0.00
Total	25.62 ± 0.27	100.00	16.49	4.25

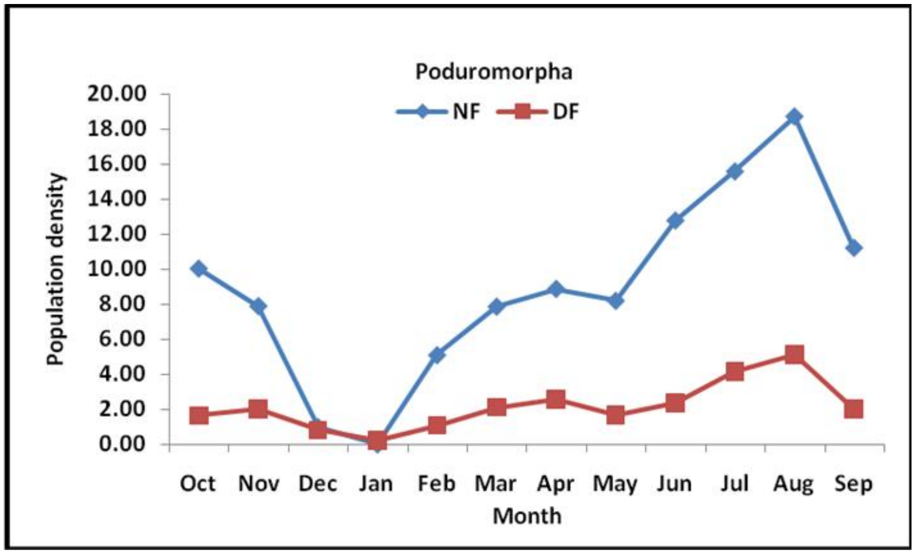
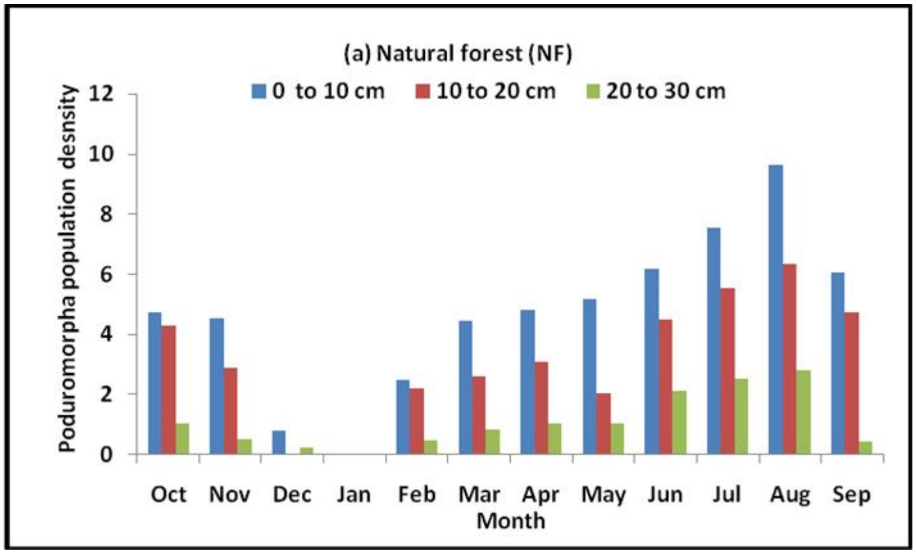


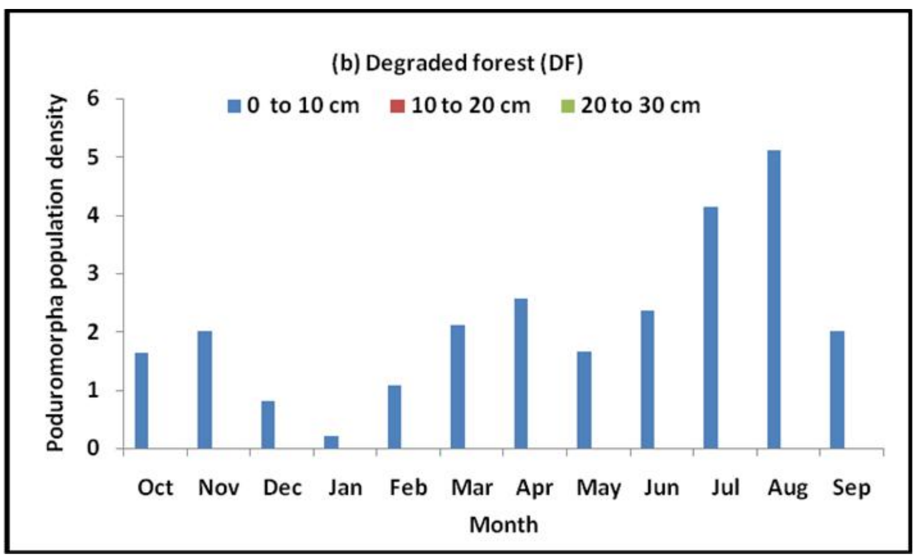
Figure 25: Monthly fluctuation of Poduromorpha population density (Numbers x10^2m^{-2}) in natural (NF) and degraded (DF) forest ecosystem

In natural forest, Poduromorpha population at 0-10 cm soil Depth showed maximum in the month of August (9.62 x $10^2 m^{-2}$) and minimum in the month of December (0.76 x $10^2 m^{-2}$). At 10-20 cm soil depth, maximum was recorded in the month of August (6.31 x$10^2 m^{-2}$) and minimum in the month of December (0.01 x $10^2 m^{-2}$). While at 20-30 cm soil depth, maximum was recorded in the month of August (2.76 x $10^2 m^{-2}$) and minimum in the month of December (0.21 x 10^2 m^{-2}). No individual was recorded in the month of January at all soil depths (**Fig. 26 a**).

In degraded forest, Poduromorpha population at 0-10 cm soil layers showed maximum in the month August (5.11x $10^2 m^{-2}$) and minimum in the month of January (0.21 x$10^2 m^{-2}$) however no individual was recorded in 10-20 cm and 20-30 cm soil depth (**Fig. 26 b**).



(a)



(b)

Figure 26: Monthly vertical distribution of Poduromorpha population (Numbers x $10^2 m^{-2}$) in different soil layers of (a) natural (NF) and (b) degraded (DF) forest ecosystem

Symphypleona

The number and percentage contribution of Symphypleona, which was recorded only in natural site, is shown in (**Table 27)**. The total density of Symphypleona was recorded to be 40.65 $x10^2m^{-2}$ contributing 11.61% and 4.02% to the Collembola and total soil microarthropods population respectively. The population was concentrated only the top soil layer i.e., 0-10 cm and no individual was recorded in 10-20 cm and 20-30 cm. In degraded site symphypleona population was not recorded at all.

Population density was found to be maximum in the month of August (9.75 $x10^2m^{-2}$) and minimum in the month of April (2.06 x 10^2m^{-2}) having no record during December and January (**Fig. 27 and 28**).

Table 27: Total numbers and percentage of Symphypleona

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)
(B= Percentage contribution to the total Collembola in each layer respectively)
(C= Percentage contribution to the total soil microarthropods in each layer respectively)
(Numbers ± S.E) x 10^2m^{-2}.

(a) Natural forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B	C
0-10	40.65 ± 0.61	100.00	22.70	8.81
10-20	0	0	0	0
20-30	0	0	0	0
Total	40.65 ± 0.61	100.00	11.61	4.02

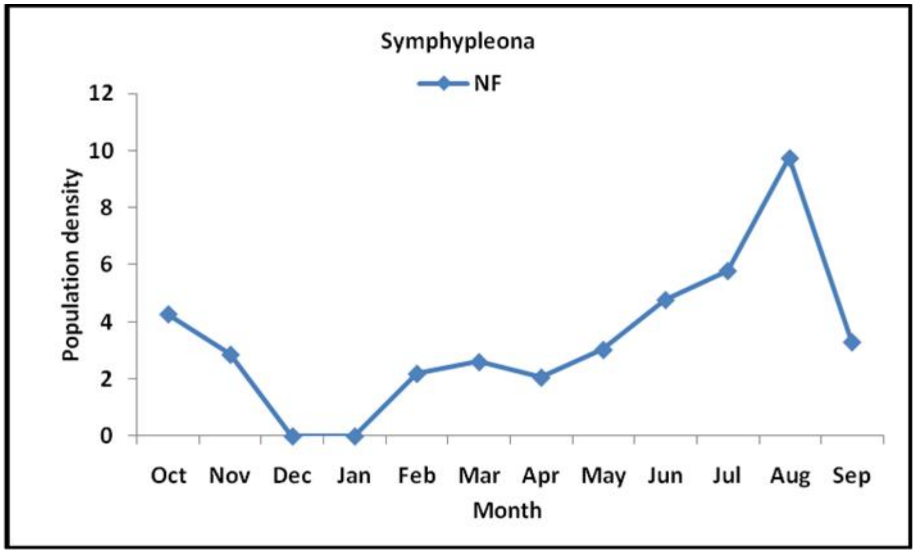


Figure 27: Monthly fluctuation of Symphypleona population density (Numbers x $10^2 m^{-2}$) in natural forest ecosystem.

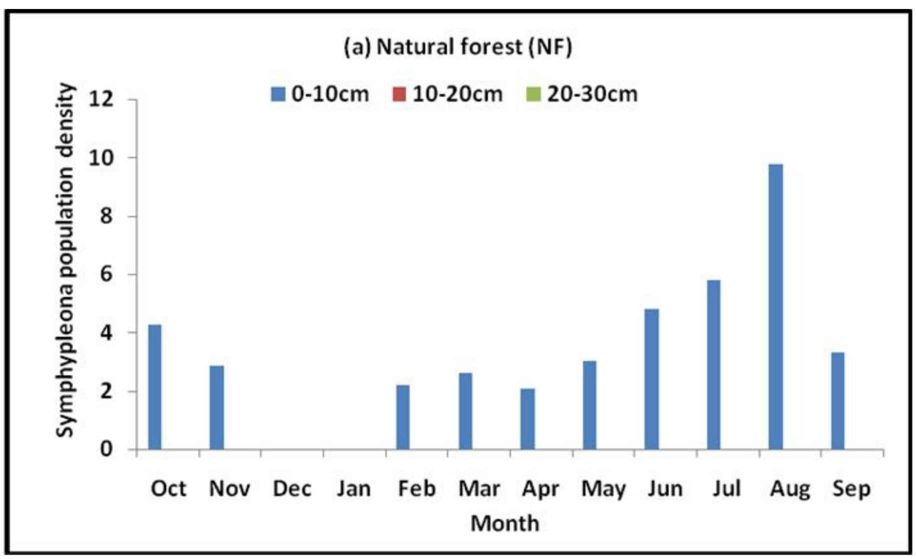


Figure 28: Monthly vertical distribution of Symphypleona population In natural forest ecosystem.

In natural forest site, Entomobryomorpha was found to be the most dominant group contributing 57.8% to total collembolan followed by Poduromorpha (30.59%) and Symphypleona (11.61%). However in degraded site Syphypleona was not recorded and collembolan population constituted of Entomobryomorpha (83.51%) and Poduromorpha (16.49). In present investigation Entomobryomorpha constituted about 20% and 21% of the total soil microarthropods in natural and degraded site respectively. The vertical dominancy of Entomobryomorpha among different suborders of Collembola in all the soil layers in both natural and degraded sites indicated wide range of tolerance ability and adaptation of this group to different climatic factors such as moisture content, organic carbon and possibly pH. While working in natural and degraded forest site in Imphal, Chitrapati (2002) observed that Collembola population was represented by Poduromorpha and Symphypleona of which the former group was richly represented with 99% as compared to the later group with only 1% through out the study period. She also observed Symphypleona population only in protected sites in the upper most layer i.e. 0-5 cm with the lowest annual population density of only 5 x $10^2 m^{-2}$. Doulo and Kakati (2009) recorded 50% contribution of Entomobryomorpha, 33-34% of Poduromorpha and 17% of Symphypleona to the Collembola population In natural and degraded forest ecosystem at Lumami. Hutson and Veitch (1983) recorded 93% of Poduromorpha as compared to the 7% of Symphypleona density in south Australian forests. As Symphypleona were generally common in loosely packed soil surface layer with very thin population distribution pattern (Wallwork, 1970), it was found to be confined only on top soil in natural forest site and not at all recorded in degraded site. Guru *et al.* (1988) observed that the species belonging to Entomobryomorpha are dominant group among the Collembola population having distribution pattern in different soil layers i.e. 0-5, 5-10 and 10-15cm with higher concentration in top layer. The marked difference in the population density among the different groups of Collembola in the present study and others as reported may be attributed to some physiological or behavioral adaptation as group and tolerant ability in different environmental factors.

Other soil microarthropods

Annual population density and vertical distribution of other soil microarthropods

The soil microarthropods other than Acarina and Collembola, contributing very less to the total microarthropods population and exhibited inconsistence presence in both the study sites are group as “other soil microarthropods”.

The total annual population density of other soil microarthropods and their distribution pattern in different soil layers in the natural forest site was higher than that of the degraded forest site **(Table 28).**

In natural forest, the total annual population density of others was recorded to be 264.23x10^{2}m^{-2},contributing 26.14% to the to tal soil microarthropods. Population density at 0-10 cm, 10-20 cm and 20-30 cm soil layers was recorded to be 93.86x10^{2}m^{-2} (35.52%), 84.98x10^{2}m^{-2} (32.16%) and 85.39x10^{2}m^{-2}(32.32%) respectively. Further the percentage contribution of others to total soil microarthropds was 20.34 %, 25.28% and 40.03% at 0-10 cm, 10-20 cm and 20-30 cm soil layer respectively.

In degraded forest, the total annual population density of Others recorded was 221.74 x10^{2}m^{-2}, which constituted 36.75% of the total soil microarthropos population. It exhibited maximum density of 94.62 x 10^{2}m^{-2} (42.67%) in 0-10 cm and followed by 69.86 x 10^{2}m^{-2} (31.51%) and 57.26 x 10^{2} m^{-2}(25.82%) in 10-20cm and 20-30 cm soil layer respectively. Further, it contributed 27.65%, 42.91% and 58.24% to the total soil microarthropods in 0-10 cm , 10-20 cm and 20-30 cm soil layers respectively.

Table 28: Total number and percentage of others

(A= Percentage contribution among the soil layers i.e. 0-10, 10-20 and 20-30cm)

(B= Percentage contribution to the total soil microarthropods in each layer respectively)

(Numbers ±S.E.) x $^{2}10$ *m*$^{-2}$

(a) Natural forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B
0-10	93.86 ± 0.37	35.52	20.34
10-20	84.98 ± 0.31	32.16	25.28
20-30	85.39 ± 0.35	32.32	40.03
Total	264.23 ± 1.08	100.00	26.14

(b) Degraded forest ecosystem

Soil layer (cm)	Numbers ± S.E.	A	B
0-10	94.62 ± 0.34	42.67	27.65
10-20	69.86 ± 0.20	31.51	42.91
20-30	57.26 ± 0.17	25.82	58.24
Total	221.74 ± 1.87	100.00	36.75

Seasonal variation of other soil microarthropods

The seasonal variation of others for the natural and degraded ecosystem is shown in **(Table 29).**

In the natural forest ecosystem, population density of others was more abundant during the rainy season ($125.23x10^2m^{-2}$), followed by summer ($95.33x\ 10^2m^{-2}$) and winter season ($43.77x10^2m^{-2}$) respectively.The seasonal vertical distribution pattern also followed trend of rainy>summer>winter season in all soil layers having maximum ($46.91\ x\ 10^2m^{-2}$) and minimum ($13.74\ x10^2m^{-2}$) in 0-10 cm. While other soil microarthropods migrated more along with increasing depth during winter, population density was recorded to be higher in top layer (0-10 cm) during summer and rainy season and decreased but remained equal in lower depth.

In the degraded forest ecosystem also, population density of others were more abundant during the rainy season ($107.09x10^2m^{-2}$), followed by summer ($76.08x10^2m^{-2}$) and winter season ($38.57x10^2m^{-2}$) respectively. The seasonal vertical distribution pattern of others also showed decreasing trend with increase in soil depth in all seasons with a record of maximum density during rainy season in 0-10 cm ($45.43x10^2m^{-2}$) and minimum during winter in 20-30 cm ($10.02x10^2m^{-2}$).

Table 29: Seasonal variation of others soil micro arthropods *(Numbers ± S.E) x 10^2m^{-2})*

(a) Natural forest ecosystem

Soil micro arthropods group	Season	Soil layers (cm)			Total
		0-10	10-20	20-30	
Others	Winter	13.74 ± 0.79	14.81 ± 0.87	15.22 ± 3.02	43.77 ± 2.36
	Summer	33.21 ± 4.02	31.06 ± 1.77	31.06 ± 2.14	95.33 ± 3.01
	Rainy	46.91 ± 2.82	39.11 ± 1.89	39.11 ± 1.93	125.13 ± 1.38
	Annual	93.86 ± 0.89	84.98 ± 1.85	85.39 ± 1.18	264.23 ± 3.55

(b) Degraded forest ecosystem

Soil micro arthropods group	Season	Soil layers (cm)			Total
		0-10	10-20	20-30	
Others	Winter	16.23 ± 0.39	12.32 ± 0.83	10.02 ± 0.56	38.57 ±1.28
	Summer	32.96 ± 0.62	25.26 ± 0.96	17.86 ± 0.64	76.08 ± 2.16
	Rainy	45.43 ± 0.81	32.28 ± 1.33	29.38 ± 0.77	107.09 ± 2.53
	Annual	94.62 ±1.77	69.86 ± 3.60	57.26 ± 1.29	221.74 ± 2.78

Monthly variation of other soil microarthropods

Monthly fluctuation of other soil microarthropods in both the study site (natural and degraded forest ecosystem) is shown in (**Fig. 29).**

Monthly variation of population density of others in natural forest was found to be the highest in the month of August (34.48 x$10^2 m^{-2}$) and lowest in the month of January (3.46x$10^2 m^{-2}$). In degraded forest population density also showed maximum in the month of August (32.23x$10^2 m^{-2}$) while minimum in the month of January (2.64x$10^2 m^{-2}$).

In natural forest, population at 0-10 cm soil depth showed maximum in the month of September (13.24 x$10^2 m^{-2}$) and minimum in the month of January (1.22 x$10^2 m^{-2}$). However both at 10-20 cm and 20-30 cm soil layer maximum was recorded in the month of August (11.05x$10^2 m^{-2}$) and minimum of the month of January (1.12x$10^2 m^{-2}$) (**Fig. 30 a**).

In degraded forest, population was mostly concentrated at 0-10 cm soil layer ranging from a maximum of 13.60 x$10^2 m^{-2}$ during July to a minimum of 1.52x$10^2 m^{-2}$ during January. At 10-20 cm, maximum population was recorded in the month of July (10.13 x$10^2 m^{-2}$) and minimum in the months of December and January (1.12 x $10^2 m^{-2}$). While at 20-30 cm soil depth, maximum and minimum population was recorded during August (9.62x$10^2 m^{-2}$) and December (76x$10^2 m^{-2}$) respectively having no individual in January (**Fig. 30 b**).

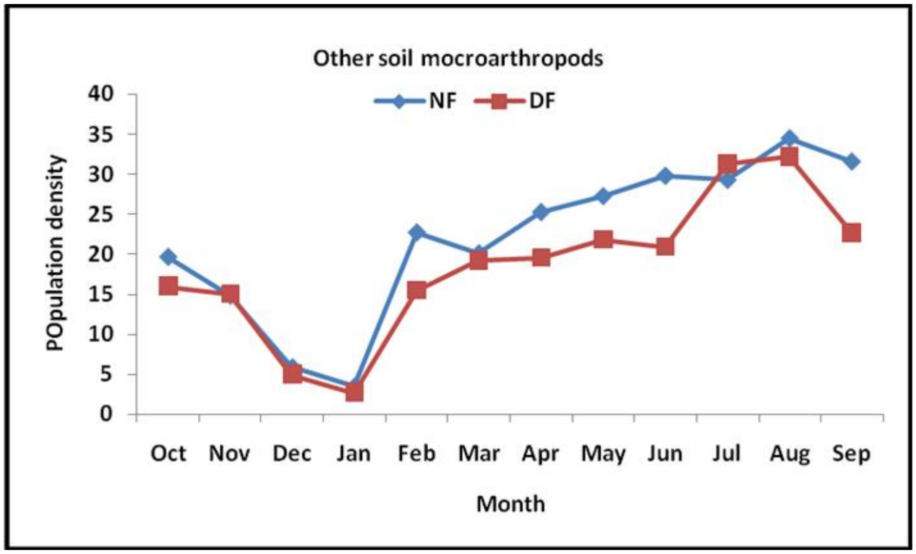


Figure 29: Monthly fluctuation of Other soil microarthropod population density (Numbers x $10^2 m^{-2}$) in natural (NF) and degraded (DF) forest ecosystem

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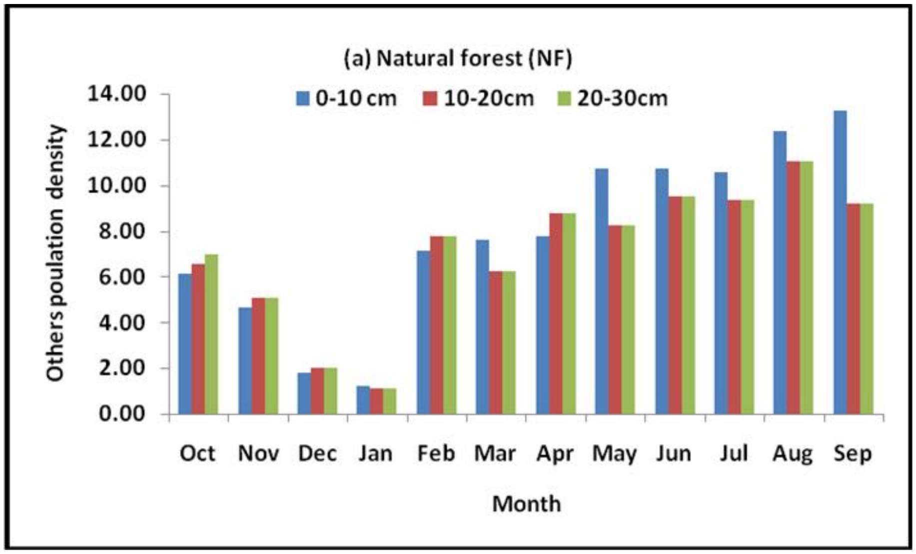
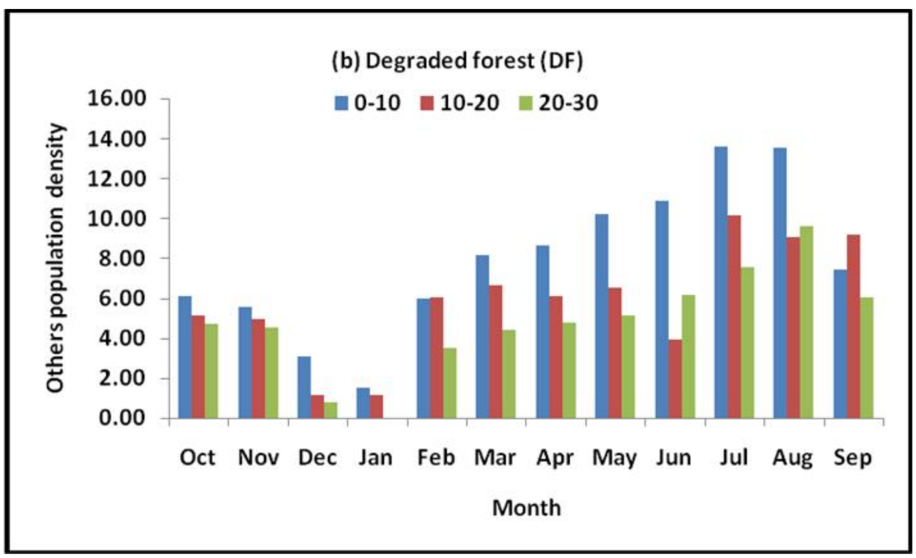


(a)



(b)

Figure 30: Monthly vertical distribution of other soil microarthropod population density (Numbers x $10^2 m^{-2}$) in different soil layers in (a) natural and (b) degraded forest ecosystem.

The result of ANOVA indicated a comparative of variation in the population density of other soil microarthropods in different seasons in the vertical distribution at soil layers of 0-10 cm, 10-20 cm and 20-30 cm in both natural and degraded forest ecosystem (**Table 30 to 35**). The analysis of variance of other population in the natural forest ecosystem showed highly significant variation in all seasons at 0-10 cm soil layer i.e. winter season (F=21.073,p<.001), summer season (F=8.051,p<0.002) rainy season (F=10.075, p<0.001) and annual (F= 4.446,p<0.019); at 10-20 cm soil layer highly significant difference was observed in winter season (F= 22.010,p<0.001), annual (F=7.954,p<0.002), while in summer and rainy season it was not significant. At 20-30 cm soil layer, except for rainy season, difference was significant in winter (F = 77.534, p<0.001), summer (F = 5.162, p<0.011) and total annual (F = 3.546, p<0.039).

In degraded forest ecosystem the analysis of variance of others showed highly significant difference at 0-10 cm in winter (F = 9.935, p<0.001), rainy season (F=4.187, p<0.023) and total annual (F = 4.416, p<0.019), however variation was insignificant during summer season. At 10-20 cm soil layer, except for summer season variation was highly significant in winter (F = 8.105, p<0.002), rainy season (F =13.720, p<0.001) and annual total (F = 14.417, p<0.001). At 20–30 cm soil layer, highly significant difference was observed in winter (F =12.8450,p<0.001) and rainy season (F=6.621 p<0.004), having shown insignificant variation during summer season and total annual population.

The total analysis of variance of other soil microarthropod population density in different months recorded highly significant difference both in natural ($F= 5.499$, $p<0.001$) and degraded ($F= 20.924$, $p<0.001$) forest ecosystem (**Table 36 and 37**).

In the present investigation, the other soil microarthropods altogether constitute 26.14% and 36.75% of the total micro arthropods population density in natural and degraded sites respectively. While other soil microarthropods in natural site was increased over 1.2 times than the degraded site, no much variation was recorded along the vertical distribution in the respective sites. There was an aggregation of 35.52% and 42.67 only in 0-10cm layer in natural and degraded sites respectively. The soil microarthropods in both the study sites have been found to be adapted to different physico-chemical characteristics of the soil. Being the dominant groups among total soil microarthropods, Acarina and Collembola determine the distributional pattern, seasonal and monthly variation and express the effect of physical factors and nutrient status of the soil.

Table 30: Analysis of variance (ANOVA) of Others population in different months of natural forest ecosystem (0 – 10cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	9.389	3.130	21.073	P<0.0 01
	Within the months	16	2.376	.149		
	Total	19	11.765			
	Summer season					
	Between the months	3	5.065	1.688	8.051	P<0.002
	Within the months	16	3.355	.210		
	Total	19	8.419			
0-10						
	Rainy season					
	Between the months	3	7.954	2.651	10.075	P<0.001
	Within the months	16	4.211	.263		
	Total	19	12.165			
	Annual season					
	Between the months	11	.477	.159	4.446	P<0.019
	Within the months	48	.572	3.577		
	Total	59	1.049			

Table 31: Analysis of variance (ANOVA) of Others population in different months of natural forest ecosystem (10 – 20cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	14.892	4.964	22.010	P<0.0 01
	Within the months	16	3.608	.226		
	Total	19	18.500			
	Summer season					
	Between the months	3	.626	.209	.726	P < 0.551
	Within the months	16	4.596	.287		
	Total	19	5.222			
10-20						
	Rainy season					
	Between the months	3	1.868	.623	2.581	P<0.090
	Within the months	16	3.859	.241		
	Total	19	5.726			
	Annual					
	Between the months	11	2.132	.711	7.954	P<0.002
	Within the months	48	1.430	8.934		
	Total	59	3.561			

Table 32: Analysis of variance (ANOVA) of Others population in different months of natural forest ecosystem (20 – 30cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	27.723	9.241	77.534	P<0.001
	Within the months	16	1.907	.119		
	Total	19	29.629			
	Summer season					
	Between the months	3	7.271	2.424	5.162	P<0.011
	Within the months	16	3.355	.470		
	Total	19	14.783			
20-30	**Rainy season**					
	Between the months	3	1.768	.589	1.199	P< 0.342
	Within the months	16	7.863	.491		
	Total	19	9.631			
	Annual					
	Between the months	11	1.339	.446	3.546	P<0.039
	Within the months	48	2.014	.126		
	Total	59	3.353			

Table 33: Analysis of variance (ANOVA) of Others population in different months of degraded forest ecosystem (0 – 10cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	9.827	3.276	9.935	P<0.0 01
	Within the months	16	5.275	.330		
	Total	19	15.102			
	Summer season					
	Between the months	3	7.622	2.541	16.566	P<0.001
	Within the months	16	2.454	.153		
	Total	19	10.075			
0-10						
	Rainy season					
	Between the months	3	4.391	1.464	4.187	P<0.023
	Within the months	36	5.594	.350		
	Total	39	9.985			
	Annual					
	Between the months	11	.902	.301	4.416	P<0.0 19
	Within the months	48	1.089	6.807		
	Total	59	1.9991			

Table 34: Analysis of variance (ANOVA) of Others population in different months of degraded forest ecosystem (10 – 20cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	11.212	3.737	8.105	P< 0.002
	Within the months	16	7.378	.461		
	Total	19	18.590			
	Summer season					
	Between the months	3	1.328	.443	1.296	P< 0.310
	Within the months	16	5.466	.342		
	Total	19	6.794			
10-20						
	Rainy season					
	Between the months	3	8.107	2.702	13.720	P<0.001
	Within the months	16	3.151	.197		
	Total	19	11.259			
	Annual					
	Between the months	11	4.262	1.421	14.417	P<0.001
	Within the months	48	1.577	9.854		
	Total	59	5.839			

Table 35: Analysis of variance (ANOVA) of Others population in different months of degraded forest ecosystem (20 – 30cm)

Soil Layer (cm)	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	6.753	2.251	12.845	P<0.0 01
	Within the months	16	2.804	.175		
	Total	19	9.556			
	Summer season					
	Between the months	3	.378	.126	.773	P<0.145
	Within the months	16	2.608	.163		
	Total	19	2.986			
20-30	**Rainy season**					
	Between the months	3	4.502	1.501	6.621	P<0.004
	Within the months	16	3.626	.227		
	Total	19	8.128			
	Annual					
	Between the months	11	.202	6.741	.986	P<0.424
	Within the months	48	1.094	6.836		
	Total	59	1.296			

Table 36: Analysis of variance (ANOVA) of Other population in all months of natural forest ecosystem.

Sourc of variation	Df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	5.061	.460	5.499	P < 0.0 01
Within the months	48	4.016	8.366		
Total	59	9.077			

Table 37: Analysis of variance (ANOVA) of Other population in all months of degraded forest ecosystem.

Source of variation	Df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	18.036	1.640	20.924	P < 0.0 01
Within the months	48	3.761	7.836		
Total	59	21.798			

Total soil microarthropods

Annual population density and vertical distribution of total soil microarthropods

The annual population density of total soil microarthropods with their vertical distributon in different soil layers of the natural and degraded forest sites was given in (**Table 38)**.

In natural foresrt, annual population density of total soil microarthropods was recorded to be 1011.01x10^2m^{-2} while vertical distribution was recorded maximum at 0-10 cm layer (461.55 x10^2m^{-2}) and minmum at 20-30 cm layer (213.33x10^2m^{-2}). In degraded forest, annual population density of total sol microarthropods recorded was 603.38 x10^2 m^{-2} with maximum density at 0-10 cm layer (342.25x10^2m^{-2}) and minimum at 20-30 cm layer (98.32 x10^2m^{-2}).

Table 38: Annual population density of total soil microarthropods
(Numbers ± S.E) x 10^2m^{-2}

Soil layer (cm)	**Population density in natural forest**		**Population density in degraded forest**	
	Numbers ± S.E.	**Percentage**	**Numbers ± S.E.**	**Percentage**
0-10	461.55 ± 2.72	45.65	342.25 ± 4.52	56.72
10-20	336.13 ± 2.53	33.25	162.81 ± 6.10	26.98
20-30	213.33 ± 4.88	21.10	98.32 ± 6.42	16.29
Total	1011.01 ± 8.34	100.00	603.38 ± 4.28	100.00

Seasonal variation of total soil microarthropods

The seasonal variation of total soil microarthropods for the natural and degraded ecosystem is given in (**Table 39**).

In the natural forest ecosystem, population density of total soil microarthropods was more abundant during the rainy season (543.36 x $10^2 m^{-2}$) which was followed by summer (305.62x$10^2 m^{-2}$) and winter season (162.03x$10^2 m^{-2}$) respectively. The seasonal vertical distribution pattern of total soil microarthropods showed a decreasing trend with increase in soil depth. Among the soil layer, maximum vertical population density was recorded in 0-10cm during rainy season (238.94x$10^2 m^{-2}$) and minimum was recorded in 20-30cm during winter season (34.11x$10^2 m^{-2}$).

In the degraded forest ecosystem also, population density of total soil microarthropods was more abundant during the rainy season (314.18 x$10^2 m^{-2}$) which was followed by summer (189.41x$10^2 m^{-2}$) and winter season (99.79x$10^2 m^{-2}$) respectively. The seasonal vertical distribution pattern showed a decreasing trend with increase in soil depth. Maximum vertical population density was recorded in 0-10cm during rainy season (174.17x$10^2 m^{-2}$) and minimum was recorded in 20-30cm during winter season (16.16x$10^2 m^{-2}$).

Monthly variation of total soil microarthropods

With initial population of 75.8 x$10^2 m^{-2}$ in October, total soil microarthropods decreased to 10.94x$10^2 m^{-2}$ (January), thereafter gradually increased to reach the maximum peak in the month of August (166.18x$10^2 m^{-2)}$. Similar trend was also observed in degraded site exhibiting a decreasing trend from October (44.09x$10^2 m^2$) to January (6.3x$10^2 m^{-2}$) and thereafter reached the maximum of 100.31x$10^2 m^{-2}$) during August **(Fig. 31).**

In both natural and degraded sites, total soil microarthropods in all soil strata were recorded to be maximum in the month of August and minimum in the month of January. In natural forest, minimum and maximum population ranged from 5.92x 10^2m^{-2} to 72.66 x 10^2m^{-2} at 0-10 cm, 2.33 x 10^2m^{-2} to 56.7 x 10^2m^{-2} at 10-20 cm and 2.65 x 10^2m^{-2} to 36.82 x 10^2m^{-2} at 20-30 cm soil layer. In degraded site, variation at 0-10, 10-20 and 20-30 cm were found to be 4.67 x 10^2m^{-2}-54.93 x 10^2m^{-2}, 1.35 x 10^2m^{-2}-27.75 x 10^2m^{-2} and 0.28 x 10^2m^{-2}-17.63 x 10^2m^{-2} respectively **(Fig. 32)**

Table 39: Seasonal variation of total soil microarthropods*(Numbers ± S.E.x10 ^{2}m^{-2})*

(a) Natural forest ecosystem

Total Soil microarthropod	**Soil layers(cm)**				**Total**
	Season	**0 – 10**	**10 – 20**	**20 - 30**	
	Winter	77.56 ± 2.13	50.36 ± 0.77	34.11± 0.59	162.03 ± 2. 67
	Summer	145.05 ± 5.30	97.94± 1.38	62.63 ± 4.07	305.62± 2. 48
	Rainy	238.94 ± 7.01	187.83 ± .38	116.59 ± 3.68	543.36 ± 8. 64
	Annual	461.55 ± 8.74	336.13 ±7.04	213.33 ± 4.15	1011.01 ± 8. 76

(b) Degraded forest ecosystem

Total Soil microarthropod	**Soil layers(cm)**				**Total**
	Season	**0 – 10**	**10 – 20**	**20 – 30**	
	Winter	55.89±1.59	27.74±1.87	16.16±0.96	99.79±1.68
	Summer	112.19±3.16	48.81 ± 2.12	28.41±1.06	189.41±3.09
	Rainy	174.17±2.78	86.26± 4.15	53.75±2.17	314.18±2.92
	Annual	342.25± 8.79	162.81± 4.06	98.32±6.21	603.38±6.33

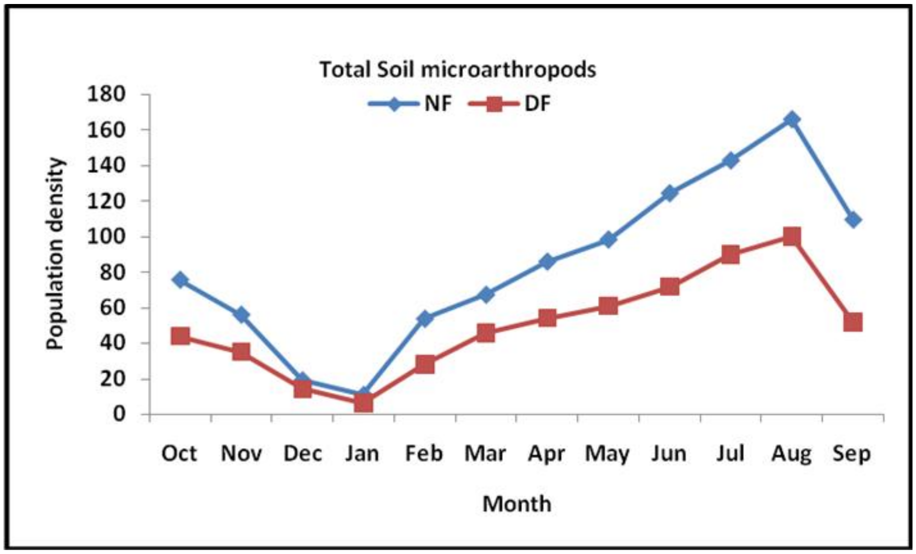
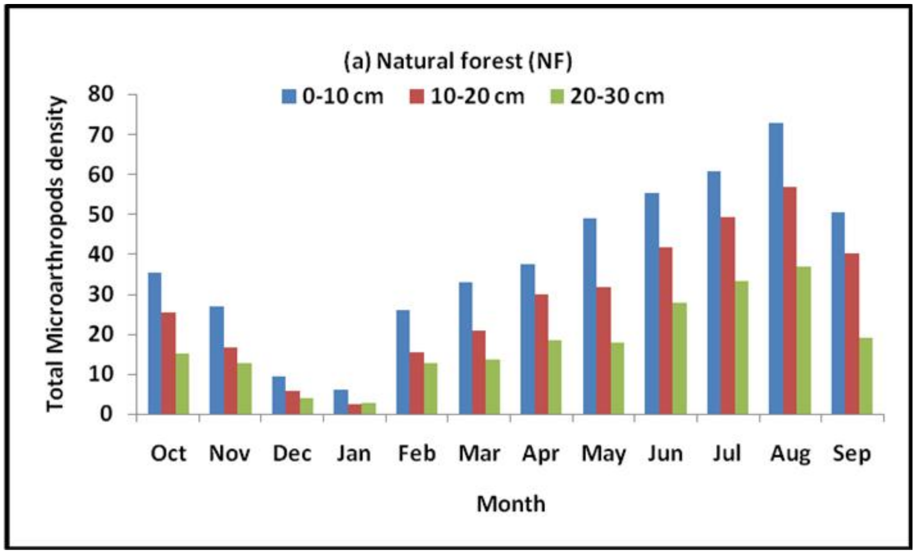
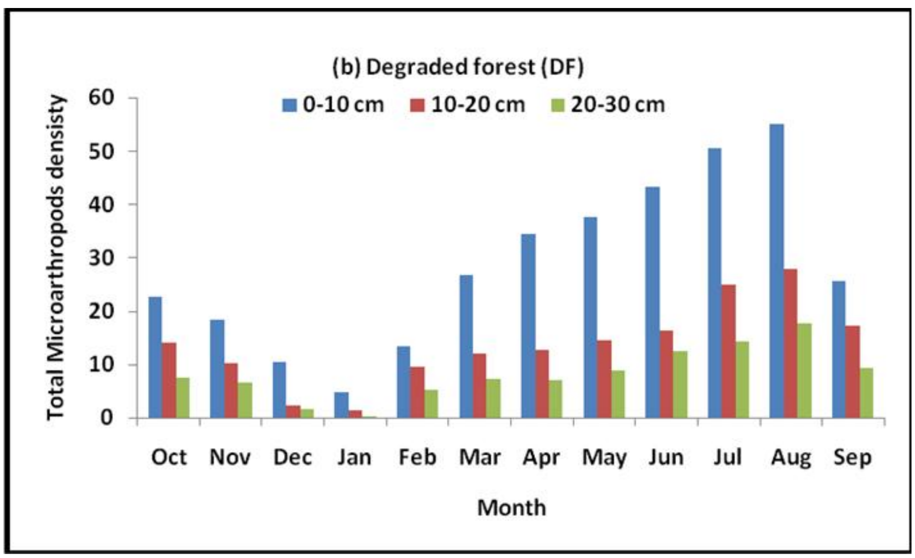


Figure 31: Monthly fluctuation of total soil microarthropods Population density (Numbers x $10^2 m^{-2}$) in natural (NF) and degraded (DF) forest ecosystem



(a)



(b)

Figure 32: Monthly vertical distribution of total soil microarthropods population (Numbers x $10^2 m^{-2}$)in (a) natural (NF) and (b) degraded (DF) forest ecosystem

Natural forest exhibited higher concentration of 40.32% of total population density than the degraded forest site. Among the different soil layers i.e. 0-10cm, 10-20cm and 20-30cm, there was higher population percentage of 25.85%, 51.56% and 53.91% respectively in natural forest site than the degraded forest site.

The result of ANOVA indicates comparative variation in different seasons along with vertical distribution of population density at soil layers of 0-10 cm, 10-20 cm and 20-30 cm in both natural and degraded forest ecosystem (**Table 40 to 45**). In natural forest total soil microarthropods population at 0-10 cm layer showed significant variation during winter ($F= 6.953$ $p<0.003$), summer ($F= 3.384$, $p<0.044$), rainy season ($F= 5.078$, $p< 0.012$) as well as in total annual ($F= 74.848$, $p<0.001$). At 10-20 cm soil layer highly significant difference was showed in all the seasons: winter ($F=10.693$, $p<0.001$), summer ($F =21.133$, $p<0.001$) and annual ($F =5.799$, $p<0.001$) and significant at rainy season ($F =3.248$, $p<0.05$). However at 20-30 cm soil layer, except for summer season, there was significant variation during winter season ($F =3.892$, $p<0.029$), rainy season ($F =6.035$, $p<0.006$) and total annual ($F =18.631$, $p<0.001$).

In degraded forest ecosystem ANOVA at 0-10 cm layer showed significant difference during winter season ($F =4.719$, $p<0.015$) and for total annual ($F =23.669$, $p <0.001$). At 10-20 cm soil layer difference was significant to highly significant in all the seasons i.e. winter ($F =4.297$, $p<0.021$), summer ($F=3.387$, $p<0.044$), rainy season ($F=4.447$, $p<0.019$) and total annual ($F=32.72$, $p<0.001$).At 20-30 cm soil layer, except for winter season there was significant variation in summer ($F=4.376$, $p<0.02$), rainy season ($F=4.845$,$p<0.014$) and also in total annual ($F=21.030$, $p<0.019$).

The analysis of variance considering all months for total soil microarthropod population showed highly significant difference both in natural ($F= 58.670$, $p<0.001$) and degraded forest ecosystem ($F=57.287$, $p<0.001$) (**Table 46 and 47**).

Table 40: Analysis of variance (ANOVA) of total soil microarthropods population in different months of natural forest ecosystem. (0-10cm)

Soil layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	10.393	3.130	6.953	P<0.0 03
	Within the months	16	7.972	.498		
	Total	19	18.365			
	Summer season					
	Between the months	3	19.842	6.614	3.384	P<0.044
	Within the months	16	31.272	1.954		
	Total	19	51.114			
0-10						
	Rainy season					
	Between the months	3	68.058	22.686	5.078	P<0.012
	Within the months	16	71.474	4.467		
	Total	19	139.531			
	Annual					
	Between the months	11	37.989	3.454	74.848	P<0.001
	Within the months	48	2.215	4.614		
	Total	59	40.204			

Table 41: Analysis of variance (ANOVA) of total soil microarthropods population in different months of natural forest ecosystem. (10-20cm)

Soil layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	35.887	11.962	10.693	P<0.0 01
	Within the months	16	17.899	1.119		
	Total	19	53.786			
	Summer season					
	Between the months	3	106.719	35.573	21.133	P<0.001
	Within the months	16	26.933	1.683		
	Total	19	133.652			
10-20						
	Rainy season					
	Between the months	3	12.484	4.161	3.248	P<0.050
	Within the months	16	20.496	1.281		
	Total	19	32.979			
	Annual					
	Between the months	11	11.779	1.071	5.799	P<0.001
	Within the months	48	8.863	.185		
	Total	59	20.642			

Table 42: Analysis of variance (ANOVA) of total soil microarthropods population in different months of natural forest ecosystem. (20-30cm)

Soil layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	5.957	1.986	3.892	P<0.0 29
	Within the months	16	8.162	.510		
	Total	19	14.118			
	Summer season					
	Between the months	3	7.802	2.601	2.582	P<0.090
	Within the months	16	16.113	1.007		
	Total	19	23.915			
20-30						
	Rainy season					
	Between the months	3	14.806	4.935	6.035	P<0.006
	Within the months	16	13.085	.818		
	Total	19	27.890			
	Annual					
	Between the months	11	45.295	4.118	18.631	P<0.001
	Within the months	48	10.609	.221		
	Total	59	55.904			

Table 43: Analysis of variance (ANOVA) of total soil microarthropods population in different months of degraded forest ecosystem. (0-10cm)

Soil layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	16.316	5.439	4.719	P<0.015
	Within the months	16	18.438	1.152		
	Total	19	34.754			
	Summer season					
	Between the months	3	7.592	2.531	1.753	P<0.197
	Within the months	16	23.094	1.443		
	Total	19	30.686			
0-10						
	Rainy season					
	Between the months	3	18.782	6.261	3.062	P<0.058
	Within the months	16	32.713	2.045		
	Total	19	51.496			
	Annual total					
	Between the months	11	14.464	1.315	23.669	P<0.001
	Within the months	48	2.667	5.556		
	Total	59	17.131			

Table 44: Analysis of variance (ANOVA) of total soil microarthropods population in different months of degraded forest ecosystem. (10-20cm)

Soil layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	8.534	2.845	4.297	P<0.0 21
	Within the months	16	10.592	.662		
	Total	19	19.127			
	Summer season					
	Between the months	3	9.421	3.140	3.387	P<0.044
	Within the months	16	14.834	.927		
	Total	19	24.255			
10-20						
	Rainy season					
	Between the months	3	16.122	5.374	4.447	P<0.019
	Within the months	16	19.334	1.208		
	Total	19	35.456			
	Annual					
	Between the months	11	24.803	2.255	32.721	P<0.001
	Within the months	48	3.308	6.891		
	Total	59	28.111			

Table 45: Analysis of variance (ANOVA) of total soil microarthropods population in different months of degraded forest ecosystem. (20-30cm)

Soil layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	1.032	.344	1.190	P<0.345
	Within the months	16	4.624	.289		
	Total	19	5.656			
	Summer season					
	Between the months	3	10.133	3.378	4.376	P<0.020
	Within the months	16	12.350	.772		
20-30	Total	19	22.484			
	Rainy season					
	Between the months	3	8.974	2.991	4.845	P<0.014
	Within the months	16	9.879	.617		
	Total	19	18.853			
	Annual					
	Between the months	11	20.593	1.872	21.030	P<0.019
	Within the months	48	4.273	8.902		
	Total	59	24.866			

Table 46: Analysis of variance (ANOVA) of total soil microarthropods, population in All months of natural forest ecosystem.

Annual

Source of variation	df	SS	MS	F	P
Between the months	11	30.799	2.800	58.670	P<0.001
Within the months	48	2.290	4.772		
Total	59	33.090			

Table 47: Analysis of variance (ANOVA) of total soil microarthropods, population in All months of degraded for ecosystem.

Annual

Source of variation	df	SS	MS	F	P
Between the months	11	19.601	1.782	57.287	P<0.001
Within the months	48	1.493	3.110		
Total	59	21.094			

Higher percentage of microarthropods in natural site may be due to close canopy of vegetation that enrich litter accumulation on the forest floor and maintained optimum temperature and relative humidity. Degraded forest site was mostly represented by open area with few scattered left uncut trees while clearing the forest, small herb and shrub vegetation which leads to less contribution of litters. Moreover, the forest floor was exposed directly to the sunlight which leads to rapid evaporation of soil moisture. The differences in the local microclimatic conditions, lower organic carbon, lower soil moisture content and lack of vegetation cover in degraded forest ecosystem may be the reason for the decrease in the population density and its activity. Badejo *et al* (1997) while studying the distribution patterns and abundance of mite and Collembola in the tropical rain forest reported higher soil temperature and lower soil moisture content in the unshaded areas and lower densities of Collembola than shaded area.

In both the study sites, total soil microarthropods population was more during rainy season followed by summer and winter season which emphasized on the variation of physical factors in different seasons. It may be mentioned that Acarina, and Collembola which were the dominant group of soil microarthropods, exhibited maximum population density during rainy season. Further the highest and lowest peak during August and January in both sites was correlated with the differential climatic and edaphic fators. Bhattacharya and Raychoudhuri (1979) reported two peaks population density of microarthropods during post monsoon period (September-October) and during late summer or pre monsoon (May-June) period. Similar trend of population density have also been reported by Mukharji and Singh (1970), Choudhuri and Roy (1972) and Prabhoo (1976). Doulo and Kakati (2009) observed three peaks in natural forest ecosystem which was due to variation in abundance of dominant groups in different months. Yadava and Singh (1988) while working in the subtropical forest ecosystem of Shiroi hills of Manipur also found a higher population density during rainy season with a decreasing trend towards winter season. Sharon *et al.* (2001) while working in an oak forest reported that the abundance of soil fauna was influenced by season and not only by the upper leaf layer as shown by Argyropoulou *et al.* (1993). Narula *et al.* (1998) reported seasonal maximum density during summer and rainy season having moderate soil temperature and moisture and minimum during winter with low value of soil moisture and temperature. Thus the time of peak density appeared to vary depending upon the sites and treatment as observed by Culik *et al* (2002) who recorded overall maximum population density of Collembola in winter and minimum in summer.

The upper most soil layer (0-10cm) exhibited maximum aggregation with 45.65% and 56.72% of soil microarthropods in the natural and degraded sites respectively. The higher percentage of soil microarthropods in 0-10cm soil layer was characterized by adequate living space, favourable moisture condition, aeration rate, and rich accumulation of humus soil (Hale, 1967; Wallwork, 1970). Different factors both physical and edaphic at deeper soil layer may be unsuitable which result for less concentration of soil microarthropods. However the gradual rather than drastic declination of micro arthropods population in lower layers of 10-20cm and 20-30cm in both natural (33.25% and 21.10%) and degraded area (26.18% and 16.29%) respectively in present investigation may suggest that the microclimatic condition in lower level still favour the activity and growth of microarthropods at minimum level.

Darlong (1984) reported 94% of migration of the soil fauna in the litter-top layer sub system in the protected ecosystem while nearly 73-79% aggregation in top soil layer of Jhum ecosystem and also observed that a dense cover of litter in an undisturbed forest system enables in accumulation and aggregation large number of microarthropods. Chitrapati (2002) reported 73 % and 62% of aggregation in protected and degraded forest ecosystem in Imphal. Doulo and Kakati (2009) recorded 46% and 54% of soil microarthropods in 0-10 cm layers of natural and degraded forest of Lumami, Nagaland. Takeda (1981) reported mean population density of about 160 x 10^2m^{-2} up to 8 cm depth in the sub tropical forest ecosystem. However Drift (1951) reported higher mean total population density of 681 x 10^2m^{-2} in temperate forest and Wallwork (1967) estimated 1546 x 10^2m^{-2} individuals of mites and Collembola in Northern Michigun. Seastedt and Crossley (1981) reported over 90% of microarthropods in the top 5cm layers in undisturbed Coweeta watershed.

Kevan (1982) reported that soil moisture content was of vital importance to the soil fauna. Nijima (1971) reported that low soil temperature results in the reduction of activity of soil microarthropods, and that a rise in temperature and the rainy season favour multiplication and increase in the density. Similar observation was also reported by Takeda (1981). Higher percentage of Collembola were aggregated in the soil layer due to soil structure and its limitation to soil organic matter was reported by Hazra and Choudhuri (1983) and Guru *et al* (1988). The differences in percentage contribution to total soil microarthropods with the increase of depth in the two study sites may be due to unfavourable physical factors and less accumulation of soil nutrients in degraded forest site and the combine effects of all these factors would substantiate the reasons for the low population density of soil microarthropods in degraded site.

Being located in sub tropical region at an altitude of 101 m amsl, total microarthropod population was found to be comparatively lower than other temperate forest soil as Wallwork (1976), Swift *et al*. (1979), Williams (1941), Madge (1965), Peterson and Luxton (1982), Heneghan *et al*, (1998) reported that population density of soil microarthropods are generally lower in the tropical or subtropical forest soils than the temperate forest soils. Drift (1951) reported mean population density of soil microarthropods of 3365 x $10^2 m^{-2}$ and Price (1973) recorded 2207 x$10^2 m^{-2}$ in the temperate pine forest ecosystem which were quite higher than the present findings. Chitrapati (2002) recorded 240x$10^2 m^{-2}$ and 160x$10^2 m^{-2}$ number of soil microarthropods in protected and degraded forest ecosystem located at an altitude of 780-1100 meter in subtropical regime in Manipur. Doulo and Kakati (2009) recorded 1106.77 x $10^2 m^{-2}$ and 755.80 x $10^2 m^{-2}$ numbers of soil microarthropods from natural and degraded forest ecosystem located in a higher altitudinal area of Lumami. Wallwork (1976) reported the mean population density of mites and Collembola ranging from 100 to 260 x $10^2 m^{-2}$ and 100 x $10^2 m^{-2}$ in the tropical forest of Brazil and Chile. Singh and Singh (1975) reported mean population density of 250 x$10^2 m^{-2}$ soil microarthropods in the deciduous forest. Culik *et al*. (2002) reported high Collembola densties upto 2710-5560 x $10^2 m^{-2}$ in the soil of agro – forestry ecosystem in Nigera providing additional evidence that high soil fauna densities may also occur in tropical soils. There was considerable variation in the microarthropods population and it was often difficult to assess whether or not these variations were due to intrinsic difference between the many kinds of habitat studied or to differences in emphasis of individual workers and in the techniques employed (Price, 1973).

LITTER COMPONENT

Acarina (Mites)

Annual population density and seasonal variation

The total annual population density of Acarina and their distribution pattern in different seasons were recorded to be higher in the natural forest than the degraded forest sites **(Table 48).**

Litter Acarina population in natural forest was 1.6 times higher than the degraded site. In natural forest, total annual population density of Acarina recorded was $1616.34 x 10^2 m^{-2}$ which were 45.70% of the total litter microarthropods population. In degraded forest, total annual population density of Acarina was $1012.78 \times 10^2 m^{-2}$, contributing 40.44% to the total soil microarthropod population.

Seasonally, population density of Litter acarina in natural forest ecosystem was more abundant during the rainy season ($788.21 \times 10^2 m^{-2}$), followed by summer ($502.88 \times 10^2 m^{-2}$) and winter ($325.25 \times 10^2 m^{-2}$). In degraded site also, population abundance also exhibited similar trend with maximum record of $506.78 \times 10^2 m^{-2}$ (Rainy season) followed by $299.18 \times 10^2 m^{-2}$ (summer season) and $206.18 \times 10^2 m^{-2}$ (winter season).

Table 48: Total Numbers and percentage of Acarina

(A= *Percentage contribution among the different seasons*

(B= *Percentage contribution to the total litter microarthropods (Numbers± S.E. x* $10^2 m^{-2}$*)*

(a) Natural forest ecosystem

Season	**Numbers ± S.E.**	**A (%)**	**B (%)**
Winter	325.25 ± 3.54	20.12	9.20
Summer	502.88 ± 3.49	31.11	14.21
Rainy	788.21 ± 6.04	48.77	22.29
Annual	1616.34 ± 7.28	100.00	45.70

(b) Degraded forest ecosystem

Season	**Numbers ± S.E.**	**A (%)**	**B (%)**
Winter	206.82 ± 3.57	20.42	8.26
Summer	299.18 ± 2.84	29.54	11.94
Rainy	506.78 ± 4.82	50.04	20.23
Annual	1012.78 ± 7.05	100.00	40.44

Monthly variation of Litter Acarina

Monthly variation of total population density of Acarina exhibited similar trend in both natural and degraded forest. With the initial record of 114.64 x 10^2m^{-2} and 84.28 x 10^2m^{-2} during October, the number decreases to minimum during January (47.07 x 10^2m^{-2} and 29.02 x10^2m^{-2}) in natural and degraded forest respectively. Thereafter, population in both sites exhibited increasing trend with the maximum in the month of July (235.39 x 10^2 m^{-2}) in natural forest and August (159.78 x10^2m^{-2}) in degraded forest. **(Fig. 33)**

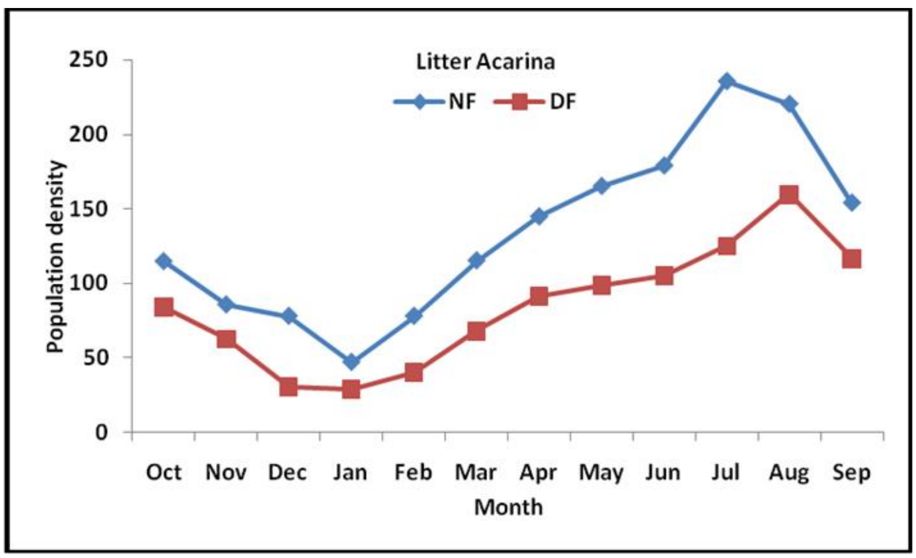


Figure 33: Monthly fluctuation of Litter Acarina population density (Numbers x10^2m^{-2}) in natural (NF) and degraded (DF) forest ecosystem

The analysis of variance (ANOVA) of litter Acarina population in natural forest ecosystem showed highly significant variation in winter season (F= 45.449, p<0.001), rainy season (F= 16.413, p<0.001) and total annual (F= 18.642, p<0.001) having shown insignificant difference during summer season. However in degraded forest ecosystem population exhibited highly significant difference during winter season (F= 17.919, p < 0.001) and annual total (F= 7.632, p<0.001) only and no significant difference in summer and rainy seasons **(Table 49 and 50).**

The total analysis of variance (ANOVA) of Litter Acarina considering average population density in different months exhibited highly significant difference in both natural (F= 18.642, p<0.001) and degraded (F= 7.632,p<0.001) forest ecosystem (**Table 51 and 52**).

Table 49: Analysis of variance (ANOVA) of litter Acarina population in different months of natural forest ecosystem.

Source of variation	df	SS	MS	F	P
Winter season					
Between the months	3	14.558	4.853	45.449	P<0.001
Within the months	16	1.708	.107		
Total	19	16.267			
Summer season					
Between the months	3	4.996	1.665	1.929	P<0.162
Within the months	16	13.812	.863		
Total	19	18.808			
Rainy season					
Between the months	3	4.886	1.629	16.413	P<0.001
Within the months	16	1.588	9.922		
Total	19	23.367			
Annual					
Between the months	11	73.087	6.644	18.642	P<0.001
Within the months	48	17.108	.356		
Total	59	90.19			

Table 50: Analysis of variance (ANOVA) of litter Acarina population in different months of degraded forest ecosystem.

Source of variation	df	SS	MS	F	P
Winter season					
Between the months	3	17.789	5.930	17.919	P< 0.001
Within the months	16	5.295	.331		
Total	19	23.084			
Summer season					
Between the months	3	1.725	.575	1.367	P< 0.289
Within the months	16	6.7288	.421		
Total	19	8.453			
Rainy season					
Between the months	3	7.438	2.479	.026	P< 0.994
Within the months	16	15.473	.967		
Total	19	15.547			
Annual season					
Between the months	11	48.093	4.372	7.632	P< 0.001
Within the months	48	27.496	.573		
Total	59	75			

Table 51: Analysis of variance (ANOVA) of litter Acarina population in all months of natural forest ecosystem.

Source of variation	df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	73.087	6.644	18.642	P< 0.0 01
Within the months	48	17.108	.356		
Total	59	90.196			

Table 52: Analysis of variance (ANOVA) of litter Acarina population in all months of degraded forest ecosystem.

Source of variation	df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	48.093	4.372	7.632	P< 0.0 01
Within the months	48	27.496	.573		
Total	59	75.589			

Collembola

Annual population density and seasonal variation

The total annual population density of Collembola and their distribution pattern in different seasons were recorded to be higher in the natural forest than the degraded forest sites **(Table 53).**

Litter Collembola population in natural forest was 1.4 times higher than the degraded site. In natural forest, total annual population density of Collembola recorded was 1150.87 x $10^{2}m^{-2}$ which were 32.53% of the total litter microarthropods population. In degraded forest, total annual population density of Acarina was 837.15 x $10^{2}m^{-2}$, contributing 23.67% to the total soil microarthropod population.

Seasonally, population density of Litter Collembola in natural forest ecosystem was more abundant during the rainy season (588.79 x $10^{2}m^{-2}$), followed by summer (327.26 x$10^{2}m^{-2}$) and winter (242.82 x $10^{2}m^{-2}$). In degraded site also, population abundance also exhibited similar trend with maximum record of 393.56 x $10^{2}m^{-2}$ (Rainy season) followed by 220.83 x $10^{2}m^{-2}$ (summer season) and 202.76 x $10^{2}m^{-2}$ (winter season).

Table 53: Total Numbers and percentage of Collembola

(A= Percentage contribution among the different seasons

(B= Percentage contribution to the total litter microarthropods

(Numbers ± S. E. x 10^2 m^{-2})

(a) Natural forest ecosystem

Season	Numbers ± S.E.	A (%)	B (%)
Winter	242.82±0.66	21.10	6.87
Summer	327.26±2.74	28.43	9.26
Rainy	580.79±3.09	50.47	16.42
Annual	1150.87±6.67	100.00	32.53

(b) Degraded forest ecosystem

Season	Numbers ± S.E.	A (%)	B (%)
Winter	202.76±1.27	24.22	8.10
Summer	240.83±1.09	28.77	9.61
Rainy	393.56±2.68	47.01	15.71
Annual	837.15±4.61	100.00	23.67

Monthly variation of Litter Collembola

Monthly variation on Collembolan population in natural site exhibited a decreasing trend from October (92.06 x 10^2 m^{-2}) until January (27.24 x 10^2 m^{-2}) and thereafter increased to have recorded the peak in the month of August (192.31 x 10^2 m^{-2}). In degraded forest, with an initial population of 86.33 x $10^2 m^{-2}$ in the month of October, it decreased gradually up to January (10.08x$10^2 m^{-2}$).The population increased again to record the maximum in the month of August (118.48x$10^2 m^{-2}$). However there was slight decrease in the month of June (91.72 x$10^2 m^{-2}$) exhibiting three peaks during study period **(Fig. 34).**

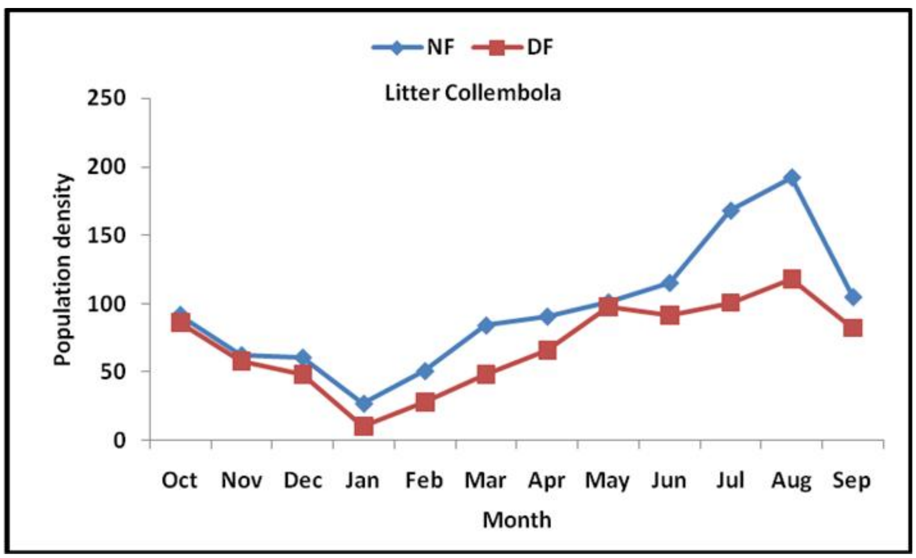


Figure 34: Monthly fluctuation of Litter Collembola population density (Numbers x$10^2 m^{-2}$) in natural (NF) and degraded (DF) forest ecosystem

The analysis of variance (ANOVA) of Litter Collembola population in the natural forest ecosystem showed significant variation in winter (F= 5.368, p<0.009) and rainy season (F= 4.192, p<0.023) and highly significant difference in annual total (F= 11.503, p<0.001), however it was not significant for summer season. In degraded forest ecosystem also difference was significant to highly significant in rainy season (F= 6.298 P<0.005), winter season (F= 21.898, p<0.001) and annual; F=13.191 P<0.001) and not significant in summer season **(Table 54 and 55).**

The total ANOVA of Litter Collembola considering average population density in different months exhibited highly significant difference in both natural (F=11.303, p<0.001) and degraded (F= 13.191, p<0.001) forest ecosystem (**Table 56 and 57**)

Table 54: Analysis of variance (ANOVA) of Litter Collembola population in different months of natural forest ecosystem.

Source of variation	df	SS	MS	F	P
Winter season					
Between the months	3	4.004	1.335	5.368	P<0.0 09
Within the months	16	3.978	.249		
Total	19	7.981			
Summer season					
Between the months	3	1.066	.355	.620	P< 0.612
Within the months	16	9.176	.573		
Total	19	10.242			
Rainy season					
Between the months	3	4.806	1.602	4.192	P<0.023
Within the months	16	6.114	.382		
Total	19	10.919			
Annual					
Between the months	11	50.788	4.617	11.503	P<0.001
Within the months	48	19.267	.401		
Total	59	70.055			

Table 55: Analysis of variance (ANOVA) of Litter Collembola population in different months of degraded forest ecosystem.

Source of variation	df	SS	MS	F	P
Winter season					
Between the months	3	9.078	3.026	21.898	P<0.001
Within the months	16	2.211	.138		
Total	19	11.288			
Summer season					
Between the months	3	3.204	1.068	.036	P<0.991
Within the months	16	4.774	.298		
Total	19	4.806			
Rainy season					
Between the months	3	5.307	1.769	6.298	P<0.005
Within the months	16	4.494	.281		
Total	19	9.801			
Annual					
Between the months	11	34.701	3.155	13.191	P<0.001
Within the months	48	11.479	.239		
Total	59	46.181			

Table 56: Analysis of variance (ANOVA) of Collembola (Litter) population in all months of natural forest ecosystem.

Source of variation	df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	50.788	4.617	11.303	P < 0.0 01
Within the months	48	19.267	.401		
Total	59	70.054			

Table 57 : Analysis of variance (ANOVA) of Litter Collembola population in all months of degraded forest ecosystem.

Source of variation	df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	34.701	3.155	13.191	P < 0.0 01
Within the months	48	11.479	.239		
Total	59	46.181			

Other Litter microarthropods

Annual population density and seasonal variation of other litter microarthropods

The litter microarthropods other than Acarina and Collembola, contributing very less to the total microarthropods population and exhibited inconsistence presence in both the study sites are group as “other soil microarthropods”.

The total annual population density of other Litter microarthropods which was 1.2 times higher in natural site than degraded site and their distribution pattern in different seasons is given in Table 58. In natural forest and degraded forest site, total annual population density of other Litter microarthropods was 769.67 x $10^2 m^{-2}$ and 654.26 x $10^2 m^{-2}$ contributing 21.77% and 26.12% to the total litter microarthropods respectively **(Table 58).**

Seasonally, population density of other Litter microarthropods in natural forest ecosystem was more abundant during the rainy season (363.31 x 10^2 m^{-2}), followed by summer (215.06 x 10^2 m^{-2}) and winter (191.30 x 10^2 m^{-2}). In degraded site also, population abundance also exhibited similar trend with maximum record of 325.27 x 10^2 m^{-2} (Rainy season) followed by 196.45 x 10^2 m^{-2} (summer season) and 132.54 x 10^2 m^{-2} (winter season).

Table 58: Total Numbers and percentage of other soil microarthropods

(A= *Percentage contribution among the different seasons*

(B= *Percentage contribution to the total litter microarthropods*

(Numbers ±S. E. x 10^2 m^{-2})

(a) Natural forest ecosystem

Season	Numbers ± S.E.	A (%)	B (%)
Winter	191.30 ± 1.22	24.86	5.40
Summer	215.06 ± 0.86	27.94	6.09
Rainy	363.31 ± 2.57	47.20	10.28
Annual	769.67 ± 5.24	100.00	21.77

(b) Degraded forest ecosystem

Season	Numbers ± S.E.	A (%)	B (%)
Winter	132.54 ± 1.08	20.26	5.30
Summer	196.45 ± 1.31	30.03	7.84
Rainy	325.27±2.03	49.71	12.99
Annual	654.26 ± 4.88	100.00	26.12

Monthly variation of other Litter microarthropods

Monthly variation of other Litter microarthropod population in natural and degraded study sites was recorded to be maximum in the month of August (102.11 x 10^2 m^{-2} and 97.49 x $10^2 m^{-2}$) and minimum during January (18.11 x $10^2 m^{-2}$ and 7.06 x 10^2 m^{-2}) respectively **(Fig. 35).**

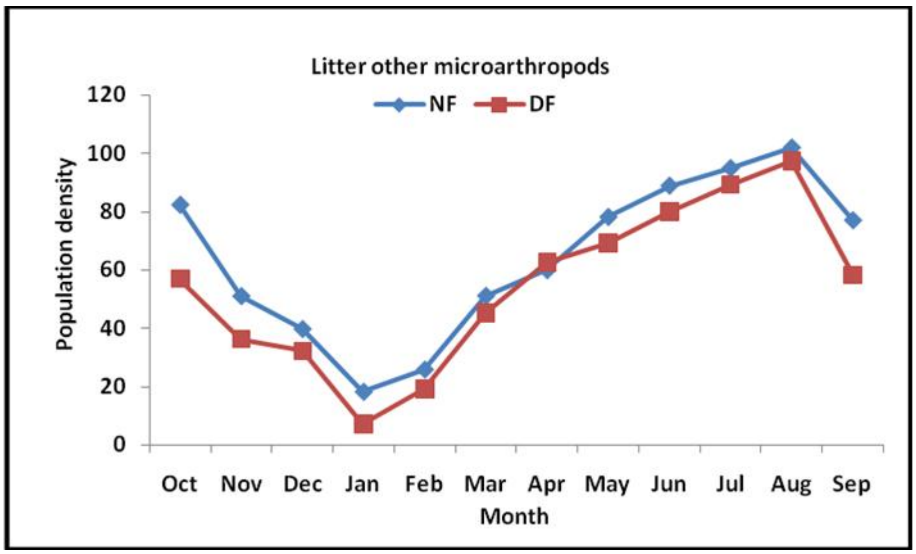


Figure 35: Monthly fluctuation of Other Litter microarthropod population density (Numbers x $10^2 m^{-2}$) in natural (NF) and degraded (DF) forest ecosystem.

The result of ANOVA indicated a comparative of variation in the population density of other soil microarthropods in different seasons.

The analysis of variance (ANOVA) of other Litter microarthropod population in the natural forest ecosystem showed highly significant variation in winter season ($F= 9.866$, $p<0.001$), annual ($F= 7.995$, $p<0.001$) however difference was not significant during summer and rainy season. In degraded site also highly significant difference was observed during winter season ($F= 8.556$, $p<0.001$), annual ($F= 4.342$, $p <0.001$) only **(Table 59 and 60)**.

The total ANOVA of other Litter microarthropods considering average population density in different months exhibited highly significant difference in both natural ($F= 7.643$, $p<0.001$) and degraded ($F= 4.342$, $p<0.001$) forest ecosystem (**Table 61 and 62**).

Table 59: Analysis of variance (ANOVA) of Litter Other population in different months of natural forest ecosystem.

Soil layer	Source of variation	df	SS	MS	F	P
	Winter season					
	Between the months	3	19.705	6.568	9.866	P<0.001
	Within the months	16	10.652	.666		
	Total	19	30.357			
	Summer season					
	Between the months	3	1.941	.647	1.624	P<0.223
	Within the months	16	6.375	.398		
	Total	19	8.317			
	Rainy season					
	Between the months	3	2.733	.911	1.167	P < 0.353
	Within the months	16	12.486	.780		
	Total	19	15.220			
	Annual total					
	Between the months	11	51.695	2.891	7.995	P<0.001
	Within the months	48	29.514	.362		
	Total	59	81.209			

Table 60: Analysis of variance (ANOVA) of Litter Other population in different months of degraded forest ecosystem.

Source of variation	df	SS	MS	F	P
Winter season					
Between the months	3	10.014	3.338	8.556	P<0.001
Within the months	16	6.242	.390		
Total	19	16.256			
Summer season					
Between the months	3	3.980	1.327	1.147	P<0.360
Within the months	16	18.501	1.156		
Total	19	22.481			
Rainy season					
Between the months	3	.939	.313	.187	P<0.903
Within the months	16	26.713	1.670		
Total	19	27.652			
Annual total					
Between the months	11	51.196	4.654	4.342	P<0.001
Within the months	48	51.456	1.072		
Total	59	102.65			

Table 61: Analysis of variance (ANOVA) of Litter Other population in all months of natural forest ecosystem.

Source of variation	df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	51.695	4.700	7.643	P < 0.0 01
Within the months	48	29.514	.615		
Total	59	81.209			

Table 62: Analysis of variance (ANOVA) of Litter Other population in all months of degraded forest ecosystem.

Source of variation	df	SS (Sum of square)	MS (Mean square)	F	P
Between the months	11	51.196	4.654	4.342	P < 0.0 01
Within the months	48	51.456	1.072		
Total	59	102.652			

Total Litter microarthropods

Annual population density and seasonal of total Litter microarthropods

The annual population density of total Litter microarthropods along with their seasonal contribution in natural and degraded forest sites is given in (**Table 63).**

In natural forest, annual population density of total Litter microarthropods was recorded to be 3536.88 x 10^2 m^{-2} (41.32% higher than degraded site) to which maximum was contributed by Acarina (45.70%) followed by Collembola (32.54%) and Others (21.76%). Similar trend was also observed in different seasons. Maximum population was recorded during rainy season (48.98%) followed by summer (29.55%) and winter season (21.47%).

In degraded site also, Acarina contributed 40.44% to total annual Litter population (2504.19 x 10^2 m^{-2}) and followed by Collembola (33.43%) and other group (26.13%). Acarina was found to be dominant groups among all microarthropods in different seasons. Further, maximum total population was recorded during rainy season (48.94%) followed by summer (29.41%) and winter season (21.65%).

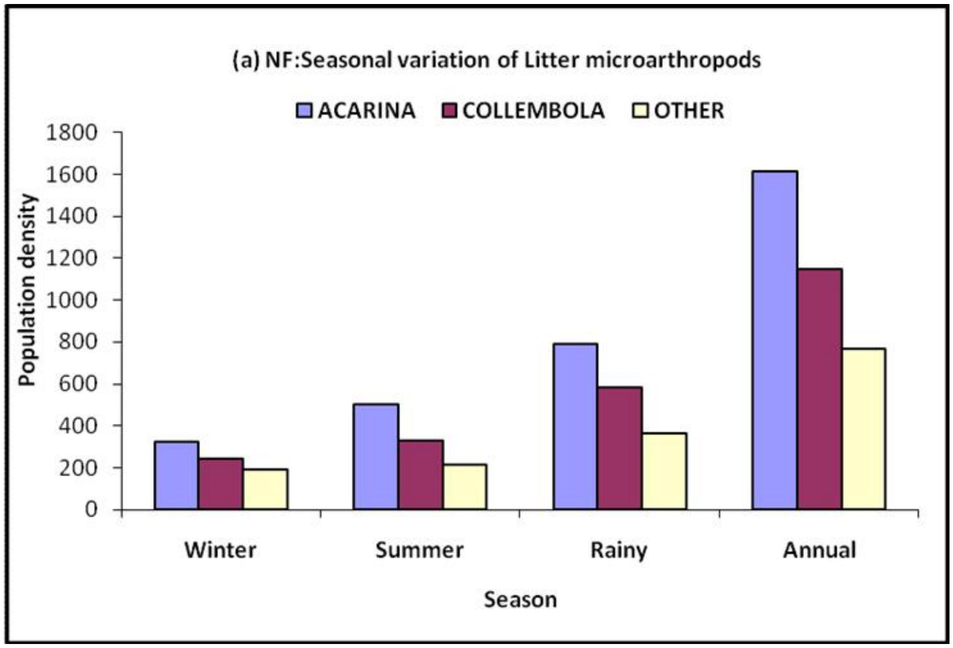
Table 63: Annual population density of total litter microarthropods (*Numbers ± S.E x10^2m^{-2}*) (In parenthesis contribution to respective seasons)

(a) Natural forest

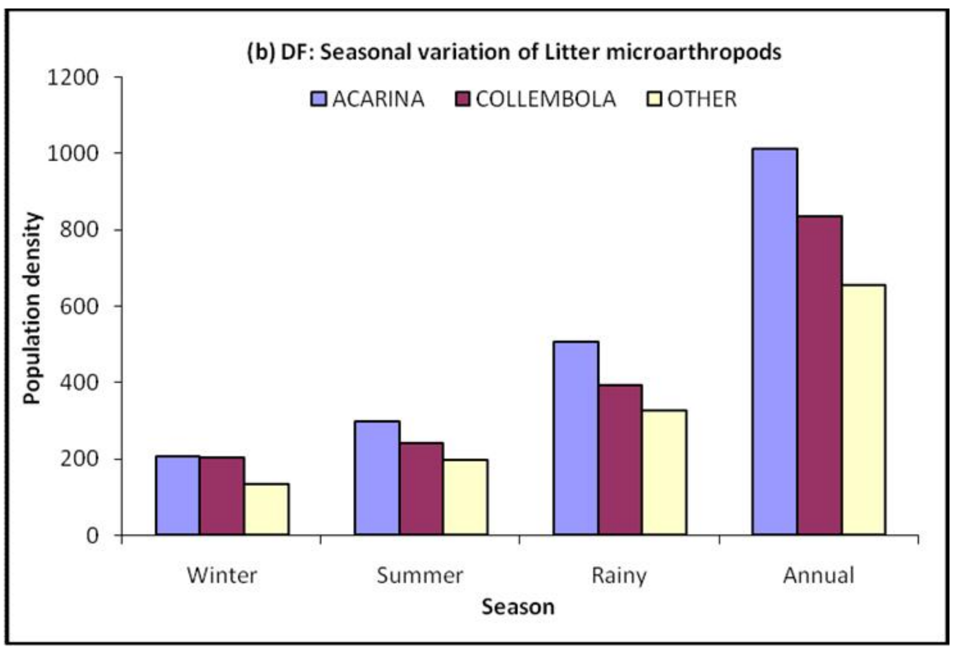
Season	Population density in natural forest (Numbers ± S.E. and Percentage)			
	Acarina	**Collembola**	**Others**	**Total**
Winter	325.25 ± 3.54 ***(42.83)***	242.82±0.66 ***(31.98)***	191.30 ± 1.22 ***(25.19)***	759.37±2.88 ***(21.47)***
Summer	502.88± 3.49 ***(48.11)***	327.26±2.74 ***(31.31)***	215.06 ± 0.86 ***(20.58)***	1045.2 ± 5.07 ***(29.55)***
Rainy	788.21 ± 6.04 ***(45.50)***	580.79±3.09 ***(33.53)***	363.31 ± 2.57 ***(20.97)***	1732.31±6.92 ***(48.98)***
Total	1616.34 ± 7.28 ***(45.70)***	1150.87±6.67 ***(32.54)***	769.67 ± 5.24 ***(21.76)***	3536.88±7.52 ***(100.00)***

(b) Degraded forest

Season	Population density in degraded forest (Numbers ± S.E. and Percentage)			
	Acarina	**Collembola**	**Others**	**Total**
Winter	206.82±3.57 ***(38.15)***	202.76±1.27 ***(37.40)***	132.54 ± 1.08 ***(24.45)***	542.12 ± 2.07 ***(21.65)***
Summer	299.18±2.84 ***(40.62)***	240.83±1.09 ***(32.70)***	196.45 ± 1.31 ***(26.68)***	736.46 ± 4.11 ***(29.41)***
Rainy	506.78±4.82 ***(41.35)***	393.56±2.68 ***(32.11)***	325.27±2.03 ***(26.54)***	1225.61 ±4.6 ***(48.94)***
Total	1012.78±7.05 ***(40.44)***	837.15±4.61 ***(33.43)***	654.26 ± 4.88 ***(26.13)***	2504.19±1.72 ***(100.00)***



(a)



(b)

Figure 36: Seasonal variation of Litter microarthropod population density (Numbers x $10^2 m^{-2}$) in Natural NF) and degraded (DF) forest ecosystem .

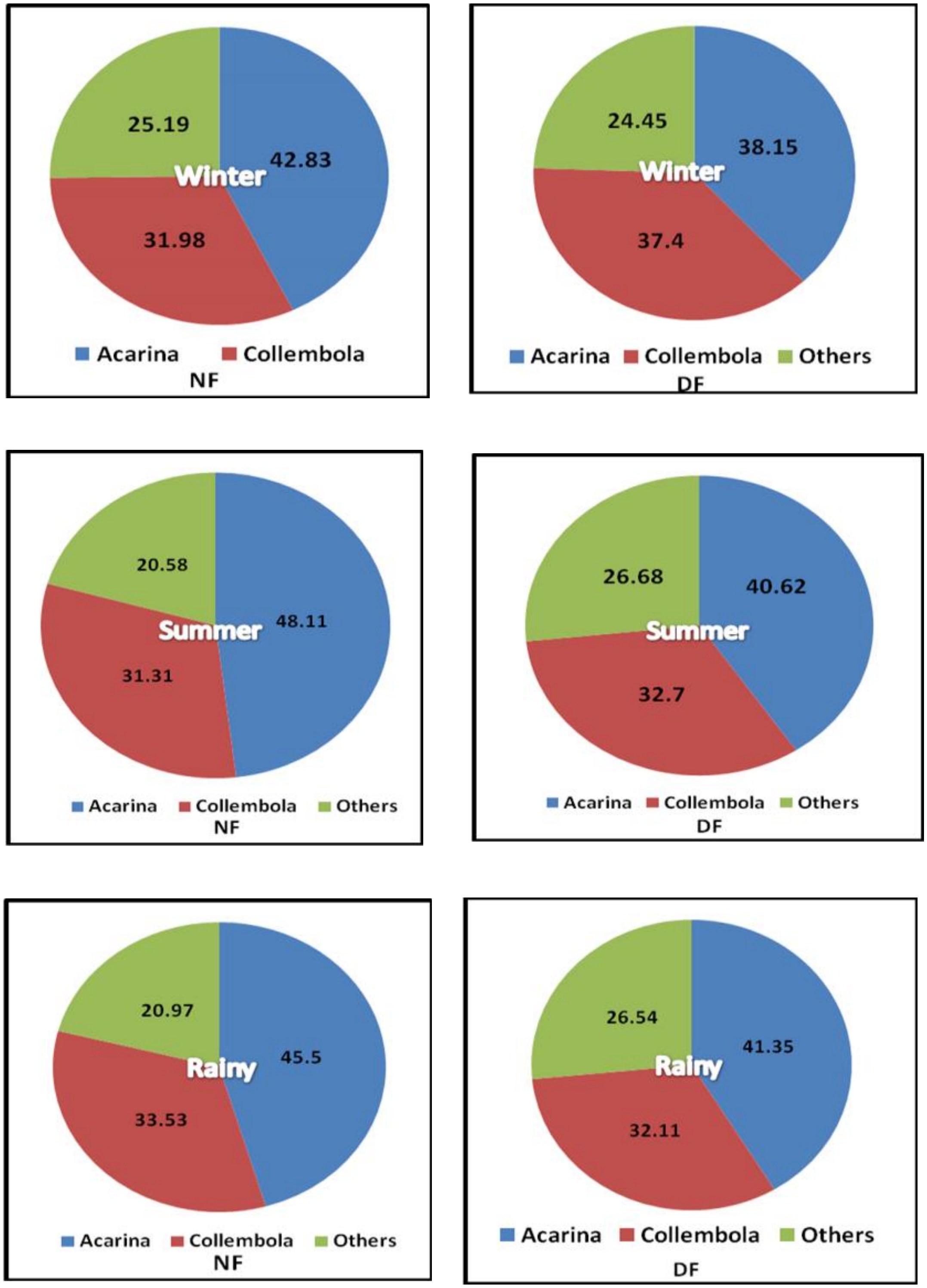


Figure 38: Seasonal contribution of Litter microarthropod groups in natural (NF) and degraded (DF) forest site in different seasons

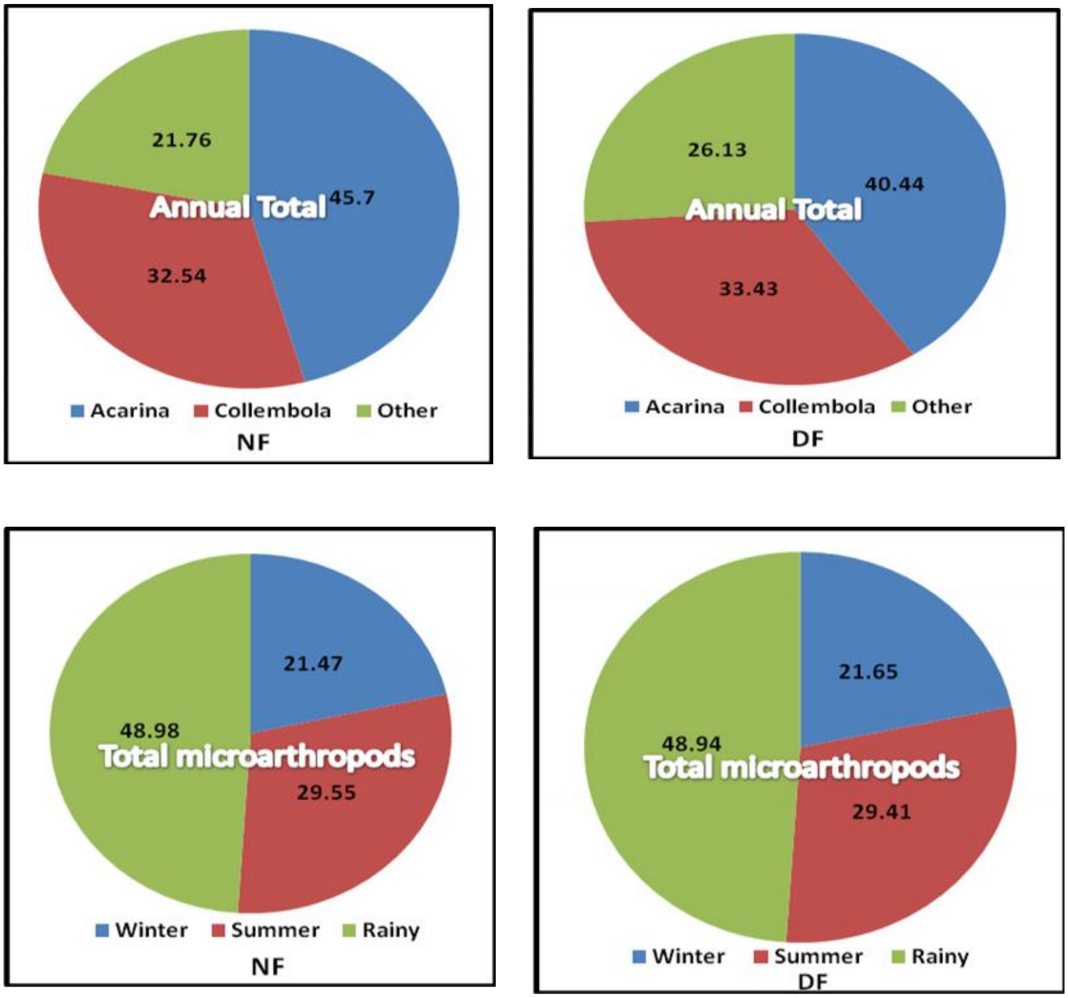


Figure 38: Annual contribution of litter microarthropods in natural (NF) and degraded (DF) forest ecosystem

Monthly variation of total Litter microarthropods

With initial population of 289.16 x 10^2m^{-2} in October, total Litter microarthropods decreased to 92.42 x 10^2m^{-2} (January), thereafter gradually increased to reach the maximum peak in the month of August (514.53 x 10^2m^{-2}). Similar trend was also observed in degraded site exhibiting a decreasing trend from October (227.63 x 10^2m^{-2}) to January (46.05 x 10^2m^{-2}) and thereafter reached the maximum of 375.75 x 10^2m^{-2}) during August**. (Fig. 39).**

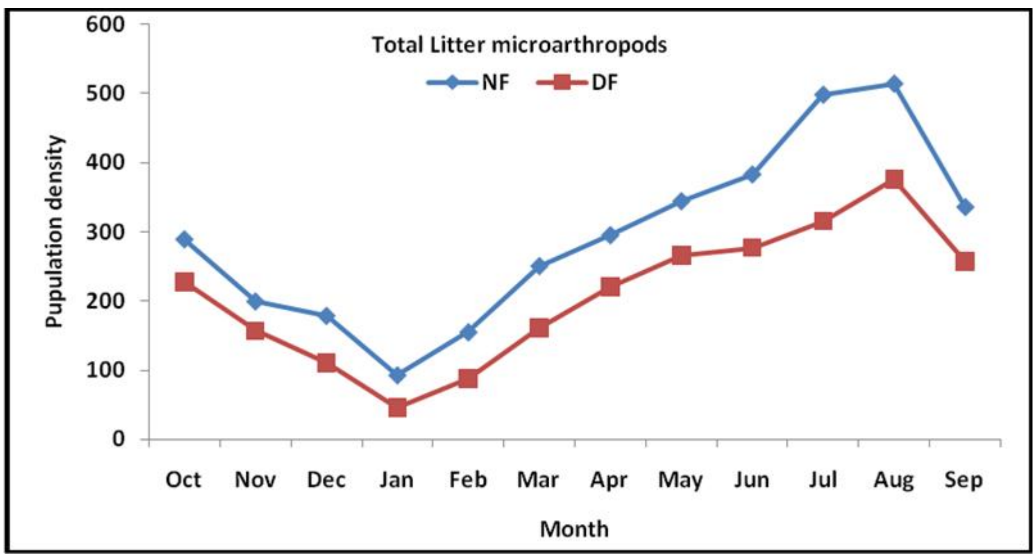


Figure 39: Monthly fluctuation of total litter microarthropods population density *(Numbers x ²10 m⁻²)* in natural (NF) and degraded (DF) forest ecosystem.

The ANOVA indicates a variation in the population density in different seasons of both natural and degraded forest ecosystem (**Table 64**). In natural forest, highly significant difference was observed during winter ($F = 29.770$ $p < 0.001$), summer ($F = 8.340$, $p < 0.001$) rainy season ($F = 21.096$, $p < 0.001$) and for annual ($F = 29.474$, $p < 0.001$).

In degraded forest ecosystem, there was significant to highly significant difference on population density in different seasons i.e. rainy season ($F = 5.854$, $p < 0.01$), winter season ($F = 4.633$, $p < 0.01$), summer season ($F = 19.929$, $p <0.001$), and f annual ($F = 10.415$, $p < 0.001$) **(Table 65)**.

Table 64: Analysis of variance (ANOVA) of total litter microarthropods population in different months of natural forest ecosystem.

Source of variation	df	SS	MS	F	P
Winter season					
Between the months	3	67.925	22.642	29.770	P< 0.001
Within the months	16	12.169	.761		
Total	19	80.094			
Summer season					
Between the months	3	15.651	5.217	8.340	P< 0.001
Within the months	16	10.009	.626		
Total	19	25.660			
Rainy season					
Between the months	3	106.175	35.392	21.096	P< 0.001
Within the months	16	26.843	1.678		
Total	19	133.017			
Annual					
Between the months	11	50.620	4.602	29.474	P< 0.001
Within the months	48	7.494	.156		
Total	59	58.114			

Table 65: Analysis of variance (ANOVA) of total litter Microarthropods population in different months of degraded forest ecosystem.

Source of variation	df	SS	MS	F	P
Winter season					
Between the months	3	11.476	3.825	4.633	P< 0.016
Within the months	16	13.209	.826		
Total	19	24.685			
Summer season					
Between the months	3	63.891	21.297	19.929	P< 0.001
Within the months	16	17.098	1.069		
Total	19	80.989			
Rainy season					
Between the months	3	36.771	12.257	5.854	P < 0.007
Within the months	16	3.498	2.094		
Total	19	70.269			
Annual					
Between the months	11	41.487	3.772	10.415	P< 0.001
Within the months	48	17.381	.362		
Total	59	58.868			

Table 66: Analysis of variance (ANOVA) of total soil microarthropods & litter microarthropods population in all months of both natural and degraded forest ecosystem.

Source of variation	df	SS	MS	F	P
Between the months	11	45.095	4.095	37.316	P < 0.001
Within the months	48	5.267	.110		
Total	59	50.306			

Aggregation of litter microarthropods in natural site and also in rainy season was accomplished with optimum microclimatic conditions and rich accumulations of organic debris in the form of thick litter cover that form suitable substratum for growth and development of animal population. In the present investigation, Acarina contributed maximum to annual and seasonal population density followed by Collembola and others in both natural and degraded forest ecosystem. Hazra (1978) reported that the patterns of seasonal variation appeared to be different in different species of Collembola, with a single population peak from the deciduous forest floor litter of *Shorea robusta* in West Bengal. Reddy (1984) reported peak Collembolan population density of 1310 x 10^2 m^{-2} in the pine litter during rainy season. Badejo *et al*. (1997) reported maximum population of Litter Acarina when there was high moisture content. Hattar *et al.* (1992) reported maximum population of litter Acarina during rainy season and decreasing trend with the onset of winter season. Darlong (1984) reported higher density of litter Collembola (7000-8000 x 10^2 m^{-2}) from pine forest ecosystem in Meghalaya. Chitrapati *et al.(*2002) recorded more than 80% of litter Collembolan and Acarina population density in a Dipterocarpus forest ecosystem of Manipur and higher density during monsoon months was synchronized with high litter moisture content and temperature.

Comparison of Soil and Litter microarthropods

Table 67 highlights comparison of population density of soil and litter microarthropods in natural and degraded forest ecosystem. Population density of total litter microarthropods was 3.5 and 4.15 times higher than soil microarthropods in natural and degraded forest respectively. Same trend was also observed in individual groups i.e Acarina, Collembola and Others that revealed that decomposing litter provided suitable substratum in the form of food and microclimate than the total soil in different depth layers. As decomposition leads into fermentation and humus phases, a variety of breakdown products accumulate in the organic horizons reducing concentration of polyphenols and thereby allowing soil animals to feed directly on the leaf litter and is paralleled by increase in the species diversity(Wallwork 1976).

Table 67: Annual population density of total soil and Litter microarthropods
(Numbers ± S.E.) x 10^2 m^{-2})

Micro arthropod group	Population density (Numbers ± S.E.)			
	Natural Forest		Degraded forest	
	Soil	Litter	Soil	Litter
Acarina	396.74 ±3.69	1616.34 ± 3.86	226.32 ± 1.74	1012.78 ± 5.11
Collembola	350.04 ±2.49	1150.87 ± 5.79	155.32 ± 1.28	837.15 ± 4.22
Others	264.23 ±1.08	769.67 ± 2.40	221.74 ± 1.87	654.26 ± 3.29
Total	1011.01 ± 8.34	3536.88 ±8.72	603.38 ± 4.28	2504.19 ± 6.68

Soil and Litter microarthropods both in natural and degraded sites were found to be decreased from October to January and there after exhibited an increasing trend to reach the maximum peak during August (**Fig. 40**). Singh (1977) recorded maximum number of Acarina and Collembola during July-August and minimum in November. Pillai and Singh (1980) recorded a definite pattern of population fluctuation with peak during rainy season followed by winter, however observed that in the hot band dry summer months Litter microarthropod population was very low. Reddy (1996) collected very few or no microarthropod in the litter of Tectona and Bamboo during the dry season, while larger density was recorded during the wet season in tropical deciduous forest.

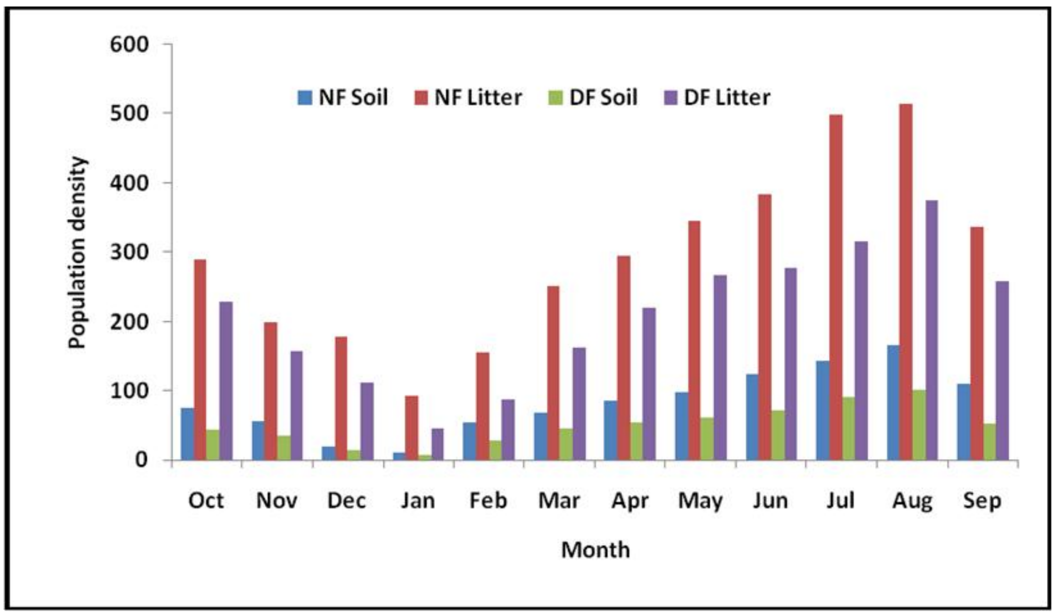


Figure 40: Monthly variation of soil and Litter microarthropods in natural (NF) and degraded (DF) forest

Chapter – VII

EFFECT OF PHYSICO – CHEMICAL FACTORS AND SOIL NUTRIENTS ON POPULATION CHANGES OF SOIL AND LITTER MICROARTHROPODS.

Relationship with soil microarthropods

The correlation studied between soil microarthropods and different soil factors was worked out statistically to show the effect of abiotic factors on fluctuation of soil microarthropods during the study period.

Effect of air temperature on different soil microarthropods

In natural forest ecosystem, air temperature showed highly significant positive correlation with Acarina ($r=0.852$, $p<0.001$), Collembola ($r=0.808$, $p<0.001$),total ($r=0.815$, $p<0.001$) and other soil microarthropods ($r=0.677,p<0.016$).

In degraded forest ecosystem also, air temperature had positive significant correlationship with Acarina ($r =0.835,p<0.001$), Collembola ($r=0.81$, $p<0.001$), total ($r=0.85,p<0.001$) and others soil microarthropods ($r=0.661,p <0.019$).

Effect of Relative humidity on different soil microarthropods

In natural forest ecosystem, the relative humidity recorded during the study period showed negative and significant correlation with Collembola ($r =-0.831$, $p<0.001$), total soil microarthropods ($r= -0.854$, $p<0.001$) and Others ($r= -0.601$, $p<0.039$) but insignificant with Acarina ($r =-0.439$, $p<0.154$).

Similar pattern of relationship was also observed in degraded sites showing negative and highly significant relation with Collembola ($r = -0.765$, $p<0.004$), total (r= -0.821, p<0.019) and Others soil microarthropods (r = -0.697, p<0.012) and insignificant with Acarina (r =-0.279, p<0.381).

Effect of rainfall on different Soil microarthropods

In natural forest ecosystem, rainfall exhibited significant positive correlation with Acarina (r=0.684, p<0.014), Collembola (r=0.589, p<0.044), Others (r=0.581, p<0.048) and total soil microarthropods (r=0.553, p<0.048).

In degraded forest ecosystem also, rainfall showed a positive and significant correlatonship with Acarina (r=0.669, p<0.017), Collembola (r=0.696, p<0.012), and Others (r= 0.619, p<0.032), however no appreciable relation ship was observed with total soil microarthropods (r=0.486, p<0.061).

Effect of Soil Temperature on different Soil microarthropods

In natural forest system, soil temperature recorded during study period showed positive and significant relationship with all groups at different soil layers i.e. at 0-10 cm (Acarina: r=0.819, p<0.001, Collembola : r=0.786,p<0.002, others :r= 0.83, p<0.001and total soil microarthropods: r=-0.712, p<0.003); at 10-20 cm (Acarina :r=0.775, p<0.003, Collembola: (r=0.87,p<0.001, Other:r=0.809,p< 0.001 and total soil microarthropods:r= 0.842, p< 0.001) and at 20-30 cm (Acarina: r=0.801, p<0.002, Collembola :r=0.751, p<0.005, Others : r=0.834, p<0.001 and total soil microarthropods: r=0.73, p<0.005).

In degraded forest ecosystem soil temperate exhibited positive and significant correlationship at 0-10 cm with all groups (Acarina :r=0.82, p<0.001, Collembola: r =0.871, p<0.001, Others:r = 0.872, p<0.001and total soil microarthropods :r=0.759, p<0.002). At 10-20 cm and 20-30 cm soil layer, the relationship was positive and significant with acarina (r=0.829, p<0.001 and r = 0.582, p<0.047), Others (r=0.856, p<0.001 and r = 0.797, p<0.002) and total soil microarthropods (r=0.921,p<0.001and r=0.752, p<0.002) respectively, having no appreciable relation with collembola.

Effect of Soil moisture on different Soil microarthropods

In natural forest system, soil moisture recorded during study period showed highly significant positive relationship with all groups at different soil layers i.e. at 0-10 cm (Acarina: r=0.856, p<0.001, Collembola :r=0.855, p<0.001, Others: r=0.832,p<0.001 and total soil microarthropods :r= 0.867, p< 0.001) ; at 10-20 cm (Acarina :r=0.89, p<0.001, Collembola : r=0.874, p<0.001, others :r=0.79, p<0.002 and total soil microarthropods : r= 0.842, p< 0.001) and at 20-30 cm (Acarina :r=0.806, p<0.002, Collembola : r=0.754, p<0.002, Others : r=0.793, p< 0.002 and total soil microarthropods :r= 0.732,p< 0.002).

In degraded forest ecosystem, soil moisture at 0-10 cm also exhibited positive and highly significant correlationship with all groups (Acarina : r=0.914, p<0.001), Collembola :r=0.922, p<0.001), Others :r=0.862, p<0.001 and total soil microarthropods :r=0.858, p< 0.001). At 10-20 cm and 20-30 cm soil layer, the relationship was positive and significant with acarina (r=0.839, p<0.001; r=0.658, p<0.02), Others (r=0.806, p<0.002 and r = 0.827, p<0.002) and total soil microarthropods ((r= 0.825, p<0.001). and r=0.715, p<0.002) respectively, however relation was insignificant with Collembola.

Effect of soil total nitrogen on soil microarthropods

In natural forest ecosystem, except for Acarina (r = 0.6, p < 0.039) and Others (r=0.58, p<0.050) at 20-30cmlayers, relationship with soil nitrogen at 0-10and 10-20 cm was not significant. No appreciable relationship between soil nitrogen and microarthropods was observed at all soil layers in degraded forest.

Effect of Soil pH on dfferent Soil microarthropods.

In natural forest ecosystem, except for highly significant and positive correlation between soil pH and Acarina at 10-20 cm (r=0.932,p<0.001) and at 20-30 cm layer (r=-0.886, p<0.001), relationship was not appreciable with other groups.

Significant relationship was also not noticed in degraded forest site.

Effect of Soil Available Phosphorus on different Soil microarthropods

No correlationship was observed in natural site.

In degraded forest, positive and significant relationship was observed between soil available phosphorous and Acarina at 10-20 cm and 20-30 cm layers (r=0.5,p<0.05 and r=0.521,p<0.05) and Others (r=0.701, p<0.01) at 10-20 cm only.

Effect of Soil Potassium on dfferent Soil microarthropods

In natural forest ecosystem, soil potassium at 0-10 cm showed negative and significant relationship with Acarina (r=-0.686,p<0.014), Collembola (r=-0.821, p<0.001), Others (r=-0.846, p<0.001) total soil microarthropods (r=-0.856,p<0.001). At 10-20 cm soil layer also, relation was significant and negative with Acarina (r=-0.31, p<0.035),Collembola (r=-0.771, p<0.003), Others (r=-0.873,p<0.001) and total soil microarthropods (r=-0.801, p<0.002). However at 20-30 cm, relation ship was significant and positive with Acarina (r=0.417,p<0.077) however negative with Collembola (r=-0.672,p<0.017) and total soil microarthropods (r=-0.725, p<0.001).

In degraded forest ecosystem, soil potassium at 0-10 cm showed a negative but significant correlationship with all groups i.e. (Acarina : r = -0.844,p<0.001), Collembola: r= -0.723, p<0.03, Total (r= -0.925, p<0.001 and others : r=-0.789, p<0.002). At 10-20 cm and 20-30 cm layers also, except for collembolan, relationship was found to be significant and negative in other groups i.e. (Acarina: r=-0.716,p<0.009 and r=-0.766,p<0.004), Other(r=-0.682, p<0.015 and r=-0.825,p<0.001) and total soil microarthropods (r=-0.832, p<0.001 and(r=-0.734, p<0.001).

Effect of soil organic carbon on dfferent soil microarthropods

Soil organic carbon showed significant negative correlation with other micro arthropod group at 10-20 cm soil layer (r=-0.873, p<0.05) in natural forest and at 20-30 cm soil layer (r=-0.774, p<0.003) in degraded site. No appreciable relationship was evident with Acarina, Collembola and total microarthropod at different depths in both study sites.

Effect of soil sodium on different Soil microarthropods

In natural forest ecosystem, soil sodium did not show significant relationship with any group at 0-10cm soil layer. However significant negative correlation at 10-20 cm was found with Acarina (r =-0.517, p<0.05) and other microarthropods (r=-0.572, p<0.05) and at 20-30 cm soil layer with Acarina (r=-0.732, p<0.007) only. In degraded site soil sodium showed significant but negative correlation with Acarina at 10-20 cm soil layer only.

Table 68: Correlationship between Acarina and physical factors in natural forest ecosystem

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil temperature (ºC)	0-10	0.819	10	4.514	< 0.001	22.25
	10-20	0.775	10	3.878	<0.003	22.33
	20-30	0.801	10	4.231	<0.002	21.63
Soil moisture (%)	0-10	0.856	10	5.236	<0.001	21.66
	10-20	0.89	10	6.173	<0.001	18.79
	20-30	0.806	10	4.306	<0.002	16.63
Air Temperature (ºC)	--	0.852	10	5.143	<0.001	20.23
Relative Humidity (%)	--	- 0.439	10	1.544	0.154	22.95
Rainfall (mm)	--	0.684	10	2.963	0.014	24.54

Table 69: Correlationship between Acarina and chemical factors in natural forest ecosystem

Variables	Soil layer (cm)	r	df	t	P	Variability (%)
Soil Total Nitrogen	0-10	0.248	10	0.81	<0.438	17.14
	10-20	- .254	10	0.83	<0.426	18.08
	20-30	0.6	10	2.37	<0.039	15.00
Soil pH	0-10	- .300	10	0.095	<0.926	17.28
	10-20	0.932	10	8.131	<0.001	18.88
	20-30	0.886	10	6.042	<0.001	18.16
Soil available Phosphor	0-10	0.105	10	0.334	<0.746	26.75
	10-20	0.126	10	0.401	<0.696	29.24
	20-30	0.417	10	0.45	<0.177	33.2
Soil potassium	0-10	-.686	10	2.981	<0.014	98.68
	10-20	-.31	10	2.433	<0.035	73.94
	20-30	0.417	10	1.45	<0.077	33.2
Soil Organic Carbon	0-10	0.004	10	0.013	<0.990	21.74
	10-20	0.228	10	0.74	<0.475	14
	20-30	0.434	10	1.522	<0.158	17.69
Soil Sodium	0-10	-0.086	10	0.273	<0.086	15.54
	10-20	-.517	10	1.909	<0.085	12.98
	20-30	-.732	10	3.395	<0.007	11.88

Table 70: Correlationship between Acarina and physical factors in degraded forest ecosystem.

Variables	Soil layer (cm)	r	df	t	P	Variabiliy (%)
Soil temperature (ºC)	0-10	0.82	10	4.527	<0.001	20.71
	10-20	0.829	10	4.684	<0.001	24.09
	20-30	0.582	10	2.262	<0.047	23.26
Soil moisture(%)	0-10	0.914	10	7.119	<0.001	14.51
	10-20	0.839	10	4.872	<0.001	17.25
	20-30	0.658	10	2.761	<0.02	15.08
Air temperature (ºC)	0-30	0.835	10	4.795	<0.001	16.63
Relative Humidity (%)	0-30	-0.279	10	0.918	<0.381	22.94
Rainfall(mm)	0-30	0.669	10	2.844	<0.017	22.14

Table 71: Correlationship between Acarina and chemical factors in degraded forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Total Nitrogen	0-10	0.305	10	1.012	<0.335	18.88
	10-20	0.263	10	0.861	<0.410	11.56
	20-30	0.393	10	1.351	<0.206	9.38
Soil pH	0-10	-0.036	10	0.114	<0.913	29.49
	10-20	-0.115	10	0.366	<0.722	18.33
	20-30	-0.084	10	0.266	<0.796	18.05
Soil Available Phosphorus	0-10	0.138	10	0.44	<0.668	25.62
	10-20	0.5	10	1.824	<0.098	17.85
	20-30	0.521	10	1.929	<0.082	19.53
Soil Potassium	0-10	-0.844	10	4.973	<0.001	91.5
	10-20	-0.716	10	3.241	<0.009	72.87
	20-30	-0.766	10	3.765	<0.004	91.18
Soil Organic Carbon	0-10	-0.44	10	1.548	<0.152	14.23
	10-20	0.422	10	1.471	<0.171	10.6
	20-30	0.126	10	0.401	<0.696	20
Soil Sodium	0-10	-0.436	10	1.531	<0.158	17.96
	10-20	-0.712	10	3.204	<0.009	15.88
	20-30	0.051	10	0.161	<0.875	13.13

Table 72: Correlationship between Collembola and physical factors in natural forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil temperature (ºC)	0-10	0.786	10	4.021	<0.002	20.71
	10-20	0.87	10	5.58	<0.001	22.56
	20-30	0.751	10	3.596	<0.005	23.32
Soil Moisture (%)	0-10	0.855	10	5.213	<0.001	20.36
	10-20	0.874	10	5.688	<0.001	19.78
	20-30	0.754	10	3.63	<0.002	16.72
Air temperature.(ºC)	0-30	0.808	10	4.334	<0.001	22.55
Relative Humidity (%)	0-30	-0.831	10	4.721	<0.001	25.15
Rainfall(mm)	0-30	0.589	10	2.303	<0.044	129.3

Table 73: Correlationship between Collembola and chemical factors in natural forest cosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Total N	0-10	-0.15	10	1.436	<0.641	20.22
	10-20	-0.131	10	0.413	<0.685	18.75
	20-30	-0.059	10	1.187	<0.855	15.4
Soil pH	0-10	-0.15	10	1.436	<0.541	19.42
	10-20	-0.148	10	0.473	<0.647	16.51
	20-30	0.055	10	0.174	<0.896	14.23
Soil Available Phosphorus	0-10	0.352	10	1.189	<0.261	24.2
	10-20	0.272	10	0.894	<0.392	16.58
	20-30	0.321	10	1.072	<0.309	17.42
Soil Potassium	0-10	-0.821	10	4.547	<0.001	85.75
	10-20	-0.771	10	2.438	<0.003	78.42
	20-30	-0.672	10	2.87	<0.017	43.05
Soil Organic Carbon	0-10	-0.024	10	0.076	<0.024	18.75
	10-20	0.277	10	0.912	<0.384	16.32
	20-30	0.159	10	0.509	<0.622	12.59
Soil Sodium	0-10	-0.1	10	0.318	<0.758	18.46
	10-20	-0.104	10	0.331	<0.759	16.51
	20-30	-0.042	10	0.133	<0.897	14.32

Table 74: Correlationship between Collembola and physical factors in degraded forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Temperature (ºC)	0-10	0.871	10	5.602	<0.001	21.34
	10-20	0.483	10	1.743	<0.112	18.76
	20-30	0.213	10	0.689	<0.506	16.55
Soil Moisture (%)	0-10	0.922	10	7.525	<0.001	21.22
	10-20	0.49	10	1.776	<0.106	18.76
	20-30	0.384	10	1.314	<0.218	20.21
Air Temperature (ºC)	0-30	0.81	10	4.365	<0.001	22.47
Relative Humidity (%)	0-30	-0.765	10	3.754	<0.004	22.63
Rainfall(mm)	0-30	0.696	10	3.663	<0.012	123.00

Table 75: Correlationship between Collembola and chemical factors in degraded forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Total N	0-10	0.178	10	0.572	<0.581	26.22
	10-20	0.089	10	0.282	<0.783	18.75
	20-30	0.011	10	0.035	<0.972	15.23
Soil pH	0-10	0.035	10	0.111	<0.914	22.46
	10-20	-0.185	10	0.595	<0.566	18.54
	20-30	0.468	10	1.673	<0.125	16.85
Soil Available phophorus	0-10	0.088	10	0.279	<0.786	25.6
	10-20	-0.185	10	0.595	<0.564	26.22
	20-30	0.188	10	0.605	<0.558	18.75
Soil Potassium	0-10	-0.723	10	3.307	<0.3.30	84.53
	10-20	-0.561	10	2.141	<2.141	76.89
	20-30	-0.496	10	1.805	<1.805	80.81
Soil Organic Carbon	0-10	-0.439	10	1.544	<1.544	20.98
	10-20	-0.012	10	0.038	<0.038	18.76
	20-30	-0.362	10	1.227	<1.227	15.42
Soil Sodium	0-10	-0.348	10	1.173	<1.173	14.32
	10-20	-0.266	10	0.872	<0.872	12.22
	20-30	0.222	10	0.719	<0.719	15.86

Table 76: Correlationship between Others and physical factors in natural forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Temperature (°C)	0-10	0.83	10	4.702	<0.001	20.41
	10-20	0.809	10	4.349	<0.001	22.32
	20-30	0.834	10	4.702	<0.001	18.32
Soil moisture (%)	0-10	0.832	10	4.739	<0.001	23.31
	10-20	0.79	10	4.072	<0.002	20.45
	20-30	0.793	10	4.113	<0.002	18.97
Air Temperature (°C)	0-30	0.677	10	2.907	<0.016	22.34
Relative Humidity (%)	0-30	-0.601	10	2.371	<0.039	20.08
Rainfall (mm)	0-30	0.581	10	2.25	<0.048	129.3

Table77: Correlationship between Others and chemical factors in natural forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Total Nitrogen	0-10	-0.058	10	0.184	<0.859	31.32
	10-20	0.062	10	0.196	<0.849	26.85
	20-30	0.058	10	0.184	<0.050	18.75
Soil pH	0-10	-0.164	10	0.525	<0.611	14.65
	10-20	-0.321	10	1.071	<0.309	12.32
	20-30	-0.241	10	0.785	<0.451	13.25
Soil Available Phosphorus	0-10	0.231	10	0.75	<0.471	26.62
	10-20	0.252	10	0.816	<0.433	22.41
	20-30	0.315	10	1.049	<0.321	23.33
Soil Potassium	0-10	- 0.846	10	5.014	<0.001	86.45
	10-20	- 0.873	10	5.656	<0.001	91.32
	20-30	0.314	10	1.045	<0.320	72.32
Soil Organic Carbon	0-10	-0.206	10	0.665	<0.520	24.56
	10-20	-0.873	10	0.781	<0.453	18.75
	20-30	0.314	10	0.936	<0.372	20.82
Soil Sodium	0-10	- 0.051	10	0.161	<0.875	16.52
	10-20	- 0.572	10	0.204	<0.052	13.51
	20-30	- 0.146	10	0.466	<0.652	14.03

Table 78: Correlationship between Others and physical factors in degraded forest ecosystem.

Variables	Soil layer (cm)	r	df	t	Variability (%)
Soil Temperature (ºC)	0-10	0.872	10	5.629	<0.001
	10-20	0.856	10	5.232	<0.001
	20-30	0.797	10	4.17	<0.002
Soil moisture (%)	0-10	0.862	10	5.374	<0.001
	10-20	0.806	10	4.305	<0.002
	20-30	0.827	10	4.648	<0.001
Air Temperature (ºC)	0-30	0.661	10	3.784	<0.019
Relative Humidity(%)	0-30	- 0.697	10	3.072	<0.012
Rainfall(mm)	0-30	0.619	10	2.491	<0.032

Table 79: Correlationship between Others and chemical factors in degraded forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Total Nitrogen	0-10	0.254	10	0.83	<0.425	32.24
	10-20	0.314	10	1.045	<0.320	28.75
	20-30	0.484	10	1.748	<0.111	30.33
Soil pH	0-10	0.081	10	0.257	<0.805	20.33
	10-20	-0.176	10	0.565	<0.585	18.75
	20-30	-0.167	10	1.535	<0.603	16.32
Soil Available Phosphorus	0-10	0.101	10	0.321	<0.755	22.82
	10-20	0.701	10	3.106	<0.011	19.35
	20-30	0.467	10	1.669	<0.126	16.88
Soil Potassium	0-10	- 0.789	10	4.058	<0.002	92.33
	10-20	- 0.682	10	2.947	<0.015	65.46
	20-30	-0.825	10	4.613	<0.001	53.63
Soil Organic Carbon	0-10	-0.409	10	1.416	<0.187	18.32
	10-20	0.121	10	0.385	<0.709	16.54
	20-30	-0.774	10	3.863	<0.003	11.32
Soil Sodium	0-10	- 0.289	10	0.954	<0.362	11.52
	10-20	- 0.477	10	1.715	<0.117	16.32
	20-30	-0.133	10	0.424	<0.081	12.34

Table 80: Correlationship between total soil microarthropods physical factors in natural forest ecosystem.

Variables	Soil layer (cm)	r	df	t	P	Variability (%)
Soil Temperature (ºC)	0-10	0.712	10	3.964	<0.003	18.65
	10-20	0.842	10	5.42	<0.001	20.41
	20-30	0.73	10	3.412	<0.005	22.56
Soil Moisture (%)	0-10	0.867	10	5.217	<0.001	18.44
	10-20	0.842	10	5.478	<0.001	20.21
	20-30	0.732	10	3.51	<0.002	15.41
Air Temperature . (ºC)	0-30	0.815	10	4.412	<0.001	24.22
Relative Humidity(%)	0-30	-0.854	10	4.987	<0.001	23.45
Rainfall(mm)	0-30	0.553	10	2.154	<0.048	122.5

Table 81: Correlationship between total soil microarthropods and chemical factors in natural forest ecosystem

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Total Nitrogen	0-10	-0.172	10	1.469	<0.695	18.76
	10-20	-0.154	10	0.402	<0.701	19.68
	20-30	-0.061	10	0.198	<0.889	14.58
Soil pH	0-10	-0.172	10	1.567	<0.496	18.79
	10-20	-0.165	10	0.412	<0.659	17.42
	20-30	0.061	10	0.182	<0.845	15.28
Soil Available Phosphorus	0-10	0.401	10	1.234	<0.236	22.23
	10-20	0.242	10	0.758	<0.321	18.32
	20-30	0.335	10	1.114	<0.285	16.58
Soil Potassium	0-10	-0.856	10	4.798	<0.001	75.57
	10-20	-0.801	10	2.698	<0.002	74.32
	20-30	-0.725	10	3.01	<0.001	41.67
Soil Organic Carbon	0-10	0.036	10	1.032	<0.017	16.88
	10-20	0.325	10	1.486	<0.179	15.65
	20-30	0.158	10	0.657	<0.565	13.66
Soil Sodium	0-10	-0.201	10	0.987	<0.357	17.89
	10-20	-0.165	10	0.602	<0.659	15.56
	20-30	-0.051	10	0.214	<0.742	15.33

Table 82: Correlationship between total soil microarthropods and physical factors in degraded forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Temperature (ºC)	0-10	0.759	10	4.321	<0.002	16.58
	10-20	0.921	10	5.856	<0.001	17.58
	20-30	0.752	10	4.286	<0.002	21.58
Soil moisture (%)	0-10	0.858	10	5.179	<0.001	19.02
	10-20	0.825	10	5.375	<0.001	21.56
	20-30	0.715	10	3.432	<0.002	16.97
Air temperature (ºC)	0-30	0.85	10	4.652	<0.001	21.78
Relative Humidity (%)	0-30	-0.821	10	4.878	<0.019	25.65
Rainfall (mm)	0-30	0.486	10	1.987	<0.061	110.65

Table 83: Correlationship between total soil microarthropods and chemical factors in degraded forest ecosystem.

Variables	Soil layer (cm)	r	df	t	p	Variability (%)
Soil Total Nitrogen	0-10	-0.201	10	1.878	<0.436	21.44
	10-20	-0.113	10	0.325	<0.801	16.59
	20-30	-0.103	10	0.203	<0.759	17.53
Soil pH	0-10	-0.203	10	1.968	<0.335	20.11
	10-20	-0.135	10	0.358	<0.732	15.63
	20-30	0.102	10	0.213	<0.749	16.37
Soil Available Phosphorus	0-10	0.458	10	1.658	<0.116	20.54
	10-20	0.287	10	1.321	<0.189	16.52
	20-30	0.412	10	1.995	<0.102	19.96
Soil Potassium	0-10	-0.925	10	5.213	<0.001	69.98
	10-20	-0.832	10	3.987	<0.001	65.85
	20-30	-0.734	10	3.021	<0.001	44.23
Soil Organic Carbon	0-10	0.027	10	1.012	<0.387	18.85
	10-20	0.401	10	1.856	<0.165	14.38
	20-30	0.152	10	0.612	<0.558	16.31
Soil Sodium	0-10	-0.198	10	0.934	<0.462	19.23
	10-20	-0.131	10	0.654	<0.712	17.78
	20-30	-0.049	10	0.314	<0.841	13.28

Relationship with litter microarthropods

The correlation studied between litter microarthropods and following physical factors was statistically analysed.

Effect of Air temperature on different litter microarthropods

In natural forest ecosystem air temperature showed significant and negative relationship with Acarina ($r = -0.775$, $p < 0.003$), however it was positive with Collembola ($r = 0.741$, $p < 0.006$), total ($r=0.875$, $p<0.001$) and miscellaneous other microarthropods ($r = 0.71$, $p < 0.005$).

In degraded forest ecosystem, air temperature showed positive and significant correlationship with Acarina ($r=0.715$, $p<0.009$), Collembola ($r=0.746$, $p<0.005$) and total ($r=0.831$, $p<0.001$) and others ($r=0.698$, $p<0.01$).

Effect of Relative humidity on different litter microarthropods

In natural forest ecosystem relative humidity was found to be negatively correlated with Collembola ($r = -0.602$, $p < 0.039$) and total microarthropods ($r=-0.868$, $p<0.001$) only.

However in degraded forest relationship was negative but significant with all groups (Acarina :$r=-0.782$, $p<0.003$; Collembola : $r=-0.851$, $p<0.001$: total :$r=-0.847$, $p<0.001$ and Others:$r= -0.758$, $p < 0.003$).

Effect of rainfall on different Litter microarthropods

In natural forest ecosystem rainfall showed significant positive correlation with total ($r=0.502$, $p<0.05$) and other ($r=0.541$, $p<0.052$) micro arthropod group only.

However in degraded forest ecosystem there was significant and positive relation ship with all groups (Acarina :$r=0.592$, $p<0.042$; Collembola :$r=0.571$, $p<0.052$; total :$r=0.478$, $p<0.068$) and Other ($r=0.601$, $p<0.041$).

Table 84: Correlationship between certain physical factors and Litter microarthropods factors in natural and degraded forest ecosystem.

Study site	Physical factor	Micro arthropopod group	r	df	t	p	Variability (%)
Natural	Air temperature	Acarina	-0.775	10	3.875	<0.003	23.28
		Collembola	0.741	10	3.487	<0.006	20.46
		Total	0.875	10	5.465	<0.001	17.89
		Others	0.71	10	3.41	<0.005	13.52
	Relative Humidity	Acarina	-0.037	10	0.111	<0.515	16.82
		Collembola	-0.602	10	2.37	<0.039	16.47
		Total	-0.868	10	5.395	<0.001	24.01
		Others	-0.214	10	1.002	<0.432	15.96
	Rainfall	Acarina	0.33	10	1.105	<0.295	57.3
		Collembola	0.411	10	1.425	<0.184	26.88
		Total	0.502	10	2.345	<0.048	20.45
		Others	0.541	10	2.076	<0.052	110.5
Degr-aded	Air temperature	Acarina	0.715	10	3.232	<0.009	25.89
		Collembola	0.746	10	3.54	<0.005	14.22
		Total	0.831	10	4.659	<0.001	20.04
		Others	0.698	10	3.113	<0.010	23.58
	Relative Humidity	Acarina	-0.782	10	3.965	<0.003	15.13
		Collembola	-0.851	10	5.121	<0.001	16.53
		Total	-0.847	10	4.985	<0.001	23.22
		Others	-0.758	10	3.665	<0.003	16.32
	Rainfall	Acarina	0.592	10	2.321	<0.042	21.53
		Collembola	0.571	10	2.198	<0.052	13.36
		Total	0.478	10	2.001	<0.068	13.65
		Others	0.601	10	2.342	<0.041	18.96

It has been observed that except for relative humidity, there was positive relationship between temporal variation of different physical factors and abundance of all groups of soil microarthropods in both natural and degraded forest ecosystem. However all chemical characteristics except soil potassium did not show any appreciable correlationship with soil microarthropods at different soil depth layers. High rain fall during rainy season increased the soil moisture, which together with high soil temperature made a congenial substratum for growth and development of soil microarthropds both in natural and degraded sites. Positive correlation between moisture and Collembola was also observed by Durrant and Richard (1966), Mukharji and Singh, (1970), Wallwork (1970), Choudhuri and Roy (1972), Singh and Pillai (1975), Usher (1976), Mitra *et al.* (1977), Hazra (1978), Gupta and Mukherji (1978), Bhattacharya and Raychoudhuri (1979), Hazra and Choudhuri (1983), Reddy (1984), Vannier (1987), Whitford (1989), Badejo and Van Straalen (1993), Narula *et al* (1998), Asikidis and Stamou (1991) and Chitrapati (2002). While studying the population fluctuations of soil microarthropods in Rubber and adjacent plantation, Chakraborti and Bhattacharya (1996) could not identify any significant correlation between the temporal variations of the factors and abundance with the sole exception of Collembola population which showed significant correlation with moisture contents of the soil. However, Gupta and Mukharji (1978), Dhillon and Gibson (1962), Choudhuri and Pande (1982) Sarkar (1991), Sanyal and Sarkar (1993), Doulo and Kakati (2009) reported negative correlation of soil fauna with soil moisture content. Guru *et al.* (1988) recorded insignificant positive correlation between soil moisture and Collembola density but significant negative relationship with soil temperature. It was generally believed that in tropical region the abundance of soil microarthropods was mainly regulated by soil moisture and rainfall (Bhattacharya and Raychoudhuri, 1979 and Corpuz-Raros, 1980). The positive correlation between soil temperature and Soil micro arthropods such Collembola and Acarina in natural and degraded forest ecosystem from Imphal Valley has been reported by Chitrapati (2002). Similar positive correlation has also been observed between soil temperature and Collembola population by Narual *et al.* (1998), Mukharji and Singh (1970), Mitra *et al* (1977), Bhattacharya and Raychoudhuri (1979). Darlong and Alfred (1982) found positive correlation with Collembola only whereas Reddy (1984) observed positive correlation with Acarina. Badejo and Van Straalen (1993) found a negative relationship between Collembola abundance and temperature under tropical climatic conditions. Lack of significant correlation between pH and Acarina has been reported by Choudhuri and Banerjee (1977), Choudhuri and Pande (1979) and Sanyal (1982). It appears that the pattern of the temporal changes in the abundance of soil microarthropods vary from area to area depending on the local micro climatic conditions. It was difficult to designate any single factor as the causative agent. However rainfall and soil moisture are the most important abiotic factors influencing the abundance. The results of the present investigation showed close similarities and striking differences with the observations made by earlier workers.

Chapter - VIII

COMMUNITY ANALYSIS OF SOIL AND LITTER MICROARTHROPODS (ACARINA AND COLLEMBOLA)

In the present investigation a total of 1011.01 x 10^2 m^{-2} and 603.38 x 10^2 m^{-2} soil microarthropods were recorded from natural and degraded forest ecosystem respectively. Vertically the total soil microarthropods density was found to be the highest in the 0-10 cm soil layer and gradually decreasing with increase in soil depth showing minimum in 20-30 cm layer.

In the uppermost layer i.e., 0-10 cm, the total soil microarthropods density was recorded to be 461.55 x 10^2 m^{-2} and 342.25 x 10^2 m^{-2} in the natural and degraded sites respectively. In soil layer 10-20 cm, the total microarthropods density was recorded to be 336.13 x 10 m^{-2} and 162.81 x 10^2 m^{-2} and at 20-30 cm soil layer the total microarthropods density was recorded to be 213.33 x 10^2 m^{-2} and 98.32 x 10^2 m^{-2} respectively.

Among the total soil microarthropods, Acarina was the most dominant group contributing 37.51 to 39.26% to the total soil microarthropods population out of which only twenty two (22) different species were identified (**Plate no. 5 to 26**). Next to Acarina, Collembola was the second major groups and represented by 25.74 to 34.62% of the total soil microarthropods population and twenty two (22) different species were identified (**Plate no27 to 48**) in the present investigation.

The smaller minor groups like Myriapoda, Hymenoptera, Diplura and Protura etc were designated as other soil microarthropods (**Plate no.49 to 74**), which together contributed 26.14% and 36.75% to the total soil microarthropods in natural and degraded site respectively.

Contribution of Litter Acarina (22 species), Collembola (22 species) and others to total litter microarthropods (3536.88 x 10^2 m^{-2}) in natural forest were 45.70%, 32.53%) and 21.77% respectively. In degraded forest also acarina, Collembola and others constitute 40.44%, 33.43% and 26.13% of total litter microarthropods (2504.19 x 10^2 m^{-2}) respectively. Altogether 16 and 15 numbers of Acarina and Collembola species respectively were recorded in degraded forest site.

Community analysis was carried out for the two major groups of soil and litter microarthropods i.e. Acarina and Collembola in the present study as their contribution are maximum in term of species, abundance and distribution (Behan-Pelletier, 2003). The difference in two sites as well as between soil and litter may be due difference in physico-chemical properties of soil as well as microclimatic conditions, therefore comparative analysis were done to find the species richness, diversity and distribution patterns of Acarina and Collembola community between the two sites. The species diversities and similarities of the communities were analyzed using the following indices of Margalef's index (Da) (1968), Shannon-Wiener index (H') (1949), Sorensen's index (Q/S) of similarity (1948), Average faunal resemblance and evenness or equitability index (Pielou, 1969).

Community analysis of Acarina

Soil Acarina

The twenty two (22) species of soil Acarina are *Megisthanus floridanus, Phthiracarus sp, Poeilochirus sp, Discoppia sp, Pergamasus crassipes, Raphignathoid mite (Cryptognathus sp), Dendrohermannia monstrouse, Eugamasoidea vaigaia cerva, Arctoseius sp, Dinychus sp, Allothrombium sp, Nothrus, Hermanniella sp, Tectocepheus velatus, Parasitus sp, Euemaerus sp, Hypochthonius sp, Hermannia sp,* *Dentachiptera sp, Holaspulus sp, Heminothrus* sp, *Podocinum sp.* Analysis was done to find their distribution patterns and similarity between the two study sites.

Analysis of data's (**Table 85 to 87)** using Margalef's index (Da) and Shannon-Wiener diversity index (H') have shown more diversity in natural forest than the degraded forest site in all soil layers. Species diversity was recorded to be maximum during rainy season followed by summer and winter season in both sites and exhibited decreasing diversity with increasing depth in all seasons.

Except for summer and rainy season at 0-10 cm soil layer, Hmax' or maximum diversity of Acarina was found to be higher in natural forest ecosystem as compared with degraded forest ecosystem in all soil layers exhibiting a seasonal trend of rainy>summer>winter. The evenness (J') studies of Acarina communities between the two study sites in different seasons have been found to exhibit almost a similar distribution patterns in different soil layers.

Litter Acarina

Among the litter acarina also, Margalef's index (Da) and Shannon-Wiener diversity index (H') have shown more diversity in natural forest than the degraded forest site (**Table 88**). Species diversity was recorded to be maximum during rainy season followed by summer and winter season in both sites.

Hmax' or maximum diversity of litter Acarina was found to be higher in natural forest ecosystem as compared with degraded forest ecosystem in all seasons exhibiting a seasonal trend of rainy>summer>winter. The evenness (J') studies of litter Acarina communities between the two study sites in different seasons have exhibited almost a similar distribution patterns in different seasons except for rainy season in degraded site wherein distribution was less even.

Table 85: Species diversity of the total identified Soil Acarina in different seasons at 0- 10cm soil layer in (a) Natural forest and Degraded forest ecosystem

(a) Natural forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	5.4213	4.2199	4.2480	0.9934
Summer	7.0647	4.2787	4.3220	0.9899
Rainy	9.7850	4.3241	4.3520	0.9936

(b) Degraded forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	4.1491	3.5511	4.1491	3.5511
Summer	5.3108	3.7158	5.3108	3.7158
Rainy	6.6314	3.7710	6.6314	3.7710

Table 86: Species diversity of the total identified Soil Acarina in different seasons at 10- 20cm soil layer in (a)Natural forest and (b) Degraded forest ecosystem

(a) Natural forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	3.9110	3.5002	3.5850	0.9764
Summer	5.7913	3.7371	3.5904	1.0409
Rainy	6.4124	3.7424	3.8073	0.9830

(b) Degraded forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	3.5170	2.9413	3.1149	0.9443
Summer	4.6139	3.2649	3.2869	0.9934
Rainy	4.8887	3.2658	3.3220	0.9831

Table 87: Species diversity of the total identified Soil Acarina in different seasons at 20- 30cm soil layer in (a)Natural forest and Degraded forest ecosystem.

(a) Natural forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	3.1220	2.8751	3.1963	0.8996
Summer	4.8621	3.2769	3.4280	0.9559
Rainy	5.8369	3.4484	3.5850	0.9619

(b) Degraded forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	2.6206	2.3050	2.3220	0.9927
Summer	3.0532	2.3263	2.3476	0.9910
Rainy	4.2699	2.3588	2.3699	0.9953

Table 88: Species diversity of the total identified Acarina, litter in different seasons in (a) Natural forest ecosystem and (b)Degraded forest ecosystem

(a) Natural forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	5.8013	4.3749	3.6894	0.9948
Summer	8.4241	4.3863	4.4120	0.9942
Rainy	9.9271	4.4149	4.6153	0.9566

(b) Degraded forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	3.7411	2.1518	2.2703	0.9605
Summer	6.3815	2.1781	2.4852	0.9968
Rainy	8.6314	2.1955	2.4973	0.8792

Community similarity of Acarina

Soil Acarina

The community similarity and faunal resemblance of soil Acarina between the two study sites in different soil layers and seasons were compared using Sorensen coefficient of community similarity index (Quotient of similarity) and average faunal resemblance (**Table 89 to 92**). Sorensen's Quotient of community similarity (Q/S) and average faunal resemblance of Acarina community between the two study sites was recorded to be high. Maximum value of Sorensen's Quotient (Q/S) was recorded during summer season (95.23%) and minimum during winter season (72.72%). Faunal resemblance was also found to be high and the value was recorded maximum during summer (95.45%) and minimum during winter season (73.33%). This high value of Q/S and faunal resemblance indicates that both the study sites were strongly similar in the species composition. In both the study sites, fourteen species of Acarina were found to be common during the study period.

Community similarity and faunal resemblance of Acarina between the two study sites in different soil layers were also calculated for different seasons. The Sorensen's quotient of similarity of Acarina communities have been recorded to be maximum in the soil layers of 0-10 cm (84.21%) and 10-20 cm (85.71%) during rainy season in comparison to other seasons which indicates similarity of species composition, however in 20-30 cm, higher value (78.28%) was observed in summer season. Average faunal resemblance at 0-10 cm (85.71%) and 20-30 cm (78.40%) soil layer was recorded to be maximum during summer season, however rainy season exhibited maximum at 10-20 cm (87.50%) soil layer.

Litter Acarina

The community similarity and faunal resemblance of litter Acarina between the two study sites and seasons were compared using Sorensen coefficient of community similarity index (Quotient of similarity) and average faunal resemblance (**Table 93**). Maximum value of Sorensen’s Quotient (Q/S) was recorded during rainy season (94.73%) and minimum during winter season (72.72%). Faunal resemblance was also found to be high and the value was recorded maximum during rainy (90%) and minimum during winter season (73.05%). Sixteen species of litter Acarina were found to be common between the two study sites.

Table 89: Community similarity of total identified soil Acarina in different seasons at 0-30 cm soil depth.

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)
Winter	72.72	73.33
Summer	95.23	95.45
Rainy	85.71	87.50

Table 90: Community similarity of total identified soil soil Acarina in different seasons at 0-10 cm soil depth.

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)

Winter	69.56	70.76
Summer	83.33	85.71
Rainy	84.21	84.44

Table 91: Community similarity of total identified Soil Acarina in different seasons at 10-20 cm soil depth.

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)
Winter	81.81	84.61
Summer	83.33	85.71
Rainy	85.71	87.50

Table 92: Community similarity of total identified soil Acarina in different seasons at 20-30 cm soil depth.

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)
Winter	67.06	68.57
Summer	78.28	78.40
Rainy	76.19	77.77

Table 93: Community similarity of total identified Litter Acarina in different Seasons.

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)
Winter	72.00	73.05
Summer	76.19	81.10
Rainy	94.73	90.00

Community analysis of Collembola

Soil Collembola

The twenty two (22) identified species of soil Collembola were *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotoma arctical, Isotomeilla minor sp, Sminthurus nigromaculatus, Weberacantha magnomucrella, Vertagopus westerlundi, Hypogastruridae sp, Kalaphorura burmeisteri, Anurida granaria, Isotomidae sp, Arrhopalites hirtus, Dicyrtomina ornate, Sminthurus cf. incisus sp, Sminthurinus quadrimaculatus, Sminthurus bivittatus, Dicyrtoma minuta, Ptenothrix marmorata, Lepidocyrtus rataensis, Tomocerus minor, Isotoma exiguadentata.* The diversity and similarity of soil Collembola were analyzed between the two study sites during study period.

The analysis of species diversity of Collembola communities belonging to different species in different soil layers i.e. at 0-10cm, 10-20cm and 20-30cm in different seasons have also been calculated (**Table 94 to 96**) and found to be more diverse in natural forest site than the degraded forest site. At 0-10 cm soil layer, Margalef's index and diversity index in natural forest was maximum during rainy season (Da= 6.9740, H'= 4.3316) and minimum during winter season (Da= 4.6894, H'= 4.1873). In degraded forest, both diversity indexes were also maximum during rainy season (Da=4.4750, H'=3.5494), however minimum of Margalef's and diversity indexes were recorded during summer (Da= 4.2301) and winter (H'= 3.2837) respectively. At 10-20 cm soil layer in natural forest, Margalef's and diversity indices exhibited the trend winter (4.8918) >summer (4.8368) > rainy (4.6766) and rainy (3.4773) > summer (3.3991)>winter (2.4947) season respectively. However, in degraded forest both indices were maximum during rainy season (Da= 3.2536, H’=2.4261) and minimum (Da=2.9614, H’=2.1780) during winter season. Similar trend was also observed i.e. rainy>summer>winter in both study sites at 20-30 cm soil layers

Hmax’ or maximum diversity of Collembola was found to be higher in natural forest ecosystem as compared to the degraded forest ecosystem. It was recorded to be maximum during rainy season followed by summer and winter season at all soil depths in both study sites. The evenness (J’) studies of Collembola communities between the two study sites in different seasons and soil depths exhibited almost a similar distribution patterns. The high value of evenness (J’) in both the study sites indicates low dominance.

Litter Collembola

Diversity of litter Colloembola was also found to be higher in natural forest than degraded forest having seasonal sequence of maximum during rainy season followed by summer and winter season in both study sites. Hmax’ or maximum diversity of litter Collembola was found to be higher in natural forest ecosystem as compared with degraded forest ecosystem in all seasons exhibiting a seasonal trend of rainy>summer>winter. However litter collembolan were evenly distributed in both study sites in different seasons (**Table 97**).

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Table 94: Species diversity of the total identified soil Collembola in different seasons at 0- 10cm soil layer in (a)Natural forest and Degraded forest ecosystem.

(a) Natural forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	4.6894	4.1873	4.2165	0.9931
Summer	5.4067	4.2545	4.2986	0.9899
Rainy	6.9740	4.3316	4.5183	0.9587

(b) Degraded forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	4.3667	3.2837	3.3220	0.9885
Summer	4.2301	3.3892	3.5194	0.9631
Rainy	4.4750	3.5494	3.5850	0.9901

Table 95: Species diversity of the total identified soil Collembola in different seasons at 10- 20 cm soil layer in (a)Natural forest and (b) Degraded forest ecosystem.

(**a) Natural forest ecosystem**

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	4.8918	2.4947	3.5850	0.6959
Summer	4.8368	3.3991	3.7004	0.9186
Rainy	4.6766	3.4773	3.8073	0.9134

(b) Degraded forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	2.4261	2.1780	2.5850	0.8426
Summer	2.9810	2.5933	2.8073	0.9238
Rainy	3.2536	2.9614	3.1528	0.9393

Table 96: Species diversity of the total identified soil Collembola in different seasons at 20- 30 cm soil layer in (a) Natural forest and (b) Degraded forest ecosystem

(a) Natural forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	2.7532	2.2783	3.5850	0.6959
Summer	3.6912	3.3991	3.7004	0.9186
Rainy	4.2718	3.4773	3.8073	0.9134

(b) Degraded forest ecosystem

Seasons	Margalef's Index (Da)	Diversity(H')	Hmax'	Evenness (J')
Winter	2.2831	2.1004	2.3852	0.8806
Summer	2.5307	2.3896	2.5422	0.9399
Rainy	3.1826	2.5213	2.7426	0.9194

Table 97: Species diversity of the total identified Litter Collembola in different seasons in (a) Natural forest ecosystem and (b) Degraded forest ecosystem

(a) Natural forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	4.7914	4.1240	4.2012	0.9817
Summer	7.6328	4.2621	4.2921	0.9931
Rainy	8.9120	4.3028	4.3363	0.9923

(b) Degraded forest ecosystem

Seasons	Margalef's Index (Da)	Diversity (H')	Hmax'	Evenness (J')
Winter	2.8615	1.8627	2.2485	0.8284
Summer	6.3815	2.1695	2.3927	0.9068
Rainy	7.6314	2.1803	2.4573	0.8873

Community similarity of Collembola

Soil Collembola

The community similarity of Collembola in natural and degraded forest ecosystem were compared using Sorensen coefficient of community similarity index (Quotient of similarity) and average faunal resemblance (**Table 98 to 101).** Sorensen's Quotient of community similarity (Q/S) and average faunal resemblance of Collembola community between the two study sites were recorded to be high. Maximum value of Sorensen's Quotient (Q/S) was recorded during rainy season (90.00%) and minimum during winter season (67.06%). Faunal resemblance was also found to be high and maximum and minimum value was recorded during rainy (91.01%) and winter (68.57%) season respectively. The value indicates similarity in the species composition having sixteen common species of Collembola between the two study sites during the study period.

Community similarity and faunal resemblance of Collembola between the two study sites in different soil layers were also calculated for different seasons. The Sorensen's quotient of similarity of Collembola communities has been recorded to be maximum during rainy season in all soil layers i.e. 0-10cm (84.21%), 10-20cm (93.33%) and 20-30cm (90%). However, minimum value was recorded during winter at 0-10 cm (80.00%) and 20-30 cm (75.00%) and during summer at 20-30 cm (82.01%) soil layer. While in 20-30cm (66.67%) higher value was observed in winter season. Similar pattern of result were also observed in the case of average faunal resemblances exhibiting maximum value during rainy season in all soil layers (0-10cm: 86.37%, 10-20cm: 93.75% and 20-30cm: 94.05%), however there was seasonal variation having shown the minimum value in different soil layers i.e. 0-10cm (83.33%) and 20-30 (76.02%) during winter and 10-20 (83.50%) during summer season.

Litter Collembola

The community similarity and faunal resemblance of litter Collembola between the two study sites in different soil layers and seasons were compared using Sorensen coefficient of community similarity index (Quotient of similarity) and average faunal resemblance (**Table 102**). Sorensen's Quotient of community similarity (Q/S) and average faunal resemblance of Collembolan community between the two study sites was recorded to be high. Maximum value of Sorensen's Quotient (Q/S) was recorded during rainy season (91.01%) and minimum during winter season (69.56%). Faunal resemblance was also found to be high and the value was also recorded maximum during rainy (91.66%) and followed by summer (85.71%) and winter (70.76%) season. Fifteen species of litter Collembola were found to be common between the two study sites.

Table 98: Community similarity of total identified soil Collembola in different seasons at 0-30 cm soil depth.

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)
Winter	67.06	68.57
Summer	78.26	79.61
Rainy	90.00	91.01

Table 99 : Community similarity of total identified soil Collembola in different seasons at 0-10 cm soil depth.

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)
Winter	80.00	83.33
Summer	82.01	84.61
Rainy	84.21	86.37

Table 100: Community similarity of total identified soil Collembola in different seasons at 10-20 cm soil depth

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)
Winter	85.71	85.90
Summer	82.01	82.50
Rainy	93.33	93.75

Table 101: Community similarity of total identified soil Collembola in different seasons at 20-30 cm soil depth

Seasons	Sorensens Coefficient (Q/S) (%)	Average fauna resemblance (%)
Winter	75.00	76.02
Summer	80.00	81.00
Rainy	90.00	94.05

Table 102: Community similarity of total identified Litter Collembola in different Seasons

Seasons	Sorensens Coefficient (Q/S) (%)	Averagefauna resemblance (%)
Winter	69.56	70.76
Summer	83.33	85.71
Rainy	91.01	91.66

Diversity of Soil and Litter microarthropods

Soil Acarina

In natural forest ecosystem, out of total number of twenty two (22) species of soil Acarina, (**Table103**), sixteen(16) species were present throughout the year. They are *Megisthanus floridanus, Phthiracarus sp, Poeilochirus sp, Arctoscius sp, Raphignathoid mite (Cryptognathus sp), Discoppia sp, Pergamasus crassipes, Eugamasoidea vaigaia cerva, Allothrombium sp, Nothrus sp, Hermanniella sp, Tectocepheus velatus, Parasitus sp, Holaspulus sp, Heminothrus sp,* and *Podocinum sp.* In rainy season, twelve (12) species viz. *Megisthanus floridanus, Phthiracarus sp, Allothrombium sp, Poeilochirus sp, Discoppia sp, Pergamasus crassipes, Eugamasoidea vaigaia cerva, Nothrus, Holaspulus sp, Heminothrus sp, Dendrohermannia monstrousesp and Arctoscius sp.* were more abundant than other species. In summer season, five (9) species viz. *Megisthanus floridanus, Poeilochirus sp, Eugamasoidea vaigaia cerva, Pergamasus crassipes, Hypochthonius sp, Arctoscius sp, Pergamasus crassipes, Heminothrus sp* and *Nothrus sp* showed dominant over other species. And in winter season, only two(2) species ie., *Megisthanus floridanus sp, Podocinum sp* showed dominant over other species.

In degraded forest ecosystem, a total of fourteen (14) species of soil Acarina were identified (**Table 104**) of which eight (8) species more present throughout the year. They are *Megisthanus floridanus, Poeilochirus sp, , Discoppia sp Dinychus sp, Allothrombium sp, Nothrus, Holaspulus sp.* In rainy season, five (6) species showed more abundant than other species viz. *Megisthanus floridanus, Poeilochirus sp, Hermanniella sp, Nothrus, Hermannia sp* and *Podocinum sp.* In summer season, four(5) species showed more abundant than other species viz. *Megisthanus floridanus,* *Poeilochirus sp, Dinychus sp, Holaspulus sp* and *Podocinum sp.* And in winter season, only one(1) species *viz. Megisthanus floridanus* showed dominant over other species.

Litter Acarina

Twenty two (22) species of Acarina were identified in litter composition in natural forest of which eighteen (18) were abundant annually. They are *Megisthanus floridanus, Poeilochirus sp, Discoppia sp, Pergamasus crassipes, Raphignathoid mite(Cryptognathus sp),Eugamasoidea vaigaia cerva, Dinychus sp, Allothrombium sp, Nothrus, Hermanniella sp, Enemaerus sp, Dentachiptera sp, Tectocepheus velatus, Parasitus sp, Holaspulus sp, Heminothrus sp, Hypochthonius sp,* and *Podocinum sp.* In rainy season, thirteen (13) species viz. *Megisthanus floridanus, Poeilochirus sp, Discoppia sp, Pergamasus crassipes, , Dinychus sp, Eugamasoidea vaigaia cerva, Nothrus, Tectocepheus velatus, Holaspulus sp, Dentachiptera sp, Enemaerus sp, Heminothrus sp,* and *Podocinum sp.* were more abundant than other species. In summer season, ten(10) species viz. *Megisthanus floridanus, Phthiracarus sp, Poeilochirus sp,Arctoscius sp,Raphignathoid mite(Cryptognathus sp), Discoppia sp, Pergamasus crassipes, Eugamasoidea vaigaia cerva, Allothrombium sp,*and *Nothrus.* showed dominant over other species. And in winter season, only two(2) species ie., *Megisthanus floridanus sp, Podocinum sp* showed dominant over other species.

In degraded forest ecosystem, a total of sixteen(16) species of litter Acarina were identified (**Table 106**) and twelve (12) species present through out the year. They are viz. *Megisthanus floridanus, Poeilochirus sp, Discoppia sp,Dendrohermannia monstrouse,Dinychus sp, Allothrombium sp, Nothrus, Enemaerus sp. Hermanniella sp, Parasitus sp,Holaspulus sp* and *Podocinum sp.* In rainy season, nine (9) species viz. *Megisthanus floridanus, Poeilochirus sp, Discoppia sp,Allothrombium sp, Holaspulus sp, Nothrus, Podocinum sp, Hermanniella sp.*and *Dendrohermannia monstrouse* sp, were more abundant than other species. In summer season, four(4) species viz. *Megisthanus floridanus,Parasitus sp,, Discoppia sp,*and *Allothrombium sp* showed dominant over other species. And in winter season, only two(2) species ie., *Megisthanus floridanus sp, Podocinum sp* showed dominant over other species.

Table 103: Distribution of soil Acarina species in different seasons of natural forest ecosystem.

− = Absent; + = Low density; ++ = High density

Name of species		Seasons	
	Winter	Summer	Rainy
1 Megisthanus floridanus	++	++	++
2 Phthiracarus sp.	+	-	++
3 Poeilochirus sp.	+	++	++
4 Discoppia sp.	+	+	+
5 Pergamasus crassipes	+	+	++
6 Raphignathoid mite	+	+	+
7 Dendrohermannia monstrouse	+	++	++
8 Eugamasoidea vaigaia cerva	+	++	++
9 Arctosius sp.	-	-	++
10 Dinychus sp.	+	+	+
11 Allothrombium sp.	+	++	++
12 Nothrus sp.	-	+	+
13 Hermanniella sp.	+	+	+
14 Tectocepheus velatus	+	++	++
15 Parasitus sp.	+	++	+
16 Enemaerus sp.	+	+	++
17 Hypochthonius sp.	+	++	++
18 Hermannia sp.	-	+	++
19 Dentachiptera sp.	+	-	++
20 Holaspulus sp.	+	++	++
21 Heminothorus sp.	-	+	++
22 Podocinum sp.	+	++	++

Table 104: Distribution of soil Acarina species in different seasons of degraded forest ecosystem.

− = Absent; + = Low density; ++ = High density

	Name of species	Winter	Seasons Sum mer	Rainy
1	Megisthanus floridanus	+	++	++
2	Phthiracarus sp.	+	+	++
3	Poeilochirus sp.	-	+	+
4	Discoppia	-	-	+
5	Dendrohermannia monstrouse	-	++	+
6	Dinychus sp.	+	+	++
7	Allothrombium sp.	+	++	++
8	Nothrus sp.	-	+	++
9	Hermanniella sp.	+	+	+
10	Parasitus sp.	+	++	+
11	Enemaerus sp.	+	+	++
12	Hermannia sp.	+	+	++
13	Holaspulus sp.	-	+	++
14	Podocinum sp.	-	-	+

Table 105: Distribution of litter Acarina species in different seasons of natural forest ecosystem.

− = Absent; + = Low density; ++ = High density

Name of species	Seasons		
	Winter	Summer	Rainy
1 Megisthanus floridanus	++	++	++
2 Phthiracarus sp.	+	+	++
3 Poeilochirus sp.	++	++	++
4 Discoppia sp.	-	+	++
5 Pergamasus crassipes	+	+	++
6 Raphignathoid mite	+	+	++
7 Dendrohermannia monstrouse	+	++	+
8 Eugamasoidea vaigaia cerva	+	+	++
9 Arctosius sp.	-	+	+
10 Dinychus sp.	+	++	++
11 Allothrombium sp.	+	-	+
12 Nothrus sp.	-	++	++
13 Hermanniella sp.	+	+	+
14 Tectocepheus velatus	+	+	++
15 Parasitus sp.	-	++	++
16 Enemaerus sp.	+	+	++
17 Hypochthonius sp.	++	++	++
18 Hermannia sp.	+	-	++
19 Dentachiptera sp.	+	+	++
20 Holaspulus sp.	+	++	++
21 Heminothorus sp.	+	+	++
22 Podocinum sp.	-	+	++

Table 106: Distribution of litter Acarina species in different seasons of degraded forest ecosystem.

− = Absent; + = Low density; ++ = High density

Name of species	Seasons		
	Winter	Summer	Rainy
1 Megisthanus floridanus	++	+	++
2 Poeilochirus sp.	+	++	++
3 Discoppia sp.	+	+	++
4 Pergamasus crassipes	+	+	++
5 Raphignathoid mite	+	++	++
6 Eugamasoidea vaigaia cerva	+	+	+
7 Arctosius sp.	-	+	+
8 Dinychus sp.	+	+	+
9 Allothrombium sp.	+	++	++
10 Hermanniella sp.	-	+	+
11 Tectocepheus velatus	+	++	++
12 Parasitus sp.	+	+	++
13 Hypochthonius sp.	++	+	+
14 Hermannia sp.	+	++	++
15 Holaspulus sp.	+	-	++
16 Podocinum sp.	+	++	++

Biodiversity of Collembola

Soil Collembola

In natural forest ecosystem, out of twenty two (22) species of soil Collembola identified (**Table 107**), sixteen (16) were present abundantly during the year. They are *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotoma arctical, Isotomeilla minor sp, Sminthurus nigromaculatus, Hypogastruridae sp, Anurida granaria, Weberacantha magnomucrella, Sminthurinus quadrimaculatus, Dicyrtomina ornate, Isotoma exiguadentata, Arrhopalites hirtus Dicyrtoma minuta, Ptenothrix marmorata, Lepidocyrtus rataensis* It was incongruous showing abundance of different species in different months and seasons. In rainy season, eleven(11) species viz. *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotoma arctical, Isotomeilla minor sp, Weberacantha magnomucrella, Vertagopus westerlundi, Hypogastruridae sp, Sminthurinus quadrimaculatus, Dicyrtomina ornate sp* and *Isotoma exiguadentata sp. showed dominant over other species*. In summer season, five(9) species viz. *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotoma arctical, Anurida granaria, Weberacantha magnomucrella, Sminthurinus quadrimaculatus, Isotoma exiguadentata,* and *Arrhopalites hirtus* And in winter season, only one(1) species ie., *showed Isotomurus stuxbergi* dominant over other species.

In degraded forest ecosystem, eleven (11) species among sixteen (16) species identified were recorded in all seasons during study period. (**Table 108**). They are *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotoma arctical, Isotomeilla minor sp, Hypogastruridae sp,Weberacantha magnomucrella, Dicyrtomina ornate, Isotoma exiguadentata, Arrhopalites hirtus sp* and *Dicyrtoma minuta*. In rainy season, seven (7) species showed more abundant than other species viz.. *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotoma arctical, Hypogastruridae sp, Arrhopalites hirtus sp* and *Dicyrtoma minuta.* In summer season, four(5) species showed more abundant than other species viz. *Isotomurus stuxbergi, Entomobrya Slitellaria, Sminthurus cf. incisus sp, Hypogastruridae sp* and *Weberacantha magnomucrella.* And in winter season, only one(1) species *viz. Isotomurus stuxbergi* showed dominant over other species.

Litter Collembola

In natural forest site, out of twenty two (22) species of litter Collembola (**Table 109**) sixteen(16) species were found abundantly during study period. They are *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotoma arctical, Isotomeilla minor sp, Weberacantha magnomucrella, Vertagopus westerlundi, Hypogastruridae sp, Sminthurinus quadrimaculatus, Dicyrtomina ornate sp, Sminthurus cf. incisus sp, Ptenothrix marmorata, Lepidocyrtus rataensis, Tomocerus minor, Dicyrtoma minuta* and *Isotoma exiguadentata sp.* In rainy season, eleven (10) species viz. *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotoma arctical, Lepidocyrtus rataensis, Tomocerus minor, Dicyrtoma minuta, Weberacantha magnomucrella, Vertagopus westerlundi* and *Ptenothrix marmorata.* In summer season, seven(7) species viz . *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos, Isotomeilla minor sp, Hypogastruridae sp, Anurida granaria* and *Weberacantha magnomucrella sp* showed dominant over other species. And in winter season, only two(2) species ie., *Isotomurus stuxbergi, Entomobrya Slitellaria sp.* showed dominant over other species.

In degraded forest ecosystem, a total of fifteen(15) species of litter Collembola were identified (**Table 110**) of which ten (10) species were abundant throughout the year. They are viz. *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus albinos,* *Isotoma arctical, Weberacantha magnomucrella, Hypogastruridae sp, Dicyrtomina ornate sp, Sminthurus cf. incisus sp,* *Dicyrtoma minuta* and *Isotoma exiguadentata* In rainy season, eight (8) species viz. *Isotomurus stuxbergi, Cyphoderus albinos, Isotoma arctical, Weberacantha magnomucrella, Dicyrtoma minuta ,Arrhopalites hirtus, Anurida granaria* and *Hypogastruridae* sp, were more abundant than other species. In summer season, five (5) species viz. *Isotomurus stuxbergi sp, Dicyrtoma minuta, Weberacantha magnomucrella, Sminthurus cf. incisus sp* and *Isotoma exiguadentata* showed dominant over other species. And in winter season, only two (2) species i.e. *Isotomurus stuxbergi sp, Cyphoderus albinos* sp showed dominant over other species.

The present investigation indicates that overall number of individuals, species and the value of diversity were found to be higher and more consistent in the natural forest ecosystem than that of degraded forest ecosystem. Certain species of Acarina and Collembola that were found in natural forest site were totally absent in degraded forest site which brings about a decrease or disappearance of the least abundant species, while the most abundant species persist (Gurrea *et al*, 2000).

Higher species richness and diversity in soil and litter microatrthropods in natural forest ecosystem than that of degraded forest ecosystem may be attributed to combined positive effect of different microclimatic factors (Asikidis and Stamou (1991). The natural forest ecosystem having more resilience to any disturbances maintains floral diversity, stability and food availability which allow microarthropods communities to recover quickly and maintain diversity (Liiri *et al*, 2002). In natural forest site, from the forest floor till tree canopy were so thick that any external factors have least effect over the soil microarthropods community and thus soil microarthropods were more abundant in below-canopy soils (Whitford and Sobhy, 1999). And because of this rich vegetation in natural forest ecosystem, the accumulation of litters in the forest floor becomes more abundant which ultimately make available to herbivores microarthropods as a source of food to both above and below ground dwellers. Microarthropods are important components of the soil decomposer food web and organic matter was a major influence on microarthropods abundance and diversity. The microarthropods use organic matter; regulate other decomposers in the soil food web and aid in the release of nutrients bound up in residues and microabial biomass (bacteria and fungi). It was also reported that Organic matter quantity and quality influence soil microarthropods abundance and diversity (Lachnicht *et al*, 2002). Differences in microclimatic or in the accumulation of organic matter on the forest floor were likely responsible for the observed patterns of abundance. Thus diversity at any soil layer was not affected by shortage or because of limited food; instead the endemic species of that particular habitat was maintained and not lost. Therefore, in natural forest ecosystem because of its wide range in tolerance, soil and litter microarthropods tends to strive better which result into more population density as well as occurrence of more different species showing wider range of species diversity (Peck *et al*, (2005).

The fewer species richness and diversity in degraded forest as indicated by various species diversity indices value corresponds to loss of biodiversity due human disturbance and activity. Among the several factors, poor vegetation was of particular importance and lower abundance and changes in community composition was likely due to disturbance of the forest floor. Oribatid mites species showed significantly lower abundance in clearcuts than in uncut sites (Lindo 2004). Further several studies have shown a decline in Collembola abundance in response to clear cutting, at least in the short-term (Vlug and Borden, 1973; Huhta, 1976; Bird and Chatarpaul, 1986; Hoekstra *et al*, 1995; Donegan *et al*, 2001). Prabhoo (1986) recorded 20 species of collembolan from two different sites of bamboo groove and a grass plot. In general, it can be stated that there was environmental negative feedback on the soil microarthropods community, which allow only the most abundant, and with wide tolerance species to persist. The abundance of soil microarthropods species in this degraded forest site are therefore depends much on the physico-chemical factors of the soil. Since the vegetation was very scarce when compared with natural forest site, the organic matter through litters was found to be less abundant which mean the forest floor have scarcity of food for microarthropods though their food was not limited only to organic matters. The physical factors such as rainfall, humidity and air temperature were common to both the study sites, therefore it was those factors present within the forest community itself that influence the abundance and diversity of soil microarthropods community. Factors such as absent of tree-canopy, less soil-water retention and continuous disturbances by human activity may be the major hindrance which the forest community cannot sustain itself and changes according to its environmental factors. A serious environmental concern regarding clearcutting (degraded) forest was that biodiversity will decrease, and that species will be extirpated (Moldenke and Lattin, 1990; Carey, 1998). Thus the degraded forest ecosystem suffered much in many respects, which ultimately have impact on the biodiversity of soil microarthropods community.

Community analysis of both soil and litter microarthropod (Acarina and Collembola) population in natural and degraded forest ecosystem have shown maximum abundance and species diversity in rainy season and slowly decreased in summer and winter season. Doulo (2007) also recorded higher species diversity of microarthropods in rainy season and less in winter season from natural and degrdaed forest ecosystem in Laumami, Nagaland.These seasonal differences in the abundance was due to enormous fluctuations in numbers of microarthropods that are being susceptible to small changes in microclimatic factor influencing population size (Block, 1965; Niijima, 1971; Lasebikan, 1974; Usher, 1975). The temporal pattern has been related to transition from one season to another which was mostly due to shift in soil moisture and temperature (Wallwork, 1970; Fujikawa, 1970 and Anderson, 1978). Litterfall has also been identified as an environmental factor influencing the temporal distribution of microarthropods (Santos *et al,* 1978 and Luxton, 1981). Raghuraman *et al*. (2010) recorded 1789 collembolans of 18 genera with maximum abundance of *Isotumurus* sp. Followed by *Entomobrya* sp., *Cyphoderus* sp. and *Lepidocyrtus* sp. in five different habitats of Varanasi. In acomparative study from tropical evergreen forest of Cachar district, Assam, Ray *et al*. (2012) observed that the great difference in community structure and diversity of microarthropod species composition between the canopy litter and soil litter was due to the edaphic and climatic factors that effect on the dynamics of microarthropods.

Table 107: Distribution of soil Collembola species in different seasons of natural forest ecosystem.

− = Absent; + = Low density; ++ = High density

Name of species	Season		
	Winter	Summer	Rainy
1 Isotomurus stuxbergi sp	+	++	++
2 Entomobrya slitellaria sp.	+	+	++
3 Cyphoderus albinus sp.	-	+	++
4 Isotoma arctical	+	++	+
5 Isotomeilla minor sp.	-	-	++
6 Sminthuras nigromaculatus	-	+	++
7 Weberacantha magnomucrella	+	++	++
8 Vertagopus westerlundi sp.	+	+	++
9 Hypogastruridae sp.	-	-	+
10 Kalaphorura burmeisteri.	+	-	++
11 Anurida granaria	+	++	++
12 Isotomidae sp.	+	+	++
13 Arrhopalites hirtus	+	++	+
14 Dicyrtomina ornate	+	+	++
15 Sminthurus cf. incisus sp.	-	++	++
16 Sminthurus quadrimaculatus	+	+	++
17 Sminthurus bivittalus	-	+	++
18 Dicyrtoma minuta	-	++	+
19 Ptenothrix marmorata	+	+	+
20 Lepidocyrtus rataensis	-	-	++
21 Tomocerus minor	+	+	++
22 Isotoma exiguadentata	+	++	++

Table 108: Distribution of soil Collembola species in different seasons of degraded forest ecosystem.

− = Absent; + = Low density; ++ = High density

	Name of species	Winter	Seasons Summer	Rainy
1.	Isotomurus stuxbergi sp.	+	++	++
2.	Entomobrya slitellaria sp.	+	++	++
3.	Cyphoderus albinus sp.	-	+	++
4.	Isotoma arctical	+	++	+
5.	Isotomeilla minor sp.	+	+	+
6.	Weberacantha magnomucrella	+	+	++
7.	Hypogastruridae sp.	+	+	++
8.	Anurida granaria	+	++	++
9.	Isotomidae sp.	+	+	++
10.	Arrhopalites hirtus	+	+	+
11.	Dicyrtomina ornate	+	+	++
12.	Sminthurus cf. incisus sp.	-	++	++
13.	Sminthurus bivittalus	-	+	++
14.	Dicyrtoma minuta	+	++	+
15.	Lepidocyrtus rataensis	+	-	+
16.	Isotoma exiguadentata	-	+	+

Table 109: Distribution of litter Collembola species in different seasons of natural forest ecosystem.

− = Absent; + = Low density; ++ = High density

Name of species	Seasons		
	Winter	Summer	Rainy
1 Isotomurus stuxbergi sp.	+	++	++
2 Entomobrya slitellaria sp.	+	++	+
3 Cyphoderus albinus sp.	-	+	++
4 Isotoma arctical	+	+	++
5 Isotomeilla minor sp.	+	++	+
6 Sminthuras nigromaculatus	+	-	+
7 Weberacantha magnomucrella	-	++	++
8 Vertagopus westerlundi sp.	+	+	+
9 Hypogastruridae sp.	+	++	++
10 Kalaphorura burmeisteri.	-	-	++
11 Anurida granaria	+	++	++
12 Isotomidae sp.	+	+	+
13 Arrhopalites hirtus	+	++	+
14 Dicyrtomina ornate	+	++	++
15 Sminthurus cf. incisus sp.	-	++	++
16 Sminthurus quadrimaculatus	++	+	++
17 Sminthurus bivittalus	+	++	++
18 Dicyrtoma minuta	-	+	++
19 Ptenothrix marmorata	+`	+	++
20 Lepidocyrtus rataensis	+	++	++
21 Tomocerus minor	-	+	++
22 Isotoma exiguadentata	-	+	+

Table 110: Distribution of litter Collembola species in different seasons of degraded forest ecosystem.

− = Absent; + = Low density; ++ = High density

	Name of species		Seasons	
		Winter	Summer	Rainy
1.	Isotomurus stuxbergi sp.	+	++	++
2.	Entomobrya slitellaria sp.	+	+	++
3.	Cyphoderus albinus sp.	-	+	++
4.	Isotoma arctical	+	+	++
5.	Isotomeilla minor sp.	+	++	++
6.	Weberacantha magnomucrella	+	++	++
7.	Hypogastruridae	+	++	++
8.	Anurida granaria	-	+	++
9.	Isotomidae sp.	+	+	++
10.	Arrhopalites hirtus	+	++	+
11.	Dicyrtomina ornate	+	++	+
12.	Sminthurus cf. incisus sp.	-	++	++
13.	Sminthurus bivittalus	-	++	++
14.	Dicyrtoma minuta	++	++	+
15.	Isotoma exiguadentata	+	-	++

Acarina

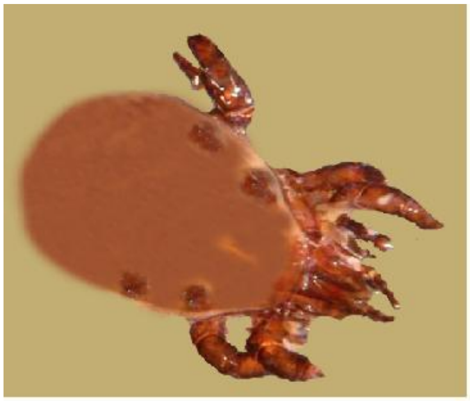

Plate no. 5 *Megisthanus floridanus*

Plate no. 6 *Phthiracarus sp.*

Plate no. 7 *Poeilochirus sp.*

Plate no. 8 *Discoppia sp.*

Plate no. 9 *Pergamasus crassipes*

Plate no. 10 *Raphignathoid mite (Cryptognathus sp.)*

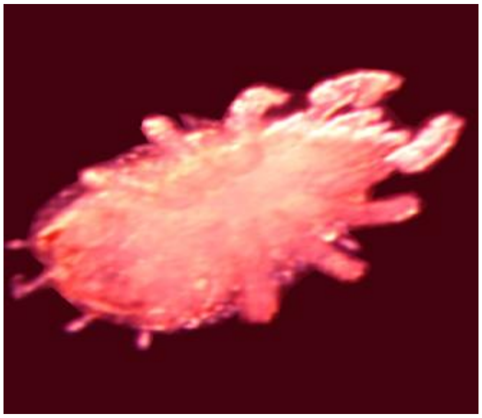

Plate no. 11 ***Dendrohermannia Monstrouse***

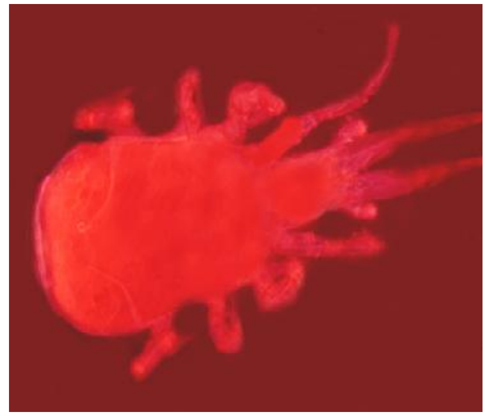

Plate no. 12 ***Eugamasoidea vaigaia cerv***

Plate no. 13 ***Arctoseius sp.***

Plate no. 14 ***Dinychus sp.***

Plate no. 15 ***Allothrombium sp.***

Plate no. 16 ***Nothrus***

Plate no. 17 ***Hermanniella sp.***

Plate no. 18 ***Tectocepheus velatus***

Plate no. 19 ***Parasitus sp.***

Plate no. 20 ***Euemaerus sp.***

Plate no. 21 ***Hypochthonius sp.***

Plate no. 22 ***Hermannia sp***

Plate no. 23 ***Dentachiptera sp.***

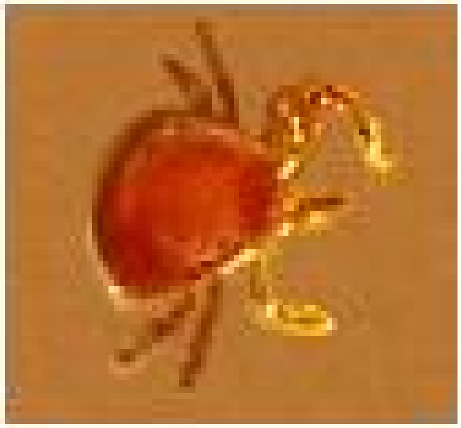

Plate no.24 ***Holaspulus sp.***

Plate no. 25 ***Heminothrus sp.***

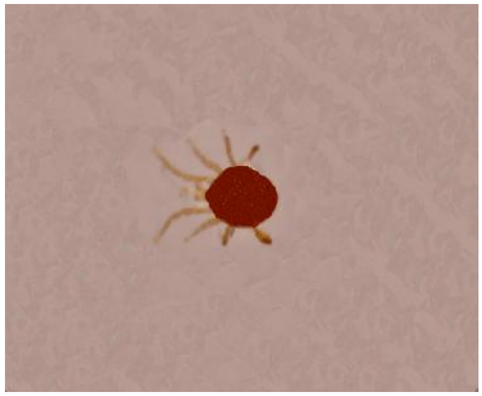

Plate no. 26 ***Podocinum sp***

Collembola

Plate no. 27: ***Isotomurus stuxbergi Slitellaria***

Plate no. 28: ***Entomobrya***

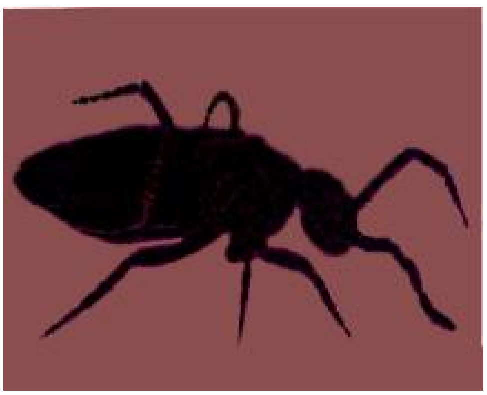

Plate no. 29: ***Cyphoderus albinos***

Plate no. 30: ***Isotoma arctical***

Plate no. 31: ***Isotomeilla minor sp. nigromaculatu***

Plate no. 32: ***Sminthurus***

Plate no. 33: ***Weberacantha Magnomucrella***

Plate no. 34: ***Vertagopus vesterlundi***

Plate no. 35: ***Hypogastruridae sp. urmeisteri***

Plate no. 36: ***Kalaphorura***

Plate no. 37: ***Anurida granaria***

Plate no. 38: ***Isotomidae sp.***

Plate no. 39: ***Arrhopalites hirtus***

Plate no. 40: ***Dicyrtomina ornata***

Plate no. 41: ***Sminthurus cf. incisus sp***

Plate no. 42: ***Sminthurinus quadrimaculatus***

Plate no. 43: ***Sminthurus bivittatus minuta***

Plate no. 44: ***Dicyrtoma***

Plate no. 45: ***Ptenothrix marmorata***

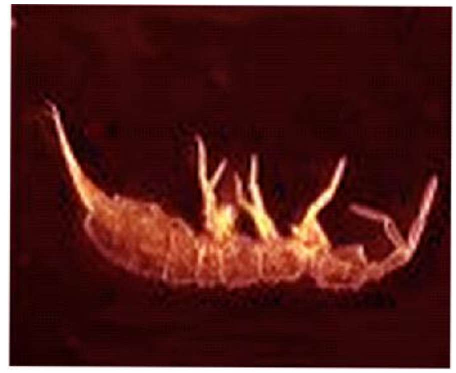

Plate no. 46: ***Lepidocyrtus rataensis***

Plate no. 47: ***Tomocerus minor***

Plate no. 48; ***Isotoma exiguadentata***

Others

Plate no. 49: ***Hetero Japyx (Diplura)***

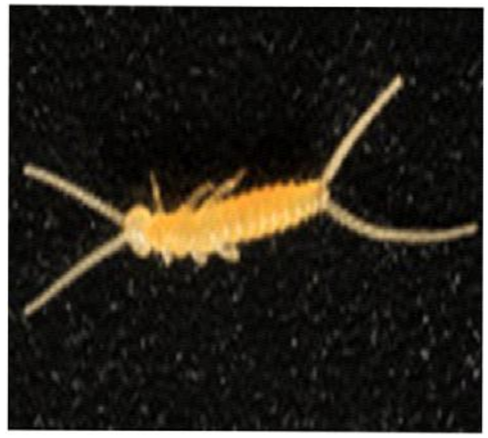

Plate no. 50: ***Campodedae(Diplura)***

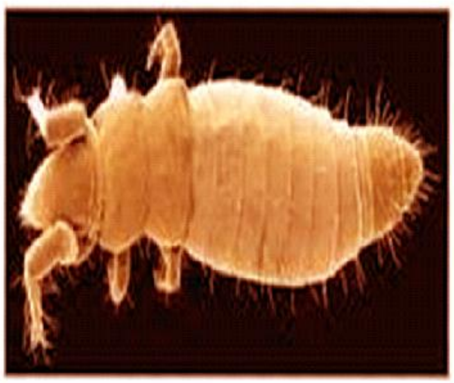

Plate no. 51: ***Proturan larva***

Plate no. 52: ***Proturan***

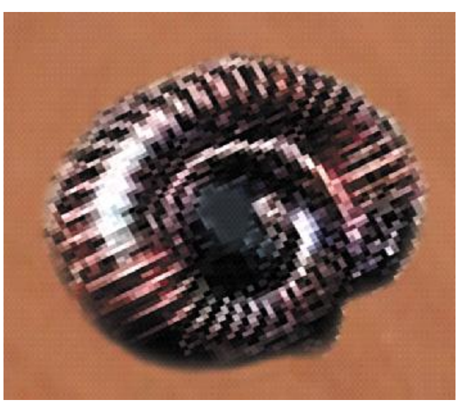

Plate no. 53: ***Myriapoda***

Plate no. 54: ***Centipede***

Plate no. 55: ***Centipede***

Plate no. 56: ***Blaniulus guttulatus (Millipede)***

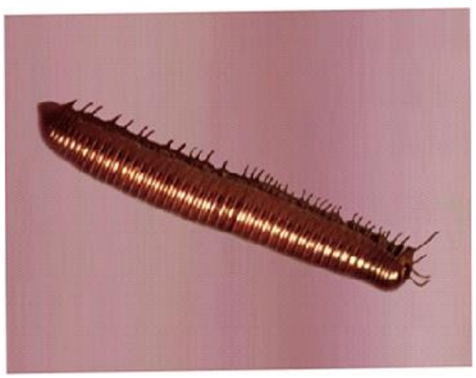

Plate no. 57: ***Millipede***

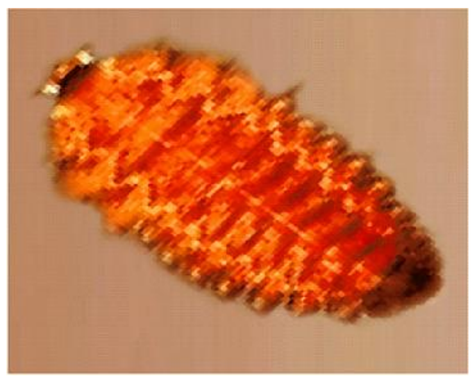

Plate no. 58: ***Armadillidium vulgare (Isoptera larva)***

Plate no. 59: ***Pterostichus melanarius (Carabid beetle)***

Plate no. 60: ***Pterostichus sp. (Carabi***

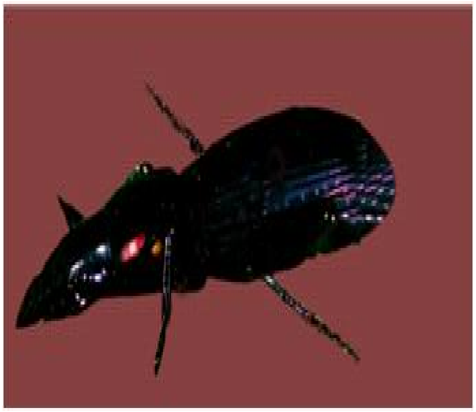

Plate no. 61: ***Ground beetle***

Plate no. 62: ***Pterostichus novus (Carabid beetle)***

Plate no. 63: ***Carabid larva***

Plate no. 64: ***Formicidae (Hymenoptera)***

Plate no. 65: ***Spider (Araneae)***

Plate no. 66: ***Stonemyia tranquilla (Diptera)***

Plate no. 67: ***Stonemyia tranquilla (Diptera)***

Plate no. 68: ***Dipteran sp***

Plate no. 69: ***Forficula auricularia (Dermaptera, Earwig)***

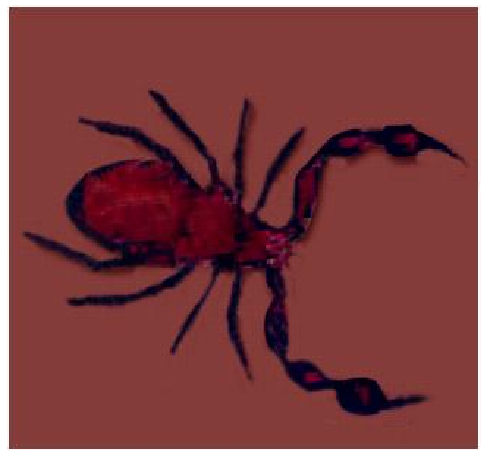

Plate no. 70: ***Pseudoscorpion***

Plate no. 71: ***Megodontus caelatus larva (Coleoptera)***

Plate no. 72: ***Longhorn beetle schreiberi(coleoptera)***

Plate no. 73: ***Amarotypus edwardsii***
(Coleoptera-carabides)

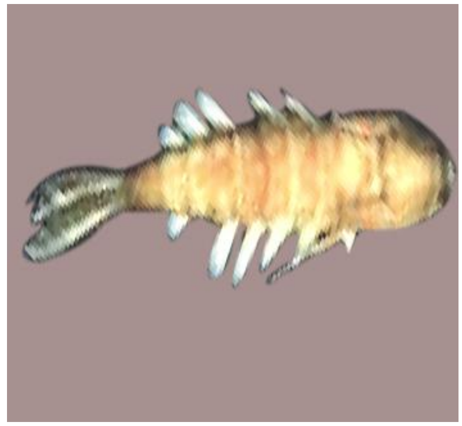

Plate no. 74 ***Ephemeroptera***
simphlonuridae
(nymph of May fly)

Chapter IX
SUMMARY

The present investigation was carried out for one year (October 2006 to September 2007), in two adjacent area of natural and degraded forest ecosystem in Pathalipam of Lakhimpur district, Assam which lies at 26 º 48´- 27 º 53´N latitude and 93 º 42´- 94 º 20´E longitude. The approximate area of the study site was 9900 hector having both plain and high elevation and located at an altitude of 101 above mean sea level. The natural forest comprised of rich vegetation with deciduous and evergreen trees having distinct canopy layers of small trees, shrubs and herbs and was not disturbed for more than forty years. The dominant trees in natural site were *Keyia assamica* (30%) and *Mesua ferrea* (15%). The degraded forest site comparatively had thin vegetation due to frequent human activities and interference. The climate of the area was monsoonic with three distinct seasons i.e. summer, rainy and winter and received the maximum annual rainfall of 3753 mm ranging from a minimum of 13.mm (December and January) to 853.8 mm (June).

Data on soil and litter microarthropods on different treatment was analyzed through appropriate statistical analysis and correlated with physico-chemical characteristics of soil. Soil temperature and moisture were recorded to be maximum during rainy season and minimum winter season in both sites. Among physico-chemical factors, soil temperature and soil moisture was found to play important role in population dynamics of microarthropods in both sites. Except for relative humidity, soil and litter microarthropods were positively correlated to physical factors in both study sites. However relationship was both positive and negative towards various chemical factors in different soil depth which emphasized that cumulative effect of various edaphic and climatic factors rather than the individual influence was responsible for the variation in the microarthropods population. Soil pH was acidic to neutral in nature ranging from 3.9 to 7.2 in different soil layers in natural and degraded sites. Organic carbon, an important constituent of soil was found to produce some direct influence on the fluctuation of soil dwelling microarthropods through its role on vegetation and other physico-chemical properties of soil.

Acarina was found to be the dominant group both in soil and litter component. Acarina population in soil consist of 38.3% and 34.7% of the total soil microarthropods while in litter it ranges from 45.7%, to 40.4% in natural and degraded site respectively. The soil acarina population was recorded to be 1.7 times higher in the natural forest (378.80 x $10^2 m^{-2}$) than the degraded site (223.82 x $10^2 m^{-2}$). Result from analysis of variance (ANOVA) at different soil layer showed significant difference among the seasons. The Acarina were significantly more abundant during rainy season followed by summer and recorded minimum during winter season in both sites. The natural site with least disturbance and favourable microclimatic condition than that of degraded sites possessed higher Acarina population as mites exhibited uneven distributional patterns depending on its adaptational behaviour towards the microhabitat and affinities with the change of the abiotic factors. Acarina was further classified into four sub-orders: Cryptostigmata, Mesostigmata, Prostigmata and Astigmata. Among the sub-order of Acarina, Cryptostigmata was found to be the most dominant group followed by Mesostigmata and Prostigmata while Astigmata exhibited the lowest population in both natural and degraded sites. Cryptostigmata contributed 53-65%, Mesostigmata 24-35%, Prostigmata 12% and Astigmata contributed only 10% to the Acarina population during study period. The vertical distribution patterns exhibited decreasing trend with increasing depth.

Soil Collembola population was recorded to be 1.8 times higher in the natural ($344.38 \times 10^2\ m^{-2}$) than the degraded forest ecosystem ($197.87 \times 10^2\ m^{-2}$) which was due to rich vegetation area and optimum microclimatic condition in natural forest. At different soil layer, the analysis of variance (ANOVA) showed significant difference among seasons The degraded site of the present investigation, with less vegetation cover and low litter accumulation had always a tendency of wide fluctuation in the micro climatic condition of the soil profile and formed a critical period for the survival of Collembolan populations. Since Collembolan was vulnerable to low moisture condition and thus combined effect of all these factors might be attributed for the lower population density in degraded site. The Collembolans were significantly more abundant during rainy season and recorded as $162.93 \times 10^2\ m^{-2}$ and $94.34 \times 10^2\ m^{-2}$ in natural and degraded site respectively. The collembolan population decreased with the increase in soil layers, but more population of Collembola was recorded at 10-20 cm (middle layer) than upper soil layer (0-10cm) in the natural site. In the present investigation Collembola was further classified into three sub-orders: Entomobryomorpha, Poduromorpha and Symphypleona. Among the sub-order of Collembola, Entomobryomorpha was found to be the most dominant group followed by Poduromorpha and Symphypleona in both natural and degraded sites. Entomobryomorpha contributed about 59%, Poduromorpha 31% and Symphypleona contributed 12% to the total Collembola population in the present study site.

The other soil microarthropods which comprised of Protura, Myriapoda, Isoptera, carabatid, Dermaptera, Hymanoptera and Diptera, were recorded to be $264.23 \times 10^2\ m^{-2}$ and $221.74 \times 10^2\ m^{-2}$ in natural and degraded sites respectively contributing 27-34% to the total soil microarthropods. The analysis of variance

(ANOVA) of other soil microarthropod population density showed highly significant difference in all months of natural and degraded site respectively.

Annual population density of total soil microarthropods was 987.41 x 10^2 m^{-2} and 643.43 x 10^2 m^{-2} in natural and degraded site respectively. Maximum population of soil microarthropods recorded during rainy season both in natural (512.14 x 10^2 m^{-2}) and degraded (210.42 x 10^2 m^{-2}) site was correlated to optimum physico-chemical factors such as soil temperature, soil moisture, organic carbon etc. which had a significant effect on the growth of soil microarthropods, while low population density in winter season was due to the unfavourable micro climatic condition leading to death due to desiccation or restriction in reproduction of soil microarthropods. Concentration of soil microarthropod was recorded to be maximum at 0-10cm soil layer in both study site i.e. 379 .55 x 10^2 m^{-2} and 323.28 x 10^2 m^{-2} respectively which had constant deposition of decay materials that might have been continuous food source for most of the young and immature stages as well as adults population in this soil layer. Both physical and edaphic factors at deeper soil layer might be unsuitable which resulted in less concentration of soil microarthropods. Monthly fluctuation exhibited maximum population density of 154.40 x 10^2 m^{-2} and 95.32 x 10^2 m^{-2} in the month of August in natural and degraded site respectively. The analysis of variance (ANOVA) for total soil microarthropod population density showed highly significant difference in all months in both natural and degraded forest ecosystem. Physical factors showed significant positive correlation with the changes in the abundance of soil microarthropods in both natural and degraded sites.

Microarthropod community in litter component was recorded to be 3536.88 x 10^2 m^{-2} and 2504.19 x 10^2 m^{-2} in natural and degraded forest respectively which was due to difference in the microclimatic condition and availability of organic food source. In both natural and degraded sites, maximum population of litter acarina ($788.21 \times 10^2 m^{-2}$ and $506.78 \times 10^2 m^{-2}$), collembolan ($580.9 \times 10^2 m^{-2}$ and $393.56 \times 10^2 m^{-2}$) and other microarthtopods ($363.31 \times 10^2 m^{-2}$ and $325.27 \times 10^2 m^{-2}$) respectively was recorded during rainy season only. The analysis of variance (ANOVA) for litter Acarina, Collembola, Other and total microarthropod population density showed highly significant seasonal and monthly differences both in natural forest ecosystem and degraded forest ecosystem. Litter microarthropods showed negative correlation with different physico-chemical factors in natural forest ecosystem while was positive relationship in degraded site. Microarthropod of litter component was 3.6 and 3.9 times higher than soil component in natural and degraded sites respectively.

Community analysis was carried out with two major groups of soil microarthropods i.e. Acarina and Collembolan in the present study as their contribution were maximum in term of species, abundance and distribution. A total of forty four (44) different species with twenty two (22) species in each group (Acari and Collembola) were identified from the two study sites i.e. natural and degraded forest ecosystem. The species diversity and similarities of the communities were analysed using the following indices of Margalef's index (Da) (1968), Shannon-Wiener index (H') (1949), Sorensen's index (Q/S) of similarity (1948), Average faunal resemblance and evenness or equitability index (Pielou, 1969).

In community analysis of soil and litter Acarina, the higher values of diversity indices for both study sites were recorded in rainy season. Acarina community was recorded to be maximum in the soil layers of 10-20cm (73.68%) and 20-30cm (87.50%) during rainy season in comparison to other seasons which indicates similarity of species composition The Sorensen's quotient of similarity of soil Acarina communities were recorded to be maximum in soil layers of 0-10cm (84.21%) and 10-20cm (85.71%) during rainy season but in 20-30cm maximum was recorded during summer season (78.27%), while minimum value of 69.56%, 81.81% and 67.06% at 0-10cm,10-20cm and 20-30cm was recorded during winter season. The Sorensen's quotient of similarity of litter Acarina was recorded to be maximum in rainy season (94.73%) followed by summer (76.19%) and winter (72%) season. This indicates resemblance of different species composition having fourteen (14) species of soil Acarina and sixteen (16) species of litter Acarina common to both study sites. The maximum values of average faunal resemblance of soil Acarina community between two study sites was recorded to be 85.71% and 78.40% at 0-10cm and 20-30cm during summer and 87.50% at 10-20 cm during rainy season. However minimum value of average faunal resemblance of soil Acarina was recorded as 70.76%, 84.61%, 68.57% at 0-10, 10-20, 20-30 cm during winter seasons respectively. Further maximum and minimum similarity of litter Acarina was recorded during rainy (90%) and winter (73.05%) season. Out of 22 species of acarina, 14 species of soil Acarina and 16 species of litter Acarina were found to be common in both study sites. The 22 species recorded both in soil and litter component are *Megisthanus floridanus, Phthiracarus sp, Poeilochirus sp, Discoppia sp, Pergamasus crassipes, Raphignathoid mite (Cryptognathus sp), Dendrohermannia monstrouse, Eugamasoidea vaigaia cerva, Arctoseius sp, Dinychus sp, Allothrombium sp, Nothrus, Hermanniella sp, Tectocepheus velatus, Parasitus sp, Euemaerus sp, Hypochthonius sp, Hermannia sp, Dentachiptera sp, Holaspulus sp, Heminothrus* sp, *Podocinum sp.*

In community analysis of soil and litter collembola, the higher values of diversity indices for both study sites were recorded in rainy season. Collembola community was recorded to be maximum in the soil layers of 10-20cm (73.68%) and

20-30cm (87.50%) during rainy season in comparison to other seasons which indicates similarity of species composition. The maximum and minimum values of Sorensen's quotient of similarity of soil Collembola community at 0-10 cm layer ranges from 84.21% (rainy) to 80% (winter), at 10-20 cm layer from 93.33%(rainy) to 82.01% (summer) and at 20-30 cm from 90% (rainy) to 75% (winter) season. The Sorensen's quotient of similarity of litter collembola was recorded to be maximum in rainy season (91.01%) and minimum in winter (69.56%) season. The maximum value of average faunal resemblance of soil Collembola community between two study sites was recorded to be 86.37%, 93.75%, and 94.05% at 0-10, 10-20, 20-30cm respectively during rainy season. However minimum value was recorded to be 83.33% and 76.02% at 0-10 and 20-30cm respectively during rainy season and 82.50% at 10-20 cm during summer season. Further maximum and minimum similarity of litter collembolan was recorded during rainy (91.66%) and winter (70.66%) season respectively. This indicates resemblance of different species composition having 16 species of soil and 15 species of litter collembola common to both study sites. The 22 species collembolan recorded both in soil and litter component are *Isotomurus stuxbergi, Entomobrya Slitellaria, Cyphoderus lbinos, Isotoma arctical, Isotomeilla minor sp, Sminthurus nigromaculatus, Weberacantha magnomucrella, Vertagopus westerlundi, Hypogastruridae sp, Kalaphorura burmeisteri, Anurida granaria, Isotomidae sp, Arrhopalites hirtus, Dicyrtomina ornate, Sminthurus cf. incisus sp, Sminthurinus quadrimaculatus, Sminthurus bivittatus, Dicyrtoma minuta, Ptenothrix marmorata, Lepidocyrtus rataensis, Tomocerus minor, Isotoma exiguadentata.*

Diversity and resemblance of Acarina and Collembola was more in rainy season followed by summer in natural and degraded site as well as soil and litter component. Both groups are more diverse in Litter component. Certain species of Acarina and

Collembola that were found in natural site are totally absent in degraded site that bring about decrease or disappearance of least abundant species, while the most abundant species persist. Overall the number of individuals, species and the value of diversity are found to be higher and more consistent in natural site than that of degraded site. Changes in number of taxa and density were correlated to various physic chemical factors particularly with temperature and rainfall. Distribution of microarthropods fluctuate seasonally reaching the peak density during rainy and minimum during winter months. This temporal pattern has been related to transition from one season to another and mostly due shift in soil moisture and temperature.

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