

Pest Complex and Management of Soil Borne Pest(s) in Forest Nursery

Nadeem Ahmad Dar
(2013-A-975-M)



Division of Entomology
Faculty of Agriculture
**Sher-e-Kashmir University of Agricultural Sciences &
Technology of Kashmir**

2015

**Pest Complex and Management of Soil Borne Pest(s) in
Forest Nursery**

Nadeem Ahmad Dar
(2013-A-975-M)



Thesis

Submitted to

**The Faculty of Agriculture
Sher-e-Kashmir University of Agricultural Sciences &
Technology of Kashmir**
in partial fulfilment of requirement for the award of the degree of

**Master of Science in Agriculture
(Entomology)**

2015

Dedicated

to

My Beloved Parents

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Entomology

Certificate – I

This is to certify that the thesis entitled, “**Pest Complex and Management of Soil Borne Pest(s) in Forest Nursery**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Entomology)**, to the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir is a record of bonafide research work carried out by **Mr. Nadeem Ahmad Dar (Regd. No. 2013-A-975-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

(Dr. Ishtiyahq Ahad)
Chairman
Advisory Committee

Endorsed

Prof. & Head,
Division of Entomology, Shalimar

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Entomology

Certificate – II

We, the members of the Advisory Committee of **Mr. Nadeem Ahmad Dar (Regd. No. 2013-A-975-M)**, a candidate for the degree of **Master of Science in Agriculture (Entomology)** have gone through the manuscript of the thesis entitled, **“Pest Complex and Management of Soil Borne Pest(s) in Forest Nursery”** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

Advisory Committee

Chairman

Dr. Ishtiyaq Ahad,
Assistant Professor (Plant Protection),
FoA, SKUAST-Kashmir, Wadura

Members

Dr. G.M. Mir,
Professor & Head, Division of Entomology,
SKUAST-Kashmir, Shalimar

Dr. S.A. Mir,
Professor & Head, Division of Agri-Statistics,
SKUAST-Kashmir, Shalimar

Dr. Mehraj-Ul-Din Shah,
Assistant Professor, Division of Plant
Pathology, SKUAST-Kashmir, Shalimar

Dean’s Nominee

Dr. Jagvir Dixit,
Associate Professor & Head, Division of Agri
Engineering, SKUAST-Kashmir, Shalimar

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Entomology

Certificate – III

This is to certify that the thesis entitled, “**Pest Complex and Management of Soil Borne Pest(s) in Forest Nursery**” submitted by **Mr. Nadeem Ahmad Dar (Regd. No. 2013-A-975-M)** to The Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Entomology)** was examined and approved by the Advisory Committee and External Examiner on

Chairman
Advisory Committee

External Examiner

Prof. & Head,
Division of Entomology

Dean,
Faculty of Agriculture,
SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Agriculture, Division of Entomology

Name of the student : **Nadeem Ahmad Dar**

Registration No. : 2013-A-975-M

Major subject : Entomology

Minor subjects : Plant Pathology

Major advisor : **Dr. Ishtiyaq Ahad,**
Assistant Professor (Plant Protection),
FoA, SKUAST-Kashmir, Wadura

Title of the Thesis : **“Pest Complex and Management of Soil Borne Pest(s) in Forest Nursery”**

ABSTRACT

Investigations entitled “Pest complex and management of soil borne pest(s) in forest nursery” were carried out at forest nursery of Faculty of Agriculture, Wadura in open choice conditions. A part of experiment was carried out at social forest nursery, Kulangam to study the soil borne insect pests of *Robinia pseudoaccacia*. White grub and wire worm caused the damage of 20.58 and 11.94 per cent, respectively hence both appeared as major pest. However, mole cricket and cutworm appeared as minor pests with cumulative damage of 4.97 and 6.96 per cent, respectively. Chaffer beetles and click beetles attained their peak in the 25th meteorological week. Correlation between damage of white grubs, wire worm mole cricket and cutworm with abiotic factors showed a positive correlation with maximum and minimum temperature except cutworm which showed negative correlation with minimum temperature. Whole insect populations were negative correlated with rainfall, while white grub and mole cricket were positively correlated with relative humidity. Imidacloprid showed significant results in reducing the plant mortality infested by white grubs with 89.01 in *Cedrus deodara*; 83.20 in *Cupressus torulosa*; 82.37 in *Pinus*

wallichiana and 69.30 per cent reduction over control in *R. pseudoaccacia*, respectively. Similar trend of results were found in management wire worm and mole cricket in the forest nurseries, where as damage of mole cricket was found to be absent in the *R. pseudoaccacia* and *C. deodara*. Overall performance of chemicals followed a trend of imidacloprid > thiamethoxam > cartap hydrochloride > carbofuran > thiacloprid > clothianidin.

Key words: White grubs, wire worms, mole cricket, management, imidacloprid and abiotic factors

Signature of Student

Signature of Major Advisor

Dated : _____

Dated: _____

ACKNOWLEDGEMENT

. In the name of Almighty, "Allah", the most Beneficent and Merciful, peace and blessings be upon Holy Prophet (SAW). I bow in reverence to Almighty for giving me enough courage, patience and success in this venture.

I express my sincere and profound gratitude to the un-paralleled advisor Dr. Ishtiyaq Ahad, Assistant Professor (Entomology), FoA, SKUAST-Kashmir, Wadura, Sopore for his valuable guidance and constant encouragement throughout the course of study. His dynamic attitude, inspiring guidance, never failing interest, excellent supervision and constructive criticism and wholehearted encouragement led this task to its success and shall remain a life-long gifted memory for me.

I extend my sincere thanks to members of my advisory committee Dr. G. M. Mir, Professor and Head, Division of Entomology, Dr. Mehraj-Ul-Din Shah, Assistant Professor, Division of Plant Pathology, Dr. S.A. Mir, Prof. & Head, Division of Agricultural-Statistics and Dr. Jagvir Dixit, Associate Professor, Division of Agri-Engineering (Dean's Nominee) for their valuable guidance and suggestions during the study and for helping in finalization of the manuscript.

I would like to thank Prof. Mushtaq Ahmad, Registrar, SKUAST-Kashmir, Principal Investigator of HTMM-2.40 Project entitled "Forecasting based management of apple scab and alternaria leaf blotch" for providing weather data of the experimental period from the newly established Automatic Weather Station at FoA, Wadura.

My special thanks to Dr. Z.A. Baba, Professor; Dr. G.M. Lone, Associate Professor; Dr. Sajjad Mohiuddin; Dr. Muneer A. Sofi of Division of Entomology for their help from time to time.

Sincere thanks are also due to all the non-teaching staff members - Mr. Naseer, Mr. Ayoub, Mr. Fayaz, Mr. Rayaz, Mr. Ashiq and Mr. Gh. Mohd of Division of Entomology, SKUAST-Kashmir for their cooperation.

Cheerful acknowledgement is expressed to my colleagues and friends for their cooperation, appreciation and camaraderie during the course of this study.

I am highly grateful to members of ARIS and Library staff of SKUAST-Kashmir for their constant encouragement, valuable suggestions and generous help during preparation of this manuscript.

I take pride on myself in being the son of great ideal parents, whose everlasting desire, selfless sacrifice and untiring struggle paved my way to path of perfection. Though it is beyond the worth of my pen but today, I record my everlasting indebtedness to them and salute their generosity and greatness. Also, I shall forever remain indebted to my brothers and sister for their constant encouragement during the course of studies. May Almighty Allah who is the giver of all things reward and bless you abundantly.

Finally I extend my sincere thanks to Mr. M. Rafiq Bhat of M/s Universal Computers, Shalimar for taking lot of care in composing this manuscript beautifully in shortest possible time.

Nadeem Ahmad Dar

Place : Shalimar, Srinagar

Dated :

CONTENTS

Chapter	Particulars	Page No.
1.	INTRODUCTION	1-4
2.	REVIEW OF LITERATURE	5-19
	2.1 Status of insect pests of forest nurseries	5
	2.2 Seasonal incidence of soil borne insect pests	10
	2.3 To manage soil borne insect pests through insecticides	15
3.	MATERIALS AND METHODS	20-23
	3.1 To ascertain the status of insect pests of forest nurseries	20
	3.2 Seasonal incidence of soil borne insect pests	21
	3.3 Meteorological data	21
	3.4 Management of soil borne insect pests	22
	3.5 Details of treatments	22
	3.6 Statistical analysis	23
4.	EXPERIMENTAL FINDINGS	24-42
	4.1 Status of insect pests of forest nurseries	24

4.2	Seasonal incidence of soil borne insect pests in forest nurseries	28
4.3	Management of soil borne insect pests	32
5.	DISCUSSION	43-48
5.1	Status of insect pests of forest nurseries	43
5.2	Seasonal incidence of soil borne insect pests in forest nurseries	45
5.3	Management of soil borne insect pests	46
6.	SUMMARY AND CONCLUSION	50-52
	LITERATURE CITED	i-xii

LIST OF TABLES

Table No.	Particulars	Page No.
1.	Per cent damage of (white grub, wire worm, mole cricket and cutworm) along with weather parameters	25-26
2.	Status of insect pest fauna observed in forest nursery	27
3.	Correlation between white grub, wire worm, mole cricket and cutworm with weather parameters	29
4.	Seasonal incidence of major soil borne insect pests along with weather parameters	30-31
5.	Correlation between insect pests viz. chaffer beetle and click beetle with weather parameters	33
6.	Effect of various insecticides on plant mortality of <i>Cedrus deodara</i> infested by white grub and wire worm	34
7.	Effect of various insecticides on plant mortality of <i>Cuprous torulosa</i> infested by white grub and wire worm	36
8.	Effect of various insecticides on plant mortality of <i>Pinus wallichiana</i> infested by white grub and wire worm	38
9.	Effect of various insecticides on plant mortality of <i>Robinia pseudoaccacia</i> infested by white grub and wire worm	39
10.	Effect of various insecticides on plant mortality of <i>Cuprous tolerosa</i> and <i>Pinus wallichiana</i> infested by mole cricket	42

LIST OF FIGURES

Fig. No.	Particulars	After Page No.
1.	Seasonal incidence of soil borne insect pests (adult activity) along with weather parameters	31
2.	Seasonal incidence of soil borne insect pests (larval activity) along with weather parameters	31

LIST OF PLATES

Plate. No.	Particulars	After Page No.
1.	Insect pest complex	24

Chapter – 1

INTRODUCTION

India is a large and diverse country; its land area includes regions with some of the world's highest rainfall to very dry deserts, coast line to alpine regions, river deltas to tropical islands. The variety and distribution of forest vegetation is large: there are 600 species of hardwoods, including sal (*Shorea robusta*). India is one of the 12 mega biodiverse regions of the world. Forests in India, is a significant rural industry and act as prime source to the environmental balance. As of 2002, the food and agriculture organisation of the United Nations estimates India's forest cover 64 million hectares, which is 19.5 per cent of the total geographical area. Indian forest types include tropical evergreens, tropical deciduous, swamps, mangroves, sub-tropical, scrub, sub-alpine and alpine forests. These forests support a variety of ecosystems with diverse flora and fauna (Anonymous, 2002).

The state of Jammu and Kashmir is a fascinating geographical region situated in the northern-most niche of India. Geographically, it has three distinct regions: Jammu, Kashmir and Ladakh, comprising the area of 2,22,236 sq. km (Vidyadhar, 2005). North Kashmir consists of Baramulla and Kupwara districts with an area of 2690 and 1703 km², respectively. These two districts provide enough timber, firewood to the whole state (www.jkforest.com/jkforest/files/geography.html). The average height of the Valley above sea level is about 6000 feet (Majid, 2008). Forests are one of the main resources of Kashmir Valley spreading over an area of 8128.00 sq. km. comprising of 50.97 per cent to the total geographical area (Anonymous, 2001). With great diversity in species and varieties, the state forest catchment area of Kashmir is delimited into six vegetational zones: Fur, Deodar, Blue pine, Chir pine, Broad leaved and Shrub trees. The main species of economic forests are: *Acacia catechu*, *Abies pindrow*, *Betula utilis*, *Bombax ceiba*, *Cedrus deodara*, *Dalbergia sissoo*, *Juglans regia*,

Pinus roxburghii, *P. wallichiana*, *Picea smithiana*, *Populus alba*, *P. ciliata*, *P. deltoids*, *Quercus* spp., *Ulmus wallichiana* and *Ulmus villosa*.

The land is the combination of mighty splendor of mountains, of lovely glades and lush green forests. They range from the tropical deciduous forests in the foothills of Muzafarabad and Jammu, to temperate forests in the middle altitudes of the Kashmir Valley. Higher up, in Gilgit, Baltistan, Ladakh, and the higher areas of the Kashmir Valley coniferous, sub-alpine, and alpine forests spring up. These eventually give way to alpine grasslands and high altitude meadows just below the towering mountains and glaciers. They are followed by scrublands which lead up to the permanent snowline (Anonymous, 2012). This State is richly endowed with diverse forest resources which play an important role in preserving the fragile ecosystem of the region and also serve as catchments for important Himalayan rivers. Forests are essential for soil conservation, water security, and for meeting the needs of local population for timber, firewood, fodder and other forest produce. Forests of the State were constituted along with the initial revenue settlement as per State specific demarcation rules. Being the largest land based resource in the State, forests have immense potential for supporting livelihoods and alleviating poverty. Therefore, forests are integral to the sustainability of primary sectors like agriculture, horticulture and animal husbandry, particularly in hilly regions. In this context, the famous Kashmiri saint, Sheikh Noor-ud-din Wali^{RA} (1377-1440 CE) has aptly stated, “*Ann poshi teli, yeli wann poshi*” i.e., food will last as long as forests last.

Besides, forests provide environmental services like carbon sequestration, pollution abatement and amelioration of climate, in-situ conservation of biodiversity and maintenance of ecological balance. In nutshell, the economy of the State, environmental security and livelihood opportunities are intimately linked to the tangible and intangible benefits that flow from forests.

Insects are found in all types of environment and they occupy little more than two thirds of the known species of animals in the world. Insects affect human

beings in a number of ways. Insects that cause less than 5 per cent damage are not considered as pests. The insects which cause damage between 5 – 10 per cent are called minor pests and those that cause damage above 10 per cent are considered as major pests (Paul, 2007). Forest nursery seedlings are sometimes damaged by white grubs feeding on the roots. C-shaped white grubs are the larval stage of scarab beetles (Family Scarabaeidae). In Michigan, most of the damage is caused by either European chafer beetle (*Rhizotrogus majalis*) or June beetle (*Phyllophaga* spp) European chafer is now spread throughout the lower peninsula of Michigan to the latitude of Midland. It has also been found in several locations north of Midland, including Traverse City and Alpena. Because we lack the proper natural enemies to keep populations of European chafer under natural control and may become abundant in some areas, causing substantial damage. In several nursery fields, blue spruce (*Picea pungens*) and arborvitae shrubs (*Thuja occidentalis*) up to 61 cm tall have been so severely damaged that 25 per cent of the shrubs were lost. Similar damage can be caused by June beetle grubs anywhere in Michigan. Larvae of several moths (order Lepidoptera) occur incidentally in forest nurseries and often cause cutworm-like damage, they are not true cutworms. This designation applies only to larvae, of moths in the family Noctuidae, of which the variegated cutworm *Peridroma saucia* is probably the most common and damaging in local forest nurseries. Some cutworm like damage occurs in all nurseries every year. All coniferous species in both bare root and container nurseries throughout the province may be attacked, but severity of infestation varies greatly. Damage is generally confined to young, succulent seedlings before their stems become woody. A single larva can destroy many seedlings each night, thus only a few cutworms per m² can destroy thousands of seedlings in a few weeks. Cutworms feed on foliage and often cut through the stems just above ground, leaving a short stump. Besides the presence of bark beetles is of concern as they are capable of killing even healthy trees in natural and commercial forests (Schowalter *et al.*, 1981; Paine *et al.*, 1997; Raffa *et al.*, 2005), resulting in considerable economic impact (Lieutier *et al.*, 2004). Beetles

may also undergo a host switch to attack native tree species, with potentially serious ecological consequences (Six and Paine, 1999).

There are a number of abiotic factors which affect the health of a forest such as moisture issues like drought, winter drying, waterlogging or precipitation such as hail, snow, storm. Wind is also an important abiotic factor as wind throw (the uprooting or breaking of trees due to high winds) causes an obvious and direct loss of stability to a forest or its trees. Often, abiotic factors and biotic factors affect a forest at the same time.

Keeping the above in view the present study entitled “Pest complex and management of soil borne pest(s) in forestry nursery” was under taken with the following objectives:

- To ascertain the status of insect pests of forest nurseries
- To study seasonal incidence of soil borne insect pests
- To manage soil borne insect pests through insecticides

Chapter – 2

REVIEW OF LITERATURE

The present investigation entitled “Pest complex and management of soil borne pest(s) in forest nursery” were carried out during 2014-15 in free choice conditions in north Kashmir of Jammu and Kashmir. Literature in relation to the present studies is reviewed under the following headings.

2.1 Status of insect pests of forest nurseries

For healthy forest stand always a healthy and sound tree is must the only bottle neck is the insect attack which has been recognised long back as Craighead (1950) and Keen (1952) discussed more than 50 species that attack living forest trees, the majority of which are coniferophagous, including phloem and wood borers in the roots, stems and branches; twig girdles; and gall forming species, where as Edwards (1961a,b) studied the biology of the immature stages of *Prionopus reticularis* and furnished a general account on the reproduction of Cerambycid beetles under two sub families viz. Prioninae and Lamiinae. On the other hand Cook and Solomon (1976) worked out the known biological information of major insect pests in cottonwood, *Populus deltoid* Bartr. They summarized that the trees of all size and age groups are subject to injury by insect pests and infestation varies greatly from locality to locality, but damage was generally maximum to open grown trees, stressed trees and those grown in poor sites.

Godfrey *et al.* (1986) reported various combinations of soil borne organisms like clover root curculio, *Sitona hispidulus* (F.), Alfalfa weevil, *Hypera postica* (Gyllenhal), and substantial numbers of dipteran larvae, *Delia* spp. to determine mortality factors that affect spring-seeded alfalfa seedlings in an alfalfa-following-alfalfa cropping system. While, Anderbrant and Schlyter (1987) worked out the distribution and phenology of the Dutch elm disease vectors, *Scolytus laevis* and *S. scolytus*. By using the sticky traps (white cardboard), their

results indicated a low proportion of dispersion beetles, and emergence from logs and trap catches showed a first peak in July in the three years studied and second peak of activity was evident in August in two of the years for *Scolytus scolytus*, indicating a second generation. However, Marshall *et al.* (1990) conducted a survey of 24 forest nurseries in British Columbia yielded 22 collembolan taxa, 10 of which are reported for the first time from this province. The species most frequently encountered was *Sminthurinus quadrimaculatus* found in 13 out of 24 nurseries. Only one species was collected, *Bourletiella hortensis* on conifer seedlings. Moreover, Mchowa and Ngugib (1994) carried out a survey of insect species associated with multipurpose trees and *Phaseolus* beans and found eleven insect species belonging to 11 genera. Among these pests leaf beetle, *Mesoplatys ochroptera* (Stal.), which caused severe defoliation of *Sesbania* spp. and an unidentified lepidopteran caterpillar species fed gregariously on *Sesbania* spp., causing considerable defoliation. Some other factors that are likely to influence pest severity and may be altered by crop/tree mixed cropping systems are also described. However, Hillocks *et al.* (1996) described various host ranges, interactions and environmental factors affecting the major weed, insect and disease pests in the region as well as the effects of cultivation practices on pest occurrence. Similarly, Girma *et al.* (2000) studied abundance of different arthropod species and their population dynamics under hedgerow and monitored pests through counts of infested plants using yellow pan and pitfall traps. During their studies, Beanfly (*Ophiomyia* spp) infestation was significantly higher (35%). It was also reported that the effect of hedgerows on pest infestations of crops and their role as refugia for predators cannot be generalized but depends on the specific arthropods.

Bhat *et al.* (2005) conducted a systematic survey for white grubs in Kashmir Province, Jammu and Kashmir State, India by direct collection of beetles from their host plants and indirect sampling using light traps. Nine chaffer species trapped from host plants were recorded in three locations (Harwan, Shalimar and

Shopian) in different cropping systems, of which *Melolontha indica*, *Anomala rufiventris*, *Lasiotropus ponnesis* and *Oryctes nasicornis* are new records for Kashmir. Also a preliminary study on the behaviour and biology of *Brahmina* sp., one of the collected taxa, was carried out under both laboratory and field conditions. Similarly Anitha *et al.* (2006) collected scarabid beetles from trees on which they feed and mate, and larvae (white grubs) from the ground nut fields. Among these white grubs two species of *Holotricha* viz, *H. reynaudi* and *H. Serrata* appeared as major pests.

Jedlicka and Frouz (2007) studied the community of elaterid larvae representing different stages of secondary succession, by using soil sampling. Six species of Elateridae larvae were found including *Agriotes obscurus*, *Athous niger*, *Athous subsuscius*, *Dalopius marginatus* and *Athous vittatus*. Similarly Cherrya and Stanslyb (2008) determined the abundance and spatial distribution of wireworms in Florida sugarcane on muck versus sandy soils. Fourteen commercial sugarcane fields were sampled for wireworms on farms in southern Florida. *Melanotus communis* (Gyllenhal) was the most abundant wireworm found in both soil types. Other less abundant wireworms were *Conoderus* spp., *Ischiodontus* sp., and *Glyphonyx bimarginatus* Schaeffer.

Pandey *et al.* (2007) reported different insect pests causing damage to forest plantations particularly to poplar and willow in Ladakh, Jammu & Kashmir. It was found that gypsy moth (*Lymantria* spp), Willow scale (*Chionaspis salicis* L.), Tent caterpillar (*Malacosoma* spp), willow leaf beetle (*Altica* spp), goat moth (*Cossus cossus* L.), ermine moth (*Yponomeuta rorellus* Hubner), poplar petiole gall insect (*Pemphigus* spp), willow apple gall (*Pontania* spp) were major pest species found causing damage to poplar and willow. However, Mckenna *et al.* (2009) studied that the key insect pests of *Actinidia arguta* kiwi fruit were determined by monitoring tagged fruit bunches for insects and insect damage in six orchard blocks, and by examining samples of picked fruit at harvest. During the research they found that the Leaf rollers and greenhouse thrips are the key

production pests, while leaf rollers, greedy scale and some mealy bug species are potential quarantine species. However, Alao *et al.* (2011) conducted an experiment on the current status of forest pests, by reviewing the main problems faced by these tree species commonly planted and appropriate measures to manage these pests. For instance seed pests such as *Dichocrosis punctiferalis* and *Sitophilus* spp bore fruits in the standing trees and nursery pests that cause serious damages to roots are *Holotrochia consanguinea* and *Apogonia uniformis*. Pests problem in plantations are mainly defoliators, sap suckers and xylophagous pests. However, access to improved breed of tree species would have a long way to reducing the incidence of pests attack in social forestry.

Verghese *et al.* (2012) surveyed various drying deodar trees in the Gulmarg area of Jammu & Kashmir and found many factors responsible for drying up among these factors insect pests viz., spider, mites, mealy bugs, white flies, some lepidopteron caterpillars and borers were of major concern. Various borers had been recorded viz. *Apriona cinerea*, *Aeolesthes holosericea*, *Bactrocera rufomaculata*, *B. horsefieldi*, *Coelosterna scabractor*, *C. spinator*, *Sphenoptera lifertei*, *Linda nigrosculata*, *Sthenias grisator*, *Pitogenes* sp., *Alcidoides mali*, *Dialeges undulates*, *Epepeotes luscus*, *Glenea beelsoni*, *Morimopsis lachrymans*, *Prionus corpulentus*, *Rhaphuma horsfieldi*, *Scolytus juglandis*, *Capnodis carbonaria*.

Gradinariu *et al.* (2012) studied the dynamics of pest species found in forest nurseries of the Forest Directorates Botosani, Iasi and Suceava during 2009-2011 and reported that biotic pests represent the largest percentage of harmful factors, *i.e.* 93.81 per cent and from these 72.60 per cent are insects compared with plant parasites (19.81%) and harmful mammals (7.59%). The most dangerous pests for saplings from the forest nurseries are root insects (87.20% of all harmful insects), out of which the largest share (70.87%) is *Melolontha* spp Larvae, followed by species of Elateridae with (13.20%). However, Qureshi *et al.* (2013) carried out survey in district Kupwara of Jammu and Kashmir from 2007-

2009 to know butterfly fauna, their abundance, seasonal distribution, flight periods, and other bio-ecological components. During survey 36 species belonging to 8 families and 36 genera were collected which were mostly active during summer season (June-August), while no butterfly was observed during winter season (December-February). The most dominant family was Nymphalidae followed by Pieridae, Satyridae, and Lycaenidae. While, Aneni *et al.* (2013) studied that the leaf miner (*Coelaenomenodera elaeidis*) is the major pest of the oil palm. This study analyses temporal patterns in leaf miner abundance, and elucidates general patterns and factors influencing leaf miner abundance. Multiple linear regressions were used to analyze the relationship between abundance of leaf miner, its parasitoids and predators and the following climatic variables: maximum and minimum temperature (°C), rainfall (mm) and relative humidity (%).

Blackshaw and Hicks (2013) studied the landscape scale distributions of adult male click beetles of the species *Agriotes lineatus*, *A. obscurus* and *A. sputator*, and the crane fly *Tipula paludosa* by using traps along transects over 2 years. *Agriotes lineatus* was the most numerous click beetle caught even though its larvae were absent from these fields. Greater trap counts were found for all taxa except *A. obscurus* in grassland. The number of click beetles were influenced by the sampling year, crop type, species and interactions of other variables, suggesting that sex pheromone trap counts exhibit variability because of the complexity of the environment, where as Morales-Rodriguez *et al.* (2014) studied that wireworms are an increasing threat to the sustainable production of cereal, potato and other crops in Montana since the delisting of lindane, an effective and inexpensive insecticidal seed treatment. With this study, we have initiated long term research to investigate the diversity of wireworm species infesting Montana's cropland. The prairie grain wireworm, *Selatosomus aeripennis* was thought to be the most common species in the region. However, *Limonius*

californicus L. *infuscatus*, *Hypnoidus bicolor* and *Aeolus mellillus* were identified as the most common species in this study.

Varga *et al.* (2014) studied that in forestry nurseries, biological material is often heavily damaged by a rich complex of pests that attack in the soil, or at the level of soil. The purpose of this research was the monitoring of the population structure of click beetles (wireworms). The monitoring of the wireworms in the larval stage was done by the method of catching the worms with baited traps. In 2011 with the help of 20 traps during the monitoring period have been captured 69 larvae of *Elateridae* family which is an average of 3.45 larvae/trap. The species captured were *Agriotes lineatus* L., *Agriotes sputator* L., *Agriotes obscurus* L., *Agriotes ustulatus* Schall., *Selatosomus aneus* L., *Athous niger* L., *Athous haemorrhoidalis* F., *Athous subfuscus* Mull., *Prosternon tessellatum* L. and *Lacon murinum* L. but *Agriotes lineatus* L. was the dominant species.

2.2 Seasonal incidence of soil borne insect pests

Linsley (1959) summarized that the adult long-horned beetles feed on variety of plant substrates, such as, flowers, bark, foliage, cones, sap, fruits, roots, and fungi. The author concluded that after copulation, males of many cerambycid species remain with females as they search for and prepare oviposition sites, repeat copulation and fending off rival males. However, Day *et al.* (1969) carried out the response of adult southern potato wireworms (*Conoderus falli* Lane) to light traps. Various collections were made during each month of the year in a trap equipped with a 15-w fluorescent black light (BL) lamp operated continuously in different locations. Maximum numbers were found between June and September while least between December and March. Catches in this trap during midsummer were highest between 8 and 9 PM EST, and 94.6% of the total catch occurred before midnight. Similarly, Cantelo and William (1974) studied the strong phototactic response of many insect species to black light (BL) has encouraged considerable study of means to use this phenomenon to control insect pests. It provides references for all of the known published efforts to control natural

populations of insects with black light traps. The usual approach in a control effort has been to combine the BL lamp with a collection device to form a trap.

Marshall (1974) carried out various ecological studies on soil nematodes, collembolans and mites at Shawnigan, British Columbia. Collembolans and mites exhibited significant downward seasonal distribution, and urea treatment would be required to observe the full impact of urea fertilization on the soil fauna. Except for enchytraeids, seasonal population fluctuation contrasted with the generally observed pattern in temperate regions of spring and fall peaks and showed increases through the spring, culminating in summer and autumn maxima. However, Harcourt *et al.* (1983) reported two temperature-dependent models have been derived for use in management of the alfalfa blotch leafminer, *Agromyza frontella* (Rondani). A linear function, designed for grower use and based on heat units above 5°C, will give accurate predictions of the seasonal occurrence of the life stages together with critical biological events such as adult emergence, hatch, and larval dropout. A nonlinear function, based on a polynomial algorithm, will give even more precise simulations and is amenable to computerized forecasting.

Singh and Prasad (1985) reported the infestation of *Apriona cinera* Chevrolat (Coleoptera: Cerambycidae) can be prevented by pruning the host plants before their grubs enter the main stem and that of last year's infestation (old infestation) by fumigation. Whereas, Gibbs and Wainhouse (1986) reported four main forest regions in the Northern hemisphere, each containing many of the same genera of trees. An organism (insect, fungus, etc) living in balanced relationship with its host tree in one of these forest regions may cause major damage if moved to another. However, Robertson (1993) studied False wireworms (particularly *Pterohelaeus alternatus* and *Gonocephalum macleayi*) are major pests of seedling field crops in central Queensland. Population densities are spatially and temporally dynamic. Adult movement in summer in response to changes in habitat suitability is suggested as the cause of population changes similarly natural enemies, particularly entomopathogenic fungi, may also have a role in

suppressing high population densities. The dynamic nature of false wireworm population size makes prediction of pest levels difficult. Similarly, Rodriguez-Del-Bosque and Magallanes-Estala (1994) studied that the abundance and seasonality of *Diabroticina* species were investigated by using black light traps. The results revealed that *Diabrotica balteata* Leconte was the most abundant species other species captured included *D. undecimpunctata howardi* Barber, *D. longicomis* (Say), *D. tibialis* Jacoby, *Paranapiacaba connexa* (Leconte), and *Acalymma trivittatum* (Mannerheim). However, Mistretta (2002) studied that both native and exotic insects and diseases affect southern forest health and vitality and therefore have ecological and economic effects. In addition, there are abiotic factors, such as climate change and air pollution, that may interact with and sometimes exacerbate the dynamics of insect and disease outbreaks. Managing for forest health in this changing environment remains a critical challenge for forest managers in the South.

Kovacs *et al.* (2006) studied the dominance of dangerous *Agriotes* species with pheromone traps in the Transdanubian region of Hungary in the examined period. The trapped species was: *A. lineatus*, *A. sputator*, *A. ustulatus*, *A. obscurus* and *A. rufipalpis*. The volumetric quadrat method was found to be the most suitable method for soil sampling, as it resembled the natural conditions best. Occurrence of larva populations was surveyed. Soil temperature, density and water content of dug samples were measured. Moreover, Skarpaas and Okland (2008) worked out the timber import and the risk of forest pest introductions. They found that many invasive species are introduced by trade and evaluated that the most effective measures for reducing introduction risk were those aimed at isolating the storage from forest (storage enclosure, location) followed by those reducing the available resources for forest pests (debarking, timber irrigation, rapid processing), whereas delayed import was least effective. Similarly, Salasaraiza *et al.* (2008) studied the population dynamics of the agave scale, *Acutaspis agavis* (Townsend and Cockerell), on *Agave tequilana* Weber

var. azul in the state of Guanajuato, Mexico. They found that the stages (first instars, or crawlers) of the agave scale were most susceptible to chemical control and were significantly more abundant in May (first generation) and September (second generation).

Wani *et al.* (2009) studied the status of bark beetle, *Scolytus nitidus* (Schedl.) severity on apple trees of different age group and varieties under three situations undertaken in two districts of North Kashmir. The authors concluded that highest severity on trunks of apple trees was recorded from Baramulla block (41.8%) and lowest from Tangmarg block (16.9%). Highest pest severity (30.9%) was noticed in October and lowest severity of 23.7 per cent in May. Apple trees of more than 30 year's age were infested more severely as compared to the other age groups indicating that the older trees are more susceptible to bark beetle infestation. Similarly, Dimitri *et al.* (2009) studied the influence of mass trapping on the population dynamics and damage effect of bark beetles. They concluded that the clean-management is the best, most reliable and reasonable method against the propagation and the attack of the bark beetles. However, Stephen *et al.* (2009) studied the bark beetle-host tree interactions and prediction of its infestation. To use information in a management oriented predictive model, resistance properties of pines must be correlated to easily measurable tree and/or stand characters, resulting in improved predictions over a variety of site and stand conditions, thus leading to better management decisions.

Ulyshen and Hanula (2010) investigated that the patterns of beetle succession in dead wood remain unclear, particularly beyond the first several years of decay. The saproxylic beetles were sampled from loblolly pine (*Pinus taeda* L.) logs aged between 1 month and 9 years old, using both emergence traps attached to logs in the field and rearing bags in the laboratory. Beetle communities differed significantly among decay classes, with 25 and seven species being significantly associated with young and old logs, respectively. Kleespies *et al.* (2012). Studied that wireworms of the genus *Agriotes* (Coleoptera: Elateridae)

are severe and widespread agricultural pests affecting numerous crops throughout the world and causing damage of economic importance. During the research a survey of the occurrence of natural microbial antagonists of wireworms was conducted for the management of wireworm. Similarly, Alalouni *et al.* (2013) studied the population dynamics of the gypsy moth (*Lymantria dispar*; Lepidoptera: Lymantriidae) which may reach outbreak levels that pose considerable economic and environmental impacts to forests in Europe, Asia, Africa and North America is mainly due to natural enemies, especially parasitoids, can cause delayed density-dependent mortality, which may be responsible for population cycles and cause for high feeding damages. However, few parasitoids were introduced and the parasitism rates were considerably lower in America than Europe. Many other factors seem to influence the population dynamics of the gypsy moth such as the host plants, weather and natural enemies.

Although, Bracalini *et al.* (2013) studied that cone and seed insects have played a key role in the decline of stone pine nut production in Italy where cones were attacked by anobiid beetles and *Dioryctria* spp. A low number of cones damaged by *Dioryctria* spp. was recorded whereas high percentages of cones showed resin exudates. Similarly, Kozina *et al.* (2013) studied the distribution and abundance of *Agriotes lineatus* and correlated the abundance with the prevailing climatic conditions to establish how temperature and rainfall are influencing the dominance, and to determine the activity characteristics of the adults by using sex pheromone traps the most important *Agriotes* species (*A. lineatus* L., *A. sputator* L., *A. obscurus* L., *A. brevis* Cand. and *A. ustulatus* Schall.) were collected and it has been shown that abundance and dominance of *A. lineatus* were significantly higher.

Staudacher *et al.* (2013) reported that *Agriotes* wireworms (Coleoptera: Elateridae) are abundant soil-dwelling herbivores. In Europe up to 40 species occur, differing in their ecology and pest status. Their distribution in the larval stage, however, has rarely been assessed because of the considerable effort

in collecting wireworms and the difficulties in identifying them to species-level. During the research it has been shown that there occur a characterization of species-specific traits in *Agriotes* larvae in agricultural land, an important prerequisite to develop efficient control strategies for these wireworms. Similarly Sufyan *et al.* (2013) reported that the use of sex pheromones as an option to control wireworms via mass trapping and the biology of *Agriotes lineatus* (L.). Plots supplied with sex pheromone traps were compared with untreated control plots. During the research various species of wireworms like, *A. lineatus*, *Agriotes obscurus* (L.) and *Agriotes sputator* (L.) were captured and it has been seen that *A. lineatus* was the dominant species followed by *A. obscurus* and *A. sputator*.

Gupta and Gavkare (2014) Works regarding the abundance of *Brahmina coriacea* beetles on light trap and host trees were recorded during May-July. About 26.37 per cent tuber infestation in potato was recorded during second week of October in Shimla hills. Due to large scale deforestation, the beetles have moved into areas near the agriculture fields for feeding on shrubs/fruit trees and resulted in egg laying in the cultivated areas and thus becoming pest of crops.

2.3 To manage soil borne insect pests through insecticides

Malik (1966) found mixing of 1 part of 10% BHC powder with 6 parts of soil and plastering the entire infested area on trees covering up with paper and rope most effective method of controlling shot-hole borers (*Scolytoplatypus sp.* and *Scolytus nitidus* Schedl.). The thicker branches and trunks of the infested trees should be plastered in the beginning of May in Kashmir. However, Byers *et al.* (1980) studied the pruning schedules and reported that wounding trees by pruning will attract the bark beetle vectors of Dutch elm disease. The authors recommended that ideally, routine pruning should be done in the dormant season or should be restricted to periods of beetle inactivity. Similarly, Waters and Stark (1980) carried out studies on forest pest management and furnished an account that the adverse impacts should be prevented or kept at tolerable levels by ecological sound means, which are compatible with forest management objectives

and practices. However, Donley (1981) described an account on the control of red oak borer, *Enaphalodes rufulus* Haldeman. (Coleoptera: Cerambycidae) by removal of infested trees and reported 50 and 90% reduction in borer population after treatments in first and second generations, respectively. Cultural control is effective in reducing the cerambycid borer infestation rate in forests and it reduced the treated red oak borer population by 63-68%, compared to untreated populations (Donley, 1983).

Sharma and Tara (1985a, 1986b) evaluated some control measures and screened kerosene oil and para-dichlorobenzene mixture; carbon tetrachloride; carbon disulphide and para-dichlorobenzene mixture; chloroform; petrol, naphthalene and carbolic acid mixture; benzene; ethyl acetate; petrol and kerosene oil mixture; metasystox; ethylene dibromide and nuvan against insect pests of mulberry in Jammu. Whereas, Mandal *et al.* (1989) furnished an account on the control measures of round headed stem borer, *Aeolesthes holosericea* Fabr. in tropical ecosystems. The authors explored the efficacy of five synthetic insecticides *viz.* dimethoate, phosphamidon, fenitrothion, aldrex, and cypermethrin against the stem borer. However, Pajars and Lanier (1989) demonstrated that the commercial formulations of 4 Pyrethoid insecticides [fluvalinate (Mavrik), permethrin (Pounce), cypermethrin (Ammo) and esfenvalerate (Asana)] were 222-548 times more toxic to *Scolytus multistriatus* than was methoxychlor. Compared with methoxychlor, all of the pyrethoids provided superior protection from twig feeding, cypermethrin and esfenvalerate killed all beetles contacting sample twigs and prevented twig feeding throughout an 18-week period of bioassays after spraying.

Neumann and Marks (1990) reported insect pests and diseases destructive to *Pinus radiata* and other exotic conifers and in pine nurseries are reviewed, as are the control measures for minimizing tree mortality, loss of growth increment and wood degrade. The wood wasp *Sirex noctilio* and the pine needle blight *Dothistroma septospora* have caused significant tree mortality and

defoliation respectively in plantations, whereas the root rot fungus *Phytophthora cinnamomi* and the root lesion nematode *Pratylenchus penetrans* have been linked to substantial seedling deaths in nurseries. However, Cinti *et al.* (1993) listed the insecticides and acaricides registered for use on principal pests of peach including *Scolytus rugulosus* in Italy, and presented details of their spectrum of activity, waiting period and toxicological class. Drinkwater and Groenewald (1994) found the efficacy of imidacloprid (a nitromethylene) and furathiocarb (a carbamate) as seed dressing insecticides for control of the black maize beetle adults, *Heteronychus arator*, in maize was compared in laboratory and greenhouse trials. The numbers of damaged plants, extent of plant damage and numbers of dead adults were recorded and it was reported that imidacloprid had a systemically translocated antifeedant action in the stems of plants while as it is absent in the furathiocarb treatments. Whereas, Hagen (1995) carried out the management of bark beetles in urban and rural areas of California. He recommended both chemical and cultural control against the effective eradication of the infestation of borers. Similarly, Li-JiangLin *et al.* (1995) studied the control of *Scolytus seulensis* on fruit trees in Xinjiang and proposed enforcing quarantine and improving orchard management as control measures. They tested that spraying 2.5% Decis (deltamethrin) and 20% Sumicidin (fenvalerate) at 1000-2000 (dilution) on tree stems during the period of peak adult occurrence of the pest resulted in >85% control.

Patial and Bhagat (2005) reported imidacloprid 70 WS @ 3.5 g a.i per kg of seed (seed treatment) against white grubs in maize with least plant mortality percentage (3.74%) it was followed by chlorpyrifos 5 g a.i per kg of seed (4.43%). However, Kulkarni *et al.* (2007) reported application of phorate 10G @ 20 g/m² most effective against white grub *Schizonycha ruficollis*, it was followed by chlorpyrifos 20 EC @ 5 ml/m². While *Beauveria bassiana*, *Metarhizium anisopliae* and m- parathion remained at par. Although, Mohi-ud-din *et al.* (2007) evaluated various concentrations of *B. Bassiana* against white grubs (*Holotricha*

spp) and found 1×10^8 spores ml^{-1} most effective in managing the pest. On the other hand Borden (2009) discussed two tree baiting tactics for the management of bark beetles with semiochemicals. Baiting of trees with semiochemicals to contain and concentrate populations of the mountain pine beetle, *Dendroctonus ponderosae* and *Ips typographus* has been an effective tactic used in IPM programmes in Britain.

Holopainen *et al.* (2009). Reported that elicitors are compounds, which activate chemical defences in plants in order to have suppressive effects on fungal diseases and insect pests of plants. Various biosynthetic pathways are activated in treated plants depending on the compound used. The most intensively studied elicitor for manipulating defense pathways in plants is methyl jasmonate, which modifies e.g. the production of terpenoids, the main constituents of conifer oleoresin. Other commonly tested chemical elicitors are salicylic acid, methyl salicylate and benzothiadiazole, which affect production of phenolic compounds in plants.

Mendel *et al.* (2009) worked out some foundations for the application of aggregation pheromone to control pine bark beetle in Israel. To optimize mass trapping of *Orthotomicus erosus* and *Pityogenes calcaratus* (Col., Scolytidae) in *Pinus halepensis* and *P. brutia*, some stand and soil characters of thinned pine plantations, time of thinning as related to bark beetle outbreak and various characters of trees susceptible to scolytid attack were investigated.

Pawson and Watt (2009) described an experimental test of a visual based push-pull strategy for control of wood boring phytosanitary pests. Control “push” lights had the highest average catch of *Arhopalus fesus*, while as white ‘push’ light was most attractive to *Prionoplus reticularis*. The results obtained suggest that a push-pull strategy combining yellow site lighting with UV kill traps could provide site-specific control of wood borers. However, Meshram (2010) evaluated various plant extracts against six major insect pests of forests in the laboratory and field conditions and found neem leaves highly deterrent to *Plecoptera reflexa* and

Pyrausta bambucivora while *Aloe vera* leaf extract @ 0.5% proved to be best/most effective against *Eutectona machaeralis*. Whereas, Bucurean and Bunta (2011) studied the prevention and fighting of wireworms (*Agriotes* spp) through the method of chemical seed treatment. The newest chemical products have been selected in order to analyze their efficiency against attacks on both the germinating seed and the underground stem. While as, Kalia *et al.*(2011) found up to 11.6% infection in white grubs through *Beauveria bassiana* at various locations in Himachal Pradesh.

Chapter – 3

MATERIALS AND METHODS

Present investigations entitled “Pest complex and management of soil borne pest(s) in forest nursery” were carried out at forest nursery of Faculty of Agriculture, Wadura in open choice conditions during 2014-15. A part of experiment was carried out at social forest nursery, Kulangam to study the soil borne insect pests of *Robinia pseudoaccacia*. The details of the experimental materials used, procedures and techniques followed during the course of investigations are presented below:

3.1 To ascertain the status of insect pests of forest nurseries

Different insect pests were observed at the experimental sites, including their per cent damage on *Pinus wallichiana*, *Cedrus deodara*, *Cupressus torulosa* (nursery in poly bags) and *R. pseudoaccacia* (on nursery beds). Per cent damage was recorded by observing dead and live plant material in the nurseries. One square meter area containing 169 poly bags of *P. wallichiana*, *C. deodara* and *C. torulosa*. However, in *R. pseudoaccacia* beds were observed and per cent damage was calculated as under:

$$\text{Per cent damage} = \frac{\text{No. of damaged plants}}{\text{Total No. of plants}} \times 100$$

Soil arthropods viz. white grubs, wireworms and cutworms were quantified by digging pits of different dimensions near the experimental field which are described below:

- i) White grubs 20 × 20 × 21 cm (Toba and Turner, 1981)
- ii) Cut worms 25 × 25 × 10 cm (Chandla, 1986)
- iii) Wireworms 20 × 20 × 21 cm (Toba and Turner, 1981)

3.2 Seasonal incidence of soil borne insect pests

Seasonal incidence of soil borne pests were monitored throughout the growing season by installing light traps.

3.2.1 Adult activity

It is established fact that visible light attracts a wide range of insects and in the management part this has led to the development of various forms of light traps. It offers an efficient means of obtaining information regarding the distributions, seasonal flight periods and peak of abundance of various insect species, thereby helping in the suppression of pest through suitable plant protection measures at appropriate time. Hence, investigations were carried out to determine the seasonal population fluctuations of adults of soil arthropods through light trap and climatic factors influencing them. To achieve this objective, a multi directional light trap was operated from 1800 to 600 hours daily. The collections were made weekly throughout the experiment. Number of adults of soil arthropods on the basis of weekly catches were correlated with important abiotic factors (temperature, relative humidity and rainfall).

3.2.2 Larval activity

Larval activities were determined by counting the total number of larvae/grubs at weekly interval. To assess the larval/grub populations at experimental sites, random sampling had been done within the selected experimental plots. Three samples for cutworm were taken by excavating 625 cm² area (25 cm × 25 cm) of 10 cm deep soil in the field. Similarly, three samples for white grub and wireworm were taken by excavating 8400 cm² area (20 cm × 20 cm) of 21 cm deep soil in the field. Mean number of larvae/grubs present per three samples were recorded in the vicinity of experimental site.

3.3 Meteorological data

Data on maximum temperature and minimum temperature (°C), relative humidity (%) and rainfall (mm) were collected from Automatic Weather Station

Wadura (installed by Prof. Mushtaq Ahmad, Principal Investigator of HTMM-2.40 Project, Division of Plant Pathology, SKUAST-Kashmir, Shalimar). Multiple correlations were worked out to determine the cumulative and individual effects of important weather parameters (temperature, relative humidity and rainfall) on population build up of the insect pests.

3.4 Management of soil borne insect pests

One square metre area from *P. wallichiana*, *C. deodara* and *C. torulosa* was selected in the experimental site, dried/dead plants were counted from the selected area of 1 sq m, consisting of 169 plants each. Mortality per cent in plants was calculated and further comparison was made between treatments and control. Reduction of plant mortality in treated plots over control was calculated as under:

$$\text{Per cent reduction over control} = \frac{\text{Control} - \text{Treated}}{\text{Control}} \times 100$$

Data collected from experimental site, was analyzed in Randomized Block Design (RBD). Experiment comprised of 7 treatments each replicated thrice including untreated control. The details of the experiment are given below:

Treatments : 7 (including control)

3.5 Details of treatments

- T₀ - Untreated (control)
- T₁ - Cartap hydrochloride 4% G @ 0.6 kg ha⁻¹
- T₂ - Thiamethoxam 25 WG @ 0.08 kg a.i ha⁻¹
- T₃ - Carbofuran 3G @ 0.75 kg a.i ha⁻¹
- T₄ - Clothianidin 50 WDG @ 0.12 kg a.i. ha⁻¹
- T₅ - Imidacloprid 70 WG @ 0.02kg a.i. ha⁻¹
- T₆ - Thiacloprid 48 SC @ 0.02% a.i. ha⁻¹

Soil application of above mentioned insecticides were made in the experimental plots. Granular insecticides were mixed with sand while, liquid

formulations were diluted with water for even distribution. Insecticides were applied in the evening to escape the effect of sunlight on chemicals. Moreover, liquid formulations were applied in the soil through drenching.

Replications : 3

Design of experiment : Randomised Block Design (RBD)

3.6 Statistical analysis

Data collected from the experimental site was subjected to standard statistical procedure using statistical software STATISTICA-AG from Stat-Soft (USA) licensed to SKUAST-Kashmir, Wadura, Sopore.

Chapter – 4

EXPERIMENTAL FINDINGS

Present investigations entitled “Pest complex and management of soil borne pest(s) in forest nursery” were carried out at forest nursery of Faculty of Agriculture, Wadura in open choice conditions during 2014-15. A part of experiment was carried out at social forest nursery, Kulangam to study the soil borne insect pests of *Robinia pseudoaccacia*. Forest nursery consisting of *Pinus wallichiana*, *Cedrus deodara*, *Cupressus torulosa* (in poly bags) and *R. pseudoaccacia* (on nursery beds) were studied and the experimental findings are described as under.

4.1 Status of insect pests of forest nurseries

4.1.1 Insect pest damage

Soil borne insects viz. white grubs (*Holotrichia longipennis*, *Brahmina* spp, *Centonia* spp, *Anomala* spp, *Brahmina* spp, *Melolontha furcicauda*, *Oryctes* spp (♂), and *Oryctes* spp (♀), wireworms (*Agriotes* spp), mole cricket (*Gryllotalpa* spp), cutworms (*Agrotis* spp) and Green stink bug (*Nezara viridula*) together they form a pest complex were observed at the experimental sites. The per cent damage of white grub starts from 14th meteorological week (0.33%) which increased and reached its maximum in the 26th meteorological week (2.66%) and then shows gradual decrease in the 35th meteorological week (0.33%). While as the per cent damage of wire worm commenced from 15th meteorological week (0.33%) which increased gradually and reached its maximum (1.66%) in the 24th meteorological week and then decreased (0.33%) in the 30th meteorological week. However, mole cricket damage appeared from 18th week (0.33%) and reached peak (1.00%) in the 21st and 22nd meteorological week. Cutworm damage was not found in the one year old nursery plantations but appeared in the fresh germinated seedlings from 15th meteorological week (0.33%) which increased gradually and reached its maximum (1.33%) in the 21st

Plate 1 : Insect pest complex

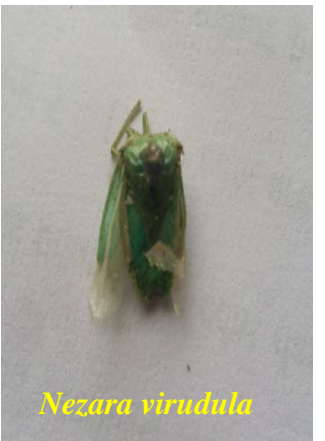


Plate 1 continue . . .



Oryctes Spp (♀)



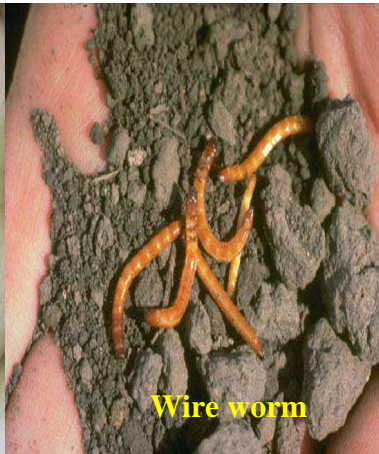
Mole cricket



White grub



Cut worm



Wire worm

Table 1: Per cent damage of (white grub, wire worm, mole cricket and cutworm) along with weather parameters

Standard week	Per cent damage				Temperature (°C)		Rainfall (mm)	Relative humidity (%)
	White grub	Wire worm	Mole cricket	Cutworm	Max.	Min		
12	0.00	0.00	0.00	0.00	13.28	6.94	9.48	81.71
13	0.00	0.00	0.00	0.00	17.78	4.64	2.91	64.14
14	0.33	0.00	0.00	0.00	15.14	6.24	6.00	77.35
15	0.33	0.33	0.00	0.33	22.91	6.90	0.00	61.29
16	0.33	0.33	0.00	0.33	25.00	8.92	0.02	66.85
17	0.33	0.33	0.00	0.33	21.71	9.64	4.37	70.00
18	0.66	0.66	0.33	0.66	19.92	8.92	3.17	73.07
19	0.66	1.00	0.33	0.66	24.00	7.65	2.21	64.07
20	0.66	1.00	0.66	1.00	26.25	9.00	2.05	64.85
21	1.00	1.33	1.00	1.33	30.00	10.24	0.00	54.28
22	1.00	1.00	1.00	1.33	30.87	10.62	0.00	54.07
23	1.33	1.33	0.66	0.66	27.42	12.92	0.10	61.50
24	1.33	1.66	0.00	0.33	30.42	13.80	1.28	59.14
25	2.33	0.66	0.33	0.00	27.50	14.28	8.14	64.85
26	2.66	0.66	0.33	0.00	31.87	16.50	0.00	59.50
27	2.00	0.66	0.33	0.00	28.95	16.00	1.94	69.14

Contd...

Table-1 contd...

Standard week	Per cent damage				Temperature (°C)		Rainfall (mm)	Relative humidity (%)
	White grub	Wire worm	Mole cricket	Cutworm	Max.	Min		
28	1.66	0.33	0.00	0.00	33.00	19.64	0.20	63.85
29	1.33	0.33	0.00	0.00	32.31	17.24	0.00	79.39
30	0.66	0.33	0.00	0.00	31.08	16.41	0.00	82.23
31	0.66	0.00	0.00	0.00	27.92	14.85	0.32	83.64
32	0.33	0.00	0.00	0.00	28.85	13.35	0.01	82.88
33	0.33	0.00	0.00	0.00	23.92	12.95	0.02	86.8
34	0.33	0.00	0.00	0.00	19.92	10.45	1.37	94.17
35	0.33	0.00	0.00	0.00	21.00	5.50	0.00	83.74
36	0.00	0.00	0.00	0.00	28.25	10.18	0.00	82.93
37	0.00	0.00	0.00	0.00	26.57	9.97	0.04	84.61
38	0.00	0.00	0.00	0.00	27.71	10.57	0.00	72.21
39	0.00	0.00	0.00	0.00	20.01	5.74	2.48	81.57
40	0.00	0.00	0.00	0.00	20.21	6.08	0.80	81.57
41	0.00	0.00	0.00	0.00	18.58	5.07	0.00	83.64
Cumulative damage	20.58	11.94	4.97	6.96	-	-	-	-

Table 2: Status of insect pest fauna observed in forest nursery

Sr. No.	Common name	Scientific name	Family and Order	Nature of damage	Host range	Period of prevalence	Period of peak incidence	Status
1	White grubs	<i>Holotrichia longipennis</i> <i>Brahmina</i> spp <i>Centonia</i> spp <i>Anomala</i> spp <i>Brahmina</i> spp <i>Melolontha furcicauda</i> <i>Oryctes</i> spp (♂) <i>Oryctes</i> spp (♀)	Scarabaeidae: Coleoptera	Grubs feed on roots	<i>C. torulosa</i> <i>P. wallichiana</i> <i>C. deodara</i> <i>R. pseudoaccacia</i>	May - September	2 nd fort night of July	Major
2	Wireworm	<i>Agriotes</i> spp	Elateridae: Coleoptera	Feed on roots	<i>C. torulosa</i> <i>P. wallichiana</i> <i>C. deodara</i> <i>R. pseudoaccacia</i>	May-August	1 st fort night of July	Major
3	Cutworm	<i>Agrotis</i> spp	Noctuidae: Lepidoptera	Cut tender seedlings above the ground surface	Newly germinated seedlings of <i>C. torulosa</i> <i>P. wallichiana</i> <i>C. deodara</i>	April – June	2 nd fort night of May	Minor
4	Mole cricket	<i>Gryllotalpa</i> spp	Gryllotalpidae: Orthoptera	Feed on seedling roots & lower stems	<i>C. torulosa</i> <i>P. wallichiana</i>	April – September	2 nd fort night of May	Minor
5	Green stink bug	<i>Nezara viridula</i>	Pentatomidae: Hemiptera	Suck cell sap	<i>R. pseudoaccacia</i>	June-August	1 st fortnight of July	Minor

and 22nd meteorological week and then decreased (0.33%) in the 24th meteorological week. White grubs and wire worms fed on roots appeared as a major pests, with their peak incidence in July. Other pests *viz.* cutworm and mole cricket appeared as minor pests with their cumulative damage of 6.96 and 4.97 per cent respectively (Table-1&2).

4.1.2 Correlation studies between per cent damage and abiotic factors

Correlation between abiotic factors and per cent damage through white grubs, wire worm, mole crickets and cutworm revealed that white grubs and mole cricket exhibited a significant positive correlation with maximum, minimum temperature, relative humidity and negatively correlated with rainfall. While as, wireworm showed a positive correlation with maximum temperature and minimum temperature, where as it was negatively correlated with relative humidity and rainfall. However, cutworm was positively correlated with maximum temperature only rest of the weather parameters exhibited negative correlation (Table-3).

4.2 Seasonal incidence of soil borne insect pests in forest nurseries

4.2.1 Adult Activity

The data presented in Table-4 & Fig. 1 on the status of insect pest fauna observed in forest nursery revealed that white grub, wireworm and mole cricket were of regular occurrence and caused considerable damage to the forest nursery. Light trap catches of chaffers depicted that, adult beetles (chaffers) appeared from the second week of April (13th meteorological week) and continued up to fourth week of September (36th meteorological week) during the year. The population increased gradually, reached its peak 25 adults/light trap/week in the 25th meteorological week. However, neither of the chaffers were caught in light trap during 12, 37, 38, 39, 40 and 41th meteorological weeks. Thereafter the population showed declined trend with decrease in temperature.

Table 3: Correlation between white grub, wire worm, mole cricket and cutworm with weather parameters

S. No.	Insect pests	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum		
1.	White grub	0.62**	0.72**	0.03	- 0.54**
2.	Wireworm	0.46**	0.26	- 0.02	- 0.77**
3.	Mole cricket	0.33	0.08	0.05	- 0.65**
4.	Cutworm	0.19	- 0.12	- 0.10	- 0.64**

**Significant at the 0.01 level.

*Significant at the 0.05 level.

Table 4: Seasonal incidence of major soil borne insect pests along with weather parameters

Standard week	Chaffer beetle		Click beetles		Meterological parameters			
	No. of adults/ trap/week	No. of larvae/ 8400 cm ³	No. of adults/ trap/week	No. of larvae/ 8400 cm ³	Temperature (°C)		Rain fall (mm)	Relative humidity (%)
					Max.	Min.		
12	0.00	0.00	0.00	0.00	13.28	6.94	9.48	81.71
13	2.00	0.00	0.00	0.00	17.78	4.64	2.91	64.14
14	4.00	1.00	0.00	0.66	15.14	6.24	6.00	77.35
15	3.00	2.33	2.00	1.66	22.91	6.90	0.00	61.29
16	3.00	3.33	3.00	1.33	25.00	8.92	0.02	66.85
17	7.00	4.66	5.00	2.66	21.71	9.64	4.37	70.00
18	8.00	4.66	5.00	3.00	19.92	8.92	3.17	73.07
19	8.00	5.00	9.00	3.66	24.00	7.65	2.21	64.07
20	10.00	5.33	10.00	4.00	26.25	9.00	2.05	64.85
21	14.00	6.66	8.00	3.66	30.00	10.24	0.00	54.28
22	11.00	7.33	8.00	3.66	30.87	10.62	0.00	54.07
23	12.00	7.00	11.00	4.33	27.42	12.92	0.10	61.50
24	17.00	7.66	13.00	4.66	30.42	13.80	1.28	59.14
25	25.00	7.66	16.00	5.00	27.50	14.28	8.14	64.85
26	18.00	8.33	12.00	3.66	31.87	16.50	0.00	59.50

Contd...

Table-4 contd...

Standard week	Chaffer beetle		Click beetles		Meterological parameters			
	No. of adults/ trap/week	No. of larvae/ 8400 cm ³	No. of adults/ trap/week	No. of larvae/ 8400 cm ³	Temperature (°C)		Rain fall (mm)	Relative humidity (%)
					Max.	Min.		
27	14.00	8.00	10.00	3.66	28.95	16.00	1.94	69.14
28	11.00	8.66	7.00	3.00	33.00	19.64	0.20	63.85
29	10.00	7.33	4.00	2.66	32.31	17.24	0.00	79.39
30	8.00	6.66	3.00	2.00	31.08	16.41	0.00	82.23
31	7.00	6.66	0.00	1.33	27.92	14.85	0.32	83.64
32	7.00	5.33	1.00	1.00	28.85	13.35	0.01	82.88
33	5.00	5.00	0.00	0.66	23.92	12.95	0.02	86.8
34	5.00	4.00	1.00	0.33	19.92	10.45	1.37	94.17
35	3.00	3.66	0.00	0.00	21.00	5.50	0.00	83.74
36	1.00	3.66	0.00	0.00	28.25	10.18	0.00	82.93
37	0.00	3.33	0.00	0.00	26.57	9.97	0.04	84.61
38	0.00	3.00	0.00	0.00	27.71	10.57	0.00	72.21
39	0.00	2.66	0.00	0.00	20.01	5.74	2.48	81.57
40	0.00	1.66	0.00	0.00	20.21	6.08	0.80	81.57
41	0.00	0.33	0.00	0.00	18.58	5.07	0.00	83.64

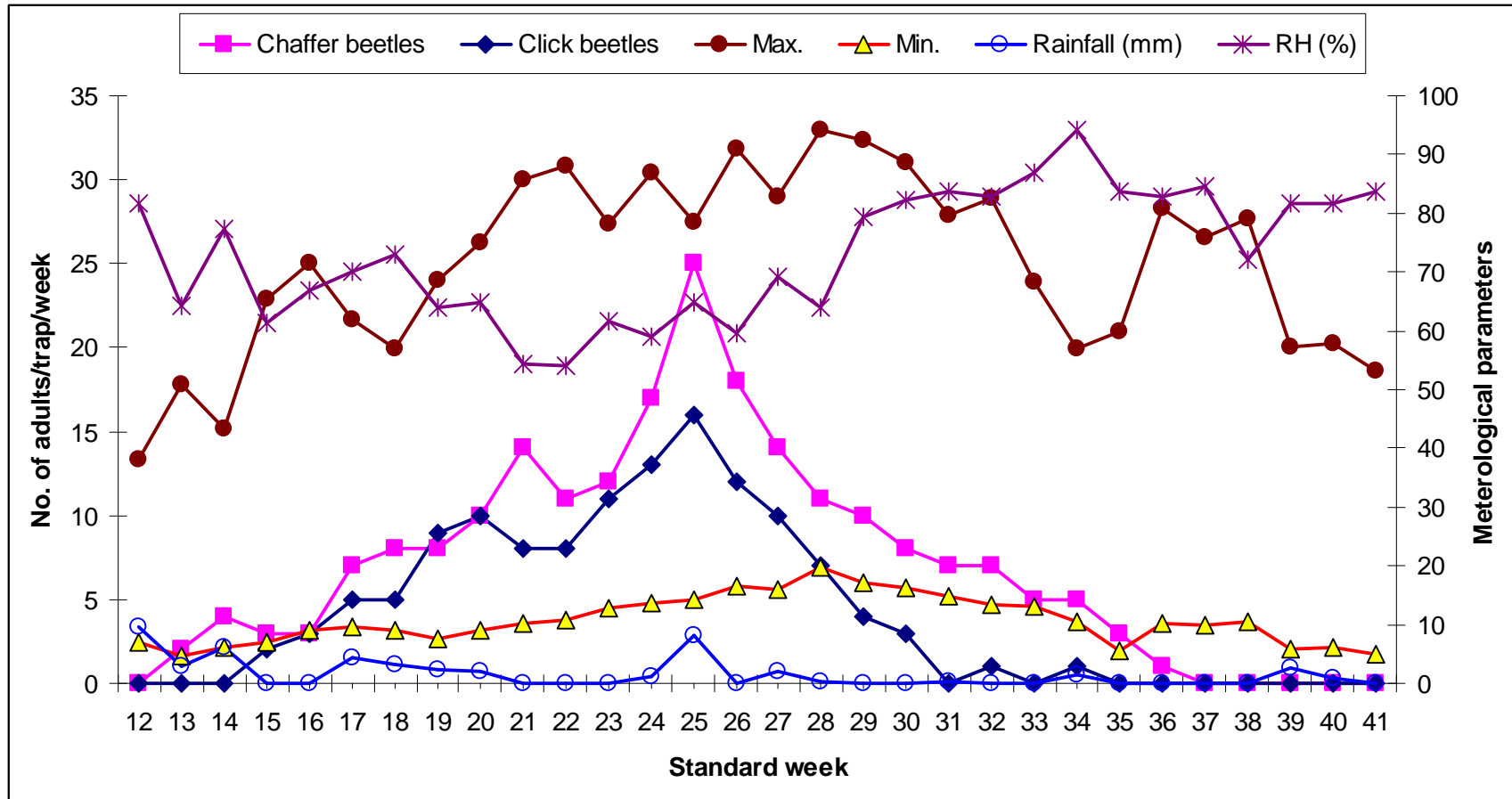


Fig. 1: Seasonal incidence of soil borne insect pests (adult activity) along with weather parameters

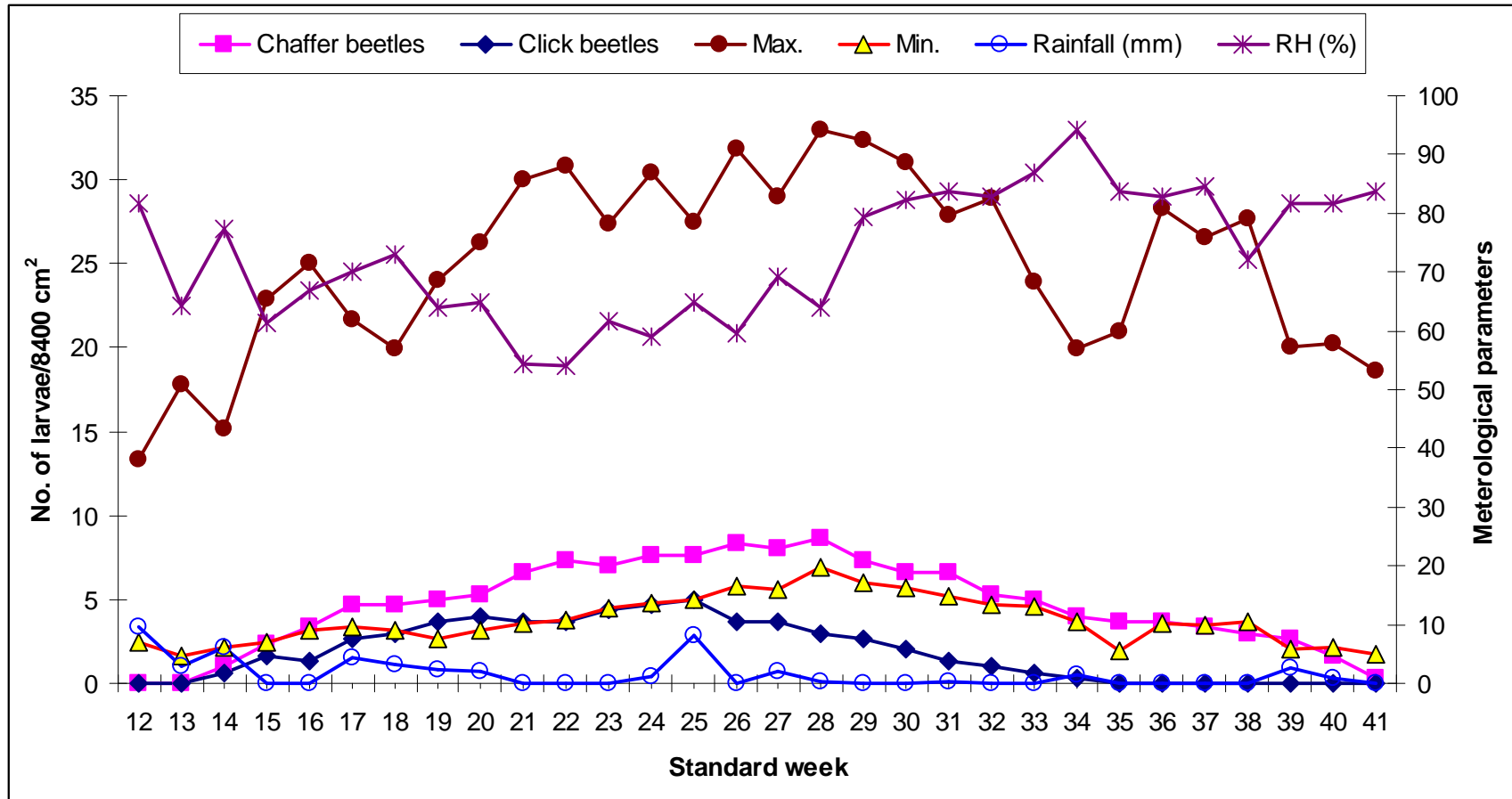


Fig. 2: Seasonal incidence of soil borne insect pests (larval activity) along with weather parameters

Click beetles were reported from the fourth week of May (15th meteorological week) and continued till second week of September (34th meteorological week) during the year. Likewise that of chaffers, click beetles also reached its peak in the 25th meteorological week with 16 adults/light trap/week. While, none of the click beetles were found in light trap during 12, 13, 14, 31, 33, 35, 36, 37, 38, 40 and 41st meteorological weeks.

4.2.2 Correlation studies of adult population with important abiotic parameters

Correlation between meteorological factors and soil borne insect pest population (chaffer beetle and click beetle) revealed that the population exhibited a positive correlation with maximum and minimum temperature and negative correlation with relative humidity. The white grub showed negative correlation with rain fall while, wire worm exhibited positive correlation with rain fall (Table-5).

4.2.3 Larval Activity

Larval activity of white grubs and wire worms were observed from 14th meteorological week with 1.00 and 0.66 larvae/8400 cm², respectively. Peak of larval population of white grubs was recorded 8.66 in 28th meteorological week, while in case of wire worm it was 5.00 in 25th meteorological week. There was decline in the larval population of both these pests with decrease in temperature (Table-4 & Fig. 2).

4.3 Management of soil borne insect pests

4.3.1 Effect of various insecticides against white grub and wire worm on *C. deodara*

Six chemicals *viz.* cartap hydrochloride 4G, thiamethoxam 25WG, carbofuran 3G, clothianidin 50WDG, imidacloprid 70WG, thiacloprid 48SC were evaluated against white grubs, wireworms and mole crickets. In case of *C. deodara* infested by white grub, imidacloprid showed significant results in reducing the plant mortality to 1.00 per cent each after 15, 30, 45 days of

Table 5: Correlation between insect pests viz. chaffer beetle and click beetle with weather parameters

S. No.	Insect pests	Temperature (°C)		Relative humidity (%)	Rainfall (%)
		Maximum	Minimum		
1.	Chaffer beetle	0.59**	0.64**	- 0.58**	0.12
2.	Click beetle	0.52**	0.48**	- 0.71**	0.14

**Significant at the 0.01 level.

*Significant at the 0.05 level.

Table 6: Effect of various insecticides on plant mortality of *Cedrus deodara* infested by white grub and wire worm

Treatments	Dosage per ha	White grub					Wire worm				
		Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control	Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control
		15 th	30 th	45 th			15 th	30 th	45 th		
T ₁ Cartap hydrochloride 4G	0.60 kg	3.66 (2.15)	3.33 (2.07)	3.00 (2.00)	9.99	63.43	2.66 (1.91)	2.33 (1.82)	2.00 (1.73)	6.99	62.52
T ₂ Thiamethoxam 25 WG	0.08 kg	3.33 (2.07)	3.00 (1.98)	2.66 (1.91)	8.99	67.09	2.33 (1.82)	2.00 (1.71)	1.66 (1.62)	5.99	67.88
T ₃ Carbofuran 3G	0.75 kg	4.33 (2.30)	4.00 (2.22)	3.66 (2.15)	11.99	56.11	3.33 (2.07)	3.00 (1.98)	2.66 (1.91)	8.99	51.79
T ₄ Clothianidin 50 WDG	0.12 kg	5.00 (2.44)	5.00 (2.44)	4.66 (2.37)	14.66	46.33	4.33 (2.30)	4.00 (2.22)	3.66 (2.15)	11.99	35.71
T ₅ Imidacloprid 70 WG	0.02 kg	1.00 (1.38)	1.00 (1.41)	1.00 (1.41)	3.00	89.01	1.33 (1.52)	1.00 (1.41)	1.00 (1.41)	3.33	82.14
T ₆ Thiacloprid 48 SC	0.50 lit	4.33 (2.30)	4.00 (2.22)	3.66 (2.15)	11.99	56.11	3.33 (2.07)	3.00 (1.98)	2.66 (1.91)	8.99	51.79
T ₀ Untreated (water)		9.33 (3.21)	9.33 (3.21)	8.66 (3.10)	27.32	-	6.66 (2.76)	6.33 (2.70)	5.66 (2.58)	18.65	-
S.Em		0.32	0.35	0.13	-	-	0.20	0.41	0.17	-	-
C.D (P≤0.05)		0.32	0.33	0.20	-	-	0.25	0.36	0.23	-	-

DAT = Days after treatment

Figures in parenthesis are Arc sine transformations

treatment. This was followed by thiamethoxam, however maximum mortality of 9.33, 9.33 and 8.66 per cent were recorded in control after 15, 30, 45 days after treatment, respectively. Cumulative mortality of *C. deodara* seedlings were recorded maximum in control 27.32, whereas it was found least in imidacloprid treated plots *i.e.*, 3.00 per cent. Imidacloprid was the most effective to rest of the chemicals tested against the pests which resulted 89.01 per cent reduction of *C. deodara* seedling over control followed by thiamethoxam (67.09%), cartap hydrochloride (63.43%), carbofuran (56.11%), thiacloprid (56.11%) and clothianidin (46.33%), respectively.

Similarly imidacloprid showed significant results in reducing the plant mortality to 1.33, 1.00 and 1.00 after 15, 30, 45 days of treatment, respectively. This was followed by thiamethoxam, however maximum mortality of 6.66, 6.33 and 5.66 per cent were recorded in control after 15, 30, 45 days of treatment, respectively. Cumulative mortality of *C. deodara* seedlings were recorded maximum in control 18.65 per cent, whereas it was found least in imidacloprid treated plots *i.e.*, 3.33 per cent. Imidacloprid was found to be most effective to rest of the chemicals tested against the pests which resulted 82.14 per cent reduction of *C. deodara* seedling over control followed by thiamethoxam (67.88%), cartap hydrochloride (62.52%), carbofuran (51.79%), thiacloprid (51.79%) and clothianidin (35.71%), respectively (Table-6).

4.3.2 Effect of various insecticides against white grub and wire worm on *C. torulosa*

In case of *C. torulosa* again imidacloprid showed significant results in reducing the plant mortality to 2.33, 2.00 and 1.66 per cent in white grub and 1.33, 1.00 and 0.66 per cent in wire worm infestation after 15, 30, 45 days of treatment, respectively. Imidacloprid was followed by thiamethoxam, however maximum mortality of 12.00, 12.00 and 11.66 in white grub and 7.66, 8.33 and 8.33 per cent in wire worm were recorded in control after 15, 30, 45 days of treatment, respectively. Cumulative mortality of *C. torulosa* seedlings were

Table 7 : Effect of various insecticides on plant mortality of *Cupressus torulosa* infested by white grub and wire worm

Treatments	Dosage per ha	White grub					Wire worm				
		Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control	Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control
		15 th	30 th	45 th			15 th	30 th	45 th		
T ₁ Cartap hydrochloride 4G	0.60 kg	4.66 (2.37)	4.33 (2.29)	4.33 (2.30)	13.32	62.64	3.00 (1.98)	2.66 (1.91)	3.33 (2.07)	8.99	63.03
T ₂ Thiamethoxam 25 WG	0.08 kg	3.33 (2.07)	3.33 (2.07)	4.66 (2.37)	11.32	68.25	2.33 (1.82)	2.33 (1.82)	3.66 (2.15)	8.32	65.78
T ₃ Carbofuran 3G	0.75 kg	4.33 (2.30)	4.33 (2.29)	5.33 (2.51)	13.99	60.76	3.33 (2.07)	3.33 (2.06)	4.33 (2.30)	10.99	54.81
T ₄ Clothianidin 50 WDG	0.12 kg	4.66 (2.37)	5.66 (2.57)	6.33 (2.70)	16.65	53.30	3.66 (2.15)	4.66 (2.37)	5.33 (2.51)	13.65	43.87
T ₅ Imidacloprid 70 WG	0.02 kg	2.33 (1.82)	2.00 (1.73)	1.66 (1.62)	5.99	83.20	1.33 (1.52)	1.00 (1.41)	0.66 (1.27)	2.99	87.70
T ₆ Thiacloprid 48 SC	0.50 lit	4.66 (2.37)	5.66 (2.58)	4.66 (2.37)	14.98	57.99	3.66 (2.15)	4.66 (2.37)	3.66 (2.15)	11.98	50.74
T ₀ Untreated (water)		12.00 (3.60)	12.00 (3.59)	11.66 (3.55)	35.66	-	7.66 (2.93)	8.33 (3.04)	8.33 (3.05)	24.32	-
S.Em		0.15	0.43	0.27	-	-	0.19	0.43	0.24	-	-
C.D (P<0.05)		0.22	0.37	0.23	-	-	0.25	0.37	0.27	-	-

DAT = Days after treatment

Figures in parenthesis are Arc sine transformations

recorded maximum in control 35.66 in white grub and 24.32 per cent in wire worm infested plots, respectively. Whereas it was found least in imidacloprid treated plots 5.99 per cent in white grub and 2.99 per cent in wire worm. Imidacloprid was found to be most effective among the given treatments against the white grub and wire worm which resulted 83.20 and 87.70 per cent reduction over control, respectively (Table-7).

4.3.3 Effect of various insecticides against white grub and wire worm on *P. wallichiana*

(Table- 8) depicts similar trend of results in *P. wallichiana* infested by white grubs and wire worm that imidacloprid showed significant reduction in plant mortality to 2.66, 2.33 and 2.00 and 1.66, 1.33 and 1.00 per cent after 15, 30, 45 days of treatment, respectively. Imidacloprid was followed by thiamethoxam, however maximum mortality of 12.66, 13.33 and 13.66 in white grub and 8.88, 8.33 and 9.33 per cent in wire worm were recorded in control after 15, 30, 45 days of treatment, respectively. Cumulative mortality of seedlings were recorded maximum in control 39.65 in white grub and 25.99 per cent in wire worm infested plots, respectively. Whereas it was found least in imidacloprid treated plots 6.99 per cent in white grub and 3.99 per cent in wire worm. Imidacloprid was found to be most effective among the given treatments against the white grub and wire worm which resulted 82.37 and 84.64 per cent reduction over control, respectively.

4.3.4 Effect of various insecticides against white grub and wire worm on *R. pseudoaccacia*

R. pseudoaccacia infestation by white grub and wire worm reveals that imidacloprid registered significant results in reducing the plant mortality to 3.66, 4.33 and 5.00 and 3.66, 6.33 and 7.00 after 15, 30, 45 days of treatment, respectively. This was followed by thiamethoxam, however maximum mortality of 13.66, 14.00 and 14.66 in white grub and 14.33, 12.66 and 12.33 per cent in wire worm were recorded in control after 15, 30, 45 days of treatment, respectively. Cumulative mortality of seedlings were recorded maximum in

Table 8: Effect of various insecticides on plant mortality of *Pinus wallichiana* infested by white grub and wire worm

Treatments	Dosage per ha	White grub					Wire worm				
		Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control	Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control
		15 th	30 th	45 th			15 th	30 th	45 th		
T ₁ Cartap hydrochloride 4G	0.60 kg	4.33 (2.30)	4.66 (2.37)	4.33 (2.30)	13.32	66.40	3.33 (2.07)	3.66 (2.15)	3.33 (2.07)	10.32	60.29
T ₂ Thiamethoxam 25 WG	0.08 kg	3.66 (2.15)	4.00 (2.22)	4.66 (2.37)	12.32	68.92	2.66 (1.91)	3.00 (1.98)	3.66 (2.15)	9.32	64.14
T ₃ Carbofuran 3G	0.75 kg	5.00 (2.44)	4.66 (2.37)	5.66 (2.57)	15.32	61.36	4.00 (2.22)	3.66 (2.15)	4.66 (2.37)	12.32	52.59
T ₄ Clothianidin 50 WDG	0.12 kg	6.33 (2.70)	5.66 (2.58)	6.33 (2.70)	18.32	53.79	5.33 (2.51)	4.66 (2.37)	5.33 (2.50)	15.32	41.05
T ₅ Imidacloprid 70 WG	0.02 kg	2.66 (1.91)	2.33 (1.80)	2.00 (1.71)	6.99	82.37	1.66 (1.62)	1.33 (1.48)	1.00 (1.38)	3.99	84.64
T ₆ Thiacloprid 48 SC	0.50 lit	5.33 (2.51)	5.00 (2.44)	5.66 (2.57)	15.99	59.67	4.33 (2.30)	4.00 (2.22)	4.33 (2.29)	12.66	51.28
T ₀ Untreated (water)		12.66 (3.67)	13.33 (3.78)	13.66 (3.82)	39.65	-	8.33 (3.05)	8.33 (3.05)	9.33 (3.20)	25.99	-
S.Em		0.50	0.39	0.56	-	-	0.26	0.56	0.61	-	-
C.D (P<0.05)		0.40	0.35	0.42	-	-	0.28	0.42	0.44	-	-

DAT = Days after treatment

Figures in parenthesis are Arc sine transformations

Table 9: Effect of various insecticides on plant mortality of *Robinia pseudoaccacia* infested by white grub and wire worm

Treatments	Dosage per ha	White grub					Wire worm				
		Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control	Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control
		15 th	30 th	45 th			15 th	30 th	45 th		
T ₁ Cartap hydrochloride 4G	0.60 kg	6.66 (2.74)	7.66 (2.94)	8.33 (3.05)	22.65	46.47	7.00 (2.82)	7.33 (2.88)	8.00 (2.99)	22.33	43.20
T ₂ Thiamethoxam 25 WG	0.08 kg	5.33 (2.50)	7.00 (2.82)	7.33 (2.88)	19.66	53.54	5.00 (2.44)	6.33 (2.70)	7.00 (2.82)	18.33	53.38
T ₃ Carbofuran 3G	0.75 kg	8.33 (3.05)	8.66 (3.10)	9.00 (3.16)	25.99	38.58	8.00 (2.99)	8.00 (2.99)	8.66 (3.10)	24.66	37.28
T ₄ Clothianidin 50 WDG	0.12 kg	8.66 (3.10)	9.66 (3.26)	9.66 (3.26)	27.98	33.88	8.66 (3.10)	9.00 (3.15)	9.33 (3.20)	26.99	31.35
T ₅ Imidacloprid 70 WG	0.02 kg	3.66 (2.13)	4.33 (2.30)	5.00 (2.44)	12.99	69.30	3.66 (2.13)	6.33 (2.69)	7.00 (2.82)	16.99	56.79
T ₆ Thiacloprid 48 SC	0.50 lit	8.33 (3.05)	9.66 (3.26)	8.33 (3.05)	26.32	37.88	8.33 (3.05)	9.00 (3.15)	8.33 (3.05)	25.66	34.74
T ₀ Untreated (water)		13.66 (3.82)	14.00 (3.87)	14.66 (3.95)	42.32	-	14.33 (3.90)	12.66 (3.69)	12.33 (3.65)	39.32	-
S.Em		0.70	0.14	0.12	-	-	0.58	0.31	0.20	-	-
C.D (P≤0.05)		0.47	0.21	0.20	-	-	0.43	0.31	0.25	-	-

DAT = Days after treatment

Figures in parenthesis are Arc sine transformations

control 42.32 in white grub and 39.32 per cent in wire worm infested plots, respectively. Whereas it was found least in imidacloprid treated plots 12.99 per cent in white grub and 16.99 per cent in wire worm. Imidacloprid was found to be most effective among the given treatments against the white grub and wire worm which resulted 69.30 and 56.79 per cent reduction over control, respectively (table-9).

4.3.5 Effect of various insecticides against mole cricket on *C. torulosa* and *P. wallichiana*

Mole cricket infestation on *C. torulosa* depicts that imidacloprid showed significant results in reducing the plant mortality by 0.66, 1.66 and 2.00 per cent after 15, 30, 45 days of treatment, respectively. Imidacloprid was followed by thiamethoxam, however maximum mortality 3.66, 4.33 and 4.66 per cent were recorded in control after 15, 30, 45 days after treatment, respectively. Cumulative mortality of *C. torulosa* seedlings were recorded maximum in control 12.65 per cent, whereas it was least in imidacloprid treated plots (*i.e.* 4.32 per cent). Imidacloprid proved to be most effective among the given treatments against the white grub, which resulted 65.84 per cent reduction of *C. torulosa* seedling over control followed by thiamethoxam (57.94%), tartap hydrochloride (42.13%), carbofuran (34.22%), thiacloprid (31.54) and clothianidin (13.12%), respectively.

Infestation of mole cricket in *P. wallichiana* revealed similar significant results in reducing the plant mortality to 1.66, 1.33 and 0.66 per cent after 15, 30, 45 days of treatment, respectively. This was followed by thiamethoxam, while maximum mortality of 4.33, 4.00 and 3.66 per cent were recorded in control after 15, 30, 45 days of treatment, respectively. Cumulative mortality of *P. wallichiana* seedlings were recorded maximum in control 11.99 per cent, whereas it was least in imidacloprid treated plots 3.65 per cent. Imidacloprid proved to be most effective to rest of the chemicals tested against the pests which resulted 69.55 per cent reduction of *P. wallichiana* seedling over control followed by thiamethoxam

(63.96%), cartap hydrochloride (50.04%), carbofuran (41.70%), thiacloprid (42.01%) and clothianidin (19.51%), respectively (Table-10).

Thus the order of efficacy of insecticides is shown as under:

imidacloprid > thiamethoxam > cartap hydrochloride >
carbofuran > thiacloprid > clothianidin

The maximum damage was caused by white grub followed by wire worm in *R. pseudoaccacia*, *P. wallichiana*, *C. torulosa* and then least damage was seen in *C. deodara*. Thus the order of infestation is shown below:

C. deodara < *C. torulosa* < *P. wallichiana* < *R. pseudoaccacia*

While as the mole cricket causes maximum damage on *P. wallichiana* followed by *C. torulosa*.

Table 10: Effect of various insecticides on plant mortality of *Cupressus torulosa* and *Pinus wallichiana* infested by mole cricket

Treatments	Dosage per ha	<i>Cupressus torulosa</i>					<i>Pinus wallichiana</i>				
		Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control	Plant mortality per cent (DAT)			Cumulative mortality	Per cent reduction over control
		15 th	30 th	45 th			15 th	30 th	45 th		
T ₁ Cartap hydrochloride 4G	0.60 kg	2.33 (1.82)	2.33 (1.82)	2.66 (1.91)	7.32	42.13	2.33 (1.82)	2.00 (1.73)	1.66 (1.62)	5.99	50.04
T ₂ Thiamethoxam 25 WG	0.08 kg	1.66 (1.62)	1.66 (1.62)	2.00 (1.72)	5.32	57.94	1.66 (.62)	1.33 (1.52)	1.33 (1.52)	4.32	63.96
T ₃ Carbofuran 3G	0.75 kg	2.66 (1.91)	2.66 (1.91)	3.00 (2.00)	8.32	34.22	2.66 (1.91)	2.33 (1.82)	2.00 (1.73)	6.99	41.70
T ₄ Clothianidin 50 WDG	0.12 kg	3.33 (2.07)	3.66 (2.15)	4.00 (2.23)	10.99	13.12	3.66 (2.15)	3.33 (2.07)	2.66 (1.91)	9.65	19.51
T ₅ Imidacloprid 70 WG	0.02 kg	0.66 (1.27)	1.66 (1.62)	2.00 (1.73)	4.32	65.84	1.66 (1.62)	1.33 (.52)	0.66 (1.27)	3.65	69.55
T ₆ Thiacloprid 48 SC	0.50 lit	3.00 (2.00)	2.66 (1.91)	3.00 (2.00)	8.66	31.54	2.66 (1.91)	2.33 (1.82)	2.00 (1.73)	6.99	42.01
T ₀ Untreated (water)		3.66 (2.15)	4.33 (2.30)	4.66 (2.37)	12.65	-	4.33 (2.30)	4.00 (2.23)	3.66 (2.15)	11.99	-
S.Em		0.29	0.23	0.20	-	-	0.27	0.24	0.28	-	-
C.D (P≤0.05)		0.27	0.17	0.13	-	-	0.23	0.18	0.24	-	-

DAT = Days after treatment

Figures in parenthesis are Arc sine transformations

Chapter – 5

DISCUSSION

Experimental findings obtained from the experimental site in the Forest Nurseries of Wadura and Social Forest of Kulangam, are discussed as under :

5.1 Status of insect pests of forest nurseries

5.1.1 Damage of insect pests

Soil borne insects *viz.* white grubs (*Holotrichia longipennis*, *Brahmina* spp, *Centonia* spp, *Anomala* spp, *Brahmina* spp, *Melolontha furcicauda*, *Oryctes* spp (♂), and *Oryctes* spp (♀), wireworms (*Agriotes* spp), mole cricket (*Gryllotalpa* spp), cutworms (*Agrotis* spp) and Green stink bug (*Nezara viridula*) together they form a pest complex were observed at the experimental sites. Among these white grub damage was found maximum in the 26th meteorological week (2.66%) and showed gradual decrease before and after this week. While, wire worm damage was found maximum in the 24th meteorological week (1.66%). However, cutworm damage was not found in the one year old nursery plantations but appeared in the fresh germinated seedlings from 15th meteorological week (0.33%) which increased gradually and reached its maximum (1.33%) in the 21st and 22nd meteorological week after that it decreases because the seedlings gets older, hard and stiff as they are unable to damage on one year old seedlings one possible reason could be there was continuous rains after 22nd meteorological week that leads to suffocation of the pest and then death. Similarly, mole cricket damage also reached its peak (1.00%) in the 21st and 22nd meteorological week. White grubs and wire worms fed on roots, appeared as a major pest with its cumulative damage of 20.58 and 11.94 per cent, respectively. Other pests *viz.* cutworm and mole cricket appeared as minor pests with their cumulative damage of 6.96 and 4.97 per cent, respectively. Although, 50 species has been reported that attack living forest trees, the majority of which are coniferophagous, including phloem and wood borers in the roots, stems and branches; twig girdles;

and gall forming species (Craighead, 1950 and Keen, 1952). Similar reports were found by Marshall *et al.* (1990) who conducted a survey of 24 forest nurseries in British Columbia yielded 22 collembolan taxa, 10 of which are reported for the first time from the province. Girma *et al.* (2000) studied abundance of different arthropod species and their population dynamics under hedgerow and monitored pests through counts of infested plants using yellow pan and pitfall traps. Bhat *et al.* (2005) reported nine chaffer species at three locations (Harwan, Shalimar and Shopian), Out of these *Melolontha indica*, *Anomala rufiventris*, *Lasiotropus ponnesis* and *Oryctes nasicornis* are new records for Kashmir. Moreover, six species of Elateridae larvae including *Agriotes obscurus*, *Athous niger*, *Athous subsuscus*, *Dalopius marginatus* and *Athous vittatus* were found by using soil sampling (Jedlicka and Frouz, 2007). In addition to this Pandey *et al.* (2007) found gypsy moth (*Lymantria* spp), Willow scale (*Chionaspis salicis* L.), Tent caterpillar (*Malacosoma* spp), willow leaf beetle (*Altica* spp), goat moth (*Cossus cossus* L.), ermine moth (*Yponomeuta rorellus* Hubner), poplar petiole gall insect (*Pemphigus* spp), willow apple gall (*Pontania* spp) in Ladakh of J&K on forest plantation. Gradinariu *et al.* (2012) reported that the most dangerous pests for saplings from the forest nurseries are root insects. Only *N. viridula* was found to feed on above ground parts of *R. pseudoacacia* (*i.e.* leaves) this is in close conformity with sharma *et. al* (2008) who reported *N. viridula*, *Bagrada cruciferarum*, *Cyclopelta siccifolia*. However, *N. viridula* infestation were mostly seen in *R. pseudoacacia* in social forest nursery followed by Chaffer beetles feed profusely on the foliage of this tree and take heavy toll of the leaves.

5.1.2 Correlation studies

Correlation between abiotic factors and per cent damage through white grubs, wire worm, mole crickets and cutworm revealed that white grubs and mole cricket exhibited a significant positive correlation with maximum, minimum temperature, relative humidity and negatively correlated with rainfall. While as, wireworm resulted a positive correlation with maximum temperature and

minimum temperature, where as it was negatively correlated with relative humidity and rainfall. However, cutworm was positively correlated with maximum temperature only rest of the weather parameters exhibited negative correlation. There was no earlier report on correlation studies of white grubs, wire worms and mole cricket in the forest nurseries of Kashmir, however our results are in close conformity with Garg *et al.* (2005) who reported strong and positive correlation of *H. serrata* with temperature while, humidity was contradictory with our results, this might be attributed due to variation in climatic conditions. Although, Blackshaw and Hicks (2013) studied distribution of adult male click beetles out of which *Agriotes lineatus*, was the found to be most abundant even though its larvae were absent from these fields. Recently, Varga *et al.* (2014) monitored the population structure of click beetles (wireworms) in forestry nurseries.

5.2 Seasonal incidence of soil borne insect pests in forest nurseries

5.2.1 Adult and larval activity

It is evident from the data that, adult beetles (chaffers) appeared from the second week of April (13th meteorological week) and continued up to fourth week of October (36th meteorological week) during the year with its peak of 25 adults/light trap/week in the 25th meteorological week. Thereafter the population showed declined trend with decrease in temperature. Whereas, click beetles appeared from the fourth week of May (15th meteorological week) and continued till second week of September (34th meteorological week) with its peak in the same week *i.e.* 25th meteorological week. Peak of larval population of white grubs was recorded 8.66 in 28th meteorological week, while in case of wire worm it was 5.00 in 25th meteorological week. These results are in agreement with Day *et al.* (1969) who made various collections of wire worms on monthly basis in light trap and found maximum number between June and September. Similarly, Ahad *et al.* (2012) reported the abundance of soil borne insects white grubs, wire worms and cutworms higher reaches at Udhampur, Jammu and Kashmir.

5.2.2 Correlation studies

Correlation between meteorological factors and soil borne insect pest population (chaffer beetle and click beetle) revealed that the population exhibited a positive correlation with maximum and minimum temperature and negative correlation with relative humidity. The white grub showed negative correlation with rain fall while, wire worm exhibited positive correlation with rain fall. This might be due the temperature. Such findings on correlation studies of white grubs, wire worms and mole cricket in the forest nurseries were not reported, however Ahad *et al.* (2012) reported similar type of results on soil borne insects on maize crop in higher reaches of intermediate zone of Jammu, (J&K).

5.3 Management of soil borne insect pests

Various chemicals *viz.*, cartap hydrochloride 4G, thiamethoxam 25WG, carbofuran 3G, clothianidin 50WDG, imidacloprid 70WG, thiacloprid 48SC were evaluated against white grubs, wireworms and mole crickets. It was evident from the experimental findings that imidacloprid showed significant results in reducing the plant mortality by 1.38, 1.41 and 1.41 after 15, 30, 45 days after treatment, respectively. This was followed by thiamethoxam, however maximum mortality was found in control. Imidacloprid was the most effective to rest of the chemicals tested against the pests which resulted 89.01 per cent reduction of *C. deodara* seedling over control.

Similar trend was found in case of wireworm management where imidacloprid was found to be most effective to rest of the chemicals tested against the pests which resulted 82.14 per cent reduction of *C. deodara* seedling over control followed by thiamethoxam (67.88%)> cartap hydrochloride (62.52%) > carbofuran (51.79%) > thiacloprid (51.79%) > clothianidin (35.71%).

Likewise that of *C. deodara* white grub infestation on *C. torulosa* depicted same type of results imidacloprid showed significant results in reducing the plant mortality and was found to be most effective among the given

treatments, which resulted 83.20 per cent reduction in mortality of seedlings over control followed by thiamethoxam (68.25%) > cartap hydrochloride (62.64%) > carbofuran (60.76%) > thiacloprid (57.99%) > clothianidin (53.30%). As per the reduction in plant mortality through wire worm over control is concerned similar trend of results were found with imidacloprid (87.70 %) > thiamethoxam (65.78%) > cartap hydrochloride (63.03%) > carbofuran (54.81%) > thiacloprid (50.74%) > clothianidin (43.87%).

Imidacloprid showed also significant reduction in plant (*P. wallichiana*) mortality through white grubs and wireworms with net mortality of 6.99 and 3.99 per cent, respectively. Overall, imidacloprid was found most effective to rest of the chemicals tested against the pests which resulted 82.37 and 84.64 per cent reduction of *P. wallichiana* seedling over control in white grubs and wire worm respectively.

In *R. pseudoaccacia* analogous results were found with net mortality of seedlings in imidacloprid treated plots infested by white grub 12.99 per cent and 16.99 per cent in case of wire worm. 69.30 per cent reduction of seedlings over control was found in white grub infested plot while it is 56.79 per cent in wire worm. Our findings are in agreement with Patial and Bhagat (2005) who reported that imidacloprid 70WS seed treatment against white grubs in maize with least plant mortality percentage (3.74%).

Mole cricket infestation on *C. torulosa* depicts that imidacloprid showed significant results in reducing the plant mortality by 65.84 per cent over control while as in case of *P. wallichiana* it is 69.55 per cent reduction over control. Whereas, damage of mole cricket was absent in the *R. psuedoaccacia* and *C. deodara*. The maximum damage was caused by white grub followed by wire worm in *R. pseudoaccacia*, *P. wallichiana*, *C. torulosa* and then least damage was seen in *C. deodara*. Overall performance of chemicals followed a trend of imidacloprid > thiamethoxam > cartap hydrochloride > carbofuran > thiacloprid > clothianidin.

Present findings are in close conformity with reports of Shaohui Wu (2013) who proved the Merit 75 WP (imidacloprid) most effective against white grubs than those of entomopathogenic fungi and entomopathogenic nematodes. Similarly, Patial and Bhagat (2005) reported seed treatment of imidacloprid 70WS @ 3.5 g *a.i* per kg of seed, most effective against white grubs in maize. Pandey (2010) found imidacloprid the most effective in reducing the white grub population by 82.28 per cent with subsequent increase in yield by 206.86 per cent over control. The efficacy of imidacloprid as seed dressing insecticides for control of the black maize beetle adults, *Heteronychus arator*, in maize reported that imidacloprid had a systemically translocated antifeedant action in the stems of plants (Drinkwater and Groenewald, 1994). Whereas, Hagen (1995) found effectiveness of both chemical and cultural control against the borer infestation. However, synergetic effect has been reported by combined application of *H. bacteriophora* and *M. anisopliae* isolate MM against the barley chafer, *C. curtipennis* (Ansari *et al.*, 2004).

It was evident from the data that infestation of soil borne insects was found maximum in *R. pseudoaccacia*, while it was least in *C. deodara*. Thus the order of infestation is *C. deodara* < *C. torulosa* < *P. wallichiana* < *R. pseudoaccacia*. *C. deodara* registered least infestation this might be attributed due to essential oils produced by this tree species. Our findings are supported by Chaudary *et al.* (2011) who reported the impact of essential oils as larvicidal against diamond back moth (*Plutella xylostella*). While as the mole cricket causes maximum damage on *P. wallichiana* followed by *C. torulosa*. However, our results are in contradict with Bhat (2011) who evaluated various chemicals viz., Dichlorvos, Imidacloprid, Monocrotophos, Carbendazim, Endosulfan and Benzene hexachloride (BHC) screened against the shot-hole borer, *S. kashmirensis*. Out of all the chemical concentration evaluated Dichlorvos 1% was the most effective to rest of the chemicals tested against the borer population, controlled 92.70% borer population followed by Monocrotophos and

Carbendazim mixture which controlled 86.33% and Imidacloprid. Similarly Rajagopal (1990) showed chlorpyrifos to be effective for at least more than six months against termites attacking eucalypts. It must be pointed out that the persistence of insecticides in soil will depend on the structure of soil and many other factors.

Chapter – 6

SUMMARY AND CONCLUSIONS

Investigations entitled “Pest complex and management of soil borne pests in forest nursery” were carried out at forest nursery of Faculty of Agriculture, Wadura in open choice conditions during 2014-15. A part of experiment was carried out at social forest nursery, Kulangam to study the soil borne insect pests of *Robinia pseudoaccacia*. Forest nursery containing *Pinus wallichiana*, *Cedrus deodara*, *Cupressus torulosa* (in poly bags) and *Robinia pseudoaccacia* (on nursery beds) were studied to know the status and management of soil borne insect pests.

White grub damage was found maximum in the 27th meteorological week (2.66%) and showed gradual decrease before and after this week. While, wire worm damage was found maximum in the 24th meteorological week (1.66%). However, cutworm damage reached its maximum (1.33%) in the 21st and 22nd meteorological week. Similarly, mole cricket damage also reached its peak (1.00%) in the 21st and 22nd meteorological week. Other pests *viz.* cutworm and mole cricket appeared as minor pests with their cumulative damage of 6.96 and 4.97 per cent, respectively. Seasonal incidence of soil borne insect pests depicts that, adult beetles (chaffers) appeared from the second week of April (13th meteorological week) and continued up to fourth week of October (36th meteorological week) during the year with its peak of 25 adults/light trap/week in the 25 meteorological week. Thereafter the population showed declined trend with decrease in temperature. Whereas, click beetles appeared from the fourth week of May (15th meteorological week) and continued till second week of September (34th meteorological week) with its peak in the same week *i. e.* 25th meteorological week. Peak of larval population of white grubs was recorded 8.66 in 28th meteorological week, while in case of wire worm it was 5.00 in 25th meteorological week.

Correlation between abiotic factors and per cent damage through white grubs, wire worm, mole crickets and cutworm revealed that white grubs exhibited a positive correlation with maximum, minimum temperature, relative humidity and negatively correlated with rainfall. While, wire worm resulted a positive correlation with maximum, minimum temperatures. However, it showed negative correlation with relative humidity and rainfall. Similarly, mole cricket damage was positively correlated with maximum temperature, minimum temperature and relative humidity however, it was negatively correlated with rainfall. However, the cutworm shows positive correlation with maximum temperature only while as it is negatively correlated with minimum temperature, relative humidity and rainfall.

Various chemicals viz., cartap hydrochloride 4G, thiamethoxam 25WG, carbofuran 3G, clothianidin 50WDG, imidacloprid 70WG, thiacloprid 48SC were evaluated against white grubs, wireworms and mole crickets. It was evident from the experimental findings that imidacloprid showed significant results in reducing the plant mortality infested by white grub is 89.01 per cent over control in *C. deodara* seedling, 83.20 per cent over control in *C. torulosa*, 82.37 per cent reduction over control in *P. wallichiana* seedling, 69.30 per cent reduction over control in *R. pseudoaccacia*. Similar trend was found in case of wireworm management where imidacloprid was found to be most effective to rest of the chemicals tested against the pests which resulted 82.14 per cent reduction of *C. deodara* seedling over control, 87.70 per cent in *C. torulosa*, 84.64 per cent in *P. wallichiana* seedling, 56.79 per cent in *R. pseudoaccacia*. Mole cricket infestation on *C. torulosa* depicts that imidacloprid showed significant results in reducing the plant mortality by 65.84 per cent over control while as in case of *P. wallichiana* it is 69.55 per cent reduction over control. Whereas, damage of mole cricket was absent in the *R. psuedoaccacia* and *C. deodara*. The maximum damage was caused by white grub followed by wire worm in *R. psuedoaccacia*, *P. wallichiana*, *C. torulosa* and least damage was observed in *C. deodara*.

CONCLUSION

Among the insects pests attacking forest nurseries, white grub and wire worm appeared as major, however mole cricket and cutworm were as minor pests, respectively and there is urgent need to manage these pests. Overall performance of chemicals depicted that Imidacloprid resulted significant decrease in plant mortality hence this insecticide shall be incorporated in the management practices. Order of infestation is *C. deodara* < *C. torulosa* < *P. wallichiana* < *R. pseudoaccacia*. Further investigations should be carried out on this aspect to achieve more and efficient results as our experimental findings are pertaining to a single year only.

LITERATURE CITED

- Ahad, I., Bhagat, R.M., Ahmad, H., Sharma, D. and Jamwal, V.V.S. 2012. Insect pest complex and their succession on Maize. *Annals of Plant Protection Science* **20**(2) : 464-509.
- Alalouni, U., Schadler, M. and Brandl, R. 2013. Natural enemies & environmental factors affecting the population dynamics of gypsy moth. *Journal of Applied Entomology* **137** : 721-738.
- Alao, J.S., Sale, F.A. and Ojo, A.S. 2011. Problems and management of insect pests in social forestry in Nigeria. *African Journal of Agricultural Research* **6**(33) : 6755-6758.
- Anderbrant, O. and Schlyter, F. 1987. Ecology of the Dutch elm disease vectors, *Scolytus laevis* and *S. scolytus* (Coleoptera: Scolytidae) in Southern Sweden. *Journal of Applied Ecology* **24** : 539-550.
- Aneni, T.I., Aisagbonhi, C.I., Iloba, B.N., Adaigbe, V.C. and Ogbebor, C.O. 2013. Influence of weather factors on seasonal population dynamics of *Coelaenomenodera elaeidis* (Coleoptera: Chrysomelidae) and its natural enemies in NIFOR, Nigeria. *International Academy of Ecology and Environmental Sciences* **3**(4) : 344-352.
- Anitha, V., Rogers, D.J., Wightman, J. and Ward, A. 2006. Distribution and abundance of white grubs (Coleoptera: Scarabaeidae) on groundnut in southern India. *Crop Protection* **25** : 732-740.
- Anonymous. 2002. Food and Agriculture organization report. www.Fao.org/..y6000e00.htm.

- Anonymous. 2001. State forest report. Kashmir Environment Watch Association. (www.geocites.com/rainforest/canopy/3572/nonjava.html)_www.kewa.org/forest.html
- Anonymous. 2012. Kashmir environment watch association. ([www.geocites.com/rain forest/ canopy/3572/nonjava.html](http://www.geocites.com/rainforest/canopy/3572/nonjava.html)) [http:// www.kewa.org/forest.html](http://www.kewa.org/forest.html).
- Ansari, M.A., Tirry, L. and Moens, M. 2004. Interaction between *M. anisopliae* CLO 53 and entomopathogenic nematodes for the control of *Hoplia philanthus*. *Biological Control* **31** : 172-180.
- Bhat, O.K., Bhat, A.A. and Koul, V.K. 2005. Faunistic studies of white grubs in Kashmir. *Insect Environment* **11**(1) : 14-15.
- Bhat, P.A. 2011. Management of Elm Bark Beetle, *Scolytus kashmirensis* Schedl Infesting Elm Trees (*Ulmus* species) in Kashmir. Phd thesis submitted to the University of Kashmir for the award of the degree of Master of philosophy (M.Phil) in Zoology (Entomology).
- Blackshaw, R.P. and Hicks, H. 2013. Distribution of adult stages of soil insect pests across an agricultural landscape. *Journal of Pest Science* **86**(1) : 53-62.
- Borden, J.H. 2009. Two tree baiting tactics for the management of bark beetles with semiochemicals. *Journal of Applied Entomology* **114**(1-5) : 201-207.
- Bracalini, Matteo, Benedettelli, Stefano, Croci, Francesco, Terreni, Perla, Tiberi, Rizio, Panzavolta and Tiziana 2013. Cone and Seed Pests of *Pinus pinea*: Assessment and characterization of damage. *Journal of Economic Entomology* **106**(6) : 229-234.

- Bucurean, E. and Bunta, G. 2011. Control of wireworms (*Agriotes* spp.) by chemical seed treatment. *Analele Universitaatii din Oradea, Fascicula: Protectia Mediului* **17** : 23-26
- Byers, J.A., Svirhra, P. and Koehler, C.S. 1980. Attraction of elm bark beetles to cut limbs on the elm. *Journal of Arboric* **6** : 245-246.
- Cantelo and William, W. 1974. Black light Traps as Control Agents: An Appraisal. *Entomological Society of America* **20**(4) : 279-282.
- Chandla, V.K. 1986. Pest complex of potato crop in Shimla hills and their management. *Ph. D. Thesis*. Y.S.P. University of Horticulture and Forestry, Solan (H.P.)
- Chaudhary, A., Sharma, P., Nadda, G., Tewary, D. K. and Singh, B. 2011. Chemical composition and larvicidal activities of the Himalayan cedar, *cedrus deodara* essential oil and its fractions against the diamond back moth, *plutella xylostella*. *Journal of Insect Science* **11** : 1-10.
- Cherrya, R. and Stanslyb. P. 2008. Abundance and Spatial Distribution of Wireworms (Coleoptera: Elateridae) in Florida Sugarcane Fields on Muck versus Sandy Soils. *Florida Entomologist* **91**(3) : 383-387.
- Cinti, S., Cristofaro, A. and Vigilante, G. 1993. The defense of peach: control of the principal insects and mites. *Terra- e- Sole* **48**(608) : 215-219.
- Cook, J.R. and Solomon, J.D. 1976. Damage, biology and natural control of insect borers in cottonwood (*Populus deltoids*). *Proceedings: Symposium on Eastern Cottonwood and Related Species* pp.272-279.
- Craighead, F.C. 1950. Insect enemies of Eastern forests. *Misc. Publ.* No. 657. USA, WA- Washington, DC; USDA.

- Day, Reid, A. and Jr., W.J. 1969. Response of Adult Southern Potato Wireworms to Light Traps. *Journal of Economic Entomology* **62**(2) : 314-318.
- Dimitri, L., Gebauer, U., Losekrug, R. and Vaupel, O. 2009. Influence of mass trapping on the population dynamics and damage effect of bark beetles. *Journal of Applied Entomology* **114**(1-5) : 103-109.
- Donley, D.E. 1981. Control of the red oak borer by removal of infested trees. *Journal of Forestry* **79**(11) : 731-733.
- Donley, D.E. 1983. Cultural control of the red oak borer (Coleoptera: Cerambycidae) in forest management units. *Journal of Economic Entomology* **76**(4) : 927-929.
- Drinkwater, T.W. and Groenewald, L.H. 1994. Comparison of imidacloprid and furathiocarb seed dressing insecticides for the control of the black maize beetle, *Heteronychus arator Fabricius* (Coleoptera: Scarabaeidae) in maize. *Crop Protection* **13**(6) : 421-424
- Edwards, J.S. 1961a. Observations on the biology of the immature stages of *Prionoplus reticularis* White (Coleoptera: Cerambycidae). *Transactions of the Royal Society of New Zealand* **88**(4) : 727-731.
- Edwards, J.S. 1961b. On the reproduction of *Prionoplus reticularis* (Coleoptera: Cerambycidae), with general remarks on reproduction in the Cerambycidae. *Quarterly Journal of Microscopical Science* **102**(4) : 519-529.
- Garg, V.K., Kulkarni, N. and Meshram, P.B. 2005. Influence of weather parametres on the incidence of white grub, *Holotrichia serrata* Fabr. on teak seedlings in chhindwara forest division. *Indian Journal of Tropical Biodiversity* **13** : 48-51.

- Gibbs, J.N. and Wainhouse, D. 1986. Spread of forest pests and pathogens in the Northern Hemisphere. *Forestry* **59** : 141-153.
- Girma, H., Rao, M.R. and Sithanatham, S. 2000. Insect pests and beneficial arthropod populations under different hedgerow intercropping systems in semiarid Kenya. *Agroforestry Systems* **50**(3) : 279-292.
- Godfrey, L.D., Legg, D.E. and Yeargan, K.V. 1986. Effects of Soil-borne Organisms on Spring Alfalfa Establishment in an Alfalfa Rotation System. *Journal of Economic Entomology* **79**(4) : 1055-1063.
- Gradinariu, F., Mutu, M.E. and Jaluba, I. 2012. Aspects regarding the dynamics of pests found in forest nurseries in North-East of Moldova during 2009-2011. *Journal of Horticulture, Forestry and Biotechnology* **16**(4) : 1-9.
- Gupta, S. and Gavkare, O. 2014. Whitegrub (*Brahmina coriacea*): A Potential Threat to Potato. *Popular Kheti* **2**(2) : 124-126.
- Hagen, W.B. 1995. Managing bark beetles in urban and rural trees. *Tree Notes*, California, Department of Forestry and Fire Protection Publ., No. 19.
- Harcourt, D.G., Yee, J.M. and Guppy, J.C. 1983. Two Models for Predicting the seasonal occurrence of *Agromyza frontella* (Diptera: Agromyzidae) in Eastern Ontario. *Entomological Society of America* **12**(5):1455-1458.
- Hillocks, R.J., M. Logan, J.W., Riches, C.R., Russell-Smith, A. and Shaxson, L.J. 1996. Soil pests in traditional farming systems in sub-Saharan Africa-a review. *International Journal of Pest Management* **42**(4) : 241-251.
- Holopainen, J.K., Heijari, J., Nerg, A.M., Vuorinen, M. and Kainulainen, P. 2009. Potential for the Use of Exogenous Chemical Elicitors in Disease and Insect Pest Management of Conifer Seedling Production. *The Open Forest Science Journal* **2** : 17-24.

- Jedlicka, P. and Frouz, J. 2007. Population dynamics of wireworms (Coleoptera, Elateridae) in arable land after abandonment. *Biologia* **62**(1) : 103-111.
- Kalia, M., Chandel, R.S., Mehta., P.K, Pathania, M. and Paul, Y.S. 2011. *Beauveria bassiana*: A potential entomopathogenic fungus for the management of white grub in Himachal Pradesh. *Plant Disease Research* **26**(2) : 172.
- Keen, F.P. 1952. Insect enemies of Western forests. *Misc. Publ.* No. 273. USA, WA-Washington, DC: USDA.
- Kleespies, R.G., Ritter, C., Zimmermann, G., Burghause, F., Feiertag, S. and Leclerque, A. 2012. A survey of microbial antagonists of *Agriotes* spp wireworms from Germany and Italy. *Journal of Pest Science* **86**(1) : 99-106.
- Kovacs, T., Kuroli, G., Pomsar, P., Nemet, L., Pali, O. and Kuroli, M. 2006. Localisation and seasonal positions of wireworms in soils. *Communications in Agricultural and Applied Biological Sciences* **71**(2) : 357-367.
- Kozina, A., Cacija, M., Barcic, J.I. and Bazok, R. 2013. Influence of climatic conditions on the distribution, abundance and activity of *Agriotes lineatus* L. adults in sex pheromone traps in Croatia. *International Journal of Biometeorology* **57**(4) : 509-519.
- Kulkarni, N., Chandra, K., Wagh, P.N, Joshi, K.C. and Singh, R.B. 2007. Incidence and management of white grub, *Schizonycha ruficollis* on seedlings of teak (*Tectona grandis* Linn. f.). *Insect Science* **14** : 411-418.
- Lieutier, F., Day, K.R., Battisti, A., Gregoire, J.C. and Evans, H.F. 2004. Bark and wood boring insects in living trees in Europe, A synthesis. **In** : (Eds.

- M., Knizek and R. Beaver). Taxonomy and Systematics of bark and ambrosia beetles. Kluwer Academic Publisher, Netherland. pp. 41-54.
- Li-Jiang, L., Zhhang, Tao., Li-Xin, T., Yang-Dao, Q., Wei-Xue., W. and Wang-Deng, Y. 1995. Study on the bionomics of *Scolytus seulensis* Murayama on fruit trees in Xinjiang and its control. *Plant Protection* **1** : 8-10.
- Linsley, E.G. 1959. Ecology of cerambycidae. *Annual Review of Entomology* **4** : 99-138.
- Majid Hussain 2008. The Geography of Jammu and Kashmir, pp. 3-15.
- Malik, R.A. 1966. Improved technique to control shot-hole borers and bark beetles. *Plant Protection Bulletin* **18**(1) : 29-30.
- Mandal, K.C., Singh, R.N., Bhengra, S.R., Dhar, S.L., Sinha, S.S. and Sengupta, K. 1989. Control measure of rounded stem borer *Aeolesthes holosericea* Fabr. (Coleoptera: Cerambycidae) in sericultural zones under tropical ecosystem. *Sericologia* **29**(1) : 135-137.
- Marshall, V.G. 1974. Seasonal and vertical distribution of soil fauna in a thinned and urea-fertilized douglas fur forest. *Canadian Journal of Soil Science* **54**(4) : 491-500.
- Marshall, V.G., Shrimpton, G.N. and Battigelli, J.P. 1990. A preliminary survey of Collembola in forest nurseries of British Columbia. *Journal of Entomological Society of British Columbia* **87** : 85-89.
- Mchowa, J.W. and Ngugib, D.N. 1994. Pest complex in agroforestry systems: the Malawi experience. *Forest Ecology and Management* **64**(2-3) : 277-284.

- Mckenna, C.E., Dobson, S.J. and Phare, J.M. 2009. The insect pest complex of *Actinidia arguta* Kiwifruit. *New Zealand Plant Protection* **62** : 262-267.
- Mendel, Z., Bonch, O. and Riov, J. 2009. Some foundations for the applications of aggregation pheromone to control pine bark beetles in Israel. *Journal of Applied Entomology* **114**(1-5) : 217-227.
- Meshram, P.B. 2010. Role of some biopesticides in management of some forest insect pests. *Journal of Biopesticides* **3**(1) : 250- 252.
- Mistretta, P.A. 2002. Southern Forest Resource Assessment highlights: Managing for Forest Health. *Journal of Forestry* **4**(100) : 24-27.
- Mohi-ud-din, S., Zaki, F.A., Munshi, N.A. Jan., A. and Wani., R.A. 2007. Comparative susceptibility of different grub stages to the local strains of *Beauveria bassiana*. *Journal of Entomology* **4**(1) : 56- 59.
- Morales-Rodriguez, A., O'Neill, R.P. and Wanner, K.W. 2014. A Survey of Wireworm (Coleoptera: Elateridae) Species Infesting Cereal Crops in Montana. *The Pan-Pacific Entomologist* **90**(3) : 116-125.
- Neumann, F.G. and Marks, G.C. 1990. Status and management of insect pests and diseases in Victorian softwood plantations. *Australian Forestry* **53**(2) : 131-144.
- Paine, T.D., Raffa, K.F. and Harrington, T.C. 1997. Interactions among scolytid bark beetle, their associated fungi, and live host conifers. *Annual Review of Entomology* **42** : 179-206.
- Pajars, J.A. and Lanier, G.N. 1989. Pyrethroid insecticides for control of European elm bark beetle (Col. Scolytidae). *Journal of Economic Entomology* **82**(3) : 873-878.

- Pandey, A.K. 2010. Field evaluation of *Beauveria bassiana* and *Metarhizium anisopliae* against the white grub *Holotricha longipennis* damaging soyabean in Uttrakhand hills. *Journal of Biological Control* **24**(4) : 327-332.
- Pandey, A.K., Namgyal, D., Mir, M.S. and Sheikh, B.A. 2007. Major insect pest associated with forest plantations in cold arid region, Ladakh of Jammu and Kashmir. *Journal of Entomology Research* **31**(2) : 155-162.
- Patial, A. and Bhagat, R.M. 2005. Field evaluation of some Insecticides against white grub in maize under mid-hill conditions of Himachal Pradesh. *Journal of entomological Research* **29**(2) : 123-125.
- Paul A.V. 2007. Insects pests & their management. Kolos Publishers Moscow, Russia pp 3-5.
- Pawson, M.S. and Watt, S.W. 2009. An experiment test of a visual based push-pull strategy for control of wood boring phytosanitary pests. *Journal of Agricultural and Forest Entomology* **11**(3) : 239-245.
- Qureshi, A.H., Bhagat, R.C. and Pathania, P.C. 2013. Rhopalocera diversity (lepidoptera) of district Kkupwara from Jammu and Kashmir State (India). *Biological forum-an International Journal* **5**(1) : 100-106.
- Raffa, K.F., Aukema, B.H., Erbilgin, N., Klepzig, K.D. and Wallin, K.F. 2005. Interaction among conifer terpenoids and bark beetles across multiple levels of scale: An attempt to understand links between population patterns and physiological processes. **In** : *Recent Advances in Phytochemistry* (Ed. T.R. John), **39** : 79-118.

- Rajagopal, D. 1990. Evaluation of Lentrek 50 EC for control of termites in forest plantations: Interim Report, University of Agricultural Sciences, Bangalore, 6 p.
- Robertson, L.N. 1993. Population dynamics of false wireworms (*Gonocephalum macleayi*, *Pterohelaeus alternatus*, *P. darlingensis*) and development of an integrated pest management program in central Queensland field crops: a review. *Australian Journal of Experimental Agriculture* **33**(7) : 953-962.
- Rodriguez-Del-Bosque, L.A. and Magallanes-Estala, A. 1994. Seasonal Abundance of *Diabrotica balteata* and other diabroticina beetles (Coleoptera: Chrysomelidae) in northeastern Mexico. *Environmental Entomology* **23**(6) : 1409-1415.
- Salasaraiza, M.D., Jones, R.W., Montesinos-silva, G., Salazar-solis, E., Parranegrete, L.A., Martinez-jaime, O., Ramirez-malagón, R. and Flores-mejia, S. 2008. Population Dynamics of the Agave Scale, *Acutaspis Agavis* (hemiptera: Diaspididae), on Agave Tequilana Var. Azul (agavaceae) in Central Mexico. *Southwestern Entomologist* **33**(4) : 289-298.
- Schowalter, T.D., Coulson, R.N. and Crossley, J.D.A. 1981. Role of southern pine beetle and fire in maintenance of structure and function of the southeastern coniferous forest. *Environmental Entomology* **10** : 821-825.
- Shaohui, W. 2013. Efficacy of entomopathogenic nematodes and entomopathogenic fungi against masked chaffers white grubs, *Cyclocephala* spp (Coleoptera: Scarabaeidae). Ph D thesis submitted to the Faculty of the Virginia Polytechnic Institute, Blacksburg.

- Sharma, A., Sood, A. and Verma, T.D. 2008. Insect-pests associated with *R. Pseudoacacia* in the Agroforestry system in mid-hill regions of Himachal Pradesh **134**(1) : 120-124.
- Sharma, B. and Tara, J.S. 1985a. Prevention and control of important insect pests of mulberry in Jammu, Jammu and Kashmir state. *Research and Development Reporter* **2**(2) : 72-74.
- Sharma, B. and Tara, J.S. 1986b. Studies on the chemical control of *Batocera rufomaculata* De Geer (Col. Cerambycidae) a serious pest of mulberry in Jammu and Kashmir State, India. *Indian Journal of Sericulture* **XXV**(2) : 84-87.
- Singh, P. and Prasad, G. 1985. Poplar stem borer, *Apriona cinerea* Chevrolat (Coleoptera: Cerambycidae), its biology, ecology and control. *Indian Forester* **111**(7) : 517-524.
- Six, D.L. and Paine, T.D. 1999. A phylogenetic comparison of ascomycete mycangial fungi and Dendroctonus bark beetles (Coleoptera: Scolytidae). *Annals of Entomological Society of the America* **92** : 159-166.
- Skarpaas, O. and Okland, B. 2008. Timber import and the risk of forest pest introductions. *Journal of Applied Ecology* **46**(1) : 55-63.
- Staudacher, K., Schallhart, N., Pitterl, P., Wallinger, C., Brunner, N., Landl, M., Kromp, B., Glauninger, J. and Traugott, M. 2013. Occurrence of *Agriotes* wireworms in Austrian agricultural land. *Journal of Pest Science* **86**(1) : 33-39.
- Stephen, F.M., Paine, T.D. and Lih, M.P. 2009. Understanding bark beetle/host intersections; a means for improving decision strategies. *Zeitschrift fur Angewandte Entomologie* **96**(1-5) : 257-265.

- Sufyan, M., Neuhoff, D. and Furlan, L. 2013. Effect of male mass trapping of *Agriotes* species on wireworm abundance and potato tuber damage. *Bulletin of Insectology* **66**(1) : 135-142.
- Toba, H.H. and Turner, J.E. 1981. Seed piece examination: A method for sampling wireworms on potatoes. *Journal of Economic Entomology* **74** : 718-720.
- Ulyshen, M.D. and Hanula, J.L. 2010. Patterns of saproxylic beetle succession in loblolly pine. *Journal of Agricultural and Forest Entomology* **12**(2) : 187-194.
- Varga, M.I., Oltean, I., Muntean, V., Florian, T. and Mandru, M. 2014. Monitoring the species of Elateridae family in the nursery of Gurghiu Forestry High School. *Bulletin UASVM Horticulture* **71**(1) : 1843-5394.
- Verghese, A., Shivananda, T.N., Mahendiran, G., and Ahmed, N. 2012. Decline of deodar (*Cedar deodara*) in Gulmarg, Kashmir-India. *Insect Environment* **17**(4) : 190-192.
- Vidyadhar 2005. Jammu and Kashmir-Past and Present, pp 8-169.
- Wani, N.A., Wani, A.R. and Wani, A.A. 2009. Status of bark beetle, *Scolytus nitidus* (Schedl.) severity on apple trees in North Kashmir of J & K State. *Applied Biological Research* **11**(1-2) : 21-25.
- Waters, W.E. and Stark, R.W. 1980. Forest Pest Management: Concept and reality. *Annual Review of Entomology* **25** : 479-509.

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Shalimar Campus Srinagar – 190 025

-::0::-

CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Hafeez Ahmad, Professor, Division of Entomology, SKUAST-Jammu, Chatha, Jammu Viva-Voice examination held September 3, 2015 have been incorporated in the manuscript entitled **“Pest Complex and Management of Soil Borne Pest(s) in Forest Nursery”** submitted by **Mr. Nadeem Ahmad Dar (Regd. No. 2013-A-975-M)**.

(Dr. Ishtiyaq Ahad)
Chairman
Advisory Committee