STUDIES ON INSECT - PLANT INTERACTIONS IN SOME AGROFORESTRY SYSTEMS OF MIZORAM

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I Rosy. Lalnunsangi, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to be the best of my knowledge to anybody else, and that this thesis has not been submitted by me for any research degree in any other University/Institute.

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LIST OF ABBREVIATION:

A.D	:	Anno Domini
°C	:	Degree Celcius
E	:	East
N	:	North
Sq km	:	Square kilometer
m	:	metrum : metre
mm	:	millimetrum: millimeter
msl	:	mean sea level
Fig	:	Figure
Ed: ed(s)	:	Edition:editor (s) or edited
et al	:	*et alii* : and others
etc	:	etcetera or cetera: and the others
p.,pp.	:	pigina: page, pages
sp., spp	:	species (singular); species (plural)

CHAPTER 1

INTRODUCTION

1.1 An overview

According to the state of Forest Report, published by the Forest Survey of India (FSI) in 1997, India has a recorded forest area of 76.5 million hectares, which is equivalent to 23.3 per cent of the total geographic area of the country. However, the actual forest cover is 63.34 million hectares (18.27 per cent of the country's area), of which 31.85 million hectares are either degraded or open forests.

The rate of deforestation in the country has been considerably reduced during the last few years. The average annual rate of deforestation fell from 1.3 million hectares in the 1970s to 339 hectares in 1980s and to 129 hectares during 1990 to 1995. However, considering that the most important objective of the National Forest Policy, 1988 is to increase the forest tree cover to 33 per cent, from the present level of 19.27 per cent, even this reduced level of deforestation amounts to being a negative achievement, although it does help us take a feeble step towards the actual goal.

Currently, the area of private tree planting (under agroforestry, farm forest in block and line plantations) covers an area of over 6 million hectares. These private initiatives are not adequately supported by the Government through relevant research, extension, technological packages, input delivery, market information or credit facilities. In the interest of sustainable forestry development, it is necessary to encourage these small operators to keep up their interest, and to ensure that their needs are adequately understood and addressed. About 7 million hectares of farmlands (5 per cent of 142 million hectares) would be available for farm forestry and agroforestry (National Forestry Action Programme of India).

National Commission of Agriculture had also recommended under production Forestry, large scale plantations of economically important indigenous species as well as fast growing exotics on all available vacant lands. Under social forestry, which aims to promote fodder, firewood and small timber to the rural community, fast growing tree species are planted mostly as monoculture.

1.2 Agroforestry

Agroforestry is as old as agriculture itself and is widely practiced in all the developing countries of the world. Farmers have been raising trees with crops for variety of purposes such as shade, tools and implements, buildings, furniture, fuel and fodder. Resource poor farmers have been growing trees to supplement their income and assure some security in high-risk farming. The practice continued, with variations in structure and function, over time and space. With tremendous increase in demand for food, fuel, fodder and wood, agriculture and forestry cannot be considered in isolation, but one has to complement the other to serve the society as a whole. Thus, agroforestry has an increasingly important role to play in times to come (Singh *et al.*, 1990).

Agroforestry has been defined in different ways by researchers. Nair, (1984) defined agroforestry as a "*land use system that involves deliberate retention, introduction or mixture of trees or other woody perennials in crops/animals production systems to benefit from the resultant ecological and economic interactions*".

Other definitions are those given by Jha, (1983); Lundgren and Raintree, (1983); Torres, (1983); Walt, (1989); Westly, (1990); Young, (1990); Jha, (2000a,b). Each definition may have some limitations but some basic ideas emerging from all the definitions as summarized by Singh *et al.*, 1990 are as follows: -

- Agroforestry is a land use system including combinations of agriculture, forestry, horticulture, animal husbandry etc.

- Integration of trees with crops and / or animals has the main objective of reducing risk and increasing total productivity.

- Agroforestry system should ideally be stable and sustainable.

- Integration of trees with agricultural systems may results in more efficient use of sunlight, moisture, and plant nutrients, than is generally possible by monocropping of either agricultural crops or trees. There may be competition between the trees and crops for these resources, but the net effect is positive, and includes increased productivity, and more importantly, conservation of the biophysical, edaphic and fertility status of the system, therefore enhancing overall sustainability.

Research efforts are being made to screen multipurpose tree species suitable for agroforestry system, in most of the states of India. The noted contributors from the hilly states are Mathur and Joshi (1975), Borthakur *et al.* (1981), Arora and Mohan (1986), Sud *et al.* (1986), Toky and Khosla (1987), Singh *et al.* (1987; 1988), Grewal (1988), Dhyani and

Chauhan (1989), Gupta *et al.* (1989), Jha (2000a,b), Madiwalar *et al.* (2000), Nadagoudar *et al.* (2000), Sharma and Manoj (2000), Singh and Singh, (2000), etc.

From Mizoram, Jha (2000a, b) and Jha and Lalnunmawia (2003) innovated agroforestry systems and named them as Tree-Greenhedge-Crop farming system and Bamboo based agroforestry system respectively. Adoption of tree based farming system developed and tested by various workers are almost non-existent in Mizoram. They normally practice tree based cropping systems on the basis of knowledge inherited from earlier generations. Lalramnghinglova and Jha (1996) also reported various multipurpose tree species and predominant agroforestry systems prevalent in Mizoram. The most common and successful agroforestry practice is intercropping of *Oryza sativa* and/or *Zea mays* along with *Tectona grandis*. They also noted that over the years, farmers of Mizoram have been practicing various traditional forms of Agroforestry.

Evidently, agroforestry is fast becoming an extremely important sector, not only contributing to the total forest cover and towards maintenance of environmental stability, but is also augmenting the total productive potential and sustainability of land. Additionally, it is also helping decrease the pressure over forests for anthropogenic needs.

Ecologically, agroforestry systems are unique, and in sharp contrast to either the natural forests which are generally of mixed vegetational composition, with associated undergrowth, where insect pests along with other fauna are kept in a state of equilibrium; or to agroecosystems and plantations which are either monocultures, or having low diversity, often having a single canopy, and being extremely vulnerable to pestilence and disease. On a world-wide scale pests account for losses of about 36% of potential yield, while another 14% is lost in storage (FAO, 1973).

On a gradient, agroforestry would probably fit between high diversity sustainable natural forests and low diversity, unsustainable agroecosystems and plantations.

1.3 Pest management in agroforestry system

Farm forestry practices are exposed to greater risk of insect pests epidemics because of the absence or failure of natural regulatory factors. Since the introduction of plantation forestry, it has been experienced and recorded that insect pests are one of the serious biological determinants of productivity. On account of high reproductive potential and short life cycles, most insect pests of plantation forestry are capable of multiplying to amazing numbers within a short period of time, affecting the success of plantations. Agroforestry introduces another dimension to tree plantation entomology. It is desirable to gain insight in to the evolving plant-insect interactions particularly pest problems of agroforestry system.

Species diversity frequently causes significant reduction of insect pest (Altiera and Liebman, 1986). Manipulation of plant elements in an ecosystem also encourages built-up of the natural enemies of the pest, simultaneously creating ecological conditions that will suppress population build-up of the pest. This is mainly done through encouraging beneficial plant species (perennial/annual) that support 10-12 polyphagous parasitic species and discouraging the plant species (perennial/annual) that act as alternate hosts of pests.

It is also well known that mixed culture (polyculture) of plant species faces much lesser problem from insect pests than in monoculture comprising of even aged genetically similar population of crop. Agroforestry, which is also another type of polyculture can be designed so as to control or reduce damage by insect pests (Sen Sarma, 1993; 2000).

Agroforestry can be an efficient, productive and sustainable alternative to conventional cropping systems, and a lot of research is being directed towards maximizing such potential. However, very little is known about the pest interactions in such systems although the relevance of such interactions has long been recognized (Epila, 1986).

1.3.1 Polyculture-species diversity

Sen Sarma (1993) mentioned that the pest population builds up rapidly due to sustained supply of quality and quantity of food, which also acts as a reproduction stimulator. The situation is, however, different in a polyculture in which the total available food is less for the pest, and finding the host plant for oviposition or feeding is often difficult on account of physical barriers caused by the presence of non-host plants. In addition, in mixed vegetation where appropriate species diversity and composition has been formed, competition for food and feeding space may take place among herbivorous communities or between individuals of the same species. These regulatory factors definitely affect the abundance of the pest species often through natural regulation of the population of the pest. Competition among individuals of the same species results mainly from excessive egg-laying and consequent production of young larvae far in excess of the carrying capacity of the host plant. This often leads to internecine competition especially when the food supply is much less than is required, resulting in unusually high mortality of the competing larvae and consequent decline of pest population (Beeson, 1941).

1.3.2 Ecological aspect of pest management in agroforestry

An approach to augment natural increase in the enemy complex of the pest through environmental manipulation can be fruitfully experimented and applied through agroforestry. Encouraging plants that provide pollen and nectar, or those that harbour honeydew-producing aphids could enhance the abundance of natural enemies in altered man-made ecosystems. The flowering plants especially those belonging to Umbelliferae are an important food of adults of certain hymenopterous parasites and have been experimentally proved in Canada and USSR (Leius, 1960, 1967; and Sen Sarma, 1972). Mai *et al* (1979) stated that polyculture has been found to provide more pollen and nectar source to adult parasites and predators when compared with monoculture. Agroforestry ecosystems seem to be ideal to generate data on such aspects (Paul *et al,* 2000).

1.3.3 Characteristics of agroforestry systems for biological control of pests

Ecologically, agroforestry is very distinct either from crop husbandry or tree husbandry. In agroforestry or mixed cropping, insects may often find it difficult to locate the host-plant on account of the presence of non-host crops in good numbers (Sen Sarma, 1993). These companion crops may hinder the dispersal of pests by mechanical means (Root, 1973), may camouflage the host plant (Altieri and Liebman, 1986), and may repel the pest due to unpleasant odours and unacceptable morphological features (Levin, 1973).

Agroforestry system can also be a tool to manipulate microclimate in such a manner that these become unfavourable for the pests and be favourable to the natural enemies of pests. High humidity encourages infection of the pests by entomopathogenic fungi (Jaques, 1983). Some parasites and predators may flourish in an optimum temperature and relative humidity. The biotypes created by agroforestry combinations improve the biological characteristics of parasites and predators through improved nutrition and adequate shelter. It also improves the chance of survival and multiplication of polyphagous parasites on account of availability of secondary and tertiary host insects, which can occur in high biological diversity systems (Sen Sarma, 1993).

1.4 Scope of research in pest management in agroforestry systems

The facts explained above indicate that the agroforestry systems may be efficient in maintaining population of pest at lower levels than those causing economic damage. These systems have certain build-in mechanisms that militate against pest population build up.

Agroforestry is now well-established discipline but lacks data on pest, parasites and predators complexes. Thus these systems need to be studied, documented and experimented by means of on-farm data. The present study was undertaken to achieve the following objectives.

- Qualitative and quantitative survey of the insect pests of the prominent agroforestry system of Mizoram i.e Teak (Tectona *grandis*), Tung (*Aleurites fordii*) and Subabul (*Leucaena leucocephala*) based agroforestry system.

- Study on nature and extent of damage, seasonal incidence and seasonal abundance of insect pests and determination of pest status and host specificity of major species.

- Survey and identify natural enemies of insect key pests and

- Identification of pests common to both tree and crop component.

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CHAPTER 2

REVIEW OF LITERATURE

2.1 Human population versus food production

Agriculture and Forestry are two essential sectors in the economies of developing countries. These countries face large social and economic problems due to unabated population growth, and consequently, increasing need for food, fodder, energy and lumber. As a result, most of the accessible forest lands in Asia have already given way to agriculture and other forms of land use, creating a conflict between agriculture production and forest management and conservation. By 2020 A.D., the population of India will touch 1.3 billion mark with a projected food grain demand reaching a staggering 241 million tons. The cattle population too will increase substantially, creating more pressure for grazing land which has not only reduced in area, but has also been degraded to the extent that during the dry summer months these lands are totally barren. (Sen Sarma, 1993). Under such a scenario, there is hardly any alternative to agroforestry systems in order to meet the increasing requirement of food, fuel, fodder and timber and for environmental conservation and ecological security (Gordon and Bentley, 1990; Sen Sarma, 1993; Tejwani, 1994).

2.2 Agroforestry

Westly (1990) very correctly pointed out that researchers may define agroforestry differently depending on the focus of their work. Torres (1983) defined agroforestry as the deliberate combination of trees with crop plantation or pastures, or both, in an effort to optimize the use of accessible resources to satisfy the objectives of the producer in a sustainable way. Definitions and explanations of agroforestry are given by various researchers viz, Lundgren and Raintree (1983), Rao (1989), Walt (1989), Wesley (1990), Young (1990) are some examples of different explanations covering diverse information on agroforestry.

The concept of agroforestry eschews the artificial dichotomy of agriculture and forestry and is the step in right direction and evolves an integrated land use pattern (Sen Sarma and Jha, 1993). The aim of agroforestry system is to optimize positive interactions between various biological components like tree/shrubs and crops/animals so as to generate sustainability and ecological stability (Lundgreen and Raintree, 1983).

2.3 Traditional agroforestry Systems

Agroforestry is a comparatively new as a scientific discipline, but an old traditional practice modeled to address very specific needs of different local conditions in India (Tejwani, 1987, 1988 and 1994 Jha 1996). A recent survey conducted by various workers to identify traditional agroforestry systems in North East India (De, 1932, Hadfield, 1974; Bhattee, 1984; Dharda, 1984; Dogra, 1984; Sarma, 1984; Suchiang, 1984; Tejwani, 1989), in rest of India (Hussain, 1925; Nair, 1982,1983; Malhotra, 1984; Muthana *et al.,* 1985; Nair and Sreedharan, 1987; Singh *et al.,* 1994; Singh and Misra, 1994) and outside India (Khattak, *et al.,* 1980; Caleda and Esteban, 1981; Bhunibhaman, 1984; El-lankany, 1984; Hsiung, 1984; Khaleque, 1984; Mohd and Othmen, 1984; Sheikh, 1984; Dennis and Nair, 1985; Peter and Oberholzer, 1989 etc) gives clear impression that introducing trees species in the agricultural field is an age old practice and is done not only to cover the risk of crop failure but also to meet the demand of fuel, fodder and timber. Besides, trees also enhance soil fertility and conserve soil (Pathak and Maiti, 1974; Jha, 1996; Young, 1989).

2.4 Pest management under monoculture and polyculture

The possibility of multiplication of insect pests is the maximum in pure crops without much genetic and/ or age variation (Sen Sarma, 1993). Host searching and locating by a pest are easy in monocultures. In such situations, pests can locate, undertake egg laying and feeding activities without any hindrances and difficulty. The pest population builds up rapidly due to sustained supply of quality and quantity of food material that also act as reproduction stimulator (Butani, 1975; Cromortie, 1981; Hill, 1983).

Polyculture has been found to provide more pollen and nectar source to adult parasites and predators when compared with monoculture (Mai *et al*, 1979). Agroforestry ecosystem seems to be ideal to generate data on this aspect. However, in polyculture or mixed cropping, a situation which agroforestry aims, an insect pest may often find it difficult to locate the host-plant on account of the presence of non-host crops in good numbers (Sen Sarma, 1993). These companion crops may hinder the dispersal of pests by mechanical means (Root, 1973), may camouflage the host plant (Altieri and Liebman, 1986), or may repel the pest due to unpleasant volatiles and unacceptable morphological features (Levin, 1973). Altieri (1986) has reported that mixture of various volatile chemicals released by different plants/trees is capable of creating confusion and difficulty among pests in locating the host plants for oviposition and or feeding. High humidity level in agroforestry farm in comparision to monoculture favours infection of pests by entomopathogenic fungi (Jaques, 1983).

Agroforestry also moderates both macroclimate and microclimate and this would be conducive to survival and multiplication of parasites and predators either native or introduced. Some parasites and predators may flourish in an optimum temperature and relative humidity (Sen Sarma, 1993 and Jha, 1996). Agroforestry provides shelter and nesting sites to insectivorous birds and bats. These augment biological control of noxious insects when they damage the crops (Sen Sarma, 1993).

On the contrary Jha (1996) states agroforestry system may also be congenial for the pest multiplication due to regular supply of food and shelter throughout the year. A tree pest may develop palatability for agricultural crops, and alternately, a pest of agricultural crops may develop a fancy for the tree species growing in the agroforestry plot during shortage or absence of the primary food source. This system may lead to evolution and change in the food habit of pests from mono or oligophagous to polyphagous and may lead to great loss to tree species as well as crops or fodder. Selection of tree species and crops should also ensure that they are not prone to attack by the same pest (Jha, 1996, Paul *et al*, 2000).

Very little is known about the type of ecological interactions that operate in agroforestry systems, much less with respect to insect- plant interactions. Thus, extensive and intensive survey is needed in such traditional agroforestry system to determine pest, parasites and predator complexes (Bhandari and Kumar, 1993 and Sen Sarma, 1993).

2.5 Seasonal incidence and seasonal abundance of key pests

Seasonal abundance of *Hyblaea puera*, the teak defoliator, was reported April to early June in Nilambur, May to June in Coorg and July in Bombay (Mumbai) and Dehra Dun. It is also reported that some time a second phase of abundance occurs in August to September in Dehra Dun. No noticeable defoliation occurs during the rest of the year (Beeson, 1941). Nair *et a*l (1985) reported that the number of population peaks at Nilambur varied from one to three per year. During the study period the first peak occurred in the third week of April (1981), third week of May (1980) or the first to second week of June (1979 and 1982). Usually it occurred during the pre monsoon season. In some years (1980 and 1982) the first build up was smaller. A second peak occurred in three of the four years. Vaishampayan and Bahadur (1983) reported that major activity period of teak defoliator, *Hyblaea puera* was July and August. September to June was off period with no indication of breeding in Madhya Pradesh, whereas major active period of *Pyrausta machaerelis* was August to October. From December to June the activity was almost nil. *Eutectona Machaeralis* (generally known as the teak skeletoniser) is distributed in the Indo-Malayan region up to Australia (Beeson, 1941). Vaishampayan and Bahadur (1983) reported presence of moths from July to December with peak catch in the months August-September in Madhya Pradesh. In Karnataka, Patil and Thontadarya (1983a, b) observed the presence of larvae throughout the year with prevalence of adults in September to November and a very small population during January to March. Their study also revealed that the timings of population peaks varied between years and between plots.

Varma (1991) has found that larvae of *Eurema hecabae* and *E. blenda* occur with the same intensity in a pure plantation as well as *A. triphysa* mixed with *Tectona grandis*. Larvae of *Eurema hecabae* and *E. blenda* and *Laodemia striqvenata* feed gregariously *on Kala siris*, stripping the leaf to the midrib during June to October whereas leaves of *Safed siris* are webbed together by the Lepidoptera larvae, *Cacoecia micacaceana* which feeds on mesophyll tissues from inside the surface during July.

It is generally believed that extensive monoculture of any crop including tree crops may lead to serious pest problems. Mathur *et al* (1970) have reported that in Maharashtra, *Ailanthus* plantation mixed with other species like *Boswellia serrata*, *Dalbergia paniculata, Erythrina suberosa* and *Gmelina arborea* was free from *A. fabriciella* damage.

Other notable contributions made on seasonal incidence and abundance of insect pests are, Mathur (1960), Gupta (1972), Chatterjee and Misra (1974), Nair (1983), Vaishampayan and Bahadur (1983), Gupta *et al.* (1989), Nair *et al.,* (1989), Chaudhury and Sharma (1990), Singh *et al.* (1990), Katua (1997).

2.6 Population dynamics

Studies on population dynamics are essential to predict the population level on insects at any point of time and to select the correct time of pest suppression operation (Singh, 1990). Minchin (1929) and Champion (1934) had evaluated impact of population changes of pest on trees. The correlation between population level and the intensity of damage that they inflict should be established in order to determine economic thresholds. Study on population dynamics of insect pest is still not properly understood in case of majority of insect pests. Much efforts are needed to explain the intermittent absence or rarity of the insect in teak plantation. The field studies showed that epidemic by *E. machaeralis* is not a regular annual phenomenon in teak plantation in Kerala (Nair *et al*, 1985; Sudheendrakumar *et* al., 1988). They noted measurable defoliation due to *E. machaeralis* only during two years- 1980 and 1981 in the experimental plots. In general, measurable defoliation ranged from 14 to 40 per cent. Though small numbers of larvae were present at other times particularly in May to June and October to January, the insects were not seen in July to September and February to April in the experimental plots.

The contribution made by Cobbinath, (1990) is important in the area of study on population dynamics of insect pests.

2.7 Impact of insect pests on growth and yield and economic damage

This area is hardly studied in the field of plantation forestry sector. During 1930, a rough estimate based on several assumptions placed the loss of 6 to 16 per cent of the potential volume increment of teak plantation but a 1941 estimate of 13 per cent loss based on fewer assumptions (Beeson, 1941) was generally accepted and quoted extensively in subsequent publications. Nair *et al.* (1985) showed that natural defoliation by *H. puera* resulted in loss of about 44 per cent of the potential volume increment in 4 to 9 years old trees. It was estimated that during the study period, the protected trees put forth a mean annual increment of 6 m^3/ ha compared to the mean annual increment of 3.7m^3/ha of unprotected trees.

Qualitative survey of the insect pests of Teak (*Tectona grandis*), Tung (*Aleurites fordii*) and Subabul (*Leucaena leucocephala*) based agroforestry system to determine pest status and host specificity and to identify natural enemies complex of key pests and also to record pest common to both tree and crop component are the objectives of the present study. Thus it is important to document insect pest associated with Teak, Tung and Subabul Plantation, and Teak, Tung and Subabul based Agroforestry System and of Maize and Vegetables grown as Intercrop to provide base-line information from which pest profiles of each individual tree species and crops can then be compiled. The major and key pests can then be identified (Pong, 1990).

2.8 Insect pests

2.8.1 Tree component

(a) *Tectona grandis*:

About 174 species of insects are associated with living teak (Mathur, 1960; Mathur and Singh, 1960). Among the pests recorded on teak, 136 are defoliators. *Hyblaea puera* and *Eutectona machaeralis* are major leaf defoliators. Biology of *Hyblaea puera* is reported by Beeson, (1941) and Sudheendrakumar, (1991). Its seasonal incidence and defoliation dynamics were studied by Beeson (1941), Nair *et al* (1985) and Nair and Sudheendrakumar (1985). The natural enemies of *H. puera* include 34 species of parasites, 14 species of insect predators and 48 species of birds (Beeson, 1941; Chatterjee and Mishra, 1974; Sudheendrakumar, 1986; Zacharias and Mohandas, 1990). The quantitative aspects of the relationship between the parasites and *H.puera* have been studied by Sudheendrakumar, 1985; Nair *et al*, 1985 and 1989). A scheme for biological control using silvicultural measures to augment the efficacy of natural enemies was proposed by Beeson (1934). The life history of the teak skeletonizer (Eutectona *machaeralis)* had been studied in detail by Beeson (1941), Patil and Thontadarya (1983a) and Vaishampayan and Bahadur (1983) have reported seasonal incidence where as its population dynamics were studied in details in Kerala (Nair *et al.*, 1985; Sudheendrakumar *et al.*, 1988), central India (Vaishampayan and Bahadur, 1983). A total 75 species of parasites, 31 species of insect predators, 38 species of spider and 3 species of pathogens have been reported as natural enemies (Beeson and Chatterjee, 1935a,b, c; Chatterjee and Mishra, 1974; Patil and Thontadarya, 1983b; Sudheendrakumar, 1986).

Of the eight species of the trunk borers reported on teak, the Lepidoptera *Alcterogystia cadambae* (*Cassus cadonbae*) and *Sahyadrassus malabaricus* are considered to be economically important.

Alcterogystia cadambae was reported on teak by Beeson (1941). Impact of attack and control were reported by Sharma *et al.*, (1985) and Mathew, (1990) respectively. Beeson (1941) summarized the existing information on the life history and habits of *Sahyadrassus malabaricus*. The biology, ecology and control of this pest were studied by Nair, (1982).

(b) Leucaena leucocephala:

Leucaena psyllid, *Heteropsylla cubana*, which originated from Central America and spread throughout the specific countries since 1982, has almost wiped out *Leucaena* trees in these areas (Mitchell and Waterhouse, 1986). In India this insect has been reported from many parts of south and central India, and is believed to be spreading towards the north (Singh and Bhandari, 1986, 1988, 1989a,b; Sivaramakrishnan, 1988). Thakur and Pillai (1985) have reported about 12 native insect pests attacking subabul in south India. Bhandari and Kumar (1993) suggested use of systemic insecticides to suppress the population of psyllid. Singh and Bhandari (1989b) advocated introduction of the predators *Curinus coeruleus* and *Olla abdominalis* as they may readily predate upon the psyllid.

Several entomopathogenic fungi, i.e. *Conidiobolus coronatus, Paeciolomyces javanicus* have been isolated from diseased psyllids and tested for their effectiveness as biological control agents (Hsieh *et al*, 1987).

(c) *Aleurites fordii*:

Reports relating to insect pests of *Aleurites fordii* are not available till date.

2.8.2 Crop component

(a) Maize (*Zea mays*)

After rice, maize is the second most important crop of North Eastern Indian region. Despite wide variations in abiotic and biotic stresses there is great potential of increasing maize production in North Eastern Hill Region (Singh and Singh, 2002). Although 139 insect pests cause varying degree of damage to maize crop, only about a dozen of these are quite serious (Siddiqui and Marwaha, 1993). Jha (1987) reported that *Chilo partellus* Swinhoe (maize stem borer) is the most serious of the maize pest and is a limiting factor in the successful cultivation of this crop. Besides, damage is also caused by polyphagous insect pest larvae of *Sesamia inferens* Walker, which bores the stem and kills the central shoot causing dead-hearts, occurs as a serious pest in peninsular India (Panwar *et al.*, 1997). Nature of damage, life history and control of maize pests are reported by Rahman, 1945; Khan and Khan, 1968; Bleszynski, 1970; Panwar and Sarup, 1979; Lynch *et al*, 1980; Ram *et al*, 1981a,b, c, d; Alghali, 1985; Kumar and Saxena, 1985; Atwal,1986a; Shelton *et al.*, 1986; Jha,1987; Umeozor *et al.*, 1987; Calvin, *et al.*, 1988; Seshu Reddy, 1989; Chaudhary and Sharma, 1990; Seshu Reddy and Walker, 1990; Sithole, 1990; Ngi-Song *et al.*, 1995; Kfir, 1997; Overholt *et al.*, 1997; Panwar *et al.*, 1997; Overholt, 1998; Kfir, 2000; Chaufaux *et al.*, 2001; Chinwada and Overholt, 2001; Ebenebe *et al.*, 2001; Lewis *et al.*, 2005)

(b) *Cajanus cajan*

Pigeon pea is known to harbour nearly 200 species of insects causing injuries to different parts of the plant, from seedling to maturity stage (Davies and Lateef, 1975; Sithananthan, 1987). About 20 to 72 per cent of yield loss in pigeon pea was estimated by Lateef and Reed (1983). The major losses, however, are caused by a complex of pod borers attacking the flowers as well as the pods (Saxena, 1988; Jeswani and Baldev, 1990). Gram pod borer, *Helicoverpa armigera* tur pod fly, *Melanagromyza obtuse* Malloch and tur plume moth *Exelastis atomosa* Walshingham collectively referred to as the pod borer complexes, are considered as major pests of pigeon pea (Srivastava, 1964; Singh and Singh, 1978; Singh *et al.*, 1979; Thakre *et al.*, 1983; Ayyar, 1984 and Siddappaji *et al.*, 1985). *Helicoverpa armigera* has been recorded feeding on 181 cultivated and uncultivated plant species belonging to 45 families (Manjunath *et al.*, 1989). The damage to pigeon pea crop in India was reported by several workers (Ponnuswami, 1967; Bindra, 1968; Reddy, 1968; Singh, 1970a; Murkuta *et al.*, 1993; Sison and Shanower, 1994; Bantewad and Sarode, 2000). It has been reported feeding on cotton (Fletcher, 1919; Heinrich, 1921; Khan and Rao, 1960; Tunstall, 1960; Reed, 1965; Reddy, 1968; Kaushik *et al.*, 1969; Patel *et al.*, 1973; Jayaraj, 1981; Mathews, 1996 and Venkataiah *et al.*, 1997), maize

(Anonymous, 1954; Bindra, 1968; Reddy, 1968 and Kachroo and Arif, 1970), tomato (Lefroy, 1907; Fletcher, 1914; Floyd, 1947; Kachroo and Arif, 1970; Singh, 1970a; Patel *et al.*, 1973; Dhandapani and Balasubramanian, 1984; Prasad, 1997), tobacco (Fletcher, 1914; Reddy, 1968; Patel and Patel, 1969 and Singh, 1970b).A number of works has been carried out on the natural enemies of *H. armigera*. There are 77 parasites recorded in India (Achan *et al.*, 1968; Rao, 1968; Manjunath *et al.*, 1989). Achan *et al.*, 1968, Anonymous, 1974, Bhatnagar *et al.*, 1983, Pawar *et al.*, 1985 and Manjunath *et al.*, 1989 have provided information on the influence of seasons and host plants on parasitism of *H. armigera* by various species. Hymenopterans were predominant on sorghum and chickpea and dipterans on pigeon pea. Parasitism by dipterans on sorghum was 4.9 percent, pigeon pea 5 per cent and chickpea 17.2 per cent (Bhatnagar *et al.*, 1982, 1983). Predators such as *Delta, Orius, Chrysoperia, Cheilomenes, Rhynocoris, Geocoris, Nabis*, carabids, ants, mantids, spiders and birds feed on *H. armigera* egg, larvae, prepupae and pupae (Singh *et al*, 2002). In India, the wasps *Delta* spp. and *Chrysoperia* spp. have been observed to be important predators of *H. armigera* (Manjunath *et al.*, 1989). Among the pathogens, Nucleopolyhedrovirus (NPV) has been recorded from South Africa (Parsons, 1936), Uganda (Coakar, 1958), India (Patel *et al.*, 1969), Azerbaijan (Simonova, 1969), Israel

(Harpav, 1987), Russia (Singh, 1972), Indonesia (Van der Laan, 1981), Thailand (Napompeth, 1982), China (Li, 1986), Yugoslavia (Sidor *et al.*, 1977). From India, agranulovirus (GV) (Narayanan, 1987) and a cytoplasmic polyhedrovirus (Rabindra and Subramaniam, 1973) have been recorded from *H. armigera*, among the bacterial pathogens, the records include *Bacillus thuringiensis* Berliner (Majumdar *et al.*, 1995) and the important fungal diseases isolated from *H. armigera* include *Beauveria bassiana* (Balsamo) Vuillemin and *B. brongniartii* (Saccardo) Petch (Jayaramaiah, 1981), *Metarhizium anisopliae* (Metschnikoff) Sorokin (Urs and Govindu, 1971), *Nomuraea rileyi* (Farlow) Samson (Gopalakrishan and Narayanan, 1988). *Beauveria* sp. was found infecting *H. armigera* on cotton, pigeon pea and other legumes in Andhra Pradesh in October to December, 1987 (Abbaiah *et al.*, 1988)

(c) Brinjal (*Solanum melongena* L)

Nature of damage, life cycle and control of brinjal shoot and fruit borer *(Leucinodes arboriali*) have been described by Jha (1987). The other pests reported are the brinjal mealy bug (Coccidihystrix *(Centrococcus solitus* Gr,), lace wing bug (*Urentius sentis* Distant.), the stem borer (*Euzophera perticella* Raj), brinjal leaf roller (*Antoba (Eublemma) olivacea* Walk.), the Epilachna beetle

Henisepilachna vignitioctopunctata , *Anoplocnemis phasiana* F., including many minor pests (Maheswariah and Putturudriah, 1956; Srivastava, 1961; Ayyar, 1963; Rawal and Modi, 1969; Ram *et al.*,1981c; Atwal,1986b).

(d) Mustard (*Brassica juncea*)

Mustard is a major oil seed crop grown in the trees based farming system. The major pests of mustard are *Bagrada cruferarum, Athalia lugens proxima* and *Phytomyza atricornis.* Adult and nymphs of *Bagrada cruciferarum* suck the sap of tender parts of the plant. *Bagrada cruciferarum* have a number of natural enemies like *Alophora sps, Liophanurus samueli* etc. but none has so far proved to be much useful in their control. *Athalia lugens proxima* eats edge of leaves, thereafter eats buds and flowers. (Tripathi, 1963; Ram *et al.*, 1981d; Atwal, 1986c; Jha, 1987 and Nair, 1995 a, b, c).

Study on pest problems and their management have been restricted mostly to monoculture. Scientific study on insect pests under agroforestry system is ignored till date. Only a few reports gives preliminary ideas about the pest management in agroforestry system (Bhandari and Kumar, 1993; Sen Sarma, 1993; Jha, 1996 and Paul *et al.*, 2000,) and it is agreed that very little is known about pests and their interactions with plants in agroforestry situations (Banwo and Adamu, 2003). During the last few decades, there has been a paradigm shift in the overall approach to pest management. The inbuilt mechanisms of control such as natural enemies and predators (Sunderland, 1975; Allen, 1979; Sunderland *et al.*, 1980; Wallin, 1985; Booij and Noorlander, 1992; Clark *et al.*, 1993; and Brust, 1994; Heimbach and Garbe, 1995 and Collins *et al.*, 1996) are being accorded their due importance. Further, manipulations within the system to enhance natural control and mitigate pest problems are also attempted through control of crop density (Baker and Dunning, 1975), controlled tillage (Barney and Pass, 1986; Clark *et al.*, 1993 and Heimbach and Garbe, 1995) and inclusions of adjacent non cropped area (the Fringe area in the present study) as a management option (Boatman *et al*, 1989; Duelli *et al.*, 1990; Thomas *et al.*, 1991; Dennis and Fry, 1992; Lys and Nentwig, 1992; Burel, 1996; Collins *et al.*, 1996; Anderson, 1997; Fournier and Loreau, 1999 and Thomas and Marshall, 1999), particularly for the habitation of faunal components during the non - cropping period and also as islands for the maintenance of natural control agents.

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CHAPTER 3

STUDY AREA

3.1 Location

Mizoram is a state located in the southeastern extremity of the northeastern region of India, sandwiched between Myanmar in the east and Bangladesh in the west border (Fig. 3.1). The state has a strategic importance because of its proximity to such international boundaries. Besides, it also shares borders with other states like Assam, Manipur and Tripura. The state lies between the coordinates of 21°58′N to 23°35′N and 92°15′E and 93°29′E, the tropic of cancer passing through the southern periphery of the capital town Aizawl at 23^0 30′ N latitude. The population of the state as per 2001 census is 8,91,058 and the geographical area is 21,087 Sq Km. (Govt. of Mizoram, Statistical Abstract, 2002 - 2003).

3.2 Physiography

The physiography of Mizoram can be broadly divided into hills and valleys. Hills consist of high hills (above 1300 msl), medium hills (between 500m and 1300m), and Low hills (below 500m above msl). Blue Mountain is the highest peak at 2360m whereas the lowest spot is Bairabi at 40m. The average hill ranges is 920 metres. The hills run in a north south direction parallel to each other, with valleys interspersed between them. Dissected hills and hillocks are dominant in most of the river valleys in the western part of the state.

3.3 Climate

The climate of Mizoram is generally moderate probably due to its tropical location and altitude, with temperatures varying between 21° C to 31° C during Summer (May - September) and 11° to 23°C during Winter (November - February). The average rainfall in the state is 2226 mm, which occurs mainly due to southwestern monsoons during summer and northeastern monsoon during late autumn.

3.4 Geomorphology and soils

Soils are mostly acidic and vary from sandy loam, clayey loam to clay. In the hilly terrain, they are well drained, deep, and moderately rich in organic carbon, low in available phosphate and medium in potash content. They are poor in bases, rich in iron and have low pH value.

Soils in the valley and flat land have a heavy texture, with a poorly permeable water table (1m depth). They are mostly fertile and productive alluvial and colluvial soils. The narrow valleys have light and coarse texture, well-drained, well aerated and young soils. They are capable of retaining moisture and maintain its supply throughout the growing season of most of the crops (Thangsanga, 2000).

3.5 Forest cover

The state has 75% of the geographical area under forest, which is among the highest in the country. The total forest area as per reported by the various government statistics is 15935 Km. The diverse forest type ranges from Wet Evergreen Tropical to Moist Deciduous forest dotted with patches of oak, pine and bamboo. Considering the land use system in Mizoram adopted by various government agencies, the forest cover can be categorized into four classes viz; National park, Reserve Forest, Jhum Forest and Jhum Fallows.

3.6 Land use

Agriculture and animal husbandry are the predominant occupations of the people of Mizoram.

There are two methods of cultivation in the state, the most common type being shifting cultivation (*jhum*) practiced along the hill slopes, and the other being settled agriculture practiced in the limited amounts of land in the valleys and plains. Recently, a new method of farming such as different forms of agroforestry and contour trench farming systems are being promoted by Department of

Agriculture (Anonymous, 1995) and these new initiatives are gaining popularity among the hill farmers. The principal crops cultivated in Mizoram are paddy (*Oryza sativa*), maize (*Zea mays*), Pulses like Arhar (*Cajanus cajan*), Cowpea (*Vigna sinensis*) Rice bean (*Vigna spp*) Oilseeds like Soybean (*Glycine Max*) Mustard (*Brassica spp*) Groundnut (*Arachis hypogea*), Sunflower (*Helianthus annanus*) etc. Tree components in Agroforestry systems are species like *Aleurites fordii*, *Leucaena leucocephala* and *Tectona grandis*.

3.7 Experimental sites

The study was conducted in Aizawl and Kolasib districts of Mizoram (Fig.3.1). In Aizawl, three experimental plots were selected, one each at Chanmari west, Zemabawk, and Sakawrtuichhun. The tree components of these sites were respectively Teak (*Tectona grandis*), Tung (*Aleurites fordi*) and Subabul (*Leucaena leucocephala*). At Kolasib, two sites were selected, one each in Upper Kolasib (zero point) and another in the western fringe, each having Teak and Tung respectively as the tree component. No *Leucaena* based Agroforestry system could be located at Kolasib.

The crop component in all the sites was maize (*Zea mays*), *Phaseolus vulgaris* and/ or *Vigna sinensis*. Besides, the Chandmari site of Aizawl also had *Clerodendrum* and

Teak site

Aleurites site

Leucaena site

Plate 3.1 Experimental sites in Aizawl

Teak site

Tung site

Plate 3.2 Experimental sites in Kolasib

Solanum as other components. The cropping area in the sites was approximately 100 X 100 sq.m (excluding the fringe area). Weed species such as *Imperata cylindrical*, *Drymaria chordata*, *Cyperus rotundas*, *Epatorium sp*, *Ageratum conyzoides* etc were common in the sites.

Fig 3.1 Map of Mizoram

References

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CHAPTER 4

MATERIALS AND METHODS

4.1 Components of experimental plots

Each experimental plot was subdivided into three components viz. tree component, crop component, and fringe area. The fringe area consisted of the natural vegetation immediately outside the cropping plots.

4.2 Sampling and data collection

4.2.1 Meteorology

Monthly records for maximum and minimum temperature, and rainfall was collected from Economics and Statistics office (for Aizawl sites) and from ICAR, Kolasib (for Kolasib sites).

4.2.2 Sampling of fauna

A random Sampling program (Southwood, 1978), replicated five times, was undertaken for 29 months (August 2000 to December 2002) in each component of each site to account for the following:

(a) Total arthropod fauna:

The arthropod fauna of the different components of each site was monitored through a replicated monthly sampling program. Sweep net sampling was used for this purpose. This was undertaken with the objective of recording the pests and natural enemies present in the experimental sites.

(b) Seasonal dynamic study:

The monthly sampling detailed above was analyzed for the seasonal dynamics of various orders of arthropods encountered during the study.

The pest of crop and tree components collected through the random sampling program detailed above, and also through handpicking were identified from Forest Research Institute, Dehra Dun, Zoological Survey of India, Shillong and Indian Council of Agricultural Research, Shillong.

(c) Spatial and temporal distribution:

The spatial distribution of the total fauna was worked out for the three different components of each experimental site. Similarly, the temporal (seasonal) distribution of the total fauna was determined.

(d) Natural enemy complex:

The natural enemies were also segregated and identified wherever possible from the monthly samples.

4.3 Laboratory experiments

4.3.1 Life cycle studies

The different pests encountered during the study were reared in the laboratory at room temperature to determine their life cycles. The insects (and their larval stages) were reared in wooden insect boxes (Plate 4.1) of dimensions 12″ x 8″ x 6″. They were fed with the host plant leaves (in case of the larval stages of defoliators) and woody tissue (woody branches and twigs) in case of borers.

4.3.2 Food preference studies

For food preference studies, the larval stages of defoliators were reared in the laboratory. Leaves of their food plants were mixed with leaves of other associate species found in the locality.

Important naturally occurring predatory species were also reared in the laboratory, and different larvae and adult insect pests were included as food. For the hymenopteran species, a 25% honey solution in distilled water was used as the base food, along with potential prey.

Plate 4.1 Insect rearing boxes

4.4 Statistical analysis

The population data generated from the different sites and components were subjected to analysis of variance (ANOVA) test using the statistical package SYSTAT 11.0.

Reference

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CHAPTER 5

RESULTS AND DISCUSSION

5.1 Meteorological factors

The meteorological factors accounted for during the present study were temperature (maximum and minimum), and rainfall.

The mean monthly temperatures are depicted in Fig 5.1. During the whole length of the study, the temperatures recorded at Kolasib were higher than the temperatures recorded at Aizawl, true for both the maximum and minimum temperatures except for the highest record of the maximum temperature for Aizawl, which was higher than that of Kolasib (Fig. 5.1). For the duration of the study, the maximum and minimum temperatures recorded at Aizawl and Kolasib were respectively 31.5^0 C and 9.5^0 C, and 30.6^0C and 15.9^0 C. The minimum temperatures were recorded during December and January while the maximum temperatures occurred during the May- June period (Fig. 5.1).

The monthly average rainfall of the two stations is depicted in Fig. 5.2. The monsoons were generally well distributed throughout the year except for a short dry period spanning 2-3 months between December and February (Fig. 5.2).

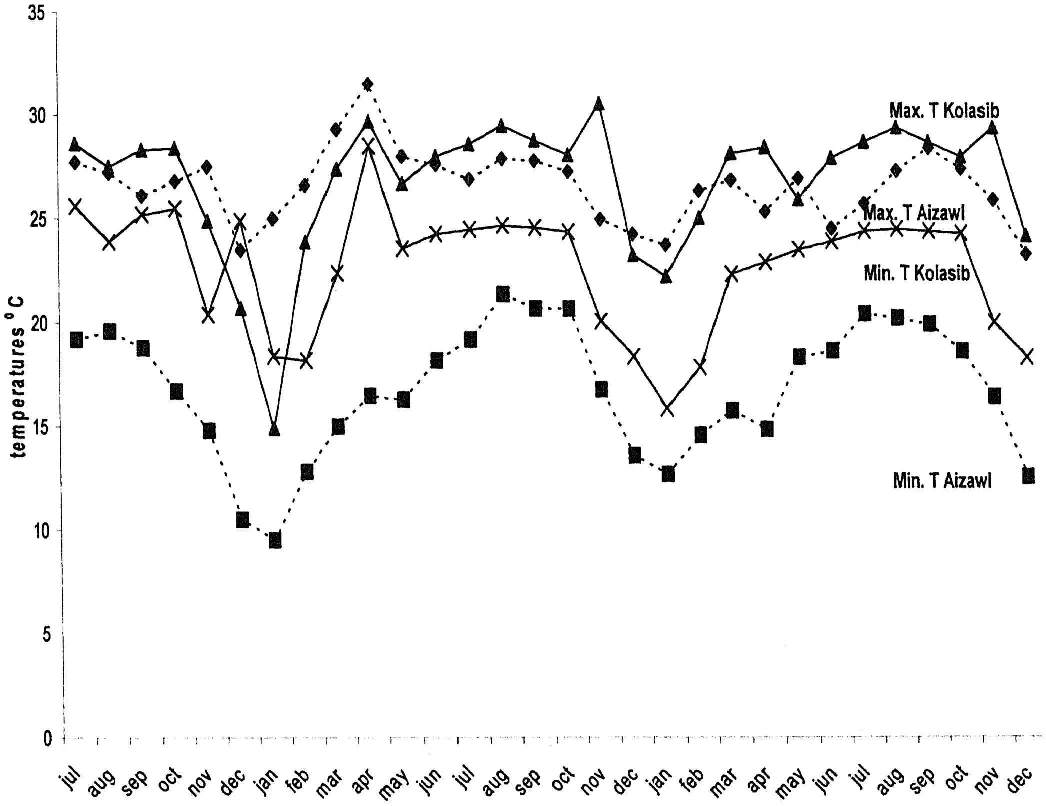


Fig. 5.1 Showing monthly means of maximum and minimum temperatures at Aizawl and Kolasib.

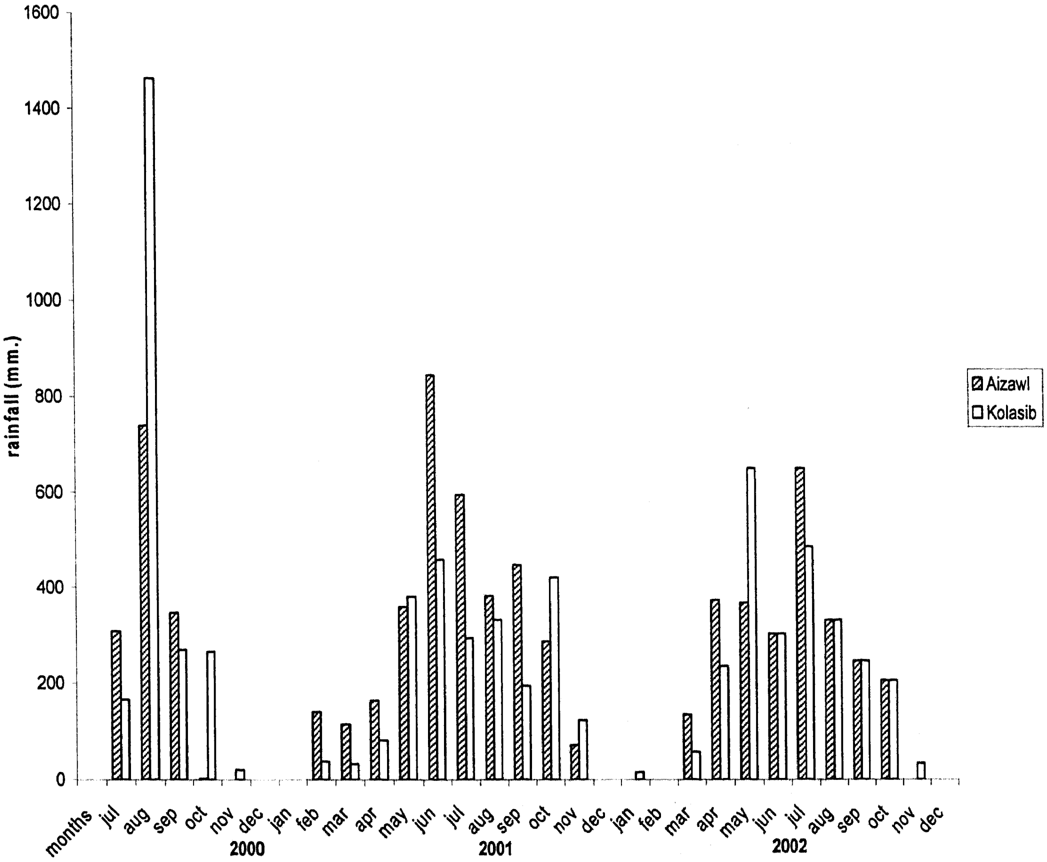


Fig. 5.2 Showing monthly totals of rainfall at Aizawl and Kolasib.

Comparing between Aizawl and Kolasib, for the length of the study, Kolasib registered the highest rainfall in August 2000 (1463 mm.), while the highest record for Aizawl was in the month of June 2001 (845.9 mm).

Temperature and moisture are crucial in the growth and development of insects. The cold and dry periods are generally spent as resting stages, either in the form of cocoons, or as overwintering eggs. Temperature triggers development and metamorphosis of the resting stages (Dent, 1991), while moisture (rainfall) ushers in the growing season of plants, thus ensuring ample food for the new recruits of insects in the ecosystem.

Thus, the meteorological factors are a key to the development of the population of insects and this is very often synchronized with the growing season of plants, particularly for herbivores or pests. This contention is further strengthened in the following section, where the population builds up is actually seen to be in tandem with ambient environmental and biotic conditions.

5.2 Seasonal dynamics

Seasonal population dynamic study is an important tool in assessing the population trends of animal populations in response to different abiotic and biotic cues. In general, the dry and cold periods are synchronous with hibernating stages, either in the form of overwintering pupae or eggs. With the onset of summer, ambient humidity and temperature regimes trigger the release of active adults and/ or larvae from the hibernating stages. Most often this is also synchronous with the new sprout of leaves in trees with the onset of the growing season, and germination of seeds of the crop.

The seasonal dynamics of total fauna of all three components of the different agroforestry sites was monitored for 29 months from August 2000 to December 2002.

A monthly sampling programme was undertaken to account for the different insects and arthropods present in the different components of the agroforestry sites. The sampling was replicated five times. The insect and other arthropod orders and classes encountered during the sampling are listed below: -

Insecta :

Lepidoptera

Coleoptera

Orthoptera

Hemiptera

Homoptera

Mantoidea

Isoptera

Thysanoptera

Dermaptera

Diptera

Hymenoptera

Insect larvae

<u>Arthropoda :</u>

Araneida

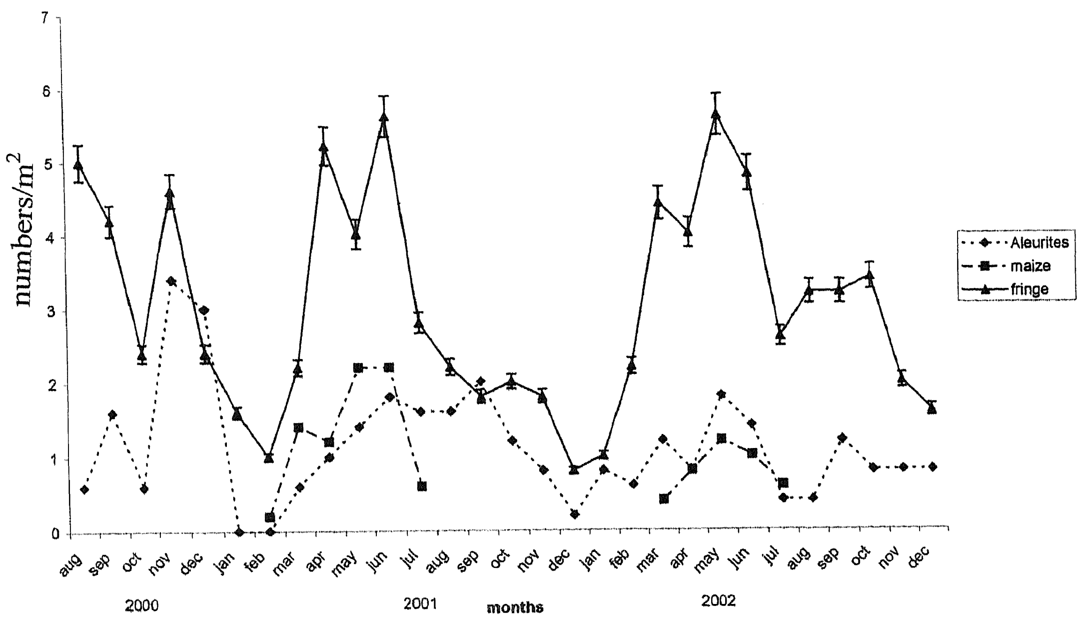
Chilopoda

Diplopoda

The seasonal fluctuation of the total fauna in the three components of the *Aleurites* agroforestry site of Aizawl is depicted in Fig.5.3. The monsoonic peaks and low winter/ dry period population values were exhibited in both the tree and fringe area components. The overall population table of the tree component was markedly lower than that of the fringe area component.

In the crop component too, the population buildup was seen to occur during the growing season, but the total population was low compared to the tree and fringe area components (Fig. 5.3).

Seasonal fluctuation of total arthropods in the different components of the Aleurites site (Aizawl)



Percentage composition

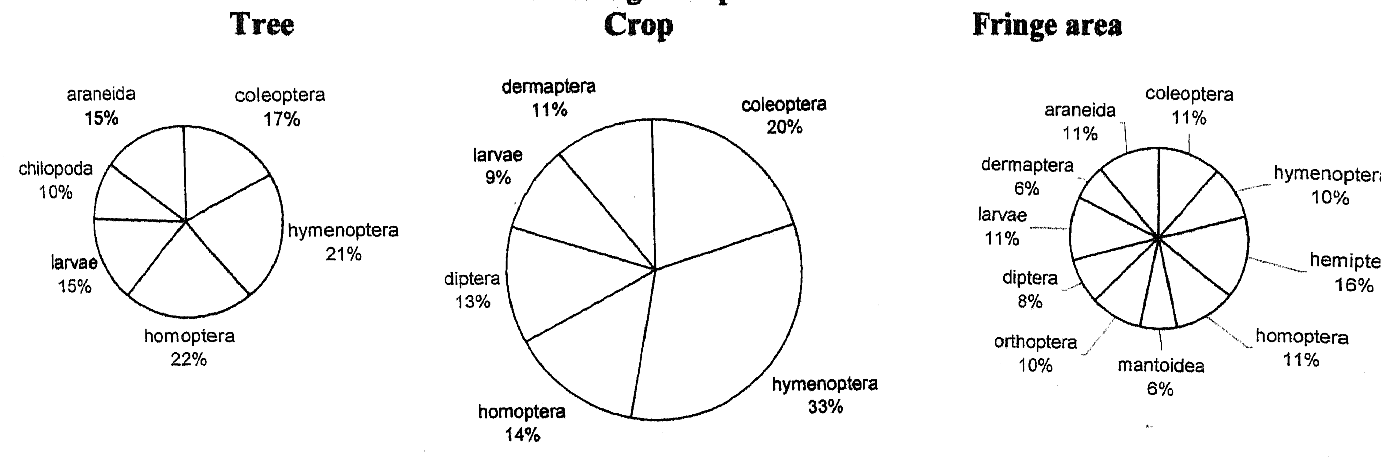


Fig. 5.3: Seasonal fluctuation and percentage composition of arthropods in the *Aleurites* (Aizawl) site.

The percentage composition of the different arthropod orders in the *Aleurites* site of Aizawl is depicted in Fig. 5.3. The tree component had 6 representative groups with araneida and chilopoda, the two predatory groups constituting 25 % of the total fauna. The crop component also had 6 representative groups (Fig. 5.3). The fringe area had 10 representative groups including larvae and the predatory fauna constituted 17 % of total fauna. Although the actual crop plots had lower numbers of predators, the proximity of the tree and fringe area components suggest that they are able to operate from the habitat provided by these two components. Further, the population values and the diversity of faunal groups were higher in the fringe area as compared to the other two components (Fig. 5.3).

Fig. 5.4 depicts the seasonal fluctuation of the total fauna in the three components of the *Aleurites* agroforestry site of Kolasib. In the tree component, the population increased gradually to register a peak in November-December (2000), probably indicating the build up for an overwintering population, and another during the monsoons in June. Barring these, the populations were always at low levels. Similarly, the fringe area too exhibited small monsoonic peaks, and another peak of overwintering population in November 2002 (Fig. 5.4).

The crop component too had low numbers for both the cropping seasons. Maize was the only crop cultivated along with the trees. A monsoonic peak during July 2001 is indicative of aphid infestation and accompanying large numbers of ants.

The general trend of the population was to increase during the monsoons, with low numbers during the dry and cold period.

The percentage composition of the different orders in the *Aleurites* site of Kolasib is depicted in Fig. 5.4. Both the tree and crop components were represented by six orders and larvae. In the tree component chilopoda, a predatory group contributed 8 % to the total population. Other potential natural enemies belonged to the coleoptera, hymenoptera, dermaptera and hemiptera. In the crop component however, the predatory fauna constituted 33% through the orders chilopoda and araneida, besides having representatives from hymenoptera and coleoptera. A large number of ants (hymenoptera-31%) were encountered due to the presence of aphids (homoptera), which infested the maize.

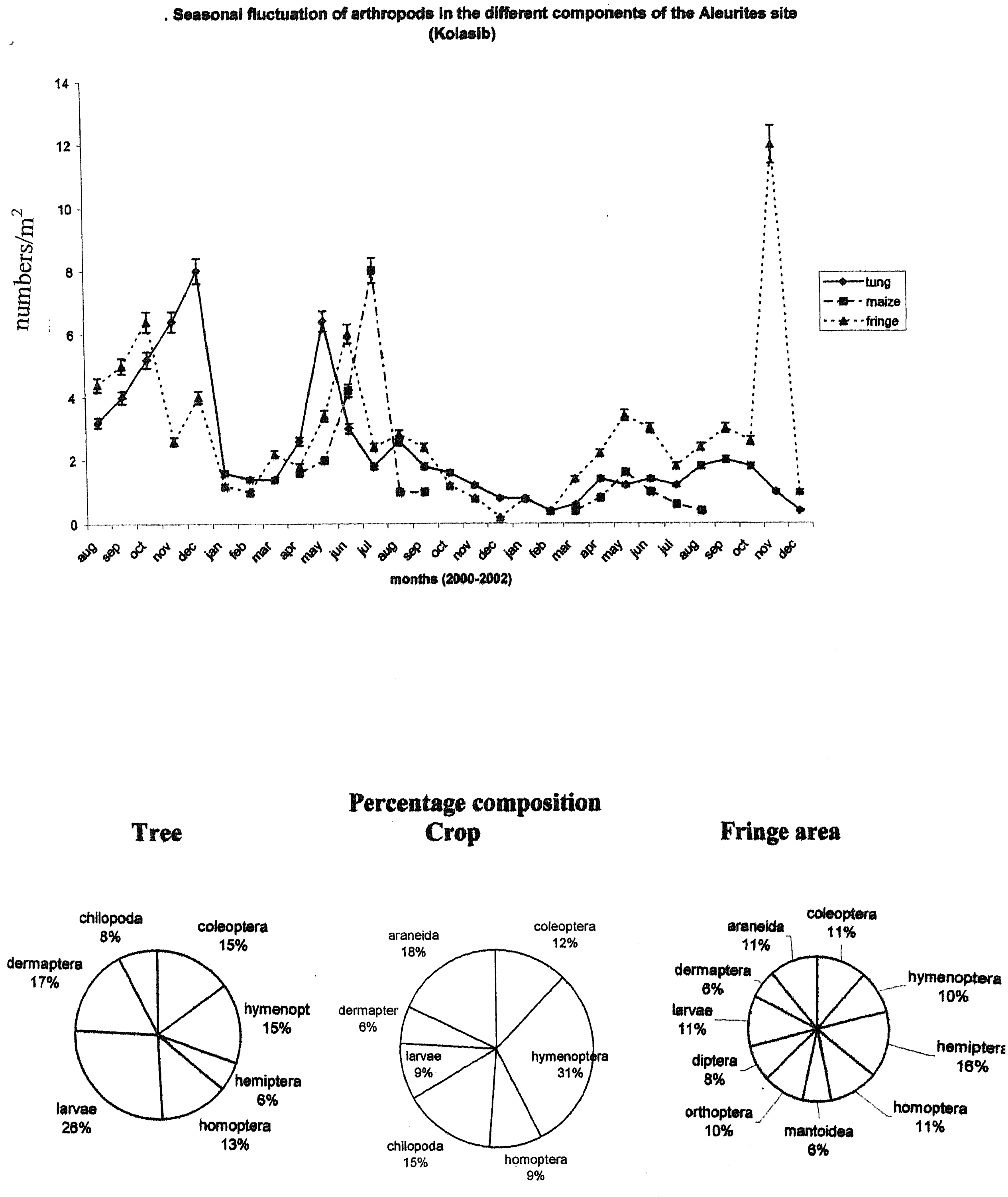
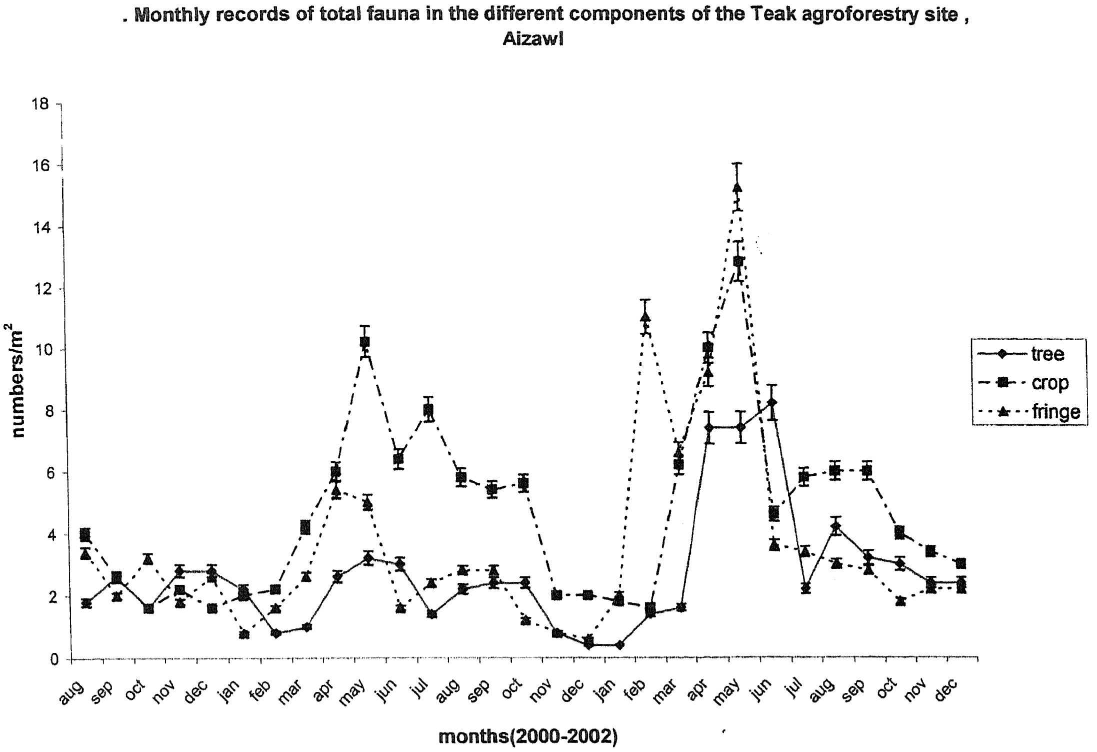


Fig. 5.4: Seasonal fluctuation and percentage composition of arthropods in the *Aleurites* (Kolasib) site.

In the fringe area component, predators constituted only 17 % (araneida and mantoidea), besides the other potential predatory groups. Diptera, a group not present in the other components was represented in this component. The low numbers of predators in this component could be indicative of a temporary shift to the crop and tree components where the probability of predation was higher, especially because of the presence of a large population of homoptera.

The seasonal fluctuation of the total fauna in the three components of the Teak agroforestry site of Aizawl is depicted in Fig. 5.5. The monsoonic peaks and low winter/ dry period population values were exhibited in both the tree and fringe area components. The highest population peak of the tree and fringe area components were attained in 2002. The overall population table of the tree component and that of the fringe area component were higher than the crop.

The percentage composition of the different arthropod orders in the Teak site of Aizawl is depicted in Fig. 5.5. The tree component had 8 representative groups with araneida, and mantoidea, the two exclusively predatory groups constituting 33 % of the total fauna.



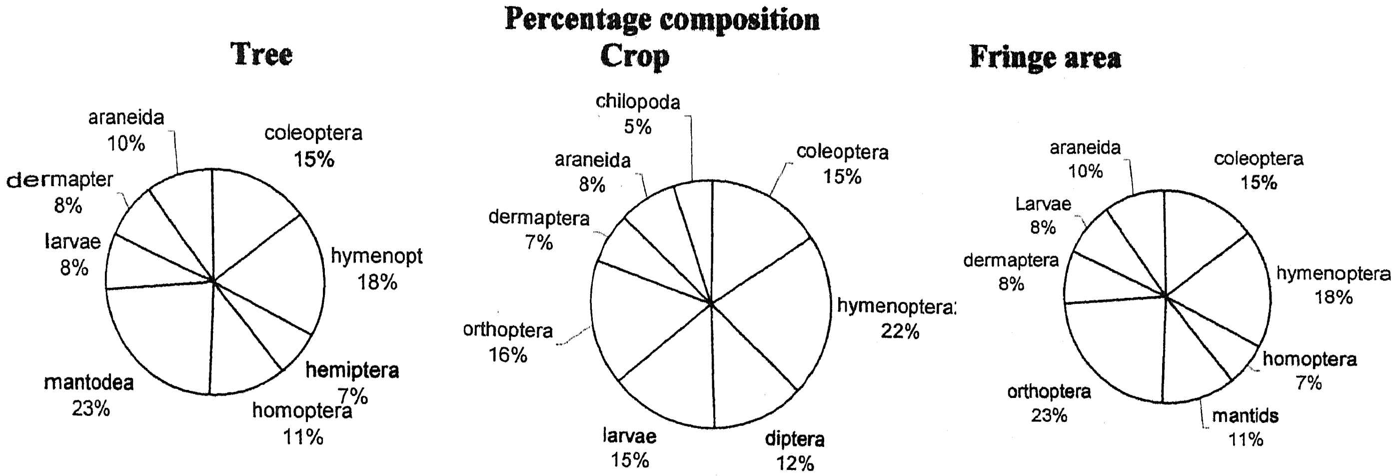


Fig. 5.5: Seasonal fluctuation and percentage composition of arthropods in the Teak (Aizawl) site.

The crop component also had 8 representative groups and predators constituted 13% of the fauna. The fringe area component had 8 representative groups, and predators, constituted 21 % of the fauna, and consisting of mantoidea and araneida.

The comparatively higher population table in the crop component is because of the presence of other crops besides maize i.e. *Solanum indicum, Clerodendrum colebrookianum, Vigna sinensis* and *Phaseolus vulgaris*. This may also have been instrumental in creating a higher diversity of groups presents, being equal to that of the other two components.

Fig.5.6 depicts the seasonal fluctuation of the total fauna in the three components of the Teak agroforestry site of Kolasib. In the tree and fringe area components, three distinct monsoonic peaks occurred during 2000, 2001 and 2002. However, the population table was highest in the 2000 peak, and as true for both the components. The crop component harboured considerably lower numbers (Fig. 5.6) during the whole of the study period.

In this site too the population fluctuations were in consonance to the abiotic and biotic cues such as temperature, moisture and the growing season.

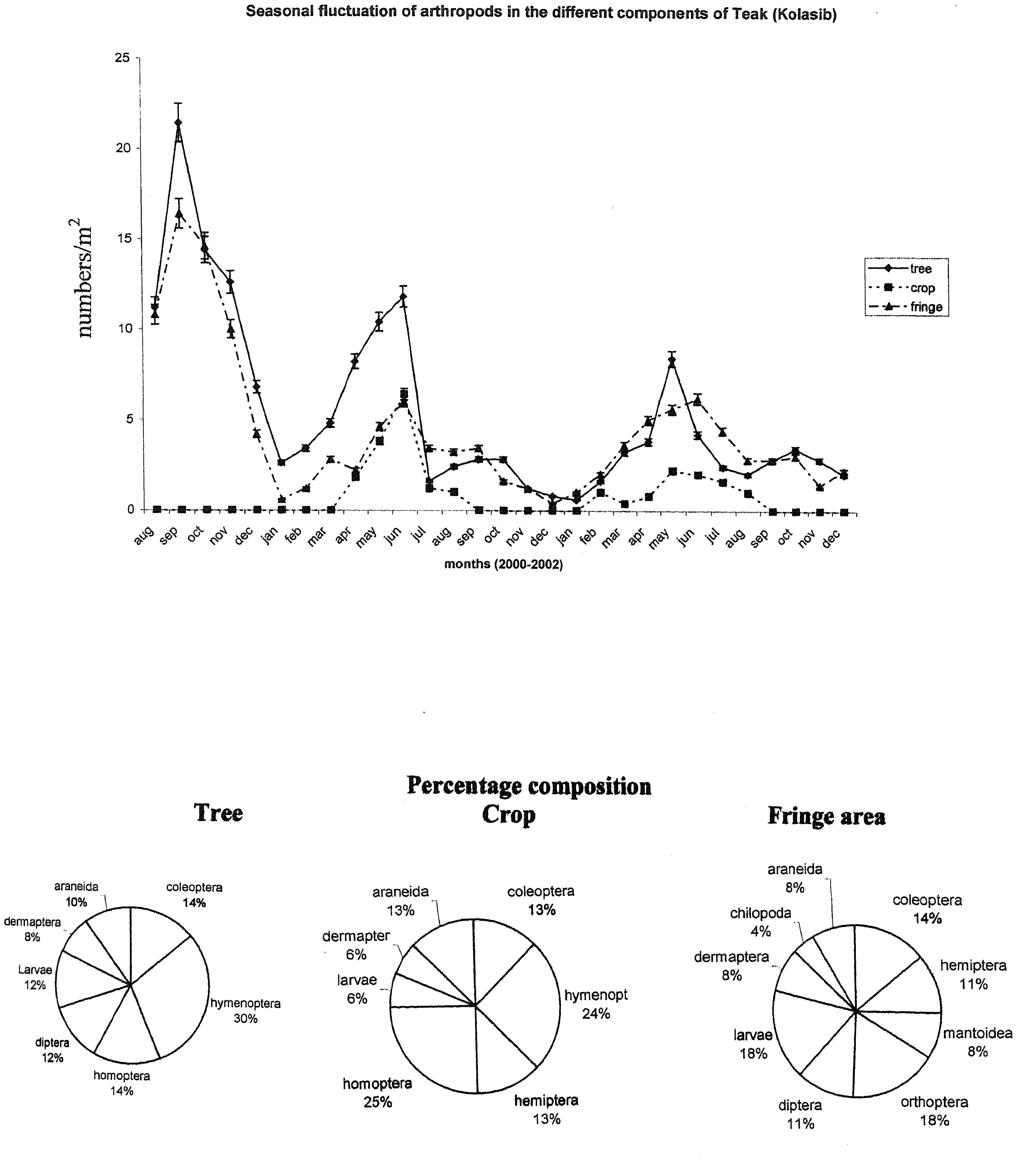


Fig. 5.6: Seasonal fluctuation and percentage composition of arthropods in the Teak (Kolasib) site.

The percentage composition of the different arthropod orders in the Teak site of Kolasib is depicted in Fig. 5.6. The number of representative groups was 7, 7 and 9 respectively in the tree, crop and fringe area components. The predatory fauna constituted 10%, 13% and 20% in the tree, crop and fringe area components respectively. The order mantoidea was not encountered in the crop component, although it was present in the fringe area probably indicating the potential for predation in the crop component, while actively inhabiting the fringe area.

Fig. 5.7 depicts the seasonal fluctuation of the total fauna in the three components of the *Leucaena* agroforestry site of Aizawl. The general trend of population buildup during the growing season, synchronizing with the onset of monsoons, and decreased population table during the cold and dry period was true for this site too. However, in the tree component, the peaks were skewed towards the late monsoon in 2000, early spring (growing period) and autumn during 2001, and oscillations during 2002 (Fig. 5.7).

In the crop component, population levels were low and more or less synchronized to the crop growth season.

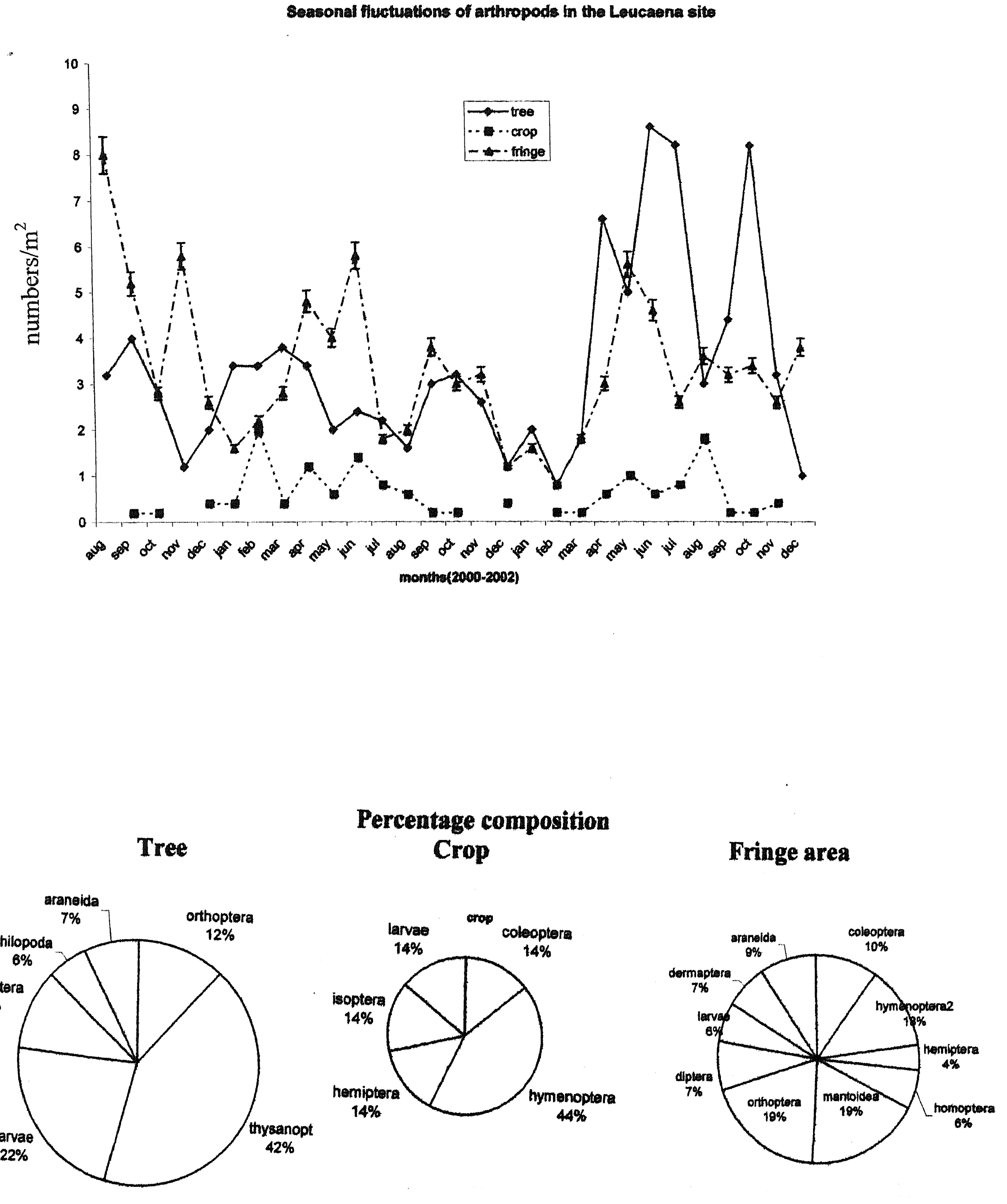


Fig. 5.7: Seasonal fluctuation and percentage composition of arthropods in the *Leucaena* (Aizawl) site.

In the fringe area component, oscillations occurred during the first year and pronounced monsoonal peaks in the next two years (Fig. 5.7).

The percentage composition of the different arthropod orders in the *Leucaena* site of Aizawl is depicted in Fig. 5.7. The number of representative groups was 6, 5 and 10 in the tree, crop and fringe area components respectively and the predatory fauna constituted 13%, 0% and 28% in the tree, crop and fringe area components respectively. Although no predatory group was represented in the crop component, the proximity of predators in both the tree and fringe area is indicative of potential predation. Isoptera and thysanoptera were two groups exclusive to this site. Thysanoptera, which occurred in the tree component (Fig. 5.7).

The seasonal fluctuations exhibit an overall trend of population increases with optimum climatic conditions, particularly temperature and moisture, as observed by a host of earlier workers (Dent, 1991). Further, the recruitment of new population is also synchronized with the growing season, to ensure availability of food. Insects generally overwinter through resting stages like pupae or cocoons, and eggs. The onset of the early spring with favourable temperature, moisture and food (host plants for pests and prey for predatory fauna) triggers the release of active members to the population. The recruitment is often in the form of small pulses staggered over a period of time, thus ensuring a continuous increase in numbers, leading to population peaks as exhibited in the present study. The autumn, winter and subsequent dry months are characterized by lower temperatures and/ or moisture, and also an end of the growing period of plants. These factors catalyze the overwintering process through resting stages which can effectively overcome the unfavourable conditions.

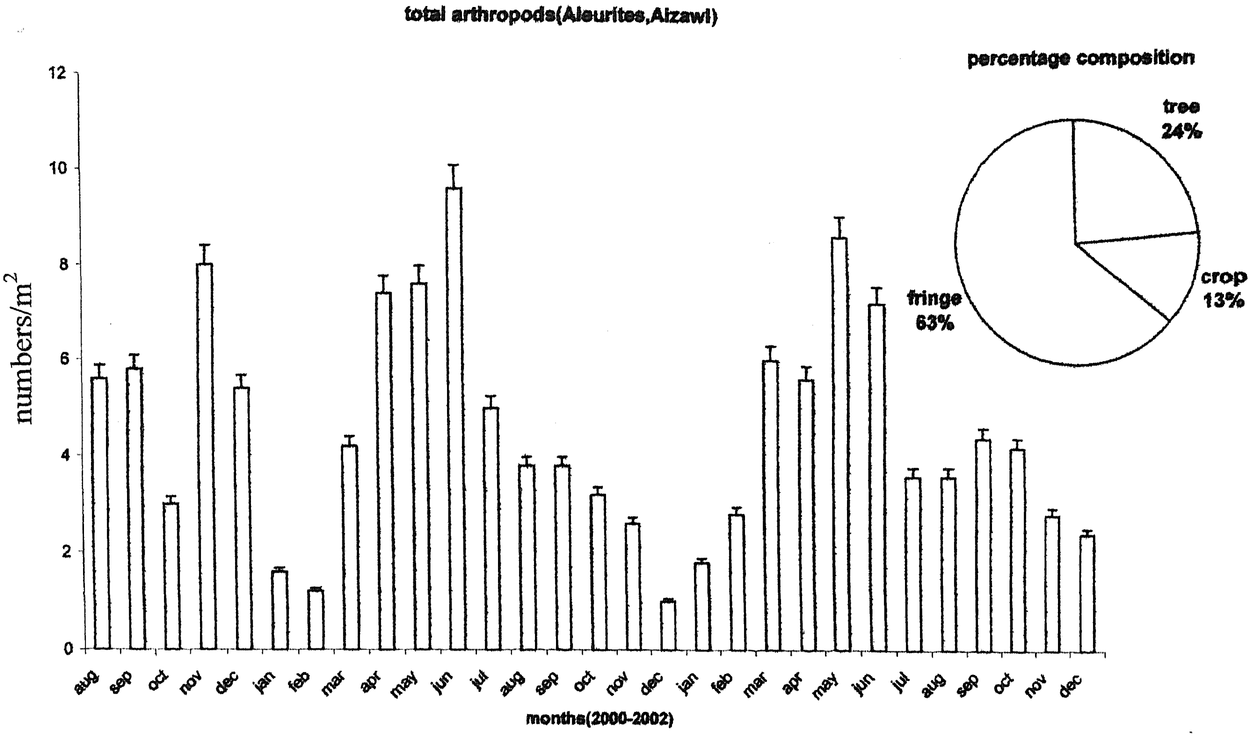
The natural enemy complex in any natural ecosystem is geared to ensure the maintenance of population at levels within the carrying capacity. This is achieved through a dynamic harmony of oscillating prey and predator populations (Pimental, 1961a,b and Pimental and Stone, 1968 and Odum, 1971), based on the availability of food. The manipulation of ecosystems as through monocultures (agroecosystems and plantations) shifts the balance to the benefit of pest populations by ensuring ample food plants. This results in disruption of the harmonic oscillations and replacement with occasional eruptive peaks of pest populations, causing reductions or loss of yield. Further, many indigenous predatory fauna which are sensitive to disturbance (Wallork,

1970) are eliminated from such systems, thus increasing the potential for pest population to multiply and cause increased damage. In this context, the soil litter interface is a habitat for many important predatory groups like chilopoda, araneida, predatory coleopteran, hemiptera, hymenoptera and mites. The agroecosystems generally does not have this crucial layer intact, and therefore inadvertently ensures the elimination of some of these groups.

5.3 Spatial and temporal distribution

Considering the distribution of the total fauna in the different sites, temporally, the faunal numbers were highest during the monsoons (Figs. 5.8, 5.9 and 5.10), thus coinciding with the ambient conditions with respect to the environment, which are conducive for reproduction, feeding and growth. Presence of the tree component and the natural vegetation in the form of fringe area further enabled the population to maintain continuity through the lean period (cold and dry seasons), although the crop component did not contribute fauna during such periods.

Spatially, the fringe area component had the highest numbers in the *Aleurites* sites. (Fig.5.8). In the Teak sites (Fig. 5.9), at Aizawl, the crop component had the highest numbers. This is reflective of the high numbers of pests associated with *Clerodendrum,* a representative of the crop component. Barring this, the tree component had the highest numbers, and this was also true for the *Leucaena* site of Aizawl (Fig. 5.10).



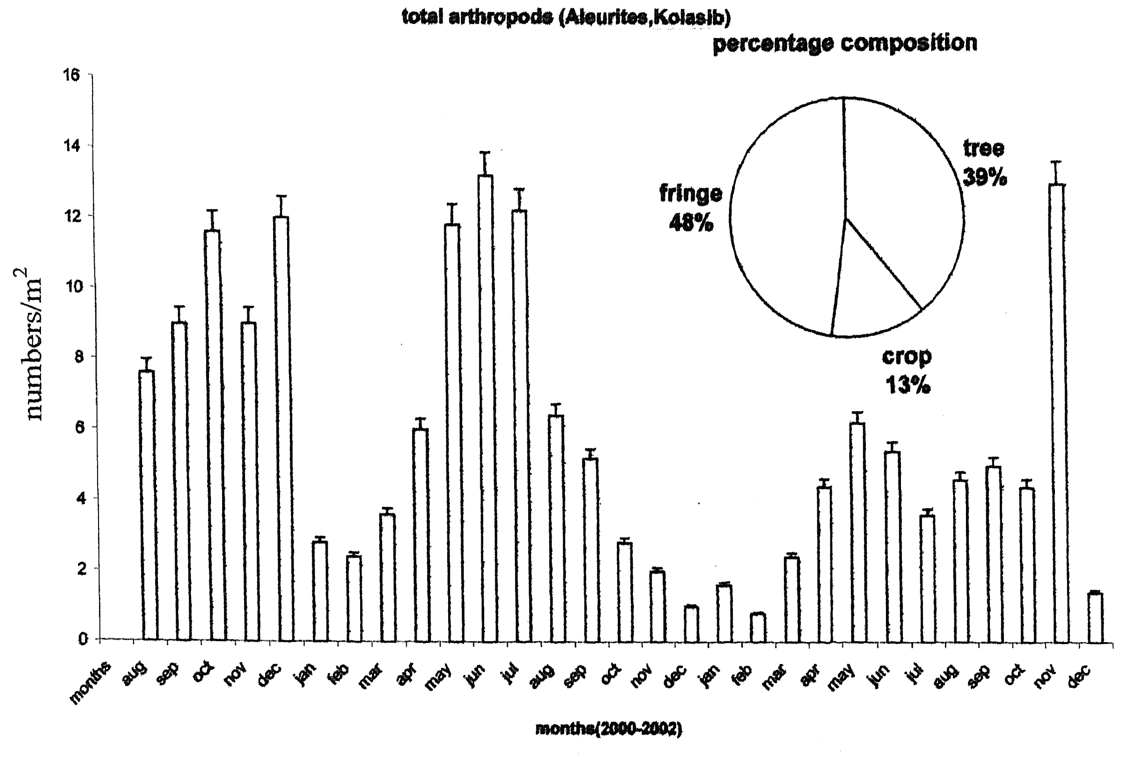
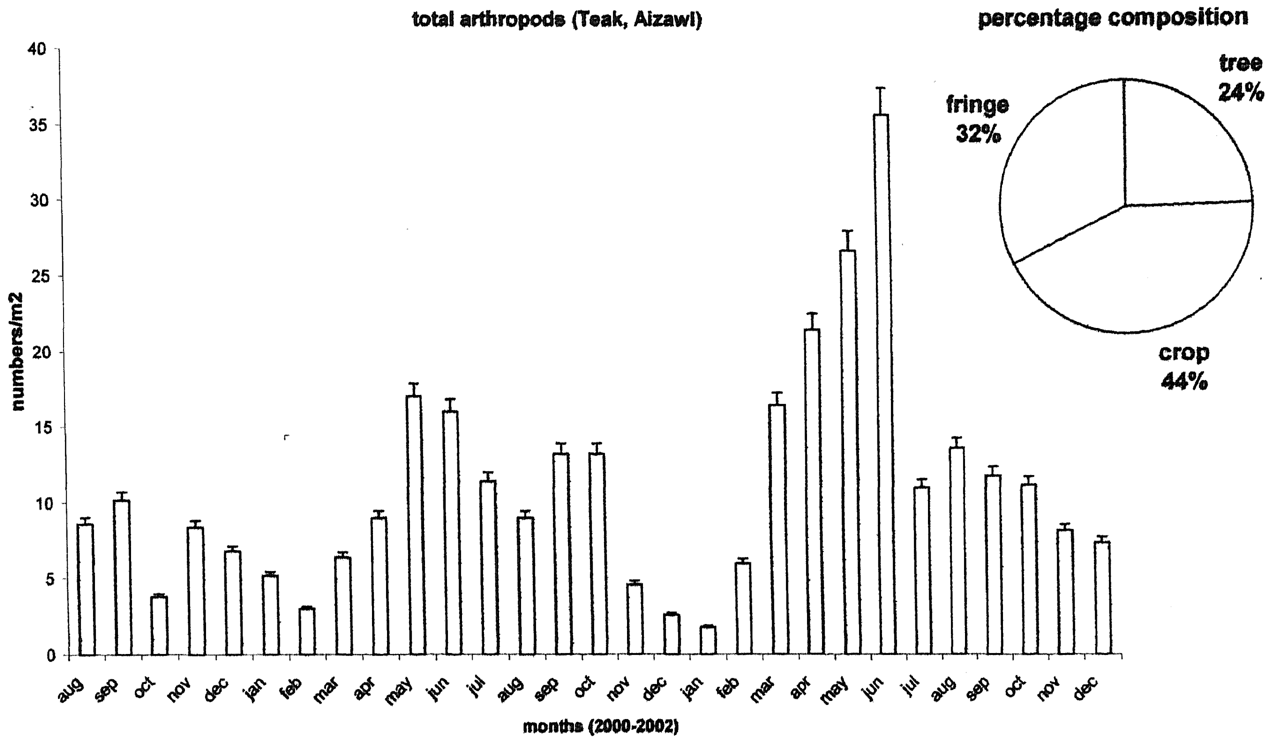


Fig. 5.8: Spatial and temporal distribution of arthropods in the *Aleurites* sites.



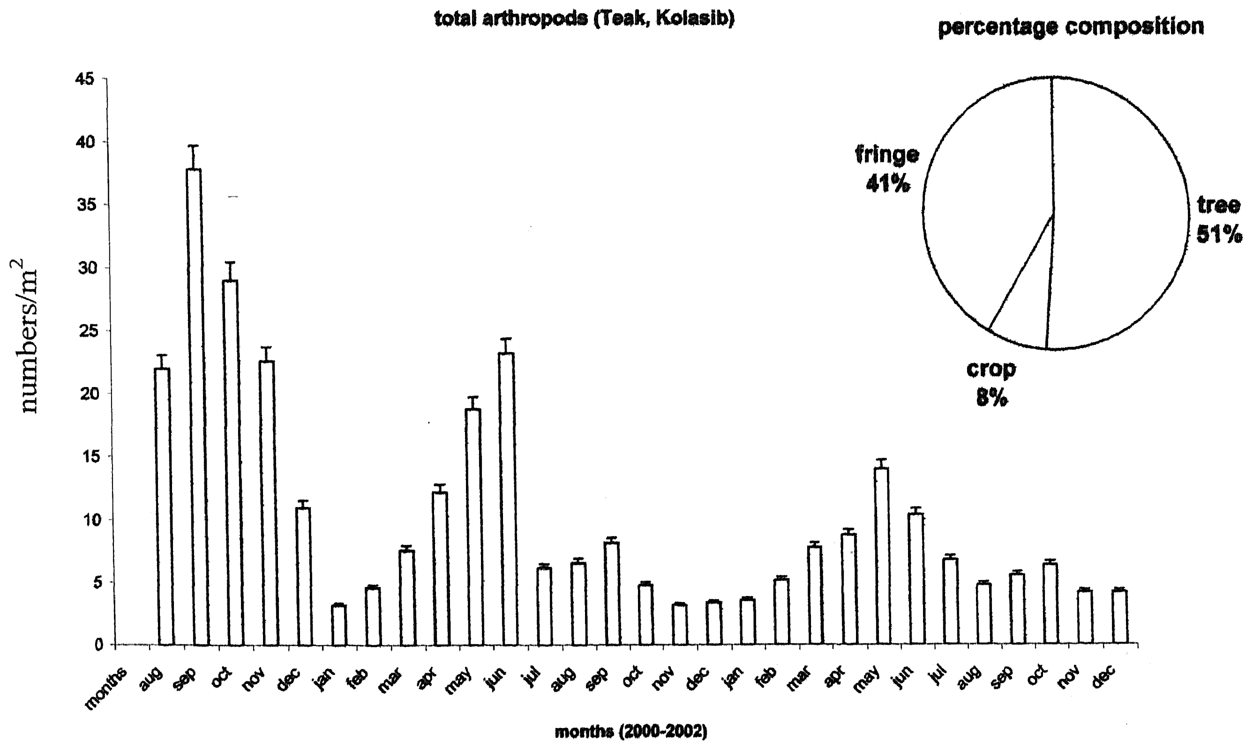


Fig. 5.9: Spatial and temporal distribution of arthropods in the Teak sites.

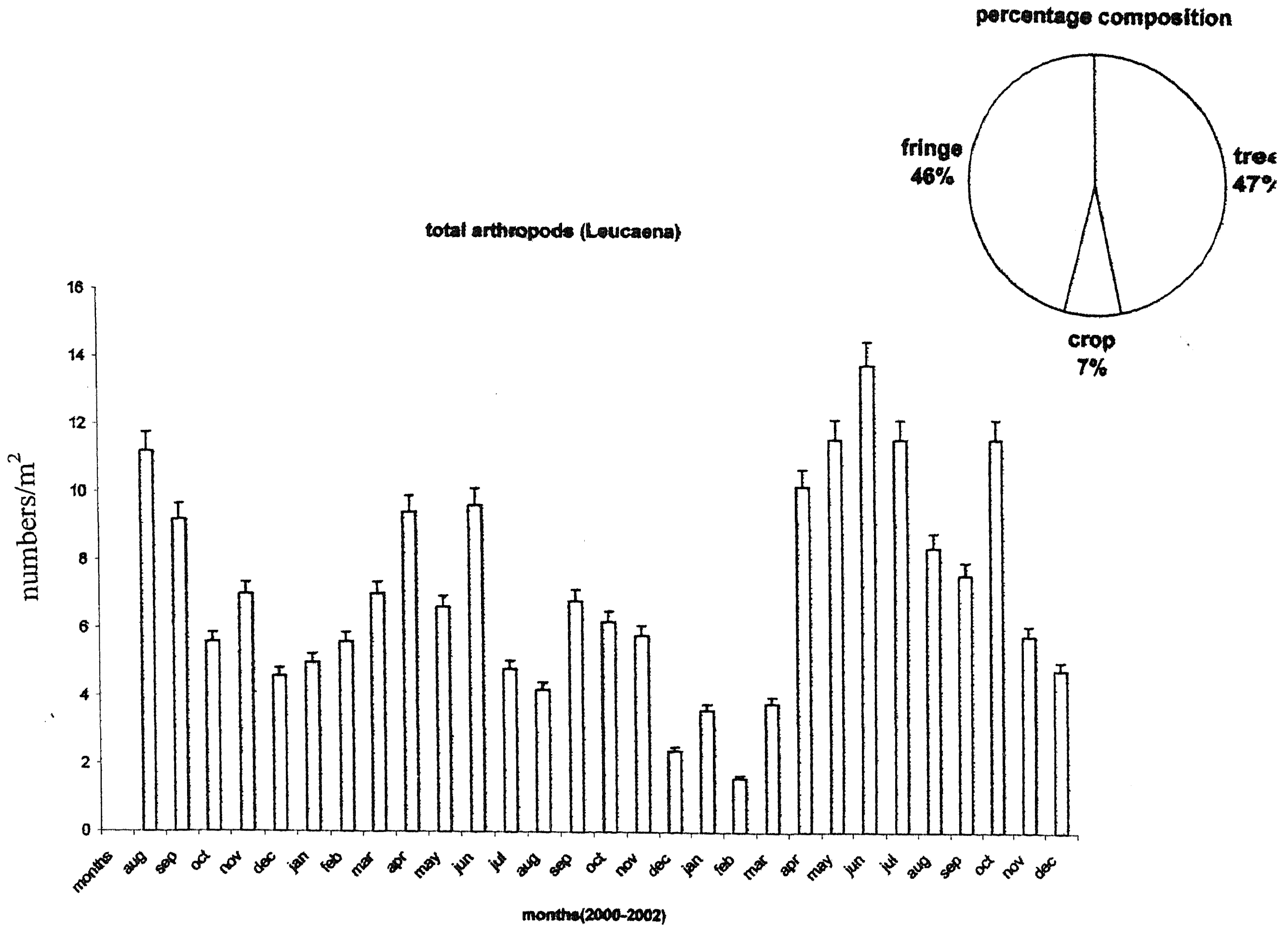


Fig. 5.10: Spatial and temporal distribution of arthropods in the *Leucaena* site.

Of the three components designated in the present study, the crop component is envisaged to be the most disturbed. This is because of the interferences by way of tilling, sowing, weeding and other activities, which are indispensable for the maintenance of crops. In comparison, the tree and fringe area components are less disturbed as no such activities are undertaken in these components. Further, even with respect to diversity, the fringe area having a diverse natural vegetational complex is superior to either the crop or the tree components. Such a situation is probably conducive for the habitation of the faunal elements in the less disturbed habitat and is exemplified by the presence of a higher diversity as well as higher densities in the tree and fringe area components, when compared to the crop component. The effects of such disturbance on the reduction of faunal diversity have been earlier reported (Baker and Dunning, 1975; Barney and Pass, 1986; Clark *et al.*, 1993; Heimback and Garbe, 1995).

5.4 Life cycle studies

Life cycle studies help in determining the stages of the pest that are detrimental to the crop in question, the overall climatic conditions that trigger the onset and culmination of development, and also the length of the different stages, particularly those which cause damage to the crop. In combination with seasonal dynamic studies, this can be an important tool in formulating effective cultural control prescriptions, keeping in mind the seasonality of occurrence and the abiotic triggers that initiate the processes of development (Borror and De Long, 1971)

Egg:

All insects develop from eggs. Most insects are oviparous and the developing embryo hatches from the egg. In certain insects, the eggs develop within the body of the female, and living young ones are produced.

The eggs vary greatly in size and shape, but most are oval to spherical in shape. Eggs are laid in surroundings, which may offer some protection to the young, and is also close to the potential food source. Many insects enclose the eggs in a protective egg case or capsule. The number of eggs laid varies from only one in certain aphids, to few thousands in many social insects. Most however lay between 50 to a few hundred eggs.

Embryonic development:

Embryonic development takes place within the egg after which the young either actively chews through the egg shell or its wriggling movements cause the shell to break along weakened lines.

Post embryonic growth:

Postembryonic growth is achieved through a periodic shedding of the rigid exoskeleton, which otherwise impedes growth. This process is called molting or ecdysis. Prior to the actual shedding of the skeleton, a new cuticle secreted by the epidermal cells begins to form under the old one. Secretion of a fluid, the molting fluid, first separates the old cuticle from the epidermis, and then the new cuticle is deposited. Once the new cuticle is formed, the insect is ready to shed the old cuticle. The shedding process begins with the breakage of the old cuticle along lines of weaknesses, usually the midline of the dorsal side of the thorax. The insect now wriggles out of the old cuticle. On emergence the new cuticle is still somewhat soft and pale. Once in contact with air, this cuticle now hardens and also darkens within an hour or two.

The stage of an insect between successive molts is called instar. The number of molts varies between 4 to 8 in most insects, but some odonata undergo 10-12 molts while some ephemeropterans undergo as many as 28 molts. The period spent in an instar also varies, as does the amount of growth from one instar to the next. The final molt takes place to release the adult, after which the insect does not grow further in size and also does not molt (Borror and De Long, 1971).

Metamorphosis:

The changes an insect undergoes during postembryonic development before reaching adult stage is termed Metamorphosis. The process varies in different types of insects, but generally two different types are recognized viz. Simple metamorphosis in which type the wings (if any) develop externally, there is no 'resting stage' prior to the last molt, and the instars resemble the adult in form and are called nymphs or naiads; and Complete metamorphosis in which the wings develop internally, there is a definite 'resting stage' also called pupa during which remarkable changes occur in the insect prior to the last molt, resulting in the emergence of an adult which is strikingly different and dissimilar from the instars.

Larvae and/ or eggs collected from the field were reared in insect rearing boxes (Plate 4.1). Fresh leaves of the host plant was provided on a daily basis and a petri dish containing moist cotton was kept in the boxes to provide sufficient moisture. Boxes were cleaned regularly to ensure hygienic conditions. Wherever possible, the emerging adults were allowed to mate and initiate a second generation so as to complete the study. The results of the life cycle studies are depicted in Table 5.1.

Table 5.1: The duration in days(means± SD) of the different life cycle stages of some of the pests (values are means of three observations)

species	month	egg	Larval instar period (days)				pupa	adult	life cycle period (days)
			1st. instar	2nd. instar	3rd. instar	4th. instar			
Hyblaea puera	April	--	3.33 ±0.57	3.66 ±0.57	5.33 ±0.57	6.33 ±0.57	15.66 ±0.57	4.33 ±0.57	39
	November	--	6.33 ±0.57	6.66 ±0.57	8.33 ±0.57	9.33 ±0.57	22.33 ±0.57	3.33 ±0.57	56
Diacrisia obliqua	April	12	2.33 ±0.57	3.66 ±0.57	7.33 ±0.57	7.33 ±0.57	12.66 ±0.57	4.33 ±0.57	38
	November	18	4.33 ±0.57	4.66 ±0.57	9.33 ±0.57	8.33 ±0.57	16.66 ±0.57	3.33 ±0.57	47
Amata psalis	April	15	2.33 ±0.57	3.33 ±0.57	5.0 ±0.0	5.33 ±0.57	22.0 ±1.0	6.33 ±0.57	44
	November	27	3.0 ±0.0	4.33 ±0.57	6.0 ±1.52	8.0 ±1.0	26.33 ±1.15	4.66 ±0.57	52

The life cycles of the following pests were attempted:-

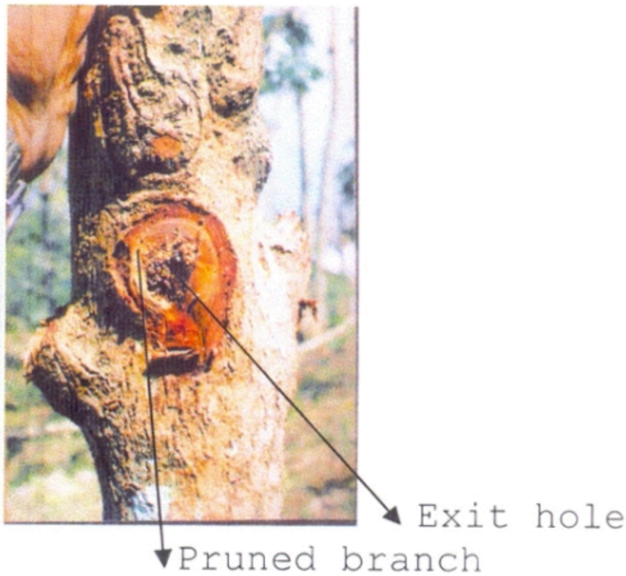
***Aleurites fordii*:**

ORDER: Coleoptera

FAMILY: Cerambycidae

Xylotrechus subcarinatus Gard.: This cerambycid coleopteran was also encountered in mature woody tissue of *Aleurites* sp. Two cases of infested tissue collected in the field were reared in the laboratory and the different stages were observed. One batch of larvae which bore into the wood in April-May completed the life cycle and emerged in August-September while the second (overwintering) generation infesting during September-October emerged in April. The age of the larval instars could not be determined.

Lepidoptera: A lepidopteran larva was seen to occur inside the mature secondary branches of *Aleurites*. Apparently, the entry point of the larvae was through the exposure of tissue due to pruning of branches (Plate 5.1). The larvae actively bore through the innermost tissue of the stem, and four instars could be recorded. The adult lepidopteran emerged out through the hole bored by the larvae. The duration of larval instars could not be determined (Plate 5.1)



Adult lepidopteran Larval instars Damaged timber

Cerambycid coleopteran

Xylotrechus subcarinatus

Plate 5.1 Pests associated with *Aleurites fordii*

Tectona grandis:

ORDER: Lepidoptera

FAMILY: Hyblaeidae

Hyblaea puerea Cramer: Eggs or adults were not directly encountered in the field. First instar larvae were collected and reared in the laboratory. Table 5.1 shows the duration of the different instars and the total period in the life cycle. The total life cycle period varied between the summer and autumn batches (Table 5.1), the former being 39 days while the latter was 56 days. Although the adults emerged after completion of the life cycle under laboratory conditions, mating and egg laying did not occur. The incidence of the larvae in natural conditions was extremely patchy and numbers were extremely low. Larvae generally inhabited the ventral surface of leaves during the day.

ORDER: Coleoptera

FAMILY: Curculionidae

Alcides ludificator Fst. This cerambycid coleopteran (Plate 5.2) was a woodborer pest of Teak. Eggs could not be detected but larvae were located in the twigs and branches of Teak. Three larval instars could be detected during the period February-August. The adults emerged during late August-September. Attempts at breeding in the laboratory failed. The beetle had one generation in an annual cycle.

Hyblaea puera

Homoptera

Eupterote undata

Alcides ludificator

Plate 5.2 Pests associated with *Tectona grandis*

***Leucaena leucocephala* :**

ORDER: Coleoptera

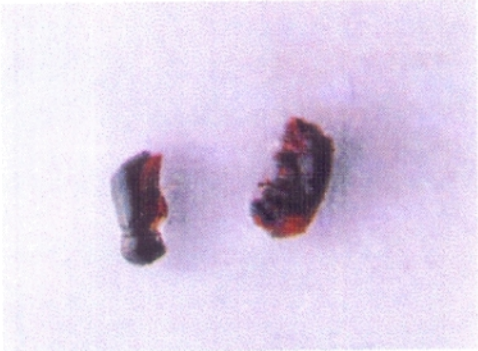
FAMILY: Scolytidae

Scolytus sp. This coleopteran borer (Plate 5.3) was also observed in the field as having 4 larval instars, although no eggs could be detected. The total period in the life cycle was around 7 months and the adults emerged during March to May.

ORDER: Homoptera

FAMILY: Psyllidae

Heteropsylla cubana Crawford*:* This psyllid is found infesting the young flowers and shoot of *Leucaena* during the period March-May



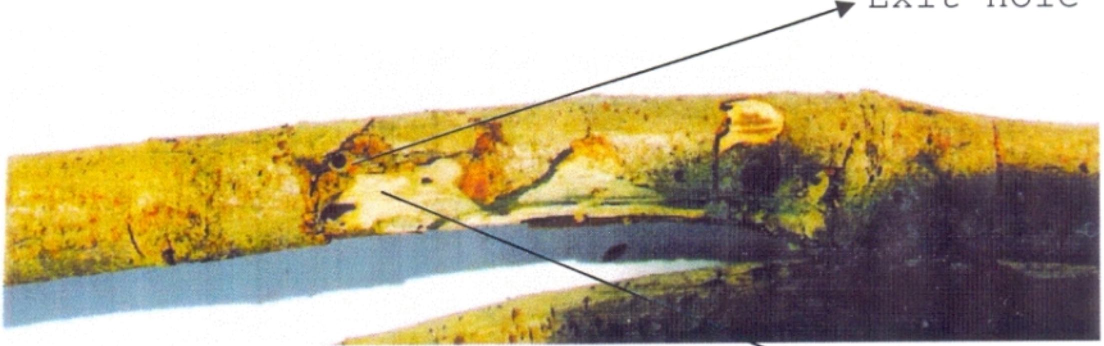
Scolytus sp.

larval instars

cerambycid coleopteran

larval instars

Exit hole



Damaged timber

Heteropsylla cubana

Plate 5.3 Pests associated with *Leucaena leucocephala*

***Clerodendrum colebrookianum*:**

ORDER: Lepidoptera

FAMILY: Arctiidae

Diacrisia obliqua Wlk: *Diacrisia obliqua* is a pest of *Clerodendrum colebrookianum* and *Solanum indicum*

Diacrisia obliqua was seen to infest the *Clerodendrum* (Plate 5.4), a tree species and common in kitchen gardens and households. The leaves of the tree are eaten as a vegetable, and are even believed to have medicinal properties. During the late monsoons- early autumn period, the pest shifted its feeding behavior with a preference for *Solanum indicum*, a vegetable crop.

Egg:

The egg of the lepidopteran was seen to be creamy white in colour, each female laying 60-80 eggs on the underside of leaves. The egg size was 2mm in diameter and round in shape. The hatching percent in the lab was seen to vary between 75% and 88%. Incubation period was 10-12 days in the April batch of eggs and 15-18 days in the November batch.

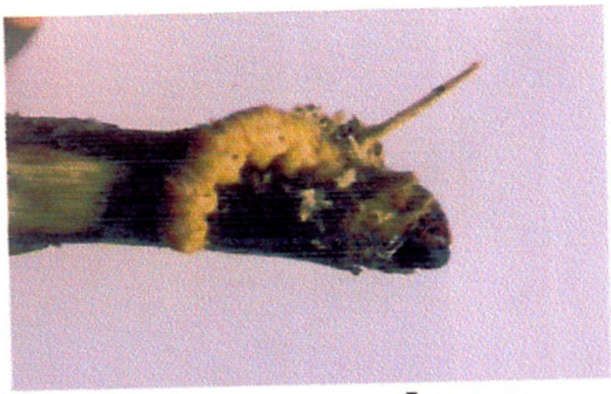
Larval development, feeding and molting:

The young hairy caterpillars that emerge out are blackish on the dorsal side and creamy whitish on the ventral side. The first instar larvae molted within 2-4

Diacrisia obliqua

larval instars

Homoptera



Lepidopteran larva

Plate 5.4 Pests associated with *Clerodendrum colebrookianum* days and the second instar after another 3-5 days. Thus the first two instars had a short feeding time, probably indicating the smallness of the cuticle. The third instar fed for another 7-10 days before molting and the last or fourth instar continued to feed for another 7-9 days before passing on to the pupa stage. The April batch had a comparatively shorter metamorphosis period as compared to the November batch (Table 5.1)

Adult:

After a resting period of 12-18 days, the imago emerged by bursting of the pupal case on the dorsal mid line along the thoracic region. A total of two generations of eggs could be observed, one during the May- June period and the second during November-early December. The feeding habit of the second generation was often seen to be slower, probably due to the absence of tender leaves of *Clerodendrum* at this time of the growing season. Further, the presence of *Solanum indicum* an annual crop, often triggered a shift in feeding preference of the larvae which showed preference to *Solanum indicum* leaves and fruits, resulting in stunted growth of the leading shoots, reduced leaf numbers and underdeveloped fruits. The total length of the life cycle varied between 38 days (April) and 47 days (November) batch.

Vigna sinensis:

ORDER: Lepidoptera

FAMILY: Amatidae

Amata psalis: This species is a pest of *Vigna sinensis* (Plate 5.5)

Egg:

The adult female lays a batch of 80-140 eggs on the stem and underside of tender leaves. The eggs are round and white in colour measuring 1-2 mm in diameter. As embryonic development proceeds the onset of tanning to a blackish hue is evident in the embryos, and this is also an indicator of viable eggs. Under laboratory conditions, 80 to 100 % hatching was observed. The incubation period varied between 15 days to 27 days, depending on the seasons. Incubation period was shorter during March-May and progressively increased during October-December.

Larval development, feeding and molting:

Emergence from the egg was affected by chewing through the eggshell. Immediately thereafter, the eggshell was fed upon, leaving behind only the portions of the eggs attached to the plant. The first instar larvae generally fed only upon the epidermal tissue of the leaves, so that the leaves presented a blotched appearance with dry bleached patches.

(a) Pest of *Vigna sinensis*

Amata psalis larval defoliation

(b) Pest of *Phaseolus* sp

Maruca testulalis

Cocoon

(c) Pest of *Solanum indicum*

Psylliodes shira

(d) Pest of *Cajanus cajan*

Apion clavipes

Plate 5.5 Pests of other crop components

Such leaves subsequently shriveled up and dried probably due to the damage to the chlorophyll. The first instar larvae molted within 2-3 days in the March-May egg generation. The new larva emerged by bursting of the head capsule and wriggling through the hole, while the exuviae's was firmly attached to the underside of either the leaf or the stem and branches. The second instar larvae started feeding on the whole tissue of the leaf but the midriff and strong venation was avoided. Moreover, preference was for very tender leaves, often resulting in damage to the leader shoot, and initiating the accelerated growth of branches as alternate leaders, probably as a response of the plant. The second instar larva molted within 3-5 days followed by the third instar, which was seen to be a voracious feeder, feeding upon the whole leaf, effectively reducing the number of leaves. The third instar larvae also molted within 5-7 days, passing into the last instar, which showed markedly decreased feeding after 2-3 days, and then passed on to the pupa between the 5-9 day. Thus under laboratory conditions, the March-May generations had a larval period of 15-22 days. The November generation had a comparatively longer larval period. The imago emerged from the pupa after 21-27 days (Table 5.1).

Adult:

Emergence was by breakage of the pupal case along the dorsal line in the thoracic region. The freshly emerged adults required about an hour for hardening of the wings before being capable to fly. In this case too the summer (April) batch had a shorter life cycle of 44 days as compared to the autumn batch (November) of 52 days.

The life cycle studies reveal that the summer (April-May) batch of reared insects had a comparatively shorter life cycle than the autumn (November-December) batch. The growth and development of insects are dependent on the quality of food as well as ambient conditions of the environment. The absence of fresh flush of leaves and the lower temperature regimes during autumn could have been instrumental in delaying the whole development process, resulting in longer time required to complete the life cycle in autumn.

5.5 Food preference studies

Food preference studies were attempted for three species viz. *H. puera, D. obliqua, and A. psalis.* The natural associates which occur in proximity of the host plant were used for such studies. The host plant leaves were mixed with such associate species and the feeding activity was observed. Except for *D. obliqua,* no other species fed on alternate food. Even when small amounts of alternate food were accidentally consumed, larval development did not occur to the optimum levels, resulting in failure to molt. In case of *D. obliqua,* besides the host plant, larvae also fed on leaves of *Solanum* sp. and *Phaseolus* sp. under laboratory conditions. However, in the field the larvae fed exclusively on *Clerodendrum* and *Solanum.*

As for the predatory fauna, only mantoidea could be successfully reared in the laboratory, and the feeding preferences observed. The members of this group were seen to feed on larvae and adults of lepidoptera, orthoptera and hemiptera, indicating their potential role in the natural conditions. Similarly, it was observed (in field conditions) that araneida and vespidae and ichneumonidae (Hymenoptera) were efficient predators, having a preference for lepidopteran larvae and adult insects. Chilopoda, hemiptera and hymenopterans were also reared in the laboratory. The latter were fed on a 25 % honey solution. However, no predation could be detected, and the specimens did not survive long under laboratory conditions.

5.6 Comparative analysis of pest incidence

Although not within the purview of the objectives of the present study, in the course of field sampling, the presence of two plots, one a monoculture of maize and the other a Teak based agroforestry system with maize as the crop component were detected in the same locality. Thus it was desired to analyze the incidence of the cob borer *Stenachroia elongella* and compare the same between the two sites. The results obtained were presented in a Regional Seminar on Biodiversity. The paper is appended along with (See Appendix).

5.7 Checklist of pests and extent of damage

The extent of damage and status of pests encountered in the course of the present studies is listed in Table 5.2. As is evident from the extent of damage, *Hyblaea puera* , a pest of Teak, *Diacrisia obliqua* a pest of *Clerodendrum* and *Solanum,* and *Apion clavipes* a pest of *Cajanus cajan* qualify as major pests while the others are maintained at levels lower than that which would cause economic damage. Those causing minimum damage (+) can be classified as incidental and minor pests (Table 5.2).

Table 5.2 Checklist of pests encountered and extent of damage

Host	Pest	Alternate host	Type of damage	Extent of damage*
Tectona grandis	*Hyblaea puera*	none	Leaf skeletonization	+ +
	Eupterote undata	none	Leaf skeletonization	+
	Alcides ludificator	*Clerodendrum colebrookianum*	Spotting of leaf and young leaders	+ +
	Homoptera	none	Sap sucking	+ +
Aleurites fordii	Lepidoptera (unidentified)	none	Boring through lopped branches	+ +
	Xylotrechus subcarinatus	none	Boring through timber	+ +
	Cerambycid (unidentified)	none	Boring through timber	+
Clerodendrum colebrookianum	*Diacrisia obliqua*	*Solanum indicum*	Leaf skeletonization	+ + +
	Lepidoptera (unidentified)	none	Boring through leader shoots	+
	Homoptera (unidentified)	none	Sap sucking	+ +
Leucaena leucocephala	*Scolytus* sp.	none	Boring through timber	+ +
	Cerambycid (unidentified)	none	Boring through timber	+
	Thysanoptera (larvae)	none	Leaf skeletonization	+ +
	Heteropsylla cubana	none	Sap sucker	++
Zea mays	*Stenachroia elongella*	none	Stem borer	++
	Chilo partellus	none	Cob borer	+ +
	(Lepidoptera unidentified)	none	Cob borer	+
	Rhopalosiphum maidis	none	Sap sucker	++
Vigna sinensis	*Amata psalis*	Other herbaceous vegetation	Leaf skeletonization	+ + +
Cajanus cajan	*Apion clavipes*	none	Pod borer	+ + +
Phaseolus vulgaris	*Maruca testulalis*	none	Pod borer	+ +
Solanum indicum	*Psylliodes shira*	Other herbaceous vegetation	Damage to epidermis of leaf	+ + +
	Diacrisia obliqua	*Clerodendrum colebrookianum*	Leaf skeletonization	+ + +

* (extent of damage): + low ++ medium +++ high

The pests encountered in the different sites are depicted in Plates 5.1 - 5.6.

Plate 5.1 depicts the pests associated with *A. fordii*. All the three pests encountered were woodborers, one being a lepidopteran and the other two being coleopterans. The lepidopteran larvae were seen to be present in pruned branches, entering the central stele, and thus entering the young growing branches. Such affected branches exhibited dieback and shriveled conditions. The adult emerged through the holes bored by the larvae. The other two coleopterans (Fam.: cerambycidae) too were borers and damaged the woody tissue.

In Teak (Plate 5.2), besides *H. puera*, the other pests encountered were a lepidopteran *Eupterote undata* the larvae being defoliators, a homopteran was seen to attach to the young branches causing dieback of the shoots and secondary infections. Another coleopteran pest was *Alcides ludificator* which caused spotting and abrasion of young leaves, resulting in death of the abrased tissue and sometimes, under severe conditions curling of the leaves.

The pests encountered with L. *leucocephala* is depicted in Plate 5.3. *Scolytus* sp. and a cerambycid coleopteran were borers and caused damage to the woody tissue under the bark. The other pest associated was the psyllid *Heteropsylla cubana* that is found to infest the young branches and twigs of *L. leucocephala*. Plate 5.4 depicts the pests of *Clerodendrum colebrookianum, D. obliqua* was a defoliator while another lepidopteran was a borer of the young branches (Plate 5.4). A homopteran (sap sucker) was also encountered.

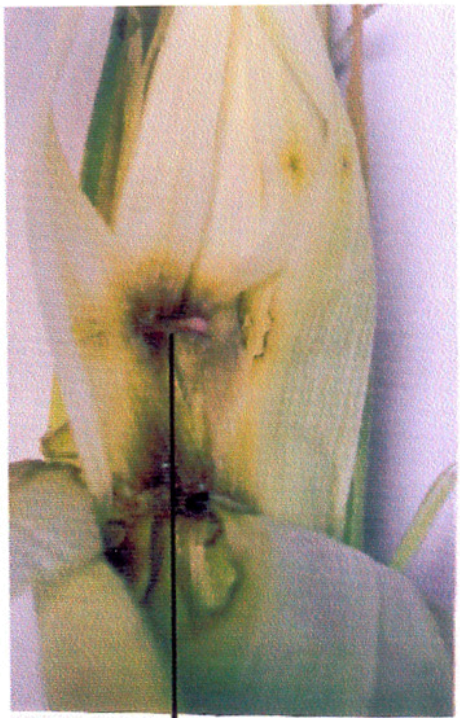
Plate 5.5 shows the pests associated with other common crops. *Amata psalis* was a defoliator of *V. sinensis* while *Maruca testulalis* and *Apion clavipes* were pod borers of *P. vulgaris* and *C. cajan* respectively. *Psylliodes shira* was a pest of *S. indicum* abrasing the leaves and fruits.

The pests of maize are depicted in Plate 5.6. Both *Stenachroia elongella* and *Chilo partellus* were borers causing damage to the cobs and stems. The other pest encountered was the maize aphid *Rhopalosiphum maidis* Fitch that was found infesting the crop at the pretasselling stage (Plate5.6)

Stenachroia elongella

Chilo partellus

Damaged maize cob



Larva inside cob

Rhopalosiphum maidis

Plate 5.6: Pests associated with *Zea mays*

5.8 The natural enemy complex

The natural enemy complex encountered in course of the present investigation (Plates 5.7a,b) belonged to the following orders: -

CLASS: Insecta

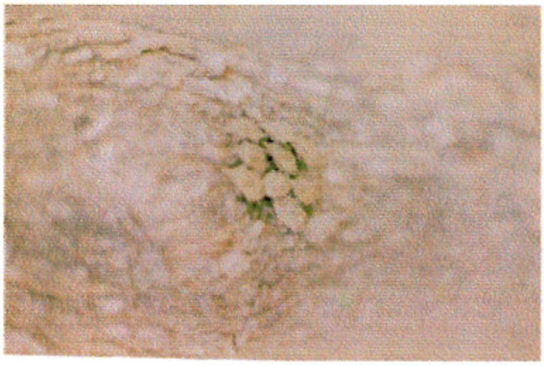
- Orthoptera (Mantoidea)
- Coleoptera
- Hemiptera
- Hymenoptera
- Dermaptera
- Other Arthropoda
- Chilopoda
- Araneida

Of these orders and classes, Mantoidea, Chilopoda and Araneida are exclusively predatory (Plates 5.7a, b). The other groups contain members, which are either phytophagous or predatory (Allen, 1979; Wallin, 1985; Den Boer, 1990; Duelli *et al.*, 1990; Heimbach and Garbe, 1995 and Holland and Luff, 2000).

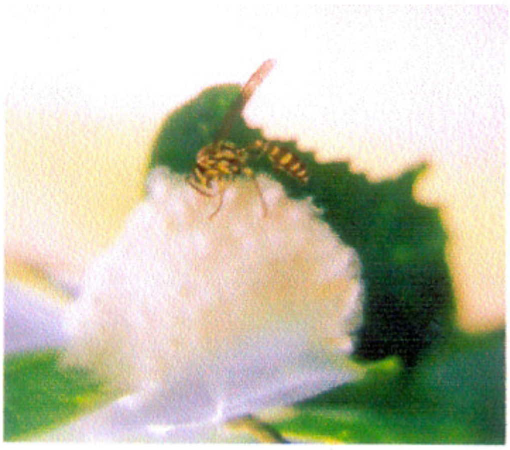
The habitation and maintenance of a diverse natural enemy complex is dependent on the presence of conducive habitat conditions free of disturbance. This was one of the primary reasons for selecting the fringe area as a component

(a) Praying mantis (Predator)

(b) Predatory Hemiptera



(c) Hymenoptera



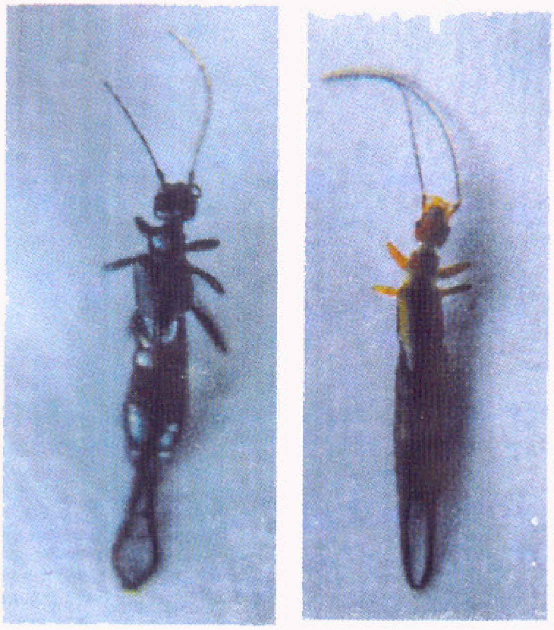
Predatory wasp

predatory ant

Parasitoid

Plate 5.7a Natural enemies of pests

Predatory Dermaptera



Predatory Araneida

Predatory Chilopoda

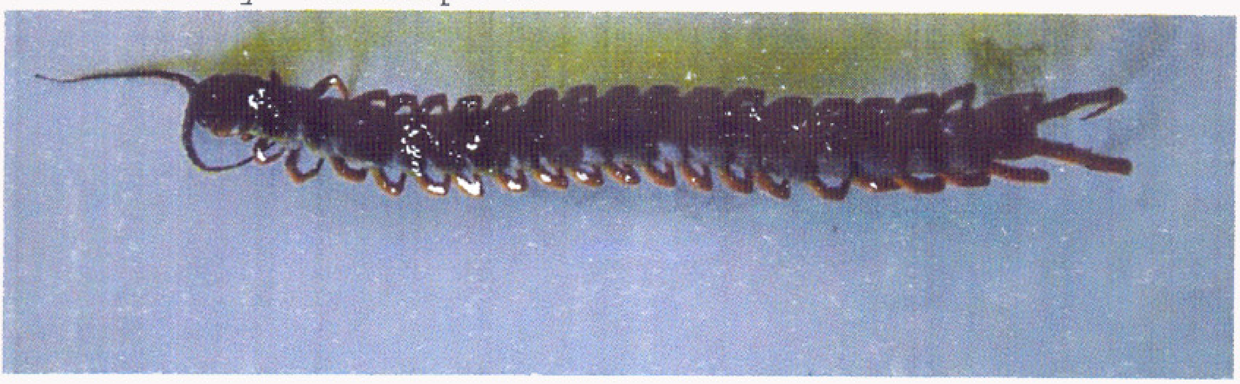


Plate 5.7b Natural enemies of pests

in the study, so as to elucidate the natural enemy complex. As the results indicate, the natural enemy complex of the fringe area, and to a great extent the tree component is rich in faunal diversity. This is probably a strong indication of the low disturbance in these components, and is in consonance to earlier works (Collins *et al.*, 1996; Anderson, 1997; and Dennis and Fry, 1992)

5.9 Statistical analyses

SYSTAT 11.0 statistical package was used to analyze the variance of the data among the different combinations. A 5 x 3 x 29 (5 sites x 3 components x 29 times) ANOVA with repeated measure on the last component was undertaken. Table 5.3 shows the results of analysis of variance (ANOVA). The results indicate significant differences in all the combinations analyzed (P> 0.001).

Table 5.3: 5 x 3 x 29 (5 sites x 3 components x 29 time) ANOVA with repeated measure on the last component

Between Subjects

Source	SS	df	MS	F	P
SITE	57.481	4	14.370	54.581	0.000
COMPONENT	60.402	2	30.201	114.710	0.000
SITE x COMPONENT	62.390	8	7.799	29.622	0.000
Error	15.797	60	0.263		

Within Subjects

Source	SS	df	MS	F	P
TIME	1048.698	28	34.957	144.031	0.000
TIME x SITE	353.589	112	2.947	12.141	0.000
TIME x SAMPLE	114.990	112	1.916	7.896	0.000
TIME x SITE x SAMPLE	177.351	448	0.739	3.045	0.000
Error	436.864	1800	0.243		

5.10 Conclusions

The results of the present investigation indicate the close synchrony of the growth and development of the faunal population to that of the growing season of the vegetational complex. This is further tuned to the climatic regimes operative in the systems, principally ambient conditions of temperature and moisture (Dent, 1991). These two factors are not only crucial to the development and release of the dormant stages of the faunal entities, but is also instrumental in triggering the growth of new flush of leaves and germination of crop plants, ensuring productivity of the system, based upon which the activities of feeding and reproduction operates through the different trophic levels. Thus population fluctuations were in consonance to the meteorological conditions.

The cropping systems chosen for the present study were small-scale sustenance level systems. The population estimates of insects and arthropods indicate higher densities and diversity in the comparatively less disturbed fringe area and the tree components, as compared to the crop component. The results are in agreement with earlier works (Allen, 1979; Duelli *et al.*, 1990; Dennis and Fry, 1992 and Collins *et al.*, 1996)

Although a variety of pests were encountered, their seasonal distribution was seen to be extremely patchy and incidental. This prompts us to speculate that the pest burden of the systems is maintained at levels lower than those causing economic damage. The functioning of insect populations and their distribution is dependent on the presence of the host plant. More importantly, in fragmented habitat (such as the present study), their survival and maintenance depends on their ability to disperse and locate food. The pest complex, being mostly the larval stages, is disadvantaged in this respect, particularly in comparision to the natural enemy complex, which are often large species able to forage over large areas (Den Boer, 1990 and Davies et al, 2000) as they are affected by such fragmentation (Debinsky and Holt, 2000; Kuussaari *et al.*, 2000; S'oderstr'om *et a.l*, 2001; Tscharntke et al., 2002 and Duelli and Obrist, 2003). Thus, the presence of a natural vegetation area around the cropping zone was probably instrumental in the successful control of the pests below threshold levels, causing damage.

The natural enemy complex operative in the systems is diverse and constitute a sizeable percentage of the total fauna. The presence of the fringe area of natural undisturbed vegetation is probably crucial in maintenance of such a healthy predatory complex. Further, the small size of the crop holdings (≈100 m^2) ensures easy access of the whole plot to the natural enemy complex.

Combining trees with crops and the presence of natural buffer of vegetation surrounding the crop plot thus seem to provide ambient conditions for the suppression of pest populations (Cromartie, 1981) and at the same time enhancing the faunal complex, consisting of natural enemies (Allen, 1979; Den Boer, 1990; Duelli *et al.*, 1990 and Burel, 1996). Further, the tree component provides habitation to fauna beyond the cropping seasons, and also moderates the climatic conditions. This contention is also strengthened by the comparative study, wherein; the monoculture had a higher incidence of maize cob borer compared to the agroforestry system.

It is felt that the inclusion of islands of natural vegetation even in large commercial agricultural situations would improve the faunal complex and could help in the process of pest management (Thomas *et al.*, 1991 and Sen Sarma, 2000). Additionally, such undisturbed patches would ensure an undisturbed litter/ground layer which is extremely important for the predatory carabid beetles, staphylinid beetles, many hemipterans and chilopoda for purposes of breeding and hunting (Baker and Dunning, 1975; Allen, 1979 and Anderson, 1997). Further, inclusion of species flowering at different times of the year would attract predatory hymenoptera and parasitoids, which are efficient in suppressing pest populations.

The functioning of populations and communities are complex (Wiens, 1997) issues and this complexity is further increased by the fragmentation of habitat, as in the case of the present investigation. Although metapopulation models (Levins, 1969, 1970) provide a conceptual framework for analyzing the dynamics of insect populations in fragmented habitat, and may explain the occurrence of populations across such habitat, at the landscape level, alternate explanations also arise (Gaston *et al.*, 1997). Thus a holistic understanding of plant-animal interactions needs investigations at the landscape levels, and that too on a large spatial and temporal scale (Tscharntke and Brandl, 2004). Although this is not within the purview of the present study, it may be a promising and fruitful area for future investigation.

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CHAPTER 6

SUMMARY

The present investigation attempted to analyse the pests and total insect and arthropod fauna of Teak (*Tectona grandis*), Tung (*Aleurites fordii*) and Subabul (*Leucaena leucocephala*) based agroforestry systems in two districts of Mizoram, N. E. India so as to elucidate their seasonal population dynamics in relation to meteorological factors (temperature and rainfall), their incidence, food preference and life cycles of the pests, and the seasonal dynamics and population values of the natural enemy complex. For the purpose of the study, the experimental plots were divided into three components viz. Tree, Crop and Fringe area having undisturbed natural vegetation. A random sampling (replicated) programme was undertaken for 29 months for the seasonal dynamics and population table studies, and laboratory experiments were initiated for the life cycle studies. The results reveal a seasonal population dynamics of lower values during the cold and dry periods, and increasing numbers with the onset of the monsoons, and the plant-growing season, a general trend, true for the total population of all sites, barring few differences. This is probably indicative of the hibernation of the faunal entities through the lean seasons by way of resting stages such as overwintering eggs and pupae/ cocoons. The release

of the new individuals into the population is triggered by ambient temperature and moisture conditions, and is synchronized to the plant-growing season, so as to ensure ample food for the population. The population table of total insect and arthropod fauna was found to be distributed unevenly among the three components, having generally higher representation in the fringe area, and the tree components, as compared to that of the crop component. This probably signifies the levels of disturbance in the system, being higher in the cropping area as compared to the other two components. Further, the diversity of fauna was also seen to be higher in the fringe area component. The natural enemy complex of the tree and fringe area components were seen to be higher, with actively moving groups like mantoidea, araneida and vespidae probably preferring to inhabit these components and hunt in the cropping area. The superiority of agroforestry as compared to a monoculture was revealed through higher incidence of a maize cob borer in the latter. The differences of the various population estimates were found to be significant when analyzed for variance (ANOVA). The laboratory studies to decipher the life cycles were successful for three species, and it was revealed that the summer populations took less time to complete metamorphosis as compared to the autumn populations. This was probably due to the differences in temperature regimes and food quality between the two seasons, the former having higher temperatures and new flush of leaves as food, while the latter had comparatively lower temperatures and the quality of food also was poorer, being the end of the growing season. The low pest burden of the system is probably a result of a complex of factors including small plot holdings, presence of the tree component, and the proximity of undisturbed natural vegetation in the fringe area, making allowances for the successful habitation and operation of the natural enemy complex.

APPENDIX

INCIDENCE AND POPULATION DYNAMICS OF S. ELONGELLA (LEPIDOPTERA), A MAIZE COB BORER IN A MONOCULTURE AND AN AGROFORESTRY SYSTEM.

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Introduction:

Shifting cultivation (jhum) is still the predominant form of agriculture practiced in Mizoram. In steep terrain such as prevailing in the state, this type of agriculture is associated with enormous erosive soil loss during the heavy monsoons. Compounded to this, a reduction of the fallow period to 3-7 years has been instrumental in deterioration of soil fertility, and a steady decline of crop productivity.

Among .the various alternatives to jhum agroforestry is increasingly becoming popular because of its ameliorative potential and conservation of the biophysical characteristics of soil. In simple terms, agroforestry may be defined as the deliberate retention and/or introduction of' woody perennials in cropping systems in a designated spatial and temporal arrangement so as to generate better economic gains.

Maize is an important cereal crop of the world. In Mizoram and the North East, it is the second most important crop after paddy. Maize is known to be infested by more than I 39 insect pests, of which only a dozen are serious, warranting the use of control measures (Siddiqui and Marwaha, 1993). Cob borer of maize (Stenachroia ellongella) is an important pest and is reported from Meghalaya (ICAR, 1999).

Teak is an indigenous timber species of Mizoram occurring both naturally and in plantations. Traditional systems having teak and crops like maize and paddy are common in Mizoram, particularly during the seedling/sapling/pole stages of growth of the tree component. Subsequently, depending on the existing spacing, cropping is abandoned if the canopy of the tree component closes, otherwise it is continued, simulating true agroforestry systems.

The present investigation focuses on comparing the incidence of Stenachroia ellongella between a monocultur and agroforestry system. Further, the abundance and diversity of other insects/arthropods associated with these systems are also reported in an attempt to determine the prevalence of the natural enemies, ad to detect any differences between the two systems.

Materials and Method:

Site:

The study was conducted in the outskirts of Aizawl, the capital of Mizoram (20°58' - 24°35' N latitudes and 92°15' - 93°29'E longitudes). The climate is humid tropical with short winters and long summers. The average annual rainfall is 2500 mm. Two sites, one a monoculture of maize and the other an agroforestry system having teak and maize as the tree and crop components respectively, were selected. Each had an area of approximately 100 m x 50 m.

Sampling:

A monthly triplicate random sampling program was initiated in the month of February 2001 and continued till September 2001. During each sampling, insects/arthropods were collected recorded from the following units:

a. Crop- maize aerial parts (incidence of cob borer injury was recorded and the plant tagged. Other insects were recorded and/or collected)

b. Tree- (the incidence of insects etc. on tree were recorded and specimens collected whenever necessary

c. Fringe area- (area around the cropping systems having natural vegetation was sampled using sweep net).

Results:
The insect and arthropod fauna recorded during the study were as follows:

Insecta:
Coleopteran
Diptera
Derm aptera
Homo ptera
Hymenoptera
Orthoptera
Isoptera
Lepidoptera
Thysanoptera
Larvae

Arthropods:
Chilopoda
Diplopocla
Isopoda
Araneida

Keeping in view the objectives of the present study, the fauna was grouped as follows:

Total fauna: All orders/groups taken together.
Lepidoptera: Cob borer of the present study.
Predator fauna: Mantoidea
Derm aptera
Chilopoda
Hymenoptera
Araneida

Others:

All other orders/groups except the cob borer and predators.

Figure: 1 depicts the seasonal incidence pattern of cob borer in the two systems. (A/F Agroforestry). The incidence of the borer was initiated during cob settings and the population table increased with the maturing of the cobs, reaching the peak during the harvest. Between the two systems, the monoculture evidenced a higher population table(about 2 borers/ 1 borer/cob). Comparison of the percentage contribution of cob borer to the total faunal complex of the two systems, revealed that is the Agroforestry system, borer constituted 3% of the total fauna while the monoculture it constituted 10% (fig. 1).**Picture(1) should be paste**

Figure: 2 depicts the seasonal incidence of total fauna in the two systems. A general trend of low population during the preemanson period and the highest population peaks during the monsoon coinciding with crop growth phase was observed. During the population table in both the systems were also quite similar. However one marked departure was observed during the end of the study when the population of the monoculture was seen to decline to a low level probably doe to senescence of the crop growth the absence of other herbage/foliage for habitation. It contrast, the Agroforestry with the tree component probably afforded habitatable conditions missing in the monoculture, and reflected in the maintains of the fauna.**(Fig.2)**

When the total fauna of the two systems was considered, having included the three component fauna a of the Agroforestry systems, it was seen that the numbers were at a higher table in the Agroforestry systems (Fig.3). This further strengths the contention that the three component of Agroforestry system acts as a refuge to the faunal complex. **(Fig3.)**

The fringe area evidenced a similar trend of manssonic population peaks and law values during the pree and post mansoons. Further the populations table of the to systems were also similar (Fig.4) justifiably so, because the two system had a similar compositions of the fringe area component. **(Fig.4)**

Considering the predator fauna of the two systems (Fig.5) it was seen that the' predator faunal population also followed a similar trend of increases during the mansoons, coinciding with the increase in herbivorous insects. The table was much higher for the Agroforestry system as compared to the monoculture.

Discussion:

The results of the present investigation indicate a higher population table of different Insect and arthropod groups in the agroforestry site compared to" the monoculture. This is suggestive of the superiority of Agroforestry system in maintains of a healthy faunal complex. Further , the lower levels of infestation is the agroforestry site indicate natural control through the predator complex. Although there was no direct evidence of predation, in the case of Mantoidea and Araneidea, laboratory studies have shown the incidence of predation by these two groups. Agroforestry as a system has been reported to have positive environmental impacts like maintains of bio-physical properties and soil fertility(Young, 1989). The tree component of the Agroforestry system provides a variety of benefits like improvement of soil and enhancement of soil organic matter (Patil and Pathak, 1979); recycling of water and nutrients from subsurface layers of soil(Ngambeki and Wilson, 1983; Terges et al, 1978; Pound et al, 1983); and carbon sequestration(Pathak and Gupta, 1987; Housen, 1990; Gill et al, 1982). It is therefore logical to presume that improvement leads to more efficient functioning of the system as a whole, thus providing ample niche diversity for habitation by different faunal components. With a balanced faunal complex, operation of natural control and prey predator relationships are enhanced as indicated in the present study.

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Fig.1. Seasonal incidence pattern of cob borer

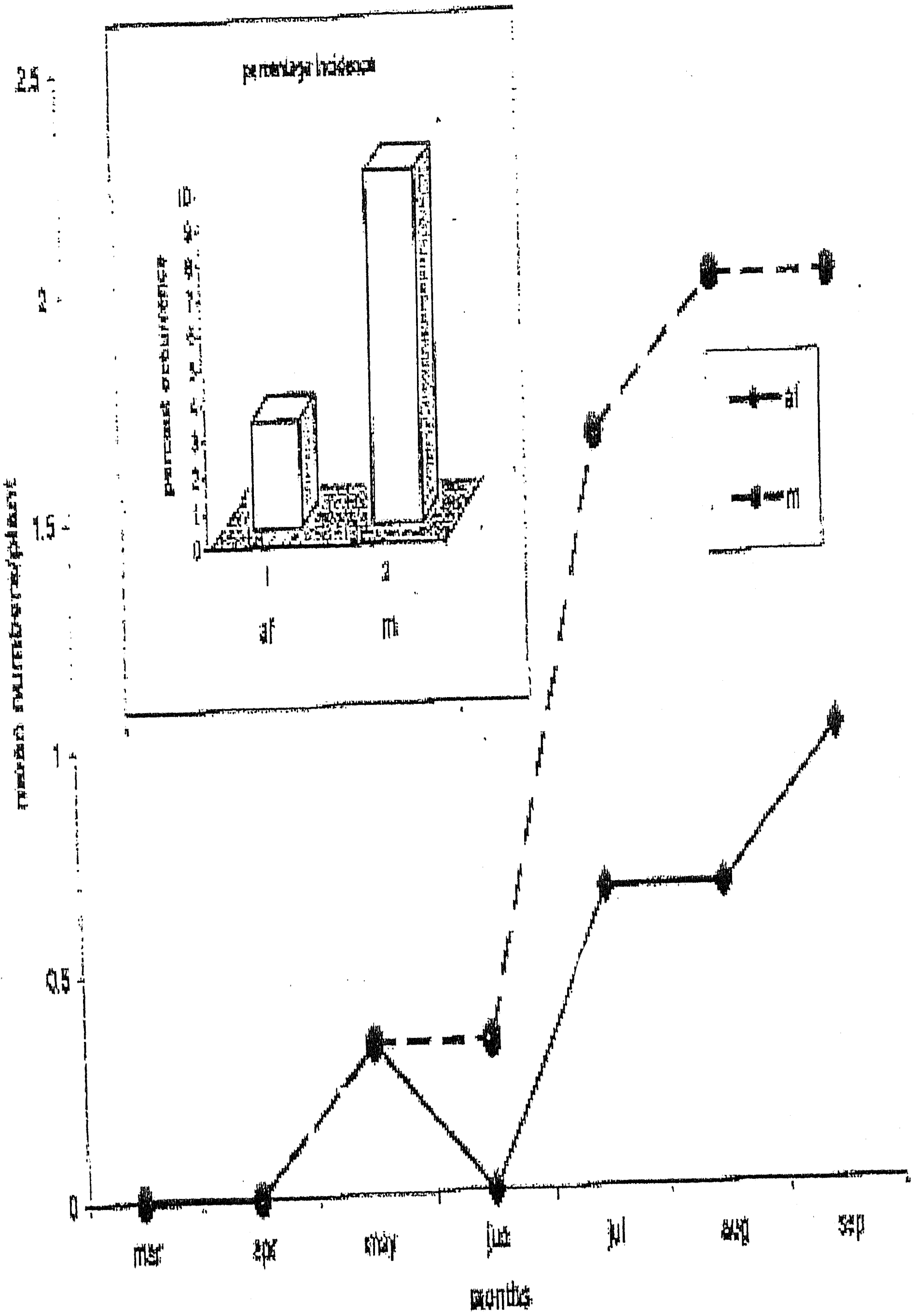

Fig. 2 Seasonal fluctuation of total fauna (crop)

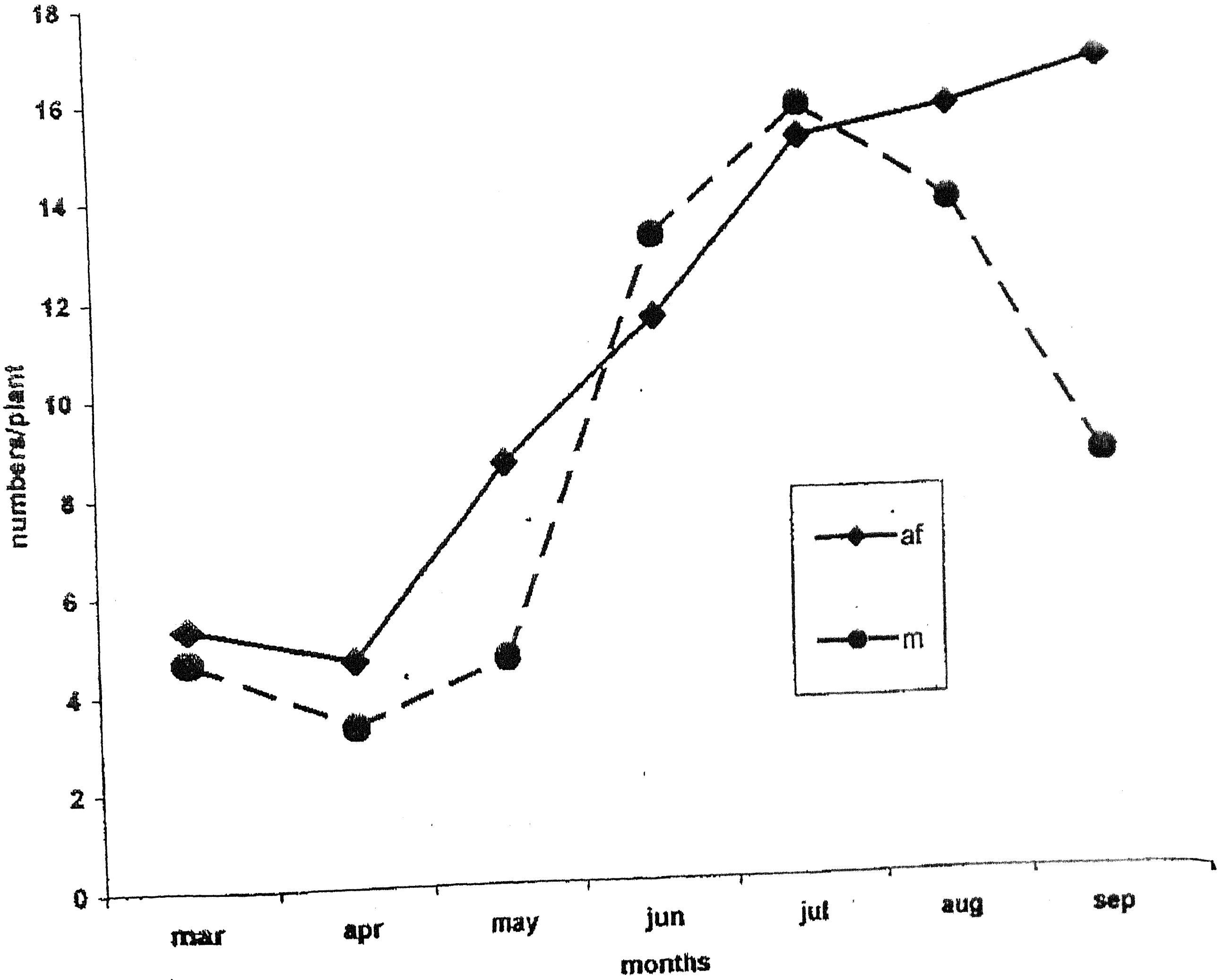

Fig. 3 Total fauna of the two sites (including tree component)

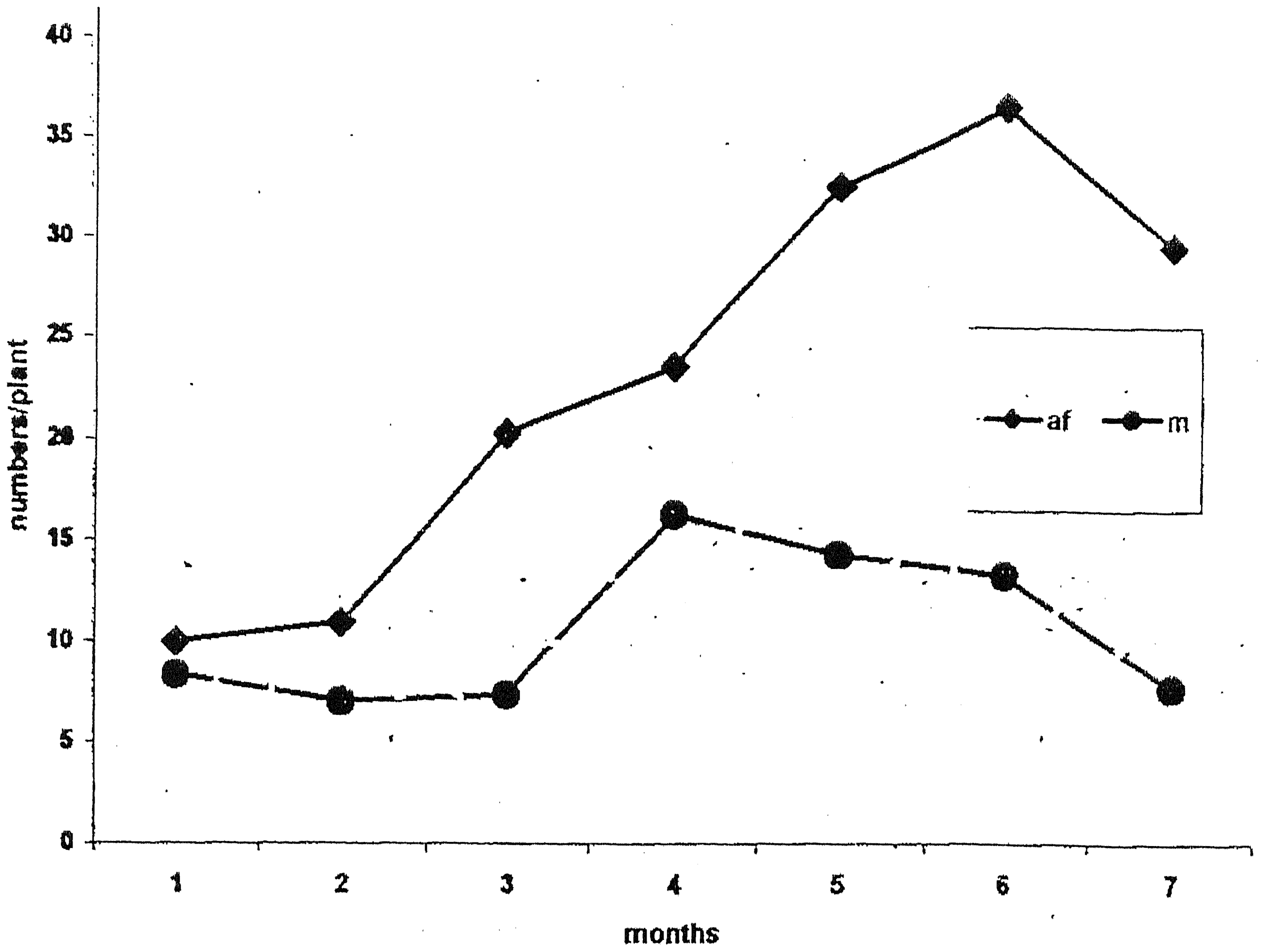

Fig. 4. Total fauna (fringe)

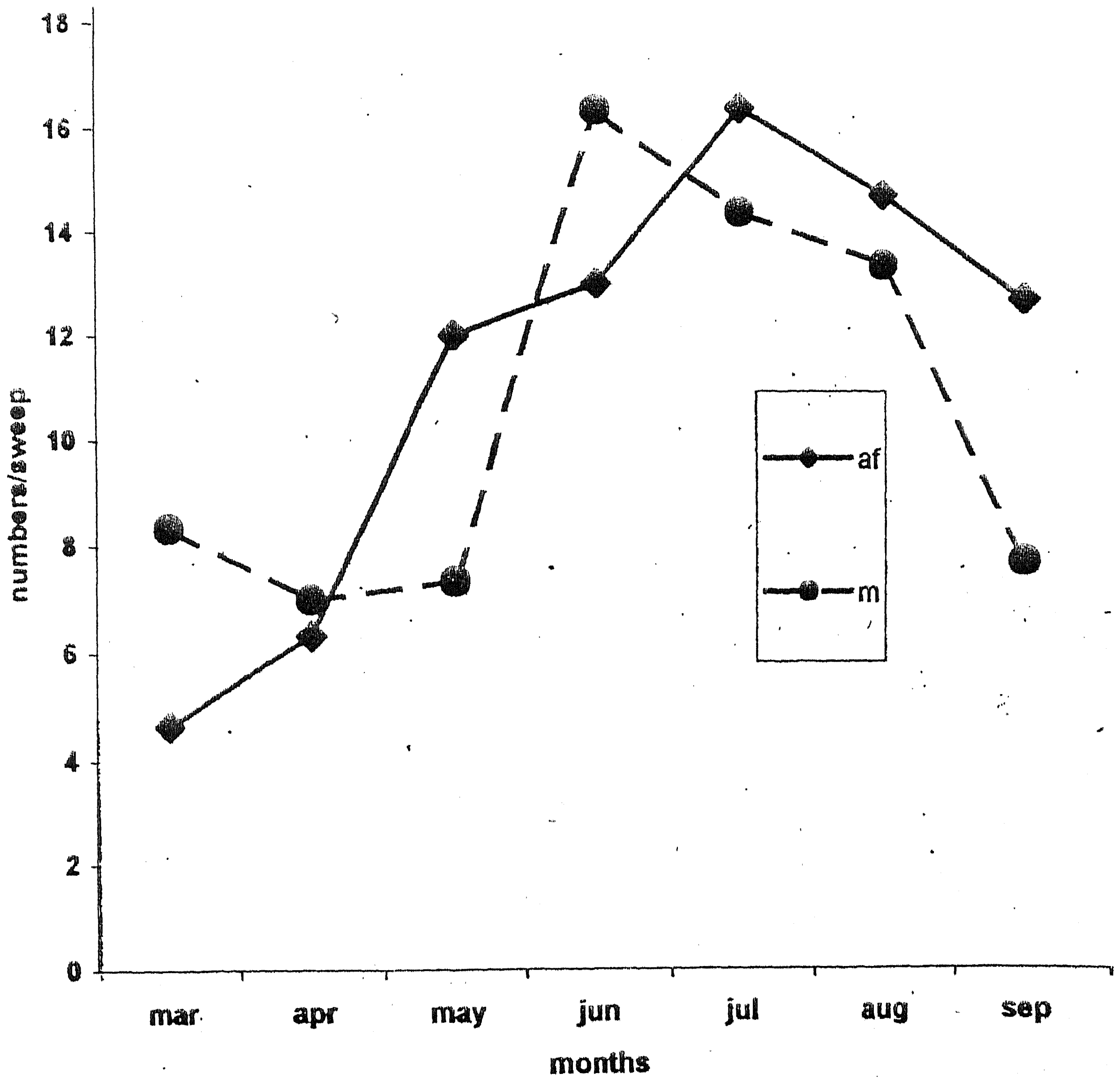

Fig. 5 Predator fauna