POPULATION DYNAMICS AND FEEDING IMPACT OF SOME SUCKING PESTS ON DARJEELING TEA

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BY

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2004

DEDICATED

TO

MY PARENTS

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Supervisor's Certificate

This is to certify that Mr. Sunil Kumar Pathak, M. Sc. has worked on a topic "Population Dynamics and Feeding Impact of some Sucking Pests on Darjeeling Tea" under my supervision and guidance during the period from 1999-2003. He has fulfilled the requirements relating to nature and period of research. This is also to certify that the research work embodies original results based on well planned investigation conducted by Mr. Pathak as an Advisory Officer and researcher in Darjeeling Branch of Tea Research Association. The dissertation submitted herewith is for fulfillment of the degree of Doctor of Philosophy in Science (Zoology) of the University of North Bengal, and has not been submitted for any degree whatsoever by him or any one else.

I sincerely wish Mr. Pathak and his endeavour success.

Date : 27 January, 2004
Place : University of North Bengal

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(Sunil Kumar Pathak)

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Introduction

I. INTRODUCTION

1.1. LOCATION AND PHYSIOGNOMY

The tea plantations of Darjeeling hills of India are situated in the extreme north of the state of West Bengal between 26 ^{0} and 27 ^{0} 13$'$ north latitude and between 87^{0} 59$'$ and 88^{0} 53$'$ east longitude. These are in the lower Himalayas and surrounded by the lower hills and valleys. The climate is temperate with average maximum and minimum temperatures 25.70 ^{0}C and 19.63 ^{0}C in summer months (June to September) and 18.38 ^{0}C and nearly zero or even sub zero in winter months (November to February). Monsoon normally reaches by mid June and continues up to October with heavy downpour with average rainfall of 2000 – 3000 mm per annum. However, around 80 % of the total rainfall is received during 4 months from June to September. Winter is severe and prolong from November to February. The main industrial crop in different valleys is tea, though fruit like orange and vegetables like squash, cabbage, cauliflower, carrot, radish etc. are also grown commercially by individual farmers. Apart from tourism, Tea is the biggest industrial activity, offering the largest employment and earning in the hills.

1.2. EARLY HISTORY OF TEA CULTIVATION

The venture of tea cultivation in Darjeeling dates back to January 1834 when Lord William Bentinck proposed to the Council of the East India

Company the setting up of a Tea Committee to investigate and make recommendations on suitable areas for tea cultivation in India. The Tea Committee decided to send their secretary G. J. Gordon to China in order to acquire tea seeds and some tea workmen familiar to tea cultivation and manufacture. Gordon left Calcutta in June, 1834 on the sailing ship "Water Witch". Meanwhile, Tea Committee got the information about the availability of indigenous tea plant near Sadiya, Assam. But, it was too late to call back Gordon and the first consignment of some 80000 tea seeds was on the way to India which reached Calcutta in January 1835. The seeds were sent to Botanical Garden Calcutta for germination under the direction of Dr. Nathaniel Wallich. From this original consignment of china seed around 42000 young plants could be raised which were allocated to three main areas, 20000 to the hill districts in the Kumaon in North India, 2000 to the hills of South India and the remaining 20000 to Upper Assam of the then North East Frontier (Weatherstone, 1992). Out of this initial trial, seeds tried in Darjeeling grew well. As per the available records one Dr. Campbell, a civil surgeon, planted tea seeds in his garden at Beechwood, Darjeeling, 2100 m above mean sea level (amsl) as an experiment with reasonable success. Subsequently the government, in 1847, selected the area to raise tea nurseries. With the plants raised in the government nurseries, the first commercial tea gardens planted out by the British in Darjeeling hill area were Tukvar, Steinthal and Aloobari tea estates in 1852.

Darjeeling was then thinly populated and used as a hill resort by the army and some affluent people. Tea, being a labour intensive crop, required large number of workers for different operations starting from planting to manufacture. To meet this requirement employment was offered to people from across the border, especially of Nepal.

It appears that in 1866, Darjeeling had 39 gardens producing a total crop of 21,000 kilograms of tea. In 1870, the number of gardens increased to 56 to produce about 71,000 kg of tea harvested from 4,400 hectares. During 1860-64, the Darjeeling Company was established with 4 gardens followed by Darjeeling Consolidated Tea Co. in 1896. By 1874, tea in Darjeeling became a profitable venture with 113 gardens covering approximately 6,000 hectares under tea (Anonymous, 2003a).

1.3. PRESENT SCENARIO OF TEA CULTIVATION

At present there are 86 running gardens producing 'Darjeeling Tea' on a total land of 19,000 hectares. The total production ranges from 10 to 11 million kilograms annually.

Darjeeling estates still restrict to original orthodox type (whole leaf) of manufacture while the tea estates in plains subsequently switched over to CTC (Crushing, tearing and curling) manufacture. The Darjeeling tea, commonly known as "Champagne of tea", is unique in the world and highly valued due to its typical flavour. It has very high demand in different countries and 90 % of total produce is exported.

The planting material of tea is mostly china type with multi-stemmed collar, large number of small branches, small leaves and shoots. However, Assam type tea was also grown earlier in considerable area, which is being replaced now by replanting with flavoury clones selected from the old china type population, because characteristics of the Assam type tea are not fulfilling Darjeeling requirement (Anonymous, 1957).

1.4. GROWTH HABIT OF TEA, THE FLUSHES AND THE HARVEST

Tea bush has a periodical growth habit with alternating states of growth and dormancy. The growing condition in between two states of dormancy is known as a flush. In North East India, though up to five flushes of growth is noticed in tea under pruning and plucking conditions, but the fifth flush is rare and found in only few genotypes (Anonymous, 1935). In commercial tea plantation of Darjeeling, there are four distinct flushes namely first, second, rain and autumn. The crop in each flush is having its own characteristics. In first flush, the new shoots starts to grow towards end February with increasing temperature and day length after a prolong dormancy during winter months from December to February. The shoots are small but dark green and having a tendency to go dormant at a small stage of 2 or 3 leaves and a bud. Along with the plucking, which removes the *banjhi* shoots, gradually the density of growing shoots and growth rate increases reaching its peak in April. Tea produced in this period is very valuable with typical first-flush flavour and characteristic thin liquor. There is great demand in the market. Around 16-18 % of season's crop is harvested during March-April. Then the first distinct dormancy (*banjhi*) spell starts from early May. After a heavy crop in April the bushes pass through a long dormancy of three to four weeks depending on weather conditions. Towards end of May the shoots again start to grow entering into the second flush reaching the peak of second flush in June. The shoots are more uniform than first flush, yellowish and not as green as in the first flush. The crop harvested during this period is also very valuable with the typical muscatel flavour and fetches very high price in the export market. The crop during May and June is around 21-22 % of the whole season. The second dormancy comes towards early July. However, it is for a very short spell of say for 12-15 days. Then the rain flush starts from mid July or end July and continued to mid September. During this period the growth is fastest with all the favourable weather conditions. The shoot size is also largest with dark green luxuriant look in this period. The crop during this flush is really heavy and bulk of the crop *i.e.* around 45 % of the total crop of the season is harvested during the rain flush (July to September). But, the quality is diluted during this period. The flavour level goes down due to weather factors, mainly heavy rain, and faster growth rate. Sometimes unmanageable leaves also come to the factory affecting the typical Darjeeling manufacture, which requires great care. Plucking at required intervals to harvest standard size shoots also is affected due to shortage of pluckers. The price is the lowest for rain teas. This is followed by the third distinct dormancy period of 15-20 days. The autumn flush starts from mid October and continues to the end of November. The crop during this period is also valuable due to good flavour and typical autumn characters and fetches good price in the market. Around 15-18 % crop is produced from October to end of the season by first week of December. The time period of flush and dormancy mentioned above may vary slightly depending on weather conditions. Though tea under plucking condition in Darjeeling undergoes into a total dormancy during winter, but during other dormancy periods some growths are always there on the plucking table though they are mixed with dormant (*banjhi*) shoots. The dormancy period varies in section to section depending on elevation and planting materials. Hence, plucking continues also during these dormancy periods (Barua, 1989; Darjeeling Planters' Associations' monthly crop data and personal observation).

In tea, the main harvestable produce is the top bud with two leaves below of a growing shoot, which is commonly known as "Two and a Bud". While plucking, ready "Two and a Buds" and soft dormant shoots *(Banjhi)* with one or two leaves are plucked leaving the immature ones. Under growing conditions these left over shoots generally achieve the harvestable stage in between 5-7 days in Darjeeling conditions. Hence, a plucking interval of 5-7 day is maintained in Darjeeling depending on the growth rate and to pluck the standard size of shoots to produce the world's finest tea.

1.5. MAJOR SUCKING PESTS OF TEA IN HILL SLOPES

In the world more than thousand species of arthropods are known to be associated with different parts of tea plants. Out of them Lepidoptera form the major component (31.53%) followed by Hemiptera (26.29%) and Coleoptera (18.76%) (Chen and Chen, 1989). But, only around 300 species of insects and mites are recorded in India as tea pests under orders Acarina, Thysanoptera, Coleoptera, Lepidoptera, Isoptera and Hemiptera. A few minor pests have also been reported under Diptera, Hymenoptera and Orthoptera (Muraleedharan *et* *al.* 2001).

Cramer (1967) estimated that tea in Asia suffers 8 % crop loss due to pests. Glover *et al.* (1961) reported 13 % crop loss, where as Banerjee (1993) reported a steady loss of 10 % due to overall pest attack as a generally accepted figure, which may at times go up to 40 % in devastating attack by defoliators. Sivepalan (1999) also reported that various assessments on crop loss by respective tea pest had been done from time to time in the different tea growing countries (most often empirically). This loss ranges from 5 to 10 to as high as over 50 percent. But, these differences are also dependent on the prevailing climate, genetic variation / uniformity (seed/clone), age of tea, soil type and the prevailing fertility status etc. As such, it is difficult to estimate the crop loss accurately caused by a particular species.

Like in plains, tea in the Darjeeling hills and its lower elevations is also attacked by a number of arthropod pests. Out of them, sap sucking pests like – thrips, green fly, aphid, tea mosquito bug, red spider mite are common. Foliage feeders like – flush worm, different lymantriid caterpillars, bunch caterpillar, red slug etc are occasionally active. Root borers and cockchafer are also found active. The sap sucking group causes considerable damage to tea every year and is a major factor of crop reduction. Out of them thrips and greenfly are most common in all the tea estates situated at higher elevations (1200 to 1800 m) of Darjeeling hills. Aphid is occasionally active mainly in pruned teas. Tea mosquito bug and red spider mite are generally found at lower elevation.

1.5.1. COMMON THRIPS – *Mycterothrips setiventris* Bagnall (Thrlpidae: Thysanoptera)

Genus *Scirtothrips* include 40 species of thrips spread through the tropics of which 10 are known to be pests of different crops (Jacot-Guillarmond, 1971). Four species of the genus namely *S. bispinosus, S. dorsalis, S. auranti and S. kenyensis* attack tea in South India, Japan and North-East India, Malawi and Kenya respectively (Mound and Palmer, 1981). However, none of them are active in the high elevations of Darjeeling hills; instead a unique species of thrips, *Mycterothrips setiventris* has become a major pest of tea in Darjeeling heights.

Early history : Thrips are amongst the oldest insect pests known in tea plantation of Darjeeling. The pest attracted attention of the planters as early as 1907. Considering its severity during 1908, two Entomologists namely– H. Maxwell Lefroy, the then Imperial Entomologist to the Government of India and C. B. Antram, Entomologist to the Indian Tea Association were entrusted to conduct independent studies on thrips in Darjeeling. The publications of their studies were the first formal records of thrips pests in Darjeeling tea (Lefroy 1909 and Antram 1909). They reported three species of thrips active in tea and Antram named them as "Common thrips", "Black thrips" and "Flower thrips". Out of them Common thrips were reported to be the common in Darjeeling tea plantation, which attacked tea shoots, other two being mainly flower dwelling thrips.

Subsequently, Bagnall (1918) first described the common thrips as

Physothrips setiventris Bagnall after receiving some specimen of the insect in 1916 from E. A. Andrews (Andrews,1925). Thereafter the species was mentioned as *Taeniothrips setiventris* (Bagnall) by Dev (1964) and in subsequent publications of Tea Research Association.

The genus *Physothrips* is no longer in use since it has been synonymised. Ananthakrishnan and Sen (1980) while reviewing Indian Thysanoptera classified this species as *Mycterothrips setiventris* (Bagnall, 1918). The taxonomic classification of Common thrips by Ananthakrishnan (after Priesner, 1964) is as follows:

Order – Thysanoptera, Suborder – Terebrantia, Superfamily – Thripoidea, Family – Thripidae, Subfamily – Thripinae, Tribe – Thripini, Subtribe – Thripina, Genus – *Mycterothrips*, Species – *M. setiventris*.

Common thrips is still a dominant species of thrips in Darjeeling, attacking tea shoots though other two species of thrips are also found to be active mainly on flowers.

Fig 1: a. Tea shoot severely infested by thrips
b. Sand papery line →

Damage symptoms: This insect lives and feeds on the unopened and partially opened buds and tender leaves. The adult and the nymph make slits in the upper surface by inserting the stylets and suck the sap oozing out through the wounds causing lacerations of the tissues. The initial symptoms of attack are light brownish discolouration of the tip and the basal part of infested buds and leaves. The leaf surface becomes uneven and curled. The puncture marks appear as minute brown spots in scattered patches and / or in continuous lines. The slit made in continuous lines in unopened buds appear as corky lines when the leaves unfold, commonly known as "sand papery line" (Fig.1b). There may be two or four such lines on a leaf with one or two on each side of the mid rib. Pruned tea under recovering stage is worst affected. The severely infested leaf shows roughened appearance, curls up and deforms. In pruned tea, severely infested shoot exhibits scorched-brownish appearance and remains stunted with short internode and small leaves (Fig.1a). The shoot will not grow further until the pest is controlled. Mkwaila (1982) reported up 20 % crop loss in late pruned teas due to attack of tea thrips *Scirtothrips aurantii*. It is also agreed by all concerned that there is a heavy loss of crop from thrips damage in Darjeeling (Anonymous 1994).

Life cycle: (Fig.: 2) Eggs are laid singly in the tissues of the buds and young leaves generally towards the veins and ribs. The incubation period is around 10 -16 days. The newly hatched pale yellow nymphs emerge through the upper surface. In case of eggs laid inside an unopened bud, the newly hatched nymphs emerge into the cavity inside the bud, where they live feeding happily until the bud unfolds. It moults to a similar second instar, but with a bigger size. It soon assumes a pale yellow colour and increases in size until it reaches around 1 mm in length. In general, the full

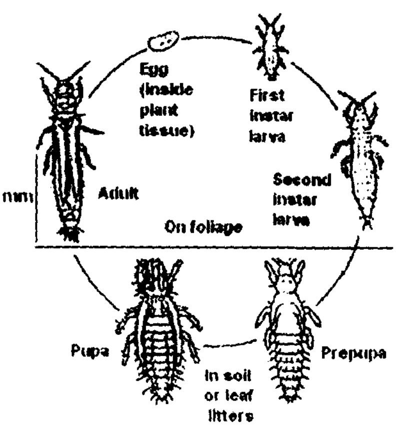


Fig 2: Diagramatic representation of life cycle of thrips (adapted from Dev 1964)

grown nymph goes to the ground and forms a prepupal stage distinguished by the shortening and swelling of the abdomen and development of two pairs of wing buds on two hinder thoracic segments. The prepupal is followed by pupal stage with more elongated abdomen, and developed wing-buds so as to reach almost half – way down the abdomen. This pupal stage gives rise to adult insect. There is considerable variation in the duration of the life cycle from the date of deposition of the egg to the maturity, which is 18 to 32 days suggesting over-lapping of generations. This in fact occurs and all stages of the insect are found throughout the season.

The adult female is minute and yellowish brown insect of 1.25 – 1.50 mm long (Fig. 3). Head and thorax are golden yellow while the abdomen is brownish black. Head bears a pair of large black compound eyes on each side and three simple eyes, red, looking like tiny rubies, arranged in a triangle with one in front and two behind. The antennae, actually consisting of eight joints, appear to consist of six due to fusion and telescoping. The ovipositor is distinct as a narrow yellow band along the centre line. The two pairs of brownish narrow wings are fringed on both margins with long hairs. The male is slightly smaller than the female, around 1 mm long and golden yellow except the hind end of abdomen which is brown (Andrews, 1925).

Fig.3: Common thrips (Female)

The species is mainly confined to high elevation and not generally found active in the plains. Dev (1964) reported that this species was not found active in the plains of the tea district of Cachar, the Assam Valley, the Dooars and Terai suggesting its specific adaptation to hilly areas.

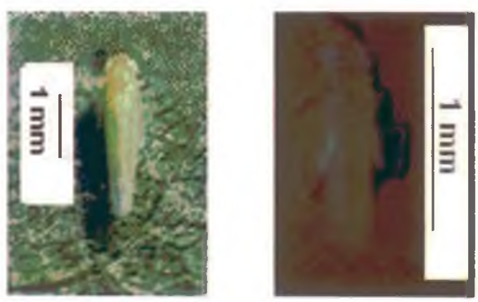
1.5.2. GREENFLY – *Empoasca flavescens* Fabricius (Cicadellidae: Homoptera)

Though there is a change in the generic name of tea greenfly in recent years, in this publication, the pest is referred to as *Empoasca flavescens*, which was most commonly used in earlier literatures. The greenfly or jassid or tea leaf hopper is another common sucking insect pest in Darjeeling particularly during the period of first and second flush i.e. March to June. However, the pest remains active at various level of intensity through out the season. It was reported that green fly alone could cause around 10 % yield loss in Darjeeling during the period from mid March to end June (Grice, 1967).

Damage symptoms: (Fig. 4) Both adults and nymphs (Fig. 5) suck the sap from young leaves and tender stems. Nymphs are more damaging than adults. The affected leaves curl downwards; the margins become recurved, subsequently turn brown and gradually dry up. This typical symptom is known as "Rim Blight". The mid rib and veins of affected leaves also show somewhat brownish discolouration. The infested shoots remain stunted and turn yellowish brown in colour. Reduced photosynthetic activities due to loss of chlorophyll coupled with likely imbalance in growth hormones as a result of jassid feeding might account for the stunted growth. The pest remains mainly on the under surface of the leaves.

Fig. 4: Tea shoot infested by greenfly

Life cycle: Whitish eggs are inserted singly inside the soft tissues of growing tea shoots and site of oviposition is indicated by swelling tissues. Eggs are elongated narrower at one end, slightly curved with smooth surface, measuring about 0.5 mm in length and 0.25 mm in width. Eggs turn to pale yellow in later stage with an incubation period of 10-13 days in March, 9-11 days in April and 6-8 days in May, June and July under laboratory condition at Tocklai , Assam.



a b

Fig. 5 : a. Greenfly adult
b. Greenfly nymph

The newly hatched nymph is a small colourless insect (Fig. 5b) with pink eyes and soon after feeding turns yellowish green. When disturbed it moves sideways. There are five instars with a total nymphal duration of 12-15 days in March, 10-13 days in April and 8-10 days in May and June. The exuvae remains attached to the leaf surface. The adult is a small yellowish green insect with pale yellow forewing (Fig. 5a). The male and female are 2.50 and 2.75 mm in length respectively (Anon., 1994).

1.5.3. APHID – *Toxoptera aurantii* Boyer de Fons (Aphididae: Homoptera)

This species of aphid is common and widely distributed throughout tea growing district of North – East India. In North East India, it was first noticed in 1873 on tea in Jorhat, Assam, then in Kumaon in 1885 and shortly afterwords in Darjeeling (Anonymous, 1994). In Tocklai (Assam, India), more tea aphids were observed in spring on young shoots of mature tea bushes as well as on seedlings in nurseries (Anonymous, 1994). Tulashvili (1930), King (1939) and Kalandadze (1956) reported *T. aurantii* as the most injurious pest of tea in Russia, Sri Lanka and in the Georgian republic respectively. Smee (1943) reported that *T. aurantii* was prevelant on tea in Nyesaland early in the season.

Damage symptoms: It is a ubiquitous pest colonizing the tender shoots, particularly of the young tea and the new growth after pruning. Both nymphs and adults suck the sap from tender stems, buds, petioles and lower surface of tender leaves along the mid rib. As a result of feeding, leaves crinkle and curl inwards (Fig. 6) resulting in marginal nacrosis at later stage of infestation. In the plains of Assam, pruned tea suffers from worst attack at the recovering stage when the fresh shoots are growing from mid January (Anonymous, 1994).

Fig.6: Tea shoot infested by aphids (inset - close up of aphids)

Aphids produce honeydew which serves as a medium on which a sooty fungus, called sooty mold, grows. Sooty mold blackens the leaf, decreases photosynthetic activity and thus vigor of the host.

Life cycle: Males are not found and reproduction takes place parthenogenitically. Females are oval, shiny black, brownish-black or reddish brown in color, either with wings (alate form) or without wings (apterous form), measuring 1 – 2 mm in length. The antennae are short having black-and-white bands. Winged individuals normally have darker abdomens and are slightly thinner. The development of alate form is dependent on the population density and leaf age. Female (both alate and apterous forms) produce young nymphs throughout the year. Newly born nymphs remain in group. The nymphs undergo four moults to develop into an adult female. Total life cycle is completed in 9-10 days, 7-8 days, 6 days, 5 days, 5-6 days and 7 days during January-February, March, April-May, June, July-October and November respectively. Apterous female produces more nymphs than alate form. (Anonymous, 1994).

The above 3 sucking insect-pests (common thrips, green fly and aphid) attack the growing shoot, which is the only harvest in tea, thus causing a considerable loss in crop every year. But, there is a common belief amongst the planters that thrips and green fly infested shoots produce more flavoury tea and they are reluctant to use control measures during quality period like March – June and October. However, the matter has not been studied scientifically and it is doubtful if the crop loss is compensated by price realization due to improvement in quality. Moreover, no detailed study was conducted so far on the population dynamics of these sucking pests from hill slopes of Darjeeling and natural enemies active under hill conditions.

Tea of Darjeeling slopes is having superior flavour and is highly priced. Any change in its quality or loss in quantity resulting from the attack of the sucking pests, specially thrips and green fly in Darjeeling valleys is worth investigating. So, a study was undertaken to know their varietal preference population dynamics, natural enemies, alternate hosts and the feeding impact on Darjeeling tea with the objectives detailed in following chapter.

Objective

II OBJECTIVE

2.1. TO KNOW THE SEASONAL INCIDENCE OF COMMON THRIPS, GREEN FLY AND APHID IN DARJEELING SLOPES AND THEIR ALTERNATE HOST, IF ANY

Though these pests are known to occur in Darjeeling tea at elevations of 1500 to 2000 m (amsl) for last several decades, systematic study on their seasonal occurrence and influence of weather factors on their population incidence were not studied. This is an important prerequisite to forecast the time and the conditions for the pest occurrence and adopt control measures against any pest. Alternate hosts also play an important role in maintaining the life cycle of a pest. Hence, studies were conducted to know their population dynamics on tea, influence of weather factors and existence of alternate host, if any at those altitude, so that the information generated could be utilized in future management of these pests.

2.2. TO KNOW THE FEEDING AND COLONIZING IMPACT OF THRIPS AND GREENFLY, ON THE QUALITY OF DARJEELING TEA AND THE CHANGES OCCURRING IN "MADE TEA" DUE TO THEIR FEEDING

There is a common belief amongst the tea planters that Green fly and thrips improve quality, particularly flavour, by infesting shoots in the field. But, it is not a established fact and it is often debated whether there is really any improvement in quality of made tea and if so, can this improvement compensate the loss incurred due to reduction in crop ! Therefore, the present study was conducted with an objective to verify this belief.

2. 3. TO STUDY THE NATURAL ENEMIES ASSOCIATED WITH PEST-INFESTED TEA PLANTATION

At present bio-organic farming is a global concept in general agriculture and tea is no exception. Being an export commodity, the demand for organic tea from Darjeeling is increasing day by day in importing countries. There are already more than 20 tea gardens in Darjeeling running under bio-organic cultivation at the moment and the trend is upward.

Under organic farming the concept of pest management is changing towards Integrated Pest Management (IPM) from sole dependence on pesticide. Rather pesticides are being phased out making room for other pest management tools. In an IPM system, conservation and application of natural enemies of pests, namely predator, parasitoids and pathogen play a vital role in keeping the pest population below the economic injury level. Hence, a preliminary survey was conducted to know the natural enemies that are actively associated with pest-infested Darjeeling tea at higher elevations, so that information generated could be of use in future IPM schedule of the pests under study.

Review of Literature

III. REVIEW OF LITERATURE

3.1. POPULATION DYNAMICS

Natural complexes of plant and animal species together with their physico-chemical environment constitute ecosystems. The interactions between the environment and population of each species determine the extent of the fluctuations and these interactions form the basis of population ecology studies. Member of any one species are affected by a large complex of factors, the biotic part being composed of a web of interactions involving many different species. A comparison of the total insect population in any agro – ecosystem under the impact of cultivation should serve to sufficiently emphasize the need for taking an overall picture of the population trends of insect pests confined to crops and weeds around (Ananthakrishan *et al.*, 1986). There are greater variety of species in the grasslands enabling a continuous inflow into the cultivated fields, where some species become better adapted, so that the role of grasses and other weeds as the original source or alternate host of pest species cannot be ignored. (Uvarov,1964). The association between insects with its host plants can often be dynamic, involving the mutual adaptations between them resulting in phytochemical diversity on the one hand, as well as the tolerance of insects to the chemical protection of plants on the other (Pitkin, 1976, Tietz, 1972).

Thus the diversity and variability of insect–plant relationships would comprise (a) the study of feeding behaviour of plant eating insects in response to the primary and secondary substances present in the host plants, (b) the impact of the quality of the host plant on the growth and fertility of the insect, and (c) the influence of crop and weed hosts on the rate of colonization and population dynamics of phytophagous insects (Ananthakrishan, 1986).

3.1.1. COMMON THRIPS

Thrips population in an agro-ecosystem is primarily determined by the host plant, ideal climatic conditions, protection from natural enemies and the density of immigrants or an equilibrium stage of immigrant and emigrant populations (Varatharajan and James Keisa, 2000). If the above factors are favourable, the density of the pest increases and at times reaches the economic threshold level. Thrips are generally known to be more active during dry season. But, at least a small proportion of them is maintained throughout the year in one or the other host due to their polyphagous nature (Ananthakrishnan, 1984).

Though considerable works has been done on population dynamics of different species of thrips on tea, very little has been done in this area for *Mycterothrips setiventris* in Darjeeling after the early study by Lefroy (1909), Antram (1909) and then Andrews (1925). Andrews (1925) reported that as a general rule, thrips began to attack the bushes towards latter part of May, which extended through June –July followed by a lull and then a second attack towards the end of the season in October. Most of the damage was caused in the early part of the season before plucking. With the commencement of plucking considerable number of young and adult insects and eggs were removed, controlling the population to some extent.

In general, adults of thrips are said to be phototactic i.e. they prefer places where intensity of illumination is greatest (Bedford, 1943). Hence, it's infestation is severe during hot dry period particularly on unshaded tea. Though Antram (1909) considered that shade encouraged the thrips species in Darjeeling, but Lefroy (1909) found the pest less active under shade.

In the plains of North-East India, the species *Scirtothrips dorsalis* Hood reported to occur almost throughout the year on tea, but rapid build up started from March – April when prolonged droughty conditions prevailed and the peak of incidence was observed during May. After the monsoon there was a decline in population. During cold weather very few thrips might prevail in the pruned sections, but in the unpruned and young tea sections it persisted (Anonymous 1994). In a population dynamic study on young tea clones (TV 1, TV 18, TV 25, TV 26) at Darjeeling plains, infestation of *S. dorsalis* was observed throughout the year on all the clones, with a population rise in the winter months (November to January) and a sharp increase in population in the summer months (May to July) (Sannigrahi and Mukhopadhyay, 1993 and Mukhopadhyay, Sannigrahi and Biswas, 1997). Maitra (1994) also observed that *S. dorsalis* occurred in highest number in May to July and the population declined with onset of heavy showers by end of August.

In tea fields of Japan, adults of *Scirtothrips dorsalis* were found in the leaf zone, branch zone, litter and soil throughout winter of 1979-1980 suggesting that the thrips hibernate in the adult stage during winter. The adult showed minimum activities from mid December to mid March, but some were active in tea grown throughout the winter. The over wintered adults emerged from litter and moved to the leaf zone in late March after a few days of high temperature. After feeding on and laying eggs in new leaves, most of them died before the end of April and some before mid May. The life span of the over wintering adults appeared to be about five months (Okada and Kudo, 1982). Sakakibara and Nishigaki (1988) also considered that adult of *S. dorsalis* over wintered as adult in the tea fields of Japan.

Sasidhar *et al.* (1999) reported that the population of thrips species, *Scirtothrips bispinosus* Bagnall, active in South India, started to build up by November – December and reached the peak in March–April, when temperature was 27 to 32 ^{0}C. Intensity of shade played a predominant role in determining the population density of thrips. Unshaded tea fields always harbour more number of thrips.

Mkwalla (1982) reported from Central Africa that *Scirtothrips auratii*, the South African citrus thrips, occurred in tea all the year round. The bulk number occurred on the host in dry season between September and December. Though the period between January and March had the optimum temperature, but wetness kept the number down. A few days of dryness in this period was likely to be reflected in a rise in number. Population was lowest during April–August, because of low temperature. All developmental stages of the insect were present at any time resulting in overlapping of generation. There was no resting stage and it was likely that the few individuals, who survived the unfavourable temperature during April –July, formed the basal population for the following period of September – December.

Population studies on *S. kenyensis* in Kericho, Kenya revealed that the pests remained in the field throughout the year, highest and lowest population being observed during dry and wet season respectively. The lowest population during wet season had been attributed to rain wash or other natural control agent. There appeared to be a negative relationship between the monthly fluctuation of thrips populations and rainfall data. However, the minimum and maximum temperature did not have any relationship with thrips population. (Sudoi, 1985). He also reported that number of thrips in unshaded area was significantly higher than the area under *Grevillia* shade.

In the above reviews, some behaviours and characters are found to be common in all the thrips species infesting tea in different parts of the world. These are :

i) They prefer unshaded condition;

ii) Their population is the highest during dry period, lowest during rainy period and winter with low temperature and

iii) They prevail throughout the year with drastic reduction in population during adverse period.

3.1.2. GREEN FLY

This insect is highly polyphagous infesting several cultivated crops. *E. flavescens* attacks tea in Bangladesh, China, Japan and Vietnam, but it is rarely seen on tea in south India (Muraleedharan, 1991). It is widely distributed in all the tea growing district of North East India including Darjeeling. It was reported from plains of North–East India where the insect occurred throughout the year. During cold weather very few active stages were found on pruned and deep skiffed tea bushes while a large number of them occurred in unpruned, newly planted young tea, and nursery having some new growth. The pest was found more active during March-July. Along with increase in temperature from March the insect multiplied rapidly to become severe in May – June. The infestation continued up to July. From August the population suddenly declined to a negligible number followed by a slight increase in November. The attack however commenced later in Darjeeling, where June – July was regarded as the green fly season (Anonymous 1994). Andrews (1923) also reported that the seasonal cycle of greenfly synchronized well the flushing period of the bushes.

E. formosana, the important pest of tea in Taiwan, was reported to cause heaviest damage from May to July which varied with tea variety (Chen *et al.*, 1978).

The green leafhopper, *E. pirisuga* was found to attack tea in china. Zhang *et al.* (1994) reported that the population density of tea jassid (*E. pirisuga*) in tea field of China was negatively correlated with the thickness of the palisade tissue, the spongy tissue and the hypoderma and the number of collenchyma layer in the undersurface of the main vein of tea shoots. The population density was found significantly and negatively correlated to the caffeine content and the soluble protein content of the shoots. A very significant and positive correlation existed between the damaging index by the pest and the amount of pubescence on tea shoots. Cheng and Cheng (1994) using the data from 9 years' observation on population of *E. pirisuga* on tea in China and related meteorological data found that the sum of 10-day average temperatures in January and February as the most appropriate factor for use in a regression equation to predict the date of the start of the first population peak of the pest. Two peaks of population of *E. perisuga* were reported to occur annually in china on tea, the first peak causing serious damage to tea production in April (Lu, *et al.* 1994).

The peak period of adult occurrence of *E. onukii* in tea field of Japan was in early July, based on captures with yellow sticky traps (Mochizuki, *et al.* 1994).

Working on incidence of *E. kerri* on pigeonpea cultivars, Sekhar *et al* (1993) reported that among the different weather factors, daily mean temperature and relative humidity (morning) had significant positive influence on the population of *E. kerri.* A good rainfall followed by a dry spell with daily mean temperature in the range of 17 – 28 ^{0}C was found favourable for *E. kerri* on pigeon pea cultivars. The population increased as the crop growth progressed with a peak from first fortnight of September to first fortnight of November.

3.1.3. APHID

The tea aphid, *Toxoptera aurantii* Boyer de Fons (Homoptera, Aphididae) is one of the most polyphagous pests attacking a number of cultivated crops. It is one of the most common pests in tea and widely distributed throughout the tea growing district of North-East India. In plains, pruned tea was reported to suffer from mid January onwards because during that period migration of winged aphid started and they settled on almost all the new growth of buds and shoots (Anonymous 1994). At Tocklai, Assam, India, it was observed that the alate females started appearing in winter months during January–February, with a highest population in February, followed by a gradual decline until August when an increase was noticed. The highest and lowest populations were recorded in the outer and inner zone of tea bushes (Das and Kakoty, 1992). Sannigrahi and Mukhopadhyaya (1993) also reported from Darjeeling plains that the months of February and March appeared to be favourable for incidence of aphid on four tea clones studied namely, TV1, TV18, TV 25 and TV 26 followed by a higher incidence during the month of July excepting that on TV 1.

Han (2002) reported that in Chinese tea garden *T. aurantii* generally reproduced 20-30 generations, whilst the young tea shoots sprouted four or five times per year and therefore always remained colonized by aphid population.

3.2. ALTERNATE HOST

Alternate hosts play a very important role in maintaining the life cycle of any pest by supplying food during the period of paucity in the main host. Van Emden (1965) had cited about 442 examples of weeds or wild plants as hosts of crop pests or disease organisms. Alternative host plants are particularly important where the cropping season is short and followed by a cold or dry season of fallow or total replacement by a different cropping system (Van Emden, 1981). The nature of weed–crop interactions with respect to the seasonal fluctuation of phytophagous Thysanoptera has been investigated in detail. Ananthakrishan and Thirumalai (1977) have mentioned the role of the weed *Chloris barbata*, abundant in *Pennisetum typhoides* fields as an alternate host of *Chirothrips mexicanus*. The inflorescence of *Echinochloa crusgalli* also harbours numerous adults and larvae of *Haplothrips ganglbaueri*, the weed acting as an important alternate host for the thrips in paddy fields. *Caliothrips indicus* an important thrips pest of groundnut, *Arachis hypogaea* was also found to colonize in large numbers on the weed host *Achyranthes aspera* (Daniel *et al.*, 1984), almost throughout the year although its infestation on *A. hypogaea* was seasonal.

However, there was no record available on any alternate host of the thrips species *M. setiventris* under this study. The greenfly (*E. flavescens*) was also reported to attack castor (Regupathy, 1989, Anonymous, 1980) other than tea. The aphid *T. aurantii* was observed to attack a number of hosts like citrus (Anonymous,1980, Regupathy, 1989), jackfruit, coffee (Regupathy, 1989) etc, but it is most common on citrus and is commonly known as citrus aphid.

3.3. NATURAL ENEMIES OF TEA PESTS

Muraleedharan *et al.* (2001) recently published a detailed list of parasitolds and predators of tea pests in India. They reported that an array of parasitic and predatory arthropods was active in the tea ecosystem. Predatory mites belonging to Acaridae, Anystidae, Ascaidae, Bdellidae, Cunaxidae, Phytoseiidae and Stigmaeidae fed on phytophagous mites. Aelothripids and thripids were the main predators of thrips and mite pests. Coccinellidae, Carabidae and Dermestidae had several representatives feeding on mites, aphids and scales. Many anthocorids, pentatomids, reduviids and lygaeids acted as general predators in tea fields. Members of Chrysopidae, Hemerobiidae and Coniopterygidae were the natural enemies of aphids, spider mite, and microlepidoptera. Under Diptera syrphids larvae were the main aphid predators. Parasitic Diptera included species of Tachnidae, Muscidae and Sarcophagidae. There were large numbers of hymenopteran parasitoids exerting control over caterpillar pests. Aphelinids, aphidiids, bethylids, braconids, ceraphronids, chaicidids, elasmids, eulophids, eurytomids, ichneumonids, pteromalids and scelionids played a vital role in the suppression of several lepidopterous pests. Das and Mukhopadhyay (2002) and Anonymous (2003 b) listed the natural control agents that were active in Darjeeling Terai, Dooars and lower elevation of Himalayan foot hills. In these areas, aphids, jassids and thrips were found to be predated by both adult and grub of coccinellids, *Coccinella septempunctata, Coccinella transversalis, Scymnus* sp.; *Aspidimerus circumflexa* (NR), *Oenopia sexareata* (NR) *and Ola* sp. (Anonymous 2003 b). The above workers also reported that the minor status of many of the tea pests in India was obviously due to the influence of biocontrol agents.

3.3.1. COMMON THRIPS

No earlier record was found on natural enemies of Darjeeling thrips - *Mycterothrips setiventris*. Muraleedharan *et al.* (2001) reported from South India that nymphs and adults of tea thrips *Scirtothrips bispinosus* was attacked by predators – *Aeolothrips intermedius*, *Mymarothrips garuda*, *Anthocoris sp.* and *Orius sp.* Predation of *Scirtothrips dorsalis* by the geocorid predator *Geocoris ochropterous* Fieber has been reported by Sannigrahi and Mukhopadhyay (1992). The predators of *Scirtothrips* spp. on tea in Kenia included Araneae, coccinellids, syrphids and formicids (Sudoi, 1987).

3.3.2. GREENFLY

A study on mortality of *Empoasca vitis (=flavescens)* caused by natural enemies in Hunan, China revealed that spiders were the most effective predators (Zhang *et al.* 1992). Chen (1992) also observed in laboratory that *E. pirisuga* was one of the main preys of spiders.

E. onukii was reported to be a major pest of tea in Japan, which was attacked by the egg parasite *Anagrus* sp. (Takagi,1978).

3.3.3. APHID

Extensive works were done on natural enemies of tea aphid, particularly on its predators and parasitoids. In Chinese tea field, population of the ladybug, *Leis axyridis* (Coleoptera : Coccinellidae), closely followed the population of tea aphid, especially from May to July and September to November. Under laboratory conditions, an adult of the lady bug could consume 90-110 tea aphids and an adult of the lacewing, *Chrysopa septempunctata* (Neuroptera, Chrysopidae) could consume 80-100 tea aphids. The aphid parasite, *Aphidius* sp. (Hym., Braconidae, Aphidiinae) also attacked both nymphal and adult aphids. The average percentage of parasitism was around 10 % in May to June and 15 % in September to October. The pattern of parasitisation usually appeared to be highly aggregated with parasitism on groups of adjacent tea branches reaching over 90 % (Han, 2002).

In tea field of Tocklai, Assam, as high as eleven species of coccinellids attacking tea aphid were recorded. They were *Cryptogonus bimaculata* Kapur, *Scymnus* sp., *Coleophora biplagiata, Verania vincta*, *Menochilus sexmaculatus*, *Coccinella repanda*, *Leis dimidiata* var *quindecimmaculata*, *Leis dimidiata*, *Paeudaspidimerus circumflexus*, *Coccinella septempunctata* var *divaricata* and *Jauravia quadrinotata*. The feeding capacity of an adult of different species in its life span was found within the range of 1300 – 7640 aphids. The syrphid predators found to feed on tea aphid were *Syrphus balteatus*, *Syrphus serarious*, *Paragus indicus*, *Paragus verburiensis*, *Xanthogramma scutellare*. and *Asarcina aegrota*. The feeding capacity of the individual larva during the larval period was 305 – 590 aphids. The larvae of ant-lion, *Micromus timidus* Hagen (Hemirobidae, Neuroptera) was also recorded to feed on tea aphids with a maximum feeding capacity of an individual larva up to 116 aphids. The internal parasites *Aphelinus* sp. and

Trioxys sp. were also found to parasitized tea aphid at Tocklai. The degree of parasitism varied in between 4-13% and 22% respectively by both the species (Das and Kakoty, 1992).

Excellent natural control of *Toxoptera aurantii* by coccinellid, syrphid and hemerobid predators and aphidiid parasitoids was reported by Radhakrishnan (1989) from South India. Muraleedharan (1991) and Muraleedharan *et al.* (988 and 2001) also from South India, reported that the tea aphid was to a very large extent naturally regulated by bio-control agents, namely the larvae of syrphids – *Paragus tibialis*, *Episyrphus balteatus*, *Betasyrphis seratus*, *Allobaccha nubilipennis*, *Ischiodon scutellaris*, and *Dideopsis aegrota*; the coccinellids – *Cryptogonus orbiculus*, *Jauravia pubescens*, *Lemnia bissellata*, *Menochilus sexmaculatus*, *Pseudaspidimerus circumflexus*, *Scymnus pyrocheilus*; the neuropteran, *Micromus timidus* and the braconids *Aphelinus* sp., *Aphidius colemani, Lipolexis scutellaris, Trioxys* sp. and *Trioxys indicus* .

A large number of syrphid larvae were also recorded as active predators of aphids in lower Himalayas (Anonymous 2003 b). Mukhopadhyaya and Sanigrahi (1993) suggested *Geocoris ochropterus* as an efficient predator and control agent of tea aphids as they kill more prey than they consume. *T. aurantii* was also used as a main prey of spiders in the laboratory in China (Chen, 1992).

3.4. FEEDING IMPACT

Infestation by pests is known to cause several changes in the biochemical and physiological process of the plant affecting the yield and quality of the harvest to a great extent (Cowgill and Prance, 1989; Raffa and Berryman, 1982; and Gangnon, 1967). The changes in host plants due to pests attack may be due to mechanical damage, or certain toxic substances, and / or microorganisms injected into the host body during feeding by the pests (Carter, 1962). These pest-mediated changes are ultimately reflected in yield and quality of agricultural crops (Prestidge, 1982 and Berberet *et al.* 1981). The biochemical changes occur in host tissue as a result of antiherbivore defenses is becoming an important area of research (Lawton and Strong, 1981). It is now clear that many of the plants secondary metabolites protect the plants against attacks of herbivores and pathogens by interfering with their growth or germination (Rice, 1974). From the studies in the recent past a lot has been learned about the expression of plant defenses following insect attack (Green and Ryan, 1972; Karban and Baldwin, 1997; Mathew and Douglas, 1997). Many of these herbivore-induced plant defenses were known to be triggered by the perception of tissue damage and subsequent jasmonic acid (JA) signaling. While plants clearly perceived and responded to insect-associated elicitors (Turlings *et al.*, 1990), it was observed that mechanical damage alone initiated a cascade of plant responses, many of which were regulated by jasmonic acid (JA). Though Jasmonic acid regulated developmental processes ranging from germination to flower development, but its role in plant responses to biotic stress has attracted the most attention (Creelman and Mullet, 1997). Jasmonic acid-induced secondary metabolites included alkaloids, steroids and terpenoids as well as protease inhibitors and polyphenol oxidase that were found to interfere with insect nutrition (Farmer and Ryan, 1990; Baldwin *et al.*, 1994; Hopke *et al.*, 1994; Thaler *et al.*, 1996). Many JA-induced responses were demonstrated to protect plants against future attack and could be triggered by mechanically damaging plant tissues in the absence of actual herbivory (Baldwin *et al.*, 1994; Thaler *et al.*, 1996; Thaler 1999).

Other than JA, pests feeding was also reported to stimulate the production of ethylene. (Kendall and Bjostad, 1990; Kahl *et al* 2000). Feeding by *Thrips tabaci* induced greater ethylene production in intact onions than mechanical damage alone (Kendall and Bjostad, 1990). Ethylene regulated a wide array of plant responses including root hair formation, fruit ripening, and senescence (Johnson and Ecker 1998). Ethylene was also found to coordinate dynamic plant responses to both biotic and abiotic stresses including pathogens, insects, flooding, and wind. Ethylene could both inhibit and synergize specific plant defense responses to pathogens and insects (Penninckx *et al.*, 1998; Kahl *et al.*, 2000). In tomato, ethylene acted in part by influencing the production of JA and salicylic acid (SA) during wounding and pathogen infection, respectively (O'Donnell *et al.*, 1996; 2001). Increased SA production during pathogen infection (Yang *et al.*, 1997) resulted in broad-spectrum resistance to subsequent pathogen attack, a response known as systemic acquired resistance (SAR). It was observed that JA alone did not entirely explain the differential plant responses following mechanical damage and insect herbivory. Induced nicotine accumulation was found to be primarily regulated by wound-induced JA levels (Baldwin *et al.*, 1994; 1997). The burst of herbivore-induced ethylene inhibited wound-induced nicotine accumulation by repressing the levels of a key biosynthetic enzyme, putrescine N-methyltransferase, located in the roots (Winz and Baldwin, 2001). Musser *et al.* reported (2002) that glucose oxidase, one of the principal components of the corn earworm, *Helicoverpa zea* saliva was responsible for suppressing production of nicotine in tobacco, which otherwise produced as an induced defense mechanism by wounding. The factor, Glucose oxidase converted the simple sugar glucose into gluconic acid and hydrogen peroxide which reduced nicotine production by 29 and 44 percent respectively. Factors responsible for the induction of ethylene during insect herbivory have not yet been identified.

In many species of plants, systemic accumulation of leaf phenolic compounds to protect themselves from the invaders was observed (Feenstra *et al.* 1963; Feldman and Hanks, 1967; Hori, 1973). The attacked cells released factors for destruction and necrosis of neighbouring cells (hypersensitive reaction leading to metaplasia) to prevent further invasion (Hori, 1973). This might encourage release of enzyme polyphenol oxydase and peroxidase from the injured cells. In *Helopeltis theivora* infested tea leaves, the levels of catalytic enzymes, peroxidase and polyphenol oxidase were found about two times higher than that in uninfested leaves (Mazumdar, 1995). These enzymes were known to catalyze the oxidation of phenol producing quinones, which was toxic to the pests and acted as a plant defense mechanism. However, quinones were reported to be reversed to phenols by quinone reductase or transformed into insoluble brown non-toxic polymers, melanine like substances and coagulative protein complexes due to further oxidation in presence of polyphenol oxidase from the plant or parasites. Some herbivores were known to have polyphenol oxidase system in their saliva and can transform quinone, into non-toxic substances (Miles, 1968 b, 1969; Mukhopadhyaya *et al.* 1997). Similar observations were made by Ishaaya (1971) and Hori (1973) in lemon buds infested by *Aonidie aurantii* and sugar beet leaf by *Lygus disponsi* respectively.

Wickremasinghe (1974) reported a positive role of sucking pests in flavour development by reducing chlorophyll content of the fresh tea leaves.

The emission of volatile compounds due to pest feeding has been well documented in some recent studies and large number of volatile compounds has been identified with their biosynthetic pathways as potential mediators of plant-insect interactions. It was reported that wounding by pests generated green leaf volatiles, such as mixtures of C6 alcohols, aldehydes and esters, through a lipoxygenase pathway mediated oxidation of membrane-derived fatty acids (Blee, 1998), The shikimic acid / tryptophan pathway resulted in the nitrogen containing volatiles, such as indole (Frey *et al.*, 2000). Some volatiles were sequestered as glycosides and immediately released during insect damage through the action of glycosidases (Boland *et al*, 1992). In contrast, *many herbivore-induced volatiles showed a significant delay between the time* of feeding and detection of emission. Unlike damage-dependent constitutive volatiles, many insect-induced volatiles display delayed induction, diurnal cycling of emission, continued emission after cessation of herbivory, and *de novo* biosynthesis (Loughrin *et al.*, 1994; Paré and Tumlinson, 1997). However, the role of herbivore saliva in volatile emission and general expression of direct defenses is unknown at present.

3.4.1. GREEN FLY

The functional mouth of green fly is formed by paired mandible and maxillae, which lies at the tip of the stylet bundles. The maxillary grooves serve as two opposing tubes during feeding. Saliva is pumped downward through one of them and host fluid is sucked upward through the other. To facilitate piercing by stylet into plant tissue while feeding, the salivary enzyme is believed to dissolve or soften pectate layers of mid lamellae (McAllan and Adams, 1961). During feeding the stylet is applied to the substrate first and then the sheath material is discharged as a viscous fluid which begins to jel as soon as it leaves the styletes. The material sticks to the surface of the plant tissue surrounding the tip of the stylet bundle which fills the space between it and the labium up to the level of labial clamp (Auclair, 1963). Then a characteristic structure is formed due to rapid jelling of the secreted material. This is variously called a plug, a collar and a flange (Miles, 1959; Sylvester, 1962; Nault and Gyrisco, 1966). Utilities of stylet sheath studies in assessing host plant susceptibility to a number of leafhopper species was demonstrated by several workers (Miles, 1972; Backus, 1985; Backus *et al.*, 1988).

Earlier workers reported the relation in between leafhopper population and crop loss in many cultivated crops (Parnell *et al.*, 1949; Allan *et al.*, 1940). It was reported that a low density of leafhopper (*Empoasca fabae*) could reduce the yield of potato to a great extent and its increase did not result in a proportionate damage (Peterson and Granovsky, 1950). However, in case of *Empoasca solana*, injury of plant tissues varied directly with insect population and the plants recovered after the insect was controlled (Martin and

Pemberton, 1942).

The plant sucking arthropods were reported to inject substances into plant tissues which increased their nutritional quality. For example, the hemlpterans were observed to contain polyphenol oxidase enzymes in their saliva which oxidized the defensive polyphenolic compounds of plant (Miles, 1968a, 1968b, 1978). Mukhopadhyay *et al.* (1997) also reported that the levels of enzymes peroxidase and polyphenol oxidase in *Helopeltis theivora* infested tea leaf significantly increased by 1.87 and 1.86 times respectively of the uninfested leaf within first 12 hours of feeding. The changing proportion of the enzymes in the infested leaf tissue indicated gearing up of biochemical mechanism related to the possible resistance in the host plant.

There is a common and age old belief amongst the tea planters of Darjeeling that infestation of tea shoot in field improves flavour in made tea of Darjeeling tea. Long back Grice (1967) tried to establish the correlation in between greenfly infestation and flavour improvement in Darjeeling tea through organoleptic taste of made tea produced from greenfly infested and uninfested tea shoots, but without any biochemical analysis. However, he did not find any significant improvement of flavour in tea made from green fly infested shoots over that made from uninfested ones. But, Borah (1996) reported that polyphenolic contents of tea cultivars increased with jassid infestation. Particularly, the catechins and their gallates namely (-) Epigallocatechin gallates, (-) Epigallocatechin and (-) Epicatechin gallates were found to increase significantly with jassid-infestation in all the cultivars under study. But, the rise in their content was found to slow down gradually with high level of infestation, though their amounts in no case had been recorded less than their normal uninfested counterparts. He observed a reduction in the protein content of the jassid-infested tea leaves in all the cultivars under study (1.5% to 2.1%). This reduction in the protein content might help to develop tea quality and to increase flavanol content in such jassid-infested leaves. Because, as a result of protein flavanol interactions, insoluble compounds could be produced thus reducing the flavanol levels and affecting the made tea quality adversely. (Bokuchava and Skobeleva, 1969). An enhance in enzyme polyphenol oxydase (PPO) activities was also noticed along with the rise in polyphenolic content. Several other workers (Gagnon, 1967; Finger, 1994; Thipyapong *et al.*, 1995; Matthew and Douglas, 1997) also reported such rise in the PPO activities as a part of plants' defense mechanism. The PPO activity plays a vital role in tea fermentation (oxidation) to convert polyphenols to characteristic pigments namely theaflavin (TF) and thearubigin (TR) of black tea. It was also reported to provide protection to tea plant against pests (Wickremasinghe, 1974).

Tamaki *et al.* (1990) observed higher ratio of linalool derivatives to linalool in Pomfon oolong tea injured by the cicadellid *Empoasca onukii* than uninjured oolong and black tea, and concluded that the chemical characteristic of aroma were probably formed as a result of damage caused by *E. onukii*.

3.4.2. THRIPS

The characteristic mouth parts of thrips are asymmetrical where only left mandible is well developed. It is protected within a mouth cone and projecting downwards from the ventral surface of the head. While feeding, the left mandible is used for rasping the leaf surface and the content of the epidermal cells are sucked using the feeding tube formed by coadapted maxillary stylets.

Sections of the mouth cone including the stylet showed that the mandible is a closed tubular structure and that the maxillary stylets are grooved, i.e. C-shaped in section (Mickoleit, 1963). Grasse (1951) stated that although the maxillary stylets did not show the mutual adaptations found in the Hemiptera they formed a tube when fitted together. Grinfel'd (1959) suggested that thrips might suck food through the tube formed by the stylets in addition to applying the mouth cone directly onto the food. Mound (1971) reported the studies with stereo-electron microscope that, though single mandible was a stout structure with a solid apex, the maxillary stylets were not simple needle like structure in any of the major groups of thrips. These stylets were actually complex and mutually adapted, although in a very different way from those of Hemiptera. Lewis (1991) suggested that the mouth cone was pressed against leaf surface while feeding and as a result mandibular stylet pierced the substrate. In the mean time, maxillary stylet formed a groove through which plant sap was sucked in by the action of cibarial pump mechanism.

Working on thrips species, *Scirtothrips dorsalis* and aphid- *T. aurantii*, Mukhopadhyay *et al.*(1997) suggested that the biochemical changes occurred in tea leaf by thrips attack had certain similarities with those of the aphid infested leaf, where the protein in the vascular bundle (mid rib) area and adjacent leaf blade region got depleted. This was possibly due to constant siphoning of the leaf sap by aphid (protein could be located in the same area of the control leaf) and its break down into amino acids due to extra oral digestion process. Depletion of starches was also evident in the aphid infested leaves. But, an increase in the lipid level in the vascular bundle and especially in the dorsal layer of tea leaf tissue was apparent. Leaf protein and starch resources were found low in thrips infested leaf also. An increase in tannin level possibly indicated the gearing up of the plant defense system (Maitra 1994).

Lefroy (1909) and Antrma (1909) reported that china hybrid *jats* were more sufferer by thrips attack than "good *jats*". But it was not clear what exactly they tried to mean by good *jats*, most probably Assam type *jats*.

Mkwaila et al. (1979) reported as high as 16 % and 36 % damage by thrips in late pruned tea at two different sites respectively in Central Africa within a certain period of the season.

Some tea planters of Darjeeling are of the opinion that like greenfly, infestation of thrips also improves the cup quality of tea by increasing the flavour. However, some are of the opinion that "thrippy" tea is devoid of flavour and it is flat. Though during the quality period i.e. March to June many planters do not like to take control measures against thrips and greenfly, it is doubtful whether the crop loss is compensated by improvement in quality or not. But, all are in agreement that they cause heavy loss of crop every year in Darjeeling (Anon, 1994; Tamaki *et al*,1990).

Though some information are available on the effect of greenfly infestation on made tea quality (Borah, 1996), but nothing has been done so far to study the impact of thrips feeding on made tea quality. Hence, present study was undertaken to investigate if there is any relation between greenfly and thrips infestation and made tea quality in Darjeeling tea.

3.5. CHEMICAL CHARACTERISTICS OF TEA

A typical harvestable tea shoot is composed of ail the essential chemical and biochemical constituents like enzyme, intermediates, structural elements, flavour and colour precursors etc. and these determine the final quality of manufactured tea (Table-1). However, their level varies depending on geographic location, agronomic practices, method of plucking etc. (Wood *et al.*, 1964, Bhatia and Ullah, 1968).

The chemical constituents of tea can broadly be grouped in phenolic and non-phenolic compound as described below.

3.5.1. PHENOLIC COMPOUNDS

In tea shoots, the phenolics or polyphenolic compounds are the major constituent making up 25 -30 % of the dry weight. They are responsible to form the precursors of the non-volatile components of black tea which are essential for the character of the beverage. There are four major categories namely the flavanols or catechins, the flavonols, the flavandiols and phenolic acids and their derivatives (Millin and Rustidge, 1967).

Table 1. : Chemical composition of green tea shoots (Assam variety)

Substance soluble in hot water		Approx. Dry weight %
Flavanols	(-) epi-gallocatechin gallate (EGCG)	9-13
	(-) epi-catechin gallate (ECG)	3-6
	(-) epi-catechin (EC)	1-3
	Other flavanols	1-2
Flavonols and flavonol glycosides		3-4
Flavandiols		2-3
Phenolic acids and esters (depsides)		5
Total polyphenols		30
Caffeine		3-4
Amino-acids		4
Simple carbohydrate		4
Organic acid		0.5
Substances partially soluble in hot water		
Polysaccharides :	starch, pectic substances,	1-2
	Pentosans, etc.	12
Proteins		15
Ash		5
Substances insoluble in water		
Cellulose		7
Lignin		6
Lipids		3
Pigments (chlorophyll, etc.)		0.5
Volatile substances		0.01-0.02

Adapted from Millin and Rustidge (1967) and Borah (1996)

3.5.1.1. The flavanols or tannins

They are most important components of the tea leaf contributing to the essential characteristic of black tea like colour, aroma and flavour. In the plant, they are produced from simple reducing sugar such as glucose either by acetic acid pathway or the shikimic acid pathway (Bokuchava and Skobeleva, 1969).

3.5.1.2. The flavonols

Though flavonol compounds are quantitatively important, but seem to play a very minor role in taste due to slight astringency or woody nature. They occur as a complex mixture in the fresh tea shoot and their characteristics are changed relatively during fermentation (Millin *et al.*, 1969).

3.5.1.3. Anthocyanin

Anthocyanin are colouring pigments and conspicuous in young shoots of first and autumn flush of growth (Baruah, 1990). They play a major role in the development of characteristic colour in processed tea.

3.5.2. NON-POLYPHENOLIC COMPOUNDS

3.5.2.1. Caffeine

Tea shoot contain caffeine up to 3-4 % which is known to increase considerably during withering (wood *et al.,* 1964). The terminal bud and first leaf of a tea shoot contain highest caffeine which may range from 4 to 5 %. This may reduce to 3 % in the second leaf and to 1.5 % in the stalk. Tea seed is devoid of caffeine. The tea shoots of *assamica* are richer in caffeine then those of *sinensis* variety (Ikeda *et al.*, 1993).

Though caffeine dose not play an active role in the chemical changes take place during manufacture, but it has an important function in forming cream or precipitation formed when a tea infusion cools, which is a mixture of caffeine, theaflavin (TF) and thearubigin (TR) (Harler, 1970). Caffeine with other alkaloids like theobromine and theophyllin provide strength in a tea cup.

3.5.2.2. Carbohydrates

There are various types of carbohydrates in tea shoots like glucose, fructose, sucrose, rhamnose etc and complex polysaccharides like cellulose and hemicellulose (Bokuchava and Skobeleva, 1969). It plays the most important role in biosynthesis of polyphenols. Sugars and amino acids through non-enzymic browing reactions contribute to tea colour.

3.5.2.3. Protein and Amino Acids

Protein level is important for determining the tea quality. As a result of protein-flavanol interactions, insoluble compounds are formed reducing flavanol levels and thus affecting the quality of made tea adversely (Bokuchava and Skobeleva, 1969).

Out of the total free amino acid content in tea, theanine alone constitutes 50 %, but its role in tea quality is not clear. The other amino acids present in tea shoots are leucine, isoleucine, valine and phenylalanine.

3.5.2.4. Chlorophylls

Other than photosynthesis, chlorophyll is primarily responsible for the appearance namely blackness and brownness of made tea. It is reported that low level of chlorophyll in tea leaf as a major factor for aroma development in tea (Wickremasinghe, 1974). Low chlorophyll in plucked shoots is a desirable character to make flavoury tea in Darjeeling.

3.5.3. ENZYMES

The two main enzymes involved in tea manufacture are : (1) Pectase and (2) Polyphenol oxidase. Pectase acts on the carbohydrate in the tea leaf cell wall making them soluble. It probably functions to form a kind of varnish on the outside of the leaf which may aid in keeping quality of tea (Agarwal, 1989).

The polyphenol oxidase (PPO) is the most important enzyme which is of copper protein type and most readily acts on the catechin group of polyphenols in tea leaf to change them to orthoquinones. These orthoquinones by a process of dimerization condense to bis-flavanols and these in turn condense rapidly to theaflavins, which are yellow bodies. An additional oxidation not controlled by enzyme action transform these theafavins into thearubigins, which are red brown bodies with tanning properties.

Higher TF value in CTC teas as compared to orthodox teas is associated with higher activity of the oxidoreductase enzyme on the catechin substrate which inhibits the action of the hydrolytic enzyme, reported to be responsible for producing monoterpene alcohols in anaerobic conditions (Takeo, 1981 and Ullah and Roy, 1982).

3.6. TEA FLAVOUR AND TEA AROMA PRECURSORS

Taste and aroma both associated with the term tea flavour. Tea taste is the contribution of non-volatile compounds like catechins and their derivatives, caffeine and amino acids. It is a balanced mixture of astringency, bitterness, umami (brothy taste) and slight sweetness. Catechins and their derivatives contribute astringency and bitterness. Caffeine has simple bitterness. Amino acids contribute the brothy taste with slight sweetness or bitterness depending on amino acids. Aroma of tea is a very complicated mixture of volatile compounds, such as terpenoids, alcohols, carbonyl compounds, etc. The aroma compounds are mostly developed during manufacturing process and composition of these compounds determines the aroma of individual made tea (Yamanishi, 1999).

3.6.1. TEA TASTE

3.6.1.1. Catechins and their derivatives

During manufacturing black tea, some of the catechins are changed to theaflavis (TF) and thearubigin (TR) by enzymatic oxidation and coupling reactions. Roberts and Smith (1961) giving the terms "theaflavin" and "thearubigin" stated that TRs were equally important for flavour and quality of black tea as the TFs. TFs imparted the mouth sensation of "briskness", "freshness" and "aliveness" while TRs were responsible for "body " and richness" of tea brew. Ding *et al.* (1992) after HPLC analysis and comparing sensory analysis of five main catechins, TF and TF-gallates in tea brew of various black teas from Darjeeling, Sri Lanka, Kenya and China concluded that the total amount of catechins had a significant effect on astringency, while TF and TF-gallates had no statistical correlation with astringency. In orthodox tea, theaflavins concentration was found in between 0.59 and 1.03 % and thearubigins in between 9.34 and11.48 % (Yamanishi, 1999).

3.6.1.2. Caffeine

Pure caffeine is bitter with a detection threshold of around 3 ppm in water. But, it forms a complex with TFs and TRs in the tea brew losing the bitterness of caffeine as well as TFs and TRs. The complex product contributes to briskness or "liveliness" and thickness of black tea brew (Wood and Roberts, 1964; Millin *et. al.*, 1969). Tea tasters' evaluation for quality of tea is associated significantly with briskness of its liquor (Biswas *et al.*, 1971) and therefore caffeine is considered as one of the quality factors.

3.6.1.3. Amino acids

Theanine (N^5-ethylglutamine) concentration alone is half of the total amount of amino acid in tea leaves with an average content of 3 % by weight. The other major amino acids are glutamic acid, aspartic acid, arginine and serine (Maeda and Nakagawa, 1977; Kawagishi and Sugiyama, 1992). They give the characteristic brothy taste "Umami". It is significantly important to the taste of green tea and much research has been devoted to the study of amino acids in green tea since Sakato (1949) discovered theamine from the Japanese green tea "gyokuro".

3.6.2. TEA AROMA

The aroma components are essential oil consisting of numerous varieties of volatile compounds popularly known as "Volatile Flavour Constituent" (VFC). They are isolated from tea leaves or made tea by steam distillation and solvent extraction with a concentration of 0.01 to 0.03 % (Yamanishi, 1999). Research on aroma of tea has advanced considerably since 1960s when Gas chromatography (GC) and Mass spectrometric method (MS) are available for separation and structure determination of minor components. Subsequently, over 600 volatile compounds responsible for aroma in different types of tea have been isolated and identified (Yamanishi, 1995).

More recent research on the precursors of aroma compounds in tea has resulted in isolation of various glycosides with their absolute chemical structure (Kobayashi's *et al.*, 1993 and Sakata *et al.*,1995). It was observed that though VFC is a complex mixture, a few components with low threshold values and high concentration could make easy impact on the sensory organs such as nose and tongue to be of significance to the tea brew during assessment. These few rosy top notes from VFC viz. linalool, their oxides, geraniol, phenyl ethanol and fatty hexenals might well represent an important part of specific tea flavour (Mahanta and Hazarika, 1985).

The main sources of flavour compounds were reported as lipids (Hatanaka and Harada, 1973; Mukherjee, 1966 and Selvendran *et al.*, 1978), amino acids (Wickremasinghe *et al.*, 1979) and terpene glycosides and/or carotenes (Mukherjee, 1966, Selvendran *et al.* 1978, Wickremasinghe, 1974 and Takeo, T. 1983). These sources changed during manufacture and each change resulted in production of specific new compounds (Owuor, 1986). The major flavour compounds with their odour are presented in the table 2.

The lipids of tea leaf tissue undergo significant changes producing volatile flavour compounds during post harvest chemical changes with a chain of reactions from the time the shoots are plucked from the plant through the process of tea manufacture (Agarwal, 1989). The characteristic volatile flavour constituents are mostly formed by the hydrolytic action of enzyme on cell constituent during leaf maceration (Takeo, 1981; Renold *et al.*, 1974). Thus the processing technique largely determines the quality of black tea. In withered leaves the quantity of volatile flavour compound is low though their formation starts at this stage with lipid degradation. It gains momentum during rolling and fermentation (Hazarika *et al.*, 1984). It was reported that amino acid added to a solution of flavanols undergoing oxidation, produced VFC (Bokuchava and Popov, 1954). Wickremasinghe and Swain (1964) showed that there was an increase in certain volatile aldehydes concomitant with a decrease in the level

Table 2: Volatile flavour compounds with their odour in black tea.

Compound	Odour	Compound	Odour
1. Trans-2-hexenal	Strong greenish	11. Methylsalcylate	Oil of wintergreen
2. Cis-3-hexenal	Greenish		
3. Acetaldehyde	Malt	12. Methyl jasmate	jasmine
4. Methylpropanal (isobutyraldehyde)	Apple	13. Benzyl alcohol	Rose honey
		14. 2-phenylethanol	do
5. 2-methylbutanal	Apple & malt	15. Geraniol	Rose
6. 3-methylbutanal (Isovalavaldehyde)	Chocolate	16. Geranic acid	Rose honey
		17. Linalool	Sweet flowery
7. Methional	Potato or soy sauce	18. Linalool oxides	Do
8. Butanol	Rancid butter	19. Linalool oxide	Woody
9. Pentanol	Greenish	20. Linalool oxide	Lilly of the valley
10. 1-octen-3-ol	Stimulating (fruity)		

Adapted from Owuor (1986)

of related amino acids. These findings suggest that amino acid is involved in the formation of VFC.

Darjeeling orthodox tea has a typical muscatel aroma accompanied by a characteristic woody and complexed heavy note (Yamanishi, 1999). It was reported that in different type of black teas, the major difference in the aroma pattern remained in concentration of linalool, linalool oxides and geraniol (Yamanishi *et al.*, 1968; Horita and Owuor, 1987; Owuor, *et al.*, 1986, Mahanta and Hazarika, 1985; Hara *et al*, 1995). The specific characteristic compounds of Darjeeling tea aroma were identified as 2, 6-dimethyl-3, 7-octadiene-2, 6-diol and reported as the photosensitized oxygenation product of linalool (Kawakami, *et al.* 1995). This was also reported as the precursor of 3, 7-dimethyl-1,5,7-octatriene-3-ol (Matsuura and Butsugan,1968; Hara, 1989).

The ability of tea clones to synthesize the characteristic and essential VFC was observed to be dependent primarily on the geographical location and climatic conditions like cold, dry, windy nights (Wickremasinghe, 1974). The VFC content of Darjeeling teas were found three times higher than the plains tea in general and the amounts of essential and characteristic VFC viz. rosy linalool and its oxides and geraniol were around five times higher than plains teas. Though the nature of reaction was not very clear, but it was understood that terpenoides were synthesized better under Darjeeling weather conditions like, cold dry windy nights and humid day with relatively low temperature. There is a well defined period in Darjeeling during May–June, known as second flush, during which tea has outstanding flavour. The chinary clones were also found to be rich in linalool, geraniol, benzyl alcohol and phenyl ethanol. Different stages of manufacture like, withering, rolling, fermentation and drying have their own importance and independent contribution toward production of VFC. In orthodox manufacture, at the end of rolling a large amount of VFC was detected, which decreased as fermentation progresses. After optimum fermentation the residual substance might produce small increase in VFC (Mahanta and Hazarika, 1985). It was observed that the orthodox tea contain twice the amount of VFC present in CTC teas (Takeo and Mahanta, 1983)

The flavour of CTC tea was found inferior to that of orthodox black tea due to the presence of high level of carbonyl compounds such as (E)-2-hexenal (grassy aroma) and the low concentration of floral and fruity aroma components, such as linalool, linalool oxides, (z)-3-hexenyl esters and other desirable compounds (Takeo and Mahanta, 1983). Higher theaflavin (TF) content in CTC teas as compared to orthodox teas was found to be associated with higher activity of the oxido-reductase enzymes on the catechin substrate which inhibited the action of the hydrolytic enzyme reported to be responsible for producing linalool and its oxides and methyl salicylate in triturated tea leaf tissues under anaerobic conditions (Takeo,1981).

Materials And Methods

IV. MATERIALS AND METHODS

4.1.SELECTION OF SITES AND PLANTING MATERIALS

Two sites were selected at mid (TRA, Clonal proving Station, Ging at 1200 m amsl) and high (Sungma tea estate at 1650 m amsl) elevations for the study, as difference in elevation has great influence in tea cultivation in Darjeeling. The experimental areas are located at 27^0-17′ N Latitude and 88^0-19′ E Longitude.

Two types of planting materials selected for the study were :

1. The common china seed *jat* (Fig. 7A)

2. A popular china hybrid clone – Tukdah 78 (Fig. 7 B).

The characteristics of both the materials under study are presented in table 3.

Table 3 : Characteristics of the planting materials (Singh, 1989)

Name	Genotype	Leaf type	Frame	Yield	Flavour
China seed jat	seed	Erect , small	Compact, multistemmed	Low	Very good
TRA/ Tukdah 78	Clone	Erect, medium	Widely spreading	High	Good

Fig. 7A: A bush of China seed jat

a → small size leaves
b → compact frame with multistemmed collar

Fig. 7B: A bush of T 78 clone

a → medium size leaves
b → widely spreading frame with single stemmed collar

4.2. POPULATION DYNAMICS

Initial attempt was made to study the population dynamics of four major sucking insect-pests of tea, namely Common thrips, greenfly, aphid and tea mosquito bug active in Darjeeling tea. But infestation of tea mosquito bug was not noticed in any of the two sites selected at mid and high elevations during any of the three seasons under study. Hence, later on the study was confined to three other species namely common thrips [*Mycterothrips setiventris*, Bagnal, (Thripidae: Thysanoptera)], greenfly [*Empoasca flavescens* Fabricius (Cicadellidae: Homoptera) and aphid [*Toxoptera aurantii* Boyer de Fons (Aphididae: Homoptera)] excluding tea mosquito bug.

4.2.1. IDENTIFICATION OF THRIPS SPECIES

At the beginning of the study on population dynamics, it appeared that more than one thrips species were associated with tea in Darjeeling. Hence, it became essential to identify the actual thrips species involved as the major pest of tea as an off shoot study. As all the thrips species were very minute soft bodied insect with an adult size of around 1.25 – 1.5 cm long, the specimens had to be mounted in slides to send for identification. The following procedure for processing the specimen was adopted :

1. Specimens of different thrips species encountered during initial observations in the field were collected and preserved in 70 % ethanol.

2. The specimens to be mounted were taken out from the preservative and put in 5 % KOH for 3-4 hours to make them soft and transparent by

dechitinization.

3. From KOH solution they were put in water for 10-15 minutes to remove KOH.

4. From water the specimens were put in 70 % alcohol for 15 minutes, then in 90 % alcohol for 15 minutes and finally in 100 % alcohol for 30 minutes.

5. From 100 % alcohol specimens were put in xylol for 15–20 minutes. Thereafter, they were checked whether they became transparent or not, if not, they were put back in 100 % alcohol and then Xylol again to make them transparent up to the desired level.

6. The above dehydrated specimen was put on a DPX drop singly on a clean glass slide. Antennae, wings, legs, and other structures of the specimens were oriented in proper position using needle under a binocular microscope (Wild M3). The DPX drop (with the specimen) on the glass slide was covered gently with a cover slip.

7. The ready slides with the specimen were dried adequately in oven and then used for taxonomic study and sending to the experts for identification.

The thrips species infesting tea shoot was identified by expert as *Mycterothrips setiventris* (Bagnall) and so the present study was confined to this species of thrips.

4.2.2. LAYOUT OF THE EXPERIMENTAL PLOTS AND SAMPLING METHODS

To study population dynamics, the field experiment was laid out in randomized block design with three replications. For this purpose, three plots having 100 tea bushes in each plot were randomly selected for both the planting materials at both the sites. These plots were kept totally out of any pesticide treatment to study the population dynamics under natural condition. A similar set of plots was also selected 50 m away from the first set to study the population dynamics under pest control measures. Insecticide (Endosulfan 35 EC) was applied in these plots as soon as infestation was noticed as per garden practice.

The plots were maintained under unpruned conditions (no pruning or skiffing was done at the end of the season) and normal weekly plucking was done after collection of samples in each week. Other cultural practices like manuring, weed control etc. were followed as per garden practices recommenced by Tea Research Association.

Weekly observations were taken on the population of the three sucking insect-pests under study on insecticide treated and untreated plots separately for 3 consecutive years from 1999 to 2001. Initially the sampling method as defined by Le Pelley (1942) for thrips and other small insects on the coffee leaves was tried. But it was found to be cumbersome, time consuming and ineffective. Subsequently the following method was followed :

Since all the three sucking pests were chiefly associated with the growing shoots on the plucking table of the bushes, 10 growing shoots (Bud with 2 leaves below) were plucked randomly in each plot, replicated thrice, in each weekly observation. Each shoot immediately after plucking was put in a small polythene packet. The open end of the packet was tied with a rubber band immediately after putting the shoot inside. The packets with shoots were carried to the laboratory of Tea Research Association, Darjeeling. Then each shoot was examined for the 3 sucking insects under study. The total number of adults and nymphs were counted for each species and tabulated for future analysis. Dissecting binocular microscope and hand lens were used to count the small immature ones. Similar sampling methods have been used in study of population abundance of insect pests by Sasidhar *et al.* (1999), Sannigrahi and Mukhopadhyaya (1993) and Atwal and Singh (1989).

4.3. ALTERNATIVE HOST

To study the alternative hosts of the above three pest species, regular observations were done on the weeds and tree species in and around the tea estates of Darjeeling. The plant species found infested by any of the pests under study were recorded.

4.4. COLONIZING AND FEEDING IMPACT

Investigation on the feeding impact of common thrips and greenfly on made tea quality was conducted at mid-elevation with the facilities available at the laboratory-cum miniature manufacturing unit of Clonal Proving Station (CPS) of Tea Research Association (TRA) at Ging, Darjeeling.

4.4.1. PREPARATION OF MADE TEA SAMPLES

Made tea samples were prepared at TRA's Miniature Factory at CPS

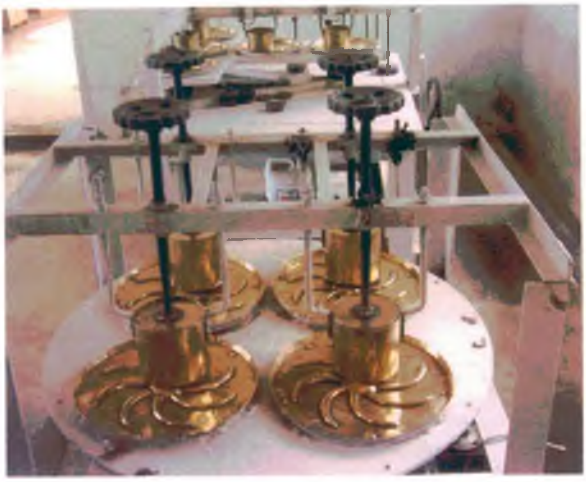
Ging (Fig. 8) during peak infestation period of the pests in the year 2002. Thrips and greenfly infested shoots of top bud and two leaves below under natural conditions in the field were plucked separately for each of these sucking pest (exclusively) with extreme care for both the planting materials. Around 600 gm green leaf was plucked for each sample. Same quantity of infestation free shoots was also plucked from the insecticide treated plots separately for each planting material and each sample under identical field conditions as control for comparison. In total, there were 4 replications of infested and uninfersted leaves each for greenflies and common thrips on both the planting materials.

In each set of manufacture, there were three replications of 200 g green leaf for each sample of 600 gm green leaf to avoid heterogeneity in manufacture. After manufacture the made tea of all the replications of each sample was mixed together and considered as one composite sample. In total 130-135 gm made tea was prepared from one green leaf sample of 600 gm with around 22-22.5 % recovery. Procedure followed to manufacture the made tea samples is given hereunder.

4.4.1.1. Withering

It was the first step of manufacture. The freshly plucked shoots were kept for 12-16 hours spread uniformly on withering trough to remove 65 – 68 % moisture from the leaves *i.e.* 100 g green leaf is reduced to 35 to 32 g withered leaf.

Withering trough



Rolling tables

Fermentation

Dryer

Fig. 8 : Miniature manufacturing factory at TRA, CPS, Ging

4.4.1.2. Rolling

In this step the cell walls were ruptured to mix polyphenol and polyphenol oxidase which were located separately in a tea leaf cell. The withered tea shoots were rolled in a miniature roller for 35 to 50 m by application of light to medium pressure.

4.4.1.3. Fermentation

In true sense it was not fermentation as no microorganism was involved, but an oxidation reaction. In this step, the oxidation reaction was completed, through conversion of polyphenol to secondary metabolites namely theaflavin (TF) and thearubigin (TR) in presence of the enzyme polyphenol oxidase, which worked as catalyst. The rolled leaves were kept spread on aluminium trays in a cool humidified room. The process started right from beginning of rolling to charging of leaf in dryer. Depending on room temperature and humidity the time required to complete fermentation was 1.5 – 3 hours.

4.4.1.4. Drying or firing

As soon as fermentation was completed the materials were dried in trays separately in small dryer maintaining an inlet temperature of 115 ^{0}C to 120 ^{0}C. The outlet temperature was 20-25 ^{0}C lesser than inlet temperature and time requirement was 20-22 minutes. The moisture content was reduced to 3-4 %. The dried leaves were called dryer mouth samples.

The tea leaf samples prepared by the above procedure were divided into two parts, one part was utilised for organoleptic taste and other for Biochemical analysis at the laboratory of Biochemistry Department, Tocklai Experimental Station (TRA), Jorhat, Assam.

4.4.2. ORGANOLEPTIC TASTE

One part of the made tea (30 g) of each sample prepared by the above method was utilized for traditional organoleptic taste (tasting by mouth). It was divided into 3 equal parts of 10 gm each and sent to three different tasters of Darjeeling for organoleptic taste with four replications. Mainly flavour, liquor, and quality of made tea were tasted to see the difference between uninfetsed and infested shoots by thrips and green fly. The volatile flavour constituents (VFC) present in made tea are known to play a crucial role in the organoleptic evaluation.

Flavour: This is the most important parameter in case of Darjeeling tea. Flavour is defined as a desirable and most apparent aroma in tea liquor perceived through the mouth and distinguished through the nose. All teas have flavour, but it varies depending on the planting material, location, plucking standards, processing procedure, pruning cycle etc. Darjeeling tea has typical pronounced rosy or muscatel flavour, which is the main characteristic of Darjeeling tea. It is more in china type (*Camellia sinensis* var. *sinensis*) and China hybrid tea than Assam type (*Camellia sinensis* var. *assamica*) tea. Higher the elevation of tea area more is the flavour in general.

Liquor: The following terms are used to express overall characteristics of tea liquor :- bakey, body, brisk, bright, character, coarse, colour, common, cream, dull, dry, flat, flavour, full, harshness, hay, heavy, high-fired, hungry, light, malty, neutral, nose, plain, pungent, quality, soft, sour, stewed, strength, thick, thin and weathery.

Quality: Quality is defined as the essential characteristic of a good tea. Subjectively "quality" is a versatile term and generally refers to consumers overall acceptability of a type of tea brew. The consumers acceptability of a tea drink can in ultimate analysis be attributed to biochemical constituent in the shoot, as well as the finished product as formed during processing through interactions with various enzymes which results in the development of desirable aroma and gradual loss of greenness (Hazarika *et al.*, 1984)

4.4.3. BIOCHEMICAL INVESTIGATIONS

One part of each made tea sample (100 gm) was utilized for biochemical analysis at Biochemistry laboratory, Tea Research Association; Tocklai. Biochemical investigations were made to see the variation in different biochemical parameters in made tea manufactured from thrips and jassid infested and uninfested tea shoots at the laboratory of Tocklai Experimental Station, Tea Research Association, Jorhat, Assam. The residual catechins, caffeine and volatile flavour compounds in made tea were estimated using HPLC and GC as per the procedure laid down below.

4.4.3.1. Estimation of individual catechin and caffeine – Method using HPLC (ISO Method)

Catechins and caffeine were extracted by refluxing 0.2 g of test sample with 70% (v/v) methanol at 70 ^{0}C. The extract was five times diluted with stabilizing agent containg 1 % acetonitrile, 0.02 % EDTA & 0.02 % l-ascorbic acid. Individual catechin and caffeine were estimated by injecting 10 µl of diluted test solution in HPLC using Luna-5µm phenyl hexyl column by HPLC. Mobile phases were : a) 2% Acetic acid, 9% Acetonitrile and b) 80% Acetonitrile.

Flow rate: 1 ml/min.

Detector: UV detector set at 278 nm.

Binary gradient conditions were 100 % Mobile Phase for 10 min, then over 15 min a linear gradient of 68 % of Mobile Phase A and 32 % of Mobile Phase B and held at this composition for 10 min.

Amount of Individual Catechins and caffeine were determined by comparing the areas given by the test sample with the areas given by individual standard Catechins under similar chromatographic conditions.

4.4.3.2. Estimation of Volatile Flavour Constituents (VFC) Method using GC

With the use of modern analytical technique like gas chromatography (GC) it is possible to detect VFC up to less than one million of a gram (10^{-6}g), which is helping enormously in understanding the role of VFC in tea quality (Mahanta and Hazarika, 1985). The following procedure was followed to study the VFC in orthodox black tea made from pest infested and uninfested tea shoots.

Fifty grams of made tea was steam distilled for 45 min in Steam Distillation Apparatus. The distillate obtained was transferred into a Separating Funnel and saturated it with NaCl. The distillate was extracted for 3-4 times with 50 ml of each of methylene chloride. The organic layer (150-200 ml) that contains VFC is concentrated under reduced pressure at 40 ^{0}C. The concentrated organic layer is transferred to a graduated eppendrops tube and further concentrated to 100 µl by purging N_2 gas.

Protocol for Extraction and Estimation of VFC by GC : The concentrate from the above were analysed for VFC profile by Varian GC, Model 3800 with FID. The instrument condition is given below:

Detector:	FID
Column:	CP Wax 52, 50m x 0.32mm and 0.22µ film thickness.
Split:	1 : 100
Inject Volume:	2 µi

Oven Temp. Program:	50 ^{0}C hold for 15 min, 2 ^{0}C /min up to 220 ^{0}C, hold for 20 min with a total runtime of 120 min.
Detector Temp.:	250 ^{0}C
Injector Temp.:	220 ^{0}C
Carrier gas flow:	1.2 ml/min & make up 30ml/min.
Air flow rate:	300 ml/min
H_2 flow rate:	30 ml/min

4.5. NATURAL ENEMIES

4.5.1. SURVEY BY SUCTION MACHINE

To study the natural enemies samplings were done during 2001 using "*D-Vac vacuum insect net*" in different tea estates of Darjeeling when the pests under study were active. "D-*Vac vacuum insect net*" is a petrol-operated machine, which works on vacuum suction principle. While in operation, air was sucked through a large flexible rubber hose of 20 cm diameter with a mouth of 33 cm diameter fitted with a nylon cloth bag. The mouth of the hose was placed on the tea bushes for few minutes and small organisms including mobile insects were sucked in along with the airflow. The insects and other organisms with dried leaves, twigs etc were collected in the nylon bag.

In total 5 bio-organic and 5 conventional tea estates were covered at different valleys to study the difference in their population between gardens under bio-organic and conventional farming system. In each estate, 3 samples (replications) were taken at mid elevation at 1200 m above mean sea level (amsl) and 3 at high elevation at 1650 amsl to know the difference in population of natural enemies at different elevations. Each sampling was done for 15 minutes. Everything collected in nylon bag during each catch was transferred to a polythene bag of 30 cm X 60 cm size. All the catches were taken to TRA Darjeeling and kept in deep freeze for 2 to 3 hrs to kill the living organisms. Then numbers of different species observed were noted and sent for identification where necessary.

The data was subjected to "Student t " test whenever necessary to see if the difference in their population mean was statistically significant or not.

4.5.2. SURVEY BY MANUAL SEARCH

Intensive manual search was also carried out to observe the natural enemies not collected by D-Vac insect net. The sucking insects were collected at their peak level of infestation along with all other organisms associated with them in polythene bag followed by observation in the laboratory.

4.5.3. BIOLOGICAL NOTE AND IDENTIFICATION

Different stages of the natural enemies encountered in the field were collected and reared up to possible extent in the laboratory of tea Research Association, Darjeeling to make observations on the morphology of different stages, feeding capacity, style of feeding and for identification.

4.6. METEOROLOGICAL DATA

The meteorological data were collected from the nearest weather recording facilities at both the sites, and these were correlated with the population incidence of different pests. At mid elevation (TRA-CPS, Ging) meteorological data on rainfall, maximum temperature, minimum temperature, relative humidity in the morning, relative humidity in the afternoon and sunshine hours were available for the study. But, at high elevation (Sungma tea estate) met data were available only on rainfall, maximum temperature and minimum temperature.

4.7. LABORATORY USED

The laboratories of Zoology Department, University of North Bengal; Tea Research Association (TRA), Darjeeling Branch, and Biochemistry Department, Tocklai Experimental Station, TRA, Jorhat were used for different purpose during the course of study.

4.8. IDENTIFICATION OF SPECIES

Identification of insect-pests, parasites and predators collected for the present study were done using literature available at the laboratories. In cases of difficulties, preserved specimens were sent to different experts for identification as far as possible.

4.9. PHOTOGRAPH

Close up as well as microscopic photographs were taken where necessary for documentation using Ashai Pentax SLR camera and micro photo binocular attachment.

4.10. STATISTICS USED

Statistical analysis was done following the guidelines from Gomez and Gomez (1984). Two online statistical packages, "Analyse-it" and "Smith's statistical package" were used to analyse the data, where necessary. The details of statistical analysis done were explained under results and discussion of each item.

Results and discussion

V. RESULTS AND DISCUSSION

5.1. POPULATION DYNAMICS

Population dynamics of three sucking insect-pests of tea, common thrips, greenfly and tea aphid were studied from 1999 to 2001 on two different planting materials of tea namely China seed *jat* and clone T 78. The study was conducted at two different sites at mid and high elevations in Darjeeling. Observations were made separately under two different conditions, with and without pest control measures. The data obtained (Appendix I to IV) were statistically analyzed wherever applicable and discussed.

5.1.1. COMMON THRIPS – *Mycterothrips setiventris* bagnall

5.1.1.1. COMMON THRIPS POPULATION (WITHOUT PEST CONTROL MEASURE)

5.1.1.1.1. Seasonal fluctuation

The weekly count of population of common thrips on two different planting materials at mid and high elevations is presented graphically along with weather data in figures 9 to 12. The mean values of the counts for three years (1999-2001) have been used.

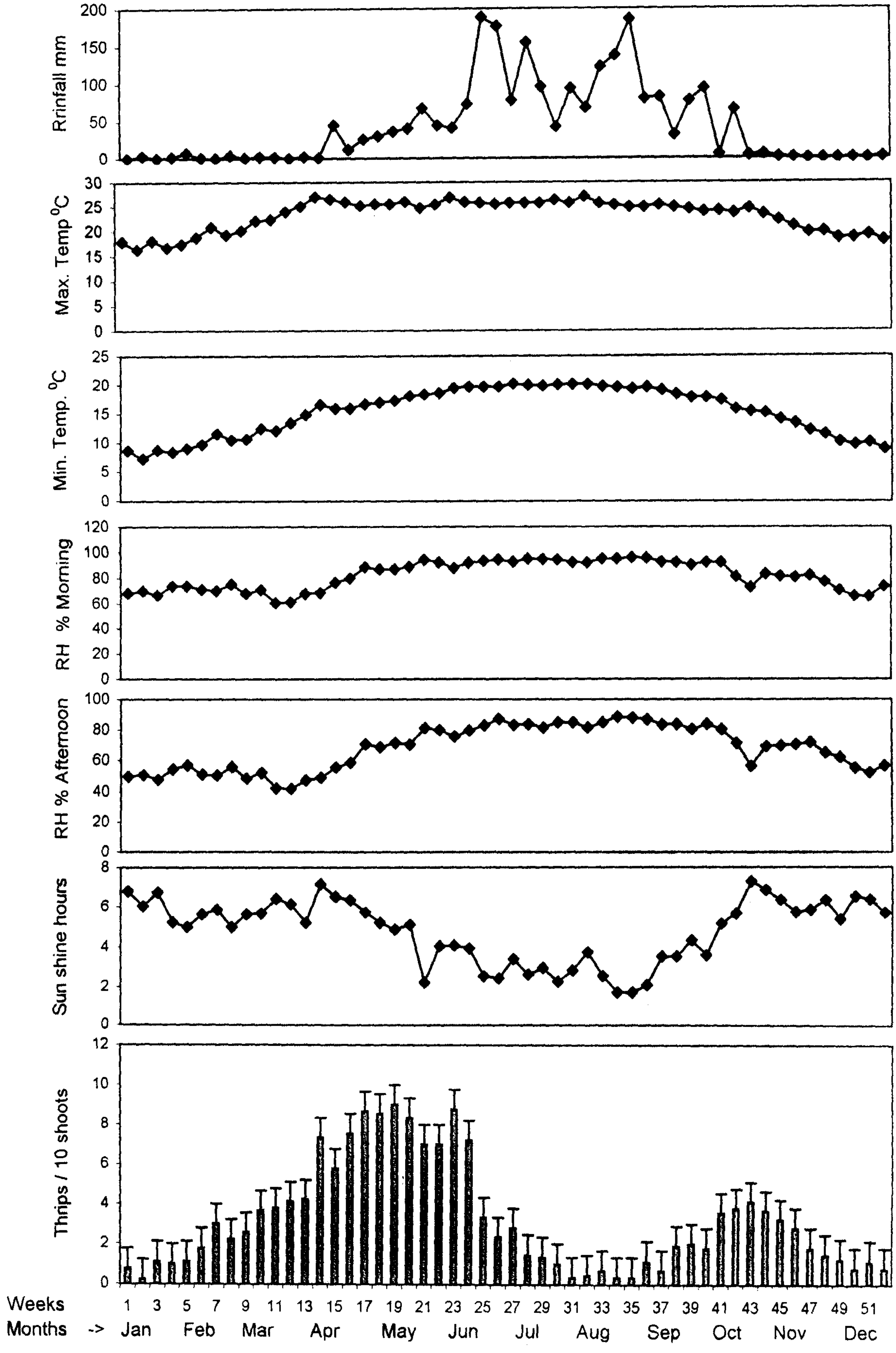


Fig. 9: Weekly changes in population of *M. setiventris (Mean + SE of 3 yrs, 1999-2001)* on **china seed jat** of tea at **mid elevation** with **a**verage weather data

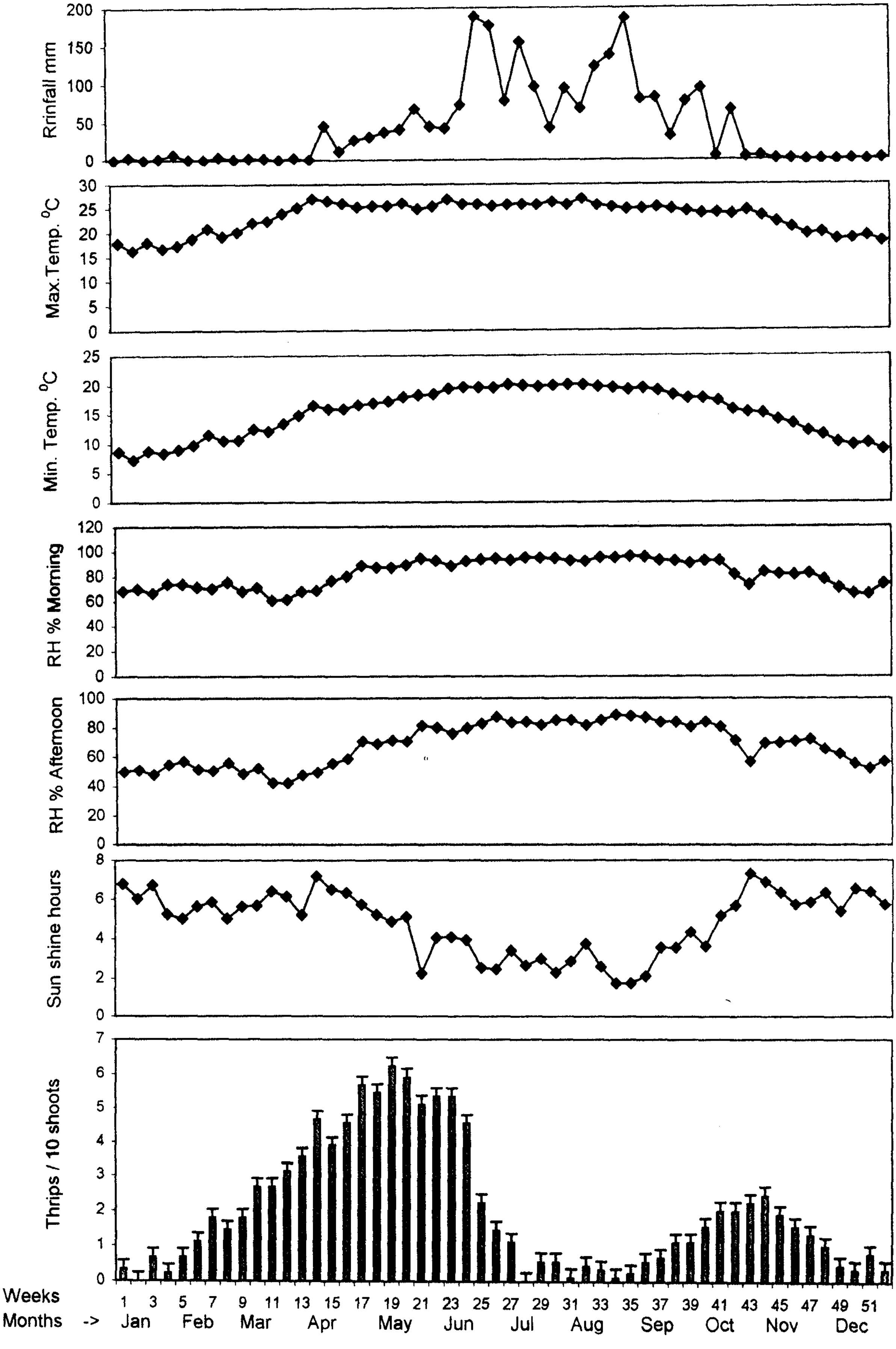


Fig. 10: Weekly changes in population of *M. setiventris (Mean + SE of 3 yrs, 1999-2001)* on tea **clone T 78 at mid elevation** with average weather data

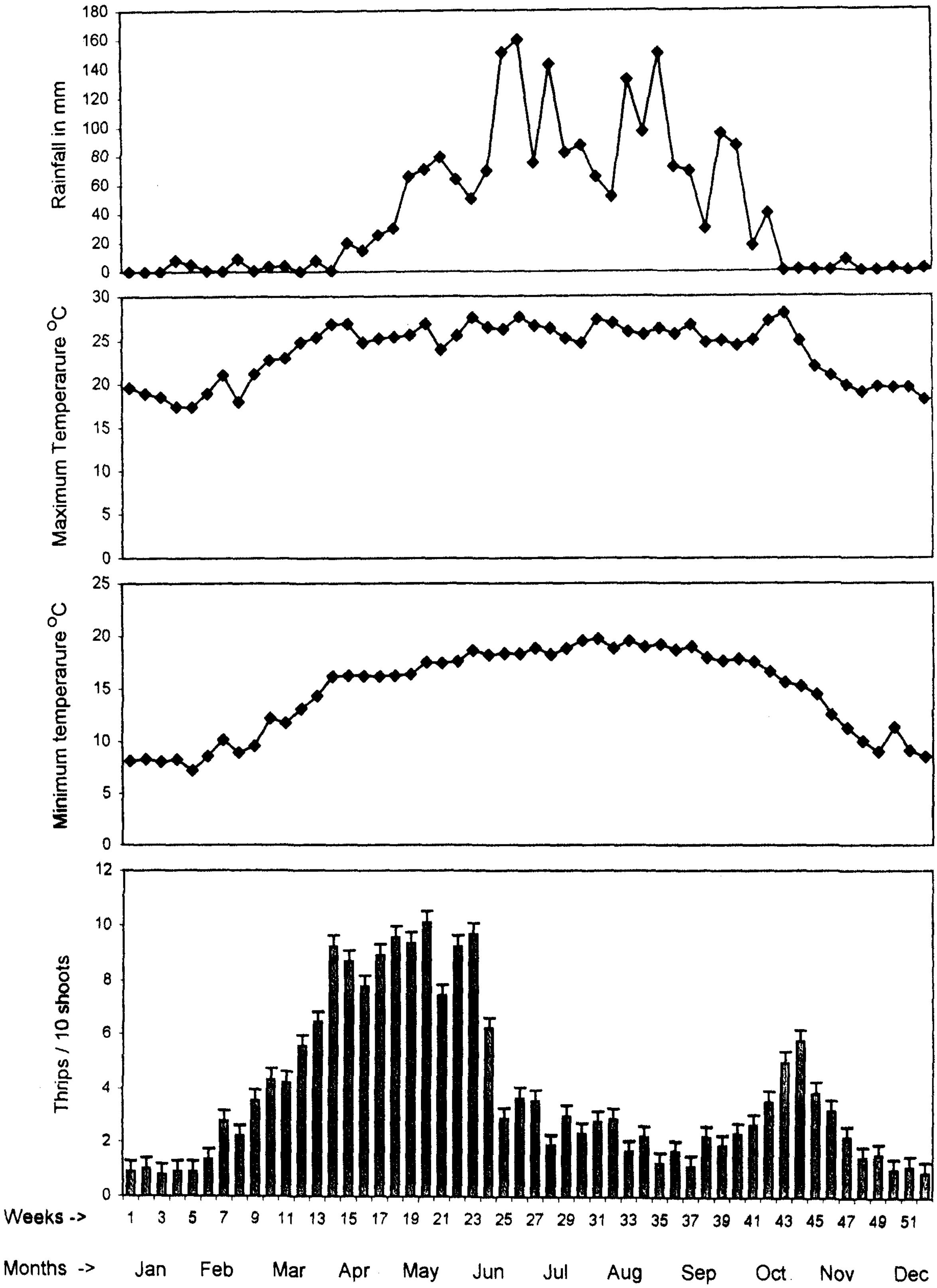


Fig 11: Weekly changes in population of *M. setiventris* (Mean + SE of 3 yrs, 1999-2001) on **china seed jat** of tea at **high elevation** with average weather data

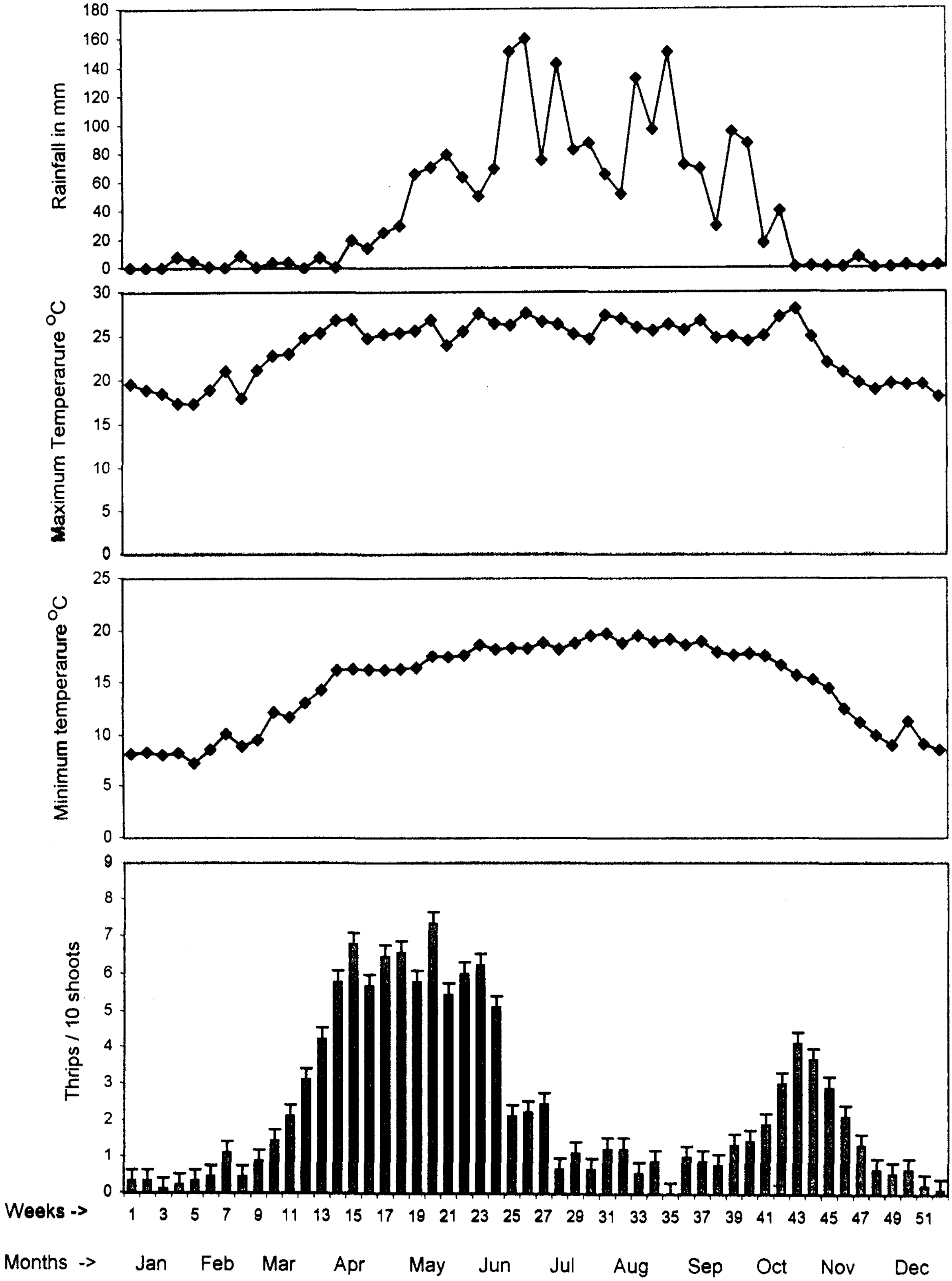


Fig. 12: Weekly changes in population of *M. setiventris* (Mean + SE of 3 yrs, 1999-2001) on tea **clone T 78** at **high elevation** with average weather data

More or less similar trends of population fluctuation of common thrips were noticed at both mid and high elevations and on both the planting materials (China seed *jat* and T 78 clone) under study. But, the number of thrips varied depending on elevation and planting material. It continued to persist through out the season in all the years under observation on both the planting materials at both mid and high elevations, but at varying intensity. The population started to build up during February – March in each season from the residual low population, which could survive the winter. The increasing trend in population continued and reached the first peak sometime in April end or May. It was observed that growth of population was checked considerably when plucking started from March. The population of yellow thrips *Scirtothrips kenyensis* on tea in Central Africa was also reported to reduce by frequent plucking which were at peak in August-September (Rattan, 1975). However, the increasing trend of *M. setiventris* continued and a sharp decline in population could be noticed only when monsoon started with heavy shower in June - July and this decline in population continued up to end of the monsoon i.e. end September. When preceded by a heavy downpour the population count was always low.

The population started to increase again from mid or end of September and reached the second peak in October. However, the level of infestation during autumn was much lower than that of the spring. As soon as winter started setting in and growth rate of the tea shoots slowing down entering into the winter dormancy (Barua, 1989), a reduction in the thrips population was observed, which became lowest during December – January.

Though Andrews (1925) reported occurrence of Darjeeling-thrips affected tea bushes towards the latter part of May, yet in the present study, considerable population build up was noticed even during March – April reaching the first peak in May. But, his observation of a 'lull' during monsoon and a 'second attack' in October is corroborated by the present observations. A spell of favourable weather conditions with increasing temperature without any rain was followed by sudden multiplication of the pest resulting in manifestation of damage symptoms within a week.

Although *M. setiventris* is observed for a long time to be unique to Darjeeling, its population dynamics was not studied systematically before, similar type of seasonal fluctuation was reported earlier in case of other species of thrips on tea. The population of *Scirtothips aurantii* that occurs throughout the year on tea in Central Africa has its bulk number in the hot dry season between September and December, but the population is lower during rainy period between January to March and lowest during April – August because of too low temperature in southern hemisphere (Mkwaila,1982). *Scirtothrips dorsalis*, the common thrips species in tea fields of North east India, also occurs throughout the year with rapid build up of population from March-April when prolonged droughty conditions prevail. The peak incidence is observed during May. After the monsoon, a decline in its population is noticed with minimum number in cold weather prevailing in the unpruned and young tea sections (Anon. 1994).

In this study, all developmental stages of *M. setiventris* were observed throughout the year indicating overlapping of generations like that of *S. aurantii*

(Mkwaila, 1982).

5.1.1.1.2. Common thrips population vs planting materials

During the course of investigation, a higher level of common thrips population was observed on china seed *jat* than the T 78 clone having some Assam character. The trend was similar in both the sites at mid and high elevations (Fig. 13 and 14). This difference in population of thrips on two planting materials at two different elevations was found statistically significant in the year 1999 and highly significant in the years 2000 and 2001 when an analysis of variance was done separately for each year's data (Table 4). A LSD test done separately for each year showed that common thrips population was significantly higher on china seed than Clone T 78 at both mid and high elevation at 5 % level of significance except in the year 2001 at mid elevation. It is significantly higher even at 1 % level of significance in mid elevation in the year 2000 and high elevation in the year 2000 and 2001. However, there was an exception in the year 2001 at mid elevation, where the difference in population was not significant, though population was higher in china seed *jat* than T 78 clone.

Similar statistical analysis of data taking average of 3 years also revealed that thrips population was significantly higher on china seed *jat* than T 78 clone at 5 % level of significance at mid elevation and 1 % level of significance at high elevation (Table 4).

It was also observed during the course of investigation in the tea

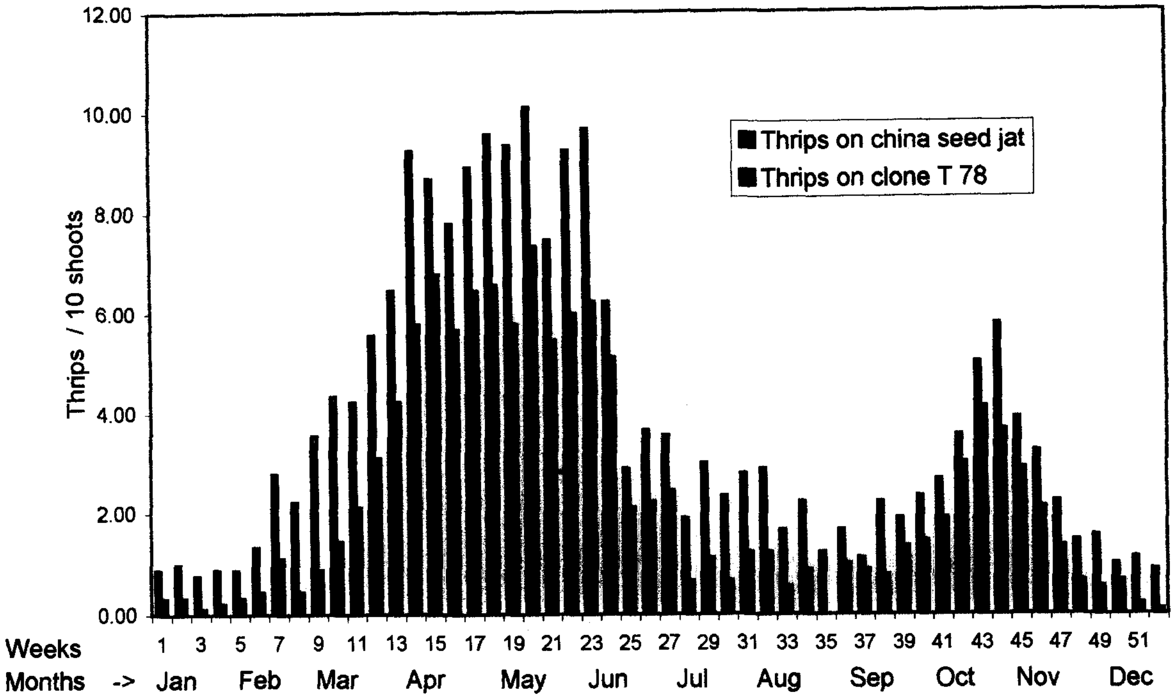


Fig. 13: Weekly changes in population of common thrips (*M. setiventris*) (Mean of 3 yrs, 1999-2001) on **china seed jat** of tea and **clone T 78** at **high elevation**

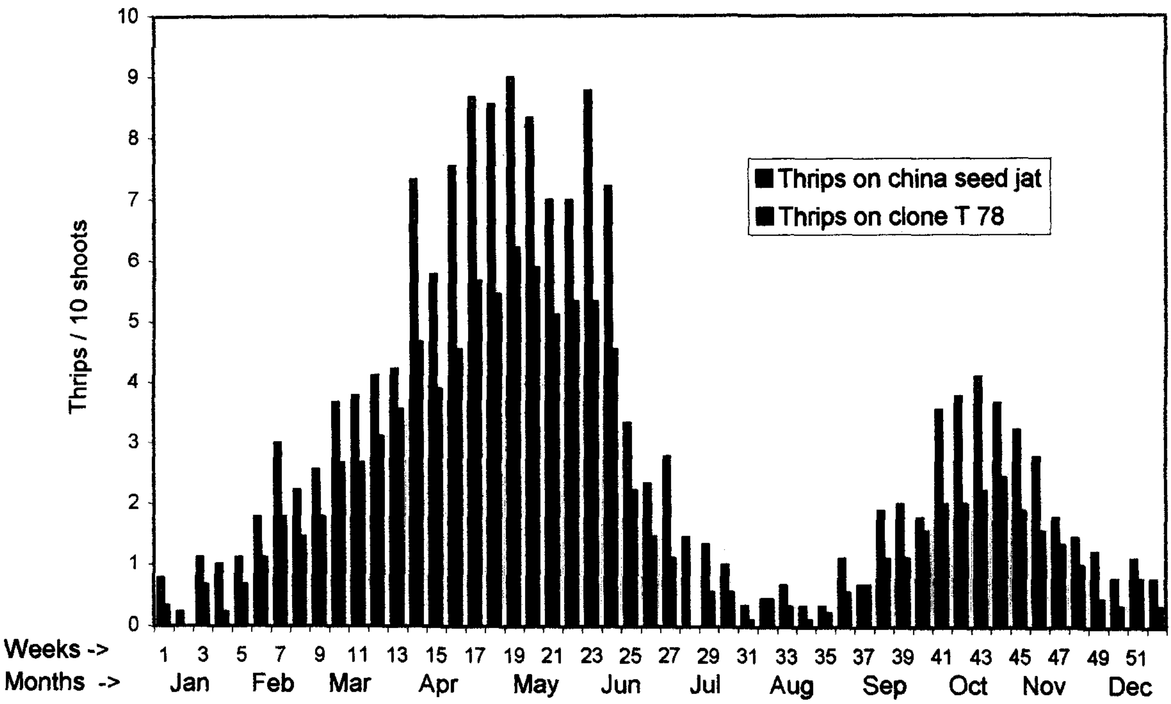


Fig. 14: Weekly changes in population of common thrips (*M. setiventris*) (Mean of 3 yrs, 1999-2001) on **china seed jat** of tea and **clone T 78** at **mid elevation**

Table 4: Analysis of variance and LSD test on of the population of Common thrips (*M. setiventris*) on two planting materials at mid and high elevation.

Treatment	No. of observation (n)	Treatment mean			
		1999	2000	2001	Av. 1999-01
A. Common thrips on China seed jat at mid elevation	52	3.65 ac	3.03 ab	2.83 ab	3.17 ac
B. Common thrips on China seed jat at High elevation	52	4.03 a	3.91 a	3.63 a	3.86 a
C. Common thrips on clone T 78 at mid elevation	52	2.30 b	1.76 c	2.01 bc	2.02 b
D. Common thrips on clone T 78 at high elevation	52	2.75 bc	2.29 cb	2.00 bc	2.35 bc
Calculated F		3.87 *	7.74 * *	4.52 * *	5.97 * *
LSD at 5 %		1.13	0.94	1.02	0.95
LSD at 1 %		1.49	1.24	1.35	1.25

Treatment means followed by the same lower case letter in each column do not differ significantly at 5 % level estates that this thrips species generally preferred to attack the china or china hybrid *jats* and china hybrid clones having more china character than Assam type tea. At times it was noticed that china *jat* was severely infested by thrips, but adjacent Assam *jat* was free from infestation. Even in a section of china seed *jat* infestation level of thrips varied bush to bush. It was always observed to be higher in bushes having more china character than the hybrid bushes towards Assam type. Lefroy (1909) and Antrma (1909) also observed higher thrips attack on china hybrid *jats*.

The typical "Darjeeling tea" is made from china or china hybrid *jats* or clones which are more flavoury where as the Assam type *jats* grown under Darjeeling condition do not produce the characteristic flavour of Darjeeling teas (Anonymous,1957). This flavour factor might have influenced the thrips population to prefer china type tea over Assam type. Because, insects seek a suitable habitat by the visual and chemical cues and are attracted to the host plant by chemical stimuli. The olfactory and gustatory sensilla enable detection of these stimuli resulting in acceptance or rejection of the host plant. (Ananthakrishnan *et al.* 1985; Ananthakrishan, 1986). Plant volatile chemicals play a decisive role in the plant-insect-chemical communication thus regulating insect behaviour (Du, 2001). Earlier studies have proved that Green Leaf Volatiles (GLVs) strongly attracted pests. Considerable works had been done in recent past in this line on aphid and other pests. The existence of an odour-conditioned anemotaxis was proved in apterous aphid *Cryptomyzus korschchelti* (Visser & Taanman, 1987). Volatiles from wheat and oat seedlings elicited attraction to apterae and alatae *Rhopalosiphum padi* (L.), where the main components were C_6

compounds, e. g. Z-3-hexenol, E-2-hexenyl acetate, etc. (Quiroz *et al.*, 1997, 1998). Tea aphid was also reported to be sensitive to other GLVs, e. g. linalool and benzaldehyde. Aphid *Rhopalosiphum padi* (L.) was also found to allure obviously by linalool (Quiroz *et al.*, 1998), which is one of the key flavors of tea (Li, 2000). The Electro-antennogram (EAG) responses of aphids to plant volatiles have been recorded in a number of aphid species (Visser *et al.*, 1996).

However, more detail investigation is necessary to establish this probable infochemical-linkage in between China type tea and the common thrips in Darjeeling.

5.1.1.1.3. Common thrips population vs elevation

In general, a higher level of population of common thrips could be noticed at high elevation than that at mid elevation on both the planting materials confirming its specificity to high elevation (Fig. 15 and 16). However, this difference in population was not found statistically significant in any of the situations even at 5 % level of significance in a LSD test (Table 4). The average of three years data on thrips population revealed that in case of china seed *jat*, it was 21.77 % higher at high elevation than that at mid elevation. This difference was 16.17 % in case of T 78.

Antram (1909) reported the common thrips [*Taeniothrips* = (*Mycterothrips*) *setiventris*] as a destructive pest in Darjeeling district which was also found to occur in the plains, but not as serious as in Darjeeling.

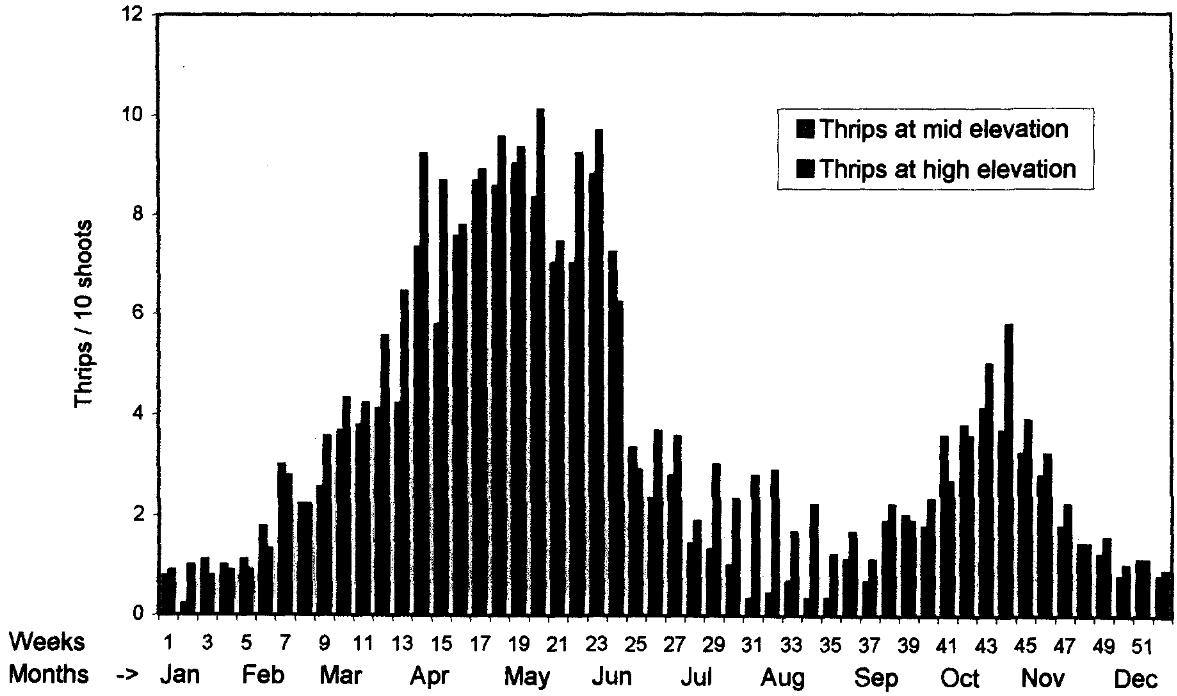


Fig. 15: Weekly changes in population of common thrips (*M. setiventris*) (Mean of 3 yrs, 1999-2001) on **china seed jat** of tea at **mid and high elevations**

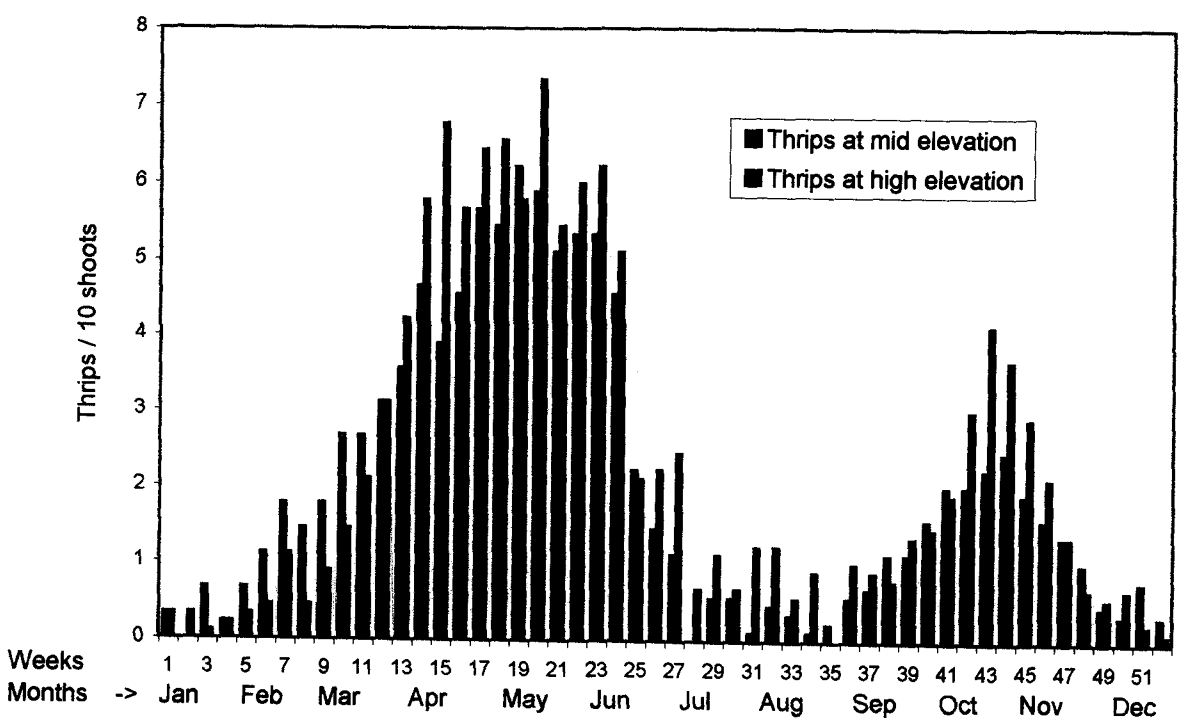


Fig. 16: Weekly changes in population of common thrips (*M. setiventris*) (Mean of 3 yrs, 1999-2001) on **tea clone T 78 at mid and high elevations**

Andrews (1925) also found this thrips on tea bushes in the Dooars and in the Brahmaputra Valley and particularly throughout Surama Valley in Assam and Tocklai. But, he did not considered it as a serious pest of tea in the plains though he found some bushes were occasionally, but severely attacked. Later on Dev (1964) discovered that the thrips species that caused damage to tea at Tocklai was not *Taeniothrips* (= *Mycterothrips*) *setiventris*, but was *Scirtothrips dorsalis*. Subsequently he found the latter species on tea in all the districts in the plains of North East India viz. Cachar, the Assam valley, the Dooars and Terai. So in none of these districts in the plains *Taeniothrips* (=*Mycterothrips*) *setiventris* occurred on tea. The present study further confirms the affinity of *Mycterothrips setiventris* towards high elevations.

5.1.1.1.4. Influence of weather factors on common thrips population

To find out the influence of weather factors on thrips population in different situations under study "multiple regression analysis" was done in between weekly weather data and population of common thrips recorded from 1999 to 2001. The common thrips population was used as dependent variable and the weather factors–rainfall, maximum temperature, minimum temperature, relative humidity (morning and afternoon) and sunshine hours (Appendix V) as independent variable at low elevation (TRA-CPS). However, at high elevation (Sungma tea estate), only rainfall, maximum temperature and minimum temperature (Appendix VI) were used as independent variables as data on other weather parameters were not locally available. The result is presented in the table 5. The table reveals that R^2 value is highly significant (1 % level of significance) at both the sites of mid and high elevations and on

Table 5: Multiple linear regression model for Common thrips (*M. setiventris*) against weather parameters

Site	Planting Material	Regression coefficient of independent variable							R^2	F Cald.
		Intercept	Rainfall	Temperature ^{0}C		Relative humidity %		Sunshine hours		
				Maximum	Minimum	Morning	Afternoon			
TRA – CPS	China seed Jat	-17.9373 (3.9161)	-0.0080 (0.0037)	1.0457 (0.3098)	-0.6103 (0.3339)	0.1854 (0.0471)	-0.1214 (0.0497)	-0.0758 (0.1649)	0.48#	23.22 * *
	Clone – T 78	-13.5010 (2.8672)	-0.0040 (0.0027)	0.8018 (0.2268)	-0.5060 (0.2444)	0.1132 (0.0345)	-0.0657 (0.0364)	0.0106 (0.1207)	0.46#	21.35 * *
Sungma tea state	China seed Jat	-6.5629 (1.3731)	-0.0227 (0.0044)	0.3712 0.0868)	0.1741 (0.0885)				0.36##	28.12 * *
	Clone – T 78	-5.3187 (1.0263)	-0.0155 (0.0033)	0.2602 (0.0649)	0.1454 (0.0661)				0.35##	26.87 **

Main figures are regression coefficients and figures in the parentheses are standard errors

n = 156, df = f_1 (k) = 6 and f_2 = (n-k-1) = 149, ## df = f_1 (k) = 3 and f_2 = (n-k-1) = 152 (Gomez and Gomez, 1984).

** Significant at 1 % level by F - test

Table 6: Simple linear regression matrix: Effect of individual abiotic factor on the incidence of Common thrips (*M. setiventris*)

Site	Planting Material	Regression coefficient of independent variable					
		Rainfall	Temperature ^{0}C		Relative humidity %		Sunshine hours
			Maximum	Minimum	Morning	Afternoon	
TRA – CPS , Ging	China seed Jat	-0.0080* (0.0034)	0.4027** (0.0573)	o.1923** (0.0521)	0.0032 (0.0187)	-0.0205 (0.0145)	0.3153** (0.1084)
	Clone T 78	-0.0058* (0.0024)	0.2774** (0.0416)	0.1237** (0.0377)	-0.0041 (0.0134)	-0.0183 (0.0104)	0.2682** (0.0770)
Sungma tea estate	China seed Jat	-0.0076 (0.0044)	0.4121** 0.0585)	0.2615** (0.0565)			
	Clone T 78	-0.0040 (0.0033)	0.3108** (0.0431)	0.2096** (0.0414)			

Main figures are regression coefficients and figures in the parentheses are standard errors

n=156; df = (n-2) = 154; * Significant at 5 % level; ** Significant at 1 % level both the planting materials of tea namely china seed *jat* and T 78 clone. This clearly indicates that the combined effects of weather factors under study contributed significantly to the variation in thrips population.

However, the value of R^2 is low for all the situations (0.35 to 0.48) under regression analysis indicating that a large portion of variability in the dependent variable (Common thrips population) remained unexplained. Because, in a regression analysis, the size of R^2 value provides information on the size of the portion of the variability of dependent variable explained by the linear function of the independent variables (Gomez and Gomez, 1984). It means that some other factors have also considerable influence on thrips population. As mentioned earlier thrips population is confined to the growing shoots which is the only harvestable part in tea. The experimental plots in this study were also kept under normal plucking after each weekly observation. By the way of plucking, lot of thrips population was removed along with the infested shoots disturbing the natural population trend. Moreover, growing habit of tea bushes had also tremendous influence on thrips population. Tea has a periodical growth habit with inter flush dormancies and a long winter dormancy (Barua,1989). During these dormant periods the growth rate of shoots reduces drastically disrupting the continuous food supply to thrips population, which affects the population trend adversely. These additional factors are also exerting influence on population of thrips disturbing their normal trend, which might have resulted in low value of R^2.

The above observations led to simple regression analysis to see the influence of each weather factor separately on Common thrips population

(Table 6) in each situation. Out of the different weather factors, rainfall had a negative influence on common thrips population in general and it was statistically significant (5 % level of significance) on both the planting materials at mid elevation. However, this was not found statistically significant at high elevation on any of the planting material. Both maximum and minimum temperatures had significant positive influence on common thrips population at 1 % level of significance on both the planting materials at both the elevations. At mid elevation, the sunshine hours had a significant positive influence at 1 % level. But, in case of relative humidity a negative trend of influence was observed except for the morning relative humidity on china seed jat at mid elevation, which was positive. But, the influence of relative humidity was not found statistically significant in any of the situations.

The negative influence of rainfall on other thrips species infesting tea like *Scirtothrips kenyensis* in Kenya and *Scirtothrips dorsalis* in the plains of North East India was also reported by earlier workers (Sudoi,1985; Anonymous, 1994). This is perhaps mainly because of its confinement to the growing shoots at plucking surface of a tea section. The beating effect of rain drops probably kills large number of population as they get exposed to it. In the present study, it was clearly observed that the population count decreased drastically at the end of a rainy week. The thrips species *Scirtothrips aurantii,* commonly known as South African citrus thrips and widely distributed in sub Saharan Africa and the Middle East on a number of crops including tea, occurs in maximum numbers in tea in the hot dry season between September and December. Though the temperature is ideal in the above African regions during the period from January to March, the wetness keeps the number down.

However, a few days dryness during this period is reflected by the rise in number. The thrips population is the minimum during April to August due to very low temperature (Mkwaila, 1982) of the southern hemisphere. Likewise, the population of *M. setiventris* was also found to increase, if weather remained dry for a week or so during the monsoon. But during heavily raining period and winter the population was always lower.

The adults of thrips, in general were reported to be phototactic and were attracted to places where intensity of illumination was the highest (Bedford, 1943). Likewise, the species under present study was also found to be significantly influenced by sunshine. During periodical visits to different tea estates of Darjeeling it was observed that the population of thrips always showed an abundance during a clear rain-free period with continuous sunshine.

In this study it is clear that influences of weather factors on *M. setiventris* are similar to that of other thrips species active on tea in different parts of the world except its preference for high altitude.

Other than the weather factors, the growth habit of tea bushes might have played a significant role in regulating thrips population, particularly during winter months. Tea plant undergoes a long dormancy in Darjeeling during winter starting from December to February due to very low temperature. During this period shoot growth is almost nil and practically there is no food for the pest as they feed only on the tender growing shoots only. The population of thrips is also reduced to the minimum during this period, probably due to lack of food as one of the reducing factors. As soon as dormant buds start to grow with fresh leaves along with increasing temperature from end February - early March the population of thrips also starts increasing reaching its peak in May.

5.1.1.2. Common thrips population (with pest control measure)

Observations were also taken simultaneously in plots kept under insecticide spray as per normal practices of the garden. Endosulfan 35 EC (Thiodan) was sprayed at 1:400 dilution with high volume hand sprayer as soon as infestation was visible to keep the population below economic injury level. The data obtained are presented graphically in Figure 17 (Appendix I to VI).

During the course of investigation, it was noticed that even after spraying insecticide the pest continued to persist during peak infestation period from February to June and October, but at much lower level. Immediately after a spray the level reduced to the minimum, but started to build up again. In total 5-6 rounds of spray were required to maintain the population below the economic injury level.

Further it was noted that during the monsoon population remained at low level like that of untreated plots, and insecticide spray was not at all necessary from end of June to mid of September. It clearly indicated that the rainfall and probably plucking took maximum care to bring down the population to almost zero level during the monsoon. So it may be suggested that no other pest control measure is necessary during this period.

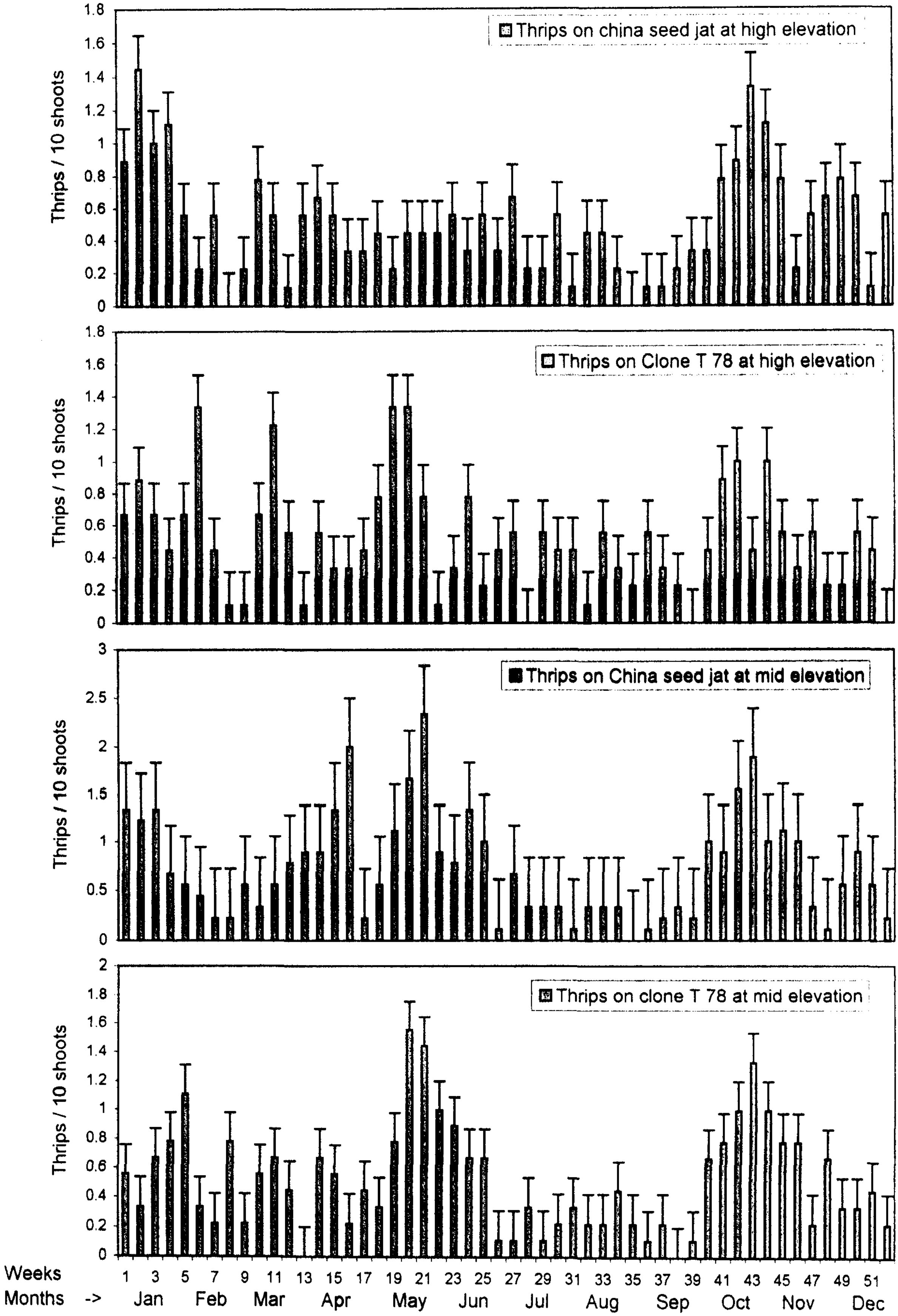


Fig 17: Weekly changes in population of *M. setiventris* (Mean + SE of 3 yrs, 1999-2001) at **different situations** with **pest control measures**

5.1.2. GREENFLY – *Empoasca flavescens* Fabr.

5.1.2.1. GREENFLY POPULATION (WITHOUT PEST CONTROL MEASURE)

5.1.2.1.1. Seasonal fluctuation

The average (1999-2001) population of Greenfly recorded weekly on two different planting materials at mid and high elevation is presented graphically along with weather data in figures 18 to 21 (Appendix I to IV).

More or less a similar trend of population fluctuation of greenfly was noticed at both mid and high elevations and on both the planting materials under study. The population was observed throughout the year during all the three years of observation. However, its number varied depending on elevation as well as planting material. But unlike thrips, the population of greenfly started to build up rather late in the season from early June from the residual population, reaching its first peak in June end - July. The population got reduced during end August and early September, which started to increase again from end of September reaching its second peak in October. Like thrips the level of population was lower during autumn surge than the first peak. The population got reduced as the winter set in and a minimum number of greenfly could be recorded during the whole of winter.

Occurrence of *E. flavescens* was reported from the plains of North East India throughout the year on tea. During cold weather its population persisted at low level on pruned and skiffed tea bushes, but in large number in

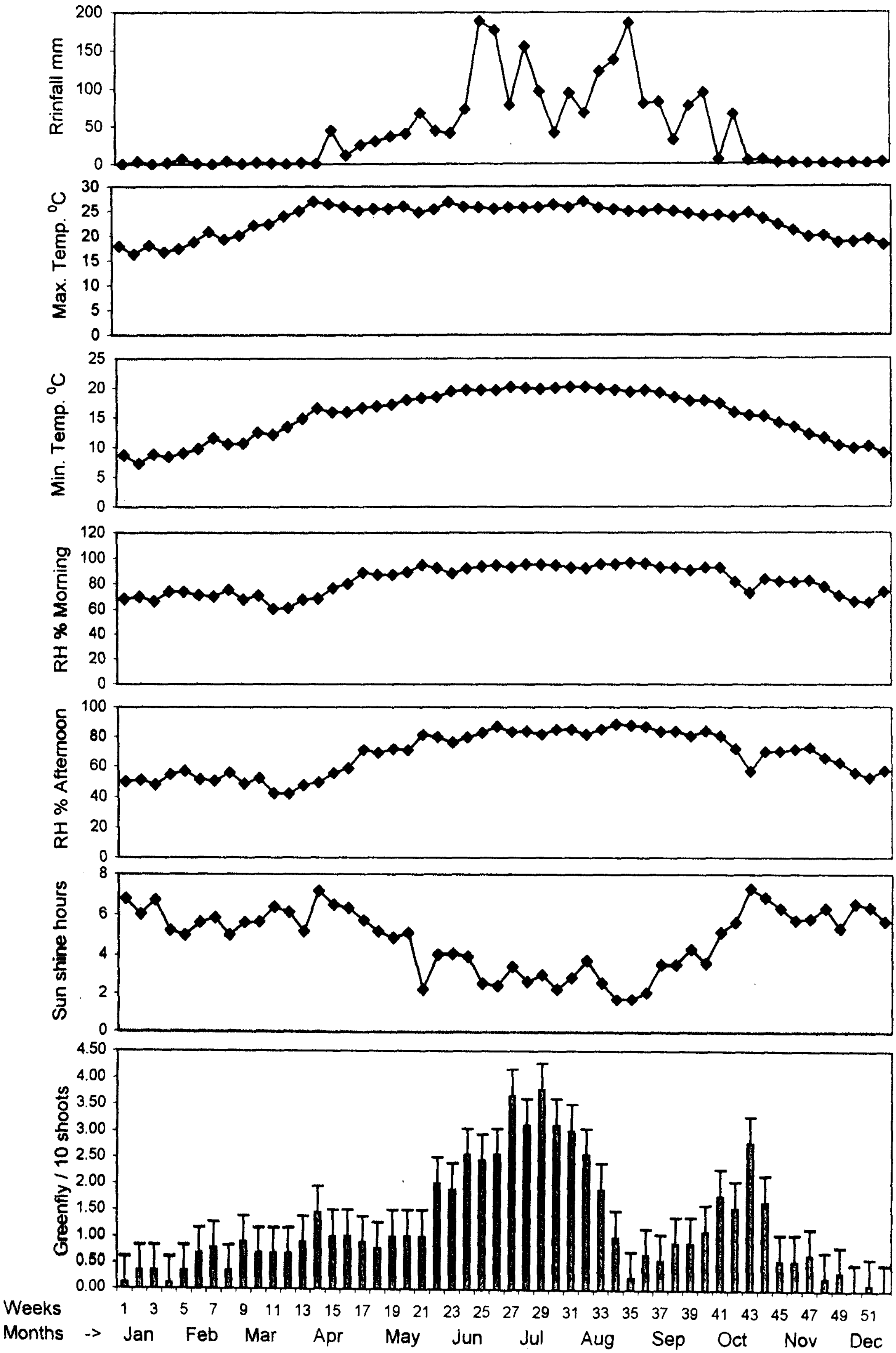


Fig. 18: Weekly changes in population of *E. flavescens* (Mean + SE of 3 yrs, 1999-2001) on **china seed jat** of tea at **mid elevation** with average weather data

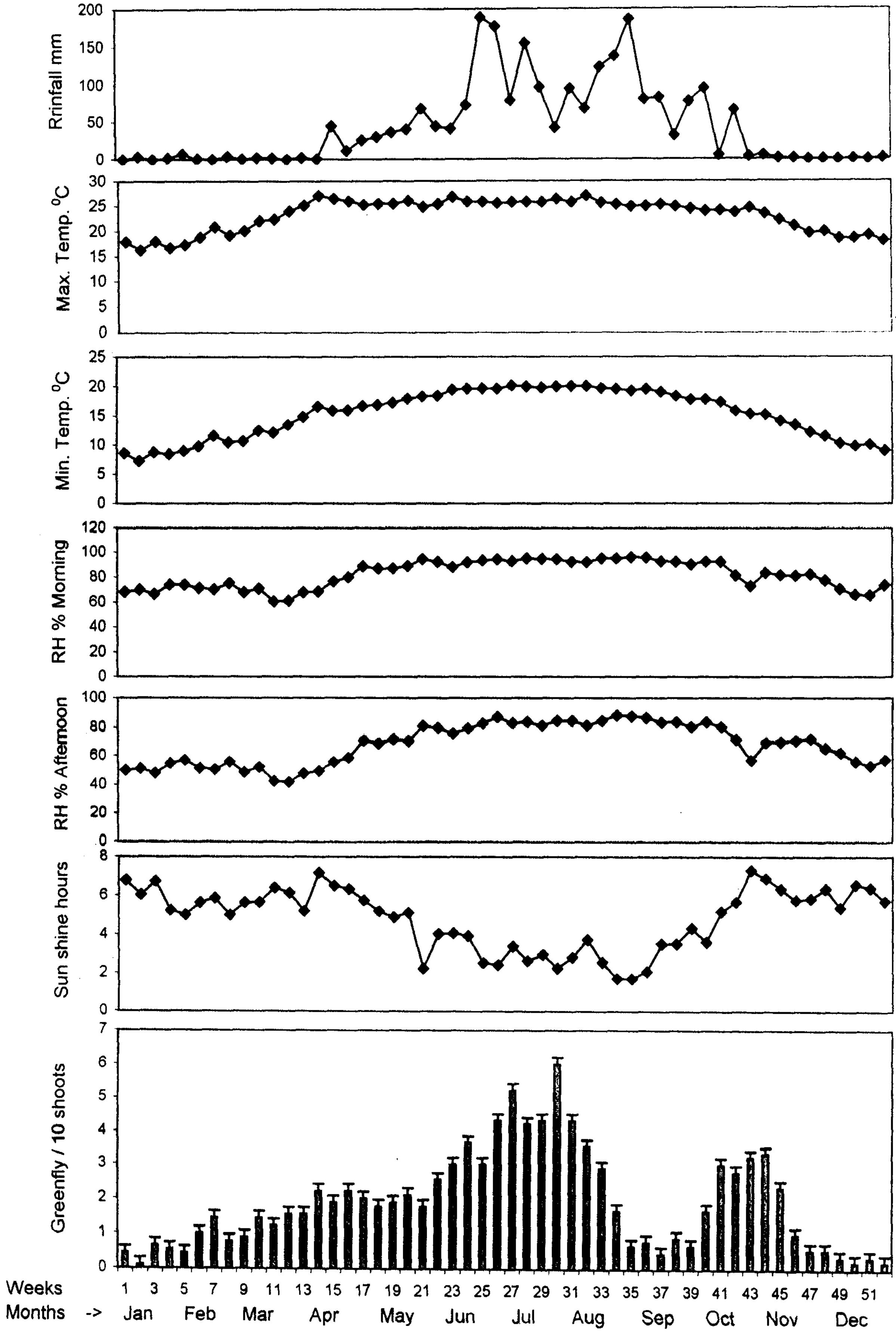


Fig. 19: Weekly changes in population of *E. flavescens (Mean + SE of 3 yrs, 1999-2001)* on tea **clone T 78** at **mid elevation** with average weather data.

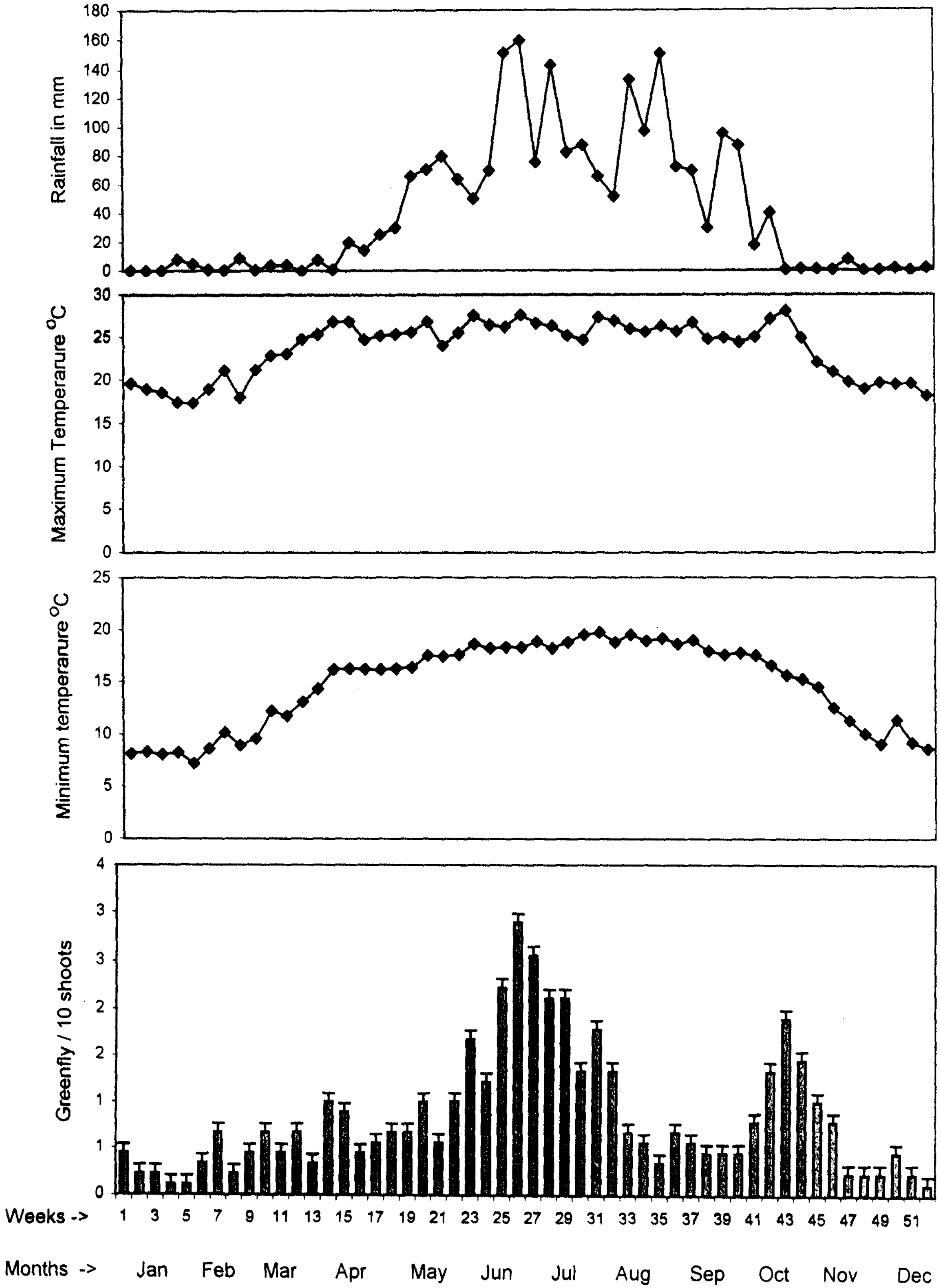


Fig. 20: Weekly changes in population of *E. flavescens* (Mean + SE of 3 yrs, 1999-2001) on **china seed jat** of tea at **high elevation** with average weather data

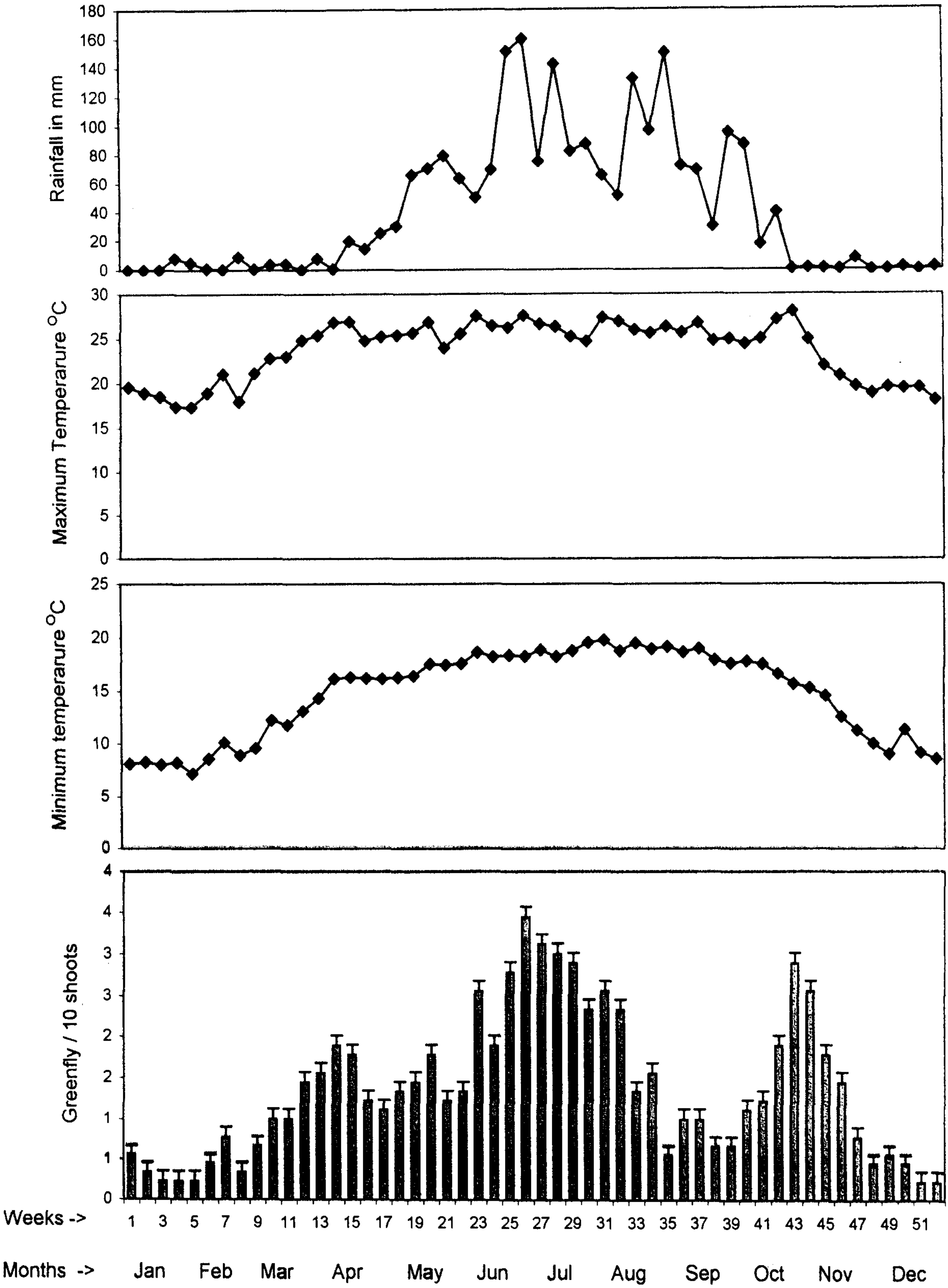


Fig. 21: Weekly changes in population of *E. flavescens* (Mean + SE of 3 yrs, 1999-2001) on tea **clone T 78** at **high elevation** with average weather data

unpruned, young and nursery teas having new growth. The pest was found more active during March – July. With increasing temperature during March the insect started multiplying rapidly to reach serious proportion in May-June and continued up to July. The population declined suddenly from August to a negligible number with a slight increase in November (Anon. 1994). Muraleedharan (1992) also reported that the pest occurred in the north-eastern part of India throughout the year and in Darjeeling June – July was regarded as the greenfly season coinciding with the "quality period".

Though a more or less similar trend of greenfly population like that of plains was noticed in this study at Darjeeling slope, the main peak was observed slightly later than that of the plains *i. e.* during June - July. There was another peak population incidence in October. It might be due to late starting of the growing season at high elevation and low temperature during the early part. The adult and nymph of green fly have a habit of remaining under the lower surface of already infested second or third leaf (from top) of a growing tea shoot, which is curved downwards due to sucking of sap by the pest (Fig. 4). So initially it requires some amount of growth with healthy shoots for its shelter. In hills, the shoot size during eariy part (first and second flush up to June) of the season remains comparatively smaller and plucking is done at a very shorter interval of 4-5 days to harvest the shoots at small size to maintain quality in comparison to 7-9 days interval in the plains thus preventing the build up of the pest. But with better growing conditions during onset of monsoon the growth rate also increases with the increased shoot size. The plucking round also generally longer during July – September (rain crop) being comparatively low quality period. The bigger shoot size naturally provides a better shelter to green fly and more succulent food.

The greenfly was found more active coinciding with the second and autumn flush in Darjeeling. Tea planters of Darjeeling generally welcome the pest during this period with a belief that it's infestation on pluckable shoots enhances the flavour level of the made tea. The earlier workers also reported that the seasonal cycle of jassid synchronises well with the flushing period of the bushes (Andrews, 1923)

5.1.2.1.2. Greenfly population vs planting materials

A general trend of higher population of greenfly was noticed on tea clone T 78 than china seed at both mid and high elevation (Fig.22 and 23). The analysis of variance and LSD test were done separately for each year's data and the average of three years under observation, and results are presented in the table 7.

The population was generally higher on clone T 78 than the China seed *jat*. The LSD test showed that during 1999 greenfly population was significantly higher on T 78 than china seed at mid elevation at 1 % level of significance. But, at high elevation though greenfly was higher on T 78 but the difference was not statistically significant. In the year 2000, the population was significantly higher on T 78 than China seed at both the elevations. Likewise, in the year 2001 the greenfly population was significantly higher on T 78 at 1 % and 5 % levels of significance at mid and high elevation respectively. The

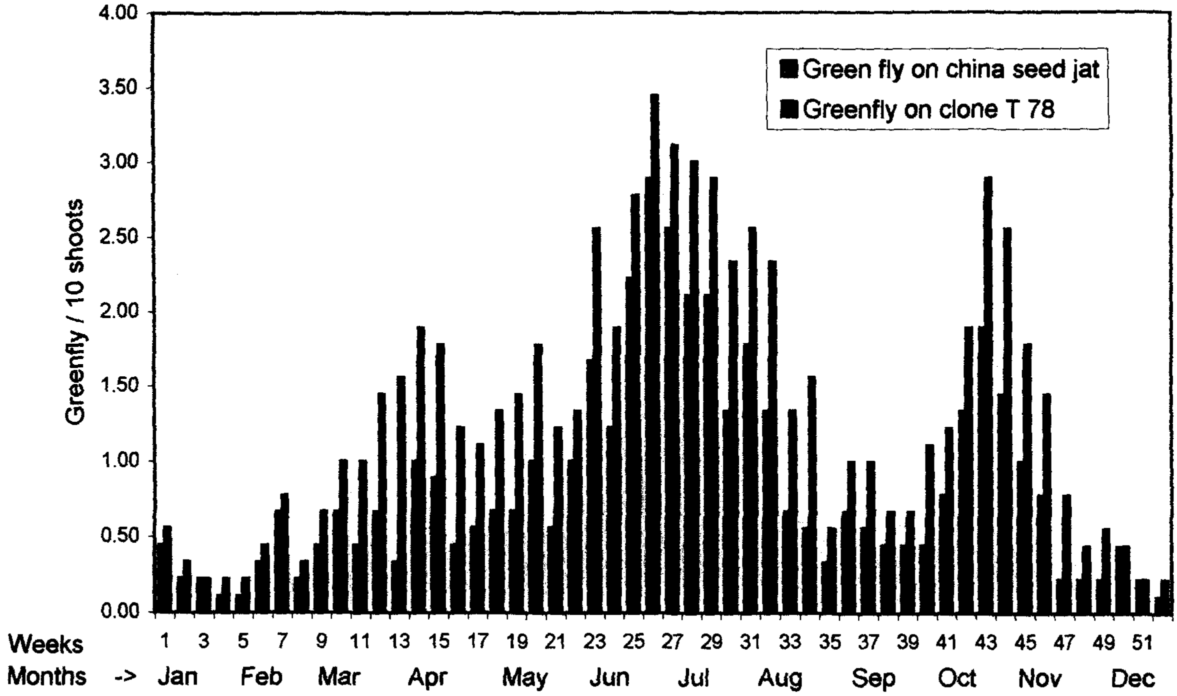


Fig. 22: Weekly changes in population of Greenfly (*E. flavescens)* (Mean of 3 yrs, 1999-2001) on **china seed jat** and **clone T 78 at high elevation**

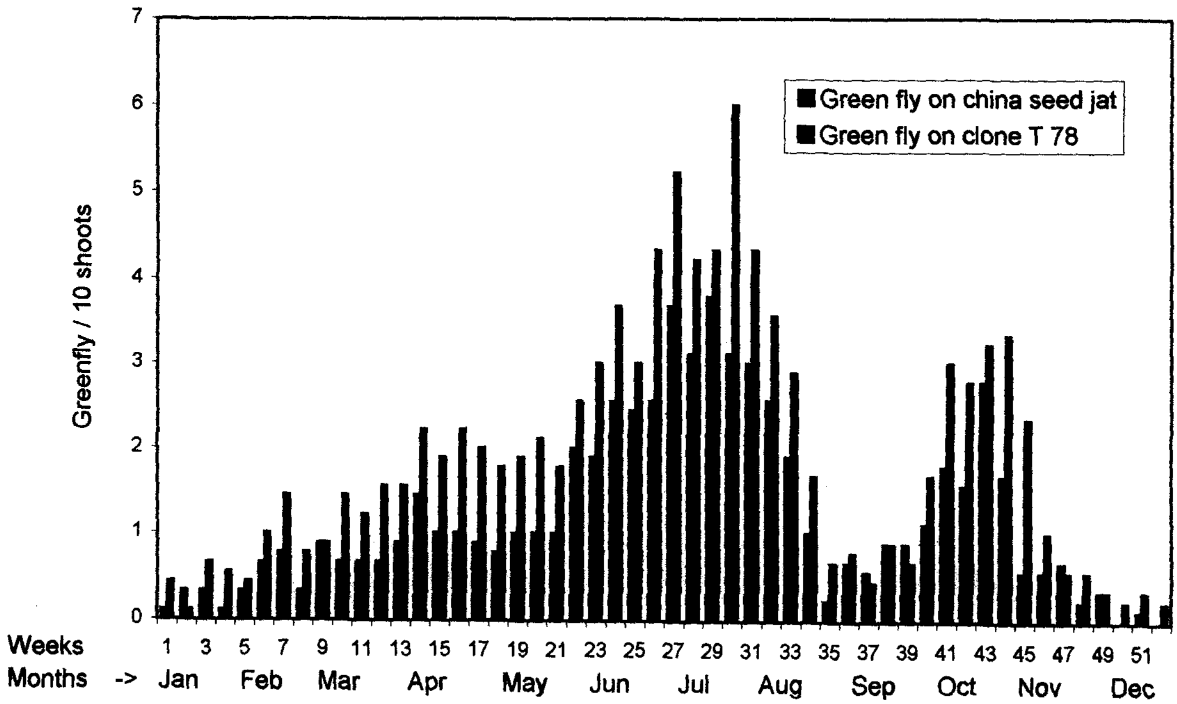


Fig. 23: Weekly changes in population of Greenfly (*E. flavescens*) (Mean of 3 yrs, 1999-2001) on **china seed jat** and **clone T 78 at mid elevation**

analysis of the weekly average data of three years also revealed that population of greenfly was significantly higher on T 78 than china seed at mid elevation. But at high elevation the difference was not statistically significant. It is clear from the above observation that the difference in greenfly population on two planting materials is more prominent at lower elevation than at the higher elevation.

It was observed that greenfly generally preferred Assam or Assam hybrid *jats* over china or china hybrid *jats* and china hybrid clones. As mentioned earlier, the foliage pattern providing shelter to greenfly might have played a vital role in selection of the tea cultivar (host). Both nymphs and adults invariably choose under surface of succulent leaves of a growing shoot for colonizing. The size of leaf in case of Assam or Assam hybrid *jats* or clones is much bigger than that of china or china hybrid *jats* or clones. Also leaf of Assam type tea is more soft and succulent than the china type, which is small and leathery. As such leaf of Assam type tea, being bigger in size, probably provides a better environment for the pest to inhabit and suck the juice from the lower surface. It's nature of staying on under surface of the curved leaf caused by sucking (Fig. 4) also provides protection to the pest against rain, so that a heavy population can continue even up to July.

Chen *et al.* (1978) also reported variation in level of infestation by tea leaf hopper *E. formosana* on different varities of tea in Taiwan.

The clone T 78, included in the present study, is a hybrid one having some Assam characters. The leaf size is distinctly bigger than the china seed *jat* under study which might have attracted green fly more over china seed *jat*. However, the infochemicals or Green Leaf Volatiles (GLV) might have also played an important role in host selectivity of greenfly, which is a matter of further investigation.

5.1.2.1.3. Greenfly population vs elevation

Unlike thrips, the population of greenfly was found generally greater at mid elevation than high elevation during this investigation (Fig. 24 and 25). The LSD test (Table 7) showed that in the year 1999, its population was significantly higher at mid elevation at 5% and 1% levels for China seed and T 78 clone respectively. In the year 2000, though the population at mid elevation was not significantly higher in case of china seed *jat*, but it was significant in case of T 78 clone at 5 % level. In the year 2001, the difference in population was found non significant in case of both china seed *jat* and T 78 clone though population remained higher at mid elevation than high elevation. The average of three years data also revealed that the population remained higher at mid elevation than high elevation. The difference was non significant in case of china seed *jat*, but it was highly significant in case T 78 clone.

This study clearly showed that greenfly population performed better with a more intensive population increase at lower elevation than at higher elevation irrespective of planting materials. Temperature, as discussed below, might have played the significant role in this difference in population as *E. flavescens* which is basically a pest of warm climate.

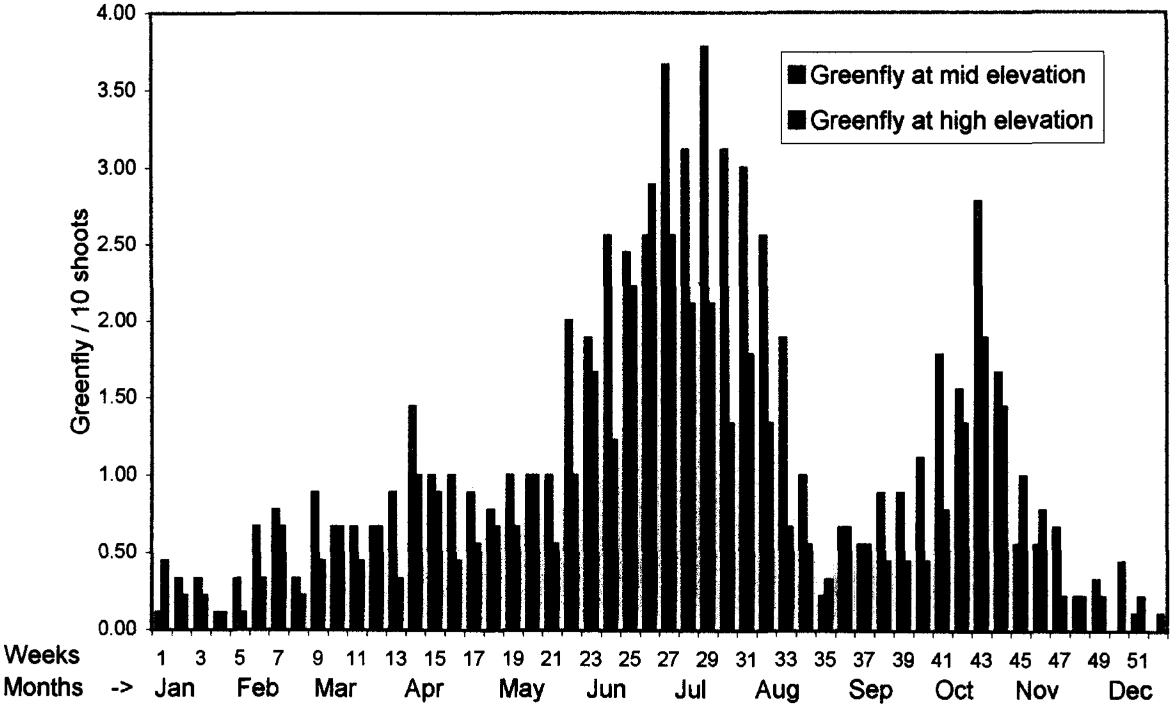


Fig. 24: Weekly changes in population of Greenfly (*E. flavescens*) (Mean of 3 yrs, 1999-2001) on **china seed jat** at **mid and high elevations**

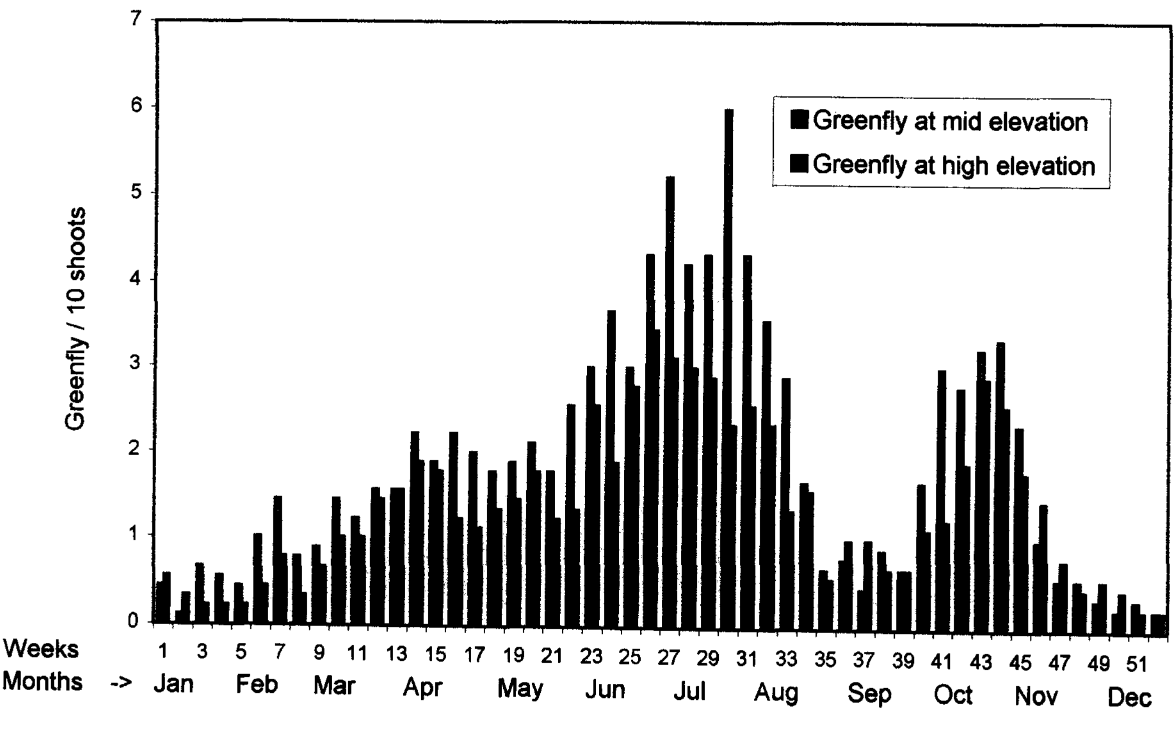


Fig. 25: Weekly changes in population of Greenfly *(E. flavescens)* (Mean of 3 yrs, 1999 to 2001) on tea **clone T 78** at **mid and high elevations**

Table 7: Analysis of variance and LSD test on weekly population of Greenfly (*E. flavescens*) on two planting materials at mid and high elevation.

Treatment	Number of observation (n)	Sample mean			
		1999	2000	2001	Av. 1999-01
Greenfly on China seed jat at mid elevation	52	1.36 a	1.15 ac	1.12 ac	1.21 ac
Greenfly on China seed jat at High elevation	52	0.86 b	0.72 a	0.94 a	0.84 a
Greenfly on clone T 78 at mid elevation	52	2.08 c	1.94 b	1.74 b	1.92 b
Greenfly on clone T 78 at high elevation	52	1.28 ab	1.38 c	1.44 bc	1.37 bc
Calculated F		11.30 * *	10.20 * *	4.49 * *	9.72 * *
LSD at 5 %		0.42	0.44	0.47	0.40
LSD at 1 %		0.55	0.58	0.62	0.53

Treatment means followed by the same lower case letter in each column do not differ significantly at 5 % level

5.1.2.1.4. Influence of weather factors on Greenfly population

Multiple regression analysis was done to study the influence of weather factors on greenfly population under different situations. Weather data was recorded from 1999 to 2001. The greenfly population was used as dependent variable and the weather factors – rainfall, maximum temperature, minimum temperature, relative humidity (morning and afternoon) and sunshine hours (Appendix V) as independent variable in the site at mid elevation (TRA-CPS). In the other site at high elevation (Sungma tea estate), only rainfall, maximum temperature and minimum temperature (Appendix VI) were used as independent variables as data on other weather parameters were not available. The results are presented in the table 8. In the table it is evident that R^2 value is highly significant in all the situations. This clearly indicates that the combined linear effects of weather factors under study contribute significantly to the variation of the greenfly population. But the R^2 values are low as in case of thrips. The possible reasons of low R^2 values explained under thrips are also applicable to greenfly. It also being a pest of growing shoots, its population trend is adversely affected by regular plucking during growing period as well as by the growth pattern of tea bush.

To see the influence of individual abiotic factor on greenfly population simple regression analysis was done and the result is presented in the Table 9. The table reveals that rainfall, maximum temperature, minimum temperature, relative humidity morning and relative humidity afternoon had positive and highly significant influence on the building up of greenfly

Table 8: Multiple linear regression model for Greenfly (*E. flavescens*) against weather parameters

Site	Planting Material	Regression coefficient of independent variable							R^2	F Cald.
		Intercept	Rainfall	Temperature ^0C		Relative humidity %		Sunshine hours		
				Maximum	Minimum	Morning	Afternoon			
TRA – CPS	China seed Jat	2.2450 (1.5264)	-0.0026 (0.0014)	-0.4008 (0.1207)	0.6333 (0.1301)	0.0249 (0.0183)	-0.0582 (0.0194)	0.1248 (0.0643)	$0.49^{\#}$	23.59 **
	Clone – T 78	-0.5637 (2.1009)	-0.0035 (0.0020)	-0.2410 (0.1662)	0.5501 (0.1791)	0.0317 (0.0253)	-0.0494 (0.0267)	0.1179 (0.0884)	$0.49^{\#}$	23.57 **
Sungma tea estate	China seed Jat	-6.5629 (1.3731)	-0.0227 (0.0044)	0.3712 (0.0868)	0.1741 (0.0885)				$0.36^{\#\#}$	28.12 **
	Clone – T 78	-2.8291 (0.3924)	0.0007 (0.0013)	0.1660 (0.0248)	0.0162 (0.0253)				$0.48^{\#\#}$	46.82 **

Main figures are regression coefficients and figures in the parentheses are standard errors

\# n = 156, df = f_1 (k) = 6 and f_2 = (n-k-1) = 149, ## df = f_1 (k) = 3 and f_2 = (n-k-1) = 152 (Gomez and Gomez, 1984).

** Significant at 1 % level by F - test

Table 9: Simple linear regression matrix: Effect of individual abiotic factor on the incidence of Greenfly (*E. flavescens*)

Site	Planting Material	Regression coefficient of independent variable					
		Rainfall	Temperature ^0C		Relative humidity %		Sunshine hours
			Maximum	Minimum	Morning	Afternoon	
TRA – CPS , Ging	China seed Jat	0.0040 * * (0.0013)	0.1968 * * (0.0203)	0.1711 * * (0.0162)	0.0382 * * (0.0066)	0.0275 * * (0.0053)	-0.1262 * * (0.0424)
	Clone T 78	0.0052 * * (0.0018)	0.2878 * * (0.0268)	0.2408 * * (0.0219)	0.0538 * * (0.0091)	0.0382 * * (0.0072)	-0.1589 * * (0.0586)
Sungma tea estate	China seed Jat	0.0039 * * (0.0010)	0.1232 * * (0.0129)	0.0971 * * (0.0123)			
	Clone T 78	0.0049 * * (0.0014)	0.1831 * * (0.0155)	0.1355 * * (0.0157)			

Main figures are regression coefficients and figures in the parentheses are standard errors

n=156; df = (n-2) = 154; *Significant at 5 % level; ** Significant at 1 % level population. But, sun shine hours had significantly negative influence on the greenfly population.

Though the rainfall has a positive influence on greenfly population, it may be during the early part of the monsoon when rain is not very heavy. This light rain also encourages growth in tea and thus in turn encourages green fly to multiply. The habit of the pest to remain on lower surface of curved leaves also provides some protection to the pest from the early rains. But as soon as rain increases towards July-August with heavy downpour the population is observed to decrease. The greenfly starts again to multiply as soon as monsoon rains get reduced by the end of September or early October. Plucking removes lot of population at different stages of growth. So heavy rainfall and plucking have considerable influence in reducing greenfly population.

The winter dormancy in tea might also play a significant role to bring down the greenfly population in winter as it is a pest of freshly growing tea shoots and during winter there is no active growth. The residual population may survive on the few fresh shoots available on the tea bushes.

Similar positive influence of daily mean temperature and relative humidity (morning) on *Empoasca kerri* population attacking pigeon pea cutivars was reported. A good rainfall followed by a dry spell with daily mean temperature in the range of 17 – 28 ^{0}C was found favourable for *E. kerri* on pigeon pea cultivars. However, a negative influence of sunshine hours was noticed on *E. kerri* though it was not statistically significant (Sekhar *et al.*, 1993).

5.1.2.2. Greenfly population (with pest control measure)

Observations were also taken simultaneously in plots kept under insecticide spray as per normal practices of the garden as mentioned earlier for common thrips. The data obtained are presented graphically in Figure 26 (Appendix I to IV).

The greenfly population remained even after insecticide spray but at a much lower level than the untreated plots, particularly during peak period of infestation. Immediately after a spray the population got reduced considerably, but started to build up again. In total 5-6 rounds of spray were required to maintain the population below the economic injury level.

The population remained at lowest level like in untreated plots during August and September, so insecticide spray was not at all necessary during this period. Although the growth in tea bushes remained fast and vigorous during this period yet weekly plucking itself might be removing lot of the greenfly population, thus keeping the population down. Heavy rainfall during the period might also be killing lot of immature ones. This study confirmed that no other pest control measure was necessary during this period.

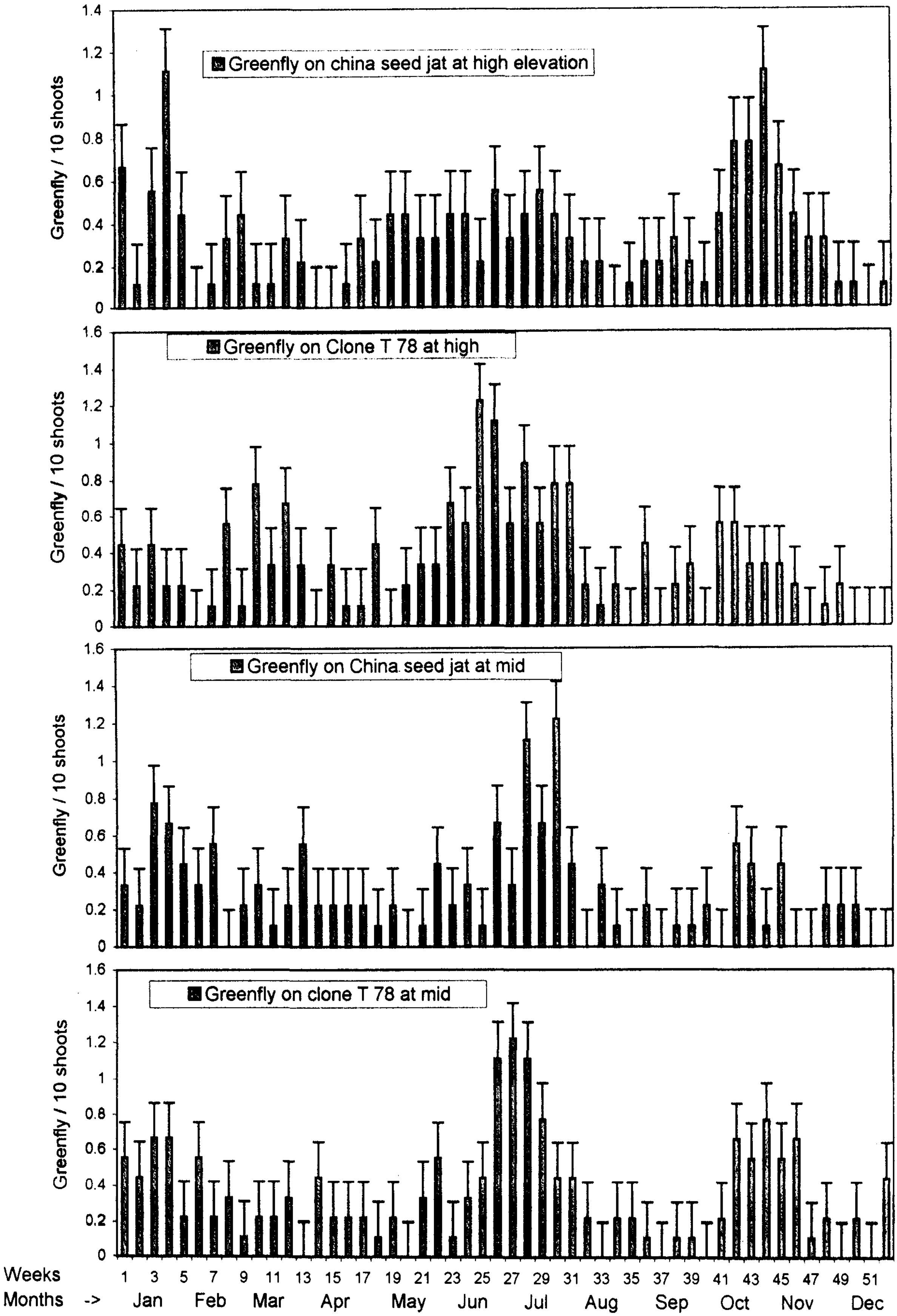


Fig. 26: Weekly changes in population of *E. flavescens* (Mean + SE of 3 yrs, 1999-2001) at **different situations** with **pest control measures**

5.1.3. APHID – *Toxoptera aurantii* Boyer de Fons

5.1.3.1. APHID POPULATION (WITHOUT PEST CONTROL MEASURE)

5.1.3.1.1. Seasonal fluctuation

The average (1999-2001) population of Aphid counted weekly on two different planting materials at mid and high elevation is presented graphically along with weather data in figures 27 to 30 (Appendix I to IV).

During this investigation, it was observed that aphid infestation was very much sporadic and it's population never built up to attain the pest status at both the elevations on any of the planting materials studied. Only occasional colonies were observed on growing shoots when samplings were done. These colonies were noticed mainly during June to October and rarely in the early and end parts of the season. However, contrary to this finding the aphid was found active on tea in plains at Tocklai, Assam, India from January-February, the highest number being in February after which there was a gradual decline in population. But, there also another increase in population was observed in August (Das and Kakoty, 1992). Mukhopadhyaya *et al.* (1997) also reported from Darjeeling Terai that aphid population on young tea clones showed peak incidence during the early summer, in particular in the month of April followed by a fair incidence in July and early August.

In Darjeeling, the low temperature prevalent during the early part of the season might be the main reason of its delayed appearance. Subsequent

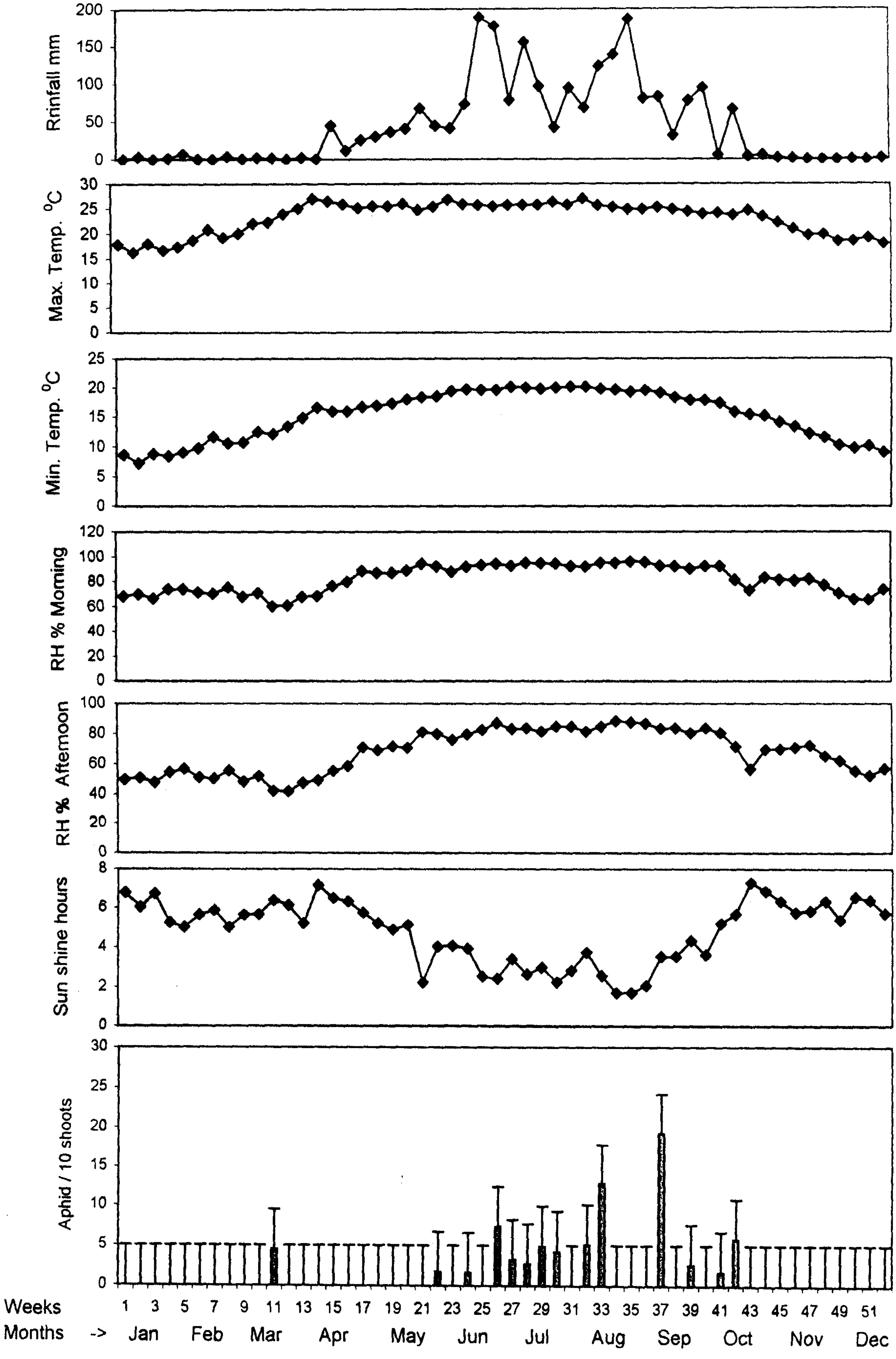


Fig. 27: Weekly changes in population *T. aurantii* (Mean + SE of 3 yrs, 1999-2001) on **china seed jat** of tea at **mid elevation** with average weather data

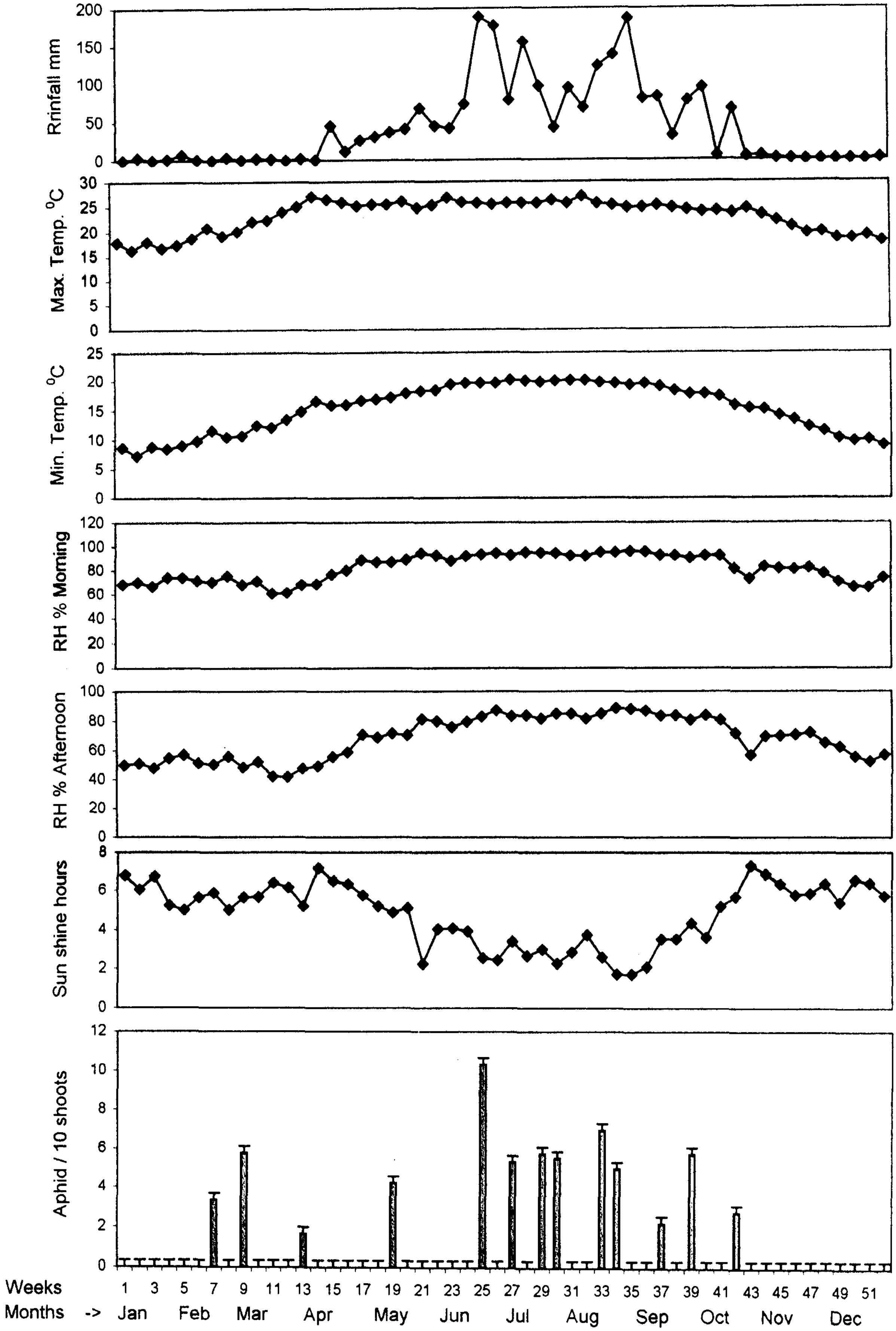


Fig. 28: Weekly changes in population of *T. aurantii* (Mean + SE of 3 yrs, 1999-2001) on **tea clone T 78 at mid elevation** with average weather data

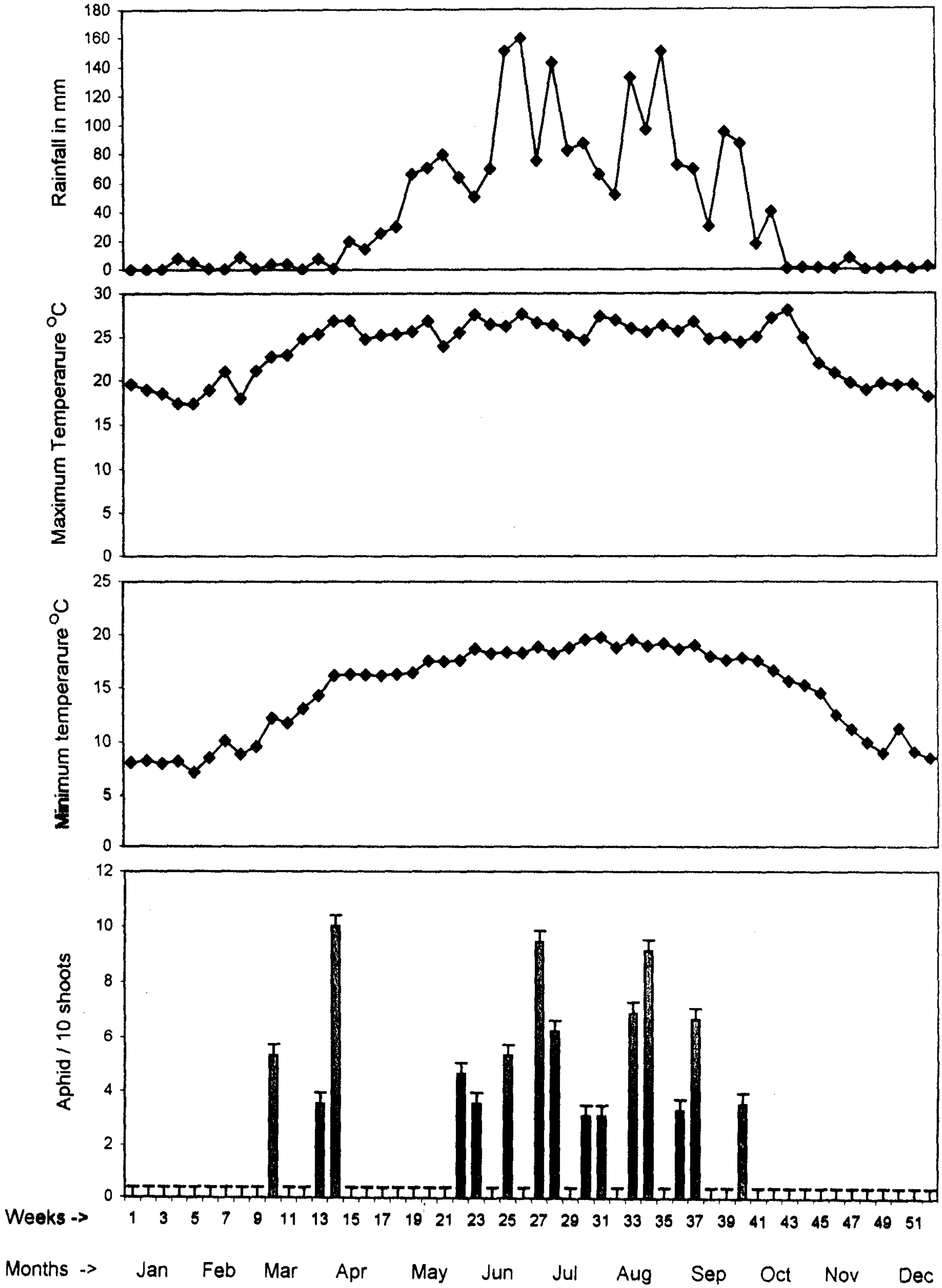


Fig. 29: Weekly changes in population of *T. aurantii* (Mean + SE of 3 yrs, 1999-2001) on **china seed jat** of tea at **high elevation** with average weather data

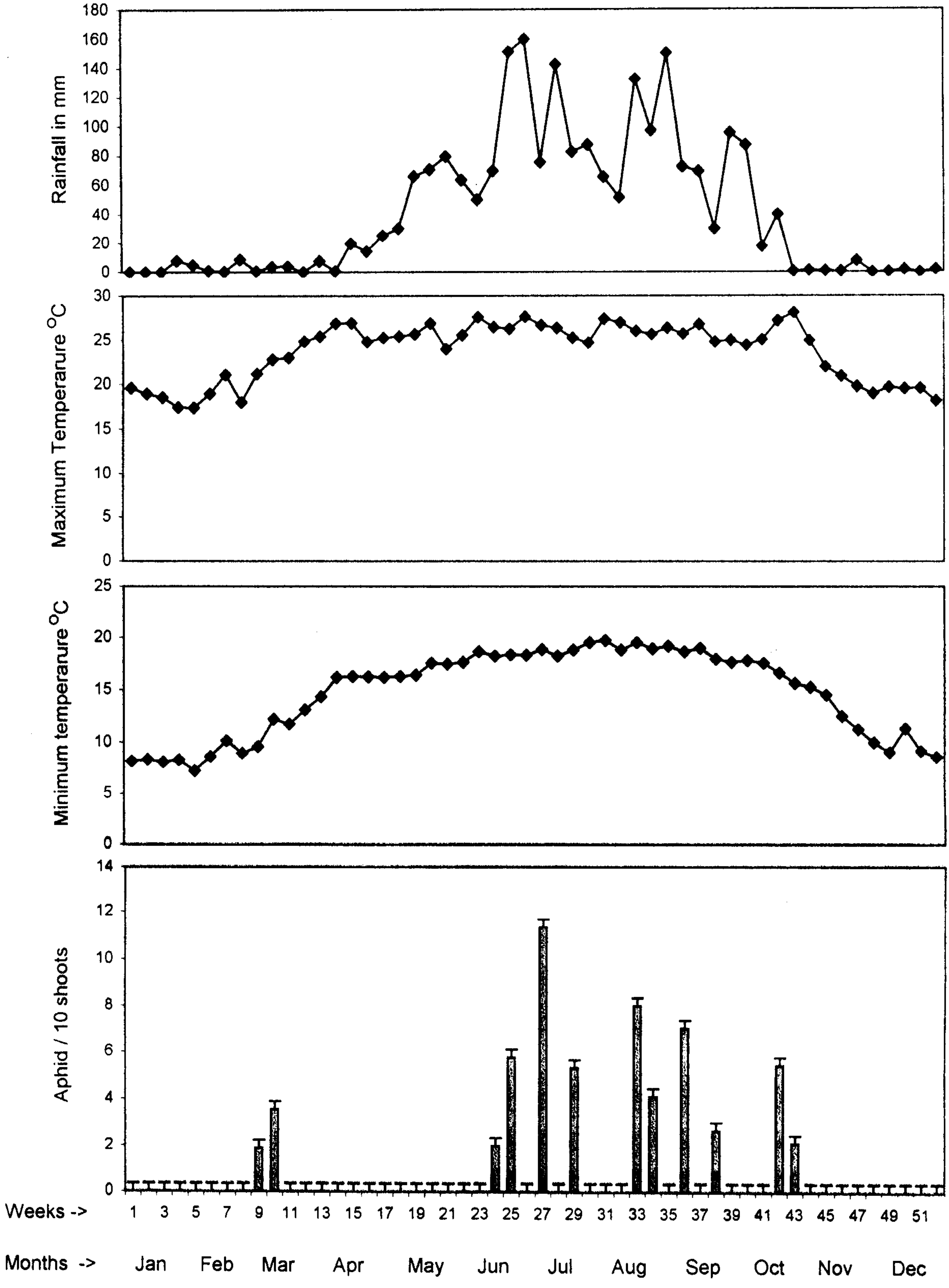


Fig. 30: Weekly changes in population of *T. aurantii* (Mean + SE of 3 yrs, 1999-2001) on tea **clone T 78 at high elevation** with average weather data

heavy downpour during monsoon and continuous plucking did not allow the pest to establish in any of the experimental sites.

Moreover, it is reported that aphid is more active on pruned teas (Anonymous, 1994), because of more succulent growth during the recovering stage after pruning coinciding with the appearance of aphid. In this study, tea bushes were kept unpruned to see the population trend throughout the season including the winter. This is also a reason why its population did not possibly build up to attain the pest status.

5.1.3.1.2. Aphid population vs planting materials and elevations

To the study the variation in aphid population on two different clones at two different elevations analysis of variance was done for the four different situations under study and the result is presented in table 10. But the difference in population of aphid was not found statistically significant in any of the situations.

5.1.3.1.3. Influence of weather factors on Aphid population

To study the influence of weather factors on aphid population under various situations, multiple regression analysis was done. The aphid population was used as dependent variable and the weather factors – rainfall, maximum temperature, minimum temperature, relative humidity (morning and afternoon) and sunshine hours (Appendix V) as independent variable at the site at mid elevation (TRA-CPS). In another site at high elevation (Sungma tea

Table 10: Analysis of variance on weekly population of Aphid (*T. aurantii*) on two planting materials at mid and high elevation.

Treatment	Sample size	Sample mean			
		1999	2000	2001	Av. 1999-01
Aphid on China seed jat at mid elevation	52	1.64	1.60	1.21	1.48
Aphid on China seed jat at High elevation	52	1.27	1.80	1.77	1.61
Aphid on clone T 78 at mid elevation	52	1.28	1.37	1.09	1.25
Aphid on clone T 78 at high elevation	52	0.99	1.27	1.16	1.14
Calculated F		0.22	0.15	0.30	0.30

estate), only rainfall, maximum temperature and minimum temperature (Appendix VI) were used as independent variables as data on other weather parameters were not available. The results are presented in table 11. It is evident in the table that the R^2 values are very low in all the cases and they are non-significant except in case of china seed at high elevation. As such the estimated regression equation may not be meaningful to predict aphid population. Nevertheless to see the influence of individual abiotic factor on aphid population, simple regression analysis was done and result is presented in the Table 12. Rainfall appeared to have a significant positive influence on both the plating materials at mid elevation, but it was not significant at high elevation. Both maximum and minimum temperatures showed a positive significant influence in all the situations except for the influence of maximum temperature on T 78 at mid elevation, which was non significant.

At mid elevation relative humidity in the morning and afternoon had significant positive influence on the aphid population of both the plating materials except that of morning humidity in case clone T 78, which was not significant. Sunshine hours had a highly significant negative influence on both the planting materials.

5.1.3.2. APHID POPULATION (WITH PEST CONTROL MEASURE)

Observations on aphid population were also taken simultaneously in plots kept under insecticide spray as per normal practice of the garden mentioned under Common thrips. The weekly observations are presented graphically in Figures 31 (Appendix I to IV).

Table 11 : Multiple linear regression model for Aphid (*T. aurantii*) against weather parameters

Site	Planting Material	Regression coefficient of independent variable							R^2	F Cald.
		Intercept	Rainfall	Temperature ^{0}C		Relative humidity %		Sunshine hours		
				Maximum	Minimum	Morning	Afternoon			
TRA – CPS	China seed Jat	4.6804 (8.2740)	-0.0011 (0.0078)	-0.5553 (0.6545)	0.7946 (0.7054)	-0.0316 (0.0995)	-0.0002 (0.1051)	0.0324 (0.3483)	0.09#	2.39
	Clone – T 78	5.8259 (7.0623)	0.0010 (0.0067)	0.0693 (0.5587)	0.1149 (0.6021)	-0.1096 (0.0849)	0.0466 (0.0897)	-0.4541 (0.2973)	0.08#	2.07
Sungma tea estate	China seed Jat	-3.0648 (2.3308)	-0.0026 (0.0075)	0.0749 (0.1473)	0.1896 (0.1502)				0.06##	3.43 *
	Clone – T 78	-2.2313 (2.0682)	0.0065 (0.0067)	0.1106 (0.1307)	0.0326 (0.1332)				0.04##	2.00

Main figures are regression coefficients and figures in the parentheses are standard errors
n = 156, df = f_1 (k) = 6 and f_2 = (n-k-1) = 149, ## df = f_1 (k) = 3 and f_2 = (n-k-1) = 152 (Gomez and Gomez, 1984).
** Significant at 1 % level by F - test

Table 12 : Simple linear regression matrix: Effect of individual abiotic factor on the incidence of Aphid (*T. aurantii*)

Site	Planting Material	Regression coefficient of independent variable					
		Rainfall	Temperature ^{0}C		Relative humidity %		Sunshine hours
			Maximum	Minimum	Morning	Afternoon	
TRA – CPS , Ging	China seed Jat	0.0132* (0.0054)	0.2582 * (0.1026)	0.2899 * * (0.0832)	0.0895 * * (0.0289)	0.0743 * * (0.0224)	-0.4686 * * (0.1730)
	Clone T 78	0.0110 * (0.0045)	0.1642 (0.0878)	0.1833 * (0.0718)	0.0448 (0.0250)	0.0429 * (0.0193)	-0.4214 * * (0.1464)
Sungma tea estate	China seed Jat	0.0120 (0.0062)	0.2504 * * (0.0924)	0.2607 * * (0.0821)			
	Clone T 78	0.0102 (0.0055)	0.1698 * (0.0817)	0.1572 * (0.0731)			

Main figures are regression coefficients and figures in the parentheses are standard errors
n=156; df = (n-2) = 154; *Significant at 5 % level, ** Significant at 1 % level

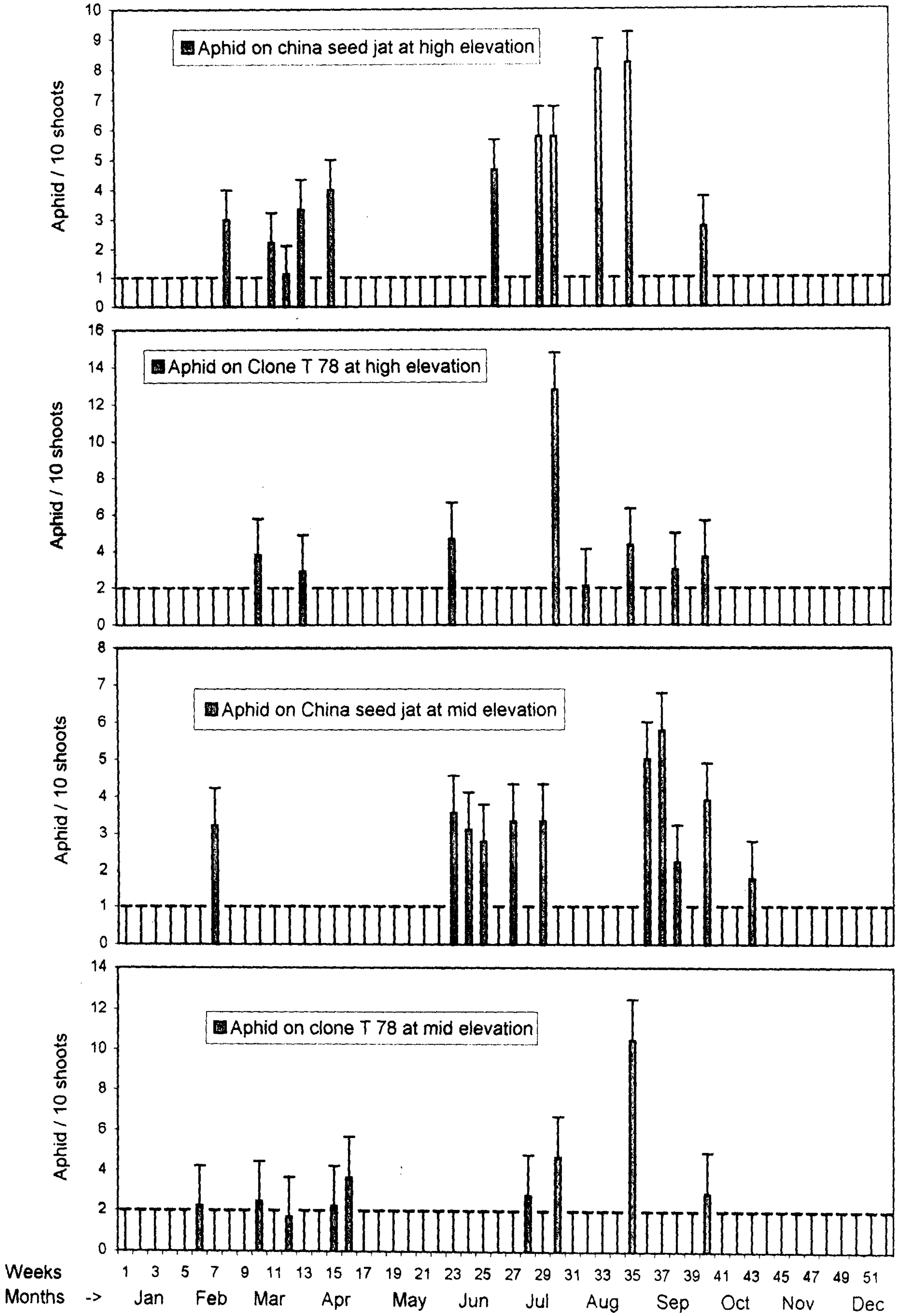


Fig. 31: Weekly changes in population of *T. aurantii* (Mean + SE of 3 yrs, 1999-2001) at **different situations** with **pest control measures**

Sporadic colonies of aphid could be noticed even in the pesticide treated plots during the rainy seasons. However, no insecticide was used from mid July to September end as thrips and greenfly were naturally controlled and infestation level of aphid was very low.

5.1.4. A COMPARISON OF THE INCIDENCE OF COMMON THRIPS, GREENFLY AND APHID

The weekly changes in population (Mean 1999 to 2001) of all the three sucking pests under different situations are graphically presented in the Figures 32 to 35. It was observed that in spring the built up of thrips population was much earlier in all the four situations than the two other sucking pests, reaching the first peak during April-May. Though greenfly population persisted at low level at the beginning of the season, the first peak was noticed sometimes in June –July, the time by which thrips population started to decline. However in autumn, mixed infestation of both the insects was noticed. The population of both the pests started increasing as soon as monsoon rains receded by end September, reaching the peak infestation level in October. Aphid, in scattered colonies, was active mainly during rainy season when population of other two sap suckers remained at low level.

While thrips were generally confined to the unopened buds and the first leaf from top of a growing shoot, the greenfly was generally confined to the second and third leaves for better shelter. Hence, their coexistence was sometimes noticed during autumn flush without much of competition in between both the suckers for food. When scattered aphid colonies started

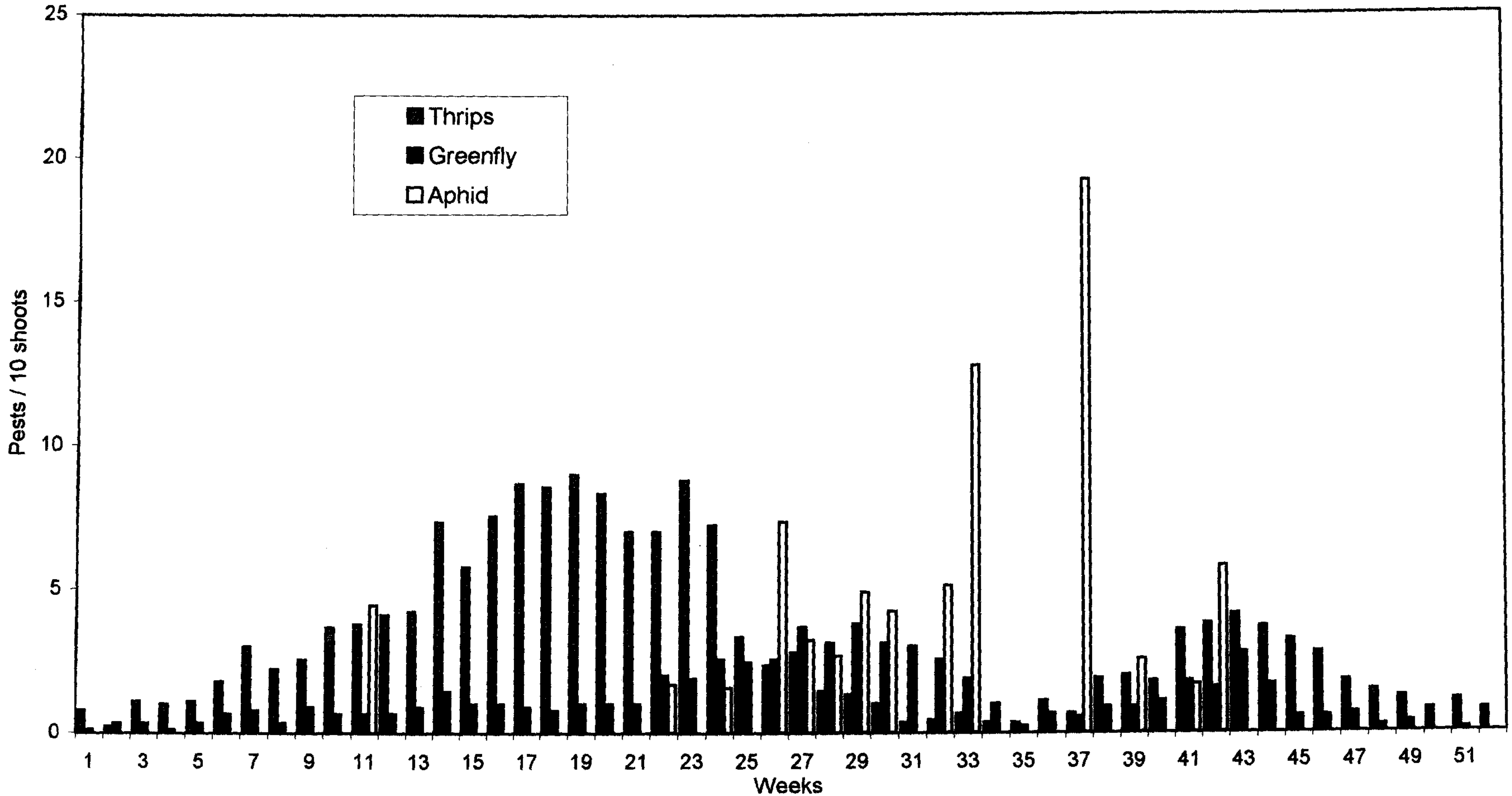


Fig. 32: A comparison of weekly changes in population of *M. setiventris, E. flavescens and T. aurantii* (Mean of 3 yrs, 1999-2001) on **china seed jat** of tea at **mid elevation**

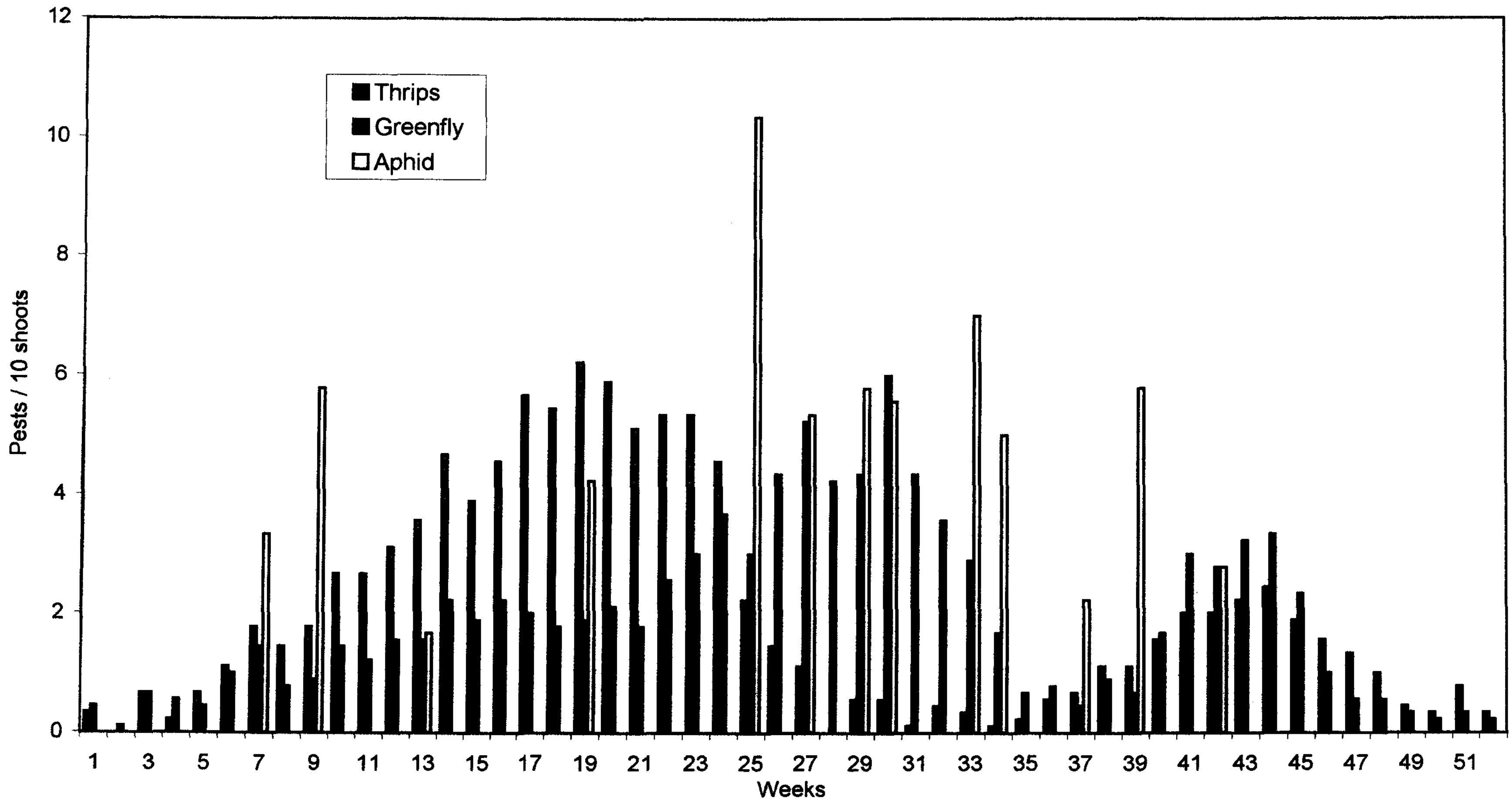


Fig. 33: A comparison of weekly changes in population of *M. setiventris, E. flavescens* and *T. aurantii* (Mean of 3 yrs, 1999-2001) on tea **clone T 78** at **mid elevation**

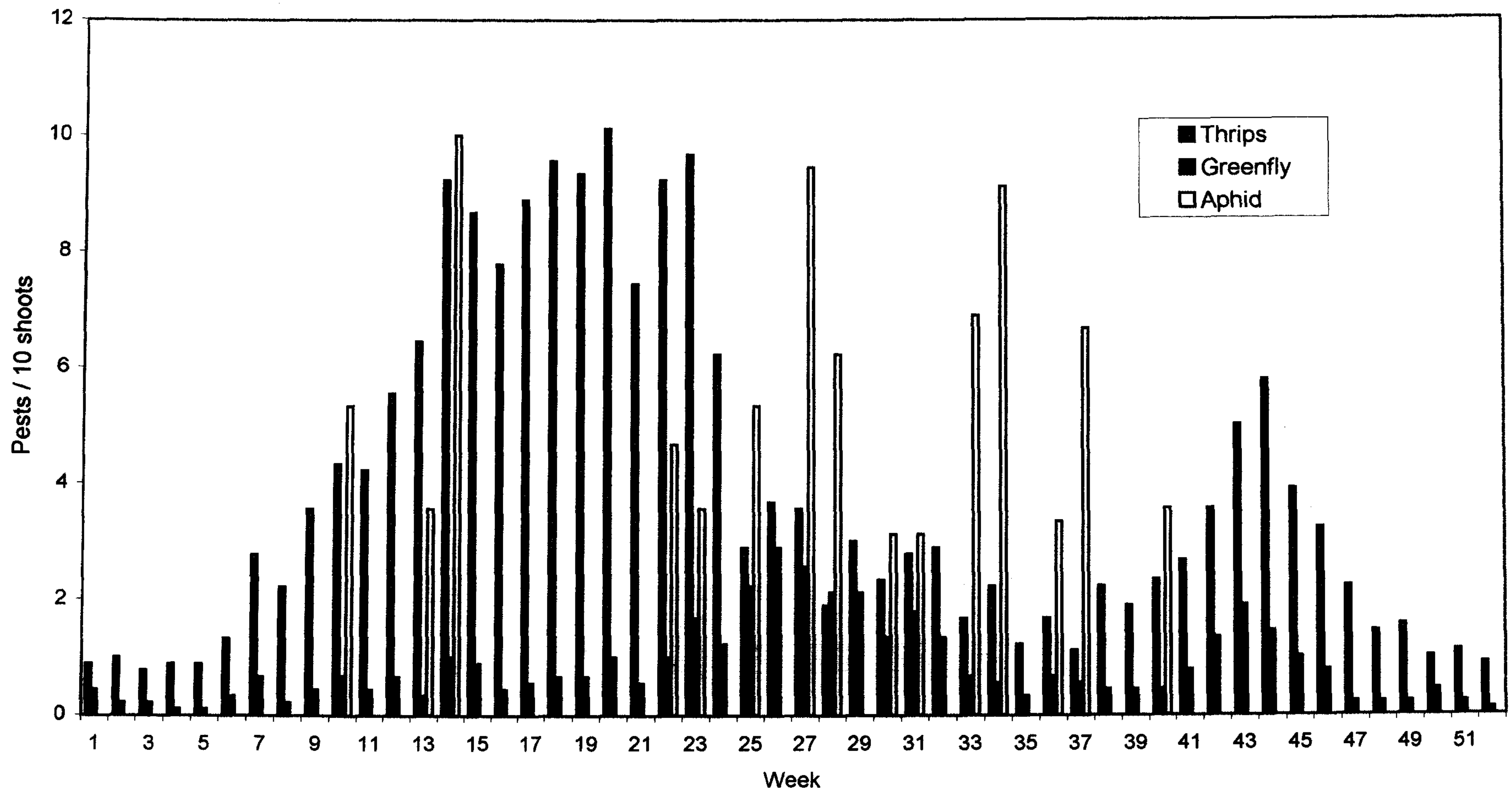


Fig. 34: A comparison of Weekly changes in population of *M. setiventris, E. flavescens* and *T. aurantii* (Mean of 3 yrs, 1999-2001) on **china seed jat** of tea at **high elevation**

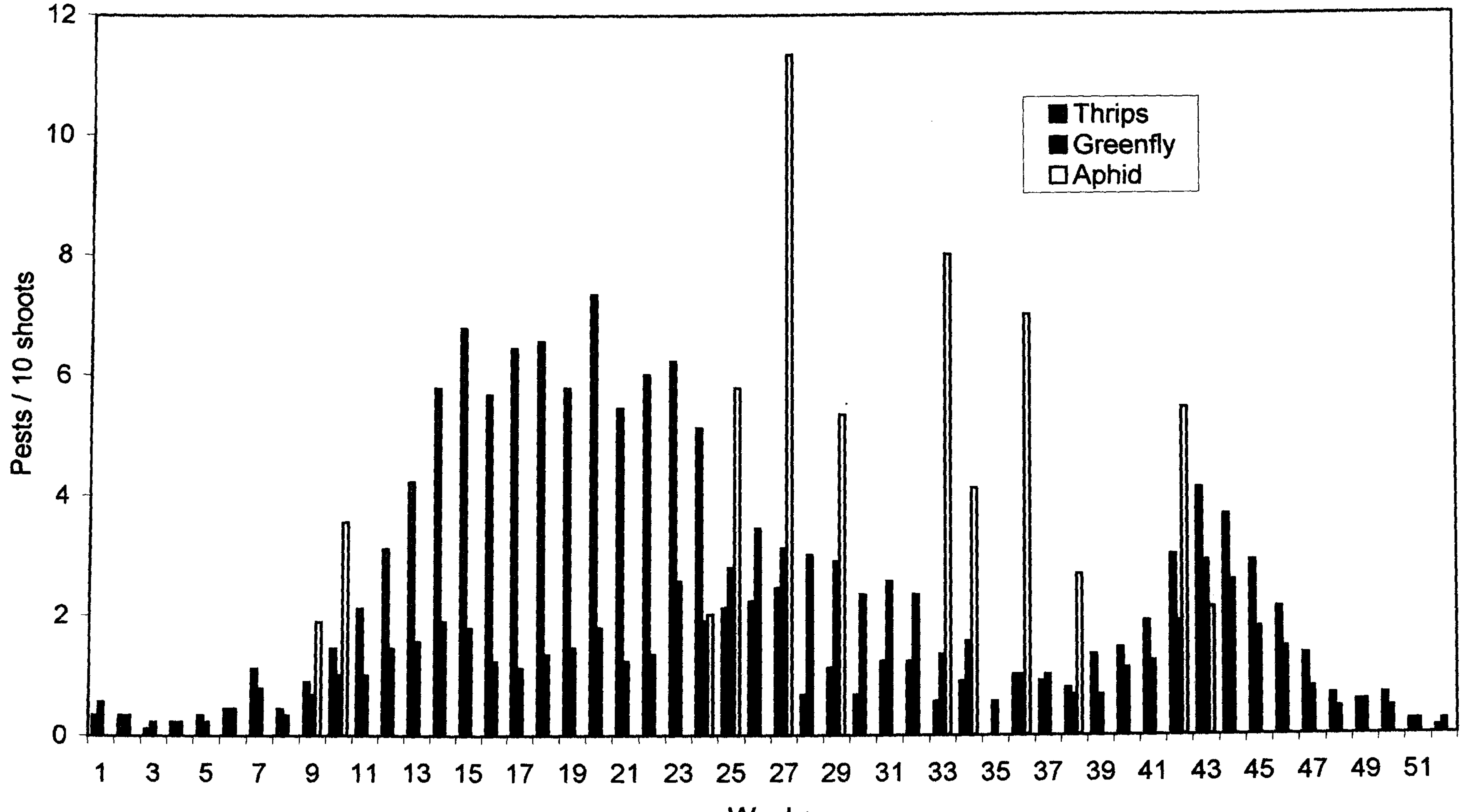


Fig. 35: A comparison of weekly changes in population of *M. setiventris, E. flavescens and T. aurantii* (Mean of 3 yrs, 1999-2001) on tea **clone T 78** at **high elevation**

appearing both common thrips and greenfly population started reducing. This is perhaps a classic example of sharing food under natural conditions as all the sucking pests attack the growing shoots of tea only.

Confinement of thrips mainly to the top of the growing shoot also makes them more susceptible to plucking than greenfly and the population reduces as soon as intensity of plucking increases along with increasing rate of growth of the tea shoot. But greenfly can protect itself under slightly older leaves at lower hamper of foliage below the plucking table though certain amount of population is always removed by plucking. It's population ultimately get reduced by beating effect of rain drops of heavy downpour during July end - August.

5.2. ALTERNATE HOST

Extensive manual search was made in and around the tea estates of Darjeeling to find out if there is any alternate host of the sucking pests under study. The observations made are presented below.

5.2.1. COMMON THRIPS

No other host of *Mycterothrips setiventris* could be detected during the study. The pest was found confined to tea only. This is one of the oldest pests of tea in Darjeeling hills, which drew attention of the tea planters and the scientists with its first appearance as early as in 1907 followed by a serious outbreak in 1908 (Andrews, 1925). Since then the pest is active on Darjeeling tea plantation occurring throughout the year, though being managed by pest control measures. Tea being a monoculture and perennial crop, the pest is getting continuous food supply to survive. Though tea in certain areas (around 35-40 %) of each estate is pruned or deep skiffed in every winter by removing the foliage, yet tea in rest of the areas remains unpruned with full set of maintenance foliage which support their life cycle. Hence, without help of any alternate host the pest can continue it's life cycle.

5.2.2. GREEN FLY

5.2.2.1. *Camellia japonica*

Fig. 36: *Camellia japonica* infested by greenfly (Inset: A close up view)

The ornamental, *C. japonica* was found under severe attack at times by green fly (Fig. 36). Heavy infestation was noticed during mid May to early July, 2003 on *C. japonica* planted in Bungalow campus of a garden at mid elevation. The damage symptoms are more or less similar to that of cultivated tea. The population of the pest was very high with hundreds of individuals at different stages of growth in a single growing primary, which is generally not noticed in tea. The leaves became yellowish with marginal necrosis and downward cupping. Almost all immature or semi mature leaves were attacked in all the primaries of infested tree. But, whether it lays eggs on the ornamental *C. japonica* or not is not confirmed.

These *C. japonica* is generally grown as ornamental plant in bungalow campuses and residential areas in and around of the tea estates. This plant was found to work as a good alternate host of greenfly. Without any human disturbance like, plucking, pruning or skiffing operation, of the plant the pest was getting a very congenial habitat to continue its life cycle. Though the infestation was reduced during peak monsoon period, it again increased in autumn on this plant without any pest control measures

5.2.2.2. *Ricinus communis*

E. flavescens infestation was noticed on castor (*R. communis*) leaves growing wild at low elevation. The leaf under attack became yellow and then brown giving an appearance of "Hopper burn". In case of severe infestation leaf curled.

5.2.2.3. *Priotropis cytisoides*

Priotropis cytisoides, a shrub, is grown as green crop, particularly in young and rejuvenated tea areas in Darjeeling to improve the organic mater in the soil and also provide shade to tea. Being a legume it is also known to fix atmospheric nitrogen in soil through symbiosis with *Rizobium* sp. This species of green crop grows well even at high elevation in the hills, hence preferred. Mild infestation of green fly was noticed occasionally on the green crop. Different stages of nymphs and adults occurred on this host plant coinciding with the greenfly infestation in tea. However, the way the pest can utilize this host for reproduction requires a detailed study.

5.2.3. APHID

5.2.3.1. *Citrus medica*

It was observed that *T. aurantii* had occasionally attacked growing lemon (*C. medica*) shoots resulting in yellowing and crinkling of tender shoots. The time of its appearance on lemon coincided with the attack in tea *i.e.* June – August.

5.3. STUDIES ON FEEDING IMPACT ON MADE TEA

In Darjeeling there is a strong and age old belief amongst the tea planters that the infestation of tea shoots in the field by thrips and greenfly improves quality, particularly flavour in made tea. This study was conducted to see if there is really any positive impact on overall quality in made tea manufactured from thrips and green fly infested leaves over that from uninfested one. Made tea samples were prepared at miniature manufacturing factory at TRA, CPS Ging from thrips and green fly infested and uninfested leaves. Oganoleptic taste (traditional tea tasting through mouth) as well as biochemical analysis was done to ascertain the impact of feeding by both the pests on made tea quality.

5.3.1. ORGANOLEPTIC TASTE

Organoleptic tasting was done on 3 main parameters viz- flavour, liquor and overall quality. The tasters' scoring was done on these 3 parameters as per Darjeeling standard on a 10-point scale. In total four repetitions (replications) were done and each sample was tasted by three different tasters. The summary of the tasters' report on tea made from Common thrips infested shoots is presented in tables 13 (Appendix VII) and that from Greenfly in table 14 (Appendix VIII). It was observed that the tasters score was always higher for all the parameters in case of tea made from the shoots infested by both the pests. "Student t" test was done to see whether these differences were statistically significant or not. In some cases they were found statistically significant as shown in the above table.

Table 13: Organoleptic taste on Common thrips infested and uninfested leaves.

Parameter	Tasters' scores on **China seed jat**				Tasters' scores on **Clone T 78**			
	Infested	Un-infested	't' value (df=4+4-2=6)	% '+' or '-' over Uninfested	Infested	Un-infested	't'value (df=4+4-2=6)	% '+' or '-' over Uninfested
Flavour	7.40+	6.58	3.08 *	12.46	6.78	5.58	3.14 *	21.51
Liquor	6.11#	5.56	1.11	9.89	7.23#	6.21	5.99 * *	16.43
Quality	5.32	4.94	0.06	7.69	5.20	4.50	1.95	15.56
Average	6.28	5.69		10.36	6.40	5.43		17.86

+ Each figure is the average of 3 Tasters' scores and 4 replications
* Significant at 5 % level
* * Significant at 1 % level
\# Liquor was graded as per Darjeeling tea specification (thinner liquor scoring more value)

Table 14: Organoleptic taste on Greenfly infested and uninfested leaves.

	Tasters' scores on **China seed jat**				Tasters' scores on **Clone T 78**			
Parameter	Infested	Un-infested	't' value (df=4+4-2=6)	% '+' or '-' over Uninfested	Infested	Un-infested	't' value (df=4+4-2=6)	% '+' or '-' over Uninfested
Flavour	7.57+	6.68	3.29 *	13.32	5.89	5.12	1.99	15.04
Liquor	5.78#	5.37	0.86	7.64	6.33#	5.58	4.71 * *	13.44
Quality	6.33	5.66	1.66	11.84	5.50	4.65	1.98	18.28
Average	6.56	5.90		11.19	5.91	5.12		15.43

+ Each figure is the average of 3 Tasters' score and 4 replications
* Significant at 5 % level
* * Significant at 1 % level
Liquor was graded as per Darjeeling tea specification (thinner liquor scoring more value)

The scores for flavour were significant in all the cases except Greenfly on T 78 indicating a positive impact on flavour due to infestation by both the pests.

The liquor was graded by the tasters as per Darjeeling tea specification *i.e.* thinner liquor scoring higher value. The scores for liquor were highly significant in case of T 78 both for thrips and greenfly infested shoots though it was found non-significant in case of China seed *jat.* The liquor is generally thin in case of china tea than any hybrid or Assam type tea under same type of manufacture, which is a desirable character in Darjeeling tea (# of table 13 and 14). The T 78 clone is a hybrid having some Assam character and produces slightly thicker liquor than china seed. Due to sucking of the sap *in situ* the shoots were pre-withered which might have helped to make the licker thinner, because higher percentage of withering helps to make thin liquor. It is likely that injury by pests affected the chloroplastidic enzyme responsible for oxidation of catechins (Mathew and Douglas, 1997). Ullah and Roy (1982), comparing the hard withered orthodox and light withered CTC tea, reported that in orthodox manufacturing process hard wither restricted and slowed down the oxidation (fermentation) of the tea flavanols by reducing the polyphenol oxidase activity resulting in light liquor with high flavour. Where as in CTC tea, wither was light resulting in extensive cell rupture. Then fast and drastic oxidation of the flavanols dominated all through the fermentation process producing strong liquor with less flavour (Ullah, 1985).

In case of overall quality, the tasters' scores on infested samples were not found statistically significant for both the pests and the planting materials though it was higher in all the cases than the uninfested one.

When the difference in between infested and non-infested teas was compared, it was noticed that this difference was more pronounce in case of flavour than the other parameters tasted.

The overall positive impact of feeding was higher in case of clone T 78 than the china seed *jat*. This can be attributed to the variation in texture of leaves of these two planting materials. The china seed *jat* having hard texture compared to T 78 make it difficult for the insect to penetrate and induce the effect on changes in flavour.

The look of the infested leaves generally turned out to be brownish due to sucking of the sap indicating a reduction in chlorophyll level in comparison to non-infested shoots, which was a desirable character in plucked shoots for Darjeeling type of manufacture. Reduction in chlorophyll content might also help to produce thin liquor as shoots with high chlorophyll content produce inferior tea with black appearance (Dev Choudhury and Bajaj, 1980) and blackish tea gives thicker liquor. Wickremasinghe (1974) also reported a positive role of sucking pests in flavour development by reducing chlorophyll content of the fresh leaf.

5.3.2. BIOCHEMICAL INVESTIGATION

Biochemical investigations were done to see the difference in catechins, caffeine and the Volatile Flavour Constituent in made tea manufactured from the sucking pest infested and uninfested tea shoots.

5.3.2.1. Feeding impact on Catechin

In tea leaves there is a considerable amount of polyphenolic compounds located in the vacuoles of the palisade cells of both lower and upper epidermis and in the vascular bundles (Wickremasinghe, *et al.*, 1967). The three important class of polyphenols which together form the complex mixture of tea tannins are Flavanols (catechins) and their gallates, flavonol glycosides and phenolic acids (Roberts, 1962). The catechins are the major class and three of them namely (-) epigallocatechin (EGC), (-) epigallocatechin gallate (EGCG) and epicatechin gallate (ECG) comprise over 90 % of the total flavanol fraction of the tea polyphenols. During tea manufacturing process (mainly rolling and fermentation) the flavanols are converted to the coloury compounds theaflavins (TF) and thearubigins (TR) through oxidation, in presence of catalytic enzyme, polyphenol oxidase (PPO) and peroxidase (PO) (Gregory and Bendall, 1966; Coggon *et al.*, 1973, Robertson and Bendall, 1983). In orthodox manufacture, this oxidation is lower than the CTC manufacture leaving certain amount of catechin unoxidised, which is known as residual catechin (Hazarika and Mahanta,1983).

Considering the major roll played by the catechins in made tea characteristic, biochemical analysis was done to study the difference in residual catechins in infested and uninfested tea shoots.

HPLC analysis of made tea samples prepared from thrips and greenfly infested and uninfested shoots was done on residual catechins and caffeine. The results are presented in the table 15 and 16 (Appendix IX & X) for thrips and greenfly respectively. Student 't' test was done to compare the difference of individual catechin in between the teas made from infested and uninfested tea shoots. Their percentage increase or decrease in infested tea over uninfested one was also calculated taking average of both the sources (China seed *jat* and T 78 clone) to see overall impact which is presented in the tables 15 and 16.

A regular trend in variation was observed in residual catechins in black tea made from thrips and greenfly infested and uninfested leaf. Major catechins were found to be higher in infested tea over uninfested one.

In case of thrips, when the student 't' test was done most of the catechins like (-) epicatechin, (-) epigallocatechin gallate, (-) epicatechin gallate were found significantly higher than the uninfested leaf for both the planting material.

In case of greenfly, the impact was found more prominent in clone T 78 having significantly higher amount in case of (-) epigallocatechin, (-) epigallocatechin gallate and (-) epicatechin gallate. In other cases, the difference was found nonsignificant though the higher trend of residual

Table15: HPLC analysis of residual Catechins and caffeine in black tea made from Common thrips infested and uninfested shoots (in % dry weight, average of four sets).

Parameters	China seed jat (A)			Clone T 78 (B)			Average of A & B		% '+' or '-' over Uninfested
	Infested	Un-infested	't' value (df=4+4-2=6)	Infested	Un-infested	't' value (df=4+4-2=6)	Infested	Un-infested	
(-) epigallocatechin (EGC)	0.88	0.82	0.75	0.95	0.88	1.27	0.92	0.85	+ 8.24
(+) gallocatechin (GC)	0.38	0.33	1.36	0.45	0.44	0.21	0.42	0.39	+7.69
(-) epicatechin (EC)	0.56	0.57	0.23**	0.64	0.48	4.07 * *	0.60	0.53	+13.21
(-) epigallocatechin gallate (EGCG)	3.94	3.78	1.78**	4.92	3.83	8.84 * *	4.43	3.81	+16.27
(-) epicatechin gallate (ECG)	2.11	2.04	0.79**	3.01	2.43	9.98 * *	2.56	2.24	+14.29
Caffeine	2.71	2.84	2.28**	2.94	3.27	3.75 * *	2.83	3.06	-7.52

** Significant at 1 % level

Table 16: HPLC analysis of residual Catechins and caffeine in black orthodox tea made from Greenfly infested and uninfested shoots (in % dry weight, average of four sets)

Parameters	China seed jat (A)			Clone T 78 (B)			Average of A & B		% + or – over uninfested
	Infested	Uninfested	't' value (df=4+4-2=6)	Infested	Un-infested	't' value (df=4+4-2=6)	Infested	Un-infested	
(-) epigallocatechin (EGC)	0.88	0.84	1.16	1.05	0.85	4.07 * *	0.97	0.84	+15.48
(+) gallocatechin (GC)	0.42	0.35	1.80	0.46	0.42	1.07	0.44	0.39	+12.82
(-) epicatechin (EC)	0.66	0.58	1.37	0.68	0.62	2.22	0.67	0.60	+11.67
(-) epigallocatechin gallate (EGCG)	4.26	3.87	2.29	4.62	3.73	5.89 * *	4.44	3.8	+16.84
(-) epicatechin gallate (ECG)	2.19	2.24	0.42	3.31	2.63	3.84 * *	2.73	2.44	+11.88
Caffeine	2.78	2.97	1.81	2.84	3.17	2.88 *	2.81	3.07	-8.47

* Significant at 5 % level, ** Significant at 1 % level

Catechins in tea made from infested shoots over uninfested was maintained.

It is most likely that sucking insect rupture the cell wall while feeding inducing formation of pathogen related protein (PRP) which in addition to providing the defensive mechanism may influence the quality during processing (Bowles, 1990). The increase in phenolic compounds, probably as a plant defense mechanism against pest attack, was reported in many species of plants including tea (Feenstra *et al.*, 1963; Feldman *et al.*, 1967; Hori, 1973 and, Maitra, 1994; Borah, 1996; Ebel and Cosio, 1994). In the present study also, accumulation of polyphenols (Catechins) in the infested leaf might be encouraged as a defensive mechanism against the infestation by the sucking pests. As mentioned earlier pest infestation also induces PRP. All these may lead to imbalances in the ratio of desired catechins to enzymes responsible for their changes influencing the level of residual catechins.

In this study, a general trend of higher level of residual catechin in thrips and greenfly infested tea indicated a possible scope for higher level of flavour. Because, an inverse relation was reported by earlier workers in between the quantum of catechin oxidized and the level of flavour in made tea. Lower the oxidation more was the quantity of residual catechin and higher was the flavour (Hazarika and Mahanta,1983).

In an earlier study also, a higher level of total polyphenol was observed in fresh tea shoots infested by greenfly. The level was dependent on degree of infestation, with higher level of infestation there was reduction in level of polyphenol. But, in no case their level was found lower than their normal uninfested counterpart (Borah,1996). This is in conformity with the present observations. A similar accumulation of higher level of polyphenols also for the thrips infested leaves indicates that the underlying reaction of the tea plants to feeding by greenfly and thrips is common and results into an improvement of tea quality in general. However, the variation in the residual catechins in China seed *jat* and T 78 clone to greenfly and common thrips infestation speaks about the different defense response of these two planting material of tea.

5.3.2.2. Feeding impact on Caffeine

The caffeine was found lower in case of tea made from thrips and greenfly infested shoots for both the planting materials of china seed *jat* and clone T 78 (Table15 and 16; Appendix IX and X). This difference was statistically significant in all the cases except for Greenfly in china seed *jat*. This observation confirms the findings of earlier worker (Borah, 1996). Such reduction of caffeine content in tea was also reported in case of feeding by tea aphid, *Toxoptera aurantii* (Radhakrishnan,1989). But, the reason for this decrease in caffeine content due to feeding by sucking insects could not be understood. Possibly injury by the pests affected the nitrogen metabolism of the plant consequent to which the caffeine decreases. The advanced oxidation due to injury may also lead to decrease in caffeine content. However, it is very difficult to arrive at a conclusion from the present observation on the exact reason for decrease in caffeine in the tea made from the infested shoots.

Caffeine is known as a vasodilator, which increases the rate of respiration and stimulates gastric secretion. It also exerts effect on the central nervous system, on muscles including cardiac muscles and on kidney. It stimulates mental alacrity, shortens reaction time and relieves mental fatigue. The stimulating effect of caffeine is not found to be associated with any subsequent depression or hangover. Caffeine in tea enhances the drug metabolizing activity of liver. (Mitoma *et al.* 1968, Bajaj,1975 b). Due to presence of caffeine tea may have a value to treat gout and in restoration of fluid balance following vomiting or diarrhoea (Das *et al*, 1965). It is also useful for recovery of mentally depressed patients (Stagg and Millin 1975). However, high level of free caffeine may have some harmful effects on human body like, rise in fatty acids in the blood (Akinyaju and Yudhin, 1967). Persons suffering from peptic ulcer, labile autonomous nervous system and hyper-thyroidism are said to have poor caffeine tolerance (Bajaj, 1975 b). Hence, tea with high caffeine content is not preferred by the consumers, particularly in European countries, which are the major importer of Darjeeling tea. As such, low caffeine content in tea made from sucking pest infested tea shoots is also a desirable character in Darjeeling orthodox tea.

5.3.2.3. Feeding impact on Voiatile Flavour Constituent (VFC)

In Darjeeling tea, flavour plays the most crucial roll than any other characters of made tea which determines the price in export market as around 90 % of Darjeeling tea is exported. Hence, biochemical analysis was done using GC to study the difference of Volatile Flavour Compounds (VFC) in between made tea manufactured from sucking pests infested and uninfested tea shoots. The results are presented in tables 17 and 18 and fig. 37 (Appendix XI and XII).

Table 17 : Flavour constituents of orthodox made tea manufactured from Common Thrips infested and uninfested tea shoots (Amounts in ratio of the peak area with "Internal Standard")

Flavour Constituents	China seed jat				Clone T 78				Average of both the sources		
	Infested	Un-infested	't' value 6 df	% '+' or '-'	Infested	Un-infested	't' value 6 df	% '+' or '-'	Infested	Un-infested	% '+' or '-'
1. Trans-2-hexanal	0.053	0.081	0.846	-34.568	0.169	0.236	2.273	-28.390	0.1110	0.1585	-29.9685
2.Nonylaldehyde	0.078	0.047	1.514	65.957	0.038	0.024	0.912	58.333	0.0580	0.0355	63.3803
3. Linalool oxide I	0.51	0.29	1.549	75.862	0.316	0.227	1.334	39.207	0.4130	0.2585	59.7679
4. Linalool oxide II	1.186	0.918	0.988	29.194	0.892	0.731	0.709	22.025	1.0390	0.8245	26.0158
5.Benzaldehyde	0.079	0.055	1.376	43.636	0.089	0.047	1.559	89.362	0.0840	0.0510	64.7059
6.Linalool	0.691	0.67	0.165	3.134	0.341	0.164	2.798*	107.927	0.5160	0.4170	23.7410
7. Phenylacetaldehyde	0.4	0.311	0.975	28.617	0.536	0.321	1.965	66.978	0.4680	0.3160	48.1013
8.Terpineol	0.104	0.078	0.898	33.333	0.623	0.512	0.789	21.680	0.3635	0.2950	23.2203
9. Methylsalicylate	0.07	0.056	0.819	25.000	0.094	0.065	1.318	44.615	0.0820	0.0605	35.5372
10. Geraniol	1.835	0.944	2.411	94.386	0.894	0.356	2.292	151.124	1.3645	0.6500	109.9231
11. Benzylalcohol	0.201	0.062	4.073**	224.194	0.182	0.106	1.766	71.698	0.1915	0.0840	127.9762
12.Phenyl ethanol	0.498	0.158	1.302	215.190	0.132	0.114	1.281	15.789	0.3150	0.1360	131.6176
13. b-Ionone	0.09	0.044	1.908	104.545	0.043	0.062	0.814	-30.645	0.0665	0.0530	25.4717
14. Caprylio Acid	0.213	0.136	1.301	56.618	0.312	0.186	1.819	67.742	0.2625	0.1610	63.0435
15. Octaldehyde	0.148	0.084	1.179	76.190	0.675	0.436	1.219	54.817	0.4115	0.2600	58.2692
16. Nonanoic Acid	0.157	0.033	3.860**	375.758	0.187	0.085	2.864*	120.000	0.1720	0.0590	191.5254
17. Jasmonic acid	0.288	0.254	0.533	13.386	0.187	0.146	1.139	28.082	0.2375	0.2000	18.7500
18. Geranic acid	0.242	0.161	1.634	50.311	0.289	0.157	3.071*	84.076	0.2655	0.1590	66.9811

* Significant at 5 % level

* * Significant at 1 % level

Table 18: Flavour constituents of orthodox made tea manufactured from <u>Greenfly</u> infested and uninfested tea shoots (Amounts in ratio of the peak area with "Internal Standard")

Flavour Constituents	China seed jat				T – 78				Average of both the sources		
	Infested	Un-infested	't' value 6 df	% '+' or '-'	Infested	Un-infested	't' value 6 df	% '+'or '-'	Infested	Un-infested	% '+' or '-'
1. Trans-2-hexanal	0.048	0.085	1.5063	-94.353	0.069	0.134	2.817*	-48.507	0.0585	0.4920	-88.1098
2.Nonylaldehyde	0.112	0.052	2.447	115.385	0.041	0.033	0.444	24.242	0.0765	0.0425	80.0000
3. Linalool oxide I	1.057	0.239	6.884**	342.259	0.650	0.436	1.726	49.083	0.8535	0.3375	152.8889
4. Linalool oxide II	2.277	0.372	8.801**	512.097	1.860	1.438	1.328	29.346	2.0685	0.9050	128.5635
5.Benzaldehyde	0.153	0.022	4.553**	595.455	0.094	0.069	2.106	36.232	0.1235	0.0455	171.4286
6.Linalool	1.189	0.312	4.674**	281.090	0.330	0.226	1.569	46.018	0.7595	0.2690	182.3420
7. Phenylacetaldehyde	0.715	0.331	2.784*	116.012	0.429	0.286	2.710*	50.000	0.5720	0.3085	85.4133
8.Terpineol	0.166	0.061	3.154*	172.131	0.820	0.659	1.448	24.431	0.4930	0.3600	36.9444
9. Methylsalicylate	0.073	0.044	1.331	65.909	0.056	0.035	1.315	60.000	0.0645	0.0395	63.2911
10. Geraniol	2.978	1.115	5.386**	167.085	0.659	6.320	3.315*	105.938	1.8185	0.7175	153.4495
11. Benzylalcohol	0.389	0.084	6.864**	363.095	0.120	0.041	4.127**	192.683	0.2545	0.0625	307.2000
12.Phenyl ethanol	0.953	0.206	5.988**	362.621	0.087	0.105	0.583	-17.143	0.5200	0.1555	234.4051
13. b-Ionone	0.124	0.047	3.371*	163.830	0.057	0.037	1.122	54.054	0.0905	0.0420	115.4762
14. Caprylic Acid	0.110	0.135	.803	-18.519	0.297	0.110	3.808**	170.000	0.2035	0.1225	66.1224
15. Octaldehyde	0.074	0.030	2.631*	146.667	0.857	1.724	1.886	-50.290	0.4655	0.8770	-46.9213
16. Nonanoic Acid	0.070	0.026	2.541*	169.231	0.244	0.129	3.438*	89.147	0.1570	0.0775	102.5806
17. Jasmonic acid	0.388	0.176	4.112**	120.455	0.149	0.080	2.728*	86.250	0.2685	0.1280	109.7656
18. Geranic acid	0.346	0.138	5.781**	150.725	0.133	0.188	1.572	-29.255	0.2395	0.1630	46.9325

* Significant at 5 % level

* * Significant at 1 % level

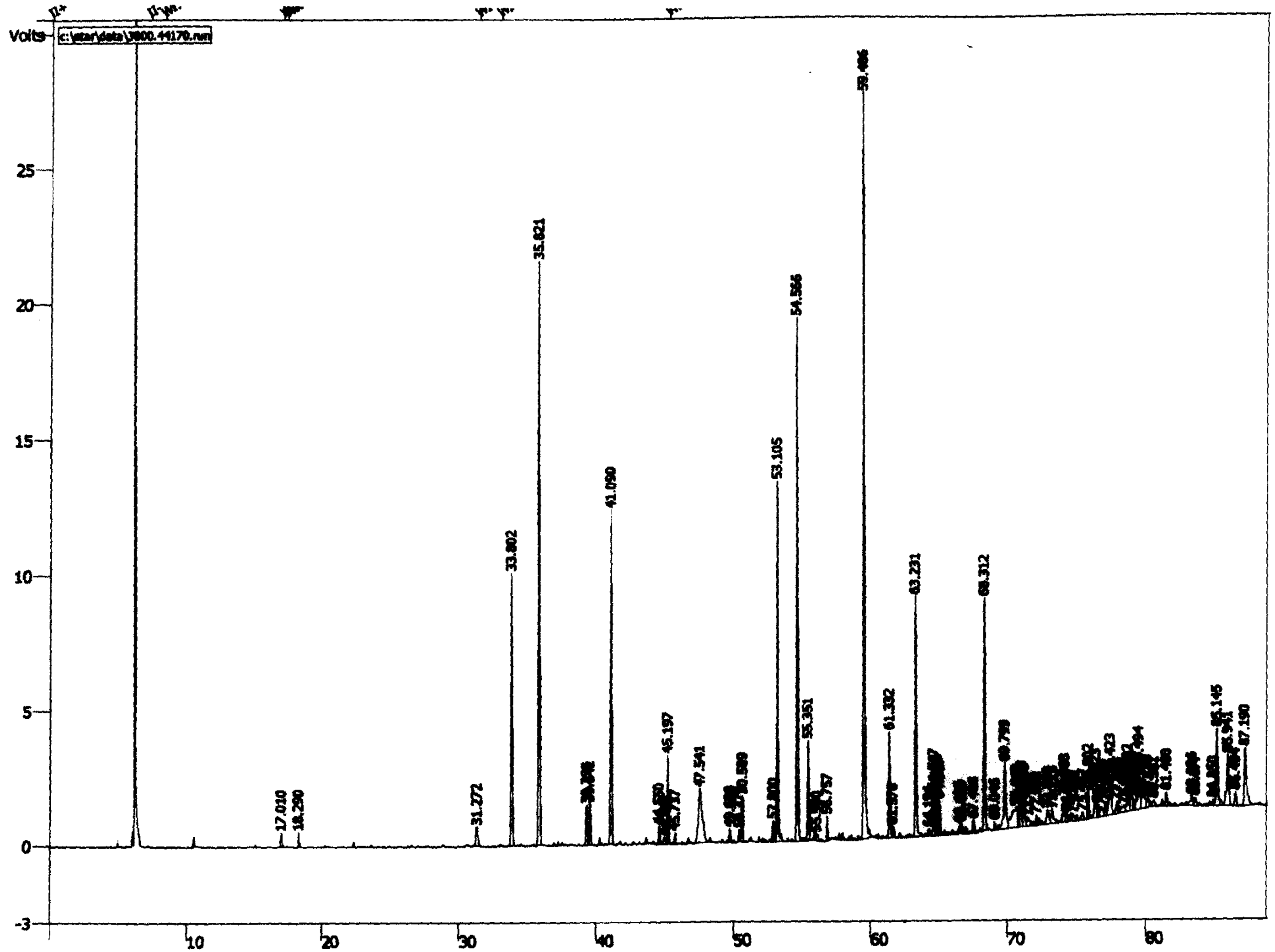


Fig. 37: A typical VFC profile of a made tea sample analyzed for VFC by GC.

It was observed that most of the constituents responsible for the flavour of made tea were higher, in case of tea made from thrips and greenfly infested shoots than their uninfested counterparts for both the planting materials. But, the result was at times variable, and with negative effect in a few cases. The average of both the sources (China seed *jat* and T 78 clone) is presented in the tables 17 and 18 for Common thrips and Greenfly respectively. Student 't' test was done to see whether the difference of individual volatile in infested and uninfested leaf was significant or not. Percentage increase or decrease of infested leaf over uninfested counterpart was also calculated and presented in the said tables.

The earlier workers reported that more withered orthodox tea was more flavoury than low withered CTC tea. This might be due to the higher content of essential volatile flavoury compounds especially linalool and its oxides together with methyl salicylate in orthodox tea (Takeo, 1984). The ratio of trans-2-hexenal to the total aroma constituents was higher in non withered teas as compared to withered teas (Takeo and Mahanta, 1983), where as the ratio of linalool and its oxides and methyl salicylate to the total volatiles was higher in withered teas (Takeo, 1984). The green notes perceived in non-withered CTC tea might be attributed to the higher value of trans-2-hexanal, and the sweet woody notes of withered black teas were due to the effect of linalool and its oxides (Takeo and Mahanta, 1983).

In the present study a general increase was noticed in case of flavour constituents like linalool and its oxides and methyl salicylate in tea made from infested shoots than that of the uninfested one. But, trans-2-hexanales was higher in tea made from uninfested shoots than the infested one. In case of infested tea, shoots were pre-withered in the field due to sucking of the sap by the sucking insect and withering was generally higher than that of uninfested leaf as equal treatment was given to both type of shoots during manufacturing. This might have increased the flavoury compounds responsible for the flavour in infested leaf than the uninfested leaf. Injury by insects might enhance the hydrolysis of terpene glycosides which are important precursors for Darjeeling flavour (Takeo and Mahanta, 1983).

Takami *et al.* (1990) also made a study on aroma component of Pomfon oolong tea made from shoots infested by cicadellid, *E. onukii* and the results were compared with the data obtained for oolong and black teas. They identified 69 compounds from Pomfon oolong tea, including 18 compounds which were tentatively identified. The major chemical compounds were linalool, linalool derivatives and geraniol. The chemical composition of the Pomfon aroma was found similar to that of the other two types of tea. The relationship between the sensory evaluation of *E. onukii* and the aroma pattern was explained by similarities in the chemical composition of the aroma pattern. The ratio of linalool derivatives to linalool was high for the Pomfon oolong tea only. They concluded that the chemical characteristic of the aroma in Pomfon oolong tea were probably formed as a result of feeding by *E. onukii*.

The salivary enzymes as well as feeding-induced-increase in some enzyme levels might be playing a role in the improvement of quality in made tea manufactured from the sucking pests infested tea shoots. Hori (1976) observed a marked increase in polyphenol oxidase and peroxidase in the activities in sugar-beet leaves attacked by *Lygus disponsi*. Miles (1964, 1972, 1987) reported that the saliva of most hemipteran insects contained polyphenol oxidase. In salivary glands of *Helopeltis theivora* that infested tea, high activities of oxidoreductase enzymes, polyphenol oxidase, peroxidase, catechol oxidase and catalase were observed (Sudhakaran, 2000), while the infested tea leaves by the same bug showed about two fold increase of polyphenol oxidase and peroxidase (Mazumdar, 1995). A similar increase of Polyphenol oxidase activities in tea shoots infested by pests was also reported by earlier workers (Bora,1996; Matthew and Douglas, 1997), which improved the quality of made tea (Bora, 1996). These oxidative enzymes play a crucial role in oxidation of tea polyphenol to the secondary metabolites giving desired characteristics to the made tea. These observations suggest that, in the present investigation also, the activities of the oxidizing enzymes might have increased in tea shoots infested by thrips and greenfly, which consequently have improved the overall tea quality.

In the present study, the finding in biochemical analysis was in corroboration with the Organoleptic taste, where a higher level of flavour was noticed in tea made from sucking pests infested shoots than that of uninfested one. From this investigation it can be inferred that there is improvement in flavour of tea made from thrips and greenfly infested tea shoots over the uninfested one. But, from the present study it is not possible to infer whether this increase in flavour can compensate the crop loss caused by the pest attack.

5.4. NATURAL ENEMIES ACTIVE IN TEA FIELDS OF DARJEELING HILLS

5.4.1. POPULATION OF NATURAL ENEMIES

The natural enemies commonly recorded in the samples collected by D-Vac vacuum sampler were Spider, Preying mantid, lady bird beetle, green lacewing and brown lace wing. The data are presented in the table 19 (Appendix XIII).

5.4.1.1. NATURAL ENEMIES VS ELEVATION

It was noticed in general that there was a higher incidence of population of natural enemies in the tea plantations of mid elevation than the high elevation at both bio-organically and conventionally managed gardens. But these differences were not found significant when subjected to "student t" test. Although population of most of the natural enemies showed a higher occurrence at middle elevation than that at higher elevation, the only exception was the population of the brown lacewing, which was found to be higher in upper elevation when compared to that of the mid elevation. However, in all situations the spiders as a group had higher representation than the other groups of natural enemies (Table 19)

The higher population of brown lacewing at upper elevation might be

Table 19 : Population of natural enemies (#) collected by vacuum suction machine

Estate	Bio Organic garden			Conventional garden		
	Mid Elevn.	High Elevn.	t' value at 8 df	Mid Elevn.	High Elevn.	t' value at 8 df
A. Spider Population	16.17 (±2.84)	10.13 (±1.88)	1.661	12.73 (±1.59)	8.47 (±1.54)	1.929
B. Preying Mantids	3.2 (±0.68)	2.67 (±0.51)	0.626	2.2 (±0.31)	1.53 (±0.29)	1.58
C. Lady bird Beetle	3.33 (±0.41)	2.87 (±0.34)	0.873	2.2 (±0.25)	2.07 (±0.12)	0.48
D. Green Lacewing	1.2 (±0.31)	0.6 (±0.19)	1.647	0.67 (±0.18)	0.27 (±0.12)	1.807
E. Brown Lacewing	2 (±0.24)	2.73 (±0.29)	1.97	1.73 (±0.29)	2.2 (±0.17)	1.396
F. Hymenopterous Parasites	1.27 (±0.29)	0.87 (±0.29)	0.974	0.8 (±0.17)	0.53 (±0.08)	1.408

Main figures are the means of catches from 5 gardens (replications) both for bio-organic and conventional gardens. Figures in parentheses are Standard Error of Mean.

Table 20 : Population of natural enemies (#) in bio-organic Vs conventional gardens (irrespective of elevations)

Estate	Bio Organic garden	Conventional garden	't'value at 8 df	% '+'or '-' over conventional
A. Spider Population	12.97 (±2.32)	10.6 (±1.26)	0.896	22.33
B. Preying Mantids	2.93 (±0.58)	1.87 (±0.29)	1.644	57.18
C. Lady bird Beetle	3.10 (±0.36)	2.13 (±0.17)	2.43 *	45.38
D. Green Lacewing	0.9 (±0.22)	0.47 (±0.15)	1.61	92.92
E. Brown Lacewing	2.37 (±0.22)	1.97 (±0.22)	1.283	20.34
F. Hymenopteran Parasites	1.07 (±0.29)	0.67 (±0.11)	1.307	59.97

Main figures are the means of catches from 5 gardens (replications) both for bio-organic and conventional. Figures in parentheses are Standard Error of Mean

* Significant at 5 % level

due to its better tolerance to low temperature as reported by earlier workers (Garland, 1981b).

In general the higher trend of natural enemies at low elevation might be related to the more pest activities at low elevation than at high elevation. Out of the major tea pests, common thrips is more active at high elevation, where as other pests like red spider mite, tea mosquito bug, greenfly etc were found more active at mid and low elevations which naturally encouraged their natural enemies also to multiply. The favourable weather conditions like higher temperature and absence of extreme cold during winter might also help the natural enemies to overwinter for a shorter time and multiply faster at lower elevations.

5.4.1.2. NATURAL ENEMIES VS FARMING SYSTEM

To study the population variation in bio-organic and conventional gardens the average of natural enemies groups was calculated separately for bio-organic and conventional gardens irrespective of elevation and this is presented in the table 20.

It was observed that though there was higher incidence of natural enemy population in bio-gardens over conventional ones, their differences were not statistically significant except that of lady bird beetle. When percentage increase or decrease was computed for bio-organic vs conventional, it was found to be the highest in case of green lace wing (92.92 %) and lowest in case of brown lacewing (20.34 %).

In Darjeeling, there is restriction in use of pesticide to avoid undue residue in made tea. Even in conventional gardens under observation, toxic pesticides were not used during the plucking period and they depended more on botanicals such as neem formulation. This might have helped to sustain a population of natural enemies even in conventional gardens, hence, reducing their difference with that of bio-organic gardens. Muraleedharan *et al.* (1988) also suggested that widespread usage of broad spectrum acaricides such as dicofol and sulfur to control mites was an important reason for low incidence of predatory mites in the tea fields of South India. It has been reported that species diversity of parasitic hymenopterans were consistently higher in mid elevation of Darjeeling hills (1000 m), the Dooars and Terai organic plantations indicating better health and ecological balance of the plantation under bio-organic practice over the conventional ones (Anonymous, 2003).

5.4.2. NATURAL ENEMIES RECORDED BY MANUAL SEARCH

Extensive manual search was also done during the course of investigation which revealed the presence of one species of minute pirate bug and one species of syrphid fly (larva) that had escaped the catch by suction sampler.

5.4.3. IDENTIFICATION OF NATURAL ENEMIES

The species commonly recorded during the study were identified by comparing with the reference collection materials at Entomology laboratory of

Table 21 : Classification of natural enemies of tea pests commonly recorded from tea bushes at the elevations of Darjeeling.

Common Name	Order	Family	No. of spp.	Scientific name
1) Green lacewing	Neuroptera	Chrysopidae	1	*Chrysoperla carnea*
2) Brown lacewing	Neuroptera	Hemerobiidae	1	*Micromus timidus*
3) Lady bird beetle	Coleoptera	Coccinellidae	2	*Coccinella septumpunctata*
				Coccinella transversalis
4) Minute pirate bug	Hemiptera	Anthocoridae	1	*Orius* sp.
5) Syrphid fly	Diptera	Syrphidae	1	*Paragus* sp. (?)
6) Praying mantis	Dictyoptera	Mantidae	1	(*indet*)
7) Hymenopteran	Hymenoptera	Ichneumonidae	1	*Apophua* sp.
Parasites		Braconidae	1	*Cotesia* sp.
		Mymaridae	1	*Polynema dhenkunde*
		Tiphidae	1	(*indet*)
		Eulophidae	1	*Pediobius* sp.
		Scelionidae	1	*Trissolcus* sp.
8) Spiders			3	(indet)

North Bengal University and some were sent to expert in related areas where necessary. All of them were identified up to family level and some up to genus and species levels. Table 21 gives a cursory look at the various groups of natural enemies encountered at the tea plantations of the Darjeeling hills. This is not a comprehensive list; nevertheless it represents the profile of the arthropod natural enemy groups active in tea plantations of Darjeeling.

5.4.4. BIOLOGICAL NOTES ON NATURAL ENEMIES

5.4.4.1. GREEN LACEWING

(Fig 38)

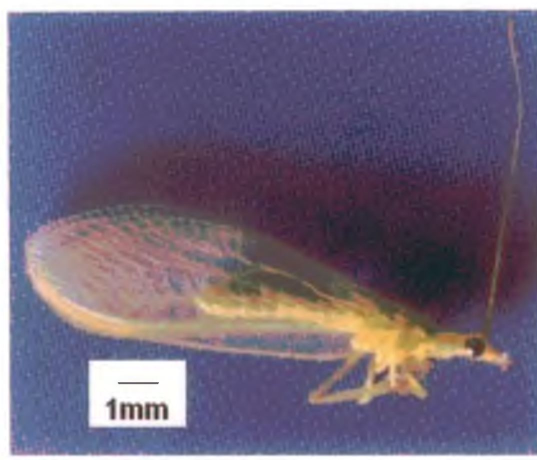


Fig. 38: *Chrysoperla carnea* adult

Green lacewings were observed in lesser number in Darjeeling heights than the brown lacewing. The species recorded in Darjeeling was identified as *Chrysoperla (Chrysopa) carnea* Stephens. Although, 67 species of the Chrysopids belonging to 21 genera have been reported on different crops and pests in India (Singh and Jalali, 1994), Bhattacharya (2001) reported 20 species under 9 genera of family Chrysopidae from Western Himalayan region of India. Out of them *Chrysoperla carnea* Stephens was most widely available and studied for its host preference (Gerling *et al.* 1997) and its predatory potential on different pest species (Balasubramanian and Swamiappan, 1994).

Life cycle : To study the different stages of the predator, males and females were collected from the field and reared separately in pairs in glass jar in laboratory at room temperature (average 22 ^{0}C). Adults were found to get attracted to florescent tube lights.

The adults were green and around 26.8 mm (Fig. 38) with expanded large membranous wings and commonly golden eyes. Wings were much longer than the body. Males were pale colour and smaller than the female. Field collected adults lived from 8–25 days on honey solution with an average of 19.5 days (n=10). The females laid eggs in between 46 and 86 eggs with an average of 65 per female.

The eggs were white in colour, elongate, less than 1 mm in length. Each egg was laid on a long slender stalk of around 9-10 mm in groups on the hard paper piece put inside the glass jar. The incubation period was 8 days (average of 50 eggs) in June. The first instar larvae were light brownish and resemble small bristled alligator type. But, they could not be reared further after the first instar due to lack of their prey.

There were 3 instars of *C. carnea.* The matured larva reached a length of about 6 mm before pupating in a spherical, tightly woven, white cocoon on the foliage. Mature third instars spinned round, parchment-like, silken cocoons usually in hidden places on plants. Emergence of the adults occurred in 10 to 14 days. The life cycle was generally completed within 4 weeks in summer conditions. There appeared to be two or more generations per year. They were found to overwinter as adults, usually in leaf litters. During the spring and summer, females were reported to lay several hundred eggs on leaves or twigs in the vicinity of prey (Canard and Principi, 1984; DeBach, 1974, Henderson and Raworth,1991 and Tauber and Tauber, 1983).

Host : The adults were collected when thrips, green fly and red spider mites were active in the tea field of Darjeeling hills. Among the tea pests, they were reported to predate on aphids, green fly, thrips, red spider mite, nymph of tea mosquito bug, mealy bugs, small caterpillars and other soft-bodied arthropods, although aphids were their most preferred host. The larvae were voracious predators. They had large, curved, pincer-like jaws, by which they grasped their prey and sucked out their body fluids. Such feeding habit has given them the name "aphid lions". One larva is reported to consume few hundred aphids per day (Canard & Principi, 1984). Hazarika *et al.* (1996) reported from a laboratory study that a green lacewing 3rd instar larva consumed 25-29 adult red spider mites per day and destroyed 12-15 eggs per hour. They further found that during the larval life, a larva consumed more than 200 aphids and 40 nymph of tea mosquito bug. Das (1959), Rao *et al.* (1970) and Anon. (1994) reported *Chrysoperla* sp. as the occasional predator of the red spider mite in the nature. Borthakur *et al.* (2001) reported that larvae of *C. camea* could grow up to adult stage when released on red spider mites in the field. There is possibility of utilizing this predator in IPM programme to suppress the tea pests in Darjeeling.

Conservation : Adult green lacewings require nectar, honeydew or pollen as food before egg laying. So planting of flowering plants in and around tea areas would be beneficial. Use of toxic insecticides should be limited. In bio tea gardens of Darjeeling the predator is getting an ideal environment to survive and multiply. This is indicated by about 93 % more occurrence of the green lacewing in bio-organic gardens over conventional ones. They also need certain population of their host insects for survival.

Artificial foods and honeydew substitutes reportedly have been used for green lacewing to enhance the number and activity of adults. Although these products promoted egg laying, yet did not encourage the dispersal behaviour of newly emerged adult lacewings (Weeden *et al.* 2001).

5.4.4.2. BROWN LACEWINGS

(Fig. 39)

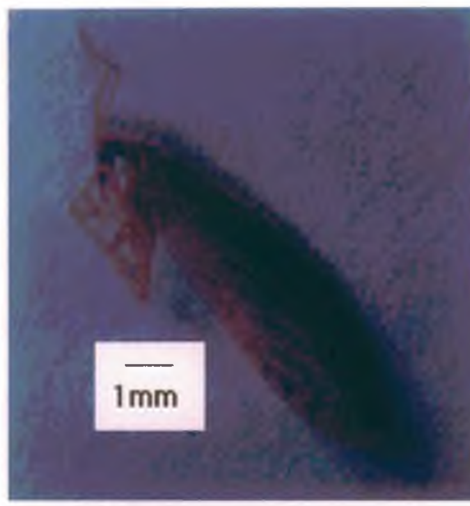


Fig. 39: ***Micromus timidus*** **adult**

The brown lacewing species commonly active in Darjeeling was identified as *Micromus timidus*. But, Bhattacharya (2001) reported two genera and six species under family Hemerobiidae from Western Himalaya from among 16 genera and 22 species known in total from India.

Life Cycle : Males and females collected from the tea field were reared in pairs separately in the laboratory in glass jar providing aphid (*T. aurantii*) colonies on tea shoots as prey and honey solution soaked with raw cotton. Eggs were laid in captivity followed by hatching.

Typically, brown lacewings adult were found more in numbers and earlier in the season than green lacewings in Darjeeling. Brown lacewing adults appeared to be similar to that of green lacewings except that they were brown to gray-brown and much smaller than the green lacewing, the average size being around 16 mm with expanded wings. The fore wings were narrowly oval (Fig. 39). They were nocturnal in habit like the green lacewings. Adults could be detected in the field by foliage beating over a sheet. They behaved "drop dead" when disturbed and remained motionless for a short time.

The field collected adult lived 24 – 45 days with an average of 32.6 days (n=10). The earlier workers reported that adults of different Hemerobiid species appeared more or less alike with colour ranging from light reddish brown to brownish gray. By critical examination of the wing venation and genitalia different species could be identified (Klimaszewski and Kevan 1985). They were found to overwinter as adults or pre-pupa and become active in early part of the season (Laidlaw 1936).

Eggs were elongated, without stalks and laid singly, glued to the tender stem of tea shoots infested with aphid colonies. Brown lacewing laid more eggs than green lacewings in the laboratory with an average of 160 per female. The incubation period was observed to be 12.4 days in May. Eggs were generally white when laid, but turned out to be orange to pink, then darker brown just before hatching. Earlier workers reported that a brown lacewing female might lay 100-460 eggs with an incubation period of 11 days (Klimaszewski and Kevan 1985 and 1992).

The larvae of brown lacewing resembled green lacewing larvae, but their mouthparts were shorter and stouter. The larvae did not carry trash on their backs. In higher elevations of Darjeeling, their larvae were found more common than green lacewings early in the growing season. The first abdominal segment was of the same size as the second and third.

Earlier workers reported that most hemerobiids had three larval instars. All instars were active feeders. They were relatively slender, with a small head and jaws compared to chrysopid larvae. The third instar entered into pupation in a silken cocoon. In contrast to the spherical, tightly woven cocoon of green lacewings, the loosely woven cocoon of brown lacewings was elliptical in shape and found in protected places rather than exposed on foliage. The pupal stage lasted about 9 –14 days in the summer. To complete the cycle from egg to adult, it took about 24 – 30 days. The brown lacewings are known to have two generations per year, but temperature could play a significant role (Henderson and Raworth, 1991, Klimaszewski and Kevan, 1992).

Host : Both nymph and adult brown lacewings were found to be predatory on aphids in the laboratory and a single female consumed as high as 26 aphids per day. When fed separately the first instar larva could consume 14.7 aphids per day. They also fed on other soft bodied tea pests like thrips, greenfly and red spider mite when tried in the laboratory.

Brown lacewings were observed to be important predators of aphids and other small soft-bodied insects sharing the prey with green lacewing. *Micromus timidus,* the species recorded in Darjeeling, have great potential as biological control agents in Darjeeling for many reasons. The adults were found to be long-lived and with high fecundity. Both larvae and adults were voracious feeders. The larvae of *M. timidus* was also observed in tea fields of Tocklai, Assam, N. E. India to feed on tea aphids with a maximum feeding capacity of an individual larva up to 116 aphids (Das and Kakoty, 1992). Brown lacewing was reported to have a wide range of preys (Klimaszewski and Kevan 1985).

It was also reported that brown lacewing were highly prized predator of temperate conditions because the females and the eggs were extremely cold tolerant. Hence, often they had a lower developmental threshold temperature than their prey, making them useful early in the season in cold climate (Garland 1981b). As such in higher elevations of Darjeeling they were distinctly more prevalent than green lacewing as is evident in table 18. Only demerit of brown lacewings as a bio-agent is that its mass rearing in insectaries is difficult, because the adults require their prey hosts (like aphids) in huge numbers for survival and optimum performance (Garland 1981a) unlike the *honey feeding adults of the green lacewing.*

Conservation : At the moment conservation appears to be the best way to encourage populations of brown lacewings in the tea fields until a cost effective insectaries rearing technique can be developed. Toxic insecticides should be avoided when they are active particularly during early part of the season. Planting trees around the estates, as windbreakers may be helpful in preventing their migration.

With further studies and by developing an insectary rearing technology, this predator can be used as important control agent against tea pests in

Darjeeling. Future study on artificial diet support for adults may prove to be very useful.

5.4.4.3. LADY BEETLES (Fig. 40)

Fig. 40 : Lady beetle adults feeding on aphids

Lady beetles, ladybugs, or ladybird beetles are among the most beneficial predatory insects all over the world. In Darjeeling also they were observed in considerable numbers on tea bushes during spring and early summer when different tea pests were also active. Their population was distinctly greater in bio tea gardens (Table 20) with 45.38 % higher population than conventional ones. Two species were commonly found active in Darjeeling, which were identified as *Coccinella septumpunctata* (seven spotted lady beetle) (Fig. 40) *and C. transversalis* (Transverse lady beetle). The former was observed to be more common.

Life cycle : The adult of *C. septumpunctata* was around 7.45 mm with a white or pale spot on either side of the head. The body was oval and domed shaped. It had usually 7 black spots in a pattern of 1 - 4 - 2 on the orange or red forewings (elytra) which helped in their easy field identification.

Adults were found to overwinter in protected sites in aggregation near the fields where they were active. In spring, the emerging adults dispersed in search of prey and suitable site for egg laying.

Adults were known to feed on pollens and aphids before laying eggs. Females might lay from 250 to more than 1,000 eggs over a period of one to three month commencing in spring or early summer. Eggs were usually deposited near the prey often in small clusters in protected sites on leaves and stems. The eggs were small, about 1 mm and spindle-shaped (Hoffmann and Frodsham,1993).

The larvae of Lady beetle observed in the field were dark in colour and alligator type with three pairs of prominent legs. It was reported that *C. septumpunctata* larvae grew from about 1 mm to 4 – 7 mm in length over a 10 to 30 day larval period depending on the availability of their prey and growing conditions. There were typically four larval instars. Large larvae might travel even up to 12 m in search of prey. The pupal stage varied from 3 to 12 days depending on the temperature, (Hoffmann and Frodsham,1993).

The adults were reported to emerge, mate, and search for prey or undergo hibernation, depending on the availability of prey and time of year. Adults might live for few weeks or months to over a year depending on the location, food and time of the year. The more common species typically had one to two generations per year (Hoffmann and Frodsham, 1993; Gordon, 1985; Henderson and Raworth, 1991)

Host : Both the species of lady beetles recorded in tea fields of Darjeeling were found beneficial as the field collected adults and larvae fed on aphids, greenfly, thrips and red spider mite supplied in the laboratory, although they were known to feed primarily on aphids. They were observed in Darjeeling plantations in large numbers when the aforesaid pests were active during March – June even without the availability of aphids.

Muraleedharan *et al.* (1988) described them as the second largest group of predators of red spider mite – *Oligonychus coffeae*. In tea field of Tockal, Assam, eleven species of coccinellids found to attack tea aphid were *Cryptogonus bimaculata* Kapur, *Scymnus* sp., *Coleophora biplagiata, Verania vincta, Menochilus sexmaculatus, Coccinella repanda, Leis dimidiata* var *quindecimmaculata, Leis dimidiata, Paeudaspidimerus circumflexus, Coccinella septempunctata* var *divaricata* and *Jauravia quadrinotata*. The feeding capacities of different species during their adult lives were found of the range of 1300 – 7640 aphids (Das and Kakoty, 1992).

When aphids are scarce, lady beetle adults and larvae were reported to feed on the eggs of moths and beetles, mites, thrips and other small insects as well as pollen and nectar. Because, of their multiple prey range, lady beetles were found to be valuable natural enemies. It was reported that seven spotted lady beetle adults might consume several hundred aphids per day and each larva could eat 200 to 300 aphids per day as it grew. But, lady beetles are thought to be less effective at low pest densities as they show cannibalistic behaviour when prey is scarce. (Gordon, 1985; Habeck *et al.*1990).

Conservation : Planting of flowering plants to produce nectar and pollen or an artificial substitute in the vicinity of the crop may attract adult beetles and reduce dispersal of these and other lady beetle species. It may also provide them over-wintering sites protecting themselves from adverse weather conditions. Spotted lady beetles after emerging from overwintering reportedly feeds on plant pollen (dandelion, spring beauty, etc.) for several weeks before moving into crop field to feed on its host insects (Hoffmann and Frodsham,1993).

5.4.4.4. MINUTE PIRATE BUG (Fig. 41)

Fig. 41: *Orius* sp. adult (dorsal & ventral views)

Minute pirate bugs are "true bugs" (Heteroptera) of the family Anthocoridae. The species found active in Darjeeling was identified as *Orius* sp. They were found active when common thrips (*Mycterothrips setiventris*) and red spider mite population remained at the peak on tea shoots. During winter it remained active on the flower thrips (*Lefroyothrips lefroyi* Bagnall), which was generally found in large number on tea flowers.

Life cycle : Adults were very small (2-2.5 mm long), somewhat oval-shaped, and black with brownish white wing patches. Wings extended beyond the tip of the body. Nymphs were yellow-orange to brown in color, teardrop-shaped. They were fast moving. Adults and nymphs occurred in considerable numbers in tea plantations of Darjeeling.

Females were reported to lay tiny eggs 2-3 days after mating within soft plant tissues of stems mid rib and petioles where they could not be seen easily. The nymphs developed through five instars. Incubation period was about 3-5 days and development from egg to adult took about 20 days under optimum conditions. Females laid an average of 129 eggs during their life spans and adults lived about 35 days (Wright, 1994; Askari and Stern, 1972). Several generations appeared to be completed during a growing season of tea as overlapping of different stages could be observed in the field.

Host : Both adults and nymphs were observed to feed by sucking their prey using a sharp rostrum made up of stylets and labium (Fig 41). While feeding, it held the prey with its front legs and sucked by inserting its stylets into the host body for several times. It was further observed that the predator left the prey before completely consuming it to attack another one. Thus it killed more preys than actually required to fulfil its nutritional requirements, which was a desirable character of a predator. Both nymphs and adults were found to predate mainly on thrips and mites. In the laboratory, a single advanced nymph could consume on an average 28.5 mites and 32.4 thrips in the laboratory.

It was reported that *Orius sp.* was common on many agricultural crops including cotton, peanuts, corn, pea, strawberry and in orchards and was being successfully used as a biological control agent in greenhouses. It was often found in corn silks and was most common where there were spring and summer flowering shrubs and weeds, because it fed on pollen and plant juices when preys were not available. (Wright, 1994; Askari and Stern, 1972). Muraleedharan and Ananthakrishan (1978) reported from South India that the *Orius* species mainly, *O. maxidentex and O. tantillus* preyed on the thrips species *Thrips tabaci, Scirtothrips dorsalis, Baliothrips biformis, Caliothrips indicus, Microcephalothrips abdominalis and Haplothrips ganglbaueri*. Muraleedharan *et al.* (1988) also reported from south India that anthocorids especially *Anthocoris* and *Orius* sp. attacked the larvae of tea thrips - *Scirtothrips bispinosus* Bagnall.

Conservation : In Darjeeling tea ecosystem, *Orius* could easily survive on flower thrips during winter which remained active and were observed in large number on tea flower. However, to support their population in other seasons planting of spring and summer flowering plants will help them to survive during periods when their prey is scarce on tea.

There is possibility of using them in future IPM programme to control tea pests, particularly thrips and mites in Darjeeling.

5.4.4.5. SYRPHID FLIES (Fig. 42)

Syrphid or hover flies were well known as predator of aphids. The larva of one species of syrphid fly was found active on aphids mainly in tea recovering from pruning during June – August. It was identified as *Paragus* sp (?).

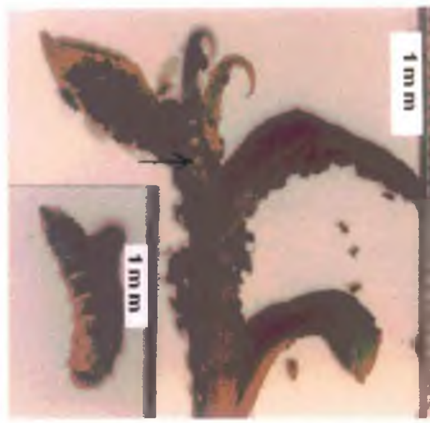


Fig. 42 : Syrphid fly larva feeding on aphids (⟶) (Inset-Close up view)

Life cycle : The adults were 8-12 mm long, some what similar to bees and wasps with abdominal stripes, but could easily be distinguished from bees by their ability to hover and absence of a sting. The larva could be collected from the tea field in sufficient numbers when active on tea aphids (*T. aurantii*). The larvae were slug-like tapering towards head and brownish in colour (Fig. 42). 3-4 larvae were observed feeding together on the aphid colony on a single shoot.

It was reported that the adults of many species of syrphid flies were pollinators, second in importance to bees. They also fed on pollen, nectar, and honeydew secreted by aphids. The females were observed to lay most of their eggs among large aphid colonies on heavily infested plants. Each female laid between 400 and 1000 oblong, white eggs singly or in small batches. Minute, slug-like larvae hatched from the eggs after a few days. When fully grown, it was 6 – 7 mm long. The full-grown larva searched for a dark place like a dried rolled leaf on the plant or burrowed into the soil and pupated for about 1 week. The adult emerges to mate and lay eggs again. There are several generations in a year (Henderson and Raworth, 1991).

It was observed in case of all the syrphid species studied that at relatively low temperatures the number of normally developed eggs, larvae and pupae was higher than at higher temperatures. For eggs and larvae, a temperature of 20 ^{0}C was found optimal and for pupae a temperature of 25 ^{0}C. (Adashkevich, 1975). Survival at low temperature of Darjeeling hills was a desirable character of syrphid and possibly due to which they were found very active when aphids were also active on pruned tea.

Host : Syrphid larvae were found to be very effective predators of aphids on tea. In Darjeeling, brownish larva (Fig. 42) of *Paragus* sp. (?) was noticed feeding on large aphid colonies in considerable numbers during June-August. It was found mostly on tea recovering from pruning where aphids were also active on the succulent growing shoots. The larvae had a characteristic feeding habit. The Larva searched for aphids by raising the front of their body and swinging it from side to side and up and down. As soon as an aphid came in contact it was grasped by the predator with its sharp mouthparts, held up in the air, and subsequently its body contents were sucked out. A single advanced larva on an average could devour 44 aphids per day.

Radhakrishnan (1989) observed the syrphid along with coccinellid and hemerobiid predators naturally controlling the tea aphid *Toxoptera aurantii* in south Indian tea. Muraleedharan (1991) also from South India reported that the tea aphid was naturally regulated to a very large extent by the larvae of syrphids – *Paragus tibialis*, *Episyrphus balteatus*, *Betasyrphis seratus*, *Allobaccha nubilipennis*, *Ischiodon scutellaris*, and *Dideopsis aegrota* along with several coccinellids, neuropteran and braconids.

From tea field of Tockal, Assam, the syrphid predators reported to feed on tea aphid were *Syrphus balteatus*, *Syrphus serarious*, *Paragus indicus*, *Paragus verburiensis*, *Xanthogramma scutellare*. and *Asarcina aegrota*. The feeding capacity of the individual larva during the larval period was 305 – 590 aphids (Das and Kakoty, 1992). Das (1974) also recorded syrphid grubs and hemerobiids on tea aphid in and around Jorhat, Assam, India.

From the tea plantations of Darjeeling foothills and plains active aphid predation by green syrphid larvae of all stages have been reported. (Annonymous, 2003 b).

Conservation : Growing flowering plants as pollen and nectar sources near tea areas is helpful to attract and maintain adult population. Umbelliferous plants in bloom reportedly attract the adult of hoverfly (Hoffmann and Frodsham 1993).

5.4.4.6. PRAYING MANTIDS (Fig. 43)

There are about 2,000 species of mantids widely distributed throughout the world (Nguyen 1999). In Darjeeling one species was recorded commonly, but the species awaits identification.

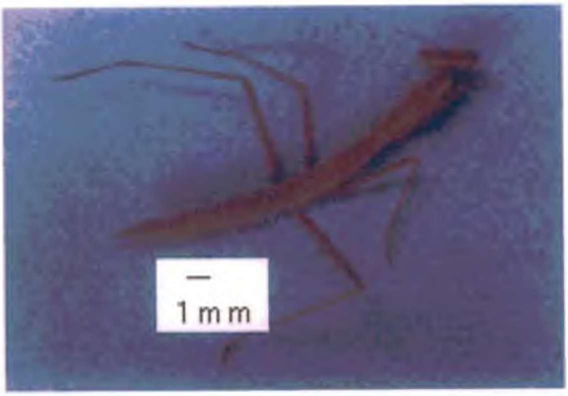


Fig. 43: Praying mantid nymph

Life cycle : The adults were brown in colour have a triangular-shaped head with a large compound eye on each side. They had straight, leathery forewings and very powerful jaws used for devouring the prey. The prothorax was long and strong with spiny front legs. These were normally held together in a praying manner.

Breeding took place in summer in Darjeeling slopes having temperate climate. After mating, the female laid eggs in a "frothy" liquid called "ootheca". This subsequently turned into a hard protective shell. Oothecae were noticed in autumn on tea branches, which remained as such through out winter. The predator was found to overwinter in this stage. It was reported that the female ate a lot and grew large and fat before laying an ootheca on a branch and one female could lay up to six oothecae, but needed to be mated once (Bragg, 1988).

Hatching occurred in the spring. Hence, nymphs could be collected in considerable numbers during April in Darjeeling. The young ones were reported to hatch all at a time or sometimes in batches over a period of several weeks (Bragg, 1988). The newly emerged nymphs were observed hanging by a thread from the ootheca in the field until their skin hardened off. They were brownish in colour.

It was reported that the first meal of the nymph was generally a sibling. So cannibalism was apparent (Nguyen, 1999). The nymph moulted many times before it turned full-grown and took the entire summer to become adult (Nguyen 1999). They were widely distributed over bushes with almost each branch harbouring one nymph in case of heavy incidence. Camouflage was found to be very important character for the survival of praying mantis from their enemies like birds. This also helped them to catch prey. Only one generation appeared to be completed in each season. Because, the young ones could not be seen in later part of the season in Darjeeling slopes.

Host : The praying mantis nymph and adult were found to feed on a large variety of preys. Nymphs fed on greenflies, aphids and thrips when tried in the laboratory and even the early instar nymph could consume huge number of prey, around 65-110 aphids per day with an average of 74.5. In the tea estates of Darjeeling, the nymphs were recorded in large numbers during spring (Table 19) when pests like thrips, red spider mite, green fly etc were active. While preying they waited standstill and were almost non-detectable on a leaf or a stem, ready to catch any insect that came within its range, using their front legs that were equipped with sharp spines. The mantid usually bit the neck of a large prey to paralyze it and stop it's movement quickly. It was noticed that most mantis almost always started eating the prey from it's neck while the latter was still alive.

Praying mantids were reported to predate on insects like – green fly, thrips, mites, aphids, beetles, butterflies, crickets, grasshoppers and even spiders. Cannibalism was also found to be common. The mantid was the only predator observed, which fed at night on moths, most of the moths being active only after darkness. It was also found to be fast enough to catch mosquitoes and flies (Lyon, 2001).

The disadvantage with mantids is that they feed also on other beneficial insects. Nevertheless, as far as tea pests management is concerned, their conservation seems to be encouraging.

5.4.4.7. SPIDERS (Fig. 44 a, b and c)

While sampling by D-Vac large number of spider could be collected from the tea bushes as is evident in the table 19. High population of spiders could be noticed during spring, March to June in the tea field, when pests like red spiders mite, thrips, green fly, aphid etc were active.

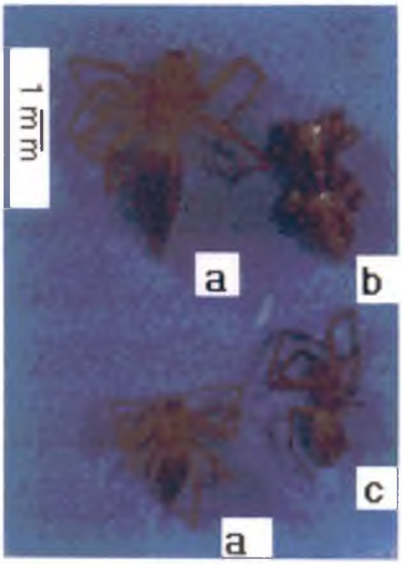


Fig. 44: Spider species a, b & c

Spiders probably find tea plantation as ideal habitat. Being a perennial crop, they colonize the stable tea bushes and multiply in large number predating on a number of tea pests, thus playing a significant role to reduce their population. In a field survey carried out in the tea plantations spread over

13 mountainous counties / cities of Zhejiang Province, China, during 1984 to 1990, a total of 110 species of spiders were recorded representing 24 families. Out of which, 93.7 % were found predatory on insect pests. Six dominant species were *Phintella bifurcilinea, Clubiona deletrix, Tetragnatha praedonia, Conopistha (Argyrodes)* sp., *Neriene oidedicata and Neriene* sp. (Chen, 1992). Zhang *et al.* (1992) observed spider as the most effective predator of *Empoasca vitis* (= *flavescens*) on tea in Hunan, China. Xie (1993 a) also reported that in tea gardens of Guangdong Province of China, spiders were the dominant natural enemies of major tea pests including *Scirtothrips dorsalis, Empoasca pirisuga, Toxoptera aurantii and Aleurocanthus spiniferus*. Single adult of the spider *Chrysilla versicolor* (=*Phintella versicolor*) could consume 47.6 adult leafhoppers, *E. pirisuga* and 80.5 nymphs per day in the laboratory in China (Xie, 1993 b).

In the present study, the *prima face* evidence of a diverse spider fauna and their fairly dominant population among the predators speak for their appreciable role in "taking care" of the various pest species on the tea bushes of Darjeeling hills.

5.4.4.8. HYMENOPTEROUS PARASITES

The parasitic hymenopterans that were commonly found to occur with pest incidence on tea belonged to the families Ichneumonidae, Braconidae, Mymaridae, Tiphidae, Eulophidae and Scelionidae.

5.4.4.8.1. Ichneumonids (Fig. 45)

Fig. 45: *Apophua* sp. adult (Mgn. 10X0.7)

Ichneumonids are large, slender, dark-coloured insects with a very long needle like ovipositor usually attacking moth, butterfly, beetle and wasp larvae. The long ovipositor, which is the distinguishing character, allows the female to inject eggs into hidden hosts like leaf-roller, flush worm etc. The larvae are parasitic within the immature stages of host insects (Henderson and Raworth,1991). Ichneumonid adult (Fig. 45) found to be common in the collection could be determined as *Apophua* sp. Muraleedharan *et al*. (1988) reported that the Ichneumonid, *Phytodietus* sp. along with the tachinid, *Palexorista solennis* effectively controlled the tea tortricids, *Homona coffearia*. The host for ichneumonids, among sucking pests of tea, from Darjeeling plantations still requires confirmation.

5.4.4.8.2. Braconids (Fig. 46)

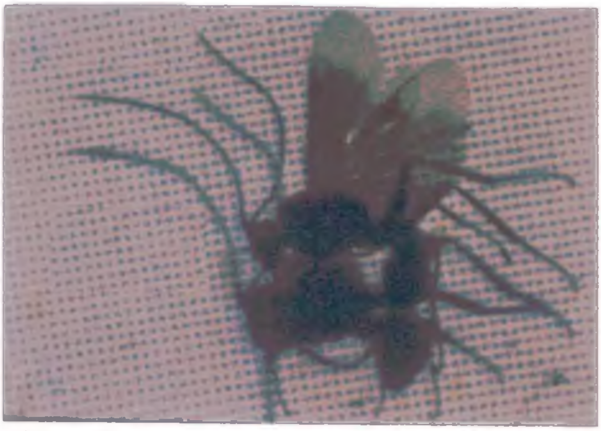


Fig. 46: *Cotesia* sp. adult (Mgn. 10 X 0.7)

Braconids are much smaller than ichneumonids and well built. The ovipositor remains inside the body until it is required to inject an egg into host body. The host range of Braconids is broader than ichneumonids like – caterpillars, flies, wasps, beetles, aphids etc. The female injects her egg with lightning speed into host while it is feeding on the host plant. The newly hatched larva feeds slowly on that single host as it grows as a typical larval parasitoid. Full grown larva pupates inside or near the dead host, sometimes in a silken cocoon, to emerge later as an adult wasp (Henderson and Raworth,1991). The commonly occurring species of braconid (Fig. 46) recorded belonged to the very broad genus *Cotesia*. Some species of *Cotesia* were also reported from the lower elevations of Darjeeling and plains of Terai attacking red slug and looper caterpillar (Anonymous, 1993). Muraleedharan *et al.* (1988) reported that the braconid, *Apanteles aristaeus* was the main parasitoid of the tea tortricids, *Cydia leucostoma*, but the efficacy of this species was rather low. The braconids *Aphidius colemani, Lipolexis scutellaris* and *Trioxys indicus* are known to exert tremendous influence on the population of tea aphid *Toxoptera aurantii*.

5.4.4.8.3. Mymarids (Fig. 47)

Mymarids are tiny, usually less than 1 mm and parasitise mainly eggs of tea pests. Two different species were recorded during the study. Hosts of the Mymaridae include eggs of Hemiptera, Homoptera, Pscoptera, Coleoptera, Diptera, and Orthoptera.

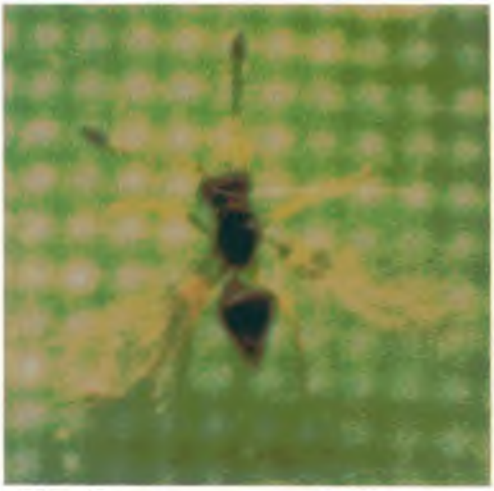


Fig. 47: ***Polynema dhenkunda*** **adult (Mgn. 10 X 2.5)**

The most distinct characters are the stalked, narrowly elongate hind wings, the long clubbed female antennae (filiform in the male) and the greatly reduced venation, which terminates within the first third of the wing. The species recorded in this study (Fig. 47) was identified as *Polynema dhenkunda*.

5.4.4.8.4. Tiphids (Fig. 48)

Fig. 48: Tiphid adult (Mgn. 10 X 0.7)

Tiphids are of moderate size with hairs on their body. These are known to parasitise scarab and cicindelid beetles. The species commonly available (Fig. 48) awaits identification.

Besides the above hymenopterans, two more egg parasitoids recorded in the collection from the tea ecosystem belonged to the families Eulophidae (*Pediobius* sp.) and Scelionidae (*Trissoleus* sp.). All these hymenopteran parasitoids as a component of the natural enemies of the tea ecosystem generally help regulating the tea pest population.

Summary

VI. SUMMARY

A. POPULATION DYNAMICS

Population dynamics of the common sucking pests of tea plantation was studied for 3 years on two planting materials at two different elevations of Darjeeling hill slope.

1. The population trends of common thrips were more or less same both at mid (1200 m) and high (1650 m) elevations showing similar fluctuations on both the planting materials under study. However, the population density of thrips varied depending on elevation and planting material. Population continued to persist throughout the plucking season in all the 3-years of observation on the planting materials, china seed jat and T 78 both at mid and high elevations, but at varying intensity. The population started to build up during February – March in each season from the residual low population, which could survive the winter. The increasing trend in population continued and reached the first peak sometime by end of April or May. It was observed that growth of population was checked considerably when plucking started from March. However, the increasing trend continued and a sharp decline in population could be noticed only when monsoon started with heavy shower in June - July. The population count was always low if preceded by a heavy downpour. It started to increase again from mid or end of September and attained the second peak in October. The level of infestation during autumn was much lower than that of the spring and lowest during winter. All developmental stages of *M. setiventris* were observed throughout the year indicating overlapping of generations. Higher

level of population of common thrips was observed on china seed *jat* than the clone T 78 having some Assam character both at mid and high elevations. The population density was more at high elevation than that at mid elevation, indicating the preference of the thrips for china seed *jat* and a high altitude.

2. The combined effect of weather factors namely rainfall, maximum and minimum temperatures, morning and afternoon relative humidity and sunshine hours were found to contribute significantly to the variation of common thrips population. Rainfall had a negative influence on the thrips population in general, which was significant at mid elevation. But, both maximum and minimum temperatures had significant positive influence on common thrips population on both the planting materials at both the elevations. At mid elevation, the sunshine hours had a significant positive influence. In case of relative humidity, a negative trend of influence was observed except for the morning relative humidity on china seed *jat* at mid elevation, which was positive. But, the influence of relative humidity was not found statistically significant in any of the situations.

3. Other than the weather factors, it appeared that the growth habit of tea bushes with inter flush and long winter dormancy might have played a significant role in regulating thrips population, particularly during winter months.

4. Common thrips population continued even under pest control measures but at a much lower level. It was naturally controlled during summer months by

heavy rains and plucking, suggesting that no pest control measures were necessary during this period.

5. In case of greenfly, more or less a similar trend of population fluctuation was noticed both at mid and high elevations and on both the planting materials under study, which persisted throughout the year with varying intensity depending on elevation as well as planting material. But unlike thrips, the population of greenfly started to build up rather late from early June from the residual population, attaining its first peak by June end - July. The population declined between end August and early September, which started increasing again from end of September reaching its second peak In October. The level of greenfly population was lower during autumn surge than the first peak and was lowest during winter. A general trend of enhanced population of greenfly was noticed on tea clone T 78 than china seed *jat* at both mid and high elevation. The population of greenfly was found generally higher at mid elevation than high elevation.

6. The combined effects of weather factors were found to contribute significantly to the variation of the greenfly population. The individual weather factor namely, maximum temperature, minimum temperature, relative humidity in the morning and aftemoon had positive and highly significant influence on the building up of greenfly population, but, sun shine hours had significantly negative influence on the greenfly population.

7. Greenfly is a pest of freshly growing tea shoots. Since in winter there is no active growth of shoots, this dormancy in tea might also be playing a

significant role in bringing down the greenfly population in winter. The residual population possibly survived on the few fresh shoots available on the tea bushes.

8. Under pest control measures, the greenfly population remained active at a much lower level than the untreated plots, particularly during peak period of infestation. Immediately after a pesticidal spray, the population got reduced considerably, but started to build up again. In total 5-6 rounds of spray were required to maintain the population below the economic injury level. During August and September the population was lowest even in untreated plots, and so insecticide spray was not at all necessary during this period. Weekly plucking of growing shoots and heavy rainfall might be responsible for keeping the population down.

9. The aphid infestation was very much sporadic and it's population never built up to attain the pest status at both the elevations on any of the planting materials studied. Only occasional colonies were observed on growing shoots when sampling was done. These colonies were noticed mainly during June to October and rarely in the early and end parts of the flushing / plucking season.

10. The combined effect of weather factors were found non-significant except in case of china seed *jat* at high elevation. However, rainfall appeared to have a significant positive influence on both the planting materials at mid elevation, but it was not significant at high elevation. Both maximum and minimum temperatures showed a positive significant influence in all the situations except for the influence of maximum temperature on T 78 at TRA CPS, which was

non significant. At mid elevation relative humidity in the morning and afternoon had significant positive influence on the aphid population of both the plating materials except that of morning humidity in case clone T 78 at mid elevation, which was not significant. Sunshine hours had a highly significant negative influence on aphid on both the planting materials.

11. In the pesticide treated plots, sporadic colonies of aphid could be noticed even during the rainy seasons. However, no insecticide was necessary from mid July to September end as aphid population was very low.

12. A comparison of the population of different sucking pests revealed that in spring the built up of thrips population was much earlier in all the four situations (elevation + planting materials) than the two other sucking pests, reaching the first peak during April-May. But greenfly reached its first peak slightly late *i. e.* in June –July, the time period, when thrips population started to decline. In autumn, mixed infestation of both the insects was noticed. The population of both the pests started increasing as soon as monsoon rains receded by end of September, reaching the peak infestation level *in October.* Aphid, in scattered colonies, was active mainly during rainy season when population of other two sap suckers remained at low level.

13. While thrips were generally confined to the unopened buds and the first leaf from top of a growing shoot, the greenfly was generally confined to the second and third leaves for better shelter. Hence, the coexistence of these two suckers during autumn flush was possibly without much of competition for food. When scattered aphid colonies started appearing both common thrips

and greenfly population had started declining.

14. No alternate host of common thrips was observed. Greenflies were found to attack *Camellia japonica, Ricinus communis,* and *Priotropis cytisoides* other than tea. Aphid occasionally attacked *Citrus medica.*

B. FEEDING IMPACT

1. Feeding by common thrips and greenfly improved flavour significantly which was confirmed by both organoleptic taste and biochemical analysis. Improvement in liquor character in infested tea was also confirmed by organoleptic taste as per Darjeeling tea standard. In case of overall quality, the tasters' scores were generally higher for tea made from infested shoots than that from uninfested shoots.

2. In biochemical analysis, a difference was observed in residual catechins in black tea made from thrips and greenfly infested and uninfested leaves. Major catechins were found to be higher in infested tea over uninfested one indicating the basis for genesis of greater flavour.

3. Caffeine was lower in case of tea made from thrips and greenfly infested shoots of both the planting materials, china seed *jat* and clone T 78.

4. Most of the Volatile Flavour Constituents (VFC) responsible for the flavour of made tea like linalool, its oxides and methyl salicylate were found to be higher

in case of tea made from thrips and greenfly infested shoots than their uninfested counterparts for both the planting materials. Moreover, the volatile, trans-2-hexanales which gives the grassy odour, not desirable for Darjeeling orthodox, was found higher in tea made from uninfested shoots than the infested one. So, infestation by these sucking pests, in general appeared to impart an enhanced flavour, much desired for Darjeeling orthodox tea.

C. NATURAL ENEMY

The natural enemies commonly recorded in the samples collected by D-Vac vacuum sampler from tea bushes of Darjeeling elevations during the productive season were: spider, preying mantid, lady bird beetle, green lacewing and brown lace wing. In addition, minute pirate bug and syrphid fly were also recorded by manual search. In general there was a higher incidence of population of these natural enemies in the tea plantations of mid elevation than that of high elevation at both bio-organically and conventionally managed gardens, except for brown lacewing, whose occurrence was higher in upper elevation. The spiders as a group had higher representation than the other groups of natural enemies in all the situations.

Highlights of the findings of the present investigation

1. Common thrips population is higher at upper elevation than the lower elevation and prefers china seed *jat* more than clone T 78 having some Assam characters, indicating that it prefers the more flavoury materials.

2. Greenfly population is more at lower elevation and on clone T 78 having some Assam-type-tea characters than at higher elevation and on China seed *jat.*

3. Aphid infestation on unprune tea in Darjeeling hills is sporadic and not generally attains the pest status.

4. The combined effect of weather factors namely rainfall, maximum and minimum temperatures, relative humidity at morning and afternoon and sunshine hours variably contribute to the fluctuation of population of these sucking pests. Generally individual weather factors like max. & min. temp. and sunshine show a significantly positive influence and rainfall a negative influence on thrips population. Max. and min. temp. also show a significantly positive and sunshine a significantly negative influence on greenfly population. By and large significant positive influence of max. & min. temperature, rainfall and relative humidity on aphid population is evident. However, the sunshine appears to influence aphid population negatively.

5. The population of common thrips, greenfly and aphid continues to persist under insecticide spray but at a much lower level.

6. During heavy rains of monsoon season population of these sucking pests reduces to the minimum and pest control measure does not seem necessary during this period.

7. Greenflies attack *Camellia japonica, Ricinus communi,* and *Priotropis cytisoides* in addition to tea in Darjeeling elevations. Aphid occasionally attacks *Citrus medica.*

8. Infestation of thrips and greenfly improves made tea quality in Darjeeling orthodox, hence the common belief of Darjeeling tea planters that the initial infestation by these pests improves quality is justified. But, whether this improvement in quality can compensate the crop loss or not by fetching higher price in the market remains a matter of further investigation.

9. The major groups of natural enemies active in tea estates of Darjeeling hills are spider, preying mantid, lady bird beetle, green lacewing and brown lacewing, minute pirate bug and syrphid fly. Out of which spiders are the most dominating group.

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Appendix

APPENDIX I

Weekly population of sucking pests on **China seed** *jat* of tea at **mid elevation** (mean value per 10 shoots)

1999	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.67	0.00	0.00	2.33	0.33	0.00
2	0.00	0.67	0.00	1.67	0.00	0.00
3	2.00	0.33	0.00	2.00	0.67	0.00
4	2.67	0.00	0.00	0.67	0.33	0.00
5	2.33	0.33	0.00	1.33	0.00	0.00
6	3.33	1.00	0.00	0.67	1.00	0.00
7	4.67	1.00	0.00	0.33	0.33	0.00
8	3.67	0.67	0.00	0.00	0.00	0.00
9	4.33	1.00	0.00	0.67	0.67	0.00
10	5.67	1.33	0.00	0.33	0.67	0.00
11	5.00	0.67	0.00	0.00	0.33	0.00
12	5.33	1.00	0.00	1.33	0.00	0.00
13	5.00	1.33	0.00	0.67	0.67	0.00
14	8.00	1.67	0.00	0.33	0.33	0.00
15	6.00	1.00	0.00	0.00	0.00	0.00
16	9.00	2.00	0.00	0.67	0.33	0.00
17	10.00	1.67	0.00	0.33	0.00	0.00
18	9.67	1.67	0.00	0.00	0.00	0.00
19	8.67	1.00	0.00	0.67	0.00	0.00
20	9.00	1.33	0.00	0.33	0.00	0.00
21	8.00	1.67	0.00	1.00	0.33	0.00
22	7.67	2.67	0.00	1.67	0.67	0.00
23	11.33	3.00	0.00	0.67	0.00	10.67
24	6.67	2.67	4.67	1.67	0.33	0.00
25	2.67	2.00	0.00	0.67	0.00	8.33
26	1.33	1.67	8.67	0.00	1.00	0.00
27	2.33	2.33	0.00	1.00	0.33	0.00
28	1.33	2.00	8.00	0.00	2.33	0.00
29	0.00	2.67	0.00	0.00	1.33	0.00
30	0.33	3.33	0.00	0.33	1.67	0.00
31	0.67	4.67	0.00	0.00	1.00	0.00
32	0.00	3.00	15.33	0.00	0.00	0.00
33	0.33	1.67	0.00	0.00	0.33	0.00
34	0.67	1.33	0.00	0.00	0.00	0.00
35	1.00	0.33	0.00	0.00	0.00	0.00
36	1.67	0.67	0.00	0.00	0.00	0.00
37	1.33	0.67	32.00	0.67	0.00	17.33
38	3.33	2.00	0.00	0.33	0.00	0.00
39	2.00	1.33	7.67	0.67	0.00	0.00
40	2.67	2.00	0.00	1.33	0.33	11.67
41	4.67	2.33	5.00	0.33	0.00	0.00
42	2.67	1.67	4.00	0.67	0.67	0.00
43	4.33	2.67	0.00	0.33	0.00	5.33
44	3.67	1.33	0.00	1.00	0.00	0.00
45	3.33	0.67	0.00	2.00	0.33	0.00
46	2.67	0.33	0.00	1.00	0.00	0.00
47	2.00	0.00	0.00	0.00	0.00	0.00
48	2.33	0.33	0.00	0.00	0.00	0.00
49	1.33	0.00	0.00	0.67	0.67	0.00
50	1.00	0.00	0.00	0.33	0.00	0.00
51	0.67	0.00	0.00	0.67	0.00	0.00
52	0.67	0.00	0.00	0.00	0.00	0.00

APPENDIX I

Weekly population of sucking pests on **China seed *jat*** of tea at **mid elevation** (mean value per 10 shoots)

2000	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	1.00	0.00	0.00	1.33	0.00	0.00
2	0.67	0.33	0.00	1.00	0.67	0.00
3	0.67	0.00	0.00	0.67	1.00	0.00
4	0.00	0.33	0.00	1.00	1.67	0.00
5	0.00	0.00	0.00	0.33	0.33	0.00
6	0.67	0.67	0.00	0.00	0.00	0.00
7	2.33	0.67	0.00	0.00	0.00	0.00
8	1.33	0.00	0.00	0.33	0.00	0.00
9	1.00	0.67	0.00	0.33	0.00	0.00
10	2.67	0.00	0.00	0.67	0.33	0.00
11	2.00	0.33	8.33	1.00	0.00	0.00
12	3.00	0.00	0.00	0.33	0.67	0.00
13	4.00	0.67	0.00	1.33	0.33	0.00
14	7.33	1.33	0.00	1.00	0.00	0.00
15	6.00	1.00	0.00	2.00	0.67	0.00
16	6.33	0.33	0.00	2.67	0.00	0.00
17	4.67	0.00	0.00	0.33	0.00	0.00
18	8.00	0.33	0.00	1.33	0.00	0.00
19	10.67	1.33	0.00	2.00	0.33	0.00
20	9.33	0.67	0.00	3.33	0.00	0.00
21	7.33	0.67	0.00	4.00	0.00	0.00
22	8.33	1.67	5.00	0.67	0.67	0.00
23	9.33	1.33	0.00	1.00	0.33	0.00
24	8.67	2.00	0.00	1.33	0.67	9.33
25	4.00	3.00	0.00	2.00	0.33	0.00
26	3.67	3.33	0.00	0.00	0.00	0.00
27	3.00	4.00	9.67	0.67	0.00	0.00
28	1.00	3.67	0.00	0.67	0.67	0.00
29	1.33	4.33	14.67	0.33	0.67	10.00
30	1.00	3.33	0.00	0.67	1.00	0.00
31	0.33	2.67	0.00	0.00	0.00	0.00
32	0.67	1.67	0.00	0.67	0.00	0.00
33	0.67	2.00	20.00	0.33	0.33	0.00
34	0.33	1.33	0.00	0.67	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00
36	0.33	0.67	0.00	0.33	0.00	15.00
37	0.67	1.00	15.67	0.00	0.00	0.00
38	0.33	0.67	0.00	0.67	0.00	0.00
39	1.33	1.00	0.00	0.00	0.33	0.00
40	2.67	1.33	0.00	1.33	0.00	0.00
41	4.00	2.00	0.00	1.67	0.00	0.00
42	5.33	1.67	10.00	2.67	0.33	0.00
43	3.33	3.00	0.00	3.33	1.00	0.00
44	4.00	2.33	0.00	1.33	0.33	0.00
45	3.67	0.00	0.00	1.00	0.67	0.00
46	2.67	0.67	0.00	1.33	0.00	0.00
47	2.00	1.00	0.00	0.67	0.00	0.00
48	1.33	0.33	0.00	0.00	0.33	0.00
49	1.33	0.67	0.00	0.67	0.00	0.00
50	1.00	0.00	0.00	1.33	0.00	0.00
51	1.33	0.00	0.00	0.67	0.00	0.00
52	1.00	0.00	0.00	0.00	0.00	0.00

APPENDIX I

Weekly population of sucking pests on **China seed** ***jat*** of tea at **mid elevation** (mean value per 10 shoots)

2001	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.67	0.33	0.00	0.33	0.67	0.00
2	0.00	0.00	0.00	1.00	0.00	0.00
3	0.67	0.67	0.00	1.33	0.67	0.00
4	0.33	0.00	0.00	0.33	0.00	0.00
5	1.00	0.67	0.00	0.00	1.00	0.00
6	1.33	0.33	0.00	0.67	0.00	0.00
7	2.00	0.67	0.00	0.33	1.33	9.67
8	1.67	0.33	0.00	0.33	0.00	0.00
9	2.33	1.00	0.00	0.67	0.00	0.00
10	2.67	0.67	0.00	0.00	0.00	0.00
11	4.33	1.00	5.00	0.67	0.00	0.00
12	4.00	1.00	0.00	0.67	0.00	0.00
13	3.67	0.67	0.00	0.67	0.67	0.00
14	6.67	1.33	0.00	1.33	0.33	0.00
15	5.33	1.00	0.00	2.00	0.00	0.00
16	7.33	0.67	0.00	2.67	0.33	0.00
17	11.33	1.00	0.00	0.00	0.67	0.00
18	8.00	0.33	0.00	0.33	0.33	0.00
19	7.67	0.67	0.00	0.67	0.33	0.00
20	6.67	1.00	0.00	1.33	0.00	0.00
21	5.67	0.67	0.00	2.00	0.00	0.00
22	5.00	1.67	0.00	0.33	0.00	0.00
23	5.67	1.33	0.00	0.67	0.33	0.00
24	6.33	3.00	0.00	1.00	0.00	0.00
25	3.33	2.33	0.00	0.33	0.00	0.00
26	2.00	2.67	13.33	0.33	1.00	0.00
27	3.00	4.67	0.00	0.33	0.67	10.00
28	2.00	3.67	0.00	0.33	0.33	0.00
29	2.67	4.33	0.00	0.67	0.00	0.00
30	1.67	2.67	12.67	0.00	1.00	0.00
31	0.00	1.67	0.00	0.33	0.33	0.00
32	0.67	3.00	0.00	0.33	0.00	0.00
33	1.00	2.00	18.33	0.67	0.33	0.00
34	0.00	0.33	0.00	0.33	0.33	0.00
35	0.00	0.33	0.00	0.00	0.00	0.00
36	1.33	0.67	0.00	0.00	0.67	0.00
37	0.00	0.00	10.00	0.00	0.00	0.00
38	2.00	0.00	0.00	0.00	0.33	6.67
39	2.67	0.33	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.33	0.33	0.00
41	2.00	1.00	0.00	0.67	0.00	0.00
42	3.33	1.33	3.33	1.33	0.67	0.00
43	4.67	2.67	0.00	2.00	0.33	0.00
44	3.33	1.33	0.00	0.67	0.00	0.00
45	2.67	1.00	0.00	0.33	0.33	0.00
46	3.00	0.67	0.00	0.67	0.00	0.00
47	1.33	1.00	0.00	0.33	0.00	0.00
48	0.67	0.00	0.00	0.33	0.33	0.00
49	1.00	0.33	0.00	0.33	0.00	0.00
50	0.33	0.00	0.00	1.00	0.67	0.00
51	1.33	0.33	0.00	0.33	0.00	0.00
52	0.67	0.00	0.00	0.67	0.00	0.00

APPENDIX II

Weekly population of sucking pests on **T 78 clone** of tea at **mid elevation** (mean of 3 replications)

1999	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.33	0.67	0.00	1.00	0.33	0.00
2	0.00	0.33	0.00	0.33	0.67	0.00
3	0.67	0.67	0.00	0.67	0.00	0.00
4	0.33	1.00	0.00	1.00	0.67	0.00
5	1.33	0.67	0.00	2.00	0.00	0.00
6	2.00	1.33	0.00	0.33	0.33	0.00
7	2.67	2.00	0.00	0.67	0.33	0.00
8	2.33	1.33	0.00	1.00	0.67	0.00
9	3.33	1.67	7.33	0.00	0.00	0.00
10	4.00	2.00	0.00	0.67	0.33	0.00
11	3.67	1.33	0.00	1.00	0.67	0.00
12	3.33	1.67	0.00	1.33	0.33	0.00
13	3.00	1.67	0.00	0.00	0.00	0.00
14	4.67	2.33	0.00	0.67	1.00	0.00
15	3.67	2.00	0.00	0.33	0.00	6.67
16	4.33	3.00	0.00	0.00	0.67	0.00
17	5.33	2.67	0.00	0.00	0.00	0.00
18	5.00	2.33	0.00	0.00	0.00	0.00
19	4.33	1.67	12.67	0.33	0.33	0.00
20	6.00	2.67	0.00	0.67	0.00	0.00
21	6.67	2.33	0.00	0.33	0.33	0.00
22	7.33	3.00	0.00	0.67	0.33	0.00
23	9.33	4.00	0.00	0.33	0.00	0.00
24	5.33	3.67	0.00	0.67	0.33	0.00
25	3.00	3.33	15.00	1.00	0.67	0.00
26	1.33	2.33	0.00	0.00	1.00	0.00
27	0.67	4.33	6.67	0.33	1.33	0.00
28	0.00	4.00	0.00	0.00	0.67	8.33
29	0.67	3.33	0.00	0.00	0.33	0.00
30	0.00	6.00	16.67	0.00	0.00	0.00
31	0.00	5.67	0.00	0.33	0.67	0.00
32	0.33	4.00	0.00	0.00	0.00	0.00
33	0.00	3.00	8.33	0.33	0.00	0.00
34	0.00	2.00	0.00	0.00	0.00	0.00
35	0.67	1.33	0.00	0.00	0.33	0.00
36	1.00	0.67	0.00	0.00	0.00	0.00
37	0.67	0.00	0.00	0.33	0.00	0.00
38	2.00	1.67	0.00	0.00	0.00	0.00
39	1.00	1.00	0.00	0.33	0.00	0.00
40	1.67	2.00	0.00	0.67	0.00	0.00
41	1.33	4.00	0.00	1.00	0.33	0.00
42	0.33	2.67	0.00	0.33	0.67	0.00
43	1.33	3.33	0.00	0.33	0.00	0.00
44	3.33	3.00	0.00	0.67	0.33	0.00
45	2.67	1.67	0.00	1.33	0.00	0.00
46	2.00	0.67	0.00	0.67	0.67	0.00
47	1.67	0.33	0.00	0.00	0.00	0.00
48	2.00	0.67	0.00	0.00	0.33	0.00
49	1.00	0.67	0.00	0.33	0.00	0.00
50	0.67	0.33	0.00	0.67	0.00	0.00
51	1.00	0.00	0.00	0.33	0.00	0.00
52	0.33	0.00	0.00	0.00	0.00	0.00

APPENDIX II

Weekly population of sucking pests on **T 78 clone** of tea at **mid elevation** (mean of 3 replications)

2000	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.67	0.67	0.00	0.00	0.67	0.00
2	0.00	0.00	0.00	0.67	0.33	0.00
3	0.67	0.67	0.00	0.33	1.00	0.00
4	0.00	0.33	0.00	1.00	0.00	0.00
5	0.00	0.00	0.00	0.67	0.33	0.00
6	0.33	0.67	0.00	0.33	0.67	6.67
7	1.00	1.00	0.00	0.00	0.00	0.00
8	0.67	0.33	0.00	0.67	0.33	0.00
9	0.00	0.00	10.00	0.33	0.00	0.00
10	1.33	1.33	0.00	0.00	0.33	0.00
11	1.00	0.67	0.00	0.67	0.00	0.00
12	2.33	1.00	0.00	0.00	0.33	5.00
13	3.33	1.33	0.00	0.00	0.00	0.00
14	4.67	2.00	0.00	0.67	0.33	0.00
15	4.00	1.67	0.00	1.00	0.00	0.00
16	3.33	2.33	0.00	0.00	0.00	0.00
17	3.00	1.67	0.00	0.33	0.67	0.00
18	4.67	1.33	0.00	0.67	0.33	0.00
19	8.00	3.00	0.00	1.33	0.00	0.00
20	6.00	2.33	0.00	2.67	0.00	0.00
21	3.67	2.00	0.00	2.00	0.33	0.00
22	4.67	2.67	0.00	1.33	0.67	0.00
23	3.33	2.33	0.00	0.67	0.33	0.00
24	4.00	3.33	0.00	0.33	0.00	0.00
25	1.67	3.00	16.00	0.33	0.67	0.00
26	2.00	6.00	0.00	0.00	1.00	0.00
27	1.33	5.33	0.00	0.00	1.33	0.00
28	0.00	4.33	0.00	0.33	0.67	0.00
29	0.33	5.00	17.33	0.00	0.33	0.00
30	0.67	5.33	0.00	0.00	0.67	14.00
31	0.33	4.00	0.00	0.67	0.33	0.00
32	0.00	2.67	0.00	0.00	0.67	0.00
33	0.67	3.00	12.67	0.00	0.00	0.00
34	0.33	1.67	0.00	0.67	0.00	0.00
35	0.00	0.67	0.00	0.33	0.00	12.67
36	0.33	1.00	0.00	0.33	0.33	0.00
37	1.33	1.33	6.67	0.00	0.00	0.00
38	0.67	0.67	0.00	0.00	0.33	0.00
39	1.67	1.00	0.00	0.00	0.00	0.00
40	2.67	2.67	0.00	0.67	0.00	0.00
41	4.00	4.00	0.00	0.33	0.00	0.00
42	3.67	3.67	8.33	0.67	0.67	0.00
43	2.33	3.33	0.00	1.33	0.33	0.00
44	1.67	3.00	0.00	0.67	1.00	0.00
45	1.33	2.67	0.00	0.33	1.33	0.00
46	0.67	1.33	0.00	0.67	0.67	0.00
47	1.00	0.67	0.00	0.33	0.33	0.00
48	0.67	0.67	0.00	0.67	0.00	0.00
49	0.33	0.33	0.00	0.33	0.00	0.00
50	0.00	0.00	0.00	0.33	0.33	0.00
51	0.67	0.33	0.00	0.33	0.00	0.00
52	0.33	0.33	0.00	0.33	0.67	0.00

APPENDIX II

Weekly population of sucking pests on **T 78 clone** of tea at **mid elevation** (mean of 3 replications)

2001	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.00	0.00	0.00	0.67	0.67	0.00
2	0.00	0.00	0.00	0.00	0.33	0.00
3	0.67	0.67	0.00	1.00	1.00	0.00
4	0.33	0.33	0.00	0.33	1.33	0.00
5	0.67	0.67	0.00	0.67	0.33	0.00
6	1.00	1.00	0.00	0.33	0.67	0.00
7	1.67	1.33	10.00	0.00	0.33	0.00
8	1.33	0.67	0.00	0.67	0.00	0.00
9	2.00	1.00	0.00	0.33	0.33	0.00
10	2.67	1.00	0.00	1.00	0.00	7.33
11	3.33	1.67	0.00	0.33	0.00	0.00
12	3.67	2.00	0.00	0.00	33.00	0.00
13	4.33	1.67	5.00	0.00	0.00	0.00
14	4.67	2.33	0.00	0.67	0.00	0.00
15	4.00	2.00	0.00	0.33	0.67	0.00
16	6.00	1.33	0.00	0.67	0.00	11.00
17	8.67	1.67	0.00	1.00	0.00	0.00
18	6.67	1.67	0.00	0.33	0.00	0.00
19	6.33	1.00	0.00	0.67	0.33	0.00
20	5.67	1.33	0.00	1.33	0.00	0.00
21	5.00	1.00	0.00	2.00	0.33	0.00
22	4.00	2.00	0.00	1.00	0.67	0.00
23	3.33	2.67	0.00	1.67	0.00	0.00
24	4.33	4.00	0.00	1.00	0.67	0.00
25	2.00	2.67	0.00	0.67	0.00	0.00
26	1.00	4.67	0.00	0.33	1.33	0.00
27	1.33	6.00	9.33	0.00	1.00	0.00
28	0.00	4.33	0.00	0.67	2.00	0.00
29	0.67	4.67	0.00	0.33	1.67	0.00
30	1.00	6.67	0.00	0.67	0.67	0.00
31	0.00	3.33	0.00	0.00	0.33	0.00
32	1.00	4.00	0.00	0.67	0.00	0.00
33	0.33	2.67	0.00	0.33	0.00	0.00
34	0.00	1.33	15.00	0.67	0.67	0.00
35	0.00	0.00	0.00	0.33	0.33	18.67
36	0.33	0.67	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.33	0.00	0.00
38	0.67	0.33	0.00	0.00	0.00	0.00
39	0.67	0.00	17.33	0.00	0.33	0.00
40	0.33	0.33	0.00	0.67	0.00	8.67
41	0.67	1.00	0.00	1.00	0.33	0.00
42	2.00	2.00	0.00	2.00	0.67	0.00
43	3.00	3.00	0.00	2.33	1.33	0.00
44	2.33	4.00	0.00	1.67	1.00	0.00
45	1.67	2.67	0.00	0.67	0.33	0.00
46	2.00	1.00	0.00	1.00	0.67	0.00
47	1.33	0.67	0.00	0.33	0.00	0.00
48	0.33	0.33	0.00	1.33	0.33	0.00
49	0.00	0.00	0.00	0.33	0.00	0.00
50	0.33	0.33	0.00	0.00	0.33	0.00
51	0.67	0.67	0.00	0.67	0.00	0.00
52	0.33	0.33	0.00	0.33	0.67	0.00

APPENDIX III

Weekly population of sucking pests on **China seed jat** of tea at **high elevation** (mean of 3 replications)

1999	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.67	0.00	0.00	1.33	0.33	0.00
2	1.00	0.00	0.00	2.00	0.00	0.00
3	0.33	0.00	0.00	1.67	0.00	0.00
4	1.33	0.33	0.00	2.00	0.67	0.00
5	2.67	0.33	0.00	0.67	0.33	0.00
6	4.00	0.67	0.00	0.00	0.00	0.00
7	5.33	0.67	0.00	0.33	0.00	0.00
8	4.67	0.33	0.00	0.00	0.33	0.00
9	6.67	0.67	0.00	0.67	0.67	0.00
10	7.67	1.00	5.33	1.33	0.33	0.00
11	6.00	0.67	0.00	0.00	0.00	6.67
12	8.00	1.00	0.00	0.00	0.67	0.00
13	5.33	0.33	10.67	0.33	0.33	0.00
14	7.00	1.00	0.00	0.67	0.00	0.00
15	7.33	1.33	0.00	0.33	0.00	12.00
16	6.67	0.67	0.00	0.00	0.00	0.00
17	11.33	1.00	0.00	0.00	0.00	0.00
18	10.67	1.00	0.00	0.33	0.00	0.00
19	10.00	0.67	0.00	0.00	0.00	0.00
20	11.00	1.00	0.00	0.67	0.00	0.00
21	8.00	0.67	0.00	0.33	0.33	0.00
22	12.33	1.33	14.00	0.00	0.33	0.00
23	12.67	2.33	0.00	0.67	0.00	0.00
24	9.33	1.67	0.00	0.67	0.00	0.00
25	4.00	3.67	0.00	0.33	0.00	0.00
26	2.33	3.00	0.00	0.33	0.67	14.00
27	1.67	2.00	16.67	0.67	0.33	0.00
28	1.33	1.33	0.00	0.00	0.67	0.00
29	0.33	1.00	0.00	0.33	0.33	0.00
30	1.67	0.67	9.33	0.67	0.33	0.00
31	3.33	1.67	0.00	0.33	0.67	0.00
32	2.00	1.00	0.00	0.33	0.33	0.00
33	0.00	0.67	0.00	0.67	0.33	16.67
34	0.00	0.00	10.00	0.00	0.00	0.00
35	1.33	0.33	0.00	0.00	0.00	0.00
36	2.33	0.67	0.00	0.00	0.33	0.00
37	1.33	0.67	0.00	0.00	0.33	0.00
38	2.00	0.33	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.33	0.67	0.00
40	1.67	0.67	0.00	0.67	0.33	0.00
41	2.00	1.33	0.00	1.00	0.33	0.00
42	0.67	0.67	0.00	0.33	0.67	0.00
43	2.67	2.33	0.00	1.33	0.00	0.00
44	6.00	1.67	0.00	0.67	0.33	0.00
45	4.67	1.33	0.00	0.33	0.67	0.00
46	3.67	0.33	0.00	0.67	0.33	0.00
47	2.00	0.00	0.00	0.33	0.00	0.00
48	0.67	0.00	0.00	0.00	0.33	0.00
49	0.33	0.00	0.00	0.67	0.33	0.00
50	0.00	0.67	0.00	0.33	0.00	0.00
51	0.67	0.00	0.00	0.33	0.00	0.00
52	1.00	0.00	0.00	0.67	0.33	0.00

APPENDIX III

Weekly population of sucking pests on **China seed jat** of tea at **high elevation** (mean of 3 replications)

2000	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	1.33	0.67	0.00	1.00	0.67	0.00
2	1.67	0.33	0.00	1.33	0.00	0.00
3	1.00	0.33	0.00	0.67	0.33	0.00
4	0.67	0.00	0.00	0.33	0.67	0.00
5	0.00	0.00	0.00	0.67	0.33	0.00
6	0.00	0.00	0.00	0.33	0.00	0.00
7	1.33	0.67	0.00	1.00	0.00	0.00
8	1.00	0.33	0.00	0.00	0.67	5.00
9	1.33	0.00	0.00	0.00	0.33	0.00
10	3.00	0.67	10.67	0.33	0.00	0.00
11	2.67	0.00	0.00	0.33	0.33	0.00
12	4.00	0.33	0.00	0.00	0.00	3.33
13	6.00	0.67	0.00	0.67	0.00	0.00
14	8.00	1.00	14.00	1.00	0.00	0.00
15	7.33	0.67	0.00	1.33	0.00	0.00
16	6.67	0.33	0.00	0.33	0.33	0.00
17	4.67	0.33	0.00	0.67	0.67	0.00
18	8.67	0.67	0.00	0.00	0.00	0.00
19	8.00	0.67	0.00	0.00	1.00	0.00
20	12.67	1.00	0.00	0.33	0.67	0.00
21	6.00	0.33	0.00	0.33	0.33	0.00
22	8.00	0.67	0.00	0.67	0.00	0.00
23	8.67	1.33	0.00	0.00	1.00	0.00
24	6.00	0.67	0.00	0.00	0.33	0.00
25	2.00	1.00	0.00	0.33	0.00	0.00
26	3.33	2.00	0.00	0.67	0.67	0.00
27	4.33	2.33	11.67	0.67	0.67	0.00
28	3.00	3.00	0.00	0.00	0.33	0.00
29	4.67	2.67	0.00	0.00	0.67	17.33
30	4.00	1.67	0.00	0.33	0.00	0.00
31	2.67	0.67	9.33	0.00	0.33	0.00
32	3.33	0.33	0.00	0.33	0.33	0.00
33	4.67	0.67	0.00	0.33	0.00	7.33
34	5.33	1.00	17.33	0.00	0.00	0.00
35	1.33	0.33	0.00	0.00	0.00	8.67
36	1.00	0.33	0.00	0.00	0.33	0.00
37	2.00	1.00	20.00	0.33	0.33	0.00
38	2.67	0.00	0.00	0.67	0.67	0.00
39	3.33	0.33	0.00	0.33	0.00	0.00
40	5.33	0.67	10.67	0.00	0.00	0.00
41	4.67	0.33	0.00	0.67	0.33	0.00
42	6.00	1.67	0.00	0.33	0.67	0.00
43	5.67	1.33	0.00	0.00	1.00	0.00
44	6.67	1.33	0.00	0.33	1.33	0.00
46	4.00	0.67	0.00	0.67	0.67	0.00
46	2.67	0.33	0.00	0.00	0.00	0.00
47	2.00	0.00	0.00	1.00	0.67	0.00
48	2.33	0.33	0.00	1.33	0.00	0.00
49	2.67	0.67	0.00	0.67	0.00	0.00
50	1.67	0.33	0.00	0.33	0.00	0.00
51	2.00	0.67	0.00	0.00	0.00	0.00
52	1.33	0.33	0.00	0.67	0.00	0.00

APPENDIX III

Weekly population of sucking pests on **China seed jat** of tea at **high elevation** (mean of 3 replications)

2001	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.67	0.67	0.00	0.33	1.00	0.00
2	0.33	0.33	0.00	1.00	0.33	0.00
3	1.00	0.33	0.00	0.67	1.33	0.00
4	0.67	0.00	0.00	1.00	2.00	0.00
5	0.00	0.00	0.00	0.33	0.67	0.00
6	0.00	0.33	0.00	0.33	0.00	0.00
7	1.67	0.67	0.00	0.33	0.33	0.00
8	1.00	0.00	0.00	0.00	0.00	4.00
9	2.67	0.67	0.00	0.00	0.33	0.00
10	2.33	0.33	0.00	0.67	0.00	0.00
11	4.00	0.67	0.00	1.33	0.00	0.00
12	4.67	0.67	0.00	0.33	0.33	0.00
13	8.00	0.00	0.00	0.67	0.33	10.00
14	12.67	1.00	16.00	0.33	0.00	0.00
15	11.33	0.67	0.00	0.00	0.00	0.00
16	10.00	0.33	0.00	0.67	0.00	0.00
17	10.67	0.33	0.00	0.33	0.33	0.00
18	9.33	0.33	0.00	1.00	0.67	0.00
19	10.00	0.67	0.00	0.67	0.33	0.00
20	6.67	1.00	0.00	0.33	0.67	0.00
21	8.33	0.67	0.00	0.67	0.33	0.00
22	7.33	1.00	0.00	0.67	0.67	0.00
23	7.67	1.33	10.67	1.00	0.33	0.00
24	3.33	1.33	0.00	0.33	1.00	0.00
25	2.67	2.00	16.00	1.00	0.67	0.00
26	5.33	3.67	0.00	0.00	0.33	0.00
27	4.67	3.33	0.00	0.67	0.00	0.00
28	1.33	2.00	18.67	0.67	0.33	0.00
29	4.00	2.67	0.00	0.33	0.67	0.00
30	1.33	1.67	0.00	0.67	1.00	17.33
31	2.33	3.00	0.00	0.00	0.00	0.00
32	3.33	2.67	0.00	0.67	0.00	0.00
33	0.33	0.67	20.67	0.33	0.33	0.00
34	1.33	0.67	0.00	0.67	0.00	0.00
35	1.00	0.33	0.00	0.00	0.33	16.00
36	1.67	1.00	10.00	0.33	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00
38	2.00	1.00	0.00	0.00	0.33	0.00
39	2.33	1.00	0.00	0.33	0.00	0.00
40	0.00	0.00	0.00	0.33	0.00	8.33
41	1.33	0.67	0.00	0.67	0.67	0.00
42	4.00	1.67	0.00	2.00	1.00	0.00
43	6.67	2.00	0.00	2.67	1.33	0.00
44	4.67	1.33	0.00	2.33	1.67	0.00
45	3.00	1.00	0.00	1.33	0.67	0.00
46	3.33	1.67	0.00	0.00	1.00	0.00
47	2.67	0.67	0.00	0.33	0.33	0.00
48	1.33	0.33	0.00	0.67	0.67	0.00
49	1.67	0.00	0.00	1.00	0.00	0.00
50	1.33	0.33	0.00	1.33	0.33	0.00
51	0.67	0.00	0.00	0.00	0.00	0.00
52	0.33	0.00	0.00	0.33	0.00	0.00

APPENDIX IV

Weekly population of sucking pests on **T 78 clone** of tea at **high elevation** (mean of 3 replications)

1999	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.33	0.00	0.00	0.67	0.67	0.00
2	0.67	0.00	0.00	1.33	0.33	0.00
3	0.33	0.00	0.00	0.67	0.00	0.00
4	0.67	0.33	0.00	0.33	0.67	0.00
5	1.00	0.67	0.00	1.33	0.33	0.00
6	1.33	1.00	0.00	2.00	0.00	0.00
7	2.00	0.67	0.00	0.67	0.00	0.00
8	1.00	0.33	0.00	0.33	0.67	0.00
9	1.67	1.00	0.00	0.00	0.33	0.00
10	3.00	1.33	0.00	1.33	1.00	7.33
11	3.33	1.00	0.00	2.00	0.33	0.00
12	5.33	1.67	0.00	0.67	0.67	0.00
13	4.67	1.33	0.00	0.33	0.33	0.00
14	6.00	1.67	0.00	0.00	0.00	0.00
15	6.67	2.00	0.00	0.67	0.33	0.00
16	5.33	1.33	0.00	0.33	0.00	0.00
17	8.00	1.33	0.00	1.00	0.00	0.00
18	7.67	1.00	0.00	1.33	0.67	0.00
19	5.33	0.67	0.00	2.00	0.00	0.00
20	7.33	1.33	0.00	1.33	0.00	0.00
21	6.00	1.00	0.00	0.33	0.33	0.00
22	9.33	1.67	0.00	0.00	0.33	0.00
23	8.67	3.33	0.00	0.00	0.00	14.00
24	7.67	2.67	0.00	0.33	0.00	0.00
25	3.33	4.67	17.33	0.00	0.33	0.00
26	1.67	3.67	0.00	0.67	0.67	0.00
27	2.33	3.00	12.00	0.33	0.33	0.00
28	0.00	2.33	0.00	0.00	1.33	0.00
29	1.00	1.33	16.00	0.67	0.67	0.00
30	1.33	1.00	0.00	0.33	1.67	6.00
31	2.67	2.00	0.00	0.33	1.00	0.00
32	1.67	1.33	0.00	0.00	0.00	0.00
33	0.00	1.00	8.00	0.33	0.00	0.00
34	0.00	0.33	0.00	0.33	0.67	0.00
35	0.00	0.67	0.00	0.00	0.00	0.00
36	1.33	1.00	0.00	0.67	0.33	0.00
37	1.00	1.33	0.00	0.33	0.00	0.00
38	0.67	0.67	0.00	0.00	0.00	0.00
39	0.00	0.33	0.00	0.00	0.33	0.00
40	1.00	1.33	0.00	0.67	0.00	0.00
41	1.67	1.00	0.00	1.00	0.67	0.00
42	1.33	0.67	0.00	1.33	1.00	0.00
43	4.00	3.33	0.00	0.67	0.67	0.00
44	3.33	3.00	0.00	0.33	0.33	0.00
45	3.67	2.00	0.00	0.67	0.00	0.00
46	2.33	1.00	0.00	0.33	0.00	0.00
47	1.67	0.67	0.00	0.67	0.00	0.00
48	0.67	0.00	0.00	0.00	0.00	0.00
49	1.00	0.33	0.00	0.00	0.67	0.00
50	1.33	0.67	0.00	0.67	0.00	0.00
51	0.33	0.00	0.00	0.33	0.00	0.00
52	0.33	0.33	0.00	0.00	0.00	0.00

APPENDIX IV

Weekly population of sucking pests on **T 78 clone** of tea at **high elevation** (mean of 3 replications)

2000	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.67	1.00	0.00	0.67	0.00	0.00
2	0.33	0.67	0.00	0.00	0.00	0.00
3	0.00	0.33	0.00	0.67	0.67	0.00
4	0.00	0.33	0.00	1.00	0.00	0.00
5	0.00	0.00	0.00	0.33	0.33	0.00
6	0.00	0.00	0.00	1.33	0.00	0.00
7	0.67	0.67	0.00	0.67	0.00	0.00
8	0.33	0.33	0.00	0.00	0.33	0.00
9	0.33	0.33	0.00	0.33	0.00	0.00
10	1.00	1.00	10.67	0.33	0.67	4.00
11	1.00	1.00	0.00	1.00	0.33	0.00
12	1.67	1.33	0.00	0.67	0.67	0.00
13	4.00	1.67	0.00	0.00	0.33	8.67
14	5.33	2.00	0.00	0.67	0.00	0.00
15	5.00	1.67	0.00	0.33	0.67	0.00
16	4.33	1.33	0.00	0.00	0.00	0.00
17	3.33	0.67	0.00	0.00	0.33	0.00
18	5.33	1.67	0.00	0.67	0.33	0.00
19	5.00	1.67	0.00	1.33	0.00	0.00
20	10.00	2.33	0.00	2.00	0.00	0.00
21	5.33	1.33	0.00	0.67	0.00	0.00
22	4.67	1.00	0.00	0.00	0.33	0.00
23	5.67	2.67	0.00	1.00	1.33	0.00
24	5.33	1.67	0.00	1.33	0.67	0.00
25	1.67	1.00	0.00	0.67	2.00	0.00
26	2.33	2.00	0.00	0.33	1.00	0.00
27	2.67	2.33	0.00	0.67	0.67	0.00
28	2.00	3.67	0.00	0.00	0.33	0.00
29	1.33	4.00	0.00	0.67	1.00	0.00
30	0.67	3.33	0.00	0.33	0.00	14.00
31	0.33	2.67	0.00	0.67	0.33	0.00
32	1.00	2.00	0.00	0.33	0.33	0.00
33	1.67	2.33	18.00	0.67	0.00	0.00
34	2.00	2.67	0.00	0.33	0.00	0.00
35	0.00	0.00	0.00	0.67	0.00	13.00
36	0.67	0.67	21.00	0.33	0.33	0.00
37	1.67	1.00	0.00	0.33	0.00	0.00
38	0.67	0.33	0.00	0.33	0.00	9.00
39	2.67	0.33	0.00	0.00	0.33	0.00
40	3.33	1.33	0.00	0.00	0.00	0.00
41	3.00	0.67	0.00	1.00	0.33	0.00
42	5.00	2.33	16.33	1.33	0.33	0.00
43	4.33	2.00	0.00	0.67	0.00	0.00
44	5.33	3.00	0.00	2.00	0.33	0.00
45	3.00	2.00	0.00	0.67	0.67	0.00
46	1.33	1.33	0.00	0.33	0.00	0.00
47	1.00	0.67	0.00	1.00	0.00	0.00
48	0.67	1.00	0.00	0.33	0.33	0.00
49	0.67	1.33	0.00	0.67	0.00	0.00
50	0.33	0.33	0.00	0.67	0.00	0.00
51	0.33	0.67	0.00	0.33	0.00	0.00
52	0.00	0.33	0.00	0.00	0.00	0.00

APPENDIX IV

Weekly population of sucking pests on **T 78 clone** of tea at **high elevation** (mean of 3 replications)

2001	Untreated plot			Treated plot		
Week	Thrips	Greenfly	Aphid	Thrips	Greenfly	Aphid
1	0.00	0.67	0.00	0.67	0.67	0.00
2	0.00	0.33	0.00	1.33	0.33	0.00
3	0.00	0.33	0.00	0.67	0.67	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.33	0.00	0.00
6	0.00	0.33	0.00	0.67	0.00	0.00
7	0.67	1.00	0.00	0.00	0.33	0.00
8	0.00	0.33	0.00	0.00	0.67	0.00
9	0.67	0.67	5.67	0.00	0.00	0.00
10	0.33	0.67	0.00	0.33	0.67	0.00
11	2.00	1.00	0.00	0.67	0.33	0.00
12	2.33	1.33	0.00	0.33	0.67	0.00
13	4.00	1.67	0.00	0.00	0.33	0.00
14	6.00	2.00	0.00	1.00	0.00	0.00
15	8.67	1.67	0.00	0.00	0.00	0.00
16	7.33	1.00	0.00	0.67	0.33	0.00
17	8.00	1.33	0.00	0.33	0.00	0.00
18	6.67	1.33	0.00	0.33	0.33	0.00
19	7.00	2.00	0.00	0.67	0.00	0.00
20	4.67	1.67	0.00	0.67	0.67	0.00
21	5.00	1.33	0.00	1.33	0.67	0.00
22	4.00	1.33	0.00	0.33	0.33	0.00
23	4.33	1.67	0.00	0.00	0.67	0.00
24	2.33	1.33	6.00	0.67	1.00	0.00
25	1.33	2.67	0.00	0.00	1.33	0.00
26	2.67	4.67	0.00	0.33	1.67	0.00
27	2.33	4.00	22.00	0.67	0.67	0.00
28	0.00	3.00	0.00	0.00	1.00	0.00
29	1.00	3.33	0.00	0.33	0.00	0.00
30	0.00	2.67	0.00	0.67	0.67	18.33
31	0.67	3.00	0.00	0.33	1.00	0.00
32	1.00	3.67	0.00	0.00	0.33	6.33
33	0.00	0.67	0.00	0.67	0.33	0.00
34	0.67	1.67	12.33	0.33	0.00	0.00
35	0.00	1.00	0.00	0.00	0.00	0.00
36	1.00	1.33	0.00	0.67	0.67	0.00
37	0.00	0.67	0.00	0.33	0.00	0.00
38	1.00	1.00	8.00	0.33	0.67	0.00
39	1.33	1.33	0.00	0.00	0.33	0.00
40	0.00	0.67	0.00	0.67	0.00	11.00
41	1.00	2.00	0.00	0.67	0.67	0.00
42	2.67	2.67	0.00	0.33	0.33	0.00
43	4.00	3.33	6.33	0.00	0.33	0.00
44	2.33	1.67	0.00	0.67	0.33	0.00
45	2.00	1.33	0.00	0.33	0.33	0.00
46	2.67	2.00	0.00	0.33	0.67	0.00
47	1.33	1.00	0.00	0.00	0.00	0.00
48	0.67	0.33	0.00	0.33	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00
50	0.33	0.33	0.00	0.33	0.00	0.00
51	0.00	0.00	0.00	0.67	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX V

Weather data at mid elevation

Year - 1999						
Week	Rainfall mm	Max. Temp.^{0}C	Min. Temp. ^{0}C	RH %,0637 hr	RH %,1337 hr	Sun shine hr
1	0.00	18.80	9.30	62.00	44.00	7.30
2	9.80	17.00	7.00	63.00	43.00	7.30
3	0.00	19.00	8.90	55.00	36.00	7.90
4	0.00	19.50	10.00	66.00	50.00	6.70
5	0.60	19.30	9.70	66.00	46.00	7.00
6	0.00	22.20	12.40	65.00	46.00	6.70
7	0.00	23.70	14.10	72.00	52.00	6.50
8	0.00	22.00	13.70	81.00	60.00	4.90
9	0.00	23.50	12.70	62.00	41.00	8.00
10	0.00	24.70	15.70	70.00	52.00	6.10
11	0.00	24.10	13.70	52.00	37.00	6.10
12	0.00	24.50	14.40	57.00	36.00	5.60
13	2.50	24.70	14.70	73.00	50.00	5.00
14	2.20	27.70	17.10	80.00	52.00	7.10
15	42.80	26.70	17.00	84.00	58.00	6.80
16	0.00	28.10	17.70	72.00	48.00	7.00
17	0.80	27.30	19.20	93.00	71.00	5.00
18	3.70	26.40	17.80	90.00	70.00	2.80
19	42.40	24.60	16.50	86.00	74.00	3.10
20	26.40	25.80	16.70	87.00	64.00	6.10
21	35.80	25.80	19.00	95.00	78.00	2.40
22	38.90	26.10	19.00	93.00	83.00	5.60
23	2.50	29.00	19.90	81.00	62.00	7.30
24	113.70	25.70	19.70	94.00	82.00	3.60
25	264.40	25.70	19.70	97.00	86.00	2.20
26	347.40	24.10	19.20	95.00	93.00	1.00
27	148.20	24.50	19.70	96.00	89.00	2.50
28	179.60	24.50	19.90	97.00	88.00	1.90
29	114.20	25.10	19.40	97.00	84.00	1.90
30	53.20	26.10	19.90	95.00	83.00	1.70
31	22.60	27.40	20.20	87.00	77.00	6.10
32	134.70	25.70	20.00	95.00	87.00	1.70
33	247.70	24.20	19.40	97.00	90.00	2.20
34	175.50	24.00	19.30	97.00	91.00	0.50
35	50.80	23.40	18.70	96.00	88.00	2.20
36	58.00	25.90	20.10	96.00	83.00	3.80
37	68.40	25.70	18.80	92.00	82.00	4.50
38	9.00	26.30	19.00	91.00	80.00	5.60
39	131.30	23.20	17.50	92.00	84.00	3.10
40	64.80	24.40	17.80	92.00	84.00	3.00
41	0.00	23.90	17.00	92.00	80.00	5.30
42	190.80	21.70	15.70	90.00	83.00	3.50
43	0.00	24.80	15.60	77.00	58.00	8.20
44	16.00	24.30	15.60	85.00	72.00	7.00
45	0.00	22.80	13.90	74.00	62.00	7.90
46	0.20	21.70	13.20	79.00	70.00	6.60
47	0.00	19.70	11.30	74.00	66.00	7.50
48	0.00	20.50	12.00	75.00	61.00	5.70
49	0.00	20.00	11.20	64.00	56.00	6.40
50	1.60	20.30	10.30	61.00	53.00	7.40
51	0.00	18.90	10.10	69.00	58.00	6.20
52	5.70	16.70	9.00	83.00	64.00	3.90

APPENDIX V

Weather data at mid elevation

Year - 2000						
Week	Rainfall mm	Max. Temp.°C	Min. Temp. °C	RH %,0637 hr	RH %,1337 hr	Sun shine hr
1	0.00	18.00	8.30	62.00	48.00	8.10
2	0.00	16.90	7.80	73.00	52.00	6.10
3	0.00	16.40	8.40	79.00	65.00	5.00
4	0.30	14.50	7.60	78.00	59.00	4.00
5	21.20	14.80	7.20	82.00	60.00	4.20
6	1.00	16.00	7.50	82.00	58.00	5.10
7	0.00	18.50	9.00	72.00	50.00	6.90
8	0.00	17.30	7.40	65.00	41.00	5.90
9	0.20	15.30	8.00	70.00	56.00	3.00
10	0.00	20.40	10.30	77.00	56.00	5.90
11	5.40	18.90	9.70	74.00	54.00	6.10
12	0.00	23.10	11.80	63.00	44.00	7.30
13	0.00	26.70	15.90	59.00	40.00	6.00
14	0.00	27.00	17.00	67.00	52.00	6.60
15	23.50	26.00	14.90	70.00	48.00	6.00
16	18.70	26.00	15.50	83.00	62.00	5.90
17	61.30	22.40	14.70	93.00	78.00	4.80
18	30.60	25.10	16.60	88.00	70.00	6.70
19	22.80	27.40	18.20	87.00	68.00	7.30
20	43.90	26.80	19.00	94.00	77.00	3.70
21	115.10	24.00	17.80	95.00	84.00	1.50
22	20.60	24.50	18.10	95.00	79.00	2.40
23	68.90	27.20	19.80	91.00	81.00	2.70
24	40.80	25.70	19.90	94.00	81.00	3.30
25	104.40	25.30	19.20	92.00	85.00	1.80
26	73.90	25.60	19.30	94.00	87.00	2.10
27	80.30	24.30	19.70	97.00	88.00	1.10
28	129.80	26.40	19.80	94.00	83.00	3.30
29	77.20	26.00	19.70	92.00	81.00	3.50
30	53.00	26.10	19.40	93.00	86.00	2.60
31	39.80	24.30	19.40	98.00	93.00	0.90
32	68.40	26.30	19.50	94.00	86.00	3.00
33	54.90	26.10	19.50	94.00	85.00	3.60
34	79.00	26.70	19.50	93.00	85.00	3.20
35	289.20	24.80	19.30	96.00	92.00	0.60
36	96.20	24.70	19.10	97.00	92.00	1.70
37	13.20	26.30	19.30	91.00	79.00	4.90
38	34.20	22.80	17.00	93.00	87.00	1.40
39	33.20	24.70	17.00	90.00	76.00	6.20
40	10.20	25.80	18.00	89.00	77.00	6.30
41	1.20	25.30	17.40	94.00	75.00	6.60
42	0.00	25.50	16.00	72.00	60.00	6.50
43	12.60	23.50	14.80	82.00	65.00	5.20
44	0.20	22.60	14.40	80.00	62.00	7.00
45	5.40	22.00	14.60	93.00	80.00	4.60
46	2.60	19.20	13.30	85.00	78.00	3.40
47	0.00	19.40	12.10	87.00	75.00	4.80
48	0.00	19.80	11.10	74.00	64.00	6.70
49	0.00	19.20	9.20	62.00	50.00	7.10
50	0.00	18.20	9.30	71.00	57.00	7.10
51	0.00	19.30	10.10	68.00	53.00	7.00
52	0.00	19.00	9.50	75.00	59.00	7.00

APPENDIX V

Weather data at mid elevation

Year - 2001						
Week	Rainfall mm	Max. Temp.^{0}C	Min. Temp. ^{0}C	RH %,0637 hr	RH %,1337 hr	Sun shine hr
1	0.40	17.00	8.50	81.00	58.00	5.00
2	0.00	15.00	7.00	74.00	58.00	4.70
3	0.00	18.80	9.10	66.00	43.00	7.30
4	4.20	16.20	7.70	78.00	55.00	5.00
5	0.00	18.10	10.20	74.00	65.00	3.80
6	0.00	18.10	9.40	67.00	50.00	5.10
7	0.40	20.50	11.80	67.00	50.00	4.20
8	11.20	18.40	10.50	80.00	67.00	4.20
9	1.00	21.50	11.40	72.00	49.00	5.90
10	6.00	21.20	11.60	66.00	49.00	5.00
11	0.00	24.20	13.10	56.00	36.00	7.00
12	0.00	24.40	14.20	64.00	46.00	5.50
13	3.90	24.00	14.00	72.00	53.00	4.60
14	0.00	26.50	15.70	59.00	44.00	7.80
15	68.40	26.80	15.90	76.00	61.00	6.70
16	16.80	23.80	14.70	85.00	66.00	6.10
17	15.00	25.90	16.20	80.00	64.00	7.40
18	56.70	25.00	16.40	83.00	67.00	6.10
19	44.70	24.50	17.10	88.00	73.00	4.20
20	50.80	25.60	18.30	86.00	71.00	5.50
21	52.10	24.60	18.20	93.00	82.00	2.80
22	73.20	25.60	18.40	89.00	78.00	4.10
23	52.10	24.30	18.60	92.00	85.00	2.20
24	64.70	26.40	19.50	88.00	76.00	4.90
25	197.00	26.40	20.10	91.00	78.00	3.60
26	109.20	26.90	20.50	94.00	82.00	4.20
27	6.00	28.50	21.10	85.00	73.00	6.60
28	155.10	26.50	20.30	94.00	81.00	2.70
29	96.30	26.20	20.30	95.00	80.00	3.50
30	19.60	26.90	20.80	95.00	86.00	2.50
31	219.90	25.60	20.80	92.00	85.00	1.50
32	1.00	29.20	20.90	87.00	72.00	6.50
33	64.70	26.70	20.40	94.00	80.00	1.90
34	157.60	25.30	20.10	95.00	90.00	1.50
35	218.30	26.50	19.90	96.00	84.00	2.40
36	86.50	24.30	19.60	94.00	86.00	0.80
37	165.90	24.00	19.30	95.00	90.00	1.20
38	51.80	25.60	19.10	93.00	85.00	3.60
39	67.70	25.50	19.00	89.00	82.00	3.70
40	206.90	21.80	17.70	96.00	91.00	1.50
41	15.80	23.30	17.70	91.00	87.00	3.60
42	6.60	24.10	15.80	82.00	72.00	7.00
43	0.00	25.70	15.70	60.00	47.00	8.50
44	0.30	23.50	15.50	85.00	75.00	6.60
45	0.00	22.10	13.80	78.00	68.00	6.50
46	0.00	22.30	13.70	79.00	65.00	7.20
47	0.80	20.10	13.20	86.00	76.00	5.20
48	0.10	19.60	11.50	83.00	71.00	6.60
49	0.00	16.70	10.40	86.00	81.00	2.60
50	0.00	17.50	9.70	66.00	57.00	5.10
51	0.00	19.60	10.10	60.00	47.00	5.90
52	0.00	18.60	8.50	63.00	48.00	6.20

APPENDIX VI

Weather data at high elevation

Year - 1999			
Week	Rainfall mm	Max. Temp.°C	Min. Temp. °C
1	0.00	16.71	9.57
2	0.00	18.14	9.29
3	0.00	18.57	8.43
4	0.00	19.57	8.71
5	0.00	19.71	8.29
6	0.00	22.00	12.15
7	0.00	22.00	13.43
8	0.00	19.43	11.43
9	0.00	23.86	12.14
10	0.00	25.00	17.57
11	0.00	24.29	13.71
12	0.00	27.00	15.43
13	16.30	25.00	15.86
14	2.20	27.14	17.57
15	24.90	28.86	18.29
16	2.80	26.00	19.14
17	3.90	27.57	20.29
18	13.80	27.00	19.00
19	48.50	25.00	18.57
20	31.60	27.29	18.29
21	31.00	22.86	18.86
22	24.40	27.86	20.43
23	48.10	30.00	21.14
24	51.10	27.71	19.00
25	204.30	27.50	19.50
26	325.40	27.30	19.20
27	111.20	26.10	19.40
28	185.80	26.20	19.00
29	132.10	23.30	19.30
30	73.60	22.57	19.29
31	30.10	29.71	21.14
32	58.20	25.14	20.00
33	239.50	24.71	19.29
34	199.50	22.43	19.29
35	121.00	23.14	18.86
36	57.10	26.57	19.71
37	43.20	26.29	19.57
38	39.00	23.43	19.00
39	190.90	21.57	18.14
40	42.70	24.43	19.57
41	0.00	23.67	19.67
42	116.30	24.50	19.50
43	0.00	27.33	18.67
44	3.00	26.86	17.71
45	0.00	24.43	17.86
46	0.00	22.29	12.57
47	0.00	22.00	10.86
48	0.00	21.00	9.86
49	1.00	22.57	9.71
50	5.40	23.00	8.86
51	0.40	21.29	8.43
52	5.60	21.43	8.29

APPENDIX VI

Weather data at high elevation

Year - 2000			
Week	Rainfall mm	Max. Temp.°C	Min. Temp. °C
1	0.00	22.14	7.29
2	0.00	19.29	7.57
3	0.00	16.71	7.29
4	14.90	16.29	7.00
5	14.80	13.71	5.71
6	2.70	15.57	5.86
7	1.20	19.57	7.86
8	0.00	17.29	6.43
9	1.50	17.29	6.86
10	0.00	21.29	9.86
11	11.80	20.29	10.29
12	0.00	22.86	11.00
13	2.20	26.43	13.71
14	0.00	26.43	15.43
15	2.00	25.57	15.00
16	18.60	24.86	15.00
17	51.70	22.29	13.86
18	12.60	23.43	15.14
19	88.80	25.86	15.43
20	82.20	26.57	17.71
21	155.80	23.71	17.00
22	74.00	23.00	16.43
23	50.00	27.57	18.14
24	33.50	24.86	18.71
25	122.40	24.86	17.71
26	96.10	25.57	17.71
27	84.40	25.86	18.71
28	93.60	26.29	18.71
29	53.20	26.43	18.14
30	83.20	25.00	17.57
31	89.50	23.43	18.29
32	60.90	25.00	16.57
33	48.40	26.14	18.71
34	46.90	27.71	18.00
35	220.60	24.86	18.71
36	66.30	23.29	16.86
37	18.00	27.71	18.57
38	41.70	23.14	16.86
39	9.00	24.43	16.29
40	17.20	27.00	17.43
41	0.00	26.71	16.14
42	2.20	28.57	15.14
43	2.10	27.29	13.71
44	0.90	28.29	13.00
45	1.00	23.14	13.43
46	1.80	20.14	12.00
47	2.60	20.29	10.29
48	0.00	21.71	9.57
49	0.00	23.86	8.86
50	0.00	20.86	12.00
51	0.00	22.50	8.50
52	0.00	20.50	8.60

APPENDIX VI

Weather data at high elevation

Year - 2001			
Week	Rainfall mm	Max. Temp.^{0}C	Min. Temp. ^{0}C
1	0.00	20.00	7.50
2	0.00	19.50	8.00
3	0.00	20.30	8.33
4	9.00	16.43	9.00
5	0.00	18.71	7.57
6	0.00	19.29	7.71
7	0.00	21.71	9.14
8	26.80	17.29	8.86
9	0.00	22.43	9.71
10	11.00	22.14	9.29
11	0.00	24.43	11.29
12	0.00	24.57	12.86
13	4.30	24.71	13.43
14	0.00	27.00	15.57
15	32.30	26.29	15.57
16	21.30	23.43	14.57
17	20.50	25.86	14.43
18	63.80	25.71	14.71
19	61.00	26.00	15.29
20	97.80	26.71	16.71
21	51.80	25.29	16.57
22	92.80	25.71	16.00
23	52.80	25.14	16.71
24	124.80	26.86	17.00
25	126.50	26.43	17.86
26	57.30	30.00	18.00
27	30.80	28.00	18.50
28	148.30	26.50	17.00
29	62.30	26.00	19.00
30	105.80	26.50	21.75
31	77.50	29.00	19.86
32	36.50	30.71	19.86
33	109.80	27.14	20.57
34	44.00	26.86	19.57
35	109.30	31.00	20.00
36	94.00	27.29	19.43
37	147.50	26.29	18.86
38	9.50	27.71	18.00
39	86.00	29.00	18.43
40	201.30	21.86	16.43
41	52.80	24.71	16.86
42	2.30	28.43	15.29
43	0.00	29.57	14.57
44	0.00	19.71	15.14
45	1.80	18.43	12.29
46	0.00	20.29	13.00
47	21.50	17.00	12.57
48	0.00	14.14	10.57
49	0.00	12.57	8.43
50	0.00	14.71	13.14
51	0.00	14.86	10.43
52	0.00	12.50	8.75

APPENDIX VII

Data on organoleptic taste of orthodox tea made from **Common thrips** infested and uninfested shoots (on 10 point scale)

Parameters	Tasters' scores on china seed Jat								Tasters' scores on clone T 78							
	Infested				Uninfested				Infested				Uninfested			
	T 1*	T 2	T 3	Avg.	T 1	T 2	T 3	Avg.	T 1	T 2	T 3	Avg.	T 1	T 2	T 3	Avg.
1. Flavour																
Replication 1	7.5	7	8	7.5	6.5	6	7	6.5	7	6.5	8	7.17	6	6.5	5.5	6
Replication 2	6.8	7.5	6.5	6.933	5.5	7	6	6.167	6	7	6.5	6.5	5.5	5	4	4.83
Replication 3	7	7.5	8	7.5	6	6.5	7	6.5	6.3	6	7.5	6.6	5.5	5.5	4.5	5.17
Replication 4	7.5	8	7.5	7.667	7	6.5	8	7.167	7	6.5	7	6.83	5.5	6.5	7	6.33
Average	7.2	7.5	7.5	**7.4**	6.25	6.5	7	**6.583**	6.575	6.5	7.25	**6.78**	5.63	5.88	5.25	**5.58**
2. Liquor																
Replication 1	5.5	6	6.5	6	5	6	5.5	5.5	7.5	8	7	7.5	6.5	6.5	6	6.33
Replication 2	6.5	4.6	5	5.367	6	4	4.5	4.833	6.5	7.5	6.5	6.83	6	6.5	5.5	6
Replication 3	7	6.5	8	7.167	6.5	5.5	7.2	6.4	7	8	6.5	7.17	6	7	5.5	6.17
Replication 4	5.5	5.2	7	5.9	5	5	6.5	5.5	7.5	7	7.8	7.43	6.5	5.5	7	6.33
Average	6.125	5.575	6.625	**6.108**	5.625	5.125	5.925	**5.558**	7.125	7.63	6.95	**7.23**	6.25	6.38	6	**6.21**
3. Quality																
Replication 1	4.5	6	5.5	5.333	4	5.5	5	4.833	4	5.5	5	4.83	4	4.5	4.5	4.33
Replication 2	5.8	6.5	7	6.433	5.5	6	6.5	6	4.4	5	5	4.8	4	4.5	4	4.17
Replication 3	5.5	4.5	5	5	5	4.3	5	4.767	5	5.5	6.5	5.67	4.5	5.5	6	5.33
Replication 4	4	4.5	5	4.5	4	4	4.5	4.167	6	5.5	5	5.5	4.5	4	4	4.17
Average	4.95	5.375	5.625	**5.317**	4.625	4.95	5.25	**4.942**	4.85	5.38	5.375	**5.2**	4.25	4.63	4.63	**4.5**
* T=Taster																

APPENDIX VIII

Data on organoleptic taste of orthodox tea made from **Greenfly** infested and uninfested shoots (on 10 point scale)

Parameters	Tasters' scores on china seed Jat								Tasters' scores on clone T 78							
	Infested				Uninfested				Infested				Uninfested			
	T 1 *	T 2	T 3	Avg.	T 1	T 2	T 3	Avg.	T 1	T 2	T 3	Avg.	T 1	T 2	T 3	Avg.
1. Flavour																
Replication 1	7	7.5	8	7.5	6.5	7	7.5	7	6	6.2	5.5	5.9	5.5	5	4.4	4.97
Replication 2	7	8	7.3	7.43	5	6.5	6.5	6	5.5	6	6.5	6	5	5	5.5	5.17
Replication 3	8	7.5	7.5	7.67	7	7.5	7	7.17	6	4.5	5	5.17	5.5	4	4	4.5
Replication 4	7.5	8	7.5	7.67	6.5	6.2	7	6.57	6.5	7	6	6.5	5.5	6.5	5.5	5.83
Average	7.38	7.75	7.58	**7.57**	6.25	6.8	7	**6.68**	6	5.93	5.75	**5.89**	5.38	5.13	4.85	**5.12**
2. Liquor																
Replication 1	5	5.5	4	4.83	4.5	5	4	4.5	6.5	7	5.5	6.33	6	6.5	5	5.83
Replication 2	7	6.5	5.8	6.43	6.5	6	5.6	6.03	6	5.5	7	6.17	5.5	5	6	5.5
Replication 3	5.5	6.5	6	6	5.5	6	5.5	5.67	7.5	6	6.5	6.67	6	5.5	5.5	5.67
Replication 4	6.5	5	6	5.83	6	4.8	5	5.27	6.5	6.5	5.5	6.17	6	5.5	4.5	5.33
Average	6	5.88	5.45	**5.78**	5.63	5.45	5.03	**5.37**	6.63	6.25	6.13	**6.33**	5.88	5.63	5.25	**5.58**
3. Quality																
Replication 1	5.5	6.5	6	6	5	6	5.5	5.5	5	5.5	4.5	5	4.5	5	4	4.5
Replication 2	7	6.5	7.5	7	6.5	6	6.4	6.3	5.5	6.5	6	6	5	5	4.5	4.83
Replication 3	6	5.5	5.5	5.67	5.5	5	4.5	5	5.5	6.5	7	6.33	4.5	5	5.5	5
Replication 4	6.5	6.5	7	6.67	6	5.5	6	5.83	4.5	4.5	5	4.67	4	4.3	4.5	4.27
Average	6.25	6.25	6.5	**6.33**	5.75	5.63	5.6	**5.66**	5.13	5.75	5.63	**5.5**	4.5	4.83	4.63	**4.65**
* Taster																

APPENDIX IX

Data on HPLC analysis of residual catechins and caffeine in black orthodox tea made from **Common thrips** infested and uninfested shoots

	China seed Jat		Clone T 78	
1. (-) epigallocatechin (EGC)				
Replication	Infested	Uninfetsed	Infested	Uninfested
1	1.02	0.78	1.04	0.98
2	0.78	0.92	0.98	0.79
3	0.97	0.87	0.84	0.88
4	0.76	0.72	0.95	0.87
Average	**0.88**	**6.82**	**0.95**	**0.88**
2. (+) gallocatechin (GC)				
1	0.45	0.36	0.54	0.48
2	0.32	0.29	0.42	0.52
3	0.41	0.38	0.39	0.39
4	0.35	0.3	0.46	0.38
Average	**0.38**	**0.33**	**0.45**	**0.44**
-) epicatechin (EC)				
1	0.64	0.62	0.68	0.48
2	0.52	0.56	0.58	0.41
3	0.48	0.52	0.7	0.54
4	0.61	0.59	0.61	0.5
Average	**0.56**	**0.57**	**0.64**	**0.48**
llocatechin gallate (EGCG)				
1	4.02	3.72	5.03	3.98
2	3.91	3.86	4.88	3.76
3	3.88	3.58	5.12	3.92
4	3.96	3.97	4.66	3.67
Average	**3.94**	**3.78**	**4.92**	**3.83**
icatechin gallate (ECG)				
1	2.33	2.15	3.08	2.54
2	2.02	1.95	2.98	2.38
3	1.98	2.01	2.95	2.32
4	2.12	2.06	3.04	2.49
Average	**2.11**	**2.04**	**3.01**	**2.43**
6. Caffeine				
1	2.81	2.94	3.06	3.38
2	2.72	2.79	2.89	3.12
3	2.68	2.85	2.97	3.17
4	2.64	2.76	2.85	3.42
Average	**2.71**	**2.84**	**2.94**	**3.27**

APPENDIX X

Data on HPLC analysis of residual catechins and caffeine in black orthodox tea made from **Greenfly** infested and uninfested shoots

	China seed Jat		Clone T 78	
1. (-) epigallocatechin (EGC)				
Replication	Infested	Uninfetsed	Infested	Uninfested
1	0.88	0.82	0.97	0.79
2	0.85	0.78	1.15	0.82
3	0.94	0.86	1.02	0.93
4	0.86	0.91	1.07	0.87
Average	**0.88**	**0.84**	**1.05**	**0.85**
2. (+) gallocatechin (GC)				
1	0.37	0.28	0.49	0.44
2	0.45	0.34	0.39	0.36
3	0.39	0.42	0.44	0.46
4	0.48	0.37	0.53	0.43
Average	**0.42**	**0.35**	**0.46**	**0.42**
3. (-) epicatechin (EC)				
1	0.68	0.51	0.71	0.64
2	0.65	0.67	0.64	0.58
3	0.74	0.66	0.65	0.62
4	0.58	0.49	0.73	0.65
Average	**0.66**	**0.58**	**0.68**	**0.62**
4. (-) epigallocatechin gallate (EGCG)				
1	3.97	3.56	4.87	3.92
2	4.45	3.96	4.48	3.84
3	4.38	4.17	4.78	3.52
4	4.22	3.8	4.36	3.65
Average	**4.26**	**3.87**	**4.62**	**3.73**
5. (-) epicatechin gallate (ECG)				
1	2.34	2.31	3.21	2.87
2	2.26	2.18	2.97	2.47
3	1.86	2.12	3.46	2.42
4	2.3	2.36	3.58	2.77
Average	**2.19**	**2.24**	**3.31**	**2.63**
6. Caffeine				
1	2.58	3.12	2.92	3.26
2	2.86	2.92	2.78	2.94
3	2.73	2.82	2.97	3.38
4	2.96	3.03	2.67	3.11
Average	**2.78**	**2.97**	**2.84**	**3.17**

APPENDIX XI

Flavour constituents of orthodox tea made from **Common thrips** infested and uninfested shoots (Amounts in ratio of the peak area with "Internal Standard"

Flavour constituent		China seed jat		Clone T - 78	
		Infested	Uninfested	Infested	Uninfested
1. Trans-2-hexanal,	R1*	0.091	0.052	0.185	0.245
	R2	0.028	0.163	0.113	0.187
	R3	0.015	0.068	0.164	0.227
	R4	0.078	0.042	0.214	0.286
	Mean	**0.053**	**0.081**	**0.169**	**0.236**
2. Nonylaldehyde,	R1	0.078	0.042	0.026	0.012
	R2	0.067	0.012	0.069	0.046
	R3	0.120	0.074	0.042	0.031
	R4	0.046	0.059	0.014	0.008
	Mean	**0.078**	**0.047**	**0.038**	**0.024**
3. Linalool oxide I	R1	0.823	0.466	0.412	0.368
	R2	0.245	0.104	0.212	0.145
	R3	0.432	0.265	0.362	0.217
	R4	0.540	0.324	0.276	0.178
	Mean	**0.510**	**0.290**	**0.316**	**0.227**
4. Linalool oxide II	R1	1.362	0.956	0.524	0.476
	R2	0.946	0.723	1.082	0.876
	R3	0.794	0.562	1.340	0.986
	R4	1.642	1.432	0.621	0.586
	Mean	**1.186**	**0.918**	**0.892**	**0.731**
5. Benzaldehyde	R1	0.107	0.083	0.064	0.021
	R2	0.068	0.065	0.046	0.032
	R3	0.053	0.022	0.152	0.082
	R4	0.086	0.048	0.092	0.052
	Mean	**0.079**	**0.055**	**0.089**	**0.047**
6. Linalool	R1	0.921	0.876	0.285	0.154
	R2	0.435	0.512	0.384	0.124
	R3	0.764	0.698	0.206	0.170
	R4	0.643	0.592	0.487	0.206
	Mean	**0.691**	**0.670**	**0.341**	**0.164**
7. Phenylacetaldehyde,	R1	0.242	0.261	0.624	0.432
	R2	0.412	0.279	0.312	0.218
	R3	0.623	0.426	0.731	0.421
	R4	0.321	0.278	0.478	0.214
	Mean	**0.400**	**0.311**	**0.536**	**0.321**
8.Terpineol,	R1	0.082	0.054	0.823	0.613
	R2	0.156	0.125	0.342	0.286
	R3	0.052	0.046	0.765	0.687
	R4	0.126	0.086	0.562	0.462
	Mean	**0.104**	**0.078**	**0.623**	**0.512**
9. Methylsalicylate,	R1	0.092	0.057	0.084	0.048
	R2	0.116	0.087	0.146	0.072
	R3	0.056	0.038	0.065	0.097
	R4	0.032	0.043	0.079	0.041
	Mean	**0.074**	**0.056**	**0.094**	**0.065**

* R=Replication

APPENDIX XI

Flavour constituents of orthodox tea made from **Common thrips** infested and uninfested shoots (Amounts in ratio of the peak area with "Internal Standard"

Flavour constituent		China seed jat		Clone T - 78	
		Infested	Uninfested	Infested	Uninfested
10. Geraniol,	R1*	2.380	1.683	1.370	0.564
	R2	1.640	0.763	0.362	0.267
	R3	1.200	0.460	0.723	0.217
	R4	2.120	0.871	1.120	0.376
	Mean	**1.835**	**0.944**	**0.894**	**0.356**
11. Benzylalcohol,	R1	0.278	0.076	0.207	0.127
	R2	0.178	0.053	0.162	0.094
	R3	0.128	0.032	0.264	0.156
	R4	0.218	0.087	0.094	0.048
	Mean	**0.201**	**0.062**	**0.182**	**0.106**
12. Phenyl ethanol,	R1	0.252	0.128	0.087	0.097
	R2	ND	0.023	0.176	0.132
	R3	0.698	0.302	0.153	0.114
	R4	0.543	0.178	0.110	ND
	Mean	**0.498**	**0.158**	**0.132**	**0.114**
13. β-Ionone,	R1	0.042	0.012	0.032	0.015
	R2	0.136	0.056	0.078	0.045
	R3	0.072	0.068	0.044	0.098
	R4	0.108	0.040	0.017	0.089
	Mean	**0.090**	**0.044**	**0.043**	**0.062**
14. Caprylic Acid,	R1	0.346	0.213	0.465	0.234
	R2	0.143	0.087	0.287	0.156
	R3	0.196	0.056	0.152	0.132
	R4	0.167	0.187	0.345	0.221
	Mean	**0.213**	**0.136**	**0.312**	**0.186**
16. Octaldehyde,	R1	0.192	0.076	0.892	0.436
	R2	0.266	0.143	0.431	0.270
	R3	0.084	0.054	0.317	0.378
	R4	0.048	0.063	1.060	0.658
	Mean	**0.148**	**0.084**	**0.675**	**0.436**
16. Nonanoic Acid,	R1	0.170	0.022	0.213	0.106
	R2	0.125	0.038	0.123	0.063
	R3	0.098	0.011	0.165	0.034
	R4	0.236	0.062	0.246	0.138
	Mean	**0.157**	**0.033**	**0.187**	**0.085**
17. Jasmonic acid,	R1	0.238	0.192	0.216	0.168
	R2	0.186	0.168	0.246	0.198
	R3	0.342	0.298	0.156	0.123
	R4	0.387	0.358	0.128	0.096
	Mean	**0.288**	**0.254**	**0.187**	**0.146**
18. Geranic acid,	R1	0.293	0.165	0.312	0.173
	R2	0.187	0.142	0.272	0.132
	R3	0.143	0.132	0.198	0.112
	R4	0.346	0.206	0.372	0.212
	Mean	**0.242**	**0.161**	**0.289**	**0.157**

* R=Replication

APPENDIX XII

Flavour constituents of orthodox tea made from **Greenfly** infested and uninfested shoots (Amounts in ratio of the peak area with "Internal standard")

Flavour constituent		China seed jat		Clone T - 78	
		Infested	Uninfested	Infested	Uninfested
1. Trans-2-hexanal,	R1*	0.030	0.067	0.072	0.176
	R2	0.040	0.084	0.106	0.093
	R3	0.022	0.056	0.038	0.117
	R4	0.100	0.132	0.058	0.148
	Mean	0.048	0.085	0.069	0.134
2. Nonylaldehyde,	R1	0.142	0.052	0.043	0.024
	R2	0.084	0.042	0.016	0.022
	R3	0.060	0.070	0.081	0.068
	R4	0.160	0.042	0.025	0.018
	Mean	0.112	0.052	0.041	0.033
3. Linalool oxide I	R1	0.892	0.182	0.522	0.436
	R2	1.180	0.240	0.762	0.523
	R3	0.875	0.126	0.450	0.221
	R4	1.280	0.407	0.867	0.562
	Mean	1.057	0.239	0.650	0.436
4. Linalool oxide II	R1	2.698	0.436	2.142	1.842
	R2	1.862	0.254	1.654	0.846
	R3	1.984	0.287	2.163	1.936
	R4	2.563	0.512	1.482	1.126
	Mean	2.277	0.372	1.860	1.438
5. Benzaldehyde	R1	0.092	0.011	0.086	0.068
	R2	0.122	0.015	0.078	ND
	R3	0.184	0.022	0.112	0.084
	R4	0.214	0.041	0.098	0.056
	Mean	0.153	0.022	0.094	0.069
6. Linalool	R1	1.420	0.342	0.289	0.167
	R2	0.846	0.215	0.346	0.112
	R3	0.926	0.224	0.432	0.268
	R4	1.562	0.468	0.254	0.356
	Mean	1.189	0.312	0.330	0.226
7. Phenylacetaldehyde,	R1	0.781	0.344	0.422	0.302
	R2	0.511	0.188	0.382	ND
	R3	1.021	0.523	0.396	0.245
	R4	0.548	0.268	0.514	0.312
	Mean	0.715	0.331	0.429	0.286
8.Terpineol,	R1	0.187	0.013	1.062	0.824
	R2	0.212	0.128	0.746	0.645
	R3	0.122	0.078	0.621	0.534
	R4	0.144	0.024	0.852	0.634
	Mean	0.166	0.061	0.820	0.659
9. Methylsalicylate,	R1	0.065	0.037	0.045	0.032
	R2	0.089	0.056	0.056	0.011
	R3	0.032	0.008	0.068	0.062
	R4	0.106	0.076	ND	ND
	Mean	0.073	0.044	0.056	0.035

*R=Replication

APPENDIX XII

Flavour constituents of orthodox tea made from **Greenfly** infested and uninfested shoots (Amounts in ratio of the peak area with "Internal standard")

Flavour constituent		China seed jat		Clone T - 78	
		Infested	Uninfested	Infested	Uninfested
10. Geraniol,	R1*	3.120	1.280	0.873	0.412
	R2	2.740	0.821	0.429	0.254
	R3	2.470	0.624	0.586	0.293
	R4	3.580	1.734	0.746	0.321
	Mean	2.978	1.115	0.659	0.320
11. Benzylalcohol,	R1	0.492	0.118	0.082	0.021
	R2	0.372	0.062	0.162	0.065
	R3	0.396	0.071	0.110	0.045
	R4	0.294	ND	0.127	0.034
	Mean	0.389	0.084	0.120	0.041
12. Phenyl ethanol,	R1	1.260	0.318	0.055	0.023
	R2	0.719	0.168	ND	0.241
	R3	0.824	0.142	0.018	0.013
	R4	1.010	0.194	0.187	0.143
	Mean	0.953	0.206	0.087	0.105
13. β-Ionone,	R1	0.168	0.073	0.071	0.046
	R2	0.095	0.026	0.023	0.018
	R3	0.148	0.058	0.094	0.058
	R4	0.086	0.032	0.041	0.025
	Mean	0.124	0.047	0.057	0.146
14. Caprylic Acid,	R1	0.172	0.183	0.327	0.102
	R2	0.082	0.123	0.267	0.072
	R3	0.061	0.097	0.214	0.058
	R4	0.126	0.136	0.381	0.206
	Mean	0.110	0.135	0.297	0.110
15. Octaldehyde,	R1	0.064	0.016	0.924	2.180
	R2	0.103	0.057	1.330	2.390
	R3	0.043	0.012	0.658	1.825
	R4	0.087	0.036	0.514	0.502
	Mean	0.074	0.030	0.857	1.724
16. Nonanoic Acid,	R1	0.083	0.018	0.278	0.104
	R2	0.054	0.008	0.189	0.137
	R3	0.102	0.057	0.208	0.092
	R4	0.042	0.022	0.302	0.181
	Mean	0.070	0.026	0.244	0.129
17. Jasmonic acid,	R1	0.403	0.221	0.144	0.078
	R2	0.357	0.106	0.167	0.092
	R3	0.308	0.124	0.187	0.112
	R4	0.482	0.252	0.096	0.037
	Mean	0.388	0.176	0.149	0.080
18. Geranic acid,	R1	0.412	0.184	0.132	0.194
	R2	0.311	0.125	ND	0.064
	R3	0.281	0.092	0.119	0.217
	R4	0.378	0.152	0.148	0.278
	Mean	0.346	0.138	0.133	0.188

*R=Replication

APPENDIX XIII

Population of natural enemies collected by vacuum suction machine

Estate	Bio Organic garden		Conventional garden	
	Mid elevation	High elevation	Mid elevation	High elevation
A. Spider population				
Replication 1	14.33 *	7.33	13.67	11.33
Replication 2	16	12.67	17.33	8.67
Replication 3	6.67	4.33	13.67	5.33
Replication 4	17.67	11.67	7.67	4.67
Replication 5	24.33	14.67	11.33	12.33
Mean	**16.1675**	**10.134**	**12.734**	**8.466**
B. Preying mantids				
Replication 1	2.33	1.67	1.67	1.33
Replication 2	4.67	3.33	3.33	2.33
Replication 3	5	4.33	2.33	2
Replication 4	1.67	2.33	1.67	0.67
Replication 5	2.33	1.67	2	1.33
Mean	**3.2**	**2.666**	**2.2**	**1.532**
C. Lady bird beetle				
Replication 1	4.67	3.67	2.67	2.33
Replication 2	3.33	2.67	2	1.67
Replication 3	2.67	3	2.33	2
Replication 4	2.33	1.67	1.33	2
Replication 5	3.67	3.33	2.67	2.33
Mean	**3.334**	**2.868**	**2.2**	**2.066**
D. Green lacewing				
Replication 1	1.33	0.33	0.67	0.33
Replication 2	0.33	0.33	0.33	0
Replication 3	0.67	0.67	0.33	0
Replication 4	1.67	0.33	1.33	0.67
Replication 5	2	1.33	0.67	0.33
Mean	**1.2**	**0.598**	**0.666**	**0.266**
E. Brown lacewing				
Replication 1	2.33	2	1.67	2.33
Replication 2	1.67	2.33	1.33	1.67
Replication 3	2	3	1	2
Replication 4	1.33	2.67	2	2.33
Replication 5	2.67	3.67	2.67	2.67
Mean	**2**	**2.734**	**1.734**	**2.2**
F. Hymenopterous parasites				
Replication 1	1	0.67	0.67	0.33
Replication 2	0.33	0	1	0.67
Replication 3	1.67	1.33	1.33	0.67
Replication 4	1.33	0.67	0.33	0.67
Replication 5	2	1.67	0.67	0.33
Mean	**1.266**	**0.868**	**0.8**	**0.534**

* Average of three catches