Insect Biodiversity and Seasonal Incidence of Major Insect Pests of Apple (*Malus sylvestris* Mill.) in Mid Hills of Meghalaya

Thesis

Submitted to the
Central Agricultural University, Imphal
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In

Entomology

by

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CENTRAL AGRICULTURAL UNIVERSITY (IMPHAL)

Umiam, Pin: 793103, Meghalaya, India

August 2019

Dedicated to

My Beloved Family Members

D. Ch. Biswas

Dipul Biswas

Debajeet Biswas

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CERTIFICATE – I

Certified that **Mr. Debanand Biswas** {Admission No. **CAU/CPGS/ENTO/M17/01;** Registration No. **U-17-ML-01-010-M-A-033**} has satisfactorily prosecuted his course of research for a period of not less than two semesters and that the thesis entitled **"Insect Biodiversity and Seasonal Incidence of Major Insect Pests of Apple (***Malus sylvestris* **Mill.) in Mid Hills of Meghalaya"** submitted by him to the Central Agricultural University, Imphal – 795 004 (Manipur) in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Entomology** is the result of original research work conducted by him under my supervision and is sufficiently of high standard to warrant its presentation to the examination.

I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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CERTIFICATE – II

This is to certify that the thesis entitled, **"Insect Biodiversity and Seasonal Incidence of Major Insect Pests of Apple (*Malus sylvestris* Mill.) in Mid Hills of Meghalaya"** submitted by **Mr. Debanand Biswas [Regn. No. U-17-ML-01-010-M-A-033]** submitted to the Central Agricultural University, Imphal – 795 004 (Manipur) in partial fulfillment of the requirement for the award of the degree of **Master of Science (Agriculture)** in the subject of **Entomology** has been approved by the student's Advisory Committee after oral examination jointly with Dean's Nominee.

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DECLARATION

I hereby declare that the thesis entitled **“INSECT BIODIVERSITY AND SEASONAL INCIDENCE OF MAJOR INSECT PESTS OF APPLE (***Malus sylvestris* **Mill.) IN MID HILLS OF MEGHALAYA”** is an authentic record of the work done by me and that no part thereof has been presented for the award of any other degree, diploma, associateship, fellowship or any other similar title.

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Date:

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LIST OF ABBREVIATIONS

@	At the rate of
°C	Degree centigrade
%	Percentage
mm	Millimeter
Fig.	Figure
m^2	Square meter (s)
mg	Miligram
g	Gram
Kg	Kilogram
ha	Hectare
Kg ha^{-1}	Kilogram per hectare
RH	Relative humidity
SMW	Standard Meteorological Week
etc.	*et cetera* ‘and so forth’
et al.	*et alii* ‘and others’
i.e.	*Id est* ‘that is’
viz.	namely
sp.	Species
S. No	Serial number
r	Correlation co-effecient
R	Regression co-effecient

NEH	North East Hilly
ICAR	Indian council of Agricultural Research

ABSTRACT

Apple (*Malus sylvestris* Mill.) is an important temperate fruit crop which belongs to the Family of Rosaceae and originated in Central Asia. It is a rich source of antioxidants, flavanoids, vitamins and fiber. China accounts for 50% of the apple production worldwide. In India, it is mostly grown in Jammu & Kashmir, Himachal Pradesh, Uttaranchal, Arunachal Pradesh, Sikkim and Nagaland. The present investigation aims at the study of insect biodiversity and seasonal incidence of major insect pests of Apple in mid hills of Meghalaya. A total of 150 insects were collected. Based on the taxonomic classification, the collected insects were identified and classified under 7 different orders viz. Coleoptera (17 species), Hemiptera (11 species), Lepidoptera (6 species), Diptera (4 species), Hymenoptera (3 species), Dermeptera and Orthoptera with one species each. A total of 43 insect species were identified which consists of 26 insect pests, 10 natural enemies, two pollinators and five insect visitors. Based on the damage caused the insects were grouped into five major insect pests viz. Green apple aphid (*Aphis pomi* De Geer), Pale tussock moth (*Calliteara pudibunda* Linneaus), Tussock moth (*Euproctis guttata* Collenette), Giant looper (*Ascotis seleneria* Denis & Schiffermuller) and Cocoa tussock moth (Orgyia postica Walker) and 21 insect species as minor insect pests of apple. Observations on the seasonal incidence of the major insect pests revealed that aphid population attained its peak on 25th SMW (3rd week of June, 2018) with the mean population of 34.75 aphids/ 10cm apical length of twig/shoot/plant. Pale tussock moth population reached to its peak during 28th SMW (2nd week of July, 2018) with mean larval population of 3.82 larva/ plant. Tussock moth attained its peak on 35th SMW (last week of August) with average larval population of 4.15 larvae/ plant. Giant looper population was highest on 28th SMW (2nd week of July, 2018) with larval population of 3.46 larvae/ plant. Cocoa tussock moth population was highest of 4.75 larvae/ plant which were obtained on 26th SMW (27th June, 2018). Correlation coefficient (r) studies indicated significant correlation between the mean population of green apple aphid and maximum temperature. Mean larval population of Tussock moth showed significant correlation with minimum temperature. Mean larval population of cocoa tussock moth showed significant correlation with minimum temperature. Regression Coefficient(R) was also worked out and fitted to determine the impact of independent variables on dependent variables.

Key words: biodiversity, seasonal incidence, SMW (Standard meteorological week).

Chapter- 1

Introduction

Apple (*Malus sylvestris* Mill.) originated in Central Asia as a temperate fruit crop which requires about 800-1600 hours of chilling below 7^0C. Apple belongs to the family Rosaceae and it is widely grown species throughout the world. Apple being a temperate fruit crop grows well in temperate climatic zones and fulfils their requirement of chilling temperature (Besufkad *et al.,* 2018). More than 7,500 apple cultivars, having a range of desired characteristics are known. Apple being the most important fruit crop grown in North Western Himalayan region of India is susceptible to variety of biotic and abiotic parameters that reduces directly or indirectly the life of trees as well the fruit yield (Gupta and Tara, 2014).

Apple production Worldwide in 2017 was about 83.1 million tonnes, of which China accounts for 50% of the total production. India ranks fifth in terms of apple production with an average of 2.2 million tonnes, yield of 7.4t/ha and land area of 3.0 lakhs ha (FAOSTAT, 2019). In India, it is mostly grown in Jammu & Kashmir, Himachal Pradesh, Uttaranchal, Arunachal Pradesh, Sikkim and Nagaland. All the three north-west Himalayan states of India are the major apple producing states in India. In these three states, the apples are grown at an altitude ranging from 1200-3500 m above the mean sea level (Basannagari and Kala, 2013). In India, Jammu and Kashmir is the largest producer of apple because of the temperate climate suited for apple production followed by Himachal Pradesh.

Apple essentially is an insect pollinated tree crop and requires a number of efficient pollinators to enhance pollination in order to achieve optimum and quality yield (Garrat *et al*., 2014). Apple trees and fruits are susceptible to a large number of fungal, bacterial and pest problems that affects the apple cultivation. Apples are mostly preferred fruit by most of the national and international markets due to its nutritional value (Riyaz *et al*., 2018). They are extremely rich in important antioxidants, which help in reducing the risk of cancer, hypertension, diabetes and heart diseases. They are also rich in flavonoids, vitamins and dietary fiber. Vitamin C content is about 7% and fiber content is about 9% in per 100g of apple.

North Eastern Hills region of India is very rich in biodiversity, fertile soil and conducive agro-climatic conditions that make them ideal for the production of horticultural crops. Wild relatives of apple and other temperate fruits are found growing

in its natural form in NE forests. Temperate fruits viz. apple, plum, peach, pear are grown semi commercially in North East Hill states particularly in Arunachal Pradesh, Sikkim, Nagaland and Meghalaya. North East is the sixth mega-centre for rich plant-biodiversity in the world and hence there is a natural home of origin of many important horticulture crops. In North East Region, large parts of Arunachal Pradesh, Sikkim and some part of Nagaland and Meghalaya fall under the sub-temperate zone. Whereas, low hills of Assam, Meghalaya, lower hills of Arunachal Pradesh and Sikkim fall under sub-tropical zone. Arunachal Pradesh is the only leading state in the North East region suitable for apple production (Jindal and Sharma, 2016).

Low productivity of apple in this regions may be due to the biotic and abiotic stresses like weather parameters, climatic conditions, insect pests, diseases and other unfavourable factors. Although the low chilling varieties of apple, pear, plum, peach and apricot are also getting popular in sub-tropical hill region of North East as a result of crop diversification. Lack of quality planting materials, proper packaging practices, modern technologies and trained manpower are the major constraints in enhancing the productivity of temperate fruits in general and apple in particular.

Biodiversity is extremely important for sustainability of life on the earth where the insects play an important role for normal functioning of ecosystems. Natural enemies considered as biocontrol agents are helpful in regulation of numerous populations of sucking and leaf eating pests. Apple trees are infested by the highest number of pest species as compared with other horticultural crops. Around 400 species of insects are associated directly or indirectly with the apple cultivation. Approximately 100 species feed on the apple tree or fruit. More than 40 species are economically important and 10 species are considered as serious pest of apple (Teparkum, 2000). Insects are involved in various processes such as: pollination, soil forming, pest control *etc.* Insects, mainly bees, are considered as important pollinator of most of the fruit, nut, and vegetable crops (Klein *et al.*, 2007).

Lepidopterans are also considered as one of the serious pests of young apple trees in the orchards. Large numbers of leaf miners are also associated with apple but are considered as indirect pest because their deterioration activity is confined to apple leaf resulting in drying and falling off of the leaves prematurely. Aphid species viz. green apple aphid, (*Aphis pomi* De Geer), Spirea aphid, (*Aphis spiraecola*), rosy apple aphid, (*Dysaphis pyri*) and woolly apple aphid, (*Eriosoma lanigerum* Hausmann) are considered as most serious pests in apple orchard worldwide (Perdikis *et al*., 2008). Among aphids, green apple aphid is considered as a major pest damaging the apple nursery severely because of its monoecious nature.

Syrphids are considered as one of the important predators feeding on aphids and are well known to regulate the prey population effectively. The predatory true bugs constitute almost 90% of all predatory insects found in apple tree (Hradil *et al*., 2013). The European earwig has been widely known predator of many pests in temperate climatic regions, but its activity against the pests may vary from region to region (Lordan *et al.,* 2015). Also, some of the species of earwig are phytophagous in nature therefore it causes economic damage to the fruits. It is also well known that the productivity of apple depends on pollination services by the insects and most importantly by the hymenopterans (Japoshvili, 2015). The process of pollination in an ecosystem has evolved over millions of years for the benefit of both flowering plants as well as pollinators. Pollination is a critical stage in the life cycle of all flowering plants which is essential to start fruit and seed production in the crop.

In Jammu and Kashmir apple is infested with more than 10 aphid species (Shah, 2015). Scale insects and mealy bugs are also considered as a serious pests of apple. They are usually not detected until they severely damage the fruit crop (Bhagat and Qureshi, 2016). Diversity of insects is usually highest in summer (April) season and lowest in winter (December) season. During summer the density of all insect groups, except houseflies and wasps is significantly higher. Whereas, during rainy (August) season there is significantly high density of wasps, houseflies and moths as recorded in apple orchards of western Himalaya (Kapkoti *et al.* 2016). Diversity, distribution and relative abundance of insect visitors in apple crop was investigated and carried out by collecting the visitors of apple flower in different apple orchards located in Shimla hills of Western Himalaya where they observed that 41 insect species visit the apple orchards (Mattu and Nirala, 2016).

Around 21 species of coleopterans are associated with apple. Many species of beetles are predators and they play an important role in reducing the numbers of various insect pests. But the larvae of Buprestids and Cerambycids cause severe damage to the crop by making tunnels. Adults of Chrysomelids and Scarabaeid beetles cause heavy damage to the foliage, flowers and roots of the plant (Bhagat, 2017). Planting of the exotic apple varieties in Kashmir valley led to introduction of the new insect pests viz. European red mite, San Jose scale, Codling moth and Woolly apple aphid which is considered as the major pests of apple. Pest establishment in this region are alarming to the fruit growers to protect the crop. Due to the lack of well-organized quarantine system, insect pests of apple in India are of major concern.

Other insects like thrips, aphids, leaf rollers and tussock moth also infest the apple trees in Jammu and Kashmir but the losses due to these insects are less (Hussain *et al.,* 2018).

Meteorological conditions of an area heavily influences the life cycle of the insect pests hence studies on the seasonal incidence of major pests are useful for development of management programmes. Basannagari and Kala (2013) also suggested that the pests attack on apple crops are considered as the indicators of climate change of an area. Weather and blossom time have an important role in the process of pollination in apple crop. Process of pollination is complex and is influenced by various environmental factors like relative humidity, temperature, light intensity, wind, *etc*. Ahmad (2015) studied the correlation of adult population of tortricid moths with weather parameters and revealed that maximum temperature, sunshine hours and minimum temperature had significant positive impact on the population.

Gupta and Sharma (2015) studied the seasonal incidence of apple stem borer (*Aeolesthes Holosericea* Fabricius) on apple plantations in Jammu province, India and revealed that the pest population started declining and disappeared during winter months and showed peak from August to October months. They also observed that maximum temperature, minimum temperature, average temperature, morning relative humidity, evening relative humidity and average relative humidity had highly significant positive correlation with the population of apple stem borer, whereas average rainfall had an insignificant effect on the pest population.

Mushtaq *et al.* (2018) studied the seasonal abundance of the insect visitors and its relation with environmental variables. The correlation coefficient analysis of apple visitors in relation to the weather parameters represents that lepidopterans and hymenopterans were significantly and positively correlated with temperature and light intensity and negatively correlated with relative humidity and vice versa correlation was observed for dipterans. Such factors strongly affect the foraging activity of pollinating insects; appear to act by imposing thresholds which limit the duration of activity.

So far no work has been done on insect biodiversity and seasonal incidence of major insect pests of apple in Meghalaya. Therefore, keeping in view of these considerations, the present investigations were carried out with the following objectives:

1. To study the insect biodiversity in Apple.
2. To study the seasonal incidence of major insect pests of Apple.

Chapter- 2

Review of Literature

Apple as a temperate fruit crop is very much suitable for growing in temperate regions. Meghalaya being sub-temperate and sub-tropical region, the agro-climatic condition is very much favourable for growing low chilling varieties of apple. Climatic conditions are also very conducive for multiplication of flora and fauna. The research work done on insect fauna in the state is quite scanty. Therefore the current research has been carried out with insect biodiversity and seasonal incidence of major insect pests of apple as its major objectives.

In this particular chapter the available literature of earlier research works has been reviewed and is cited below as per the objectives of the present study with the following heads:

2.1 Insect biodiversity in apple

2.1.1 Insect pests in apple

2.1.2 Natural enemies, pollinators and visitors in apple

2.2 Seasonal incidence of major insect pests of apple

2.1 Insect biodiversity in apple

2.1.1 Insect pests in apple

Teparkum (2000) studied the interaction between insects and apple trees in the orchards of Virginia and reported nearly 400 insect species are associated to the apple plants directly or indirectly and also revealed that 10 insect species were considered as serious pests of apple.

Perdikis *et al.* (2008) studied the diversity of aphids in apple orchards of Greece. They collected various aphid species viz. *Aphis pomi, Aphis spiraecola, Dysaphis pyri* and *Eriosoma lanigerum.* They also revealed that population densities of *Aphis pomi* was higher than other species and considered as the major pest of apple.

Velcheva (2009) studied the lepidopteran fauna in newly planted apple orchards of West Bulgaria during 2005-2008 and collected a total of 46 species of lepidopterous larvae comprising of 13 families viz. Tortricidae, Lymantriidae, Lasiocampidae, Saturniidae, Pieridae, Papilionidae, Geometridae, Yponomeutidae, Choreutidae, Chimabachidae, Noctuidae, Gelechiidae and Coleophoridae. It was also

revealed that the larvae of tortricidae family were found more dominantly during 2005 and 2006 while family Geometridae was dominant during 2007 and 2008.

Peeva and Velcheva (2009) studied the diversity of leaf eating lepidopterans in different apple orchards of Bulgaria during the year 2005 and 2006. They concluded that highest diversity of lepidopteran larvae was found in Sofia district where 44 species belonging to 11 families was recorded during 2005 and 40 species with 9 families during 2006. Dominant species found was *Hedya nubiferana* of Tortricidae family. They also revealed that biodiversity of lepidopterans was highly established in abandoned and organic apple orchards and recorded giant looper (*Ascotis seleneria*) as an important pest of apple.

Karaca *et al.* (2010) investigated the insect pests and diseases of apple in orchards of Isparta, Turkey from 2001 to 2004. They collected a total of 19 species from 4 different orders and concluded that Codling moth was the major pest in the surveyed area. Both Codling Moth and mites were also commonly observed. Apple leaf roller, San jose scale and leaf miners were also found frequently. They also revealed that most of the predators of aphids belongs to the family Coccinellidae. Also 7 parasitoid species comprising of 3 families were collected.

Johnson *et al.* (2012) studied the diversity and abundance of invertebrates of a six year old apple orchard in northwest Arkansas, Fayetteville. A total of 4342 invertebrates were collected constituting of various classes. Under the class Insecta, 7 orders were found viz. Diptera with 243 individuals, Coleoptera with 33 individuals, Lepidoptera with 3 individuals, Blattodea with 5 individuals, Hymenoptera with 2 individuals, one each of Heteroptera and Orthoptera.

Stastna and Psota (2013) investigated the arthropod diversity in abandoned apple orchards of South Moravia during 2010 and 2011. They collected 1408 individuals of Coleoptera with 29 families, 510 individuals of Diptera with 36 families, 44 individuals of Dermaptera with one family, 321 individuals of Hemiptera with 12 families, 745 individuals of Hymenoptera with 15 families, 128 individuals of Lepidoptera with 6 families, 3 individuals of Mecoptera with one family, 3 individuals of Neuroptera with 2 families, 6 individuals of Orthoptera with 3 families and 81 individuals of Psocoptera with 4 families. They concluded that diversity of Coleopterans were highest in the studied orchards.

Andreev *et al.* (2013) studied the occurrence and population diversity of aphids in apple orchards of South Bulgaria during 2006-2008 where they reported a total of seven aphid species viz. *Rhopalosiphum insertum* Walk, *Dysaphis plantaginea*

Pass, *Dysaphis devecta* Walker, *Macrosiphum euphorbiae* Thomas, *Aphis pomi* De Geer, *Aphis spiraecola* Patch and *Eriosoma lanigerum* Nausm. The dominant species *Dysaphis plantaginea*, was found in 97.8% of the surveyed orchards which is the most important economic threat for commercial apple orchards of South Bulgaria. Green apple aphids were the most important in young orchards and nurseries, where they developed during the entire vegetation period and infestation sometimes exceeded more than 50–80% of shoots.

Japoshvili (2015) studied the hymenopteran biodiversity in apple orchards of east Georgia and collected a total of 850 individuals of insects. Out of which 360 individuals belongs to order hymenoptera, 236 individuals of coleoptera, 239 of dipteral, 6 of hemiptera, 1 lepidoptera, 4 neuroptera and 2 thrips. Also 87 morphospecies of hymenoptera were collected.

Shah (2015) studied the diversity of aphids in apple orchards of Jammu & Kashmir from the year 2012 to 2015 and reported a total of 10 species of aphids infesting apple trees.

Kapkoti *et al.* (2016) studied the abundance and diversity of insects in apple orchards of Kumaun, India. They concluded that diversity of moths and wasps were higher during rainy season but the diversity of other insects was higher during summer season.

In an investigation carried out in Jammu, Kashmir and Ladakh region covering pome as well as stone fruits, a total of 26 species of scale insects/ mealy bugs belonging to 5 different families, viz. Coccidae, Diaspididae, Kerridae, Margarodidae and Pseudococcidae were recorded out of which 3 species were the serious pests of apple (Bhagat and Quershi, 2016).

Gupta and Pathania (2016) investigated lepidopteran pests diversity attacking apple plantations in Jammu region. They reported a total of eight species of insect pests viz. *Euproctis scintillans* Walker*, Lymantria obfuscata* Walker, *Calliteara pudibunda* Linneaus, *Thosea sinensis* Walker*, Altha nivea* Walker, *Malacosoma indica* Walker, *Hygroplasta spoliatella* Walker and *Ascotis seleneria* Denis & Schiffermuller.

Stanca-Moise (2017) recorded the diversity of insect pests in apple orchards of Sibiel village, Romania during 2015-2016 and collected a total of 7 species. They were representing 3 orders viz. Hemiptera with three species, Coleoptera with two species and Lepidoptera with two species. Also the maximum damage was caused by *Eriosoma lanigerum* and *Anthonomus pomorum* as observed.

Bhagat (2017) studied the coleopteran fauna infesting fruit plantations in Jammu & Kashmir state and recorded a total of 47 species out of which 21 species belonging to 8 different families viz., Cerambycidae, Chrysomelidae, Curculionidae, Scarabaeidae, Buprestidae, Anobiidae, Nitulidae and Scolytidae were found to infest the apple plantations. That accounts for 44.68% of total coleopteran fauna studied in that particular region.

Gupta and Pathania (2017) reported the pest diversity on apple plantations in different districts of Jammu & Kashmir, India and collected 12 species of hymenoptera which belongs to the families viz. Aphidae, Diaspididae, Pentatomidae, Scutelleridae, Fulgoridae, Jassidae and Membracidae.

Bhagat (2018) studies the diversity of moth caterpillar of family crambidae, erebidae and tortricidae affecting fruit crops in Jammu & Kashmir. A total of 55 species were collected out of which 10 species of moths were attacking apple trees.

Hussain *et al.* (2018) studied the insect pest complex of apple in Jammu and Kashmir, India and reported a total of 9 insects as major pest species viz. *Quadraspidiotus perniciosus, Panonychus ulmi, Cydia pomonella, Lymantria obfuscata, Eriosoma lanigerum, Malacosoma indicum, Aeolesthes sarta, Scolytus nitidus* and *Lyonetia clerkella.* They also concluded that insects like aphids, tussock moth, scale insects and thrips were also infesting apple trees but loss due to these pests were negligible.

2.1.2 Natural enemies, pollinators and visitors in apple

Childers and Enns (1975) observed the association of predatory arthropods with mites from commercial and abondoned apple orchards of Missouri, Columbia during the year 1972 and1973. They revealed that a total of 77 species of arthropods were associated with tetranychid mites constituting of 45 species of predatory mites and 32 species of predatory insects. They also concluded that *Neooseiulus fallacies* and *Agistemus fleschneri* were the most important predators of tetranychid mites as observed.

Arnoldi *et al.* (1992) studied the diversity of predatory mirid bugs in apple orchards of Quebec during the year 1983 and 1984. They collected a total of 8 species of mirid bugs viz. *Campylomma verbasci, Deraeocoris fasciolus, Plagiognathus obscures, Haliodes vitripennis, Lepidopsallus minisculus, Diaphnocoris provancheri, Phytocoris salicis and Phytocoris conspurcatus* on green apple aphid, European red mite and two spotted spider mite. High species diversity of *Hyaliodes vitripennis* nymphs and adults was also observed and was followed by *Lepidopsallus minisculus.*

Santos *et al.* (2008) investigated the parasitoid diversity in fruit orchards of Terceira Island, Portugal. They collected a total of 1722 individuals belonging to 34 genera and 47 species. They concluded that species viz. *Meteorus ictericus* and *Meteorus rufus* were recorded for the first time in Portugal.

Frechette *et al.* (2008) studied the predatory population on apple aphids in orchards of Canada at non-bearing stage of apple during the year 2005 and 2006. They collected a total of 529 predators including eggs, larvae, pupae and adults. They revealed that the most abundant predators were lady bird beetles with total of 6 species collected viz. *Coccinella trifasciata, Coccinella septempunctata, Coleomegilla maculata, Harmonia axyridis, Hippodamia spp*., and *Propylea quatuordecimpunctata*.

Khan *et al.* (2009) studied the biodiversity of lady bird beetles in Kashmir. They concluded that species viz. *Harmonia dimidiate, Oenopia conglobota* and *Coccinella septempunctata* was found more abundantly in apple ecosystem.

Japoshvili *et al.* (2010) studied the diversity of hymenopteran in apple orchards of Golchuk National Park, Turkey where they collected a total of 216 species belonging to 21 families. Apidae and Halictidae were the most abundant families as recorded. They also revealed that apple orchards provide micro-habitat for hymenopterans which results in high species diversity.

Mates (2010) investigated the diversity of parasitoid wasp (hymenoptera) in six apple orchards of Michigan, USA during 2009 and collected a total of 892 parasitoid wasps belonging to 16 families. Dominant family recorded was Aphelinidae with 6 species (280 wasps) followed by Eulophidae with 35 species (262 wasps). Also species diversity was highest during June-July as investigated.

Maurya (2011) investigated the natural enemies of Apple woolly aphid (*Eriosoma lanigerum*) in the orchards of Bharsar, Uttarakhand during 2008 and 2009. They reported a total of 14 natural enemies of the families viz. Syrphidae, Coccinellidae, Chrysopidae, Anthocoridae and Forficulidae.

Gontijo *et al*. (2012) investigated the diversity of natural enemies associated with woolly apple aphid in the orchards of Central Washington from 2006 to 2008. They concluded that Syrphidae, Crysopidae and Coccinellidae were the most common predators of woolly apple aphid. Syrphid species *Heringia calcarata* was recorded for the first time in Central Washington. They also reported that *Aphelinus mali* was the only parasitoid on woolly apple aphid.

Horton *et al.* (2012) studied the diversity of generalist predators community in apple orchards of Central Washington State during the year 2008 and

2009. They collected a total of 35000 individuals of predatory spiders, true bugs, ladybird beetles and lacewings. They also revealed that predatory spiders and mirid bugs were the highest in number. Coccinellidae comprised of 15 genera was also reported.

Raj *et al.* (2012) studied the diversity and abundance of different insect visitors to the flowers of apple crop in different orchards located at Shilaroo, Matiana and Narkanda of Shimla hills from 2007-2009. They revealed that the apple flowers were visited by 46 species of insects that belongs to 5 orders and 17 families. They concluded that 18 species belonged to the order of Diptera and 16 species of Hymenoptera , 8 species of Lepidoptera, 3 species of Coleoptera and one species of the order Thysanoptera. They also found that *A. cerana* was the most abundant species that visits the apple flower frequently.

Hradil *et al.* (2013) investigated the diversity of predatory true bugs in apple orchards of Czech Republic during the year 2010-2011. They selected two apple orchards viz. abandoned orchard and road alley. They collected a total of 55 species of true bugs comprising of 13 families, out of which 32 species were predator, 22 species were phytophagous and one mycetophagous species. They also concluded that family Miridae was most frequently occurring amongst the collected individuals.

Piekarska-Boniecka *et al.* (2013) studied the syrphid diversity in apple orchards as well as from their hedges of Poznan, Poland during the year 2008-2010. They collected 38 species from the orchard and 49 species from their hedges. Zoophagus species viz., *Episyrphus balteatus* and *Eupeodes corolla* were found dominantly in the orchards as recorded. They concluded that syrphid species were dominant in the hedges than the orchard itself.

Lashkari-Bod and Zebitz (2014) observed the diversity of parasitoids in organic apple orchards of Baden-Wurttemberg during 2011 and 2012. They collected a total 24 individuals of parasitoids constituting of 6 species belonging to two different families viz. Ichneumonidae and Braconidae. They also revealed that two species viz. *Trichomma enecator* and *Cremastus minor* were the most dominant.

Ganie *et al.* (2014) studied the abundance and the diversity of insect pollinators in the apple orchards of Kashmir and collected a total of 21 species of insects which belongs to 12 families depicting three orders Hymenoptera, Lepidoptera and Diptera. Also Diptera was the most abundant order with 11 species that accounts for 52.81% of the total species. It was also found that the maximum abundance was

documented by genus *Lasiogloossum of* family Halicitidae and least abundance by genus *Vanessa* of family Nymphalidae.

Tara *et al.* (2014) studied diversity of insect pollinators in apple orchards of Rajouri, Jammu during April 2012-2013. They recorded a total of six species of hymenoptera with 03 families viz., Vaspidae, Apidae and Scolidae. The species recorded were *Apis cerana indica, Bombus haemohoidalis, Xylocopa collaris*, *Eumeneous coarctatus, Odynerus* sp. and *Compsomeris presmatica.*

Sharma *et al.* (2015) investigated the diversity of predatory coccinellids in different apple orchards of Himachal Pradesh from March 2011 to November 2013. They collected total of 36 species belonging to 24 genera and 4 sub families. They also revealed that 18 number of species viz. *Brumoides suturalis, Rodolia octoguttata, Coccinella luteopicta, Coelophora saucia, Propylea dissecta, Cryptogonus orbiculus, Ortalia vietnamica, Ortalia sp., Stethorus sp., Pharoscymnus horni, Chilocorus nigrita, Sumnius vestita, Coelophora bissellata, Phrynocaria perrotteti, Psyllobora bisoctonotata, Cryptogonus trioblitus, Scymnus nubilus* and *Pharoscymnus flexibilis* were recorded for the first time in Himachal Pradesh.

Mattu and Bhagat (2015) studied the pollinator diversity and abundance of insect visitors of apple in different orchards at Kullu hills of western Himalaya. They collected a total of 39 species of insects which belongs to 6 orders and 9 families. Hymenopteran species were the most abundant constituting of 7 families viz., Apidae, Halictidae, Megachilidae, Andrenidae, Vespidae, Pteromalidae and Formicidae. Also the species *A. cerana* was the most abundant species that visits the insect flowers.

Mattu and Nirala (2016) investigated the insect visitors of apple flowers in different orchards located at Shimla hills of Western Himalaya. They collected a total of 41 species of insects comprising of 5 orders and 16 families of class Insecta out of which 13 species belong to Hymenoptera, 17 of diptera, 8 of Lepidoptera, 2 of Coleoptera and 1 of order Thysanoptera. They concluded that *A. cerana* was the most predominant species in all the orchards examined.

Khan and Riyaz (2017) studied the diversity as well as distribution of syrphid flies in the fruit orchards of Kashmir, India during 2013 and 2014. They collected 19 species comprising of 12 genera and 2 sub families. They also concluded that *Eristalis tenax* was the most dominant species of syrphid flies followed by *Eoseristalis cerealis, Eristalis interruptus* and *Episyrphus balteatus,* respectively.

Riyaz *et al.* (2018) studied the diversity of insects pollinators in apple orchards of Kashmir valley. They observed 17 species associated with three different

orders viz., Hymenoptera, Lepidoptera and Diptera. Hymenoptera were the most dominated order that visits the orchard frequently. They also revealed that mixed fruit crop cultivation increased the pollinator activity.

Mushtaq *et al.* (2018) conducted the study on diversity of insect pollinators visiting apple bloom during 2011 and 2012 in three major districts of Kashmir. They collected a total of 59 insect species visiting apple crop which comprise of 5 orders and 28 families. Hymenoptera with 27 species, Diptera with 24 species, Lepidoptera with 3 species, Coleoptera with 3 species and Odonata with 2 species, 12 species were the frequent visitors in all the regions examined. Remaining insects visited occasionally to the apple crop.

Happe *et al.* (2019) studied the diversity of predatory arthropods in the apple orchards of Germany, Spain and Sweden under different management programmes during the year 2015. They collected a total of 1,509 predatory arthropods comprising of 77 genera and 91 species. They belong to different orders viz. Araneae with 40 species, Coleoptera with 24 species, Dermaptera with 2 species, Diptera with 28 species and Opiliones with 2 species. They also revealed that organic management increased predatory arthropods diversity in the apple orchards studied.

2.2 Seasonal incidence of major insect pests of apple

Westigard and Madsen (1965) studied the bionomics of summer generations green apple aphid (*Aphis pomi* De Geer) in apple orchards of Northern California from 1959 to 1961. They found that aphid population was at peak during early June and July of 1959 and downwards during rest of year.

Fasih *et al.* (1989) reported the outbreak of *Orgyia postica* Walker as a new pest of Mango orchards of Uttar Pradesh during 1987. They concluded the defoliation of mango leaves by the larvae in June- July. They also revealed Cocoa tussock moth as a pest of Pear in Lucknow.

Kim *et al.* (2000) observed the emergence of *Carposina sasakii* in apple orchards of Korea. They found two peak periods of emergence in late of June and July. They also revealed that larval development decreased with the increase in temperature to 25^0C as well the survivorship of larvae decreased with the increasing temperature.

Vicens and Bosch (2000) studied the relation of weather factors on hymenopteran species viz. *Osmia cornuta* and *Apis mellifera* in apple orchard of Spain. They observed that activities of both the species occurred at lower temperatures

ranging from 9-12^{0}C. They also conclude that *O. cornuta* pollinated apple flowers for a longer period of time.

Funayama (2004) studied the seasonal incidence of brown marmorated stink bug in an apple orchard of Hiraka, Japan. It was observed that the pest population infestation was found from May to August and it reached to peak during mid July.

Mazzoglio *et al.* (2005) investigated the outbreak of pale tussock moth (*Calliteara pudibunda*) in deciduous fruit trees of Northwest Italy from 1990 to 1993. They monitored the pest from June to September. Peak flight was observed during July thereafter population decreases and reaches zero during September.

Gokturk and Aksu (2005) studied the morphology, biology and developmental characteristics of pale tussock moth in forest trees of Turkey from 2000 to 2003. They observed the larvae from May to October and peak flight of adults during late June.

Kumari and Gautam (2007) studied the life history and behaviour of green apple aphid on apple nurseries of Shimla and Mandi District of Himachal Pradesh from 2002 to 2006. They concluded that population of aphid starts increasing during early may and reaches its peak during June and thereafter starts declining and disappeared during September.

Singh and Bhandari (2010) studied the seasonal incidence of giant looper in Sal forest of Uttarakhand from 1999 to 2002. They revealed that the population was present in the forest from April to August. Also the population was peak during June- July.

Choi *et al.* (2011) studied the seasonal incidence and damage of geometrid moths with reference to *Ascotis seleneria* in citrus orchards of Jeju, Korea and revealed that the peak was present from late July to August.

Gupta and Tara (2014) studied the effects of weather parameters on tussock moth in apple plantations of Jammu province during 2008-2011. They found that the peak infestation was during September month. They observed positive correlation between pest population and temperature and relative humidity whereas rainfall didn't have significant effect on pest population.

Lordan *et al.* (2015) recorded the seasonal phenology of earwig species viz. *Forficula auricularia* and *Forficula pubescens* in the apple orchards of Spain during 2010-2013. They concluded that the peak period for both the species was from mid April to July.

Gupta and Tara (2015) studied the life history of green apple aphid on apple plantations in Jammu province, J&K, India. They concluded that the peak population was more during late June and August depending on weather factors.

Chandra *et al.* (2016) reported the occurrence of Cocoa tussock moth as a pest of *Jhum* Maize in Arunachal pradesh during 2014-15. They conclude the percent infestation of 7.89% to 12.64% from vegetative to silking stage of maize crop.

Tikoca *et al.* (2016) investigated the variation in moth abundance and species richness in Fijian forest. They also studied the correlation of *Calliteara* sp. with weather parameters and revealed that the population was positively correlated with maximum and minimum temperatures but negatively correlated with relative humidity and rainfall.

Khan and Shah (2018) studied the seasonal dynamics of green apple aphid (*Aphis pomi*) in relation to weather factors in three districts of Kashmir viz. Srinagar, Ganderbal and Budgam during 2012-2014. Peak population was observed during June- July. Correlation studies revealed that relative humidity had positive and rainfall had negative influence on the pest population.

Chandra *et al.* (2018) studied the seasonal incidence of cocoa tussock moth (*Orgyia postica*) in apple from March to October during 2014. They revealed that the larva was present from March to June with peak population during early June. Percent infestation recorded was about 86.25% in apple trees.

Gaikwad *et al.* (2018) studied the seasonal incidence of *Orgyia sp*. in cauliflower during 2017-18 and their correlation with weather factors revealed that the pest population was negatively significant with maximum and minimum temperature but non- significant correlation was found between the population and rainfall and relative humidity.

Mushtaq *et al.* (2018) studied the seasonal occurrence of insect visitors in apple orchards with respect to weather parameters. Correlation studies revealed that lepidopterans and hymenopterans were positively correlated with temperature and light intensity but negatively correlated with relative humidity. Also in case of dipterans vice-versa relationship was observed.

Chapter- 3

Materials and Methods

Studies on the research topic “Insect biodiversity and seasonal incidence of major insect pests of Apple in mid hills of Meghalaya” was conducted in the experimental farm of College of Post Graduate Studies in Agricultural Sciences, CAU, Umiam, Meghalaya located at an altitude of 1000 m above mean sea level with $25^0$40’N latitude to $91^0$54’E longitude respectively, during the year 2018. The climatic condition in this area is of mid tropical zone with maximum temperature ranging from 28^0C to 33^0C and minimum temperature from 2^0C to 4^0C and with an average rainfall of 2000mm. The studies included two objectives as follows:

1. To study the insect biodiversity in Apple
2. To study the seasonal incidence of major insect pests of Apple

Observations on biodiversity of insects (pests, natural enemies and visitors) and on the seasonal incidence of major insect pests of apple were taken during the year, 2018 at CGSAS, CAU (Imphal), Umiam, Meghalaya. The materials used and the methodologies applied are described below:

3.1 Studies on the insect biodiversity in apple

To study the biodiversity of insects (pests, natural enemies and visitors) in apple, the insects were collected from different low chilling varieties of apple viz. Gale gala, Red chief, Red scarlet, Tide’s men Worchester and Anna Dorset (Fig. 3.2) which were brought from Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh and planted in the experimental farm of CPGSAS, CAU (Imphal), Umiam, Meghalaya during January’ 2017. Observations and collection of the insects were done on weekly basis from January to December’ 2018. The insects were collected by means of hand picking, insect sweep nets, aspirator and using light trap. Larger insects were collected by hand picking, small insects were collected by using aspirator and flying insects by using sweep net. Different life stages of insects were collected and the immature stages of the insects were reared in the Entomology Laboratory, School of Crop Protection for emergence of adults required for proper identification. Insects collected were identified based on the established taxonomic keys and also by confirming with the specimens already present at the Insect museum in Division of Crop Protection (Entomology), ICAR Research Complex

for North-Eastern Hills Region, Umiam, Meghalaya. Insects collected were dry preserved with proper spreading and pinning of the adult insects in insect box, whereas the soft bodied insects were preserved in vials with 70% ethanol and proper labeling. Cataloging and documentation of the collected insects were done through images and photographs.

3.2 Studies on the seasonal incidence of major insect pests of apple

Nine plants of low chilling apple variety Gale Gala were randomly selected from the apple trees planted in January' 2017 with row spacing of 4m and 4m between the plants and tagged. Weekly observations of insect pests were recorded from these tagged plants during the year 2018. Selected plants were kept free from insecticidal treatments.

Adult population

The weekly observations were recorded on the total number of adult insects/ plant on all the nine plants from January to December, 2018.

Larval/Nymphal population

Selected apple plants were observed for the prevalence of larval population/ plant on all the nine plants throughout the year at weekly intervals starting from January' 2018.

Aphid infestation

The total number of aphids were counted on 10cm apical length of the twig/ shoot/ plant on all the nine apple plants and data for the year, 2018 was recorded.

3.3 Meteorological observations

Weather parameters viz. rainfall (mm), morning and evening relative humidity (%), maximum and minimum temperature (^{0}C) for the year 2018 were obtained from Meteorological section of Agricultural Engineering division of ICAR Research complex for North-Eastern Hills Region, Umiam, Meghalaya.

3.4 Statistical Analysis

Statistical method of correlation coefficient (r) was applied to study the influence of weather parameters on the population of major insect pests throughout the growing season by using the formula given by Pearson (1973).

$$r = \frac{N(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[N\sum X^2-(\sum X)^2][N\sum Y^2-(\sum Y)^2}}$$

Where, r – Regression coefficient

N – Number of observations

X – Mean of x variables

Y – Mean of y variables

Regression coefficient (R) was also worked out and fitted to exhibit the impact of independent variables on dependent variables by using formula:

$$Y = a + bX$$

Where, Y is the independent variable

X is the dependent variable

3.5 Experimental field layout

GG*	AD*	TW*
GG	GG	RS*
AD	GG	RS
GG	AD	TW
GG	PEAR	RS
AD	PEAR	RS
GG	AD	RC
GG	GG	TW
AD	GG	RC
GG	AD	RC
GG	GG	TW
AD	GG	RC
GG	AD	RC*

*GG- Gale Gala, AD- Anna Dorset, RC- Red chief, RS- Red Scarlet,

TW-Tide's men Worchester

Fig 3.1: Layout of experimental apple field

Fig 3.2: Experimental apple field

Chapter- 4

Results

The studies on “Insect biodiversity and seasonal incidence of major insect pests of Apple (*Mallus sylvestris* Mill.) in mid hills of Meghalaya” were carried out at experimental farm of CPGSAS, Umiam, Meghalaya during the year, 2018. During the course of study, the results obtained are presented in this particular chapter under following headings:

4.1 Insect biodiversity in apple.

4.1.1 Biodiversity of insect pests in apple

To study the biodiversity of insects, the insects were collected, identified, preserved and documented during the year 2018 from the experimental farm of CPGSAS, CAU, Umiam, Meghalaya. Insects were collected by various suitable techniques from Apple plants. The studies carried out revealed that apple was visited by various insect species. A total of 150 insect specimens were collected which comprises of 26 species of insect pests, 10 species of natural enemies, two species of pollinators and five species of associated visitors on apple. Identification of the insects collected were done based on the established taxonomic keys and also by confirming with specimens already present in the Insect museum of Division of Crop protection, ICAR Research Complex for North Eastern Hills Region. Based on taxonomic classification the insects were placed in 7 different orders viz. Coleoptera with 17 species, Hemiptera with 11 species, Lepidoptera with 6 species, Diptera with 4 species, Hymenoptera with 3 species, Dermeptera and Orthoptera with one species each. Details of the insect pests collected are given in Table 4.1.

4.1.2 Biodiversity of natural enemies, pollinators and visitors

Out of 150 insect specimens collected from apple trees during 2018, ten insect species were recorded as natural enemies, two as pollinators and five as visitors on apple plants. The predators consisted of one species of parasite Braconid wasp and one species of pupal parasitoid (*Brachymeria perflavipes*), one species each of Assassin bug, Earwig, syrphid fly and tachnid fly and 4 different species of Coccinellid beetles. Two species of pollinators viz., Indian honey bee and hoverfly and five species of occasional visitors was also collected, identified, preserved and catalogued. Details of the natural enemies, pollinator and visitors are presented in Table 4.2, 4.3 and 4.4, respectively.

Table 4.1: Insect pests recorded in Apple

Sl.no.	Common name	Scientific name	Order	Family	Pest Status
		Coleoptera			
1.	Oriental beetle	*Anomala orientalis* Waterhouse	Coleoptera	Scarabaeidae	Minor
2.	Jumping Flea beetle	*Altica cyanea* Weber	Coleoptera	Chrysomellidae	Minor
3.	Japanese beetle	*Popilia japonica* Newman	Coleoptera	Scarabaeidae	Minor
4.	Red cross beetle	*Collops quadrimaculatus* Fabricius	Coleoptera	Melyridae	Minor
5.	Flea beetle	*Arthrotus flavocincta* Hope	Coleoptera	Chrysomellidae	Minor
6.	Long jointed beetle	*Lagria villosa* Fabricius	Coleoptera	Tenebrionidae	Minor
7.	May beetles	*Phyllophaga ephilida* Say	Coleoptera	Scarabaeidae	Minor
8.	Leaf Chafer Beetle	*Anomala dimidiata* Hope	Coleoptera	Scarabaeidae	Minor
9.	Mexican bean beetle	*Epilachna varivestis* Mulsant	Coleoptera	Coccinellidae	Minor
10.	Weevil	*Deiradolcus spinipectus* Pajni	Coleoptera	Curculionidae	Minor
		Hemiptera			
11.	Common white mealybug	*Icerya seychellarum* Westwood	Hemiptera	Monophlebidae	Minor
12.	Tea bug	*Helopeltis bradyi* Waterhouse	Hemiptera	Miridae	Minor
13.	Red Cotton bug	*Dysdercus Koenigii* Fabricius	Hemiptera	Pyrrhocoridae	Minor
14.	Flatid plant hopper	*Ormenoides venusta* Melichar	Hemiptera	Flatidae	Minor
15.	Pod bug	*Anoplocnemis phasiana* Fabricius	Hemiptera	Coreidae	Minor

Sl.no.	Common name	Scientific name	Order	Family	Pest Status
16.	Spittle bug	*Homalostethus tabulates* Lallemand	Hemiptera	Cercopidae	Minor
17.	Green apple Aphid	*Aphis pomi* De Geer	Hemiptera	Aphididae	Major
18.	Stink Bug	*Coridius chinensis* Dallas	Hemiptera	Pentatomidae	Minor
19.	Pyrrhocorid Bug	*Melamphaus rubrocinctus* Stal	Hemiptera	Pyrrhocoridae	Minor

Lepidoptera

Sl.no.	Common name	Scientific name	Order	Family	Pest Status
20.	Giant looper	*Ascotis selenaria* Denis & Schiffermuller	Lepidoptera	Geometridae	Major
21.	Black looper	*Hyposidra talaca* Walker	Lepidoptera	Geometridae	Minor
22.	Handmaiden Moth	*Amata bicincta* Kollar	Lepidoptera	Arctiidae	Minor
23.	Tussock Moth	*Euproctis guttata* Collenette	Lepidoptera	Erebidae	Major
24.	Pale Tussock moth	*Calliteara pudibunda* Linneaus	Lepidoptera	Erebidae	Major
25.	Cocoa tussock caterpillar	*Orgyia postica* Walker	Lepidoptera	Erebidae	Major

Orthoptera

Sl.no.	Common name	Scientific name	Order	Family	Pest Status
26.	Grasshopper	*Trilophida annulata* Thunberg	Orthoptera	Acrididae	Minor

Table 4.2: Natural Enemies recorded in Apple

Sl.no.	Common name	Scientific name	Order	Family	Status
27.	Braconid wasp	*Cotesia congregata* Say	Hymenoptera	Braconidae	Parasite
28.	Pupal Parasitoid	*Brachymeria perflavipes* Girault	Hymenoptera	Chalcididae	Parasitoid
29.	Tachinid fly	*Cuphocera varia* Fabricius	Diptera	Tachinidae	Parasitoid
30.	Syrphid fly	Unidentified	Diptera	Syrphidae	Predator
31.	Assassin bug	*Cosmolestes picticeps* Stal	Hemiptera	Reduviidae	Predator
32.	Earwig	*Forficula auricularia* Linneaus	Dermeptera	Forficulidae	Predator
33.	Lady bird beetle	*Coccinella septempunctata* Linneaus	Coleoptera	Coccinellidae	Predator
34.	Coccinellid beetle	*Harmonia eucharis* Mulsant	Coleoptera	Coccinellidae	Predator
35.	Coccinellid beetle	*Oenopia kirbyi* Mulsant	Coleoptera	Coccinellidae	Predator
36.	Coccinellid beetle	*Oenopia sexareata* Mulsant	Coleoptera	Coccinellidae	Predator

Table 4.3: Pollinators recorded in Apple

Sl.no.	Common name	Scientific name	Order	Family	Status
37.	Indian honey bee	*Apis cerana indica* Fabricius	Hymenoptera	Apidae	Minor
38.	Hoverfly	*Syrphus ribesii* Linneaus	Diptera	Syrphidae	Minor

Table 4.4: Insect visitors recorded in Apple

Sl.no.	Common name	Scientific name	Order	Family	Status
39.	Litchi Trunk Borer	*Aristobia testudo* Voet	Coleoptera	Cerambycidae	Visitor
40.	Aquatic Fire fly	*Luciola ovalis* Hope	Coleoptera	Lampyridae	Visitor
41.	Indian Fire fly	*Luciola praeusta* Kiesenwetter	Coleoptera	Lampyridae	Visitor
42.	Rice earhead bug	*Leptocorisa acuta* Thunberg	Hemiptera	Alydidae	Visitor
43.	Melon Fruit fly	*Bactrocera cucurbitae* Coquillett	Diptera	Tephritidae	Visitor

Based on the damage caused by the insects collected were grouped in five major and 26 minor insect pests. Major insect pests observed were Green apple aphids (*Aphis pomi* De Geer), Pale tussock moth (*Calliteara pudibunda* Linneaus), Tussock caterpillar (*Euproctis gutatta* Collenette), Giant looper (*Ascotis selenaria* Denis & Schiffermuller) and Cocoa tussock caterpillar(*Orgyia postica* Walker)(Fig 4.1 to Fig 4.5).

In addition minor insects recorded were Oriental beetle (*Anomala orientalis),* Jumping flea beetle (*Altica cyanea),* Japanese beetle (*Popilia japonica*), Red cross beetle (*Collops quadrimaculatus*), Flea beetle *(Arthrotus flavocincta*), Long jointed beetle (*Lagria villosa*), *,* May beetles (*Phyllophaga ephilida),* Leaf chafer beetle (*Anomala dimidiata*), Mexican bean beetle (*Epilachna varivestis*), Weevil (*Deiradolcus spinipectus*), Common white mealybug (*Icerya seychellarum),* Tea bug (*Heliopeltis braydi*), Red Cotton bug (*Dysdercus Koenigii),* Flatid plant hopper (*Ormenoides venusta),* Pod bug (*Anoplocnemis phasiana),* Spittle bug (*Homalostethus tabulates),* Stink bug (*Coridius chinensis*), Pyrrhocorid Bug (*Melamphaus rubrocinctus*)*,* Black looper (*Hyposidra talaca*), Hand maiden moth (*Amata bicincta), and* Grasshopper(*Trilophida annulata)* (Fig 4.6 to Fig 4.26).

Natural enemies found during the course of study were Parasitic Braconid wasp (*Cotesia congregata*), Pupal parasitoid (*Brachymeria perflavipes*), Tachnid fly (*Cuphocera varia*), Syrphid flly maggot (Unidentified), Assassin bug (*Cosmolestes picticeps*), Earwig (*Forficula auricularia*), Lady bird beetle (*Coccinella septempunctata*), Coccinellid beetle (*Harmonia eucharis*), Coccinellid beetle (*Oenopia kirbyi*) and Coccinellid beetle (*Oenopia sexareata*) (Fig 4.27 to Fig 4.36).

Honey bees (*Apis cerana indica*) and Hoverfly (*Syrphus ribesii*) were observed as pollinators while visiting a few flowers only on one flowering plant of apple (Fig 4.37 and Fig 4.38).

Five insect species viz. Litchi trunk borer (*Aristobia testudo*), Aquatic fire fly (*Luciola ovalis*), Indian fire fly (*Luciola praeusta*), Rice earhead bug (*Leptocorisa acuta)* and Melon fruit fly (*Bactrocera cucurbitae)* were also observed visiting the apple plants occasionally during the course of study (Fig 4.39 to Fig. 4.43).

Major insect pests

Fig 4.1: Green apple aphid
(Aphis pomi)

Caterpillar

Pupa

Adult

Fig 4.2: Pale tussock moth (*Calliteara pudibunda*)

Larva

Pupa

Adult

Fig 4.3: Tussock moth (*Euproctis guttata*)

Larva

Adult

Fig 4.4: Giant looper(*Ascotis selenaria*)

Caterpillar

Larva

Adult

Fig 4.5: Cocoa tussock caterpillar (*Orgyia postica*)

Minor insect pests

Fig 4.6: Adult Oriental beetle (*Anomala orientalis*)

Fig 4.7: Adult Jumping Flea beetle (*Altica cyanea*)

Fig 4.8: Adult Japanese beetle (*Popilia japonica)*

Fig 4.9: Adult Red cross beetle (*Collops quadrimaculatus)*

Fig 4.10: Adult Flea beetle (*Arthrotus flavocincta*)

Fig 4.11: Adult Long jointed beetle (*Lagria villosa*)

Fig 4.12: Adult May beetle (*Phyllophaga ephilida)*

Fig 4.13: Adult Leaf chafer beetle (*Anomala dimidiata*)

Fig 4.14: Mexican bean beetle
(Epilachna varivestis)

Fig 4.15: Adult Weevil
(*Deiradolcus spinipectus*)

Fig 4.16: Common white mealybug
(*Icerya seychellarum)*

Fig 4.17: Adult Tea bug
(*Heliopeltis braydi*)

Fig 4.18: Adult Red cotton bug
(*Dysdercus Koenigii)*

Fig 4.19: Adult Flatid plant hopper
(*Ormenoides venusta)*

Fig 4.20: Adult Pod bug
(Anoplocnemis phasiana)

Fig 4.21: Adult Spittle bug
(Homalostethus tabulates)

Fig 4.22: Adult stink bug
(Coridius chinensis)

Fig 4.23: Adult Pyrrhocorid bug
(*Melamphaus rubrocinctus)*

Fig 4.24: Black looper (*Hyposidra talaca*)

Larva

Adult

Fig 4.25: Hand maiden Moth (*Amata bicincta*)

Fig 4.26: Adult Grasshopper
(*Trilophida annulata)*

Natural enemies

Fig 4.27: Adult Braconid wasp
(*Cotesia congregata*)

Fig 4.28: Adult pupal parasitoid
(*Brachymeria perflavipes*)

Fig 4.29: Adult tachnid fly
(*Cophocera varia*)

Fig 4.30: Syrphid fly – Maggot
(Unidentified)

Fig 4.31: Assassin bug- Nymph
(*Cosmolestes picticeps*)

Fig 4.32: Earwig - Adult
(*Forficula auricularia)*

Fig 4.33: Lady bird beetle – Adult
(*Coccinella septempunctata*)

Fig 4.34: Coccinellid beetle - Adult
(*Harmonia eucharis)*

Fig 4.35:Coccinellid beetle – Adult
(*Oenopia kirbyi*)

Fig 4.36:Coccinellid beetle – Adult
(*Oenopia sexareata*)

Pollinators

Fig 4.37: Indian Honey bee
(*Apis cerana indica*)

Fig 4.38: Adult Hoverfly
(*Syrphus ribesii*)

Associated visitors

Fig 4.39: Adult Litchi trunk borer (*Aristobia testudo*)

Fig 4.40: Adult Aquatic Firefly (*Luciola ovalis*)

Fig 4.41: Adult Indian Firefly (*Luciola praeusta)*

Fig 4.42: Adult Rice earhead bug (*Leptocorisa acuta)*

Fig 4.43: Adult melon Fruit fly (*Bactrocera cucurbitae)*

4.2 Seasonal incidence of major insect pests of apple.

Observations on the seasonal incidence of major insect pests of apple were recorded in the experimental farm of CPGSAS, CAU, Umiam during the year, 2018. Weekly observations were taken from 1st standard meteorological week (SMW) i.e. 1st week of January, 2018 onwards till 52nd SMW i.e. last week of December, 2018. Seasonal incidence of Green apple aphid (*Aphis pomi* De Geer), Pale tussock moth (*Calliteara pudibunda* Linneaus), Tussock moth (*Euproctis guttata* Collenette), Giant looper (*Ascotis selenaria* Denis & Schiffermuller) and Cocoa tussock moth (*Orgyia postica* Walker) in relation to weather parameters viz. evening and morning relative humidity (%), maximum and minimum temperature (^{0}C), and rainfall (mm) is depicted graphically in Fig 2,3,4,5 and 6, respectively as follows:

4.2.1 Green apple aphid (*Aphis pomi* De Geer)

Observations were made on 10cm apical length of twigs/shoot/plant and the aphids were first detected on 13th SMW (last week of March, 2018) with the mean population of 1.74 aphids/10cm apical length of twig/shoot/plant when the evening and morning relative humidity, maximum and minimum temperature and rainfall were 50%, 86%, 25°C, 14.7°C and 1.4mm, respectively. The population of aphids thereafter increased and reached to its peak on 25th SMW (3rd week of June, 2018) with mean population of 34.75 aphids/ 10cm apical length of twig/shoot/plant. Meteorological data viz. evening and morning relative humidity, maximum and minimum temperature and rainfall were 87%, 87%, 28.9°C, 19.3°C and 0.0 mm, respectively. Subsequently, the population started decreasing and reached to the lowest of 1.68 aphids/ 10cm apical length of twig/ shoot/ plant on 38th SMW (3rd week of September) when evening and morning relative humidity, maximum and minimum temperature and rainfall were 69%, 91%, 30.3°C, 21.8°C and 9.3mm, respectively as presented in Table 4.6 and Figure 2. No aphid population was observed after 38th SMW.

Table 4.6: Seasonal incidence of Green apple aphid (*Aphis pomi* De Geer) on apple variety Gale Gala during the year, 2018

Date of Observation	SMW	Mean no. of Green apple aphid/10cm twig/shoot	Relative humidity (%)		Temperature(°C)		Rainfall (mm)
			Evening	Morning	Maximum	Minimum	
28-Mar	13	1.74	50	86	25	14.7	1.4
04-Apr	14	9.13	58	86	28.4	13.3	24.3
11-Apr	15	12.72	91	87	25.3	14.2	0
18-Apr	16	14.11	65	87	27	15.4	0
25-Apr	17	15.53	42	80	28.4	15.3	0
02-May	18	13.58	94	92	23.9	15	20.6
09-May	19	19.72	89	88	27.2	19.2	8.6
16-May	20	15.99	66	88	25	15.7	15.5
23-May	21	23.75	79	82	27.1	17.9	0
30-May	22	28.86	70	90	28.8	17.9	0
06-Jun	23	26.78	62	94	28.8	17.5	43.7
13-Jun	24	23.92	77	93	28	20.3	75.1
20-Jun	25	34.75	87	87	28.9	19.3	0
27-Jun	26	24.96	71	91	27.9	20.5	3.8
04-Jul	27	23.11	95	93	27	21.2	22.2
11-Jul	28	25.02	77	88	28.8	21.8	0
18-Jul	29	28.73	71	92	29.4	20.7	5.3
25-Jul	30	21.77	74	86	28.3	20.6	2
01-Aug	31	19.73	79	88	26.8	21	17.4
08-Aug	32	25.11	78	95	30.4	20	33.3
15-Aug	33	22.11	70	88	29.7	21.4	11.6
22-Aug	34	17.96	69	83	29.8	22.4	0
29-Aug	35	15.94	93	83	30	21.5	7.9
05-Sep	36	8.79	68	90	28.4	20.3	47
12-Sep	37	6.79	84	90	23.5	18.8	22.2
19-Sep	38	1.68	69	91	30.3	21.8	9.3

Total no. of plants taken for observation (n) = 9

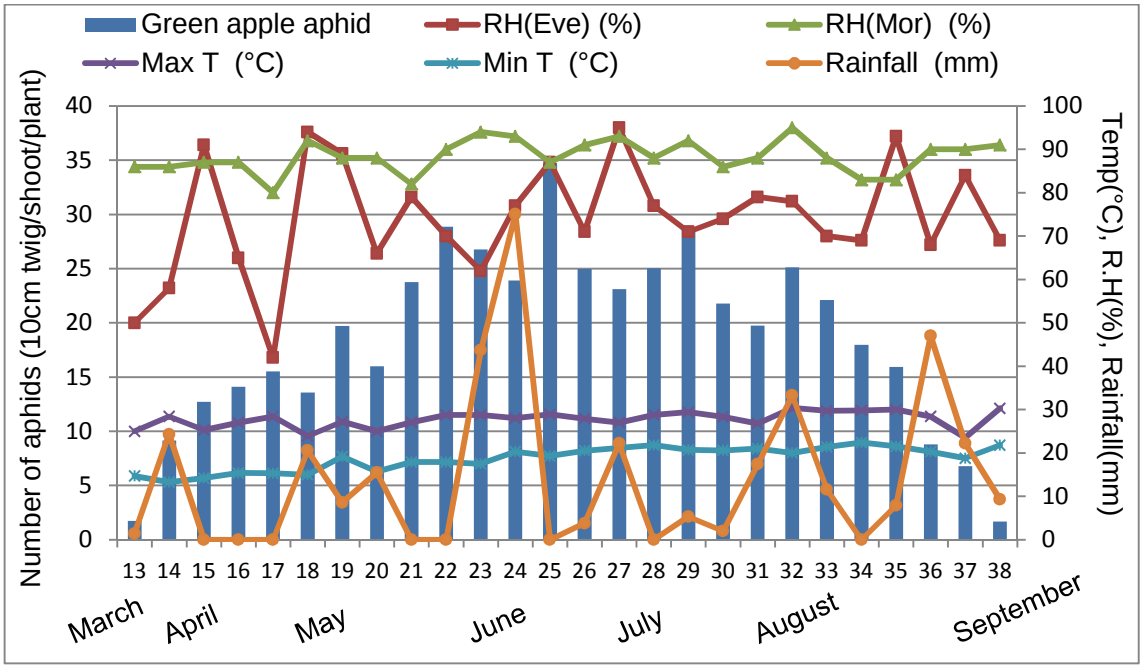

Figure 4.44: Seasonal incidence of Green apple aphid during the year, 2018.

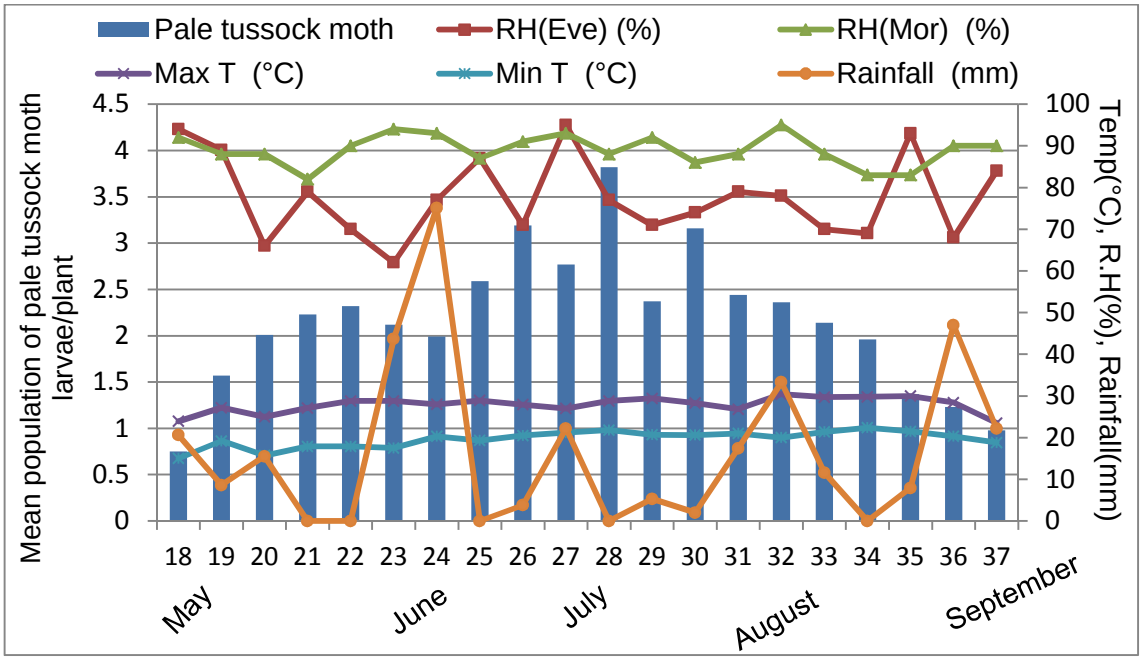

Figure 4.45: Seasonal incidence of Pale tussock moth during the year, 2018.

4.2.2 Pale tussock moth (*Calliteara pudibunda* Linneaus)

During the course of study, observations were recorded on the larval population of pale tussock moth. The larval population was observed from 18th SMW (1st week of May, 2018) till 37th SMW (2nd week of September, 2018). The mean larval population of 0.75 larva/ plant was first observed during 18th SMW when the, evening and morning relative humidity, maximum and minimum temperature and rainfall were 94%, 92%, 23.9°C, 15°C and 20.6mm respectively. Thereafter the larval population started increasing and attained its peak during 28th SMW (2nd week of July, 2018) with larval population of 3.82 larva/ plant when the, evening and morning relative humidity, maximum and minimum temperature and rainfall were 77%, 88%, 28.8°C, 21.8°C and 0.0 mm, respectively. Subsequently, the larval population started decreasing and reached to the minimum of 0.98 larva/ plant on 37th SMW (2nd week of September, 2018) when the evening and morning relative humidity, maximum and minimum temperature and rainfall were 84%, 90%, 23.5°C, 18°C and 22.2mm, respectively as presented in Table 4.7 and Figure 3.

Table 4.7: Seasonal incidence of Pale tussock moth (*Calliteara pudibunda* Linnaeus) on apple variety Gale Gala during the year, 2018

Date of Observation	SMW	Mean no. of pale tussock moth larvae/plant	Relative humidity(%)		Temperature (°C)		Rainfall (mm)
			Evening	Morning	Maximum	Minimum	
02-May	18	0.75	94	92	23.9	15	20.6
09-May	19	1.57	89	88	27.2	19.2	8.6
16-May	20	2.01	66	88	25	15.7	15.5
23-May	21	2.23	79	82	27.1	17.9	0
30-May	22	2.32	70	90	28.8	17.9	0
06-Jun	23	2.12	62	94	28.8	17.5	43.7
13-Jun	24	1.99	77	93	28	20.3	75.1
20-Jun	25	2.59	87	87	28.9	19.3	0
27-Jun	26	3.19	71	91	27.9	20.5	3.8
04-Jul	27	2.77	95	93	27	21.2	22.2
11-Jul	28	3.82	77	88	28.8	21.8	0
18-Jul	29	2.37	71	92	29.4	20.7	5.3
25-Jul	30	3.16	74	86	28.3	20.6	2
01-Aug	31	2.44	79	88	26.8	21	17.4
08-Aug	32	2.36	78	95	30.4	20	33.3
15-Aug	33	2.14	70	88	29.7	21.4	11.6
22-Aug	34	1.96	69	83	29.8	22.4	0
29-Aug	35	1.37	93	83	30	21.5	7.9
05-Sep	36	1.23	68	90	28.4	20.3	47
12-Sep	37	0.98	84	90	23.5	18.8	22.2

Total no. of plants taken for observation (n) = 9

4.2.3 Tussock moth (*Euproctis guttata* Collenette)

The caterpillars of tussock moth were first observed on 26th SMW (last week of June, 2018) with mean larval population of 0.42 larvae/ plant when the evening and morning relative humidity, maximum and minimum temperature and rainfall were 71%, 91%, 27.9°C, 20.5°C and 3.8mm respectively. The population thereafter started increasing and attained its peak during 35th SMW (last week of August) with an average larval population of 4.15 larvae/ plant when the evening and morning relative humidity, maximum and minimum temperature and rainfall were 93%, 83%, 30°C, 21.5°C and 7.9mm, respectively. Thereafter the population was found declining and the lowest mean population of 0.21 larva/ plant was recorded on 42nd SMW (3rd week of October) when evening and morning relative humidity, maximum and minimum temperature and rainfall were 66%, 85%, 25.4°C, 15.4°C and 5.4mm, respectively, as presented in Table 4.8 and Figure 4.

Table 4.8: Seasonal incidence of Tussock moth (*Euproctis guttata* Collenette) on apple variety Gale Gala during the year, 2018

Date of observation	SMW	Mean no. of tussock moth larva/plant	Relative humidity (%)		Temperature (°C)		Rainfall (mm)
			Evening	Morning	Maximum	Minimum	
27-Jun	26	0.42	71	91	27.9	20.5	3.8
04-Jul	27	0.83	95	93	27	21.2	22.2
11-Jul	28	1.24	77	88	28.8	21.8	0
18-Jul	29	1.97	71	92	29.4	20.7	5.3
25-Jul	30	2.64	74	86	28.3	20.6	2
01-Aug	31	3.17	79	88	26.8	21	17.4
08-Aug	32	2.87	78	95	30.4	20	33.3
15-Aug	33	3.77	70	88	29.7	21.4	11.6
22-Aug	34	3.14	69	83	29.8	22.4	0
29-Aug	35	4.15	93	83	30	21.5	7.9
05-Sep	36	3.27	68	90	28.4	20.3	47
12-Sep	37	2.43	84	90	23.5	18.8	22.2
19-Sep	38	1.94	69	91	30.3	21.8	9.3
26-Sep	39	1.07	78	86	29	17.9	0
03-Oct	40	1.21	58	82	27.3	16.1	0
10-Oct	41	0.88	67	88	25.7	16.6	0
17-Oct	42	0.21	66	85	25.4	15.4	5.4

Total no. of plants taken for observation (n) = 9

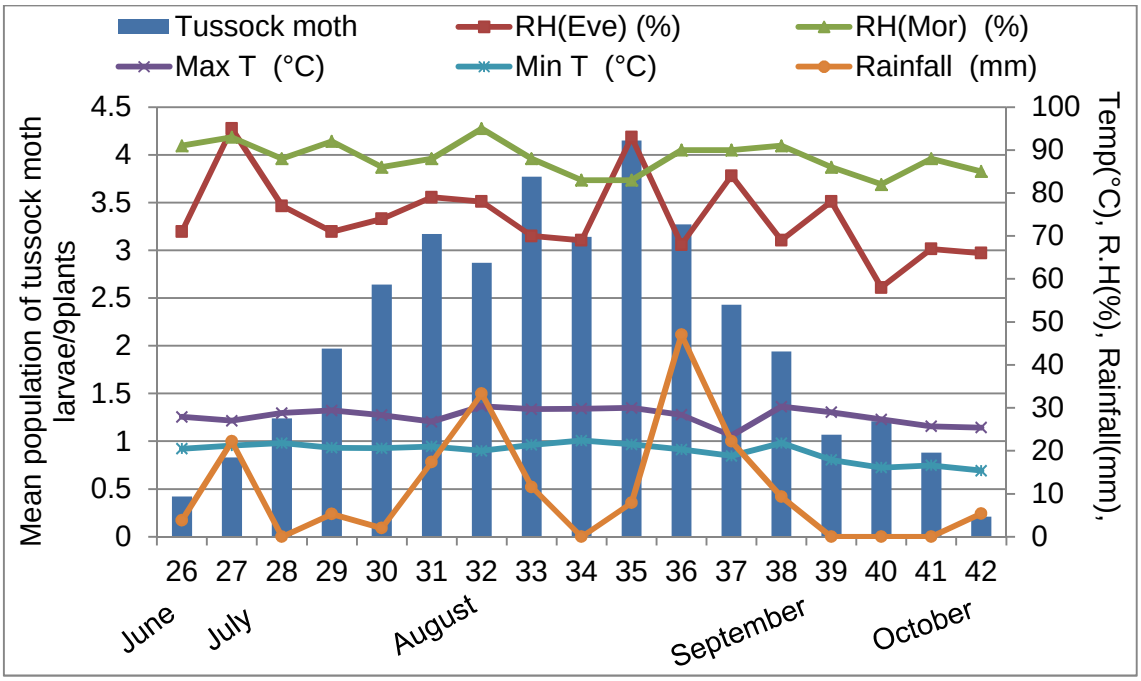

Figure 4.46: Seasonal incidence of Tussock moth during the year, 2018.

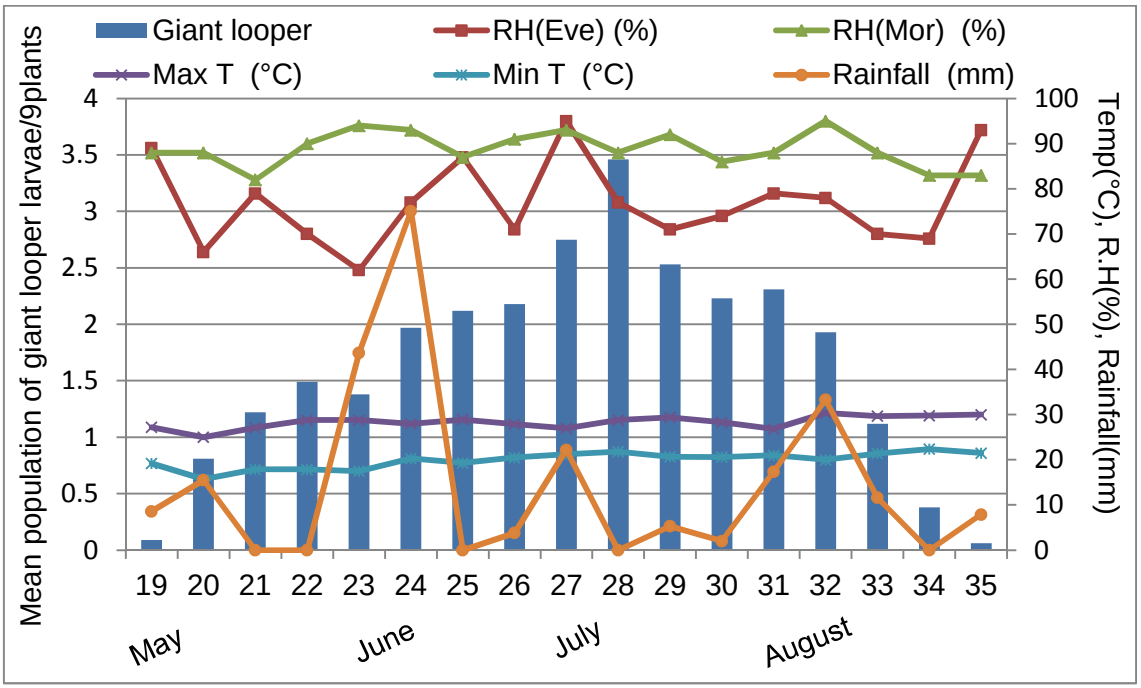

Figure 4.47: Seasonal incidence of Giant looper during the year, 2018.

4.2.4 Giant looper (*Ascotis selenaria* Denis & Schiffermuller)

The pest was first observed on 19th SMW (2nd week of May, 2018) with mean larval population of 0.09 larvae/ plant when the evening and morning relative humidity, maximum and minimum temperature and rainfall were 89%, 88%, 27.4°C, 19.2°C and 8.6mm, respectively. The highest population was observed on 28th SMW (2nd week of July, 2018) with larval population of 3.46 larvae/ plant during which evening and morning relative humidity, maximum and minimum temperature and rainfall were 77%, 88%, 28.8°C, 21.8°C and 0.0 mm, respectively. The lowest population of 0.06 larvae/ plant was observed on 35th SMW (last week of August, 2018) when evening and morning relative humidity, maximum and minimum temperature and rainfall were 93%, 83%, 30°C, 21.5°C and 7.9mm, respectively as presented in Table 4.9 and Figure 5.

Table 4.9: Seasonal incidence of Giant looper (*Ascotis selenaria* Denis & Schiffermuller) on apple variety Gale Gala during the year, 2018

Date of observation	SMW	Mean no. of giant looper/plant	Relative Humidity (%)		Temperature (^{0}C)		Rainfall (mm)
			Evening	Morning	Maximum	Minimum	
09-May	19	0.09	89	88	27.2	19.2	8.6
16-May	20	0.81	66	88	25	15.7	15.5
23-May	21	1.22	79	82	27.1	17.9	0
30-May	22	1.49	70	90	28.8	17.9	0
06-Jun	23	1.38	62	94	28.8	17.5	43.7
13-Jun	24	1.97	77	93	28	20.3	75.1
20-Jun	25	2.12	87	87	28.9	19.3	0
27-Jun	26	2.18	71	91	27.9	20.5	3.8
04-Jul	27	2.75	95	93	27	21.2	22.2
11-Jul	28	3.46	77	88	28.8	21.8	0
18-Jul	29	2.53	71	92	29.4	20.7	5.3
25-Jul	30	2.23	74	86	28.3	20.6	2
01-Aug	31	2.31	79	88	26.8	21	17.4
08-Aug	32	1.93	78	95	30.4	20	33.3
15-Aug	33	1.12	70	88	29.7	21.4	11.6
22-Aug	34	0.38	69	83	29.8	22.4	0
29-Aug	35	0.06	93	83	30	21.5	7.9

Total no. of plants taken for observation (n) = 9

4.2.5 Cocoa tussock Moth (*Orgyia postica* Walker)

The results on weekly observations made on the pest showed that the pest was first observed on 17th SMW (last week of April, 2018) with mean larval population of 0.54 larva/ plant when the weather parameters viz. evening and morning relative humidity, maximum and minimum temperature and rainfall recorded were 42%, 80%, 28.4°C, 15.3°C, 0mm, respectively. The highest mean larval population of 4.75 larvae/ plant was obtained on 27th June, 2018 (last week of June and 26th SMW, 2018) during which the evening and morning relative humidity, maximum and minimum temperature and rainfall were 71%, 91%, 27.9°C, 20.5°C and 3.8mm, respectively. Thereafter the population started declining and reached 0.47 larvae/ plant on 37th SMW (2nd week of September, 2018) when the weather factors viz. the evening and morning relative humidity, maximum and minimum temperature and rainfall were 84%, 90%, 23.5.8°C, 18.8°C, 22.2mm, respectively as presented in Table 4.10 and Figure 6.

Table 4.10: Seasonal incidence of Cocoa tussock moth (*Orgyia postica* Walker) on apple variety Gale Gala during the year, 2018

Date of Observation	SMW	Mean no. of cocoa tussock moth larvae/plant	Relative humidity (%)		Temperature(°C)		Rainfall (mm)
			Evening	Morning	Maximum	Minimum	
25-Apr	17	0.54	42	80	28.4	15.3	0
02-May	18	0.89	94	92	23.9	15	20.6
09-May	19	1.53	89	88	27.2	19.2	8.6
16-May	20	1.97	66	88	25	15.7	15.5
23-May	21	1.65	79	82	27.1	17.9	0
30-May	22	1.82	70	90	28.8	17.9	0
06-Jun	23	2.29	62	94	28.8	17.5	43.7
13-Jun	24	2.82	77	93	28	20.3	75.1
20-Jun	25	3.79	87	87	28.9	19.3	0
27-Jun	26	4.75	71	91	27.9	20.5	3.8
04-Jul	27	3.56	95	93	27	21.2	22.2
11-Jul	28	3.79	77	88	28.8	21.8	0
18-Jul	29	3.34	71	92	29.4	20.7	5.3
25-Jul	30	2.51	74	86	28.3	20.6	2
01-Aug	31	2.66	79	88	26.8	21	17.4
08-Aug	32	2.23	78	95	30.4	20	33.3
15-Aug	33	1.85	70	88	29.7	21.4	11.6
22-Aug	34	1.66	69	83	29.8	22.4	0
29-Aug	35	1.35	93	83	30	21.5	7.9
05-Sep	36	0.84	68	90	28.4	20.3	47
12-Sep	37	0.47	84	90	23.5	18.8	22.2

Total no. of plants taken for observation (n) = 9

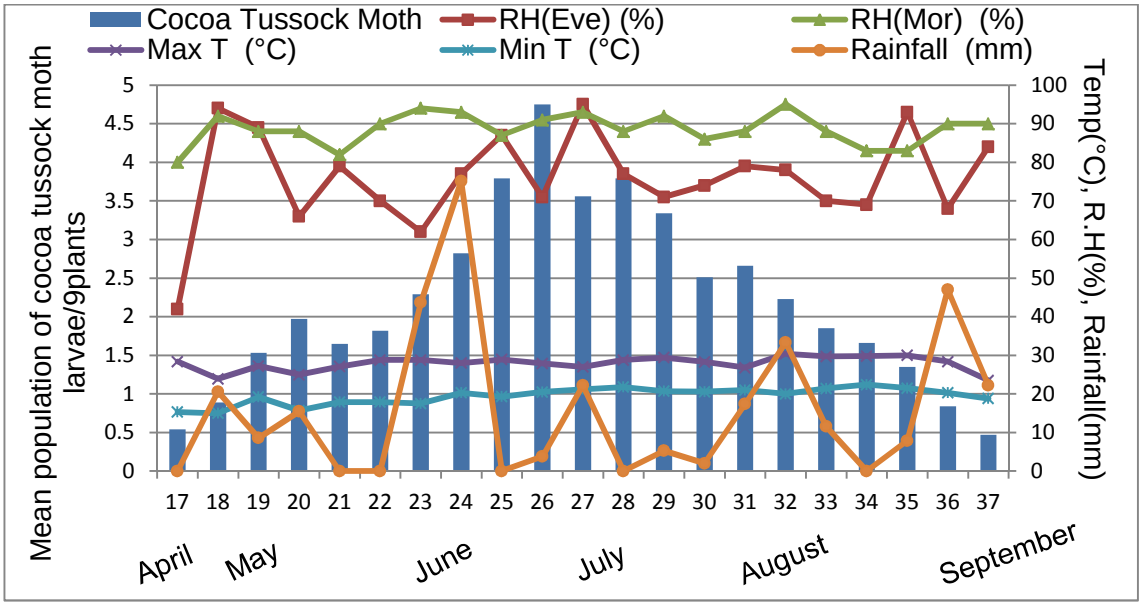

Figure 4.48: Seasonal incidence of Cocoa tussock moth during the year, 2018.

4.2.6 Correlation studies

Correlation Coefficient (r) analysis of major insect pests of apple viz. Green apple aphids (*Aphis pomi* De Geer), Pale tussock moth (*Calliteara pudibunda* Linneaus), Tussock moth (*Euproctis guttata* Collenette), Giant looper (*Ascotis selenaria* Denis & Schiffermuller) and Cocoa tussock moth (*Orgyia postica* Walker) with the weather parameters viz. evening and morning relative humidity, maximum and minimum temperature and rainfall were statistically analysed and presented in Table 4.11.

4.2.6.1 Green apple aphid (*Aphis pomi* De Geer)

Correlation study presented in Table 4.11 exhibited that association between green apple aphid and evening and morning RH and minimum temperature was non-significant positive (r = 0.255, r = 0.203 and r = 0.351 respectively) whereas non significant negative correlation (r = -0.014) with rainfall but showed significantly positive correlation (r = 0.389*) with maximum temperature.

Simple regression line of mean population of green apple aphid and maximum temperature is presented diagrammatically in (Figure 7).

4.2.6.2 Pale tussock moth (*Calliteara pudibunda* Linneaus)

Correlation analysis of pale tussock moth population with weather parameters presented in Table 4.11 showed a positive non significant correlation with the maximum and minimum temperature (r = 0.414 and r = 0.425, respectively) and non significant negative correlation with evening and morning RH (r = -0.248 and r = -0.006, respectively) and rainfall (r = -0.344).

4.2.6.3 Tussock moth (*Euproctis guttata* Collenette)

The relationship between tussock moth larval population and weather parameters as presented in Table 4.11 indicated a positive non significant relationship with evening RH (r = 0.231), maximum temperature (r = 0.426) and rainfall (r = 0.388) and negative non significant correlation with morning RH (r = -0.102). The association between tussock moth and minimum temperature showed positively significant correlation (r = 0.560*).

Regression equation has been fit to explain the relation between mean population of tussock moth and minimum temperature (Figure 8).

4.2.6.4 Giant looper (*Ascotis selenaria* Denis & Schiffermuller)

The association of giant looper population with weather parameters presented in Table 4.11 indicated that the pest population is non significantly related to the abiotic factors. It also showed a positive non-significant correlation with morning RH, minimum temperature and rainfall (r = 0.460, r = 0.250 and r = 0.067, respectively) but negative non-significant correlation with evening RH (r = -0.006) and maximum temperature (r = -0.025).

4.2.6.5 Cocoa tussock moth (*Orgyia postica* Walker)

A positive and significant correlation (r = 0.450*) was found between the cocoa tussock moth and minimum temperature but positive non-significantly correlated with evening RH (r = 0.148), morning RH(r = 0.337) and maximum temperature (r = 0.286), however there was a negative non-significantly correlation with rainfall (r = -0.099) as given in Table 4.11.

A simple regression equation has been fit by straight to explain the relation between mean population of cocoa tussock moth and minimum temperature (Figure 9).

Table 4.11: Correlation coefficient (r) between population of major insect pests of apple with weather parameters

Insect pests	Correlation coefficient (r)				
	Relative humidity (%)		Temperature (°C)		Rainfall (mm)
	Evening	Morning	Maximum	Minimum	
Green apple aphid	0.255	0.203	**0.389***	0.351	-0.014
Pale tussock moth	-0.248	-0.006	0.414	0.425	-0.344
Tussock moth	0.231	-0.102	0.426	**0.560***	0.388
Giant looper	-0.006	0.460	-0.025	0.250	0.067
Cocoa tussock moth	0.148	0.337	0.286	**0.450***	-0.099

*Significant at 5%;Non significant (Without asteric)

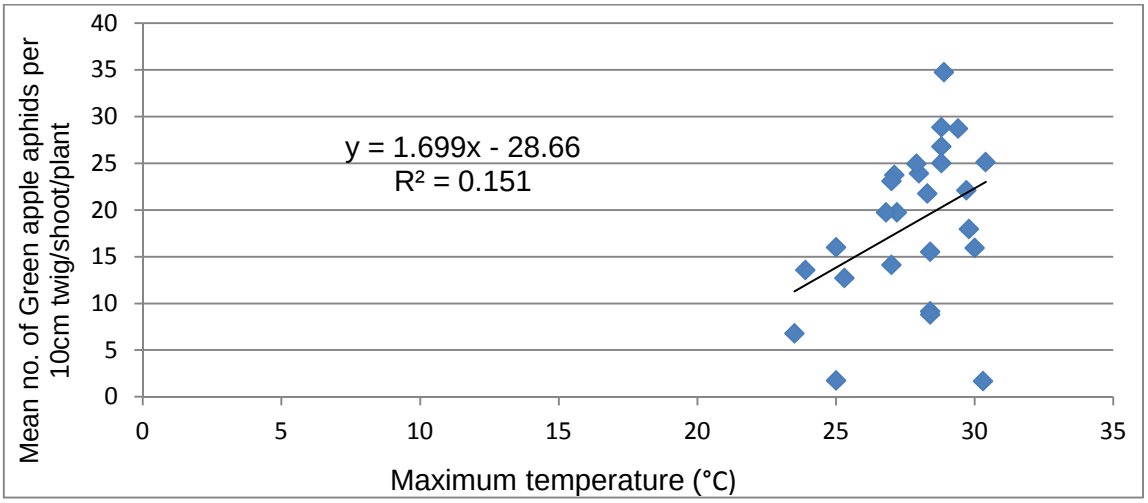

Figure 4.49: Regression coefficient (R) between the mean population of green apple aphid with maximum temperature

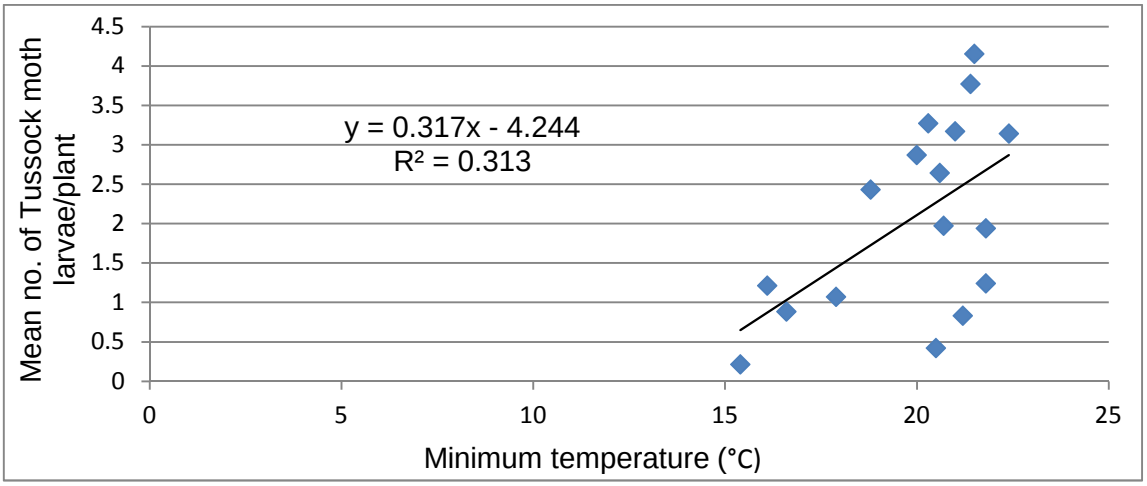

Figure 4.50: Regression coefficient (R) between the mean population of tussock moth with minimum temperature

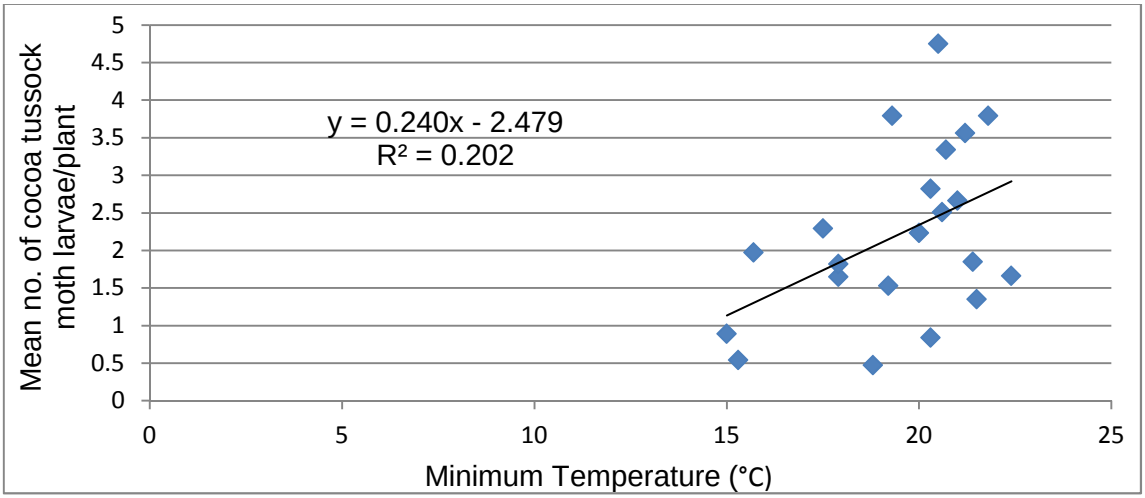

Figure 4.51: Regression coefficient (R) between the mean population of cocoa tussock moth and minimum temperature

Chapter-5

Discussion

The present investigation on “Insect biodiversity and seasonal incidence of major insect pests of apple in mid hill of Meghalaya” was carried out during the year, 2018 with two major objectives which are given below:

1. To study the insect biodiversity in apple.
2. To study the seasonal incidence of major insect pests of apple.

Insect biodiversity and seasonal incidence of major insect pests of apple were studied and the objective wise observations are discussed in this particular chapter under following headings:

5.1 Insect biodiversity in apple

5.1.1 Biodiversity of insect pests in apple

During the course of study, a total of 150 insect specimens were collected from the Experimental farm of CPGSAS, CAU, Umiam, Meghalaya. Identification of the insects collected was done based on the established taxonomic keys and previously cited literatures. The identification of insects was also confirmed with insect specimens already present in the Insect museum of Division of Crop protection, ICAR Research Complex for North Eastern Hills Region, Umiam, Meghalaya. A total of 26 species of insect pests, 10 species of natural enemies, two species of pollinators and five species of insects as visitors were collected. Based on taxonomic classification, the insects were placed in 7 different orders viz. Coleoptera with 17 species, Hemiptera with 11 species, Lepidoptera with 6 species, Diptera with 4 species, Hymenoptera with 3 species, Dermeptera and Orthoptera with one species each.

The work of Teparkum (2000), who reported about 400 insects associated directly or indirectly with the apple crop. Of these insect species, 100 species feed on apple tree or fruit is in close conformity with the present findings that 43 insect species are directly or indirectly associated with the apple crop. The less number of insect species infesting apple crop might be due to the introduction of apple crop for the first time at mid altitude hills of Meghalaya. The present findings are also in similarity with the work of Johnsan *et al.* (2012) who studied the diversity and

abundance of invertebrates on apple and collected a total of 4342 invertebrates mainly belonging to class Insecta. In the present investigations, coleopteran insects were found dominant among all the insects in apple orchard similar to the findings of Stastna and Psota (2013) who also reported the highest diversity of coleopterans in apple orchards of South Moravia.

Based on the mean population and damage caused by insect species, they were grouped into 5 major and 21 minor insect pests of apple in mid hills of Meghalaya. The major insect pests recorded on apple during 2018 were Green apple aphids (*Aphis pomi* De Geer), Pale tussock moth (*Calliteara pudibunda* Linneaus), Tussock moth (*Euproctis guttata* Collenette), Giant looper (*Ascotis selenaria* Denis & Schiffermuller) and Cocoa tussock moth (*Orgyia postica* Walker).

The present investigations showed similarity with the results obtained by Peeva and Velcheva (2009) who reported Giant looper (*Ascotis seleneria* Denis & Schiffermuller) and Pale tussock moth (*Calliteara pudibunda* Linneaus) as major insect pests of apple orchards in Bulgaria. Andreev *et al.* (2013) reported Green apple aphids (*Aphis pomi* De Geer) in apple orchards of South Bulgaria. Gupta and Pathania (2016) also found Giant looper (*Ascotis seleneria* Denis & Schiffermuller) and Pale tussock moth (*Calliteara pudibunda* Linneaus) as major insect pests in the apple orchards of Jammu region, India.

Present findings also revealed that Green apple aphid (*Aphis pomi)* and cocoa tussock moth (*Orgyia postica)* were the most destructive pests of apple in this region. These findings are supported by Gupta and Tara (2015) who reported green apple aphid as a major pest of apple in different districts of Jammu & Kashmir, India. Chandra *et al.* (2018) also reported cocoa tussock moth (*Orgyia postica)* as a major insect pest of apple.

5.1.2 Biodiversity of natural enemies, pollinators and insect visitors in apple

A total of 10 species of natural enemies, two species of pollinators and 5 species of insect visitors were collected, identified and preserved. Natural enemies identified were predators consisting of one species each of parasitic Braconid wasp (*Cotesia congregata*), pupal parasitoid (*Brachymeria perflavipes*), Assassin bug (*Cosmolestes picticeps*), syrphid fly maggot(Unidentified), Earwig (*Forficula auricularia*), and tachnid fly (*Cuphocera varia*) and 4 different species of Coccinellid beetles. These results obtained were in conformity with the findings of Frechette *et al.*

(2008), Khan *et al.* (2009) and Horton *et al.* (2012) who reported Coccinellid beetles as the most dominant predators in apple orchards.

Gontijo *et al.* (2012) also concluded that Coccinellidae and Syrphidae were the most common predators found in the apple orchards of Central Washington.Hradil *et al*. (2013) reported mirid bugs as most dominant predators in apple and also observed that coccinellid beetles were present abundantly in apple orchards.

Mates (2010) investigated the diversity of parasitoid wasp and reported that wasps belonging to eulophidae and aphelinidae families were dominant which is in disagreement with the present findings as the wasps of Braconidae and Chalcididae families were dominant during the course of study which might be due different geographical location and insect pests available in this area.

Pollinators collected, identified and preserved were hoverfly adult (*Syrphus* sp.) and Indian honey bee (*Apis cerana indica)* and the findings were in conformity with the results obtained by Raj *et al.* (2012) who reported Indian honey bee (*Apis cerana* indica) as major insect pollinator visiting apple flowers frequently. Mattu and Nirala (2013) and Tara *et al.* (2014) also reported *Apis Cerana indica* as frequent and dominant visitors of apple orchards in Himachal Pradesh.

Five species of occasional insect visitors viz. Litchi trunk borer, Aquatic fire fly, Indian fire fly, Rice earhead bug and Melon fruit fly were collected and identified during the course of study. Mushtaq *et al.* (2018) studied the diversity of insect pollinators and collected a total of 59 insect species of which 12 species were reported as occasional visitors to the apple crop, similar to the findings of present investigation that five insect species were occasional visitors to the crop

5.2 Seasonal incidence of major insect pests of apple

The seasonal incidence of major insect pests of apple in mid hills of Meghalaya was studied and discussed as below:

5.2.1 Green apple aphid (*Aphis pomi* De Geer)

The population of green apple aphid was first observed on 13th standard meteorological week (SMW) i.e. last week of March with 1.74 aphids/ 10cm apical length/ shoot/plant. The population further increased and reached maximum on 25th SMW i.e. 3rd week of June, with mean population of 34.75 aphids/ 10cm apical length/ shoot/plant. Thereafter the population started declining and reached 1.68 aphids/ 10cm apical length/ shoot/plant on 38th SMW (3rd week of September).

These findings are in close proximity with the results obtained by Westigard and Madsen (1965) and Kumari and Gautam (2007) who have also reported that the pest population started appearing during May and reached peak during the month of June and then started decreasing and disappeared during September. Present findings are also in agreement with Gupta and Tara (2015) who also concluded that the aphid population reached peak during late June.

The correlation between the weather parameters viz. evening and morning relative humidity, maximum and minimum temperature and rainfall with the mean population of aphids was done. It was observed that the aphid population showed a positive non-significant relationship with evening RH, morning RH and rainfall (r = 0.255, r = 0.203 and r = 0.351, respectively) whereas rainfall exhibited negative non-significant correlation (r = -0.014) with aphid population. A positive and significant correlation (r = 0.389) was exhibited between the aphid population and maximum temperature. The present findings are in agreement with Khan and Shah (2018) who revealed that relative humidity and maximum temperature had positive and rainfall had negative influence on aphid population.

5.2.2 Pale tussock moth (*Calliteara pudibunda* Linneaus)

Larval population of 0.75 larva/plant was first observed on 18th SMW i.e. 1st week of May, 2018. Larval population thereafter increased and reached its peak during 28th SMW (2nd week of July) with pest population of 3.82 larva/plant. Thereafter the pest population starts declining and the lowest pest population of 0.98 larva/plant was observed during 37th SMW (2nd week of September). These findings are in close conformity with the results obtained by Mazzoglio *et al*. (2005) who observed the peak activity of pale tussock moth during the month of July.

Gokturk and Aksu (2005) also revealed that the pale tussock moth population attains its peak during late June which is in close conformity with the findings which might be due to different geographical conditions.

The relationship of the mean population was non-significantly positively correlated with maximum and minimum temperature (r = 0.414 and r = 0.425, respectively) but non-significant negatively correlated with evening and morning relative humidity and rainfall (r = -0.248, r = -0.006 and r = -0.344, respectively). These findings are in accordance with the results obtained by Tikoca *et al.* (2016) who studied the seasonal incidence of *Calliteara sp*. in Fijian forest and recorded positive correlation with maximum and minimum temperatures but negative correlation with rainfall and relative humidity.

5.2.3 Tussock moth (*Euproctis guttata* Collenette)

Population of tussock moth larvae was observed from 26th SMW i.e. last week of June till 42nd SMW (3rd week of October). Peak larval population of 4.15 larva/ plant was observed during 35th SMW (last week of August). Thereafter the population started declining and reached 0.21 larvae/ plant during 3rd week of October.

These results are in agreement with the findings of Gupta and Tara (2014) who also observed the peak infestation of tussock moth during the month of August in Himachal Pradesh.

The association of mean larval population was positively and significantly correlated with minimum temperature (r = 0.560) whereas positive non significant relationship was observed between the larval population and evening RH, maximum temperature and rainfall (r = 0.231, r = 0.426 and r = 0.388, respectively) and negative non significant association was observed with morning RH (r = -0.102).

These findings are also in conformity with the findings of Gupta and Tara (2014) who recorded significantly positive correlation with minimum temperature and non-significant relation with the rainfall.

5.2.4 Giant looper (*Ascotis seleneria* Denis & Schiffermuller)

The giant looper population was first observed during 19th SMW (2nd week of May) with mean larval population of 0.09 larva/plant. Pest population thereafter increased and attained its peak in 28th SMW (2nd week of July) with larval population of 3.46 larva/plant. Subsequently, the mean population started declining and reached the minimum of 0.06 larva/ plant on 35th SMW i.e. last week of August.

The present findings are in similarity with the results obtained by Singh and Bhandari (2010) who studied the seasonal incidence of giant looper in Sal forest of Uttarakhand and revealed that peak population was during the month of June - July.

Correlation studies between mean population of giant looper and weather parameters exhibited a positive non-significant correlation with morning RH (r = 0.460), minimum temperature (r = 0.250) and rainfall (r = 0.067) but non-significant and negative correlation with evening RH (r = -0.006) and maximum temperature (r = -0.025). The literature pertaining to correlation analysis of mean population of giant looper with weather factors is not available hence not quoted.

5.2.5 Cocoa tussock moth (*Orgyia postica* Walker)

Cocoa tussock moth was first observed on 17th SMW (last week of April, 2018) with larval population of 0.54 larva/ plant. Thereafter the pest population started increasing and reached maximum on 26th SMW (last week of June). The population started declining and reached 0.47 larva/ plant on 37th SMW i.e. 2nd week of September. These results are in accordance with the results obtained by Chandra *et al.* (2018) who studied the seasonal incidence of cocoa tussock moth in apple and revealed that the peak pest population was obtained during early June.

The relationship between mean population of cocoa tussock moth and weather parameters exhibited that the pest population was non-significantly positively related with evening RH and morning RH (r = 0.148 and r = 0.337, respectively) and maximum temperature (r = 0.286). But a positive and significant association was found between the mean population of cocoa tussock moth and minimum temperature (r = 0.450) and non significant negative correlation (r = -0.099) with rainfall. These results are in contradictory with the results obtained by Gaikwad *et al.* (2018) who concluded that the mean population of cocoa tussock moth is negative and significantly correlated with minimum temperature in cauliflower ecosystem. This might be due to the different agro-climatic conditions and crop of this region.

Chapter- 6

Summary and Conclusion(s)

Present investigation on “Insect biodiversity and seasonal incidence of major insect pests of apple in mid hills of Meghalaya” was conducted in the experimental farm of CPGSAS, CAU, Umiam, Meghalaya during the year, 2018. The salient findings of the investigation are summarized below:

Insect biodiversity in apple

- A total of 150 insect specimens were collected of which 26 were identified as insect pests, 10 as natural enemies, two as pollinators and five as occasional visitors.
- Among 26 insect pests, five insect pests viz. Green apple aphids (*Aphis pomi* De Geer), Pale tussock moth (*Calliteara pudibunda* Linneaus), Tussock moth (*Euproctis guttata* Collenette), Giant looper (*Ascotis selenaria* Denis & Schiffermuller) and Cocoa tussock moth (*Orgyia postica* Walker) were recorded as major pests and remaining 21 insect pests as minor pests

Seasonal incidence of major insect pests of apple

- Green apple aphid (*Aphis pomi* De Geer) was observed first on 13th SMW i.e. last week of March, 2018 with 1.74 aphids/ 10cm apical length/ shoot/ plant. The population thereafter increased and attained peak on 25th SMW i.e. 3rd week of June, 2018 with 34.75 aphids/ 10cm apical length/ shoot/ plant. Subsequently, the population started decreasing and reached the minimum population of 1.68 aphids/ 10cm apical length/ shoot/ plant.
- The caterpillars of pale tussock moth (*Calliteara pudibunda* Linneaus) were first recorded during 18th SMW (1st week of May, 2018) with 0.75 larva/ plant and the highest population were recorded on 28th SMW i.e. 2nd week of July, 2018 with larval population of 3.82 larva/ plant. The lowest population of 0.98 larva/ plant was recorded during 37 SMW (2nd week of September,2018).
- Tussock moth (*Euproctis guttata* Collenette) larvae were recorded first during 26th SMW (last week of June) with mean population of 0.42 larva/ plant and the maximum population was noticed on 35th SMW (last week of August) with 4.15

larva/ plant and the lowest of 0.2 larva/ plant during 42nd SMW (3rd week of October, 2018).

- Giant looper (*Ascotis selenaria* Denis & Schiffermuller) was observed first on 19th SMW i.e. 2nd week of May, 2018 with larval population of 0.09 larva/ plant. The highest population was noticed on 28th SMW (2nd week of July, 2018) with mean population of 3.46 larva/ plant and the lowest population of 0.06 larva/ plant during 35th SMW (last week of August, 2018).
- The larvae of cocoa tussock moth (*Orgyia postica* Walker) were first noticed on 17th SMW (last week of April, 2018) with 0.54 larva/ plant. The population attained its peak during 26th SMW (last week of June, 2018) with larval population of 4.75 larva/ plant and the lowest population of 0.47 larva/ plant during the 37th SMW (2nd week of September, 2018).

Correlation studies

- Green apple aphid showed a positive and significant correlation with maximum temperature and positive non-significant with evening RH, morning RH and minimum temperature and a negative non-significant correlation with rainfall.
- A positive significant correlation was observed between the mean population of tussock moth and minimum temperature, positive non-significant correlation with evening RH, maximum temperature and rainfall and negative non-significant correlation with morning RH.
- Positive and significant correlation of cocoa tussock moth population with minimum temperature, negative non-significant correlation with the rainfall and positive non-significant correlation with evening RH, morning RH and maximum temperature was observed
- No significant correlation was observed between the mean population of pale tussock moth and giant looper along with any weather parameters.

Conclusion

Through the present investigation it is concluded that apple is infested by 26 species of insect pests throughout the year, 2018 of which five insect pests viz. Green apple aphids, Pale tussock moth, Tussock moth, Giant looper and Cocoa tussock moth were recorded as major pests and the rest as minor pests, 10 as natural enemies, two as pollinators and five as occasional visitors.

Seasonal incidence of the major insect pests studied showed that Green apple aphid population was observed from last week of March till 3rd week of September, 2018. Tussock moth population was seen from last week of June till 3rd week of October, 2018. Cocoa tussock moth infestation was noticed from last week of April till 2nd week of September, 2018. Mean population of green apple aphid, tussock moth and cocoa tussock moth were significantly correlated with weather parameters. It was concluded that maximum and minimum temperature were the most important factors favouring the development of insect pests.

BIBLIOGRAPHY

Ahmad, M. (2015). Diversity and taxonomy of tortricid moths (Lepidoptera: Tortricidae) in Kashmir and Ladakh. Ph.D. Thesis, Submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology,Srinagar, Jammu & Kashmir, India.

Andreev, R., Rasheva, D. and Kutinkova, H. (2013). Occurrence and population density of aphids in apple orchards of south Bulgaria. *J. Plant Prot. Res.*, 53(4): 353-356.

Arnoldi, D., Stewart, R.K. and Boivin, G. (1992). Predatory mirids of the green apple aphid *Aphis pomi*, the two-spotted spider mite *Tetranychus urticae* and the European red mite *Panonychus ulmi* in apple orchards in Quebec. *Entomophaga*, 37(2): 283-292.

Basannagari, B. and Kala, C.P. (2013). Climate change and apple farming in Indian Himalayas: a study of local perceptions and responses. *Ecosyst. Environ. Manag.*, 8(10): 1-6.

Besufkad, A., Worku, Y., Desalegn, F. and Aragaw, D. (2018).A survey on temperate fruit pests and their importance in the highland areas of North Shewa Zone, Amhara Region, Ethiopia.*J. Plant Patho. Microbiol.,*9(4): 1-8.

Bhagat, R.C. (2017). Coleoptera-fauna (Insects) infesting fruit plantations in Jammu & Kashmir State (India): an annotated checklist and biodiversity. *Int. J. Curr. Res. Biosci. Plant Biol.,*4(2): 60-66.

Bhagat, R.C. (2018). Biodiversity and systematic checklist of moth caterpillars, belonging to family crambidae, erebidae and tortricidae, affecting host crops and plant species in Jammu & Kashmir State (India). *Int. J. Curr. Res. Biosci. Plant Biol.,* 5(11): 56-67.

Bhagat, R.C. and Qureshi, A.A. (2016). Biodiversity and annotated checklist of scale-insects, and mealybugs (Hemiptera: Coccoidea) of Jammu, Kashmir and Ladakh (North-west Himalaya), India. *Int. J. Curr. Res. Acad. Rev.*, 4(3): 56-62.

Brown, M.W. (2003). Characterization of stink bug (Heteroptera: Pentatomidae) damage to mid- and late-season apples. *J. Agric. Urban Entomol.*, 20(4): 193-202.

Chandra, A., Behre, G.T., Firke, D.M., Singh, B., Kumar, P. and Bhagawati, R. (2016). Occurrence of Cacao Tussock Moth, Orgyia australis postica Walker and Other Insect Pests on Jhum Maize in Arunachal Pradesh. Proceeding of Indian Ecological Society, Pp.747. February 18-20, 2016.Jammu, India.

Chandra, A., Firake, D.M., Behere, G.T., Singh, B., Srivastava, A. and Rymbai, H. (2018). Cacao tussock moth *Orgyia australis postica* walker in Northeast India and its molecular characterisation. *Indian J. Entomol.*, 80(3): 1217-1220.

Childers, C.C. and Enns, W.R. (1975). Predaceous arthropods associated with spider mites in Missouri apple orchards. *J. Kans. Entomol. Soc.*, 48(4): 453-471.

Choi, K.S., Park, Y.M., Kim, D.H. and Kim, D.S. (2011). Seasonal occurrence and damage of Geometrid moths with particular emphasis on *Ascotis selenaria* (Geometridae: Lepidoptera) in Citrus orchards in Jeju, Korea. *Korean J. Appl. Entomol.*, 50(3): 203-208.

FAOSTAT (2019). Food and Agricultural Organization of the United Nations database. http://www.fao.org/faostat/en/#data/QC. Accessed June 2019.

Fasih, M., Srivastava, R.P., Abbas, S.R. and Sharma, S. (1989). Outbreak of *Orgyia postica* Walker (Lymantriidae: Lepidoptera), a new pest on mango in Uttar Pradesh. *Curr. Sci.*, 58(22): 1258-1260.

Frechette, B., Cormier, D., Chouinard, G., Vanoosthuyse, F. and Lucas, E. (2008). Apple aphid, *Aphis* spp.(Hemiptera: Aphididae), and predator populations in an apple orchard at the non-bearing stage: The impact of ground cover and cultivar. *Eur. J. Entomol.,* 105(3): 521-529.

Funayama, K. (2004). Importance of apple fruits as food for the brown-marmorated stink bug, *Halyomorpha halys* (Stal) (Heteroptera: Pentatomidae). *Appl. Entomol. & Zool*., 39(4): 617-623.

Gaikwad, A.D., Bhede, B.V., Bokan, S.C. and Bhosle, B.B. (2018). Seasonal incidence of major insect pests, natural enemies on cauliflower and their correlation with weather parameters. *J. Entomol. Zool. Stud.,* 6(5): 952-956.

Ganie, M.A., Pal, A.K. and Ahmed, N. (2014). Assessment of relative abundance and diversity of native insect pollinators in apple orchards of Kashmir Himalaya. *Asian J. Agri. Biol.,* 2(1): 34-43.

Garratt, M.P., Breeze, T.D., Jenner, N., Polce, C., Biesmeijer, J.C. and Potts, S.G. (2014). Avoiding a bad apple: Insect pollination enhances fruit quality and economic value. *Agric. Ecosyst. Environ.*, 184: 34-40.

Gokturk, T. and Aksu, B.Y. (2005). Pests of forest areas: some research on the morphology, biology and developmental characteristics of *Calliteara pudibunda* Linnaeus (Lepidoptera; Lymantriidae). *Orman Muhendis.,* 43(7/9): 34-35.

Gontijo, L.M., Cockfield, S.D. and Beers, E.H. (2012). Natural enemies of woolly apple aphid (Hemiptera: Aphididae) in Washington State. *Environ. entomol.*, 41(6): 1364-1371.

Gupta, R. and Pathania, P.C. (2016). Report on Lepidoptera pest diversity on apple plantations (*Malus domestica*) in Jammu province. *J. Insect Sci.,* 29(1): 140-150.

Gupta, R. and Pathania, P.C. (2017). Report on hemipteran pest diversity on apple plantations (*Malus domestica* Borkh.) in Jammu and Kashmir State of India. *Rec. zool. Surv. India,* 117(4): 356-366.

Gupta, R. and Tara, J.S. (2014). First report on the infestation dynamics of *Euproctis* Sp. (Lepidoptera: Lymantridae) on apple (*Malus Domestica* Borkh) and its relation with important weather factors in Jammu, India. *J. Entomol. & Zool. Stud.*, 2(5): 285-288.

Gupta, R. and Tara, J.S. (2014).Management of apple tree borer, *Aeolesthes Holosericea* Fabricius on apple trees (*Malus Domestica* Borkh.) in Jammu province, Jammu and Kashmir State, India. *J. Entomol. Zool. Stud.*, 2(1): 96-98.

Gupta, R. and Tara, J.S. (2015). Life history of *Aphis pomi* De Geer (Green apple aphid) on apple plantations in Jammu province, J&K, India. *Mun. Ent. Zool.,* 10(2): 388- 391.

Happe, A.K., Alins, G., Blüthgen, N. *et al.* (2019). Predatory arthropods in apple orchards across Europe: Responses to agricultural management, adjacent habitat, landscape composition and country. *Agric. Ecosyst. Environ.*, 273: 141-150.

Horton, D.R., Miliczky, E.R., Jones, V.P., Baker, C.C. and Unruh, T.R. (2012).Diversity and phenology of the generalist predator community in apple orchards of Central Washington State (Insecta, Araneae). *Can. Entomol.*, 144(5): 691-710.

Hradil, K., Psota, V. and Stastna, P. (2013). Species diversity of true bugs on apples in terms of plant protection. *Plant Prot. Sci.*, 49(2): 73-83.

Hussain, B., Buhroo, A.A., War, A.R. and Sheerwani, A. (2018). Insect pest complex and integrated pest management on apple in Jammu and Kashmir, India. In: Ahmed, N., Wani, S.A. and Wani, W.M. Apple: production and value chain analysis. Daya publishing house, New Delhi.pp.261-278.

Japoshvili, G. (2015). Hymenoptera biodiversity in the apple orchards of Eastern Georgia. Proceeding of Institute of Zoology. Pp.246-252,January 16, 2015. Tbilisi, Georgia.

Japoshvili, G., Celik, H., Aslan, B. and Karaca, I. (2010). Hymenopteran diversity and abundance in Golcuk Natural Park in Isparta, Turkey. *Turk. J. Entomol.*, 34(4): 435-446.

Jindal, K.K. and Sharma, L. (2016).Emerging horticultural crops of north-eastern states of India suitable for precision farming to improve livelihoods of farming community-with special reference to kiwi fruit. *Life Sci. Int. Res. J.,* 3(2): 2347-8691.

Johnson, C., Smith, B. and Savin, M.C. (2012). Invertebrate abundances and diversity of a six year old organic apple orchard in Northwest Arkansas. *Discov.,* 13(1): 38-45.

Kapkoti, B., Joshi, R.K. and Rawal, R.S. (2016). Variations in the abundance and diversity of insects in apple orchards of Kumaun, Western Himalaya, India. *Curr. Sci.*, 110(3): 438-443.

Karaca, G., Karaca, I., Yardimci, N., Demirozer, O., Aslan, B. and Kilic, H.C. (2010).Investigations on pests, diseases and present early warning system of apple orchards in Isparta, Turkey. *Afr. J. Biotechnol.*, 9(6): 834-841.

Khan, A.A. and Riyaz, S. (2017). Diversity and distribution of syrphid fly communities in temperate fruit orchard of Kashmir, India. *Int. J. Curr. Microbiol. Appl. Sci*., 6(7): 2794-2805.

Khan, A.A. and Shah, M.A. (2018). Population dynamics of green apple aphid *Aphis Pomi* De Geer (Homoptera: aphididae) and its natural enemies in apple orchard of Kashmir. *Indian J. Entomol.*, 80(2): 320-329.

Khan, A.A., Zaki, F.A., Khan, Z.H. and Mir, R.A. (2009). Biodiversity of predacious ladybird beetles (Coleoptera: Coccinellidae) in Kashmir. *J. Biol. Control*., 23(1): 43-47.

Kim, D.S., Lee, J.H. and Yiem, M.S. (2000). Spring emergence pattern of *Carposina sasakii* (Lepidoptera: Carposinidae) in apple orchards in Korea and its forecasting models based on degree days. *Environ. Entomol.*, 29(6):1188-1198.

Klein, A.M., Vaissiere, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C. and Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. Proceeding of the royal society B: *Biol. Sci*., Pp.303-313. October 27, 2007.Berkeley, USA.

Kumari, M. and Gautam, D.C. (2007). Studies on the morphs, life history and behaviour of green apple aphid, *Aphis pomi* De Geer on apple host in India. *Pol. J. Entomol.*, 76(2): 119-141.

Lashkari-Bod, A. and Zebitz, C.P. (2014). Diversity and abundance of parasitoids in organic apple orchards in Baden-Württemberg. Proceeding of Ecofruit 16th International Conference on Organic-Fruit Growing. Pp.195-198, February17, 2014. Hohenheim, Germany.

Lordan, J., Alegre, S., Moerkens, R., Sarasua, M.J. and Alins, G. (2015). Phenology and interspecific association of *Forficula auricularia* and *Forficula pubescens* in apple orchards. *Span. J. Agric. Res.,* 13(1): 1-12.

Mates, S.G., Perfecto, I. and Badgley, C. (2010). Parasitoid wasp diversity in apple orchards along a pest-management gradient. M.Sc. Thesis, Submitted to University of Michigan, Ann Arbor, USA.

Mattu, V.K. and Bhagat, T. (2015). Pollinator diversity and relative abundance of insect visitors on apple crop in Kullu hills of Western Himalaya India. *Int. J. Sci. Res.,* 4(6): 264-268.

Mattu, V.K. and Nirala, D. (2016). Diversity, distribution and relative abundance of insect pollinators on apple crop in Shimla Hills of Western Himalaya India. *Int. J. Sci. & Res.,* 5(6): 2087-2091.

Maurya, R.P. (2011). Natural enemies of apple woolly aphid, *Eriosoma lanigerum* Hausmann and their population dynamics in amid hill apple orchard. *Indian J. Entomol.*, 73(1): 15-18.

Mazzoglio, P.J., Paoletta, M., Patetta, A. and Currado, I. (2005). *Calliteara pudibunda* (Lepidoptera Lymantriidae) in Northwest Italy. *Bull. Insectology*, 58(1): 25-34.

Mushtaq, T., Bilal, S. and Aziz, M.A. (2018). Diversity and seasonal activity of insect pollinators visiting apple bloom in relation to weather parameters, *Int. J. Pure App. Biosci.,* 6(2): 1281-1290.

Pearson, K. (1973). Method of studying correlation. In: Gupta C. B (ed) An introduction to statistical methods. Vikash publishing house Pvt. Ltd. New Delhi-2, pp.371-378.

Peeva, P. and Velcheva, N. (2009). External complex of leaf-eating Lepidoptera on apple in two regions of Bulgaria. Proceeding of Pheromones and other Semiochemicals IOBC/wprs Bulletin. Pp.111-121. September 9, 2007. Lund, Sweden.

Perdikis, D., Lykouressis, D., Mitropoulou, G. and Tsiantis, P. (2008). Temporal asynchrony, spatial segregation and seasonal abundance of aphids on apple trees. *Entomol. Hell.*, 17: 12-27.

Piekarska-Boniecka, H., Siatkowski, I. and Trzcinski, P. (2013). The occurrence frequency of Syrphidae (Diptera) species in apple orchards and on their edges. *Acta Sci. Polonorum. Hortorum Cultus*, 12(5): 143-154.

Raj, H., Mattu, V.K. and Thakur, M.L. (2012). Pollinator diversity and relative abundance of insect visitors on apple crop in Shimla hills of western Himalaya, India. *Int. J. Sci. and Nat.*, 3(3): 507-513.

Riyaz, M., Mathew, P., Paulraj G. and Ignacimuthu, S. (2018). Entomophily of apple ecosystem in Kashmir valley, India: A review. *Int. J. Sci. Res. Biol. Sci.,* 5(5): 146-154.

Santos, A., Borges, P.A. and Lopes, D.J.H. (2008). Parasitoid (Hymenoptera, Parasitica) diversity in fruit orchards of Terceira Island (Azores), with new records for the Azores and Portugal. *Bol. Mus. Munic. Funchal*, 14: 139-144.

Shah, M.A. (2015). Taxonomic Studies on Aphididae in Temperate Horticulture Ecosystem of Kashmir. Ph.D. Thesis, Submitted to Sher-e-Kashmir University of Agricultural Sciences & Technology, Srinagar, Jammu & Kashmir, India.

Sharma, P.L., Chauhan, U.S.H.A. and Sharma, K.C. (2015).Studies on the diversity of predatory coccinellid beetles (Coleoptera) in different agro-climatic zones of Himachal pradesh. *The Bioscan*, 10(3): 981-985.

Singh, K.P. and Bhandari, R.S. (2010). Seasonal abundance of sal defoliator, *Ascotis seleneria* Denis & Schiffermuller (Lepidoptera: Geometridae). *Ann. For.*, 18(2): 303-310.

Stanca-Moise, C. (2017). A study about the pest insects in the apple trees orchards, with local sorts, specific to Sibiel village (Sibiu county), in the conditions of the years 2015-2016. *Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development*, 17(3): 379-383.

Stastna, P. and Psota, V. (2013). Arthropod diversity (Arthropoda) on abandoned apple trees. *Acta Univ. Agric. et Silvic. Mendel. Brun.,* 61(5): 1405-1022.

Tara, J.S., Zaffar, N., Gupta, M. and Bala, A. (2014). Hymenopteran insect pollinators on apple bloom in district Rajouri, Jammu (Jammu and Kashmir), India.*Int. J. Interdiscip. & Multidiscipline. Stud.,*1(8): 168-171.

Teparkum, S. (2000). Interaction between insects and apple (*Malus Domestica* Borkh.): Insect behavior, genotypic preference, and plant phenolics with emphasis on Japanese beetle (*Popillia Japonica* Newman). Ph.D. Thesis, Submitted to Faculty of the Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Tikoca, S., Hodge, S., Pene, S., Clayton, J., Tuiwawa, M. and Brodie, G. (2016). Temporal variation in Macro-Moth abundance and species richness in a lowland Fijian forest. *Pac. Sci.,* 70(4): 447-462.

Velcheva, N. (2009). Lepidopterian fauna in new planted apple orchard in west Bulgaria. *Biotechnol. Biotechnol. Equip.*, 23: 127-131.

Vicens, N. and Bosch, J. (2000). Weather-dependent pollinator activity in an apple orchard, with special reference to *Osmia cornuta* and *Apis mellifera* (Hymenoptera: Megachilidae and Apidae). *Environ. Entomol.*, 29(3): 413-420.

Westigard, P.H. and Madsen, H.F. (1965). Studies on the bionomics of summer generations in California of the apple aphid, *Aphis pomi* De Geer (Homoptera: Aphididae). *Can. Entomol.*, 97(10): 1107-1114.