INSECT PESTS OF TEA *Camellia sinensis* (L.) O. Kuntze AND THEIR INDIGENEOUS MANAGEMENT IN ILAM TEA ESTATE, ILAM, NEPAL

Sujata Pathak
T.U. Registration No: 5-2-37-554-2009
T.U. Examination Roll No: 54/070
BATCH: 2070/71

A thesis submitted
In partial fulfilment of the requirements for the award of the degree of Master of Science in Zoology with special paper Entomology

Submitted to
Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu
Nepal

April, 2019

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the authors.

Date: 18th Feb., 2019

Sujata Pathak

TRIBHUVAN UNIVERSITY
01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

Central Department of Zoology T.U., Kirtipur

RECOMMENDATION

This is to recommend that the thesis entitled **"INSECT PESTS OF TEA *Camellia sinensis* (L.) O. Kuntze AND THEIR INDIGENEOUS MANAGEMENT IN ILAM TEA ESTATE, ILAM, NEPAL"** has been carried out by Mrs. Sujata Pathak for partial fulfillment of Master's Degree of science in Zoology with special paper Entomology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this work has not been submitted for any other degree in any institutions.

21, Feb. 2019
Date

Supervisor
Indra Prasad Subedi
Lecturer
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

TRIBHUVAN UNIVERSITY
01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

Central Department of Zoology T.U., Kirtipur

LETTER OF APPROVAL

On the recommendation of supervisor Mr. Indra Prasad Subedi; Lecturer, Central Department of Zoology, Tribhuvan University, the thesis entitled **"INSECT PESTS OF TEA *Camellia sinensis* (L.) O. Kuntze AND THEIR INDIGENEOUS MANAGEMENT IN ILAM TEA ESTATE, ILAM, NEPAL"** is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirement for the Master's Degree of Science in Zoology with special paper Entomology.

Date: 21. Feb. 2019

.....

Prof. Dr. Tej Bahadur Thapa
Head of Department
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

TRIBHUVAN UNIVERSITY
01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

Central Department of Zoology T.U., Kirtipur

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Mrs. Sujata Pathak entitled **"INSECT PESTS OF TEA *Camellia sinensis* (L.) O. Kuntze AND THEIR INDIGENEOUS MANAGEMENT IN ILAM TEA ESTATE, ILAM, NEPAL"** has been accepted as a partial fulfillment for the requirement of Master's Degree of Science in Zoology with special paper Entomology.

EVALUATION COMMITTEE

.....

(Supervisor)
Indra Prasad Subedi
Lecturer
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

.....

(Head of Department)
Prof. Dr. Tej Bahadur Thapa
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

.....

External Examiner

.....

Internal Examiner

Date of Examination : ...9th April 2019.....

ACKOWLEDGEMENTS

First of all I would like to express my deep gratitude to my respected supervisor Mr. Indra Prasad Subedi, Central Department of Zoology, Tribhuvan University for his valuable suggestions, incisive guidance and co-operation.

I am also thankful to Prof. Dr. Tej Bahadur Thapa, Head, Central Department of Zoology. Tribhuvan University, for providing me essential facilities. I would also like to thank both the teaching and administrative staffs of Central Department of Zoology, Tribhuvan University for all their help during my study in all the semesters. I highly acknowledge the help provided by Urmila Dyola for her valuable advice, suggestions and guidance during my lab work.

I would like to express my heartiest thanks to Mrs. Indira Gurung, Office Incharge of ITE, Ilam for permitting me to perform the research work. I am also thankful to field staffs of ITE, Mr. Furwa Tamang, Mr. Meghnath Adhikari and Mr. Thakur Katwal for providing me all the necessary information and for their guidance during the work.

My sincere thanks go to my uncle Mr. Arjun Pathak, my aunt Mrs. Saru Pathak and my sister Mrs. Sabita Pathak Sangroula, for their enthusiastic support and diligence to my work.

I would also like to express my gratitude from the core of my heart to my parents, brother and sister for all their blessings, love and support and for being my strength and inspiration. I also express my sincere appreciation and thanks to my dear husband Mr. Puskal Khanal for all his support and co-operation during my research work.

My special thanks go to my friends Ms. Binita Pandey and Mr. Pradip Subedi and all my friends of Entomology group for their valuable help and suggestions.

Finally, I would like to thank all my friends, relatives and other people who are directly or indirectly related to my dissertation work.

- Sujata Pathak

TABLE OF CONTENTS

Page no.

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

LIST OF ABBREVIATIONS

Abbreviated Form	Detail of Abbreviations
AEC	Agro Enterprise Centre
CBS	Central Bureau of Statistics
DHM	Department of Hydrology and Metrology
FAO	Food and Agriculture Organization
FNCCI	Federation of Nepal Chamber of Commerce and Industry
GPS	Global Positioning System
HMG	His Majesty's Government
IPM	Integrated Pest Management
ITE	Ilam Tea Estate
M.P.	Megapixel
MRMC	Mahendra Ratna Multiple Campus
NKAE	Neem Kernal Aqueous Extract
NPK	Nitrogen, Phosphorus and Potassium
NTCDB	Nepal Tea and Coffee Development Board
NTDC	Nepal Tea Development Corporation
NTDCLTD	Nepal Tea Development Corporation Limited
ODA	Overseas Development Administration
RSM	Red Spider Mite

LIST OF APPENDICES

ABSTRACT

Tea is an ancient cultivated plant and it is one of the most important and widely consumed beverages in the world. Commercial tea production is being done mainly in five districts of Nepal viz. Jhapa, Ilam, Panchthar, Dhankuta and Terathum. The study was done in Ilam Tea Estate from December to June 2016/17 with an objective of finding major insect pests and their management practices. Field visits were done in winter and spring seasons. Eight plots each of area 10 m × 10 m were selected in such a way that it included two plots each from the areas of nearby road, under the shade, settlement area and untouched area. Insects were collected from the sampling area by using hand picking and shaking method. Twenty one pest species and six predator species were recorded altogether. During winter visit eight species were recorded while 16 species were recorded during spring visit. Species diversity was found to be higher in spring (H=2.335863089) than winter (H=1.334880066). Aphids were found to be the most abundant pest of ITE, which were observed in both seasons. Number of species was highest in the order Hemiptera with eight different species belonging to eight different families. Order Hemiptera included *Toxoptera aurantii*, *Lygus* sp., *Coridius* sp., *Poecilocoris* sp., Nymph of Green Leaf-hopper and Milk-weed Bug. Green Fly was the only pest species found in the order Diptera and *Forcipula* sp. was also the single pest species found in the order Dermaptera. Microsoft Excel 2010 was used for the representation and analysis of data. For the control of insect pests traditional methods and organic pesticides were found to be used in ITE. Cattle's urine, Neem, Bojho and Titepati were commonly used for killing and repelling insect pests. Beyond these, Econeem, Achook, Neemajal, Sputnik, Metarhizium, Versa, Micomite and Alcap are other branded commercial organic pesticides used there.

1. INTRODUCTION

1.1 Background

Tea*, Camellia sinensis* (L.) O. Kuntze is an ancient cultivated plant and it is one of the most important and widely consumed beverages in the world. It is generally believed that the Chinese people were the first to recognize tea as a beverage (Macfarlane and Macfarlane, 2004).

According to the history of tea, tea drinking likely began in Yunnan province during the Shang Dynasty (1500 BC–1046 BC), as a medicinal drink (Heiss and Heiss, 2011). The plant was introduced to more than 52 countries from this centre of origin (Heiss and Heiss, 2007). In India, British introduced tea production and consumption in order to compete with the Chinese monopoly on tea (Sen, 2004).

Most of the tea world production is produced in Asia (81.4%), second is in Africa (15.5%), which is being followed by Latin America (2.0%) (FAO, 1999). Tea now grows at latitude from 27 degree south to 43 degree north and from sea level up to an altitude of 2500 m (Banerjee, 1996). Growing of the tea is best with deep and well drained acidic soil (pH 4.5-5.0), well distributed rainfall of 1150-1400 mm per year, mild average temperature of 18°-20°C and sufficient sunshine (Carr, 1972). The optimum sunlight intensity for tea is 50% to 80% from full radiation (Purseglove, 1968; Eden, 1976). Tea plantation roughly resemble a "single species forest" and insect and mite species are thought to coexist by way of intra tree distribution (Hazarika *et al*., 2009).

Research indicates that tea growing regions could decline in some parts of the world by upto 40 to 55% in the coming decades (Kahn, 2015). The productivity is declining due to unusual weather and large number of insect pests and diseases and about 5-10% crop loss has been estimated due to pest incidence, while crop loss has been increasing at present, which is as high as 15-25% (Sinha, 2010).

1.2 History of tea in Nepal

In Nepal, tea cultivation started in the year 1863 AD. Bada hakim Mr. Gajaraj Singh Thapa introduced tea plantation in Ilam tea state in the eastern Nepal. He used tea seedlings that were sent as gift from China (NTCDB, 2002). However, tea industry did not grow continuously and remained stagnant for more than a century. It started growing only after the establishment of Nepal Tea Development Corporation (NTDC) in 1966, NTDC with the co-operation of Overseas Development Administration (ODA) started the out growers (small farmers) tea plantation scheme employing a large number of small farmers in 1978.

Private sectors started tea cultivation in early sixties. The pioneer was the Budhkaran Tea Estate in Jhapa (1960). Tea plantation by private sector in the hills was started in the mid-eighties only. In 1985, His Majesty's the Government of Nepal (HMG/N) declared five districts viz. Jhapa, Ilam, Panchthar, Dhankuta and Terathum as tea zone. Further, in 1997, HMG/N decided to privatize the public sector, NTDC and its tea plantations and factories (NTCDB, 2005).

Kansakar (1985) concluded that Nepal's tea plantation is characterized by very slow progress owing to the emergence of tea estates under private sector during late 1950's and early 1960's. Tea plantation in Nepal has been going on without studying the soil type, topography, environmental parameters and cultivation methods. These are the major reasons behind low yield of tea and the very slow development and expansion of tea plantation in Nepal.

1.2.1 Tea production in Nepal

At present, tea cultivation has been extended to Jhapa, Panchthar, Dhankuta, Terathum districts of Nepal. Nepal produces two types of tea, CTC (Cut, Tear and Curl) and Orthodox tea. Orthodox tea is grown in high altitudes, whereas the CTC tea is grown in low altitudes or plain areas (NTDCLTD, 2011).Orthodox tea is produced by a special process in which only the top two leaves and bud from each branch ('duee paat ek sueero') are picked at the precise moment when they are budding (Rana, 2007).

According to NTCDB (2005), there were 13 orthodox and 23 CTC tea processing factories producing more than 11.6 million kg of tea. After two years, AEC/FNCCI (2007) recorded that, the area under tea cultivation in Nepal has more than 16,420 hectares of land consisting of more than 85 tea estates and 38 tea processing factories with little more than 15.1 million kg black and orthodox tea production. Land area used for tea cultivation is increasing by approximately 11% per year and at present, 7000 small farmers supporting their 35,000 family members for their livelihoods produce 85% of tea (NTCDB, 2014).

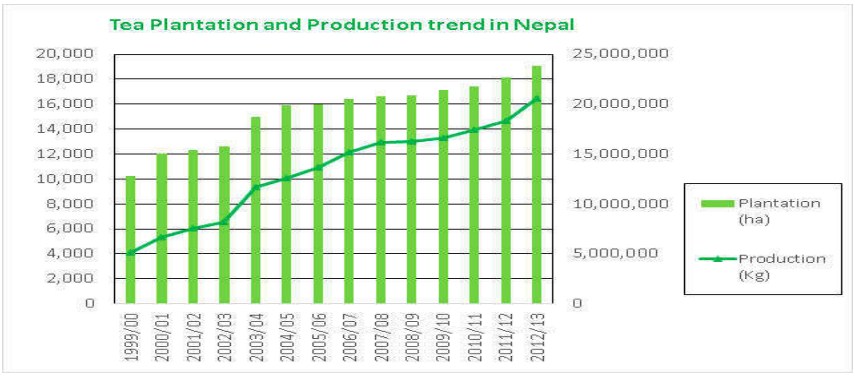

Figure 1. Tea plantation and production trend in Nepal (Source: NTCDB, 2014)

Figure 2. Tea export and import trend in Nepal (Source: NTCDB, 2014)

Table 1. District-wise plantation and production of tea.

SN	Districts	Garden		Small Farmers			Total	
		Plantation Area- ha	Production Kg	No. of small Farmers	Plantation Area- ha	Production kg	Plantation Area- ha	Production kg
1	Jhapa	7725	11784907	2962	3718	6762525	11443	18547432
2	Ilam	2845	2169797	6995	5120	2715037	7965	4884834
3	Panchathar	619	285570	1140	720	217463	1339	503033
4	Dhankuta	478	83436	491	474	99456	952	182892
5	Terathum	95	21341	665	360	67144	455	88485
6	Others	3523	114450	2850	2564	88200	6087	202650
	Total	15285	14459501	15103	12956	9949825	28241	24409326

(Source: NTCDB, 2017)

1.3 Major tea pests and nature of damages

According to Barthakur (2011) tea pests can be broadly classified into the following categories:

- **Mite pests:**

(i) Red Spider Mite *Oligonychus coffeae*: Infestation starts along midrib and veins and further spreads to the entire upper surface of leaves. The Severe infestation leads to defoliation.

(ii) Scarlet Mite *Brevipalpus phoenicis*: Symptoms of attack first appear on either side of the midrib and gradually spread to the entire leaf; feeding leads to brown discolouration of leaves and severe infestation leads to defoliation.

(iii) Pink Mite *Acaphylla theae*: During early stages of attack leaves turn pale and curl upwards while severe infestation leads to brownish discolouration.

(iv) Purple Mite *Calacarus carinatus*: Damaged leaves are characterized by the coppery brown discoloration. Purple mites are prevalent on the under surface of mature leaves.

(v) Yellow Mite *Polyphagotarsonemus latus*: Observed on young leaves, especially on the top two to three leaves and the bud. Leaves become rough and brittle and corky lines or patches on the surface.

- **Sucking pests:**

(i) Tea Mosquito Bug *Helopeltis theivora*: Adults and nymphs puncture the plant tissues with needle like rostrum and suck the sap from buds, young leaves and tender stems. Punctures appear as reddish brown spots and due to intensive feeding, leaves curl up, badly deformed and remain small.

(ii) Tea Thrips *Scirtothrips dorsalis*: Prefers young leaves and buds; continuous feeding causes lacerations which appear as streaks; leaf surface becomes uneven and curled.

(iii) Tea Jassids *Empoasca flavescens*: Adults and nymphs suck the sap from tender leaves; leaves curl downwards, gradually turn brown and dry up.

(iv) Aphids *Toxoptera aurantii*: Adults and immature stages suck the sap from tender shoots. Due to feeding leaves curl up and stunted shoot growth is observed.

(v) Lygus Bug *Lygus* sp.: Adults and nymphs injure the tender plant parts. Mouth parts are piercing and sucking type. Feeding punctures appear as reddish brown necrotic spots.

- **Leaf eaters:**

(i) Looper Caterpillar *Buzura suppressaria*: Young caterpillars feed on young leaves and mature larvae prefer older leaves; they make series of small holes along and a little away from the margin.

(ii) Red Slug Caterpillar *Eterusia magnifica*: Prefers mature foliage; by severe attack, the bush frames become naked.

(iii) Bunch Caterpillar *Andraca bipunctata*: The caterpillars eat the foliage of the host plant. Initially, they feed upon the surface tissues only but later on the whole blade is consumed.

- **Soil borne pests:**

(i) Termites:

a) *Microcerotermes* sp.: Damages tea bushes

b) *Odontotermes* sp.: Considered only as secondary pests and these are scavengers of dead and moribund wood.

(ii) Root Knot Nematodes *Meloidogyne javanica*: Causes severe galling of roots of mature tea bushes; leaves become smaller in size, yellowish in appearance, growth is retarded.

(iii) Crickets *Brachytrupes portentosus*: Destructive pest in tea nurseries.

World-over more than 1000 arthropods have been recorded to feed on different parts of the tea plant (Chen and Chen, 1989), though in Asia only 230 species of insects and mites have been reported (Muraleedharan, 1992).

The common insect pests of tea are Tea Mosquito Bug (*Helopeltis theivora*), Red Spider Mite (*Oligonychus coffeae*), Termite (*Microcerotermes* sp.), Thrips (*Scirtothrips dorsalis*), Aphid (*Toxoptera aurantii*), Jassid (*Empoasca flavescens*), Flushworm (*Laspeyresia leucostoma*), Looper Caterpillar (*Biston suppressaria*) and Nematode (*Meloidogyne* sp.) (Mamun and Ahmed, 2011).

1.4 Objectives of the study

1.4.1 General objective:

To explore the insect pests of tea and their indigenous management practices in Ilam Tea Estate.

1.4.2 Specific Objectives:

1. To explore the species diversity of tea pests in Ilam Tea Estate.
2. To access the seasonal variation and nature of damages of tea pests in Ilam Tea Estate in winter and spring seasons.
3. To know the indigenous techniques used by local people for tea pest management.

1.5 Rationale of study

Few researches have been done in tea estates of Jhapa, Ilam and other tea growing districts of Nepal (Rai, 2004; Chhetri, 2011; Koirala, 2011). Although Ilam tea estate is the oldest tea estate of Nepal, intensive survey has not been done on tea pests and damages caused by them. Detailed research is required to identify the major pests and suitable methods must be applied for their management and better crop yield. The research will be helpful to recognize the major pests, their nature of damage and suitable methods for their management which may be beneficial for better tea production. Nowadays chemical fertilizers and pesticides are being used excessively in agriculture. But, ITE claims to be completely organic. Intensive research was required for exposing the real scenario of the ITE to find the production history and effectiveness of the organic fertilizers and pesticides being used currently.

1.6 Limitations

- Challenging taxonomic work due to insufficient works done in Nepal.
- Could not identify some of the collected specimens due to lack of standard identifying keys.

2. LITERATURE REVIEW

2.1 Tea pests and their nature of damages

Based on their feedings on different plant parts, the pests were categorized into three major groups, i.e. leaf, stem and root feeders (Shrestha and Thapa, 2015).

Kawai (1997) suggested that, besides some perennial pests, most of the tea pests are seasonal; some attack only during dry season while a few are abundant in wet weather. Weeds serve as alternative hosts for pests as well as a refuge for natural enemies and hence are a major component of the tea ecosystem.

Phytophagous mites are considered as one of the most limiting factors in tea production. The second most damaging pests are *Helopeltis* bugs, which are also of economic importance in Africa. The third most important group of pests is leaf feeding Caterpillars of the Lepidoptera (Lehmann, 1994).

Roy *et al.* (2014) discovered that species diversity of arthropods in the tea ecosystem of India comprised 721 species belonging to 13 Orders and 141 Families. Out of the 721 species, 380 were phytophagous (pests) while 341 species were natural enemies.

In Teesta valley tea garden, Darjeeling, India Chhetri (2007) reported that 13 pest species within 7 orders were responsible for significant crop loss in tea. Among them higher abundance was found from family Formicidae and Aphididae.

Mites are persistent and the most serious pests of tea in almost all tea producing countries (Cranham, 1996). Nymphs and adults of RSM lacerate cells produce minute characteristic reddish brown marks on the upper surface of mature leaves, which turn red in severe cases, resulting in crop losses from 17% to 46% (Das, 1959).

Red Spider Mite (*Oligonychus coffeae*), Leaf Roller (*Caloptilia theivora*), Thrips (*Mycterothrips setiventris*) and Aphid (*Toxoptera aurantii*) were categorized as major pests and the rest as minor pests based on the observations carried out for one pruning cycle during 2010 to 2013 (Devi *et al.,* 2016).

The Red Spider Mite (*Oligonychus coffeae)* causes serious damage in India, Sri Lanka, Bangladesh, Taiwan, Kenya, Malawi, Uganda and Zimbabwe (Gotoh and Nagata, 2001; Han, 2000).

According to Hamasaki *et al*. (2008) Red and Black Flat Mites feed on plant sap and cause bronzing and/or browning of the leaves. These mites favor the upper leaf surface of mature leaves, and the damage progresses from the lower leaves to the younger leaves.

One of the study in Bangladesh, revealed that incidences of Red Spider Mites (31.29%), *Helopeltis* (17.45%) and Termites (13.15%) were found to be predominant followed by Jassids, Flushworms and Aphids (Mamun and Ahmed, 2012). Eight arthropod pests, along with 2 mites, 2 fungal diseases were recorded in the research done in Jhapa and Ilam. *Toxoptera* and *Scirtothrips* were major pests in Ilam and *Empoasca flavescence* and *Gracilaria theivora* in Jhapa (Chettri, 2011).

The Tea Green Leafhopper (*Empoasca onukii*) (Hemiptera: Cicadellidae), is one of the main insect pests in tea plantations in Asia (Shi *et al.,* 2014). The study of Hazarika *et al*., (2009) also showed that *Empoasca vitis* is one of the most serious economic pests of tea in East Asia, and its management relies heavily on chemical pesticides.

The Tea Green Fly (*Empoasca flavescens*) is one of the major sap feeding pests of tea. Heavy infestation of these jassid lead leaf-margin turning brown; a condition called rim-blight (Andrew, 1923). His study also showed that pruned tea is prone to Jassid attack particularly during drought.

Banerjee (1982) studied the aggregating behavior of the caterpillars of the moth *Andraca bipunctata* (Bombycidae: Lepidoptera). These caterpillars are found in close physical aggregations at daytime, on leaf undersurfaces, but these aggregations breakup at night and they start feeding voraciously on the foliage.

Study from south Sikkim by Chhetri (2010) reveals that most of the species of tea pests belong to family Aphididae, Formicidae and Thripidae and few species belonged to families Scarabacidae and Chrysomelidae. According to this research, Thrips and Aphids are considered as major pests of the tea.

Major pests in Jhapa and Ilam were identified as Thrips, Looper, White grub, Tea mosquito bug, Flush Worm, Red Spider, Stem Borer, Cut Worm, Leaf Roller, Twig Caterpillar, Aphids and Red Ants (Koirala, 2011). It was found that pest prevalence was higher in June/July than any other months in year round.

A survey on Kanyam tea state revealed that 9 arthropod pests were dominant. Thrips (*Scirtothrips* sp.) was considered as a major pest followed by Tea Aphid (*Toxoptera aurantii*) (Rai, 2004). Traditional synthetic pesticides as well as some neem based botanicals were used for the control of those pests.

Some 41 species of mirids in the genus *Helopeltis* have so far been described in Asia, Australia, and Africa (Sundararaju and Sundarababu, 1999). Nymphs and adults suck cell sap from tender stems, young leaves, and buds, forming reddish brown circular feeding punctures 0.29 to 2.51 mm in size. In severe infestations, damaged leaves with 76 to 210 feeding punctures curl upward and desiccate (Rattan, 1992).

Among the leaf-feeders, 19 species of Tortricids mostly of the genera *Homona* and *Adoxophyes* are economically important pests of tea in Japan, China, India, Sri Lanka, Taiwan, Turkey, Republic of Georgia, Azerbaijan, and Bangladesh (Cranham, 1996; Muraleedharan, 1992; Nabeta *et al*., 2005).

Female *A. honmai* lays oval-shaped egg masses on the undersurface of young tea leaves from which 1.5-mm-long, pale-yellow-colored neonates emerge and disperse individually to construct leaf-webs for feeding on the growing leaves and shoots (Nabeta *et al*., 2005).

2.2 Management practices of tea pest

To combat pest problems different groups of pesticides like Organochlorine, Organophosphates, Pyrethroids, Carbamates and some unclassified group have been used in the tea fields since 1960 (Kamrin, 1997).

Chemical pesticides have been used for a long time, but have serious drawbacks (Sharaby, 1988), such as direct toxicity to beneficial insects, fishes and human (Goodland *et al*., 1985), pesticides induced resistance (Georghiou and Taylor, 1977), health hazard (Bhaduri *et al*., 1989) and increased environmental and social costs (Pimental *et al*., 1980).

According to Tvedten (2002) Tetradifon is the most effective pesticide to counter a potent pest Red Spider Mite while Dicofol and Ethion are being used for other mites. Endosulphan helps to tackle pest like Thrips, Aphids, Tea Mosquito Bug and other sap feeders. For pest control, hand picking method was used for few insect pests and pesticides like Endosulphan, Kelthane, Omite, Tatamida were sprayed to kill insects pests in Jhapa and Ilam of Nepal (Chettri, 2011).

All the farmers in Jhapa and Ilam were using pesticides and it was clearly indicated that there is huge user dependency on chemical pesticides (Koirala, 2011). Prohibitions on the use of highly toxic pesticides in tea are Quinalphos, Ethion, Monocrotophos and Phorate (Palikhe, 2005).

Common control measures against mites rely on insecticidal spraying resulting in several negative effects such as suppression of natural enemies, potential development of pesticide resistant populations, and increase in production costs (Elmoghazy *et al.,* 2011).

Balanced NPK application produces robust plants that can resist *Brevipalpus phenicis* (Sudoi, 1997; Sudoi *et al.,* 2001). Phosphorus is known to induce resistance in tea to *T. kanzawai* (Cranham, 1996). Application of potash enhanced nematode resistance in plants (Kamunya *et al., 2008)*. Proper water management through regulated irrigation and mulching has been recommended for soil conservation as well as control of *Empoasca* sp. (Zhang *et al.,* 1992*).*

Sucking tea pests are controlled in three different ways as chemical control, biological control and cultural control (Borthakur and Singh, 2002). Entomologists and ecologists have urged the adoption of IPM since the 1970s (Knipling, 1972). Several strategies of IPM have been put forth for sustainable production of tea from time to time (Gurusubramaian *et al.,* 2008; Muraleedharan, 2008).

Gliricidia sepium as a shade tree acts as a diversionary host for *G. dilatus.* A systematic search for alternate host plants which can be deployed for push-pull strategy (Cook *et al.,* 2007; Khan and Picket, 2004) or stimulo-deterrent diversion (Miller and Cowles, 1990) in the tea ecosystem should be made.

In China, interplanting tea with Cedar, Peach, Plum or Pear reduced the incidence of Yellow Mite *Polyphagotarsonemus latus* by altering the microclimate (Zao *et al.,* 2003). Yongmo *et al.* (2005) used 25 pheromone traps per ha to reduce the egg and larval population of *Euproctis pseudoconspersa* by about 50 per cent.

Plants species possess the characteristics required for an ideal botanical insecticide and are therefore more promising for use in organic pest control programmes (Radhakrishnan, 2005). Neem is a natural source of eco-friendly insecticides, pesticides and agrochemicals (Brahmachari, 2004).

One important benefit of using vermicompost is, it contains a significant amount of beneficial microbes that can promote plant growth, reduce plant stress and suppress various plant pathogens and arthropod pests (Arancon *et al*., 2008).

A formulation called Exodus containing extracts of a leguminous plant *Sophora flavescens* has been proved very effective against Red Spider Mites in tea (Muarleedharan, 2005). Mamun and Iyengar (2010) reported that application of neemcake at the rate of 2 kg per bush was found to be effective for the plants suffering from the attack of Root Knot Nematodes (*Meloidogyne brevicauda*).

Dolul and Debnath (2010) observed anti-feedant activity of methanolic extracts from the flowers of *Heliotropium indicum* against the Tea Mosquito Bug (*Helopeltis theivora)*.

Debnath (2013) studied the natural mortality of different stages of scale insects *Saisettia* sp. caused by *Aschersonia* sp. in a tea plantation of Assam and the factors contributing to the survival of *Aschersonia* in tea ecosystems.

Placing sticky traps baited with blend 2 or (*E*)□2□hexenal in the tea fields significantly reduce leafhopper populations which indicates that bud□green sticky traps baited with tea shoot volatiles can provide a new tool for monitoring and managing the tea leafhopper (Mu *et al*. 2012).

In tea gardens, more leafhoppers were captured using gold sticky traps (RGB: 226, 204, 4) than using commercially available yellow sticky traps (Bian *et al*., 2014). The most effective height of gold sticky traps for trapping leafhoppers was 40–60 cm above the tea canopy.

Ovicidal activities of petroleum ether and acetone fractions of *P. hydropiper* have been reported by Sarmah *et al*. (2006) against the bunch caterpillar, *A. bipunctata*. Being polyphagous, Red Spider Mite is recorded on at least 130 host plants (EPPO, 2014). It is considered a serious pest of many agricultural, horticultural and plantation crops besides tea, such as, jute, mango, grapes, avocado, guava, citrus, strawberry, mulberry, cashew nut, rubber, coffee, cotton etc (Jeppson *et al*., 1975; Meyer, 1987; Gotoh and Nagata, 2001; CABI and EPPO, 2013).

Different concentrations of aqueous extracts of Neem seed Kernels (NKAE) have been evaluated against Tea Mosquito Bug, *H. theivora* for anti-feedant activity (Roy *et al*. 2015). They cause a low hatching percentage and shorten oviposition and nymphal periods in *H. theivora* (Dutta *et al*. 2013). Besides Neem, a number of wild plants such as *Achyranthes aspera* L. (Amaranthaceae), *Acorus calamus* L. (Acoraceae), *Aegle marmelos* (L.) Correa (Rutaceae), *Bidens pilosa* L. (Asteraceae), *Camellia sinensis* (L.) Kuntze (Theaceae), *Carica papaya* L. (Caricaceae) and weeds available in and around tea gardens have been found to possess insecticidal properties against *H. theivora* (Roy *et al*. 2015).

3. MATERIALS AND METHODS

3.1 Study Area

Ilam Tea Estate of Ilam district was selected as the study area. Ilam district is located in Mechi zone of Eastern Development Region, Nepal. The Ilam Tea Estate is geographically situated at an altitude of 1350-1550 meters above sea level with 87º55'20"-87º56'14" East and 27º00'04"-27º00'43" North geographical coordinates.

Ilam is headquarter of Ilam District, as well as headquarter of Mechi zone. Geographically, it lies in the hilly region which is mostly known as Mahabharat range. It is one of the major districts in Nepal for tea production. It is famous for natural scenery and landscapes, tea production, and diverse agricultural economy. It is one of the major horticultural crop production districts of Nepal.

The total population of Ilam district is 163412 including 76515 male and 86897 female. Population density of Ilam district is 183 persons per sq. km. Literacy rate of Ilam is 74.4% (CBS, 2011).

Although tea is grown in various places in Ilam, ITE is the oldest and main site for the production of high amount of organic tea every year. It was established in 1920 B.S. It covers an area of 49.5 ha (0.495 km^2). ITE started organic cultivation from September 2015. It produces about 6-7 thousand kg green leaves per year (ITE office, 2017). Tea leaves are sent to Kolkata port (Bandargah) for organic quality test.

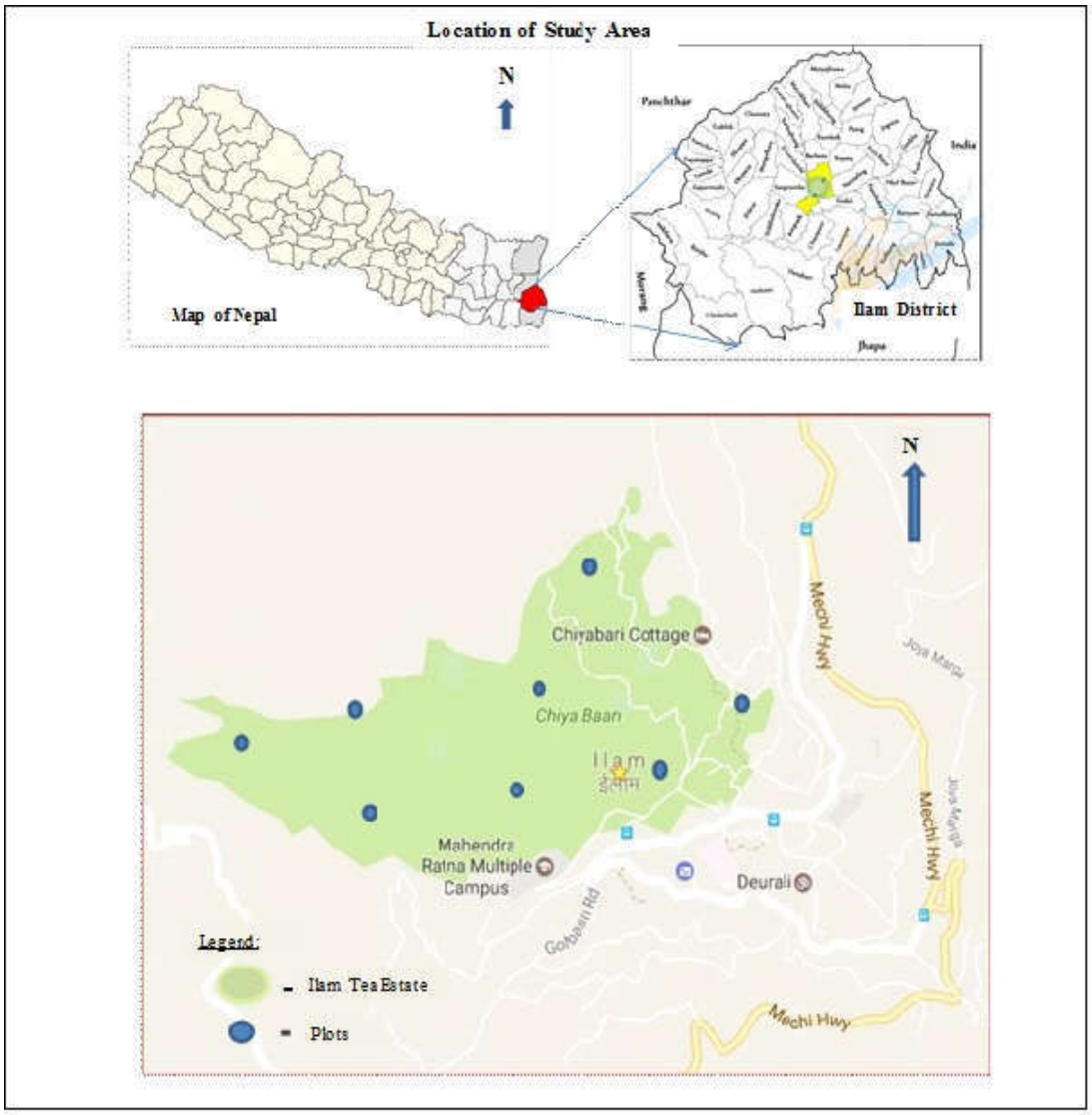

Figure 3. Location map of Study Area.

3.1.1 Climate

Ilam lies in the subtropical climatic zone of Nepal. Climate of Ilam is cold and freezing in the winter, mild warm in summer and foggy in the monsoon season. According to the data of weather station at Ilam Tea Estate, mean monthly minimum temperature ranges from 11.86°C in January to 25.43°C in July. Similarly, mean monthly maximum temperature ranges from 23.57°C in January to 35°C in April. (Figure 4).

The average annual rainfall ranges from 3.97 mm in January to 804.25 mm in July (Figure 5).

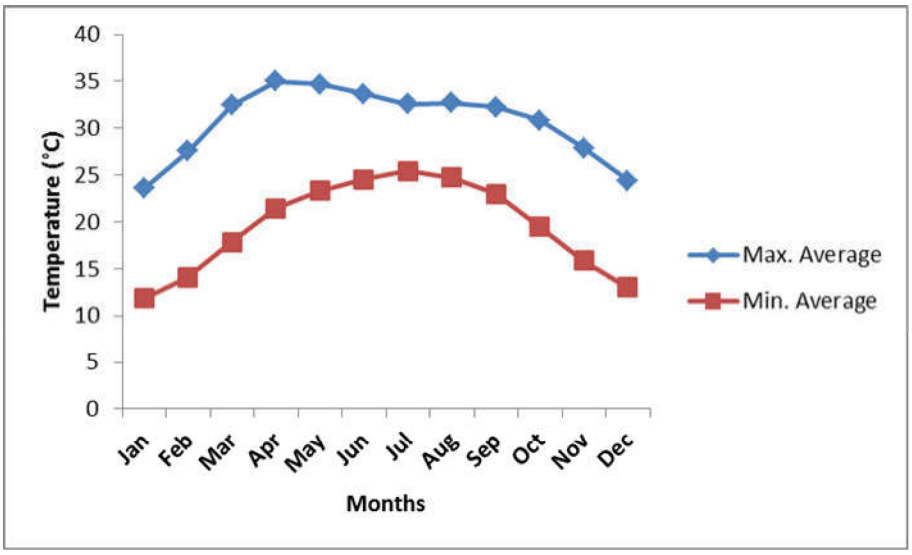

Figure 4. Mean monthly minimum and maximum average temperature of Ilam from 2009-2015 A.D. (Source: DHM, 2016)

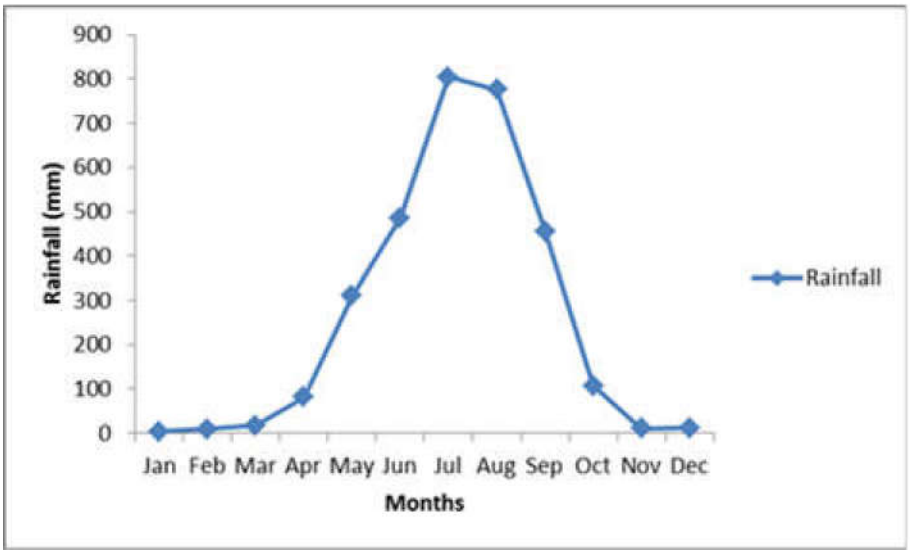

Figure 5. Mean monthly rainfall data of Ilam from 2009-2015 A.D. (Source: DHM, 2016)

3.2 Materials

(i) Measuring tape
(ii) Killing jars
(iii) Brushes
(iv) Alcohol (70%)
(v) Vials
(vi) Bottles
(vii) GPS device

3.3 Methods

3.3.1 Primary data collection

3.3.1.1 Sample collection

Field visit was done from December 2016 to June 2017. Field visit was performed twice and seasonal data were collected during consecutive seasons, winter and spring. Eight plots each of area 10 m X 10 m were selected in such a way that it included two plots each from the areas nearby road, under the shade, settlement area and untouched area. Untouched area implies the area which lies away from human interference. Geographical co-ordinates and altitudes of each plot were recorded with the help of GPS device. Within each plot, hand picking method was applied for the pests large enough to be seen readily with naked eyes. Tea bushes were shaken and umbrella was inverted just below it to collect the pest falling from the leaves and branches. The insects were collected with the help of forceps and were stored in bottles containing 70% alcohol. Soft specimens which occurred in cluster were collected by using soft brush and were put in the vials containing 70% alcohol. Sample collection was done between 10 a.m. to 5 p.m.

3.3.1.2 Interview and group discussion

Fifteen field workers with at least 3 years of work experience were selected for the interview. Interview schedules were filled according to the response given by those respondents during personal interview. Focus group discussion was performed which included six field workers, two factory workers, one supervisor and two office staff.

3.3.2 Secondary data collection

Secondary data were obtained from the publications of NTDC and NTCDB, municipal records, journals, biological abstracts, websites, theses, Govt. and non-Govt. reports found on the related topic.

3.3.3 Insect Identification

The collected specimens were identified at laboratory of Central Department of Zoology, Tribhuvan University. The identification was done by consulting insect taxonomic keys (Borror *et al*., 1981; Hill, 1993). Some species were identified with the reference of www.bugguide.net and www.insectidentification.org. Photographs were taken in the filed using camera Samsung (Model ST77, 16.11 M.P.). Photographs of preserved specimens were taken by Lenovo (Model A6020a40, 13 M.P.).

3.3.3.1 Insect identification keys (Borror *et al.*, 1981; Hill, 1993)

- **Keys to the families of order Coleoptera**

1 Form beetle like, the elytra present ……2

2 First visible abdominal sternum divided by the hind coxae. The posterior margin of the sternum not extending completely across abdomen (suborder Polyphaga) …….....3

3 Body shape various, rarely elongate; antennae moderate, not longer than body; not inserted on frontal prominence; tibial spurs well developed ……..……..…**Chrysomelidae**

4 Slender tarsi with simple tarsal claws; first ventral segment without coxal lines ……..…….……...**Endomychidae**

5 Hind coxae not prominent ……6

5' Hind coxae large, prominent; tarsal claws cleft or toothed .....**Meloidae**

6 Anterior coxae conical, prominent ……..……..7

7 Abdomen with 5 free segments, eyes small, coarsely faceted ……..**Anthicidae**

8 Prothorax firmly joined to mesothorax; antennae inserted under margin of front ……..**Elateridae**

- **Keys to the species of family Endomychidae**

1 Tarsi actually 4-segmented; anterior margin of pronotum produced forward at sides……..…….*Eumorphus*

- **Keys to species of family Anthicidae**

1 Pronotum without elongated process on anterior margin ……..…2

2 Anterior tibiae without apical tooth; tibial spurs reduced, body more slender…….……3

3 Head and thorax dark; elytra brown to dark brown with reddish basal area; size 2.75 mm ……..*Omonadus formicarius*

- **Key to the families of order Dermaptera**

1 Second tarsal segment extending distally beneath base of third; antennae with 14 segments; colour brownish ..……...……..**Forficulidae**

- **Keys to the genera of family Forficulidae**

1 General color dark blackish brown excepting elytra yellowish.forceps are provided with small tooth internally ……..……*Forcipula*

- **Keys to the families of order Homoptera**

1 Tarsi 3- segmented; antennae very short and bristle like; beak arising from back of head……..2

1' Tarsi 2-segmented; antennae long and filiform; beak arising between front coxae……..……3

2(1) Antennae arising on front of head between eyes; pronotum not extending back over abdomen; hind tibiae with 2 rows of small spines ……..……..…**Cicadellidae**

3(1') Cornicles present; M in front wing branched ……..……**Aphididae**

- **Keys to the species of family Aphididae**

1 Adults are shiny black in colour, winged and apterous; the first and second antennal segments are black, while third, fourth and fifth segments are light colored… ……*Toxoptera aurantii*

- **Keys to the families of order Hemiptera**

1 Compound eyes present ……..……2

2 Antennae as long as head, free and visible from above; head is shorter than thorax……3
3 Tarsal claws apical; tip of last tarsal segment entire …..……4
4 Antennae 4- segmented ……..……..……..5
4' Antennae 5- segmented ……..…...……...…. 7
5 Ocelli absent……..……..….6
6 Beak longer, 4- segmented and not fitting into groove in prosternum; hemielytra with a cuneus, meso- and metasternum formed of three sclerite ……,,,,,,……**Miridae**
6' Hemielytra without a cuneus, meso- and metasternum formed of a single sclerite; elongate , shining black bugs; front femora moderately swollen ……..……..……..**Lygaeidae**
7(4') Tibiae not armed with strong spines, 8.2 mm in length…….……8
8 Scutellum very large, broadly rounded posteriorly and covering most of abdomen; corium of hemielytra narrow, not extending to anal margin of wing……..……9
8' Scutellum shorter, narrowed posteriorly and triangular, corium of hemielytra broad, extending to anal margin of wing …….....**Pentatomidae**

9 Sides of pronotum without promiment lobe……..…. **Scutelleridae**

- **Key to the Genera of family Miridae**

1 Adults brown in color with a Y- shaped mark on scutellum……..……..*Lygus*

- **Key to the Genera of family Pentatomidae**

1 Shield like body shape and 5- segmented antennae……..……..…. *Coridius*

- **Key to the Genera of family Scutelleridae**

1 Adult bug is ovate, about 22mm long; scutellum very large, extending to the posterior end of abdomen; presence of spot on each anterior angle of pronotum; antennae and head violaceous black and short ……..*Poecilocoris*

- **Keys to the families of order Hymenoptera**

1 Base abdomen constricted, trochanters 2-segmented ……..…….……2
2 First abdominal segment bearing a hump and strongly differentiated from rest of abdomen……...……..**Formicidae**

- **Keys to the families of order Orthoptera**

1 Hind tarsi 3- segmented, front and middle tarsi 2- segmented; ovipositor short; antennae longer than front femora; wings present……..……..….**Acrididae**
1' Hind tarsi 4- segmented; ovipositor elongate; antennae long; femora extending beyond tip of abdomen ……....**Tettigonidae**

- **Keys to the species of family Acrididae**

1 The antenna are much shorter than the body; the auditory organs (tympana) are located on the sides of the first abdominal segment; tarsi 3- segmented and the ovipositor is short…….……....*Gastrimargus africanus*

- **Keys to the families of order Lepidoptera (caterpillars)**

1 Body with numerous short secondary setae; primary setae hiding…….……..…2

1’ Body without any short secondary setae; primary setae evident…….2
2 Secondary setae arranged in tufts ……..……..**Lymantridae**
3(1) Head equal to the diameter of prothorax; body slug like and lacks annulets ……**Limacodidae**
4(1’) Abdominal prolegs present on sixth segment ……**Geometridae**

➢ **Keys to the species of family Geometridae**
1 Larvae are dark green to black in color; measuring about 2cm in length; legs purple in color……..……..*Biston Suppressaria*

• **Keys to the families of order Lepidoptera**
1 Wings present and well developed…….……2
2 Front wing and hind wings dissimilar in venation and also in shape; hind wing with 2 anal vein ……..……...…….....3
3 Sc in wing apparently absent; dayflying moth……..**Arctidae**

➢ **Keys to the species of family Arctidae**
1 Presence of black wings with large orange yellow spots on it; forewings have five large elongated oval yellow spots with the spots nearest the wing tips crossed by a narrow black line; head black, thorax also mainly black with a yellow band at front; and the abdomen is banded black and yellow …….. *Amata sperbius*

3.3.4 Data analysis:

(i) Species Diversity

To determine the diversity of species in two different seasons, spring and winter seasons, Shannon’s Diversity Index was applied. It was based upon the relationship between total number of species and individual species.

Shannon’s Diversity Index ($\overline{H}$) is given by,

$$\overline{H} = - \Sigma \, ln\text{pi}ln$$

Where,

$\overline{H}$ =Shannon’s Diversity Index.
pi= ni/N
ni= Importance value for each species
N= Total no. of Importance Value.
[∴ Importance Value = Number of Individual]

(ii) Evenness (e) = $\overline{H}$ /*ln* (s)
Where, s = Total no. of species
$\overline{H}$ = Shannon index of diversity

Bar graphs and pie-chart were constructed to show the distribution of insect pests in different locations and Microsoft Excel 2010 was used for the calculation and analysis of data.

4. RESULTS

4.1 Insect pests of ITE

Altogether 27 Insect species were collected from the research site. Among them, 21 species of insects were identified as pests and six species were identified as predators in accordance to Borror *et al*. (1981) and Hill (1993). Among 21 pest species, eight species were recorded during winter season and 16 species were recorded during spring season. Total insect pests collected from ITE are listed in table 2 and predators are listed in table3.

Table 2. Insect pests of ITE with their nature of damage

S.N.	Name of pests	Family	Nature of Damage (Nadda *et al*., 2013)
1.	*Omonadus formicarius* (Goeze, 1777)	Anthicidae	Sap sucker
2.	Blister Beetle	Meloidae	Defoliators found on young and mature leaves
3.	Unidentified 1	Chrysomelidae	Defoliators
4.	Unidentified 2	Elateridae	Phytophagous
5.	Unidentified 3	Endomychidae	Facultatively phytophagous
6.	*Forcipula* sp. (Bolivar, 1897)	Forcipulidae	Destructor of tender foliages
7.	Green Fly		Sap sucker
8.	*Toxoptera aurantii* (Boyer de Franscolombe, 1841)	Aphididae	Sap sucker found on young leaves, buds, tenders and stems
9.	Nymph of Green Leafhopper	Cicadellidae	Sap feeder found on young leaves
10.	Milkweed Bug	Lygaeidae	Sap suckers found on seed pod
11.	*Lygus* sp. (Hahn, 1833)	Miridae	Sap suckers found on leaves
12.	*Coridius* sp. (Fabricius, 1775)	Pentatomidae	Sap sucker found on young leaves
13.	*Poecilocoris* sp. (Dallas, 1848)	Scutelleridae	Sap sucker found on seed cotyledons
14.	Bug Morphospecies 1	Pentatomidae	Sap sucker
15.	Bug Morphospecies 2	Pentatomidae	Sap sucker
16.	*Biston suppressaria* (Guenee, 1858)	Geometridae	Defoliators found on young and mature leaves
17.	Neetle Caterpillar	Limacodidae	Defoliators found on older leaves.
18.	Tussock Moth Caterpillar	Lymantridae	Defoliators.
19.	*Amata sperbius* (Fabricius, 1787)	Erebidae	Sap sucker
20.	*Gastrimargus africannus* (Saussure, 1888)	Acrididae	Chewing mature leaves.
21.	Long-horned Grasshopper	Tettigonidae	Defoliators found on leaves.

Table 3. List of predators found in the site

S.N.	Name of predators	Order	Family
1.	*Coccinella septempunctata* (Linnaeus, 1758)	Coleoptera	Coccinellidae
2.	*Harmonia* spp. (Mulsant, 1846)	Coleoptera	Coccinellidae
3.	*Oenopia sexareata* (Mulsant,1853)	Coleoptera	Coccinellidae
4.	*Crematogaster* sp. (Lund, 1831)	Hymenoptera	Formicidae
5.	*Camponotus* sp. (Mayr, 1861)	Hymenoptera	Formicidae
6.	Spiders		

4.2 Seasonal variation of pests

Insect pests recorded in each plots during winter and spring seasons are shown in table 4 and table 5 respectively. During winter season, Tea Aphids (*Toxoptera aurantii*) were found in highest number (149). Green Flies were in least number (5).

Similarly, during spring season, Tea Aphids were found in highest number (204) followed by *Omonadus formicarius* (61 in number). The number of Blister Beetle was the least (7) in this season. Some pests like *Toxoptera aurantii, Poecilocoris* sp. and Blister Beetle were recorded during both seasons. Among these, the number of *Toxoptera aurantii* was highest during both seasons.

Table 4. Insect pests recorded in different plots in winter visit.

S.N.	Name of Pest	Nearby road		Under the shade		Untouched area		Settlement area	
		Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
1.	*Amata sperbius*	-	4	7	2	-	6	8	9
2.	Blister Beetle	-	-	1	-	2	1	-	-
3.	*Gastrimargus africanus orientalis*	3	2	-	-	5	-	-	-
4.	Green Fly	-	-	-	2	3	-	-	-
5.	Long-horned Grasshopper	3	-	-	4	-	-	-	-
6.	*Poecilocoris* sp. *(*nymph)	10	8	-	-	-	-	12	-
7.	*Toxoptera aurantii*	14	20	16	18	14	20	22	25
8.	Tussock Moth Caterpillar	3	2	-	4	-	-	-	-

Table 5. Insect pests recorded in different plots in spring visit

S.N.	Name/Family of pest	Nearby road		Under the shade		Untouched area		Settlement area	
		Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
1.	*Lygus* sp.	-	14	-	-	20	-	-	-
2.	*Biston suppressaria*	2	4	-	-	-	1	-	6
3.	Fam. Chrysomelidae	6	5	5	-	2	-	3	-
4.	Blister beetle	2	3	-	1	-	-	1	-
5.	Fam. Elateridae	2	14	-	5	10	-	-	-
6.	*Forcipula* sp.	5	-	-	-	10	-	-	-
7.	*Eumorphus* sp.	-	-	-	-	-	-	15	20
8.	Milkweed Bug	5	-	4	-	-	-	-	5
9.	Nymph of g Green Leaf-hopper	-	-	-	-	15	10	-	-
10.	*Omonadus formicarius*	-	-	20	-	10	16	15	-
11.	*Poecilocoris latus*	10	16	-	-	6	-	15	10
12.	*Toxoptera aurantii*	16	20	24	18	35	40	20	31
13.	Bug Morpho-species 1	18	13	5	-	-	-	12	10
14.	Bug Morpho-species 2	6	-	8	-	-	8	-	-
15.	*Coridius* sp.	10	-	-	-	-	-	15	5
16.	Neetle Caterpillar	-	5	-	-	-	-	-	-

4.3 Order-wise distribution of pests

Order-wise distribution of pests is represented by figure 6. In ITE, it was found that Hemiptera was the most speciose order with eight species, followed by Coleoptera (five species), Lepidoptera (four species), Orthoptera (two species), while least speciose orders were Diptera (single species) and Dermaptera (single species).

Order Hemiptera consisted *Toxoptera aurantii*, *Lygus* sp., *Coridius* sp., *Poecilocoris* sp., Nymph of Green Leafhopper, Milk Weed Bug, and two unidentified species.

Order Coleoptera comprised five different species belonging to the families Anthicidae, Meloidae, Chrysomelidae, Elateridae and Endomychidae. Among five different species in order Coleoptera, only two species were identified, which were, *Omonadus formicarius* belonging to the family Anthicidae and *Eumorphus* sp. belonging to the family Endomychidae.

Four different pest species were recorded in the order Lepidoptera, which are, *Biston suppressaria*, Neetle Caterpillar, Tussock Moth larva and *Amata sperbius.*

Order Orthoptera consisted two different pest species; *Gastrimargus africannus orientalis* of family Acrididae and Long-horned Grasshopper of family Tettigonidae.

Green Fly was the only pest species found in the order Diptera and *Forcipula* sp. was also the single pest species found in the order Dermaptera.

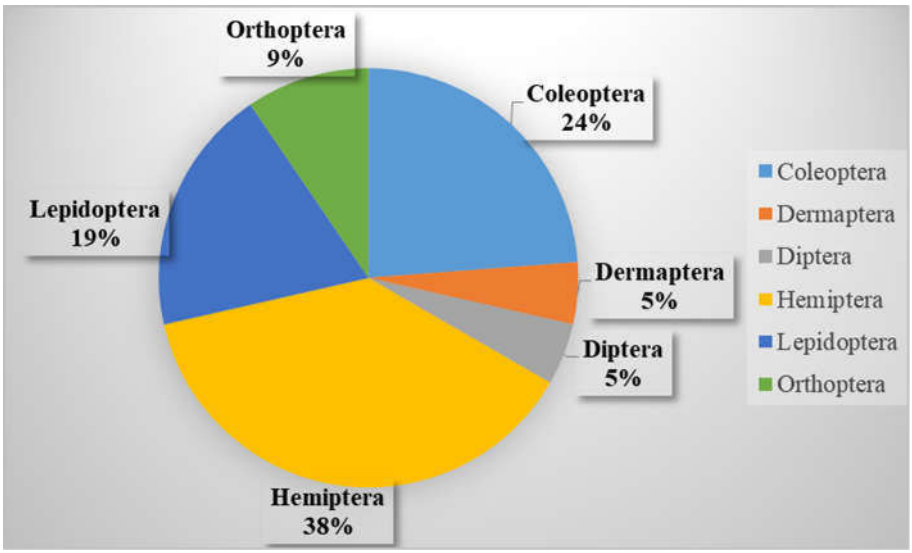

Figure 6. Order-wise distribution of pests in ITE

4.4 Diversity of pests

Number of pest species in different types of locational features viz. Under shade, Road side, Untouched area and Settlement area is shown in Figure 7.

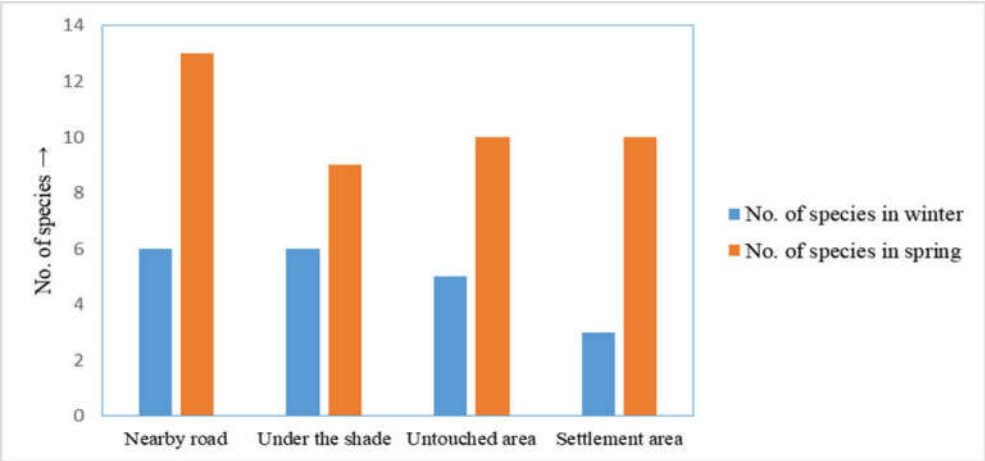

Figure 7. Number of pest species in various types of locations

Species diversity and evenness of pests during winter season were found to be 1.334880066 (Table 6) and 0.6419 respectively and that of spring season were found to be 2.335863089 (Table 7) and 0.842 respectively.

Table 6. Diversity of pest species in ITE during winter season

Name of pest	**No of species**	**Pi**	***Ln*pi**	**Pil*n*pi**	**H**
Amata sperbius	36	0.144	-1.937941979	-0.279063645	1.334880066
Blister beetle	4	0.016	-4.135166557	-0.066162665	
Gastrimargus africannus orientalis	10	0.04	-3.218875825	-0.128755033	
Green fly	5	0.02	-3.912023005	-0.07824046	
Long horned grasshopper	7	0.028	-3.575550769	-0.100115422	
Poecilocoris sp.	30	0.12	-2.120263536	-0.254431624	
Toxoptera aurantii	149	0.596	-0.517514612	-0.308438709	
Tussock moth caterpillar	9	0.036	-3.324236341	-0.119672508	
	N=250				

Evenness Index (E) $= \overline{H} / ln$ (s)
$= 1.334880066 / ln$ (8)
$= 0.6419$

Table 7. Diversity of pest species in ITE during spring season

Name of pest	**No. of species**	**Pi**	***ln*pi**	**Pi*ln*pi**	**H**
Lygus sp.	34	0.0537975	-2.9225289	-0.1572247	2.335863089
Biston suppressaria	13	0.0205696	-3.88394	-0.0798912	
Chrysomelidae	21	0.0332278	-3.404367	-0.1131198	
Blister beetle	7	0.0110759	-4.5029792	-0.0498748	
Elateridae	31	0.0490506	-3.0149022	-0.1478829	
Forcipula sp.	15	0.0237342	-3.7408392	-0.0887857	
Eumorphus	35	0.0553797	-2.8935413	-0.1602436	
Milk weed bug	14	0.0221519	-3.8098321	-0.084395	
Nymph of green leaf hopper	25	0.039557	-3.2300136	-0.1277695	
Omonadus formicarius	61	0.096519	-2.3380155	-0.2256629	
Poecilocoris sp.	57	0.0901899	-2.4058381	-0.2169822	
Toxoptera aurantii	204	0.3227848	-1.1307694	-0.3649952	
Bug Morphospecies 1	58	0.0917722	-2.3884464	-0.2191929	
Bug Morphospecies 2	22	0.0348101	-3.3578469	-0.1168871	
Coridius sp.	30	0.0474684	-3.047692	-0.1446689	
Neetle caterpillar	5	0.0079114	-4.8394515	-0.0382868	
	N=632				

Evenness Index (E) = $\overline{H}$ /*ln* (s)

= 2.335863089/ *ln* (16)

= 0.842

From the above calculations it was found that, the value of diversity index during spring season is greater than that of winter season. This shows spring season has more diverse community of pests than winter season. Since the value of evenness index in both winter and spring seasons are nearly equal we can conclude that pest species are quite evenly distributed in both seasons.

4.5 Management Practices for tea pests

ITE has become completely organic since September 2015. Hence, only organic fertilizers and pesticides are being used. For the management of pests and better tea production, 20 workers and one supervisor have been involved. Among 20 workers, 15 were field workers and were interviewed and involved in group discussion. Among them 11 were well trained and were known about the pests while four of them were assistants. 12 workers are working in ITE since eight years. Training is provided to the staff at least twice a year.

According to the office record of ITE, it appears that more concentration is given on the control of Thrips, Red Spider Mites and aphids as they are responsible for (15-20%) of crop loss annually. Mainly the infestation of pests is seen near the road and mainly leaves are the main part of attack. Weeds are responsible to suppress the productivity after pests. Only (5-10%) of crop loss is due to diseases.

Primarily weeding and pruning is done semi-annually to reduce the infestation of pests. Depending upon the severity of pests, three types of pruning methods are applied, viz. light skipper, medium skipper and deep skipper.
Soil quality of ITE is tested annually by NTDC, Charpane, Jhapa and the required accommodation is done according to it.

4.5.1 Preparation and use of local organic pesticide

From the interview and group discussion it was found that, for preparing the local organic pesticides, Neem (*Azadirachta indica*), Titepati (*Artemisia vulgaris*) and Bojho (*Acorus calamus)* are dried and cut into small pieces. Ash powder is added to a mixture and compressed into a plastic bag. Cattle's urine is poured on the top and it is let to mix into the mixture. After that, the whole mixture is packed tightly and compressed by stones or heavy objects. Meanwhile the bag is kept in dark room for a month. Finally, the decomposed mixture is mixed in water and is sprayed over the tea bushes. This recipe is completely organic and has high effectiveness with no side effect. This mixture is used for controlling overall pests in ITE. Other special methods are adopted for particular type of insect pests which is mention in table 8. Although, these local pesticides were not prepared within the study period, stored organic fertilizers and final mixture of local pesticides were observed.

Annually 4-6 rounds spraying are done in the morning time nearly at 8 am. 4-5 field workers are involved for spraying these pesticides.

Table 8. Control measures practiced against tea pests at ITE

Pests	Control practices
Aphids	5 *l* cattle's urine is mixed with 200 *l* of water and sprayed over the leaves. Organic pesticide named Alcap is used after pruning
Blister Beetle	Hand-picking method is applied
Red Spider Mite	Organic pesticides Metarhizium is mixed with water and sprayed over tea plant which is followed by Versa and Micomite
Greenfly	Organic pesticide Sputnik after pruning
Nettle Caterpillar	Spraying Econeem/ Achook/ Neemajal
Common Looper	Spraying Econeem/ Achook/ Neemajal
Tussock Moth Caterpillar	Spraying Econeem/ Achook/ Neemajal
Bugs	No particular control measures

Photo 1. Chrysomelidae

Photo 2. Blister beetle

Photo 3. *Eumorphus* sp.

Photo 4. Elateridae

Photo 5. *Omonadus formicarius*

Photo 6. Milkweed Bug

Photo 7. *Lygus* sp.

Photo 8. *Poecilocoris* sp.

Photo 9. *Coridius* sp.

Photo 10. Nymph of green leafhopper

Photo 11. Tussock moth caterpillar

Photo 12. *Amata sperbius*

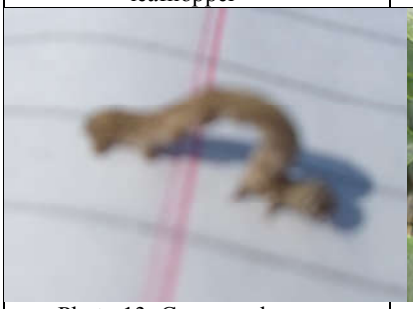

Photo 13. Common looper

Photo 14. Long horned grasshopper

Photo 15. *Gastrimargus africannus orientalis*

Photo 16. *Forcipula* sp.

Photo 17. Green fly

Photo 18. *Toxoptera aurantii* (apterous)

Photo 19. *Toxoptera aurantii* (pterous)

Photo 20. Bug Morphospecies 1

Photo 21. Bug Morphospecies 2

5. DISCUSSION

Twenty one pest species from six orders were recorded during the field visit of ITE which is quite similar to the result of Chettri (2007) in Teesta Valley Tea Garden as 13 species from seven orders were recorded there. The total number of insects collected in ITE was 882 while in Teesta Valley Tea garden 359 insects were collected. The number of species is more in ITE than Teesta Valley Tea Garden. This may be due to differences in temperature, elevation, cultivation strategy and management practices.

Similarly, Weilang (1991) recorded 173 species of insect pests of tea that belong to 29 families in eight orders. Among these, maximum number of species were from order Coleoptera (55 species), 51 species from Hymenoptera, 39 species from Diptera and 19 species from Hemiptera. The results in ITE was quite dissimilar to this, as most of the pest species in ITE are from order Hemiptera (eight species), second highest is Coleoptera (5 species) followed by Lepidoptera (four species).

The study documented that order Hemiptera (35%) has highest number of pest species in ITE which was followed by orders Coleoptera (22%) and Lepidoptera (17%). This result varies with the results of Chettri (2007), who recorded Lepidoptera (33%), Hemiptera (16%) and Coleoptera (11%) in Teesta Valley Tea garden. The most abundant species recorded in ITE was Aphid. This corresponds the result of Chettri (2007) and Rai (2004).

Studies carried out by Shi *et al*. (2014) and Hazarika *et al*. (2009) showed that Tea Green Leafhopper is one of the main insect pests in tea plantation in Asia. Similar result was found in the study of ITE.

Diversity of pest in ITE was found to be more during spring season (H=2.335863089) and less during winter season (H=1.334880066). This shows spring season has more diverse community of pests than winter season. As the value of H is nearly two in both seasons, it can be assumed that, the community is heading towards the complex. Since the value of evenness index in both winter and spring seasons are nearly equal, we can conclude that pest species are quite evenly distributed in both seasons. Some pests like *Toxoptera aurantii*, *Poecilocoris* sp. and Blister Beetle were recorded during both seasons. The reasons for the variable diversity may be temperature range, daylight hours, humidity, rainfall etc. Every organism has its range of tolerance of temperature. When the temperature is favourable organisms are likely to reproduce more and become abundant.

Although, Gotoh and Nagata, (2001), Han (2000), Cranham (1996), Mamun and Ahmed (2012) reported that Red Spider Mite (*Oligonychus coffeae)* causes serious damage on tea plants and is more abundant in most of the tea garden throughout the year, it was not reported from ITE in both winter and spring seasons. The main reason behind this may be, more attention and focus given to this pest as it is the serious damage causing pest. Spraying of pesticides (Metarhizium, Versa and Micomite) is most commonly done targeting this pest. Shrestha and Thapa (2015) concluded that Red spider mites are absent in tea garden during flushing period in mid hills.

Maximum number of tea pests belong to family Aphididae and Formicidae which resembles with the findings in Sikkim (Chhetri, 2010). Diversity of pests is found

different in different seasons and not only pests, weeds also act as the limiting factors of tea production. According to Kawai (1997) weeds also serve as the alternative hosts of tea pests.

As the average temperature of Ilam lies between 10-35°C and the amount of average rainfall is 300-500 mm (DHM, 2016), ITE has the best requirements for the tea production (Carr, 1972). Due to the sufficient amount of rainfall, irrigation also has not become a prior issue for the tea garden.

Among the natural enemies of the pests, three different species of ladybird beetle and spiders were recorded from ITE. Agarwala and Yasuda (2000) also noted the Ladybird Beetle as a common predator of Aphids and Scale Insect. Ladybird Beetles recorded in ITE were found to be *Coccinella septempunctata, Harmonia* sp. and *Oenopia sexareata* while the lady bird species recorded by Agarwala and Yasuda (2000) was *Cheilomenes sexmaculata*.

Aphids (*Toxoptera aurantii*) were abundant in both the seasons (204 in spring and 149 in winter). It is also one of the major pests of tea at ITE which reduces the production. Tamrakar and Singh (2000) reported that Aphids suck plant sap, hamper plant growth as well as spread several viral diseases thereby causing loss of output in agriculture.

Lehmann (1994) and Mamum and Ahmed (2012) reported, *Helopeltis* bugs are the second most damaging of tea in Africa. It was not found in ITE. The reason for this may be unfavourable climate, temperature and altitude. *Helopeltis theivora* reaches peak abundance in the period from June to September and population gradually declines in November as cooler weather conditions prevail (Srikumar and Bhat, 2013). The abundance of *Helopeltis* is more in tropical areas rather than hills.

Results of Chettri (2011) revealed that hand picking method was used for larger pests and pesticides like Endosulphan, Kelthane, Omite, Tatamida were sprayed in Jhapa and Ilam of Nepal for the control of smaller pests. Similarly, hand picking method is used for the control of Blister Beetles but other chemical pesticides are not used in ITE.

Not only insect pests, bacteria and fungi are also responsible for huge crop loss in tea every year. Various bacterial and fungal diseases have been identified for causing damage on leaves of a tea plant. Some diseases of tea that cause significant crop loss are Algal leaf spot, Brown blight, Blister blight, Horse-hair blight and Stem canker (Keith *et al*., 2006).

As ITE has been registered as organic tea producing Estate, chemical pesticides are completely banned here. The fertilizers and pesticides are organic too. This does not match with the results obtained by Koirala (2011). He obtained that all the farmers in Jhapa and Ilam were using pesticides and was clearly indicated that there is huge user dependency on chemical pesticides.

Shrestha and Thapa (2015) revealed that, field sanitation method, cultural practices like healthy saplings, biological agents and judicious use of agro-chemicals and IPM are being used for controlling insect pests in most of the tea gardens of Jhapa and Ilam. But, for

immediate protection, use of chemicals is the most preferred choice of the farmers. Unlike this, Chemical pesticides are totally banned in ITE and organic pesticides and biological control are preferred for pest control.

As many as 2121 plant species have been reported to possess pest control properties (Jacobson, 1989). As explained by Radhakrishnan (2005), plants species possess the characteristics required for an ideal botanical insecticide and are therefore more promising for use in organic pest control programmes, few plant species are being used in ITE as well for pest control which comprises Neem (*Azadirachta indica*), Titepati (*Artemisia vulgaris*) and Bojho (*Acorus calamus)*. Neem is a natural source of eco-friendly insecticides, pesticides and agrochemicals (Brahmachari, 2004).

The yield and quality of Tieguanyin tea leaves were greatly affected by irrigation intervals (Chen *et al*., 2010). Yield and quality decreased with increasing irrigation interval. But ITE has not given prior importance in irrigation. ITE is fully dependent in natural rainfall.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Altogether 21 pest species belonging to six orders and 20 families were recorded in ITE. Most speciose order of pests was Hemiptera. Aphid was the most abundant pest in both winter and spring seasons. Abundance of pest species was found to be more in spring than winter. More pests were recorded on the bushes nearby road while numbers of pests were less under the shade and untouched area.

ITE was found to be completely organic. Hence, no any chemical fertilizers and chemical pesticides are being used. Usually, Ash powder, cattle's urine, botanicals such as Neem, Titepeti, Bojho are used to kill or repel the pests. Frequent spraying of organic pesticides, pruning and weeding are done to reduce the pest infestation.

6.2 Recommendations

- Farmers and field workers should be provided with frequent trainings and should be made aware of pests, their damage patterns and management practices more efficiently.
- More frequent spraying of organic pesticides should be performed during warm seasons as more number of pests were recorded during spring season.
- Different botanicals can be used to kill the pests. Alternative plant species should be identified and should be used along with the botanicals being used currently.

7. REFERENCES

AEC/FNCCI. 2007. Tea Newsletter. Agro Enterprise Centre, Kathmandu, Nepal.

Agarwala, B. and Yasuda, H. 2000. Competitive ability of ladybird predators of aphids: A review of *Cheilomenes sexmaculata* (Fabr.) (Coleoptera: Coccinellidae) with a worldwide checklist of prey, Journal of Aphidology, **14**: 1-20.

Andrews, E.A. 1923. The tea green fly (*Empoasca flavescens*). Quarterly Journal of Indian Tea Association, 109-117 p.

Arancon, N.Q., Edwards, C.A., Oliver, T.J., and Byrne, R.J. 2008. Suppression of two-Spotted Spider Mite (*Tetranychus urticae*), Mealybugs (*Pseudococcus*) and Aphid (*Myzus persicae*) populations and damage by vermin-compost. Crop Protection, **26**: 26-39.

Banerjee, B. 1996. Tea production and processing. Oxford and IBH publication, New Delhi, 213 pp.

Banerjee, B. 1982. A strategy for the control of Andraca bipunctata walker on tea, crop protection, Science direct, **1**(1): 115-119.

Barthakur, B.K. 2011. Recent Approach of Tocklai to Plant Protection in Tea In North-East India. Science and Culture, **77**: 9-10.

Bhaduri, N., Gupta, D.P., Ram, S. 1989. Effect of vegetable oils on the ovipositional behaviour of *Callosobruchus chinensis* Fab. In: Proc. 2nd Int. Symp. On Bruchids and Legumes (ISBL-2), Okayama, Japan, 81-84.

Bian, L., Sun, X.L., Luo, Z.X., Zhang, Z.Q., Chen, Z.M. 2014. Design and selection of trap color for capture of the tea leafhopper, *Empoasca vitis*, by orthogonal optimization, Entomologia Experimentalis et Applicata, **151**: 247–258.

Borror, D.J., De Long, D.M. and Triplehorn, C.A. 1981. An introduction to the study of insects 5th ed. The Dryden Press. USA. 827 pp.

Borthakur, M. and Singh, K. 2002. Biology and Control of Tea and Shade Tree Pests. Notes on Field Management, pp. 171-192.

Brahmachari, G. 2004. Neem- A omnipotent plant. A retrospection. Chem. Biochem., **5**: 408-421.

CABI, EPPO. 2013. *Oligonychus coffeae*. Database on quarantine pests [Internet] Prepared by CABI and EPPO for the EU, http://wwwcabiorg/cpc, Accessed on May 2013.

Carr, M.K.V., 1972. The climatic requirements of the tea plant: A review. Experimental Agriculture, **8**: 1-14.

Chen, Z. and Chen, X. 1989. An analysis of the world tea fauna. Journal of Tea Science, **9**: 13-22.

Chen, F.S., Ho, T.Y., Chong, K.P., Jalloh, M.B. and Wong, N.K. 2010. Organic versus conventional farming of tea plantation. Borneo Science, **26**: 19-26.

Chhetri, J. 2007. Study of arthropod pests of tea and its diversity in Teesta valley tea garden, Darjeeling, India. M.Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Chhetri, S. 2010. Study of tea pests of Temi Tea Estste, South Sikkim, India. M.Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Chhetri, S. 2011. Study of tea pests and pesticide handling practices in Tea in Jhapa and Ilam districts of Nepal. M.Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Cook, S.M., Khan, Z.R. and Picket, J.A. 2007. The use of push-pull strategies in integrated pest management. Annual Review on Entomology, **52**: 375-400.

Cranham, J.E., 1996. Tea pests and their control. Annual Review on Entomology, **11**: 491–514.

Das, G.M. 1959. Bionomics of the tea red spider, *Oligonychus coffeae* (Nietner). Bulletin of Entomological Research, **50**: 265–274.

Das, S., S. Roy and A. Mukhopadayay. 2010. Diversity of arthropod natural enemies in the tea plantaintations of North Bengal with emphasis on their association with tea pests. Current Science, **99** (10): 1457-1463.

Debnath, S. 2013. Studies on entomopathogenic fungus Aschersonia aleyrodis infectious to scale insect pest, Saissettia formicarii of tea, Camellia sinensis (L). O. Kuntze in Assam In: Proceeding of XIII International Symposium on Scale Insect Studies Sofia, ISSSIS, Bulgaria, pp 22.

Devi, K.D., Nishakanta, K. and Varatharajan, R. 2016. Diversity and Density of Tea Pests in the Tea Gardens of Manipur. Journal of Plantation Crops, **44**(1): 47-51.

DHM, 2016. Department of Hydrology and Meteorology, Government of Nepal.

Dolul, A.K. and Debnath, M. 2010. Antifeedant activity of plant extracts to an insect *Helopeltis theivora*. Journal of Environmental Biology, **31**(5): 557-559.

Dutta, P., Reddy, S.G.E., Barthakur, B.K. 2013. Effect of neem kernel aqueous extract (NKAE) in tea mosquito bug *Helopeltis theivora* (Waterhouse, 1886) (Heteroptera: Miridae). Munis Entomol Zool, **8**: 213–218.

Eden, T. 1976. Tea 3rd ed. Longman, London, U.K., 236 pp.

Elmoghazy, M.M.E., El-Saiedy, E.M.A., and Romeih, H.M.A. 2011. Integrated control of the two spotted spider mite *Tetranychus Urticae* Koch (Acari: Tetranychidae) on faba bean, *Vici faba* (L.) in an open field at Behaira Governorate, Egypt. IJESE, **2**: 93-100.

EPPO, 2014. PQR database. Paris, France: European and Mediterranean Plant Protection Organization. Available at: http://www.eppo.int/DATABASES/pqr/pqr.html

FAO, 1999. FAO yearbook of production Vol 52, 1998. FAO Statistic Series No. 148. Food and Agriculture Organization of the United Nations, Rome, 170 pp.

Georghiou, G.P. and Taylor, C.E. 1977. Pesticide resistance as an evolutionary phenomenon. In: Proc. 14th Int. Cong. Entomol., 759 pp.

Goodland, R., Watson, C. and Ledec, G. 1985. Biocides bring poisoning and pollution to 3rd world. The Bangladesh Observer, 3 pp.

Gotoh, T, Nagata, T. 2001. Development and reproduction of *Oligonychus coffeae* (Acari: Tetranychidae) on tea, Int. J. Acarol., **27**: 293-298.

Gurusubramanian, G., Kumar, N.S., Tamuli, A.K., Mridul Sarma, Azizur Rahman, Sunil Bora and Somnath Roy. 2008. Biointensive integrated management of tea pests for sustainable tea production in the north east. International Journal of Tea Science, **7**: 45-59.

Hamasaki, R.T., Shimabuku, R., and Nakamoto, S.T. 2008. Guide to insect and mite pests of tea (*Camellia sinensis*) in Hawai'i. CTAHR Cooperative Extension Service IP-28, 15 pp.

Han, B. 2000. Mechanism of Stability of insect community in tea garden. Journal of Tea Science, **20**: 1-4.

Hazarika, L.K., Bhuyan, M., Hazarika, B.N. 2009. Insect pests of tea and their management. Annual Review on Entomology, **54**: 267-284.

Heiss, M.L. and Heiss, R.J. 2007. The Story of Tea: A Cultural History and Drinking Guide, Random House, New York, 519 pp.

Heiss, M.L. and Heiss, R.J. 2011. The Story of Tea: A Cultural History and Drinking Guide, Random House, New York, 31 pp.

Hill, D.S. 1993. Agricultural insect pests of tropics and their control. Manas Saikir for foundation Books. Sanat printers, Delhi. In "Ecological engineering for Pest Management: Advances in habitat Manipulation for Arthropods" (Eds. Gurr, G. M., Wratten, S. D. and Altieri, M.A.), pp. 155-164.

Jacobson, M. 1989. Botanical pesticides. Past, present and future. Insecticide of Plant Origin (*Eds.* J.T. Arnason, B.J.R. Phlogene and P. Morand). ACS Symposium Series. American Chemical Society, Washington D.C., USA, **387**: 1-10.

Jeppson, L., Keifer, H., Baker, E. 1975. Mites Injurious to Economic Plants, University of California Press, Berkeley, USA, 614 pp.

Kamrin, M. A. 1997. Pesticide Profiles: toxicity, environmental impact, and fate. CRC Press.

Kamunya S.M., Wachira, F. N., Langat, J., Otieno, W. and Susoi, V. 2008. Integrated Management of Root knot Nematode (*Meloidogyne* sp.) in tea (*Camellia sinensis*). International Journal in Pest Management, **54**: 129-136.

Kansakar V.B.S. 1985. Migration and employment in the tea estates of Nepal. CEDA T.U. Kathmandu.

Kawai, A. 1997. Prospect for integrated pest management in tea cultivation in Japan. Japanese Agricultural Research, **31**: 213-17

Keith, L., Ko, W. H. and Sato, D. M. 2006. Identification guide for diseases of tea (*Camellia sinensis*), College of Tropical Agriculture & Human resource, University of Hawaii, 4 pp.

Khan, Z.R. and Picket, J. A. 2004. The push-pull strategy for stem borer management: A case study in exploiting the biodiversity and chemical ecology. In Ecological Engineering for pest management: Advances in Habitat Manipulation for Arthropods ed. G.M. Gurr, S.D. Wratten, M.A. Altieri, Wallington, Oxon, UK, pp 155-164.

Knipling, E.F. 1972. Entomology and the Management of Man's Environment, Australian Journal of Entomology, **11**: 153–167.

Koirala, P. 2011. Study on Pests and Pesticide Residue in Tea in Jhapa and Ilam districts of Nepal. Phd. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Lehmann, D. H. 1994. Introduction to integrated pest management of plant diseases and pests in the tropics and subtropics. 3rd ed. Six Universities Development and Rehabilition Project (SUDR), Georg-August University of Goettingen, Grisebachstr. 6, 37077 Goettingen, Germany, pp 182.

Macfarlane, A and Macfarlane, I. 2004. The Empire of Tea, The Overlook Press, New York, 32 pp.

Mamun, M.S.A. 2011. Development of tea science and tea industry in Bangladesh and advances of plant extracts in tea pest management. International Journal of Sustainable Agricultural Technology, **7**(5): 40-46.

Mamun, M.S.A. and Ahmed, M. 2011. Prospect of indigenous plant extracts in tea pest management. International Journal of Agricultural Resource Innovation and Technology, **1**(1): 16-23.

Mamun, M.S.A. and Ahmed, M. 2012. Approved insecticides, miticides and nematicides for tea (Revised & Updated). BTRI Circular no. 135, Bangladesh Tea Research Institute, Srimangal, Moulvibazar, 1-7 p.

Mamun, M.S.A. and Iyengar, A.V.K. 2010. Integrated approaches to tea pest management in south India. Int. J. Sustain. Agril. Tech., **6**(4): 27-33.

Meyer, M.K.P. 1987. African Tetranychidae (Acari: Prostigmata) with reference to the world genera. Department of Agriculture and water supply, Republic of South Africa, Entomology memoir, **69**: 1-175.

Miller, J.R. and Cowles, R.S. 1990. Stimulo- deterrent diversion: a concept and its possible application to onion maggot control. 1. Chem. Ecol., **16**: 3197-3212.

Mu, D., Cui, L., Ge, J., Wang, M. X., Liu, L.F., Yu, X. P., *et al.* 2012. Behavioral responses for evaluating the attractiveness of specific tea shoot volatiles to the tea green leafhopper, *Empoaca vitis,* Insect Science, **19**: 229–238

Muraleedharan, N. 1992. Pest control in Asia, In: Tea: Cultivation to consumption, eds. Willson, K.C.and Clifford, M.N., Chapman and Hall, London, pp 375-412.

Muraleedharan, N. 2005. Sustainable cultivation of tea. Planters' Chronicle, **101**(5): 5-17.

Muraleedharan, N. 2008. Strategies for reducing pesticide residues in tea. In "Economic crisis in Tea industry" (Eds. Jain, N.K., Rahman, F. and Baker, P.), pp 149-158.

Nabeta, F.H., Nakai, M. and Kunimi, Y. 2005. Effects of temperature and photoperiod on the development and reproduction of *Adoxophyes honmai* (Lepidoptera: Tortricidae). Appl. Entomol. Zool., **40**: 231–238.

Nadda, G., Reddy, S.G.E., Shanker, A., 2013. Science of tea technology, scientific publishers India, 317-333 pp.

NTCDB. 2002. Tea-A-Tea, Smarika, Published by Nepal Tea and Coffee Development Board.

NTCDB. 2005. Tea statistics. Nepal Tea and Coffee Development Board.

NTCDB. 2011. Tea statistics. Nepal Tea and Coffee Development Board.

NTCDB. 2014. Tea statistics. Nepal Tea and Coffee Development Board.

NTCDB. 2017. Tea statistics. Nepal Tea and Coffee Development Board.

NTDCLTD. 2011. "Flushes of tea in Nepal". Nepal Tea Development Corporation Limited.

Palikhe, B.R. 2005. Pesticide Management in Nepal. In: view of code of conduct, Paper presentation at the Regional workshop on International code of conduct on the

Distribution and use of pesticides; Implementation Monitoring and observance, Bangkok, Thailand.

Pimental, D., Andow, D., Dyson-Hudson, D., Gallahan, D., Jacobson, S., Irish, M., et al. 1980. Environmental and social cost of pesticides. A preliminary assessment. Oikos, **34**: 125-140.

Purseglove, J.W., 1968. Tropical crops: Dicotyledons 2. Longmans, London, 599-612 pp.

Radhakrishnan, B. 2005. Indigenous preparations useful for pest and disease management. Planters' Chronicle, **101**(4): 4-16.

Rai, M. 2004. Study on pests of tea and their management practices in Kanyam tea estate, Ilam, Nepal. M.Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Rana, A. 2007. Orthodox Tea in Nepal: Upgrading with Value Chain Approach. Deutsche Gesellschaft for Technische Zusammenarbeit (GTZ) GmbH, German Technical Cooperation/ Private Sector Promotion-Rural Finance Nepal (GTZ/PSP-RUFIN).

Rattan, P.S. 1992. Pest and disease control in Africa. In: Tea Cultivation to Consumption. Wilson, K.C. and Chifford, M.N. (eds), pp 331-352.

Roy, S., Muraleedharan, N. and Pujari, D. 2014. A Catalogue of arthropod pests and their natural enemies in the tea ecosystem of India. Two and a Bud, **61**(1&2): 11-39.

Roy, S., Muraleedharan, N., Mukhapadhyay, A., Handique, G. 2015. The tea mosquito bug, Helopeltis theivora Waterhouse (Heteroptera: Miridae): its status, biology, ecology and management in tea plantations. Int J Pest Manag, **61**(3): 179–197.

Sarmah, M., Rahman, A., Phukan, A. K., Gurusubramanian, G. 2006. Ovicidal, acaricidal and antifeedant activity of crude extracts of *Polygonum hydropiper* L. (Polygonaceae) against red spider mite and bunch caterpillar and its effect on *Stethorus gilvifrons* Mulsant. Uttar Pradesh. J Zool., **3**(2): 127–135.

Sen, C.T. 2004. Food Culture in India. Greenwood Publishing Group, 26 pp.

Sharaby, A. 1988. Evaluation of some Mytraceae plant leaves as protectants against the infestation by *Sitophilus oryzae* L. and *Sitophilus granarius* L. Insect Sci. Appl., **9**: 465-468.

Shi, L., Vasseur, L., Huang, H., Zeng, Z., Hu, G., Liu, X., et al. 2017. Adult Tea Green Leafhoppers, *Empoasca onukii* (Matsuda), Change Behaviors under Varying Light Conditions. PLoS ONE, **12**(1): e0168439.

Shi, L.Q., Lin, M.Z., Chen, L.L., Lin, M.Q., Vasseur, L., You, M.S. 2014. Changing the specific name of tea green leafhoppers in major tea plantations in Fujian Province, China. Journal of Fujian Agriculture and Forestry University (Natural Science Edition), **43**: 456–459.

Shrestha, G. and Thapa, R.B. 2015. Tea pests and pesticide problems and integrated management. Journal of Agriculture and Environment, **16**: 188 pp.

Sinha, M.P. 2010. World tea production and manufacturing. Wishwell Publisher, New Delhi, India.

Srikumar, K.K. and Bhat, P.S. 2013. Biology of the tea mosquito bug (*Helopeltis theivora* Waterhouse) on *Chromolaena odorata* (L.) R.M. King & H. Rob, Chilean Journal of Agricultural Research, **73**(3): 309-314.

Sudoi, V. 1997. Tea pests with special reference to mites: Research achievements and future thrusts. Tea, **18**: 156-165.

Sudoi, V., Khaemba, B.M. and Wanjala, F.M.E. 2001. Nitrogen fertilization and yield losses of tea to red crvicemite (Brevipalpus phenicis Geijskes) in the Eastern Highlands of Kenya. Int. 1. Pest Manag., **47**: 207-210.

Sundararaju, D., Sundarababu, P.C., 1999. *Helopeltis spp*. (Heteroptera: Miridae) and their management in plantation and horticultural crops of India. J. Plant. Crops, **27**:155–74.

Tamrakar, A.S. and Singh, R. 2000. Records of aphid parasitoids from Madhyanchal of Nepal, *Journal of Aphidology*, **14**: 129-132.

Tvedten, S. 2002. Tea and pesticides. Toxic Blend, www.getipm.com.

Weiliang, L.G.X. 1991. A check list of natural enemy insects of tea tree pests from Yunnan, Department of Plant Protection, Yunnan Agricultural University, Kunming, China.

Yangmo, W., Feng, G., Hui, L.X., Feng, F. and Lijun, W. 2005. Evaluation of mass trapping for control of tea tussok moth, *Euproctis pseudoconspersa* with synthetic sex pheromone in South China. International. Pest mgmt., **51**: 291-297.

Zao, J.G., Ping, T.H. and Ping, H. 2003. Relationship between tea and fruit tree interplanting and yellow mite damage in tea fields. South West China. agric. Sci., **16**: 71-73.

Zhang, W., Wang, Y.Z. and Ren, S. 1992. Ecocontrol of the tea green leafhopper (Homoptera: *Empoasca vitis*) and rational use of pesticides. Tea Science, **12**: 139-144.

APPENDIX-I

Interview schedule:

Name:……..... Date:……
Age:……..
Sex:……..
Education:……

1. How long have you been working in this tea garden?
……..

2. How many workers and office staff are being employed in ITE?
…….

3. In which section you are employed in?
   a) Field…… c) Office…….
   b) Spray division…… d) Factory……..

4. How much tea is produced by ITE per year?
…….

5. What type of fertilizers do you use in your tea garden?
……....

6. What causes the maximum loss of crops?
   a) Pests……. c) Diseases……
   b) Climatic factor……. d) Management……..

7. Do you have any idea about the pests of tea?
   a) Yes…….. b) No……

8. What are the most harmful pests in the garden?
   a) Aphids…… d) Green flies……..
   b) Thrips…….. e) Lopper……..
   c) Red spider mites…….. f) Others……..

9. Which part of a tea plant is mostly affected by pests?
   a) Leaves…… c) Root……...
   b) Stem…….. d) Others……

10. Which method do you use to control these pests?
   a) Chemical pesticides……. c) Cultural control……..
   b) Natural enemies…… d) Hand picking and killing……..

11. Do you use chemical pesticides?
   a) Yes……. b) No……

12. How often do you use the pesticides?

……..

13. Which form of pesticide do you use?

a) Liquid….. c) Fumigant…….

b) Dust…… d) Granules……

14. Where do you get the pesticides for your tea garden?

……

15. Do you prepare pesticides in local level? If yes, how?

……

16. What type of botanicals and materials do you use for preparing those pesticides?

……

17. Do you find the pesticides used in your garden effective?

……

18. Do you think the management practices applied for pests in your garden is appropriate?

a) Yes …….. b) No ……

19. Do you have any idea about IPM?

a) Yes ……. b) No ……

20. How often do you check the soil quality of the garden?

……..

21. How often is monitoring being done?

…….

22. Who do you involve during monitoring of the garden?

……

23. Are you facilitated with trainings by the office? If yes, how often?

…….

APPENDIX –II

Photo 22. Branded organic fertilizer imported from India

Photo 23. Locally prepared organic manure

Photo 24. Interview with office staff

Photo 25. Interview with field workers

Photo 26. Workers preparing organic pesticides for spraying

Photo 27. Workers spraying pesticides in tea garden

Photo 28. Collecting insects

Photo 29.Tea bushes in ITE

Photo 30. Tea garden after pruning

Photo 31. Leaves damaged by pests in ITE

Photo 32. Weeds invasion in tea garden of ITE