Assessment of insect-pest dynamics and their management in Agroforestry Systems of semi- arid tropics

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur
In partial fulfilment of the requirements for
The Degree of

MASTER OF SCIENCE

In

FORESTRY

(AGROFORESTRY)

By

Kailash Kumar

(ID No-170106002)

Department of Forestry

College of Agriculture, Jabalpur – 482004

Jawaharlal Nehru Krishi Vishwa Vidyalaya

Jabalpur - 482004 (MP)

2019

CERTIFICATE- I

This is to certify that the thesis entitled *"**Assessment of insect-pest dynamics and their management in agroforestry systems of semi-arid tropics**"* submitted in partial fulfilment of the requirement for degree of **MASTER OF SCIENCE** in **FORESTRY (AGROFORESTRY)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of bonafide research work carried out by Mr. Kailash Kumar under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

All the assistance and help received during the course of the investigation has been acknowledged by him.

Place: Jabalpur

Date: .....

Dr. R. Bajpai

Chairman of the Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Committee	Name	Signature
Chairman	**Dr. R. Bajpai**	----------
Member	**Shri Yashpal Singh**	----------
Member	**Dr. H.L. Sharma**	----------

CERTIFICATE - II

This is to certify that the thesis entitled "**Assessment of insect-pest dynamics and their management in agroforestry systems of semi-arid tropics**" submitted by Mr. Kailash Kumar to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **FORESTRY (AGROFORESTRY)** in the Department of Forestry has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination of the same.

Place: Jabalpur

Date : .....

Dr. R. Bajpai

Chairman of the Advisory Committee

MEMBERS OF THE ADVISORY COMMITTEE

Committee	Name	Signature
Chairman	**Dr. R. Bajpai**	----------
Member	**Shri Yashpal Singh**	----------
Member	**Dr. H.L. Sharma**	----------
Director Instructions and Head of the Department	**Dr. S. D. Upadhyaya**	----------

Copyright Transfer Certificate

Title of the Thesis	:	**"Assessment of insect-pest dynamics and Their management in Agroforestry Systems of semi-arid tropics"**
Name of the candidate	:	Kailash Kumar
Subject	:	Agroforestry
Department	:	Department of Forestry
College	:	College of Agriculture
Year of thesis submission	:	2019

Copyright Transfer

The undersigned Kailash Kumar assigns to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, all rights under Copyright Act, that may exist in and for the thesis entitled "**Assessment of insect-pest dynamics and their management in agroforestry systems of semi-arid tropics**" submitted for the award of M.Sc. Forestry (Agroforestry) degree.

Date: .....

Place: Jabalpur

Dr. R. Bajpai **Kailash Kumar**

Chairman of advisory committee **(Student)**

ACKNOWLEDGEMENT

I would like to express my deepest sense of gratitude and reverence to my major guide and chairman of my advisory committee Dr. R. Bajpai, Professor, Department of Forestry, J.N.K.V.V. Jabalpur, for his able guidance, keen interest, critical analysis and valuable suggestions during the course of investigation and preparation of the manuscript.

I extend my heartiest thanks to Professor and Head, Department of Forestry Dr. S.D. Upadhyaya and worthy members of my advisory committee Shri Yashpal Singh Assistant Professor, Department of Forestry, and Dr. H.L. Sharma Professor, Department of Mathematics and Agricultural Statistics for their generous help, valuable suggestions and necessary help provided during the course of present investigation.

I'm thankful to all my respected teachers Dr. K.K. Jain, Shri R.P. Dongre, Shri Rahul Dongre, Miss Poornima Malviya and all staff members of Department of Forestry, for their encouragement and support during the experiment and course work.

I feel myself duty bound to express my deep sense of gratitude and thanks to Dr. P.K. Bisen, Hon'ble Vice Chancellor, J.N.K.V.V., Jabalpur, Dr. S.D. Upadhyaya, Director of Instructions and Head of Forestry Department, Dr. D. Khare Dean Faculty of Agriculture, Dr. R. M. Sahu, Dean College of Agriculture, and Dr. V.K. Pyasi, Dean Students Welfare, J.N.K.V.V. Jabalpur for providing all necessary facilities during conduct of the research work. I wish to extend my sincere thanks to all the faculty & staff members of central library for providing valuable literatures for research work.

It is with the personal touch of emotions that I seize the opportunity to acknowledge the moral support, ever caring nature of my senior Dr. C.P. Rahangdale, Vijay Bagare, Ajay Kumar Shah, Anil Kumar Kori, Vikas Seth also my friends Sonu Pahade, Dishant Dongre and Parul Sharga.

I also thank field extension officer, Dr. M.K. Pathak, Mr. Tara chand Tawar and all my loved ones who supported directly and indirectly during the course of my investigation.

I wish to express, my unbounded love and respect towards my father Shri Chhattelal Mashram and beloved mother Late Mrs. Purnta Devi and my family members for molding my life with their love, affection, care and sacrifices, which has made me complete human being.

Lastly I would like to convey my cordial thanks to all those unmentioned persons who helped me to fulfil my dream, come true.

Place: Jabalpur

Date: ..... (Kailash Kumar)

LIST OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF ABBREVIATION

Abbreviation & Symbol	Stand for
F	Analysis of variance
et al.	And others
etc.	And the rest
@	At the rate of
Cm	Centimetre
%	Percentage
©	Copyright
SEm±	Standard error of mean
CD	Critical difference
√	Square root
°C	Degree centigrade
Df	Degree of freedom
G	Gram
Kg	kilogram
Hr	Hour
Max	Maximum
mm	Millimetre
Min	Minimum

CONNOTATION

V_1	JM-3
V_2	Urvashi
V_3	NRCDR-2
P_0	No pruning
P_1	25% pruning
P_2	50% pruning
P_3	75% pruning
D_0	No Deheading
D_1	Deheading at 1.0m plant height
D_2	Deheading at 1.5m plant height
D_3	Deheading at 2.0 m plant height
fd	Fertilizer dose
N	Nitrogen
P	Phosphorus
K	Potassium
RD	Recommended dose
RFD	Recommended fertilizer dose
RSR	Recommended seed rate
SR	Seed rate
DAS	Day after Sowing
Kg ha^{-1}	Kilogram per hectare
Mor.	Morning
Eve.	Evening

INTRODUCTION

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982).

The total area under Agroforestry in world is 1023 mh (FAO, forest resource assessment report 2000). It is estimate that 823 million hectare area globally is under Agroforestry and silvipastoral system. Of these, 307 million hectare is Agroforestry (Nair et al., 2012). However the area under Agroforestry is increasing continuously, example in India, in 2007 it is reported 7.4 million hectare (Zomer et al., 2007) but in 2013 it reached up to 25.32 million hectare (Dhyani et al., 2013).

In agroforestry systems, in which woody plants and crops are grown together, the insect-pests of one component can affect those of the other. It is, therefore, essential to know about the insect-pests of each component plant in the assemblage.

In Agroforestry systems trees and crops are attacked by insects and pest at all stages of their growth just like other annual and perennial crops. Insects may attack one or more species within a system and across systems in the landscape, so pest management strategies should depend on the nature of the insect and magnitude of its damage (Rao et al., 2000).

Insect pests are the most important group of organisms causing injury to plants in agroforestry systems. Therefore, the management of insect pests in these systems is crucial to sustained production, and even farmers have recognized this as a priority issue for agroforestry research (Prinsley R.T.,1991).

The interactions among the components of the agroforestry system can be either positive, negative or neutral. They are regarded as negative when pest problems are increased in an agroforestry system when compared with a

monoculture block plantation. A reduction in pest activity under agroforestry indicates a positive interaction, while no change in pest intensities between monoculture and agroforestry denotes a neutral interaction from the insect-pest management (Rathore 1995).

The insect-pests of an agroforestry system are essentially the pests of its components: the crops and woody perennials. The dynamics of insect-pests and their natural enemies are governed by the complexity and composition of the agroforestry system. The pest situation in these systems will be influenced by the degree of interaction between the components (Rathore, 1995).

Research involving agricultural and horticultural cropping system, however, suggests that vegetation diversity frequently result in significant reduction of insect-pest problem. Trees also affect pest infestations by acting as barriers to movement of insects, masking the odours emitted by other components of the system and sheltering herbivores and natural enemies.

Dalbergia sissoo Roxb. (Fabaceae) is one of the most important commercially valuable large deciduous fast growing tree. It can grow up to 30 meter height and 90 centimeter dbh at maturity. It is best known for its highly valued timber. In addition to its outstanding timber quality and high commercial value, the tree commonly provides high quality fuelwood and charcoal, fodder, green manure, honey, nitrogen fixation and other traditional medicines.

Guava (*Psidium guajava*) belongs to the family Myrtaceae. It's native to the American tropics, and probably originally grew from Peru north to Mexico and the Caribbean (Kwee and Chong, 1990).

Guava fruit is seriously damaged by different environmental factors and pests which include diseases, birds, insects and mites. About 80 species of insects have been recorded on guava trees, affecting yield and quality of fruits. (NHM, 2012).

Mustard (*Brassica spp.*) is a native of South-East Asia belongs to the family "Cruciferae". It is the major rabi oilseed crop of India mustard crop is grown over an area of 6.34 million hectare with a production of 7.82 million tones and productivity of 1234 kg/ha in 2012-13 in India (Bharat Lal et al., 2018).

Madhya Pradesh contributes nearly 10 per cent of the total mustard production in the country. In Madhya Pradesh mustard crop is cultivated in

area about 7.79 lakh ha with the production of 6.63 lakh tones and productivity of 851 Kg/ha. (Bharat Lal, 2018).

Pest management in agroforestry has not received much attention so far, but recent emphasis on producing high value tree products in agroforestry and using improved germplasm in traditional systems, and emergence of serious pest problems in some promising agroforestry systems have increased awareness on risks posed by pests. Trees also affect pest infestations by acting as barriers to movement of insects, masking the odours emitted by other components of the system and sheltering herbivores and natural enemies.

There are numerous types of agroforestry system in different parts of the world. There have been few studies of insect-pests in agroforestry context, although insect-pests of crops that are components of agroforestry systems have been studied. Scanty information is available about the insects associated with the multipurpose trees and shrubs that are gaining greater economic importance as components of agroforestry systems.

The present work is an attempt to cover and compile the scattered information at one place so as to provide detailed knowledge on various insect-pest species, their identification, nature of damage and period of infestation.

Keeping above facts in view, the present investigation entitled "Assessment of insect-pest dynamics and their management in agroforestry systems of semi-arid tropics" has been proposed with following Objectives:-

1. Dynamics of insect-pest communities in Agrisilviculture and Agrihorticulture system.
2. Insect-pest prevalence and its effect in intercropping system.
3. Effect of tree component on pest population.

REVIEW OF LITERATURE

Beeson (1941) observed leaf-eating beetles on *Dalbergia sissoo* in India and Pakistan. *Adoretus caliginosus* makes holes in the leaves between principle nerves. *Amblyrrhinus poricollis* damages foliage and *Halyzia sancrite* damages the surface of leaves. Others beetles are *Gynandropthalma quadripunctata, Illeis cincata, Mimastra cynura* and *Myllocerus pustulatus.*

Mathur and Singh (1959) recorded insect-pest of *D. sissoo* including wood borers, leaf defoliators, leaf miners, leaf rollers and sap suckers.

Browne (1968) listed largest known Coccoidea (*Hemaspidoproctus cinereo*) which feed on the sap of many tree species. The important record hosts include *Acacia nilotica* sub spp. indica *Anoportant latifolia*, *D. sissoo, Santalum album* and *Terminalia spp.*

Bakhetia and Brar (1982) reported that mustard sawfly, *Athalia lugens proxima* appeared during October and maximum damage was recorded during October-November.

Singh and Rawat (1983) studied seasonal incidence of *L. erysimi* and its parasite, *Aphidius sp.* on Indian mustard in Madhya Pradesh. It was reported that parasitic activity began in the second or third week of January reaching 80-90 per cent by third or fourth week of February. Both parasite and host disappeared in March.

Singh (1986) recorded considerable damage to *Acacia nilotica*, *D. sissoo* and *Prosopis cineraria* which varied with soil type. This presumably influenced the physiological status of the tree in relation to the pests.

Nair *et al.* (1986) identified leaf feeding pest *Peltotrachelus cognatus* Marshall (Curculionidae, Coleoptera) in *Dalbergia latifolia*. Weevil caused only minor leaf damage. Nineteen species of insects have been recorded earlier, of which *Plecoptera reflexa* (Noctuidae, Lepidoptera) which is known to be a serious pest of *D. sissoo.*

Ahuja (1990) studied the population dynamics of *L. erysimi* (Kalt.) on Indian mustard and concluded that the pest appeared in late December. It's population gradually increases and reached a peak between 26 January and 1St February. Weather conditions were more conductive to development of the pest population. The aphid population was negatively correlated with mean

maximum and minimum temperature and sunshine and positively correlated with humidity.

Sinha *et al.* (1990) observed that the *Lipaphis erysimi* appeared and established on the mustard crop during third week of December. The population built up in January-February. The maximum (21.7-23.5°C) and minimum (7.2-9.4°C) temperature in January- February appeared to be highly favourable to the population built up. Maximum humidity (55.7-69.4%) in January —February favoured population built up. Activity of pest ceased at 50.9 per cent humidity and below.

Shrivastava *et al.* (1995) observed the *Lipaphis erysimi* population on the flowering stage of Indian mustard (*Brassica juncea L.*). The range of maximum temperature, 15.8-24.7°C and relative humidity 61-65 per cent prevailing in February was found to be conductive for the rapid multiplication of the aphid in this crop. In addition, good rainfall in January to Mid February was the main factors causing rapid aphid population. While the 6 rainfall in the last week of February or first week of March had a deleterious effect.

Kalia and Lal (1999) conducted surveys in nurseries, plantations, and natural forests at TFRI, Jabalpur, Madhya Pradesh, India for insect-pests of *Dalbergia sissoo*, a highly valued deciduous tree. Results revealed that occurrence of 22 phytophagous insect species, on *D. sissoo* namely, *Clania crameri , Hypolixus truncatulus, Oides andrewsi, Leucoptera sphenograpta, Miresa albipuncta, Dasychira dalbergiae, D. fusiformis, Dichomeris eridantis, Heliothis armigera , Plecoptera reflexa, Spodoptera litura, Hyposidra successaria, Laspeyresia jaculatrix , Taragama siva, Euproctis lunata, E. subnotata, Chrysocoris purpureus, Dysdercus cingulatus, Nezara viridula, Oxyrachis tarandus, Homoeocerus signatus,* and *Brachytrupes portentosus*.

Joshi and Baral (2000) revealed that the tree of *Dalbergia sissoo* has been seriously attacked by the fungi *Ganoderma lucidum, Fusarium solani* and bacteria. Moderate to maximum occurrence of the pest was recorded from February to October. Periodic incidence of the pest ranged from 0.30 to 10.80 under different growth. Maximum temperature showed significant and positive correlation (r=0.912) with the population. Relative humidity had no significant effect.

Prasad et. al. (2002) carried out a study on population dynamics of defoliators *Plecoptera reflexa* and *Dichomeris eridantis* on *Dalbergia sissoo*. It was observed that the cyclic pattern in the population dynamics of defoliators of *D. sissoo* is governed by delayed density dependent factors and its growth rate.

Dogra *et al.* (2003) investigated that the parasitization of *L. erysimi* by D. -rapae appeared during second week of January. Maximum parasitization (5-10%) was recorded in the second week of March when mean maximum, temperature, mean minimum temperature and relative humidity was 22.5°C, 10.3°C and 36% respectively.

Bhatt and Bapodra, (2004) mustard sawfly infestation commenced after 3rd week of sowing and maximum population was recorded during the last week of December. The pest reached to a peak level of 1.70, 1.90 and 2.30 larvae per plant on varieties GM-1, GM-2 and Varuna, respectively.

Singh *et al.* (2004) found that 143 species of insects infest both indigenous as well as exotic species of poplars in north western India, with about 65 species infesting *Populus deltoides* alone. The survey included 36 nurseries, 84 large (≥ 3 ha) and 255 small (< 3 ha) block and bund plantations and recorded seven species causing outbreaks. However, eight insects having wide spread distribution in this region were identified as posing a threat to agroforestry with *P. deltoides* and need to be managed. Amongst these, three species *(Clostera cupreata, C. fulgurita and Apriona cinerea)* were ranked as 'major pests' as they had relatively higher incidence (>50% of attack) and caused extensive economic loss during outbreaks, coupled with tree mortality which persisted for several years in succession over large areas.

Dhakal and Kjaer (2005) conducted experiment under seedling seed orchard (SSO) that was heavily infested by *Aristobia horridula* a beetle that has become a sever pest infesting and killing young trees in *Dalbergia sissoo* plantings. Large and highly significant differences were found between families in mortality, showing some progenies seem to resist the attack much better than others.

Sah and Ali (2005) population sampling studies of *Oxyrachis tarandus* Fab. on *Dalbergia sissoo* Roxb samplings were done under

agroforestry condition (R.A.U., Pusa Farm, Bihar). The studies revealed that tarandus Fab was active from last week of June, 2000 to last week of Sep. 2000. The adult population of the pest on foliage of shisham sampling ranged from 9.12 to 18.89 per sapling with the peak population to the tune of 18.89. To find out the effect of weather factors on pest fluctuation the average population of *O. tarandus* humidity at 7.00 hrs., 14.00 hrs. and rainfall (mm). Statistically the data revealed that the average number of adult population was highly significant (r=0.810) and positive correlated with maximum temperature but non-significant with other parameters.

Sarwar M. (2006) conducted studies on monitoring, identification and control operations. The most significant finding in the research work was higher level of fruit fly damage that was severe in all selected sites tracked by mealy bugs, mites, stinkbug, red-banded thrips, guava moth, guava whitefly and scale in that order. having 10.33, 8.33, 7.33, 6.33, 5.33, 5.00, 3.33 and 3.00 mean populations per tree, respectively.

Ali, *et. al.* (2006) conducted study on the seasonal population fluctuation of sissii tree hopper, *Gargara mixta* (Membracidae : Homoptera) conducted in different growth stage of *Dalbergia sissoo* plantation at Pusa Farm of Rajendra Agriculture University, Pusa (Bihar) in 1993. The seasonal population of *Gargara mixta* per leaf per stem and per branch of *D. sissoo* sapling varied from 0.59 to 4.08, 0.58 to 5.57 and 0.68 to 9.80 during morning and evening respectively. The maximum temperature showed significant and possitive correlation with the population of *G. mixta*. Relative humidity had no significant effect.

Muhammad Sarwar (2006) identified key insect species of guava where include fruit fly, mealy bugs, mites, stinkbug, red-banded thrips, guava moth, guava whitefly and scale in that order having 10.33, 8.33, 7.33, 6.33, 5.33, 5.00, 3.33 and 3.00 mean populations per tree, respectively.

Shylesha *et al.* (2006) was statistically similar with yield in the open field (1.21 t ha-1). Lowest yield was recorded under Sissoo tree (0.78 t ha-1) which was statistically similar with Lalji Prasad, Ansari I.A and Subhash Chandra 1999. The progress is briefly described of an infestation of *Dalbergia sissoo* by *Plecoptera reflexa* which started in New Forest, Dehra Dun, Uttar Pradesh (India), and in other areas in the Doon Valley, at the beginning of May 1998.

Young plants (5 year old) were almost completely defoliated within a week, and older trees were the infested until the whole plantation had been defoliated by Mid May. The larval count reached several thousand per tree, but started to decrease after Mid May.

Ali *et. al.* (2007) conducted a systematic study on the seasonal sequence of occurrence, incidence and maximum occurrrence of *Dalbergia sissoo* leaf blinder, *Dichomeris eridantis* Mey. During 1993 it revealed that moderate to maximum occurrence of the pest was recorded from February to October. Periodic incidence of the pest ranged from 0.30 to 10.80 in different growth. Maximum temperature showed significant and positive correlation (r=0.912) with the population. Relative humidity had no significant effect.

Haseeb (2007) recorded 80 species of insect-pests on guava, few of them had been identified as pest of regular occurrence and causing serious damage e.g. Bark eating-caterpillar (*Indarbela* spp.), fruit fly (*Bactroceraspp.)* and scale insect *(Chloropulvinaria psidii)*. Bark eating-caterpillar and fruit flies have wide distribution, while scale insects and mealy bugs were more common in south India and tea mosquito bug, *Helopeltis antonii* (Signoret) in central India. Two insect-pests which were newly introduced in India need special attention, white fly, *Aleurodicus dispersus* (Russel) in South India and stem borer, *Aristobia testudo* (Voet) in North-East region.

Haseeb and Sharma (2007) result indicated that the incidence of *Deudorix isocrates* was at its peak on cv. L-49 during the month of August. While in winter crop it was more during November/December. The incidence ranged from 3.0 to 38.0 per cent during these periods. Losses in fruit weight were found directly proportional to the extent of infestation by the borer.

Rahman *et al.* (2008) the prevalence of insect-pests was studied on rice BR11 (Mukta) as understory crop grown in association with 11 years old selected tree species *viz.,* Akashmoni, Jhau and Albida in the field laboratory of the Department of Agroforestry, Bangladesh Agricultural University (BAU), Among the three species Albida and Jhau possessed the largest canopy and their light penetration rate were high. On the other hand, Akashmoni had the lowest canopy but it penetrated low amount of light. Albida-rice association showed the lowest infestation of major rice insects followed by Jhau-rice association, while Akashmoni-rice association showed the highest insect

infestation. Light intensity in the control plot (absent of tree species) was maximum and it caused minimum severity of insect's infestation as compared to other associations.

Kumar *et al.* (2008) recorded about 50 insects which are damage to Brassica crops. He was observed among these insects, mustard aphid (*Lipaphis erysimi*) is the key pest of the Brassica crops while saw fly (*Athalia proxima*), painted bug (*Bagrada cruciferarum*) causing yield losses. Yield losses due to aphid may be up to 97 per cent and sawfly and painted up to 15 and 30 per cent, respectively.

Rahman *et al.* (2008) reported Insect-pest infestation and yield performance of mungbean in association with Akashmoni (*Acacia auriculiformis*), Jhau (*Casuarinaequisetifolia*), Sissoo (*D. sissoo*) in the open field condition. Twelve different insect species were identified in the mungbean field grown in association with three MPTs of which two were natural enemies. Highest insect population was recorded under *D. sissoo* (347) followed by Akashmoni (251), open field (159) and Jhau (141), respectively. Highest yield was recorded under Jhau tree (1.23 t ha^{-1}) which yield under Akashmoni trees (0.89 t ha^{-1}).

Khedkar (2011) reported that the infestation of leaf miner (0.08 mine/3 leaves) commenced from 3rd week after sowing i.e. 3rd week of December (50th SMW) which gradually increased and reached to a peak (6.31) during 11th WAS i.e. 2nd week of February (6th SMW). Thereafter, population decreased gradually towards maturity of crop (2.56) and disappeared from the field i.e. 15th WAS (10th SMW). Thus, the activity of leaf miner was observed from December to March i.e. 3rd to 15th WAS (50th to 10th SMW) with one peak.

Singh *et al.* (2012) reported that sawfly (*A. lugens proxima*) appeared at early stage of crop growth from 0.17 to 0.55 grubs per plant during rabi 2005-06 and 0.62 to 1.78 grubs per plant during rabi 2006-07. During the two crop seasons, mustard sawfly was found attacking the crop at early stage of growth. This insect was observed from the 47th to the 51st standard week and from the 49th to the 52nd standard weeks during rabi 2005-06 and 2006-07, respectively.

Pawan (2012) recorded the incidence of insect-pests and diseases of paddy during 1999 to 2009 in major rice growing districts of H.P. During their studies over ten years, it was observed that the insects and diseases eg. whorl maggot, chaffer beetle, bacterial leaf blight were recorded.

Qureshi *et al.* (2012) studied that *Dalbergia sissoo*, *Eucalyptus cammeldulensis* and *Acacia arabica* were analyzed for their toxicity potentials against two species of termites (*Heterotermis indicola* and *Coptotermis heimi*).

Firake *et al.* (2013) reported major pest of guava e.g. trunk borer, *Aristobia testudo* (Coleoptra: Cerambycidae). *A. testudo* is the most destructive pest of Litchi in China and severe incidence of this beetle was first observed in Meghalaya on guava during 1997. Recently, the same pest was also found on pigeon-pea at the adult stage. About three species of fruit fly, *Bactrocera dorsalis*, *B. cucurbutae* and *B. tau* (*Diptera, Tephritidae*) found to attack guava fruits; *B. dorsalis* being the dominant. Maximum activity of fruit flies was observed during August to the December reaching its peak during September. Two species of bark eating caterpillars, *Indarbela quadrinotata* and *I. tetraonis* were commonly found in the North East hilly region.

Pal *et. al.* (2015) nine species of fruit fly viz., *Bactrocera affinis* and *B. zonata* active during all seasons where *B. correcta, B. diversa* and *B. dorsalis* active during kharif and rabi seasons, were trapped in methyl eugenol (ME) baited traps. *B. cucurbitae* was active during all seasons but *B. nigrofemoralis* and *B. coudata* were active during kharif and rabi seasons, while *B. yercaudiae* was active during kharif and zaid seasons, were trapped in cuelure (CL) baited traps. The maximum populations of fruit fly species were active during kharif season. All the fruit fly species attracted towards ME baited traps had positive correlation with minimum and maximum temperature (°C) except B. zonata which had highly significant and positive correlation with above abiotic parameters. *B. coudata* had highly positive correlation with rainfall (mm) during zaid season and *B. cucurbitae* had highly negative correlation with RH (%).

Kumar (2017) study was undertaken in the province of Jharkhand to find out the insect-pest fauna of *D. sissoo* their infestation and seasonal incidence. Total seventeen insect pests were recorded from the region out of which five insects belongs to Coleoptera viz., *Apoderus sissu*, *Anomala dalbergiae, A. bengalensis, Myllocerus undecimpustulatus* and *Myllocerus*

discolour were observed. Similarly, five insect-pests of order Lepidoptera viz., *Agrotis ipsilon, Plecoptera reflexa, Ascotis infixaria, Dichomeris eridantis* and *Leucoptera sphenograpta* were observed. Six insect-pests belonging to order Hemiptera viz., *Lawana conspersa, Ceroplastes rusci, Leptocentrus taurus, Myzus persicae, Icerya seychellarum, Drosicha dalbergiae* and *Odontotermes obesus*. Among these, two insect-pests *Lawana conspersa* and *Icerya seychellarum* were found first time on *D. sissoo*. Additionally, nature of damage, seasonal incidence and their infestation was also observed during the course of study.

Devi and Jha (2017) observed maximum incidence of fruit borer (*Deudorix isocrates*) during the month of August where the peak incidence was recorded in last week of July. Mean incidence indicated that July end to August end was the peak activity period of the pest and screened 18 guava varieties against the fruit borer during 2014, 2015 and 2016. Minimum infestation was recorded on Dudhkhaja (3.08%), Arka Kiran (4.63%), Kohir Round (6.13%), Mohammad Khaja (6.73%), Baruipur Local (7.61%), HissarSurkha (8.86%) and Lalit (10.08%). Maximum infestation was recorded on Hissar Safeda (26.4%), China (24.93%), Allahabad Safeda (23.43%), and Sardar (21.61%) respectively.

Umesh *et al.* (2018) highest fruit infestation due to fruit fly i.e. 26.67 and 22.43 per cent on number and weight basis, respectively were recorded during 44th SMW. No fruit infestation from 51th to 8th SMW. 68.53 per cent reduction in yield was noticed of guava in rainy season due to guava fruit fly, *Bactrocera* spp. as compared to 5.49 per cent in winter crop season with an overall yield reduction of 37.54 percent.

Meenakshi *et al.* (2018) observe infestation of oriental fruit fly, *Bactrocera dorsalis* (Hendel) (i.e. 15 maggots/5fruits) after that mealybug (4 adult/5 branches) were observed in Hissar Surkha. Maximum number of oviposition marks oriental fruit flies were observed on Hissar Surkha (i.e. 19 oviposition marks/5 fruits) followed by Banarasi Surkha, Allahabad Safeda (16 oviposition marks/5 fruits) and Punjab pink (15 oviposition marks/5 fruits) whereas minimum was observed in Lalit (8 oviposition marks/ five fruits). No infestation was recorded in hybrid guava, strawberry guava and chinese guava.

Bharat Lal (2018) more than 43 species of insect-pests have been reported to infest rapeseed-mustard crop in India, of which sawfly (*Athalia lugens proxima*), aphid (*Lipaphis erysimi*), painted bug (*Bagrada hilaris*) and leaf miner (*Phytomyza horticola*) were the important ones (Singh et. al. 2009). Among these, mustard aphid, *L. erysimi* (Aphididae:Hemiptera) is the major limiting factor causing up to 96 per cent yield losses and 5-6 per cent reduction in oil content.

Mohsen (2018) observed three order of insect on guava i.e., Hemiptera, Diptera and coleoptera and (18) species were recorded: *Coccus hesperidum* L. *Pulvinaria psidi Maskell*, *Ceroplastes floridensis comst., Ceroplastes rusci* L. *Aspidiotus nerii* Bouche, *Hemiberlesia lataniae signoret, Aonidiella aurantii* Maskell*, icerya seychellarum* Mask*, I. aegypticae* Dgl*, Empoasca decipiens* Paoli*, Empoascua decedens* Paoli, Aphis *gossypii* Glover, *Bemisia tabaci Gennadius* and *Nezera virduala* L. Diptera species were *Ceratitis capitata* wiedemann and *Bactrocera zonata* Saunders. Coleoptera species were *Carophilus hemiptrus* L. and *Carpophilus dimidiatus* L. Percentage infestation by *C. capitata* from 75% of petals fall stage up to the fruit maturity.

MATERIAL AND METHODS

A field experiment was conducted at New Dusty Acre area J.N.K.V.V College of Agriculture Jabalpur (M.P.) during Rabi season 2018 -19 to study the **"Assessment of insect-pest dynamics and their management in agroforestry systems of semi-arid tropics"**. The material used and the methods employed during the course of investigation are presented in this chapter under the appropriate heads.

3.1 Research Area

The present investigation was carried out at New Dusty Acre area, Department of Forestry, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during Rabi season of November 2018 to March 2019 in well established 20 years old both *Dalbergia sissoo* based agrisilviculture and Guava based agri horticulture system. The facilities required to conduct the experiment were available on the research farm.

3.2 Location and extent

Study area lies at 23°12'50" North latitude & 79°57'56" East longitude. Study area belongs to Kymore Plateau and Satpura Hills Agro-climatic Zone as per classification of National Agricultural Research Project. Recently, this area has been classified as agro-ecological sub-region number 10.1 (Vindhyan Scarplands, Bundelkhand, and Narmada Valley, hot dry sub-humid ecological sub region with medium deep black soil).

3.4 Topography

The topography of the area is plain to gentle slope. Slope of the land vary from 0 to 1%.

3.5 Climate and weather conditions

Jabalpur lies between 22°49' to 24°8' North Latitude and 78°21' to 80°58' East Longitude with an average altitude of 411.78 meters above the mean sea level. The climate of the locality is characterized as typically semi-humid and tropical, which is featured by hot dry summer and cool dry winter. It is classified as" Kymore Plateau and Satpura Hills" agro-climate zone, as

Table 3.1 Weekly meteorological data during the crop season 2018-19.

Months	Met. Week	Temperature (^{0}C)		Relative humidity (%)		Sunshine hours (hrs/day)	Rainfall (mm)
		Max.	Min.	Mor.	Eve.		
OCT	41	32.0	18.0	86.4	60.7	8.1	0.0
	42	32.7	17.8	85.7	53.3	8.7	0.0
	43	31.9	14.7	84.9	52.9	9.2	0.0
	44	30.5	15.1	87.7	45.6	8.6	0.0
NOV	45	29.0	10.9	84.9	28.6	8.3	0.0
	46	30.5	9.0	82.4	35.3	8.8	0.0
	47	29.7	9.9	84.3	30.3	8.0	0.0
	48	27.0	8.2	84.4	34.1	6.7	0.0
DEC	49	25.6	9.0	85.9	33.9	4.4	0.0
	50	24.4	7.9	83.3	43.3	5.1	0.0
	51	22.3	8.4	77.4	36.6	7.1	0.0
	52	28.8	8.4	75.8	31.4	8.2	0.0
JAN	1	25.0	6.6	75.8	31.4	7.8	0.0
	2	22.9	6.0	84.5	42.8	5.7	0.0
	3	23.4	5.3	73.1	27.0	8.9	0.0
	4	23.5	11.6	85.3	55.7	7.8	4.6
FEB	5	26.2	9.9	69	36.42	7.9	0.0
	6	26.2	10.7	77.5	47.71	9.1	4
	7	29.9	13.7	76.71	39	9	1.4
	8	29.5	13.7	76.71	39.65	9.4	0.0
MAR	9	26.9	12.6	76	42.6	9.6	0.8
	10	28.9	11.6	82	36.4	5.1	12
	11	31.5	14.7	85.1	48.5	5.9	4.2
	12	32.5	13.4	79.6	30.5	6.5	1.2

per norm of National Agricultural Research Project and is broadly known as rice-wheat crop zone of Madhya Pradesh.

The mean annual rainfall of Jabalpur based on last 20 years data is 1350 mm which is mostly received from south-west monsoon between mid June to end of September with little occasional rainfall of 68.9 mm during other months. The mean monthly minimum temperature varies between 5.4 to 6.5°C in December and January, and maximum temperature varies between 40.2 to 42°C during May and June, respectively, January is the coldest month of the year with minimum temperature being 5°C. Generally relative humidity remains very low during summer (18 to 22%); moderate (70 to 75%) during winter and it attains high value (80 to 95%) during rainy season.

3.6 Weather conditions during the course of investigation.

Seasonal variations prevailing during the growth period play an important role on the growth and development of the any tree as well as it determines the insect pest activity on plantation.

The weekly meteorological data during the course of investigation recorded at Meteorological Observatory, Agricultural Engineering College, J.N.K.V.V., Jabalpur are presented in Table 3.1. and illustrated in Figure.1.

3.7 Rabi season (2018 -19)

Crop season was almost favorable for crop. Maximum temperature (31.5°C) was recorded in march and minimum temperature (7.9°C) in december, relative humidity ranged between 69 to 85% in morning and 27 to 55% in evening and mean sunshine hour ranged between 4.4 to 9.6 hours per day during investigation.

3.8 Edaphic factors

In order to find out the physico-chemical properties of soil of the experimental field, soil samples were taken randomly from different spots at 0 to 30 cm with the help of screw anger before sowing of the experiment. The soil samples were well mixed together for making representative samples. The composite soil samples were analysed for their physico-chemical properties by standard soil in the laboratory, Department of soil science and Agricultural Chemistry as per standard methods. The analytical values of soil were presented in Table 3.2. and Table 3.3.

Table 3.2. Physical-Chemical properties of the soil of experimental field (*Dalbergia sissoo* based agrisilvicuture system)

Sl. No.	Particulars	Analytical values	Category	Methodology
A. Mechanical composition				
1.	Sand (%)	24.04	Clay sandy loam	International pipette method (Piper, 1967)
2.	Silt (%)	19.82		
3.	Clay (%)	56.12		
B. Chemical composition				
1.	Organic carbon(%)	0.80	High	Walkely and Black method (Black, 1965)
2.	Available N (Kg ha^{-1})	288.1	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
3.	Available P (Kg ha^{-1})	20.36	High	Olsen method (Olsen *et al.,* 1954)
4.	Available K (Kg ha^{-1})	170.45	Very low	Flame photometer method (Chapman and Pratt, 1961)
5.	Soil pH	5.95	Acidic	pH meter (Piper, 1967)
6.	Electrical conductivity (dsm^{-2} at 25°C)	0.24	Normal	Conductivity meter Solubridge method (Black, 1965)

Table 3.3. Physical-Chemical properties of the soil of experimental field (Guava based agrihorticuture system)

Sl. No.	Particulars	Analytical values	Category	Methodology
A. Mechanical composition				
1.	Sand (%)	25.22	Clay sandy loam	International pipette method (Piper, 1967)
2.	Silt (%)	20.10		
3.	Clay (%)	54.76		
B. Chemical composition				
1.	Organic carbon(%)	0.72	Medium	Walkely and Black method (Black, 1965)
2.	Available N (Kg ha^{-1})	258	low	Alkaline permanganate method (Subbiah and Asija, 1956)
3.	Available P (Kg ha^{-1})	20.2	Medium	Olsen method (Olsen *et al.,* 1954)
4.	Available K (Kg ha^{-1})	178.4	Medium	Flame photometer method (Chapman and Pratt, 1961)
5.	Soil pH	7.35	Neutrals	pH meter (Piper, 1967)
6.	Electrical conductivity (dsm^{-2} at 25°C)	0.28	low	Conductivity meter Solubridge method (Black, 1965)

3.9 Cropping history of the experimental field

The following crops were grown during past five years.

Table 3.4 (*Dalbergia sissoo* based agrisilvicuture system).

Year	Crop (Kharif)	Crop (Rabi)
2014-2015	Paddy	Wheat
2015-2016	Paddy	Wheat
2016-2017	Paddy	Wheat
2017-2018	Paddy	Mustard
2018-2019	Fallow	Mustard

Table 3.5 (Guava based agrihorticuture system).

Year	Crop (Kharif)	Crop (Rabi)
2014-2015	Fallow	Oat
2015-2016	Fallow	Oat
2016-2017	Sun hemp	Oat
2017-2018	Sun hemp	Oat
2018-2019	Sun hemp	Mustard

Table 3.6 Treatments and their composition.

Composition		
S. No.	**Agrisilviculture**	**Agrihorticulture**
Main treatment		
1.	P_0 – No pruning	D_0 – No Deheading
2.	P_1 – 25% pruning	D_1 –Deheading at 1.0 m plant height
3.	P_2 – 50% pruning	D_2 – Deheading at 1.5 m plant height
4.	P_3 – 75% pruning	D_3 – Deheading at 2.0 m plant height
5.	Open – Crop only	Open – Crop only
Sub treatment		
1.	V_1 – JM-3	V_1 – JM-3
2.	V_2 – Urvashi	V_2 – Urvashi
3.	V_3- NRCDR-2	V_3- NRCDR-2

Experimental details

The details of the experiment with regard to varieties, date of sowing, spacing, treatments, design and plot size are given below.

Design	Strip plot design
Number of replications	4
Gross plot size	5 m x 5 m
Net plot size	4.2 m x 4.2 m
Total number of plot	64
Tree species (Agrisilviculture)	*Dalbergia sissoo*
Tree species (Agrihorticulture)	*Psidium guajava*
Tree spacing	5m x 5m

3.10 OBSERVATION RECORDED

1. To record insect pests associated with agroforestry systems at weekly intervals.
2. To study pattern of infestation and intensity of damage.

$$\text{Damage (\%)} = \frac{\text{Number of branches damaged by insect pest}}{\text{Total number of branch examined}} \times 100$$

3. Effect of insect population on agroforestry systems.
4. Effect of tree component on pest population.
5. Identification of major and minor pest occurring in Agrisilvicuture and agrihorticuture system.
6. Population dynamic and period of infestation.

3.11 Characteristics of species:-

3.11.1 Varietal characteristics of mustard.

3.11.1.1 JM-3

Released from zonal agriculture research station, Jawaharlal Nehru Krishi Vishwa Vidyalay, Morena, Madhya Pradesh. Plant height was from 180185 cm, maturity 130 to 132 days, Average seed yield is 15 - 25 q. ha-1. This variety is useful in the multiple cropping systems particularly during the period of September- December. Mean oil content in this variety is 40%.

3.11.1.2 Urvashi

Released from CS Azad University of agriculture & technology, Kanpur, Uttar Pradesh. This variety is medium in plant height 140-150 cm. This variety average yield 18-17 q. ha-1 maturity 125 to 128 days. Mean oil content in this variety is 39%.

3.11.1.3 NRCDR-2

Released from National research centre on rapeseed mustard (Directorate of rapeseed-mustard research) Bharatpur, Rajasthan in 2007. In the field trial conducted by National Research centre on rape seed this variety is suitable for irrigated and rain fed condition, they found average plant height of this variety 165-212 cm, average yield 19-26 q. ha-1, maturity 131 to 156 days and mean oil content in this variety is 42%.

3.11.2 *Dalbergia Sissoo* (Shisham)

Dalbergia sissoo Roxb belong to family Fabaceae, commonly called as Shisham. It occurs naturally throughout the sub-Himalayan tract and outer Himalayan valley from the Indus to Assam. It is an important species having great value for furniture, joinery and carving. The foliage of tree is nutrition fodder. On account of its natural hardiness, fast growth and high timber value, the shisham has been widely used in afforestation and reforestation both in social forestry and agroforestry programmes throughout the India. It is planted in Nepal, Bhutan, Bangladesh, Myanmar, Malaysia, Pakistan, Afghanistan and in tropical to sub-tropical Africa.

Shisham is classical example of a pioneer species in the riverine succession of the Genetic alluvium in India. The species occurs naturally on sandy and gravelly alluvial ground along the banks of rivers and stream. There is remarkable variation in growth pattern and the yield per unit area due to the wide adaptability of the tree in different ecological sites. The leaf fall begins in November-December and also depending upon the climatic conditions. The mean temperature and humidity play an important role than rainfall in controlling leafing and flowering.

.3.11.3 Guava *(Psidium guajava L.)*

It is the most important and commercially cultivated fruit crop belonging to the family Myrtaceae. It is originated in tropical America, stretching from Mexico to Peru, and gradually became a crop of commercial significance in several countries like Brazil, Mexico, China, Malaysia, the Hawaiian Islands, Cuba and India. It was introduced to India during 17th century by Portuguese (Menzel and Paxton, 1985). It is commercially cultivated in different states, viz. Uttar Pradesh, Bihar, Punjab, Andhra Pradesh, Karnataka, Gujarat, Maharashtra, West Bengal, Madhya Pradesh and Tamil Nadu. The total guava production in our county is 40.54 lakh MT from an area of 265 thousand hectares (NHB, 2017-18). It is one of the hardiest among the fruits in productivity, adaptability with nutritional quality. It also known as 'Poor man's apple' and 'Apple of tropics'. The fruit based agroforestry system is a self-sustainable system where solar energy can be harvested at different heights, soil resources can be efficiently used and cropping intensity is increased.

3.11.3.1 L-49 (Lucknow-49)

It is a selection made at Poona and also known as 'Sardar guava'. Fruits are large, roundish-ovate in shape, skin primrose-yellow and pulp white, very sweet and tasty. The TSS and vitamin C contents are high. The plants are vigorous. Keeping quality is excellent. It is prolific bearer, greenish yellow with milky white sweet pulp and rough surface. Shell is fairly thick, contains fairly soft few seeds in inner portion of pulp. Since the number of seeds is less keeping quality is medium it is very popular in Maharashtra and Andhra Pradesh. It is suitable for table purpose and yields about 25t/ha.

3.12 Cultural practices:-

3.12.1 Field preparation

The experimental field was thoroughly prepared by using cultivator followed by rotavator to obtain a well pulverized seed bed. The field was then levelled by using a planker.

3.12.2 Fertilizer Application

The recommended dose of nitrogen, phosphorous and potash were given through Urea, DAP and MOP, respectively. The half of the nitrogen (60 kg ha^{-1}) and full quantity of phosphorous (40 kg P_2O_5 ha^{-1}) and potash (40 kg K_2O ha^{-1}) were applied at the time of sowing as basal dose and remaining half nitrogen (30 kg ha-1) was applied 30 days after sowing as top dressing on standing crop.

3.12.3 Seed and sowing

Sowing of mustard was done in all the plots of experiment on 26 November to 06 December 2018. Good treated seeds of mustard variety JM3, Urvashi, and NRCDR-2 were sown @ 6 kg ha^{-1}. Sowing was done in lines 45 cm row to row and furrows of 5 cm depth were opened with the help of pickaxe. These furrows were dressed first with fertilizer (i.e. NPK as per treatment) mixed with soil and then with seeds. After that covered the open furrow properly with the help of manual labour to prevent damage from bird and for proper germination.

3.12.4 Gap Filling

A week after the completion of germination the gap areas were reseeded manually to obtain uniform plant population in all the plots.

3.12.5 Weeding

The weeds were manually removed from all plots at 25-30 days after sowing.

3.12.6 Irrigation

Since the crop was cultivated in Rabi season, it was irrigated twice 1st irrigation was given on date 08/12/2018 and 2nd irrigation done over the field 18/01/2019 by flooding method.

3.12.7 Harvesting

The maturity period of all three varieties (JM-3, Urvashi, and NRCDR-2) was same and therefore they were harvested after 80 to 85 per cent pods turned to brown colour. Harvesting of crops was done manually with the help of sickle on 04th to 08th April 2019. One row (45 cm) from either side of each plots and at same distance from both the ends (N-S, E-W directions) were harvested separately to remove the border effect. The net plots were harvested separately and produce was left in the field for sun drying. After 2-3 days of drying, the bundles were made out of the harvested produce, and tagged.

3.12.8 Threshing and Winnowing

After sun drying the produce was tied separately according to different varieties of mustard in bundles and weighed plot wise. Threshing was done on the threshing floor manually with the help of wooden sticks. The material threshed from each plot was kept separately. Grains were separated from the straw by winnowing with the help of hand pan (Supa). After separation from straw clean grains were weighed plot wise. The straw yield was worked out by deduct grain yield from bundle weight (plot wise) per plot.

3.13 Collection of experimental observations:-

3.13.1 Daily rainfall data

The daily rainfall data during the course of investigation was recorded during crop season at Meteorological observatory, College of Agricultural Engineering, JNKVV, Jabalpur.

3.13.2 To record insect-pest distribution and associated with agroforestry systems weekly intervals:

To know the distribution and association of various insect-pest in Jabalpur (Dusty acre farm under Department of Forestry, JNKVV, Jabalpur, M.P.) both agroforestry systems (shisham, guava, and mustard) were surveyed at weekly interval and the observation were noted for the incidence of major insect-pests and minor pests from each replication where each replication consisting of 16 trees. Ten randomly selected branches in each plant were observed for major and minor pest.

3.13.3 To study the pattern of infestation and intensity of damage in agroforestry systems

The observations were recorded on the various types and number of insect-pests and their related natural enemies at weekly intervals from each agroforestry systems. To study infestation, ten trees were randomly selected per replication and from which five branches were randomly selected at lower and upper canopy levels. Based on the data collected on the infestation of various insect pests, the susceptibility and level of tolerance was screened.

3.13.4 The infestation / Damage would be consider accordingly as:

$$\% \text{ Damage} = \frac{\text{Number of branch damaged by insect/pest}}{\text{Total number of branch or grains examined}} \times 100$$

Both healthy as well as infested branches were counted and per & infestation was worked out.

3.14 Statistical analysis:-

The data calculated from the experiment were tabulated and analyzed statistically by method of analysis of variance as suggested by Cochran and Cox (1950).

The significance of the treatment mean square at 5 per cent level was tested with 'F' test. When 'F' test showed the significance of treatment using the significance of critical differences at 5 per cent level further tested the differences between the treatment means.

Table 3.7 Skeleton for analysis of variance (ANOVA)

Source of variance	**df**	**S.S.**	**M.S.S.**	**'F' value**	
				Cal. value	Tab. Value (5%)
Replication	3				
Main treatment (Pruning)	4				3.3
Error(a)	12				
Sub-treatment (three mustard varieties)	2				5.1
Error B	6				
Interaction	8				2.4
Error C	24				
Total	**59**				

$$\text{Mean sum of square (MSS)} = \frac{\text{Sum of square}}{\text{Degree of freedom}} \text{ or } \frac{\text{SS}}{\text{d.f.}}$$

$$\text{'F' value} = \frac{\text{Treatment mean sum of squares (TMSS)}}{\text{Error mean sum of squares (EMSS)}}$$

$$\text{SEm} \pm \text{ for main treatment (Pruning)} = \sqrt{\frac{E(a)}{r X v}}$$

$$\text{CD} = \text{SEm} \pm \text{ x } \sqrt{2} \text{ x } t_{5\%} \text{ for error (a) at 12 df}$$

$$\text{SEm} \pm \text{ for sub treatment } = \sqrt{\frac{E(b)}{r X t}}$$

$$\text{CD} = \text{SEm} \pm \text{ x } \sqrt{2} \text{ x } t_{5\%} \text{ for error (b) at 6 df}$$

Interaction:

SEm± for comparison of two main treatments means at same level of sub treatment means

$$\text{SEm} \pm = \sqrt{[E(a) + (b-1)E(c)] \div r \times b}$$

$$\text{CD} = \text{SEm} \pm \text{ x } \sqrt{2} \text{ x } t_{5\%} \text{ for Error(c) d.f}$$

SEm± for comparison of two sum treatment means at same level of main treatment means

$$\text{SEm} \pm = \text{SEm} \pm = \sqrt{[E(a) + (a-1)E(c)] \div r \times a}$$

$$\text{CD} = \text{SEm} \pm \text{ x } \sqrt{2} \text{ x } t_{5\%} \text{ for Error(c) d.f.}$$

Where,

r = Number of replication
t = Number of main treatments
v = Number of sub treatment
E (a) = Error variance for main plot
E (b) = Error variance for subplot
E (c) = Error variance for interaction

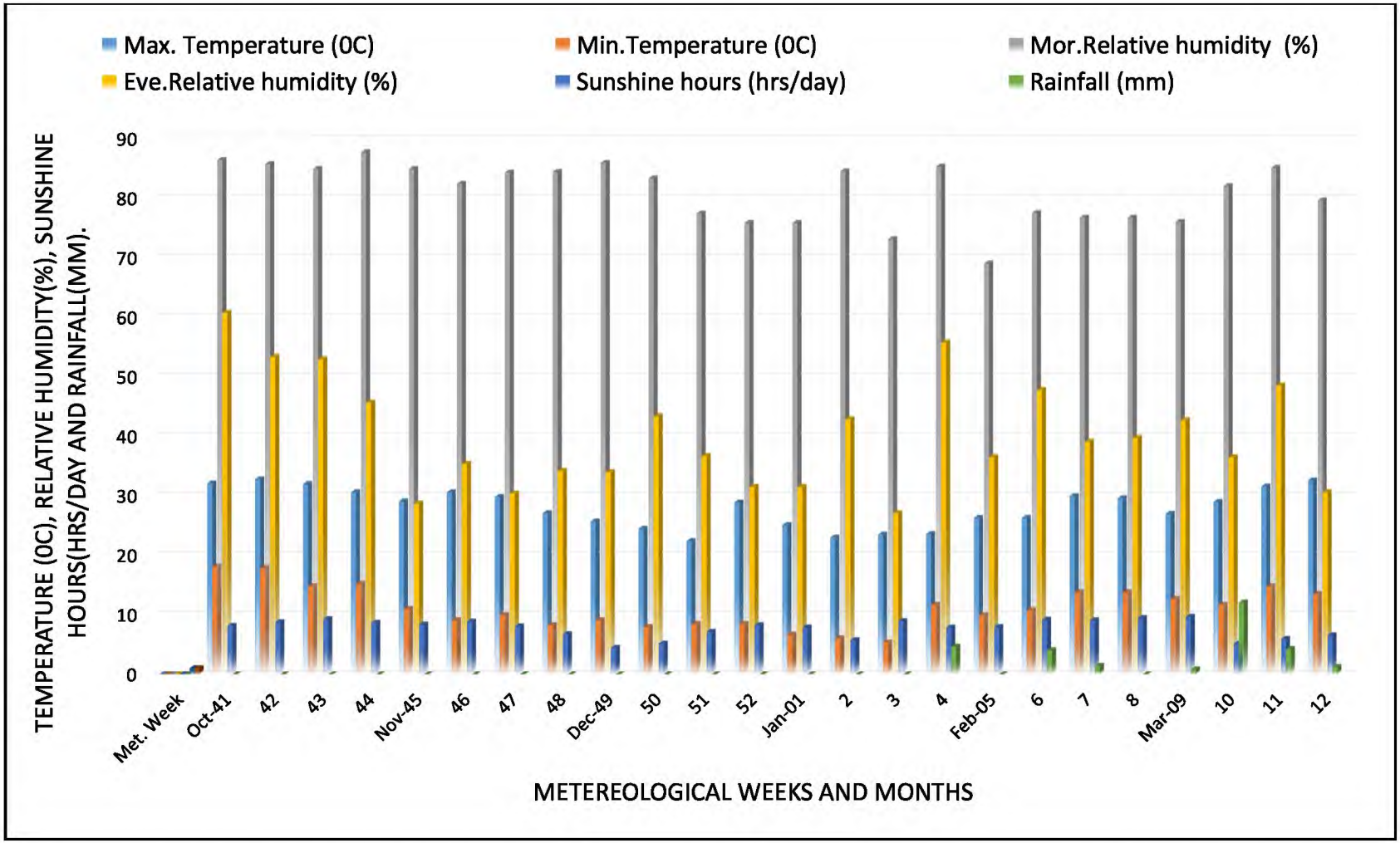


Figure.1 Weekly meteorological parameters during crop season (October 2018 to March 2019)

RESULTS

Present investigations on **"Assessment of insect-pest dynamics and their management in agroforestry systems of semi-arid tropics"** was carried out during the year 2018-19 in Rabi season at Forestry research farm, New Dusty Acre area, Department of Forestry, College of Agriculture, J.N.K.V.V, Jabalpur. The results obtained in the present study are presented in this chapter under following heads.

1. Dynamics of insect-pest communities in agrisilviculture and agrihorticulture system.
2. Insect-pest prevalence and its effect in intercropping system.
3. Effect of tree component on pest population.

Assessment of major and minor insect-pest communities under agroforestry systems during 2018 – 19.

Study was worked out on insect-pest communities under agrisilviculture (Mustard+ *D. sissoo*) system and agrihorticulture (Mustard+Guava) system at different Pruning Intensities and deheading Level respectively. Result reveal that about 4 species of insects in agrisilviculture system and 8 species in agrihorticulture system. The data on mean number of various insect-pest population was recorded at weekly interval during the crop period from November to February of winter season at Jabalpur, Madhya Pradesh during 2018-19.

Table – 4.1 Population dynamics of insect-pest communities in agrisilviculture system during 2018-19.

S. No	Common Name	Scientific Name	Order	Family
Dalbergia sissoo				
1.	Six-spotted zigzag ladybird	*Cheilomenes sexmaculata*	Coleoptera	Coccinellidae
2.	Illeis cincta	*Illeis cincta*	Coleoptera	Coccinellidae
Mustard				
1.	Mustard aphid	*Lipaphis erysimi*	Hemiptera	Aphididae
2.	Honey bee	*Apis indica*	Hymenoptera	Apidae

Table – 4.2 Population dynamics of insect pest communities in agrihorticulture system during 2018 – 19.

S. No	Common Name	Scientific Name	Order	Family
Guava				
1.	Zelus bug	*Zelus luridus*	Heteroptera	Reduviidae
2.	Leaf-footed bug /Squash bug	*Aschistocoris brevicornis*	Heteroptera	Coreidae
3.	Stink bug	*Erthesina fullo*	Heteroptera	Pentatomidae
4.	Jewel bug	*Chrysocoris purpureus*	Heteroptera	Scutelleridae
Mustard				
1.	Common evening brown	*Melanitis leda*	Lepidoptera	satyridae
2.	Dark small-branded swift	*Pelopidas mathias*,	Lepidoptera	Hesperiidae
3.	Honey bee	*Apis indica*	Hymenoptera	Apidae
4.	Mustard aphid	*Lipaphis erysimi*	Hemiptera	Aphididae

4.1 Identification and effect of insect pest under agrisilviculture system.

4.1.1. *Dalbergia sissoo*

- Six-spotted zigzag ladybird *Cheilomenes sexmaculata* (Coleoptera :Coccinellidae)
- *Illeis cincta* (Coleoptera :Coccinellidae).

4.1.2 Mustard *Brassica juncea* (L.)

- Mustard aphid *Lipaphis erysimi* (Hemiptera : Aphididae).
- Honey bee *Apis indica* (Hymenoptera : Apidae).

4.1.1.1 Six-spotted zigzag ladybird *Cheilomenes sexmaculata* (Coleoptera :Coccinellidae).

Description:

This is the commonest insect due to the occurrence of numerous colour variants. The pupae are yellow with black spots. Body outline broadly oval to sub rounded, dorsum moderately convex and shiny.

It has light red, yellow or pinkish with the following markings in the typical form: head with a black marking in posterior half and six black maculae including two zigzag lines and a posterior black spot, sutural line with a narrow to moderately broad black stripe. Antennae short and compact.

Role of insect:

Cheilomenes sexmaculatus is a beneficial insect because of their predaceous nature. it is one of the potential predators of aphids. This insect is considered as the most economical and eco-friendly predator against mustard aphids.

4.1.1.2 *Illeis cincta* (Coleoptera :Coccinellidae).

Description:

Eggs: Creamy white, round, minute in a group of 10- 15 glued on lower surface of leaves.

Larvae: pale yellow, very active with three pairs of legs and four rows of minute dots. Body is covered with minute few hairs. Body is completely dusted with powdery mildew disease.

Adult: The adult is 4-5mm in length and 3-3.6mm in width it is elongate oval convex and Head not easily visible.

Role of insect:

It was identified as a mycophagous insect. It was found on powdery mildew disease of *D. sissoo*. The feeding behaviour of larvae and adults was observed throughout the day but more specific to morning and evening hours of the day and it was hide on lower surface of leaf during after noon.

4.1.2.1 Mustard aphid *Lipaphis erysimi* (Hemiptera : Aphididae)

Description:

It is a major and very small flying insect of mustard crop. The body is faintly dusted with a white powder. The antennae and legs are dark and its colour is pale green or whitish green.

Role of insect:

Mustard aphid (*L. erysimi*) is a major pest of the mustard. It caused direct injury to leaves and stems. It feed by sucking sap from their host-plants. It lives on leaves, young shoots, inflorescences and growing points, causing rolling, chlorosis, dwarfing of whole plants, make honey dew like structure on young leaves and shoots.

4.1.2.2 Honey bee *Apis indica* (Hymenoptera : Apidae).

Description:

Males of *Apis indica* are called drones. Drones have large eyes that meet at the top of their head, no stinger, and their abdomen is thick. Queens are the reproductive females of the colony and are larger than the workers. Adults have branched hairs on their bodies to assist in pollen collection. Their workers (non-reproductive females) have a pollen basket on their hind legs to transport pollen. The worker's ovipositor (an organ for egg laying).

Role of insect:

Apis indica is a floral visitor beneficial insect. It plays a major role in honey production and crop pollination in flowering plants.

4.2 Identification and effect of insect pest under agrihorticulture system.

4.2.1 Guava

- Zelus bug *Zelus luridus* (Heteroptera : Reduviidae).
- Leaf-footed bug /Squash bug *Aschistocoris brevicornis* (Heteroptera : Coreidae).
- Stink bug *Erthesina fullo* (Heteroptera : Pentatomidae).
- Jewel bug *Chrysocoris purpureus* (Heteroptera : Scutelleridae).

4.2.2 Mustard

- Common evening brown *Melanitis leda* (Lepidoptera : Satyridae).
- Dark small-branded swift *Pelopidas mathias,* (Lepidoptera : Hesperiidae).
- Mustard aphid *L. erysimi* (Hemiptera : Aphididae).

4.2.1.1 Zelus bug *Zelus luridus* (Heteroptera : Reduviidae).

Description:

Zelus luridus also known as the Pale Green Assassin Bug, is a species of assassin bug . Adults are elongate-bodied insects with a narrow head and coloration varies from yellow-green to yellow or reddish brown.

Role of insect:

Zelus luridus is a predator of other insects that occur on leaves of trees and shrubs. It has forelegs modified to help insect prey. For this, it uses sticky traps. However, they also use sticky substances to ensnare and hold insects. It can often be seen feeding on prey such as small flies, wasps, and sawflies.

4.2.1.2 Leaf-footed bug/Squash Bug *Aschistocoris brevicornis* (Heteroptera : Coreidae)

Description:

Leaf-footed bug is fairly large with a brownish or grey body. The Young squash bugs, are grey and have black legs. They move quickly in a group.

Role of insect:

These bugs inject their sharp, sucking mouthparts into the plant and suck the sap from the leaves and fruits. The leaves will wilt because the damage prevents the flow of nutrients to the leaves.

4.2.1.3 Stink bug *Erthesina fullo* (Heteroptera : Pentatomidae)

Description:

The Stink Bug (*Erthesina fullo*) is a new pest observed on guava tree. it has dark brown and grey colour. The colour of the adult resembles with the tree trunk making it difficult to find out. its adult has tube-like long sucking mouthparts with antennae.

Role of insect:

It has an impact on timber trees and horticultural crops. It feed upon bark and trunk of the tree and sucks sap. adults feed by inserting their long, tube-like sucking mouthparts into the fruits, leaves and stems of plants from which they suck sap containing sugars and nutrients.

4.2.1.4 Jewel Bug *Chrysocoris purpureus* (Heteroptera : Scutelleridae)

Description:

Adult of *Chrysocoris purpureus* are shiny and bluish green with black five spots on the Spronotum (prothorax) and seven spots on Scutellum.

Role of insect:

It is polyphagous bug with beautiful coloration (metallic and green blue with black spots). It attacked mainly the tender shoots and fruits of plan. It was found sucking the sap from fruits, due to which the colour of fruits changed from green to yellow.

4.2.2.1 Common evening brown *Melanitis leda* (Lepidoptera : Satyridae).

Description:

It wings are dark brown with a large sub-apical patch which is black with two white spots. The butterflies are normally found in the early part of the evening. During the daytime they rest in the undergrowth but are easily disturbed from their resting places.

Role of insect:

It's have polyphagous nature. The caterpillars of *M. leda* feed on leaves and young shoots of the host plant, and hide underside of crops. Adult butterflies of *M. leda* are nectar feeders and occasionally pollen feeders. The nectar of flower is the main source of adult for nutrition.

4.2.2.2 Dark small-branded swift *Pelopidas mathias,* (Lepidoptera : Hesperiidae).

Description:

The adult butterflies are light brown with marking of white spots on the wings and curved antennae.

Role of insect:

It observed as floral visitor insect and act as a pollinator on the flowers of mustard crop. The larvae affect to the margin of leaves and backward rolling of the leaves are symptoms of damage.

4.2.2.3 Mustard aphid *Lipaphis erysimi* (Hemiptera : Aphididae)

Description:

It is a major pest of mustard crop. The body is faintly dusted with a white powder. The antennae and legs are dark and its colour is pale green or whitish green.

Role of insect:

It caused direct injury to leaves and stems. It feed by sucking sap from their host-plants. It lives on leaves, young shoots, and make honey dew like structure on young leaves and shoots.

4.3. Insect pest prevalence and its effect in intercropping system

4.3.1. *Dalbergia sissoo*

- Six-spotted zigzag ladybird *Cheilomenes sexmaculata* (Coleoptera :Coccinellidae)
- *Illeis cincta* (Coleoptera :Coccinellidae)

4.3.1.1. Six-spotted zigzag ladybird *Cheilomenes sexmaculata*.

Population dynamics:-

The six-spotted zigzag ladybird first appear below the leaf surface of sissoo as well as on the mustard crop. It was observed on 3rd week of January. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of 75%, 50%, 25% and no pruned tree.

Table 4.3. shows the result of population dynamics and prevalence of six-spotted zigzag ladybird which started from 3rd week of January that is shown in the form of standard meteorological week 3rd the minimum and maximum temperature was 5.3^{0}C, 23.4^{0}C and relative humidity was 73.1% in the morning and 27.0% in the evening. The average number of insects in open block was 1.7 and under the 75%, 50%, 25% and no pruned tree in all treatments. It was 1.9, 2.0, 2.3, and 2.6, respectively.

Maximum population was recorded on the 2rd week of February (6th meteorological week) the minimum and maximum temperature was 10.7^{0}C and 26.2 ^{0}C and the relative humidity was 77.5% in the morning and 47.71% in the

evening where the insect population was 3.8, 5.5, 6.0, 7.6, and 9.0 in open condition, under the 75%, 50%, 25% and no pruned tree, respectively.

Minimum population of six-spotted zigzag ladybird in last week of February was observed 1.8, 2.9, 3.3, 3.7 and 3.9 open condition and under 75%, 50%, 25% and no pruned tree respectively. After this six-spotted zigzag ladybird was not found. The minimum and maximum temperature was 13.7^{0}C, 29.5^{0}C and the relative humidity was 76.71% in the morning and 39.65% in the evening.

Average mean population of six-spotted zigzag ladybird in all treatments at different pruning intensities was 6.11, 5.33, 4.6, 3.9, and 2.2, in 0%, 25%, 50%,75%, and open condition respectively.

Table – 4.3 Population dynamics and prevalence of Six-spotted zigzag ladybird.

Treatments	**Standard Meteorological Weeks**					
	3	**4**	**5**	**6**	**7**	**8**
Pruning intensities	**Incidence / Population**					
Po-No Pruning	2.6	7.1	8.3	9.0	5.8	3.9
P_1-25% Pruning	2.3	6.7	6.9	7.6	4.8	3.7
P_2-50% Pruning	2.0	5.8	5.9	6.0	4.6	3.3
P_3-75% Pruning	1.9	4.2	4.8	5.5	4.3	2.9
Open- Crop only	1.7	1.8	2.4	3.8	1.7	1.8
SEm±	0.14	0.22	0.32	0.32	0.40	0.59
CD (P=0.05)	0.42 S	0.66 S	0.97 S	0.97 S	1.24 S	1.82 S
Mustard varieties		**Incidence / Population**				
V_1 – JM-3	2.20	5.05	5.55	6.50	4.35	3.25
V_2 – Urvashi	2.00	5.05	5.70	6.50	4.20	2.90
V_3- NRCDR-2	2.05	5.20	5.70	6.10	4.15	3.20
SEm±	0.20	0.35	0.18	0.24	0.16	0.34
CD(P=0.05)	0.69	1.20	0.63	0.84	0.54	1.19

4.3.1.2. *Illeis cincta* (Coleoptera :Coccinellidae)

Population dynamics:-

First appearance of the lady beetle on twigs and leaves of sissoo. It was observed during fourth week of January. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of 75%, 50%, 25% and no pruned tree.

Table 4.4. Shows the result of population dynamics and prevalence of *illeis cincta* which started from fourth week of January that is shown in the form of standard meteorological week 4th the minimum and maximum temperature was 11.6^{0}C, 23.5^{0}C and the relative humidity was 85% in the morning and 55% in the evening. The average number of insects in open block was 0.5 and under the 75%, 50%, 25% and no pruned tree in all treatments. It was 0.8, 1.1, 1.3, and 1.5 respectively.

Maximum population was recorded on the 2nd week of February (6th meteorological week) the minimum and maximum temperature was 10.7^{0}C, 26.2^{0}C and the relative humidity was 77.5% in the morning and 47.71% in the evening where the insect population was 2.1, 2.3, 2.8 3.1, and 3.3 in open condition, under the 75%, 50%, 25% and no pruned tree respectively.

Minimum population of *illeis cincta* was recorded in 4th week of February (8th meteorological week) was observed 0.7, 0.9, 1.1, 1.2, and 1.4 in open condition and under 75%, 50%, 25% and no pruned tree respectively. After this week *Illeis cincta* was not found. The minimum and maximum temperature was 13.7^{0}C, 29.5^{0}C and the relative humidity was 76.71% in the morning and 39.65% in the evening.

Average mean population of *illeis cincta* in all treatments at different pruning Intensities was 2.6, 2.1, 1.9, 1.5, and 1.3 in 0%, 25%, 50%,75%, and open condition respectively.

Table – 4.4 Population dynamics and prevalence of *illeis cincta*.

Treatments	Standard Meteorological Weeks				
	4	5	6	7	8
Pruning intensities	**Incidence / Population**				
Po-No Pruning	1.5	2.8	3.0	2.8	1.4
P_1-25% Pruning	1.3	2.5	3.1	2.7	1.2
P_2-50% Pruning	1.1	2.3	2.8	2.3	1.1
P_3-75% Pruning	0.8	2.0	2.3	1.8	0.9
Open-No tree	0.5	1.7	2.1	1.7	0.7
SEm±	0.22	0.20	0.21	0.20	0.26
CD (P=0.05)	0.67 N	0.63 S	0.66 S	0.63 S	0.82 N
Mustard varieties	**Incidence / Population**				
V_1 – JM-3	1.10	2.30	2.85	2.60	1.40
V_2 – Urvashi	0.85	2.15	2.75	2.00	0.95
V_3- NRCDR-2	1.15	2.30	2.55	2.20	0.80
SEm±	0.12	0.19	0.15	0.15	0.19
CD(P=0.05)	0.40	0.65	0.53	0.52	0.65

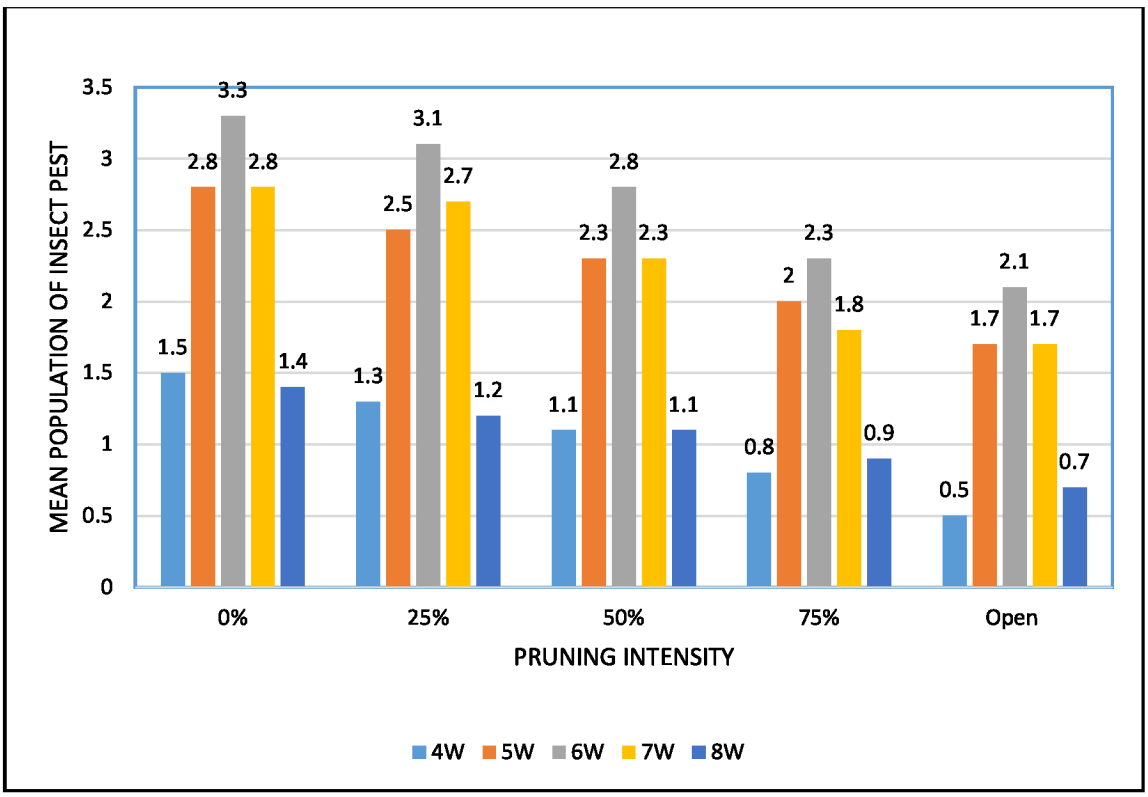


Figure.3 Population dynamics and prevalence of *illeis cincta*.

4.3.2 Mustard *Brassica juncea* (L.)

- Mustard aphid *Lipaphis erysimi* (Hemiptera : Aphididae).
- Honey bee *Apis indica* (Hymenoptera : Apidae).

4.3.2.1 Mustard aphid *L. erysimi* (Hemiptera : Aphididae).

Population dynamics:-

Mustard aphid *L. erysimi* first appear during flowering stage on the mustard crop. It was observed during second week of January. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of 75%, 50%, 25% and no pruned tree.

Table 4.5. Shows the result of population dynamics and prevalence of *L. erysimi* which started from second week of January that is shown in the form of standard meteorological week 2nd the minimum and maximum temperature was 6.0^{0}C, and 22.9^{0}C and the relative humidity was 84.5% in the morning and 42.8% in the evening. The average number of insects in open block was 2.6 and under the 75%, 50%, 25% and no pruned tree in all treatments. It was 2.8, 3.6, 3.9 and 4.3 respectively.

Maximum population was recorded on the first week of February (5th meteorological week) the minimum and maximum temperature was 26.2^{0}C and 9.9^{0}C and the relative humidity was 69% in the morning and 36.42% in the evening where the insect population was 8.6, 10.4, 11.1, 13.0, and 14.2 in open condition, under the 75%, 50%, 25% and no pruned tree respectively.

Minimum population of *L. erysimi* was recorded in 4th week of February (8th meteorological week) was observed 1.8, 2.1, 2.3, 2.6 and 3.0 in open condition and under 75%, 50%, 25% and no pruned tree respectively. After this week *L. erysimi* was not found. The minimum and maximum temperature was 13.7^{0}C, 29.5^{0}C and the relative humidity was 76.71% in the morning and 39.65% in the evening.

Average mean population of *L. erysimi* in all treatments at different pruning intensities was 7.8, 7.2, 6.5, 5.8 and 4.9 in 0%, 25%, 50%, 75%, and open condition respectively.

Table – 4.5 Population dynamics and prevalence of mustard aphid *L. erysimi*.

Treatments	Standard Meteorological Weeks						
	2	3	4	5	6	7	8
Pruning intensities	**Incidence / Population**						
Po-No Pruning	4.3	7.5	10.3	14.2	9.7	6.2	3.0
P_1-25% Pruning	3.9	7.3	9.4	13.0	9.3	5.3	2.6
P_2-50% Pruning	3.6	6.6	8.3	11.1	8.6	5.2	2.3
P_3-75% Pruning	2.8	5.8	8.0	10.4	7.3	4.3	2.1
Open-No tree	2.6	5.1	7.1	8.6	6.3	3.4	1.8
SEm±	0.51	0.28	0.25	0.60	0.30	0.24	0.13
CD (P=0.05)	1.56 S	0.87 S	0.76 S	1.86 S	0.93 S	0.75 S	0.40 S
Mustard varieties	**Incidence / Population**						
V_1 – JM-3	3.75	6.35	9.00	12.00	8.65	4.70	2.50
V_2 – Urvashi	3.05	6.70	7.90	11.40	7.65	4.45	2.25
V_3- NRCDR-2	3.30	6.30	9.00	10.95	8.35	5.45	2.30
SEm±	0.32	0.37	0.28	0.47	0.30	0.41	0.16
CD(P=0.05)	1.11	1.27	0.97	1.62	1.04	1.43	0.55

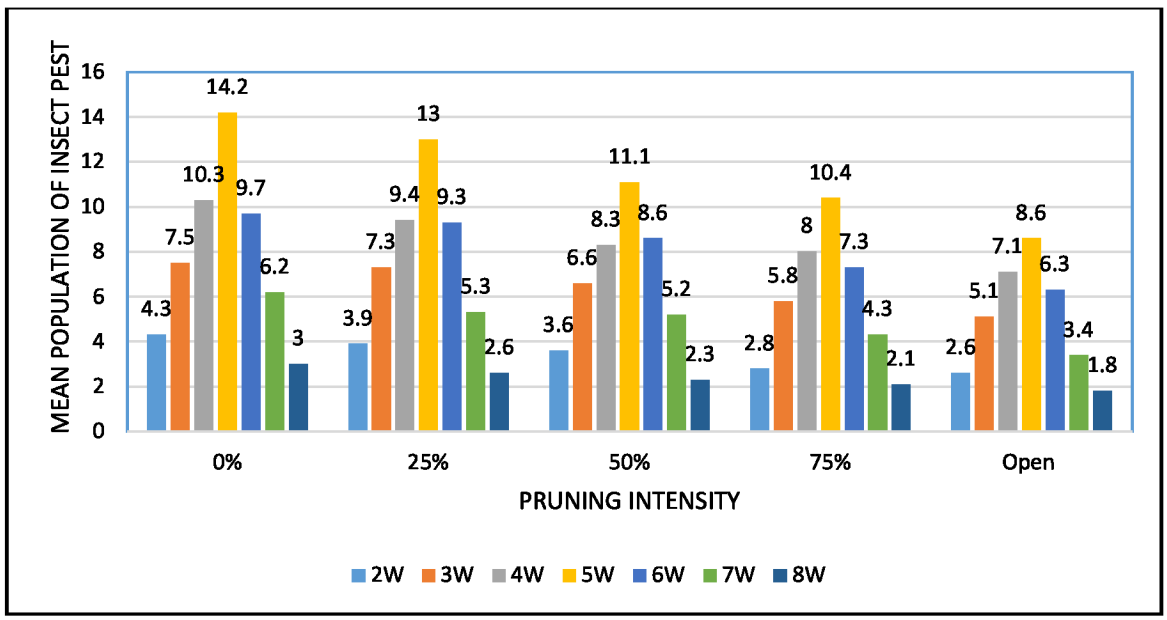


Figure.4 Population dynamics and prevalence of mustard aphid *(L. erysimi)*.

4.1.2.2 Honey bee *Apis indica* (Hymenoptera : Apidae).

Population dynamics:-

Apis indica is a beneficial insect. It act as a vector for causing pollination in crops. It was observed during fourth week of January at flowering stage of mustard. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of 75%, 50%, 25% and no pruned tree.

Table 4.6. Shows the result of population dynamics and prevalence of *A. indica* which started from fourth week of January that is shown in the form of standard meteorological week 4th the minimum and maximum temperature was 11.6^{0}C, 23.5^{0}C and the relative humidity was 85% in the morning and 55% in the evening. The average number of insects in open block was 2.0 and under the 75%, 50%, 25% and no pruned tree in all treatments. It was 2.3, 2.8, 3.9, and 4.3 respectively.

Maximum population was recorded on the 2nd week of February (6th meteorological week) the minimum and maximum temperature was 10.7^{0}C, 26.2^{0}C and the relative humidity was 77.5% in the morning and 47.71% in the evening where the insect population was 4.9, 5.8, 6.5, 6.8 and 7.3 in open condition, under the 75%, 50%, 25% and no pruned tree respectively.

Minimum population of *A. indica* was recorded in first week of March (9th meteorological week) was observed 2.8, 3.1, 3.4, 3.5, and 3.8 in open condition and under 75%, 50%, 25% and no pruned tree respectively. After this week *Apis indica* was not found. The minimum and maximum temperature was 12.6^{0}C, 26.9^{0}C and the relative humidity was 76% in the morning and 42.6% in the evening.

Average mean population of *A. indica* in all treatments at different pruning intensities was 6.0, 4.8, 4.4, 3.9 and 3.7, in 0%, 25%, 50%, 75%, and open condition respectively.

Table – 4.6 Population dynamics and prevalence of honey bee *Apis indica.*

Treatments	Standard Meteorological Weeks					
	4	5	6	7	8	9
Pruning intensities	**Incidence / Population**					
Po-No Pruning	4.3	6.9	7.3	6.3	5.5	3.8
P_1-25% Pruning	3.9	5.4	6.8	4.8	4.4	3.5
P_2-50% Pruning	2.8	4.9	6.5	4.6	4.2	3.4
P_3-75% Pruning	2.3	4.6	5.8	4.3	3.8	3.1
Open-No tree	2.0	4.6	4.9	4.2	3.7	2.8
SEm±	0.47	0.35	0.22	0.30	0.27	0.20
CD (P=0.05)	1.45 S	1.08 S	0.69 S	0.92 S	0.84 S	0.62 S
Mustard varieties	**Incidence / Population**					
V1 – JM-3	3.50	5.40	6.20	4.60	4.15	3.25
V2 – Urvashi	2.70	5.15	6.15	5.00	4.4	3.30
V3- NRCDR-2	2.95	5.30	6.45	4.95	4.40	3.45
SEm±	0.33	0.42	0.15	0.29	0.21	0.15
CD(P=0.05)	1.15	1.44	0.51	1.01	0.74	0.53

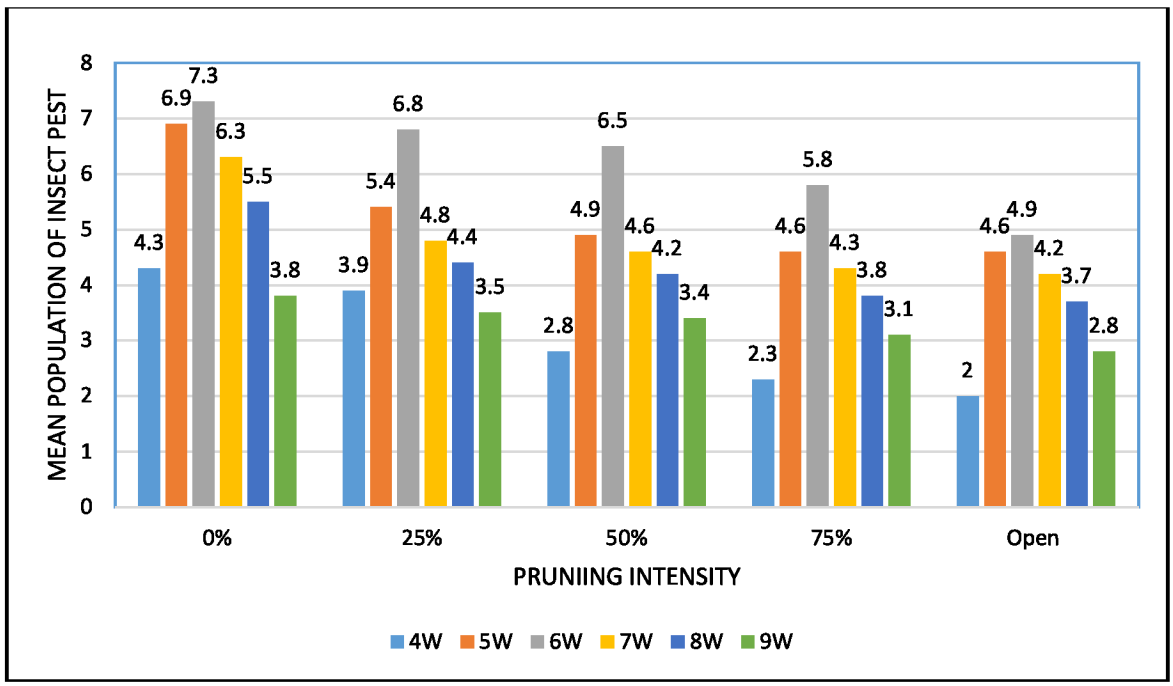


Figure.5 Population dynamics and prevalence of honey bee (*Apis indica*).

4.4. Insect-pest prevalence and its effect in intercropping system.

4.4.1 Guava

- Zelus bug *Zelus luridus* (Heteroptera : Reduviidae).
- Leaf-footed bug /Squash bug *Aschistocoris brevicornis* (Heteroptera : Coreidae)
- stink bug *Erthesina fullo* (Heteroptera : Pentatomidae)
- Jewel bug *Chrysocoris purpureus* (Heteroptera : Scutelleridae)

4.4.1.1. Zelus bug *Zelus luridus* (Heteroptera : *Reduviidae*).

Population dynamics: -

The Zelus bug first appear on guava tree. It was observed on 3rd week of December. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of D_3, D_2, D_1 and no deheaded tree.

Table 4.7. Shows the result of population dynamics and prevalence of Zelus bug which started from 3rd week of December that is shown in the form of standard meteorological week 51th the minimum and maximum temperature was 8.4^{0}C, 22.3^{0}C and the relative humidity was 77.4% in the morning and 36.6% in the evening. The average number of insects in open block was 2.4 and under the D_3, D_2, D_1 and no deheaded tree in all treatments. It was 2.6, 2.9, 3.0 and 3.3, respectively.

Maximum population was recorded on the 4th week of December (52th meteorological week) the minimum and maximum temperature was 8.4^{0}C, 28.8^{0}C and the relative humidity was 75.8% in the morning and 31.4 in the evening where the insect population was 5.8, 6.2, 6.8, 6.9 and 7.3 in open condition, under the D_3, D_2, D_1 and no deheaded tree, respectively.

Minimum population of Zelus bug in 3rd week of January was observed 1.5, 1.8, 2.0, 2.2 and 2.6 open condition and under D_3, D_2, D_1 and no deheaded tree. After this Zelus bug was not found. The minimum and maximum temperature was 5.3^{0}C, 23.4^{0}C and the relative humidity was 71.1% in the morning and 27.0% in the evening.

Average mean population of Zelus bug in all treatments at different deheading level was 4.3, 4.0, 3.8, 3.4, and 3.1, in D_0, D_1, D_2, D_3 and open condition respectively.

Table – 4.7. Population dynamics and prevalence of Zelus bug.

Treatments	Standard Meteorological Weeks				
	51	52	1	2	3
Deheading level	**Incidence / Population**				
D_0–No Deheading	3.3	7.3	4.8	3.7	2.6
D_1–Deheading at 1.0m plant height	3.0	6.9	4.6	3.4	2.2
D_2–Deheading at 1.5m plant height	2.9	6.8	4.3	3.2	2.0
D_3–Deheading at 2.0m plant height	2.6	6.2	3.8	3.0	1.8
Open – Crop only	2.4	5.8	3.3	2.5	1.5
SEm±	0.22	0.26	0.33	0.16	0.21
CD (P=0.05)	0.67 N	0.80 S	1.03 N	0.48 S	0.65 S
Mustard varieties	**Incidence / Population**				
V_1 – JM-3	3.10	6.95	4.35	3.25	2.20
V_2 – Urvashi	2.85	6.50	3.75	2.90	1.85
V_3- NRCDR-2	2.55	6.30	4.30	3.30	1.95
SEm±	0.16	0.26	0.25	0.17	0.18
CD(P=0.05)	0.54	0.91	0.88	0.57	0.61

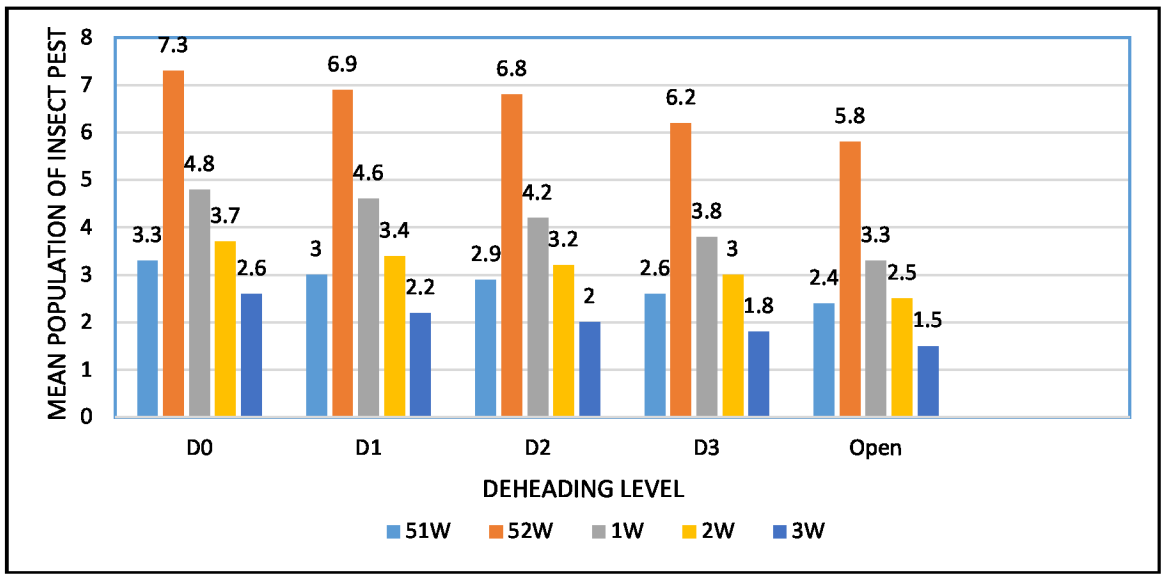


Figure.6 Population dynamics and prevalence of Zelus bug.

4.4.1.2 Leaf-footed bug /Squash bug *Aschistocoris brevicornis* (Heteroptera : Coreidae)

Population dynamics: -

The leaf-footed bug first appeared on guava tree. It was observed during 4th week of December. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of D_3, D_2, D_1 and no deheaded tree.

Table 4.8. Shows the result of population dynamics and prevalence of Leaf-footed bug which started from 4th week of December that is shown in the form of standard meteorological week 52th the minimum and maximum temperature was 8.4^{0}C, 28.8^{0}C and relative humidity was 75.8% in the morning and 31.4% in the evening. The average number of insects in open block was 1.7 and under the D_3, D_2, D_1 and no deheaded tree in all treatments. It was 2.1, 2.2, 2.4 and 2.8 respectively.

Maximum population was recorded on the 2nd week of January (2nd meteorological week) the minimum and maximum temperature was 6.0^{0}C, 23.9^{0}C and the relative humidity was 84.5% in the morning and 42.8% in the evening where the insect population was 4.6, 4.8, 5.4, 5.7 and 6.4 in open condition, under the D_3, D_2, D_1 and no deheaded tree respectively.

Minimum population of leaf-footed bug in 4th week of January was observed 0.8, 1.2, 1.4, 1.6, and 1.7 open condition and under D_3, D_2, D_1 and no deheaded tree. After this Leaf-footed bug was not found. The minimum and maximum temperature was 11.6^{0}C, 23.5^{0}C and the relative humidity was 85.3% in the morning and 55.7% in the evening.

Average mean population of leaf-footed bug in all treatments at different deheading Level was 3.6, 3.2, 2.9, 2.6, and 2.3, in D_0, D_1, D_2, D_3 and Open condition, respectively.

Table – 4.8. Population dynamics and prevalence of Leaf-footed bug / Squash bug.

Treatments	Standard Meteorological Weeks				
	52	1	2	3	4
Deheading level	**Incidence / Population**				
D_0–No Deheading	2.8	4.2	6.4	3.2	1.7
D_1–Deheading at 1.0m plant height	2.4	3.8	5.7	2.5	1.6
D_2–Deheading at 1.5m plant height	2.2	3.5	5.4	2.3	1.4
D_3–Deheading at 2.0m plant height	2.1	3.3	4.8	2.0	1.2
Open – Crop only	1.7	3.0	4.6	1.8	0.8
SEm±	0.23	0.25	0.22	0.23	0.14
CD (P=0.05)	0.72 S	0.76 S	0.67 S	0.71 S	0.43 S
Mustard varieties	**Incidence / Population**				
V_1 – JM-3	2.55	3.75	5.60	2.70	1.45
V_2 – Urvashi	2.05	3.55	5.15	2.15	1.20
V_3- NRCDR-2	2.10	3.35	5.35	2.20	1.35
SEm±	0.23	0.37	0.15	0.18	0.11
CD(P=0.05)	0.81	1.27	0.51	0.61	0.39

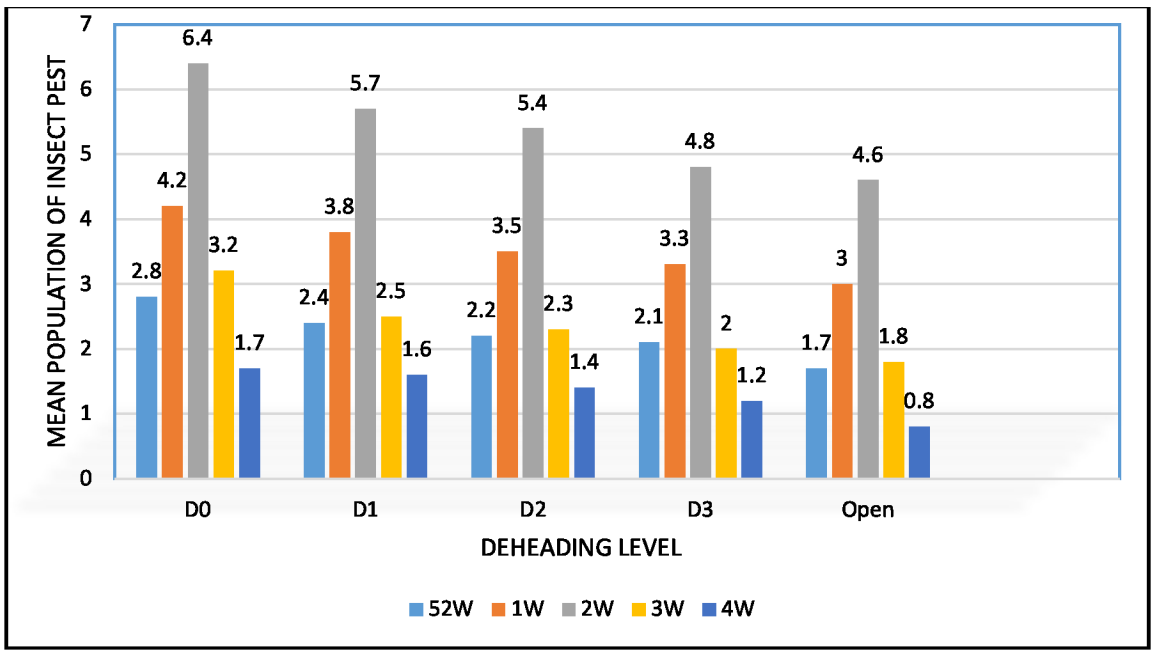


Figure.7 Population dynamics and prevalence of Leaf-footed bug.

4.4.1.3 Stink bug *Erthesina fullo* (Heteroptera : Pentatomidae)

Population dynamics: -

Stink bug was observed in guava based agrihorticulture system on guava tree at J.N.K.V.V. Jabalpur. Firstly, it was observed on 4th week of December. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of D_3, D_2, D_1 and no deheaded tree.

Table 4.9. Shows the result of population dynamics and prevalence of Stink bug which started from 4th week of December that is shown in the form of standard meteorological week 52th the minimum and maximum temperature was 8.4^{0}C, 28.8^{0}C and relative humidity was 75.8% in the morning and 31.4% in the evening. The average number of insects in open block was 1.7 and under the D_3, D_2, D_1 and no deheaded tree in all treatments. It was 0.9, 1.2, 1.3, 1.4 and 1.5, respectively.

Maximum population was recorded on the 2nd week of January (2nd meteorological week) the minimum and maximum temperature was 6.0^{0}C, 23.9^{0}C and the relative humidity was 84.5% in the morning and 42.8% in the evening where the insect population was 1.8, 2.0, 2.1, 2.4, and 2.6 in open condition, under the D_3, D_2, D_1 and no deheaded tree respectively.

Minimum population of Stink bug in 2nd week (6th meteorological week) of February was observed 0.6, 0.9, 1.1, 1.2, and 1.4 open condition and under D_3, D_2, D_1 and no deheaded tree. After this Stink bug was not found. The minimum and maximum temperature was 10.7^{0}C, 26.2^{0}C and the relative humidity was 77.5% in the morning and 47.7% in the evening.

Average mean population of Stink bug in all treatments at different deheading Level was 1.8, 1.6, 1.5, 1.3, and 1.1, in D_0, D_1, D_2, D_3 and Open condition respectively.

Table – 4.9. Population dynamics and prevalence of Stink bug.

Treatments	Standard Meteorological Weeks						
	52	1	2	3	4	5	6
Deheading level	**Incidence / Population**						
D_0–No Deheading	1.5	2.3	2.6	1.9	1.7	1.5	1.4
D_1–Deheading at 1.0m plant height	1.4	2.2	2.4	1.7	1.4	1.3	1.2
D_2–Deheading at 1.5m plant height	1.3	2.0	2.1	1.5	1.3	1.2	1.1
D_3–Deheading at 2.0m plant height	1.2	1.8	2.0	1.3	1.1	0.9	0.9
Open – Crop only	0.9	1.5	1.8	1.1	0.8	0.7	0.6
SEm±	0.14	0.19	0.17	0.25	0.22	0.23	0.17
CD (P=0.05)	0.44 N	0.60 N	0.53 S	0.76 N	0.67 N	0.72 N	0.53 S
Mustard varieties	**Incidence / Population**						
V_1 – JM-3	1.25	2.10	2.50	1.55	1.25	1.15	1.05
V_2 – Urvashi	1.25	1.90	2.05	1.45	1.20	1.15	0.95
V_3- NRCDR-2	1.25	1.80	1.95	1.50	1.30	1.05	1.10
SEm±	0.10	0.07	0.08	0.19	0.21	0.23	0.11
CD(P=0.05)	0.35	0.26	0.26	0.67	0.72	0.79	0.39

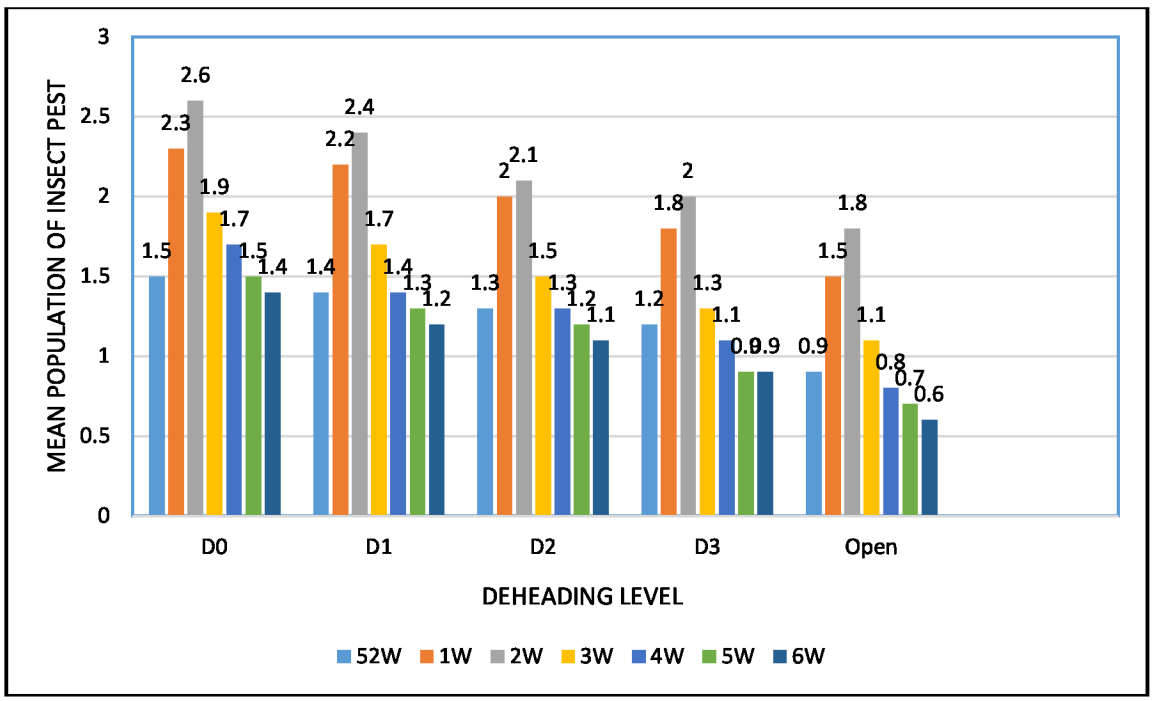


Figure.8 Population dynamics and prevalence of Stink bug.

4.4.1.4 Jewel bug *Chrysocoris purpureus* (Heteroptera : Scutelleridae)

Population dynamics:-

The Jewel bug was recorded on mustard and guava tree. It was observed during 4th week of November. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of D_3, D_2, D_1 and no deheaded tree.

Table 4.10. Shows the result of population dynamics and prevalence of Jewel bug which started from 4th week of November that is shown in the form of standard meteorological week 48th the minimum and maximum temperature was 8.2^{0}C, 27.7^{0}C and the relative humidity was 84.4% in the morning and 34.1% in the evening. The average number of insects in open block was 1.0 and under the D_3, D_2, D_1 and no deheaded tree in all treatments. It was 1.2, 1.3, 1.7 and 2.1 respectively.

Maximum population was recorded on the 3rd week of December (51th meteorological week) the minimum and maximum temperature was 8.4^{0}C, 22.3^{0}C and the relative humidity was 77.4% in the morning and 36.6% in the evening where the insect population was 3.6, 4.3, 4.6, 5.3, and 5.4 in open condition, under the D_3, D_2, D_1 and no deheaded tree respectively.

Minimum population of Jewel bug in 3rd week (3rd meteorological week) of January was observed 1.0, 1.1, 1.3, 1.6, and 1.7 open condition and under D_3, D_2, D_1 and no deheaded tree. After this Jewel bug was not found. The minimum and maximum temperature was 5.3^{0}C, 23.4^{0}C and the relative humidity was 73.1% in the morning and 27.0% in the evening.

Average mean population of Jewel bug in all treatments at different deheading Level was 4.0, 3.7, 3.1, 2.9, and 2.4, in D_0, D_1, D_2, D_3 and open condition respectively.

Table – 4.10. Population dynamics and prevalence of Jewel bug.

Treatments	Standard Meteorological Weeks							
	48	49	50	51	52	1	2	3
Deheading level	**Incidence / Population**							
D_0–No Deheading	2.1	4.3	4.8	5.4	5.1	4.9	3.8	1.7
D_1–Deheading at 1.0m plant height	1.7	4.1	4.3	5.3	4.7	4.5	3.6	1.6
D_2–Deheading at 1.5m plant height	1.3	3.5	3.8	4.6	4.0	3.8	3.2	1.3
D_3–Deheading at 2.0m plant height	1.2	3.1	3.6	4.3	3.9	3.5	2.6	1.1
Open – Crop only	1.0	2.8	3.1	3.6	2.8	2.6	2.3	1.0
SEm±	0.13	0.27	0.26	0.23	0.15	0.15	0.31	0.20
CD (P=0.05)	0.41 S	0.83 S	0.80 S	0.72 S	0.46 S	0.46 S	0.94 S	0.60 N
Mustard varieties	**Incidence / Population**							
V_1 – JM-3	1.50	3.80	3.90	4.90	4.20	4.00	3.15	1.70
V_2 – Urvashi	1.35	3.35	3.75	4.55	3.90	3.75	3.00	1.05
V_3- NRCDR-2	1.45	3.50	4.05	4.45	4.15	3.80	3.05	1.20
SEm±	0.13	0.12	0.25	0.27	0.15 c	0.16	0.25	0.18
CD(P=0.05)	0.46	0.42	0.87	0.92	0.52	0.56	0.86	0.55

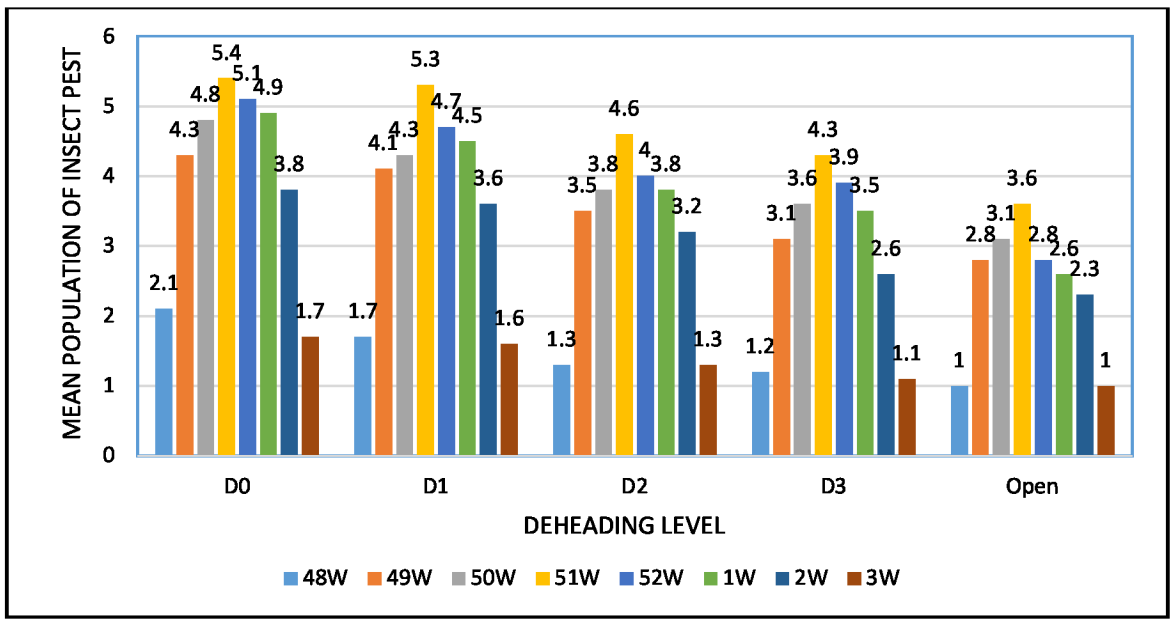


Figure.9 Population dynamics and prevalence of Jewel bug.

Mustard *Brassica juncea* (L.)

- Common evening brown *Melanitis leda* (Lepidoptera : Satyridae).
- Dark small-branded swift *Pelopidas mathias,* (Lepidoptera : Hesperiidae).
- Honey bee *Apis indica* (Hymenoptera : Apidae).
- Mustard aphid *Lipaphis erysimi* (Hemiptera : Aphididae).

4.4.2.1. Common evening brown *Melanitis leda* (Lepidoptera : Satyridae)

Population dynamics: -

The Common evening brown was reveal on mustard crop in guava based agrihorticulture system at my experiment field J.N.K.V.V. Jabalpur. Firstly, It was observed during 4th week of December. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of D_3, D_2, D_1 and no deheaded tree.

Table 4.11. Shows the result of population dynamics and prevalence of Common evening brown which started from 4th week of December that is shown in the form of standard meteorological week 52th the minimum and maximum temperature was 8.4^{0}C, 28.8^{0}C and the relative humidity was 75.8% in the morning and 31.4% in the evening. The average number of insects in open block was 1.8 and under the D_3, D_2, D_1 and no deheaded tree in all treatments. It was 2.0, 2.3, 2.6, and 2.7, respectively.

Maximum population was recorded on the 2nd week of January (2nd meteorological week) the minimum and maximum temperature was 6.0^{0}C, 22.9^{0}C and the relative humidity was 84.5% in the morning and 42.8% in the evening where the insect population was 3.4, 3.8, 4.3, 4.7 and 5.0 in open condition, under the D_3, D_2, D_1 and no deheaded tree, respectively.

Minimum population of Common evening brown in 4th week (4th meteorological week) of January was observed 1.6, 1.8, 2.1, 2.3 and 2.5 open condition and under D_3, D_2, D_1 and no deheaded tree respectively. After this Common evening brown was not found. The minimum and maximum temperature was 11.60^{0}C, 23.5^{0}C and the relative humidity was 85.3% in the morning and 55.7% in the evening.

Average mean population of Common evening brown in all treatments at different deheading Level was 3.7, 3.5 3.2, 2.8 and 2.5, in D_0, D_1, D_2, D_3 and open condition respectively.

Table – 4.11. Population dynamics and prevalence of Common evening brown.

Treatments	Standard Meteorological Weeks				
	52	1	2	3	4
Deheading level	**Incidence / Population**				
D_0–No Deheading	2.7	3.8	5.0	4.6	2.5
D_1–Deheading at 1.0m plant height	2.6	3.6	4.7	4.3	2.3
D_2–Deheading at 1.5m plant height	2.3	3.5	4.3	3.9	2.1
D_3–Deheading at 2.0m plant height	2.0	3.1	3.8	3.3	1.8
Open – Crop only	1.8	2.8	3.4	3.2	1.6
SEm±	0.22	0.21	0.23	0.24	0.30
CD (P=0.05)	0.68 N	0.63 N	0.71 S	0.73 S	0.92 N
Mustard varieties	**Incidence / Population**				
V_1 – JM-3	2.45	3.25	4.45	4.00	2.05
V_2 – Urvashi	2.00	3.55	4.10	3.50	1.90
V_3- NRCDR-2	2.30	3.30	4.15	4.05	2.20
SEm±	0.13	0.31	0.27	0.28	0.35
CD(P=0.05)	0.45	1.06	0.92	0.96	1.22

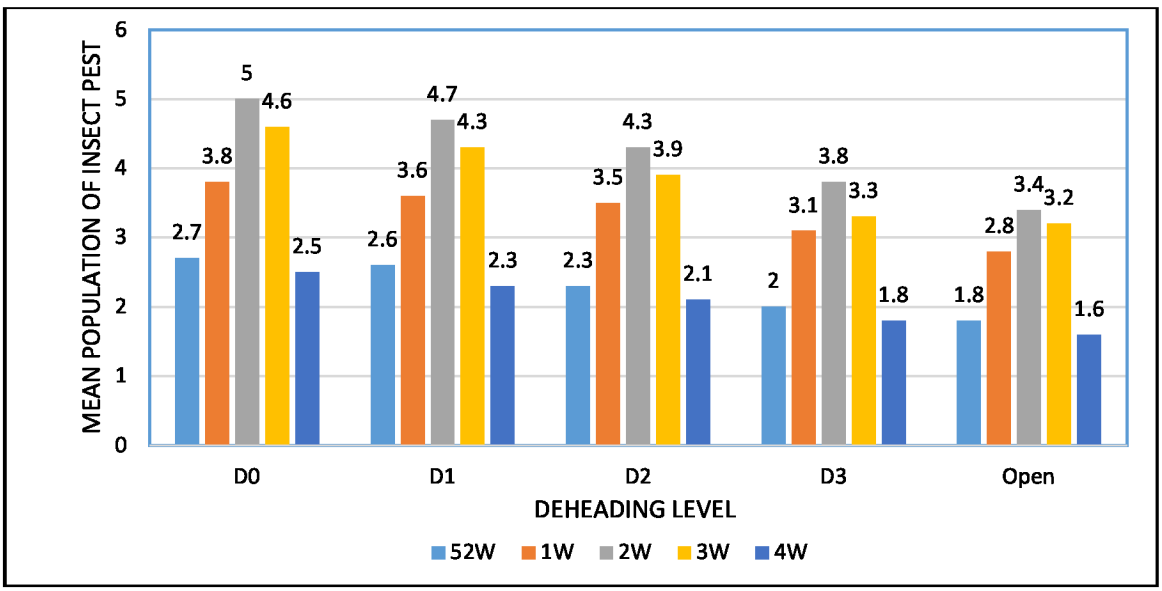


Figure.10 Population dynamics and prevalence of Common evening brown.

4.4.2.2. Dark small-branded swift *Pelopidas mathias,* (Lepidoptera : Hesperiidae).

Population dynamics: -

The Dark small-branded swift was recorded on mustard crop in agrihorticulture system at J.N.K.V.V. Jabalpur. Firstly, it was observed during 3rd week of December. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of D_3, D_2, D_1 and no deheaded tree.

Table 4.12. shows the result of population dynamics and prevalence of Dark small-branded swift which started from 3rd week of December that is shown in the form of standard meteorological week 51th the minimum and maximum temperature was 8.4^{0}C, 22.3^{0}C and the relative humidity was 77.4% in the morning and 36.6% in the evening. The average number of insects in open block was 0.9 and under the D_3, D_2, D_1 and no deheaded tree in all treatments. It was 1.0, 1.2, 1.3, and 1.5 respectively.

Maximum population was recorded on the 1st week of January (1st meteorological week) the minimum and maximum temperature was 6.6^{0}C, 25.0^{0}C and the relative humidity was 75.8% in the morning and 31.4% in the evening where the insect population was 3.4, 4.0, 4.1, 4.3 and 4.5 in open condition, under the D_3, D_2, D_1 and no deheaded tree respectively.

Minimum population of Dark small-branded swift in 3rd week (3rd meteorological week) of January was observed 0.7, 0.8, 1.0, 1.1 and 1.3 open condition and under D_3, D_2, D_1 and no deheaded tree respectively. After this Dark small-branded swift was not found. The minimum and maximum temperature was 5.3^{0}C, 23.4^{0}C and the relative humidity was 73.1% in the morning and 27.0% in the evening.

Average mean population of Dark small-branded swift in all treatments at different deheading Level was 2.6, 2.4, 2.2, 1.9 and 1.7, in D_0, D_1, D_2, D_3 and open condition respectively.

Table – 4.12. Population dynamics and prevalence of Dark small-branded swift *Pelopidas mathias*.

Treatments	Standard Meteorological Weeks				
	51	52	1	2	3
Deheading level	**Incidence / Population**				
D_0–No Deheading	1.5	2.6	4.5	3.3	1.3
D_1–Deheading at 1.0m plant height	1.3	2.4	4.3	3.2	1.1
D_2–Deheading at 1.5m plant height	1.2	2.0	4.1	2.7	1.0
D_3–Deheading at 2.0m plant height	1.0	1.8	4.0	2.3	0.8
Open – Crop only	0.9	1.7	3.4	2.2	0.7
SEm±	0.24	0.13	0.19	0.15	0.20
CD (P=0.05)	0.74 S	0.40 S	0.58 S	0.46 S	0.62 N
Mustard varieties	**Incidence / Population**				
V_1 – JM-3	1.00	2.30	4.50	3.00	0.95
V_2 – Urvashi	1.35	1.85	4.05	2.55	1.10
V_3- NRCDR-2	1.15	2.10	3.60	2.60	0.85
SEm±	0.09	0.13	0.11	0.25	0.15
CD(P=0.05)	0.30	0.44	0.37	0.87	0.51

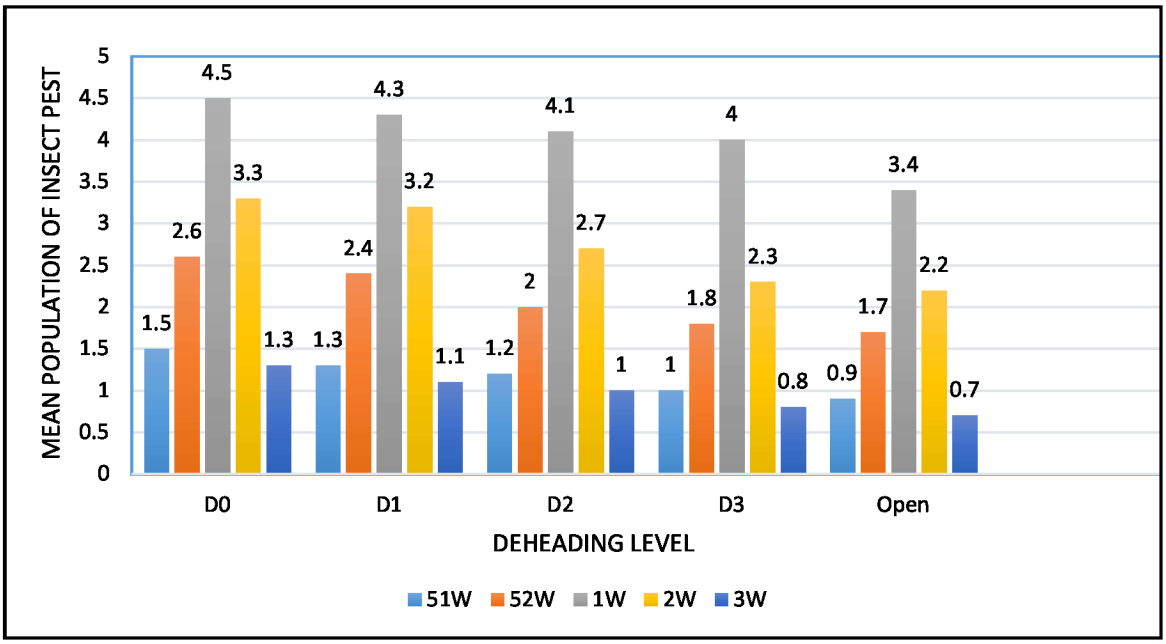


Figure.11 Population dynamics and prevalence of Dark small-branded swift (*Pelopidas mathias*).

4.4.2.3 Honey bee *Apis indica* (Hymenoptera : Apidae).

Population dynamics:-

Apis indica is a beneficial insect. It act as a vector for causing pollination in crops. It was observed during fourth week of January at flowering stage of mustard. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of D_3, D_2, D_1 and no deheaded tree.

Table 4.13. shows the result of population dynamics and prevalence of *A. indica* which started from fourth week of January that is shown in the form of standard meteorological week 4th the minimum and maximum temperature was 11.6^{0}C, 23.5^{0}C and the relative humidity was 85.3% in the morning and 55.7% in the evening. The average number of insects in open block was 2.7 and under the D_3, D_2, D_1 and no deheaded tree in all treatments. It was 2.9, 3.3, 3.6, and 3.8 respectively.

Maximum population was recorded on the 2nd week of February (6th meteorological week) the minimum and maximum temperature was 10.7^{0}C, 26.2^{0}C and the relative humidity was 77.5% in the morning and 47.71% in the evening where the insect population was 3.7, 4.1, 4.4, 4.5 and 4.6 in open condition, under the D_3, D_2, D_1 and no deheaded tree, respectively.

Minimum population of *A. indica* was recorded in first week of March (9th meteorological week) was observed 0.9, 1.1, 1.3, 1.6 and 1.9 in open condition and under D_3, D_2, D_1 and no deheaded tree respectively. After this week *Apis indica* was not found. The minimum and maximum temperature was 12.6^{0}C, 26.9^{0}C and the relative humidity was 76.0% in the morning and 42.6% in the evening.

Average mean population of *A. indica* in all treatments at different deheading level was 3.5, 3.3, 3.1, 2.8 and 2.5, in D_0, D_1, D_2, D_3 and Open condition, respectively.

Table – 4.13. Population dynamics and prevalence of Honey bee *Apis indica.*

Treatments	Standard Meteorological Weeks					
	4	5	6	7	8	9
Deheading level	**Incidence / Population**					
D_0–No Deheading	3.8	4.3	4.6	3.8	2.8	1.9
D_1–Deheading at 1.0m plant height	3.6	4.1	4.5	3.6	2.7	1.6
D_2–Deheading at 1.5m plant height	3.3	4.0	4.4	3.5	2.3	1.3
D_3–Deheading at 2.0m plant height	2.9	3.7	4.1	3.2	2.1	1.1
Open – Crop only	2.7	3.3	3.7	2.8	1.9	0.9
SEm±	0.25	0.22	0.29	0.21	0.22	0.16
CD (P=0.05)	0.77 S	0.67 N	0.88 N	0.65 N	0.68 N	0.50 S
Mustard varieties	**Incidence / Population**					
V_1 – JM-3	3.35	3.75	4.40	3.35	2.45	1.55
V_2 – Urvashi	3.25	3.95	4.20	3.40	2.40	1.40
V_3- NRCDR-2	3.10	3.90	4.15	3.35	2.25	1.15
SEm±	0.20	0.13	0.26	0.16	0.20	0.10
CD(P=0.05)	0.70	0.46	0.91	0.55	0.69	0.36

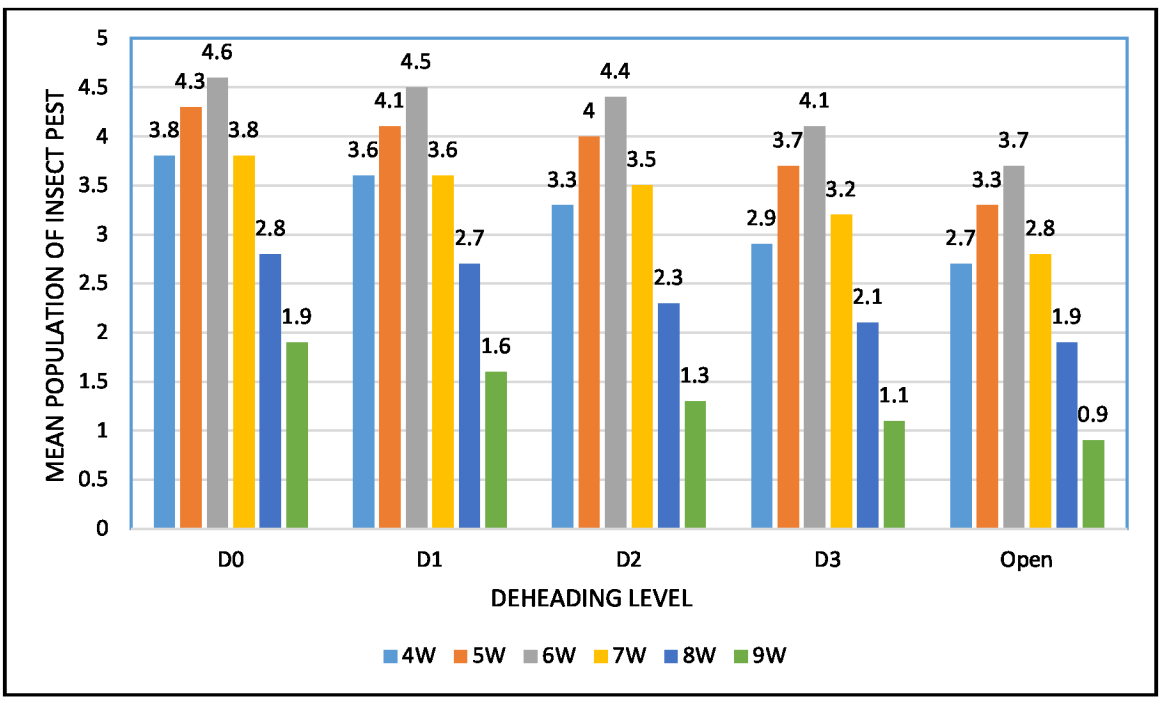


Figure.12 Population dynamics and prevalence of Honey bee (*Apis indica*).

4.4.2.4 Mustard aphid *Lipaphis erysimi* (Hemiptera : Aphididae).

Population dynamics:-

Mustard aphid *Lipaphis erysimi* first appear at flowering stage on the mustard crop. It was observed during second week of January. The number of insects varied from block to block due to shade of sissoo. The number of insects in open was less because of more sunlight as compare to the block of D_3, D_2, D_1 and no deheaded tree.

Table 4.14. shows the result of population dynamics and prevalence of *L. erysimi* which started from second week of January that is shown in the form of standard meteorological week 2nd the minimum and maximum temperature was 6.0^0C, 22.9^0C and the relative humidity was 84.5% in the morning and 42.8% in the evening. The average number of insects in open block was 3.2 and under the D_3, D_2, D_1 and no deheaded tree in all treatments. It was 4.2, 5.2, 5.3 and 6.1 respectively.

Maximum population was recorded on the 1st week of February (5th meteorological week) the minimum and maximum temperature was 11.6^0C and 23.5^0C and the relative humidity was 85.3% in the morning and 55.7% in the evening where the insect population was 10.6, 12.0, 14.3, 17.1, and 19.8 in open condition, under the D_3, D_2, D_1 and no deheaded tree respectively.

Minimum population of *L. erysimi.* was recorded in 4th week of February (8th meteorological week) was observed 2.0, 4.4, 4.5, 4.8 and 5.8 in open condition and under D_3, D_2, D_1 and no deheaded tree respectively. After this week *L. erysimi* was not found. The minimum and maximum temperature was 9.9^0C, 26.2^0C and the relative humidity was 69% in the morning and 36.42% in the evening.

Average mean population of *L. erysimi.* in all treatments at different deheading level was 13.1, 12.0, 10.7, 9.0, and 7.6 in D_0, D_1, D_2, D_3 and Open condition respectively.

Table – 4.14 Population dynamics and prevalence of mustard aphid *Lipaphis erysimi.*

Treatments	Standard Meteorological Weeks						
	2	3	4	5	6	7	8
Deheading level	**Incidence / Population**						
D_0–No Deheading	6.1	13.1	15.9	19.8	18.8	12.8	5.8
D_1–Deheading at 1.0m plant height	5.3	12.4	15.5	17.1	16.8	12.1	4.8
D_2–Deheading at 1.5m plant height	5.2	12.0	14.3	14.3	13.9	11.2	4.5
D_3–Deheading at 2.0m plant height	4.2	10.3	11.0	12.0	11.3	9.8	4.4
Open – Crop only	3.2	8.8	9.8	10.6	10.3	8.6	2.0
SEm±	0.24	0.56	0.31	0.63	0.80	0.70	0.38
CD (P=0.05)	0.74 S	1.72 S	0.96 S	1.95 S	2.45 S	2.16 S	1.18 S
Mustard varieties	**Incidence / Population**						
V_1 – JM-3	4.70	11.55	13.15	15.10	14.65	11.15	4.40
V_2 – Urvashi	4.15	11.30	13.55	13.75	13.40	10.35	4.20
V_3- NRCDR-2	5.45	11.10	13.20	15.40	14.55	11.10	4.30
SEm±	0.42	0.55	0.30	0.47	0.58	0.44	0.18
CD(P=0.05)	1.47	1.92	1.02	1.62	2.01	1.52	0.63

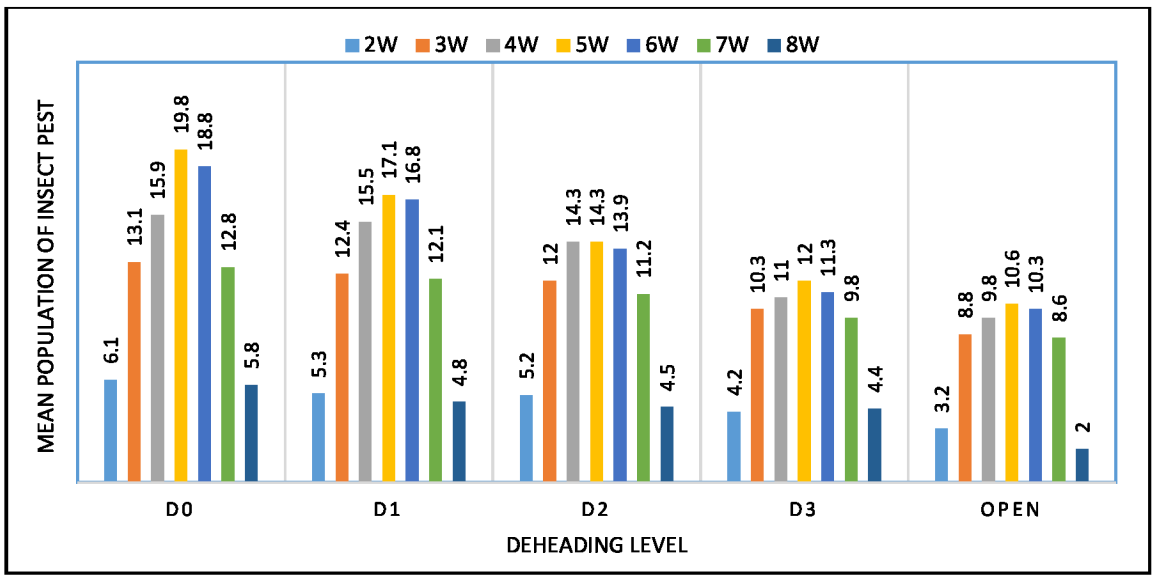


Figure.13 Population dynamics and prevalence of mustard aphid (*Lipaphis erysimi*)

4.5 Effect of tree component on pest population.

The number of insects varied from block to block due to shade of tree component. The number of insects in open was less because of more sunlight as compare to the block of 75%, 50%, 25% and no pruned tree in agrisilviculture system and compare to the block of D_3, D_2, D_1 and no deheaded tree in agrihorticulture system at different pruning intensities.

4.5.1. Overall mean population of insect-pest at different pruning intensities in agrisilviculture system.

Table – 4.15 Overall mean population of insect-pest on *Dalbergia sissoo* at different pruning intensities.

S.No.	Insect	Overall mean population of insect pest at different pruning intensities				
		0%	25%	50%	75%	Open
Dalbergia sissoo						
1.	*Cheilomenes sexmaculata*	6.1	5.3	4.6	3.9	2.2
2.	*Illeis cincta*	2.6	2.1	1.9	1.5	1.3

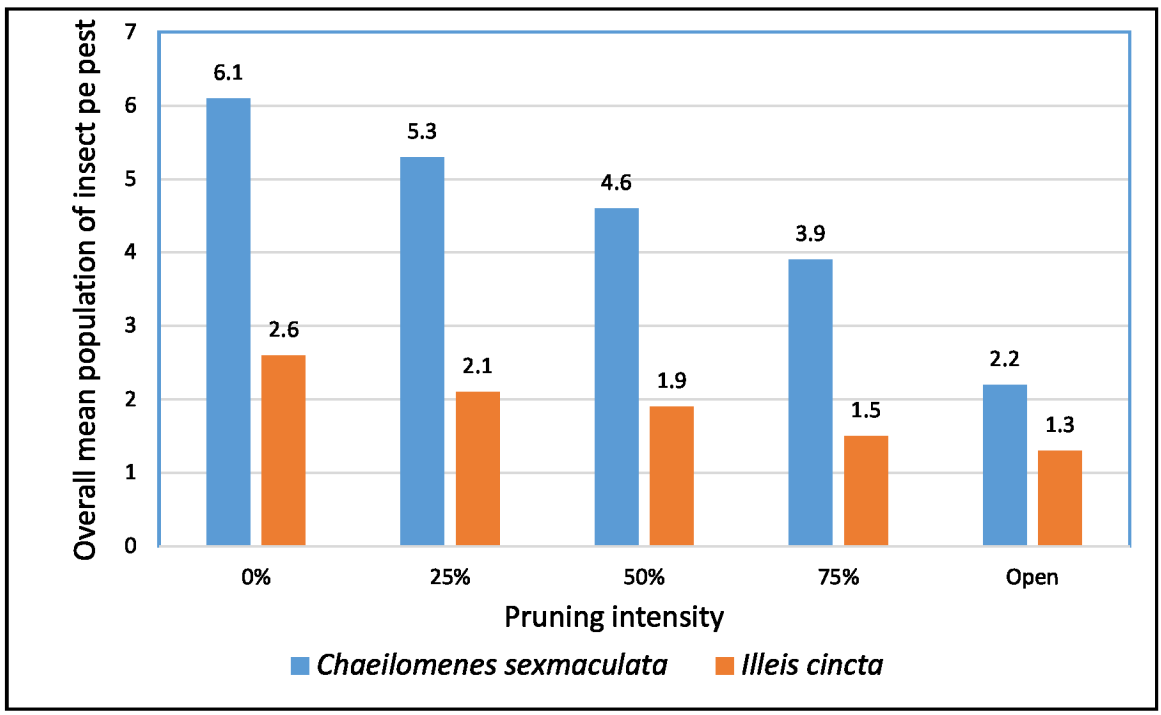


Figure.14 Overall mean population of *Cheilomenes sexmaculata and Illeis cincta* on *Dalbergia sissoo* at different pruning intensities.

Table – 4.16 Overall mean population of insect-pest on mustard at different pruning intensities.

S.No.	Insect	Overall mean population of insect pest at different pruning intensities				
		0%	25%	50%	75%	Open
Mustard						
1.	*Lipaphis erysimi.*	7.8	7.2	6.5	5.8	4.9
2.	*Apis indica*	6.0	4.8	4.4	3.9	3.7

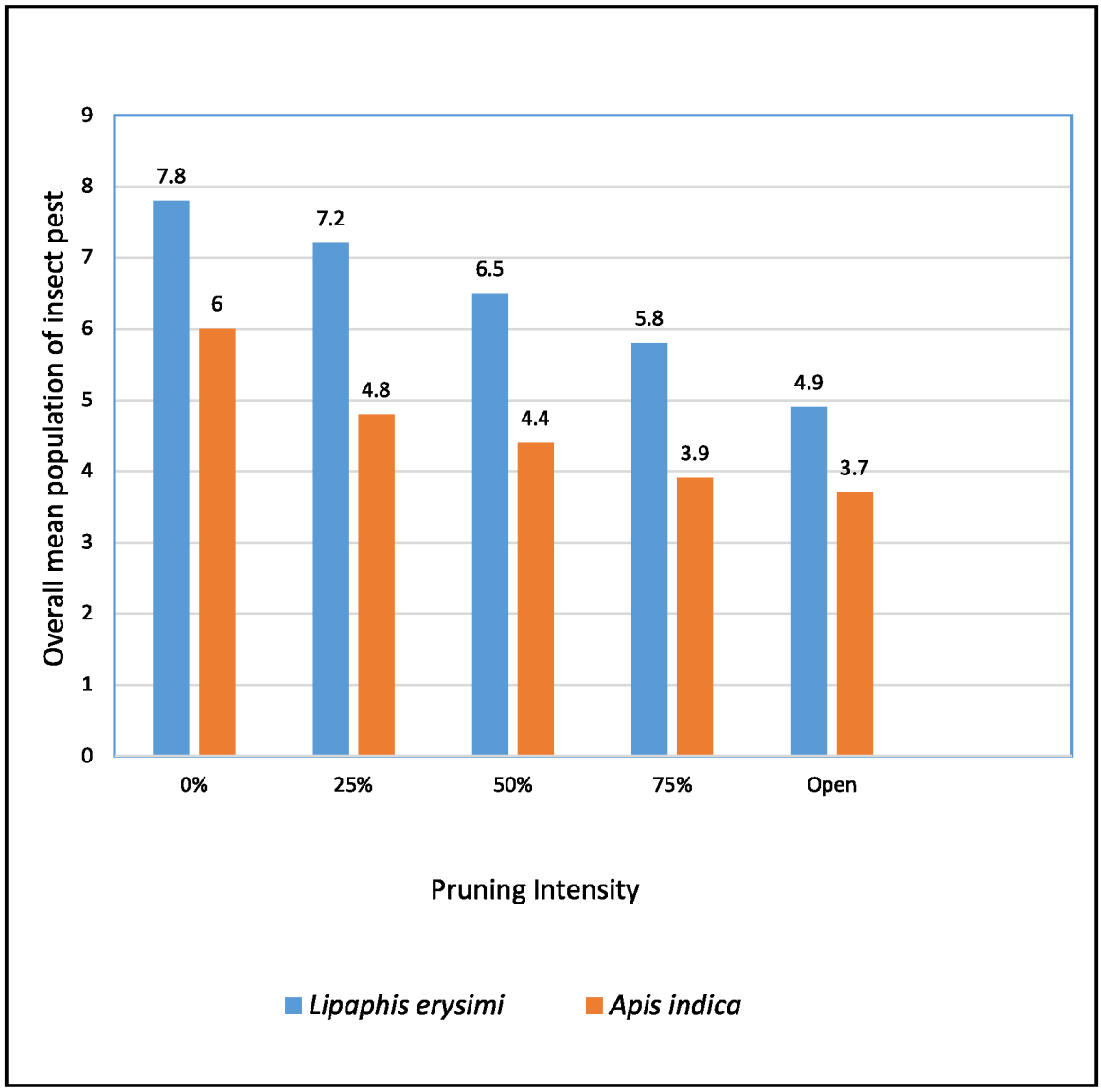


Figure.15 Overall mean population of *Lipaphis erysimi* and *Apis indica* on mustard at different pruning intensities.

4.5.2. Overall mean population of insect-pest at different deheading level in agrihorticulture system.

Table – 4.17 Overall mean population of insect-pest on guava at different deheading level.

S.No.	Insect	Overall mean population of insect pest at different deheading level				
		D_0	D_1	D_2	D_3	Open
Guava						
1.	Zelus bug	4.3	4.0	3.0	3.4	3.1
2.	Leaf-footed bug	3.6	3.9	2.9	2.6	2.3
3.	Stink bug	1.8	1.6	1.5	1.3	1.1
4.	Jewel bug	4.0	3.7	3.1	2.9	2.4

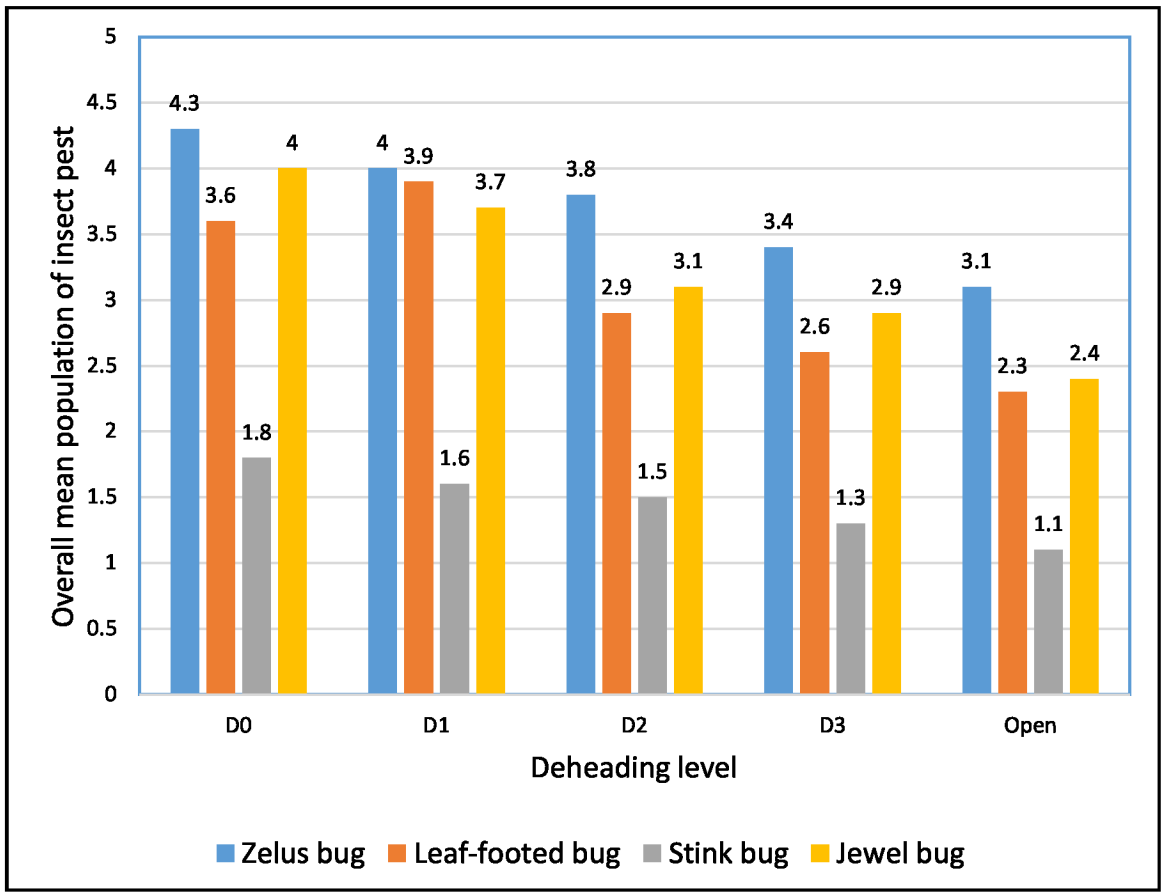


Figure.16 Overall mean population of Zelus bug, Leaf-footed bug, Stink bug and Jewel bug on guava at different deheading level.

Table – 4.18 Overall mean population of insect-pest on mustard at different deheading level.

S.No.	Insect	Overall mean population of insect pest at different deheading level				
		D_0	D_1	D_2	D_3	Open
Mustard						
1.	Common evening brown	3.7	3.5	3.2	2.8	2.5
2.	Dark small-branded swift	2.6	2.4	2.2	1.9	1.7
3.	Honey bee	3.5	3.3	3.1	2.8	2.5
4.	Mustard aphid	13.1	12.2	10.7	9.0	7.6

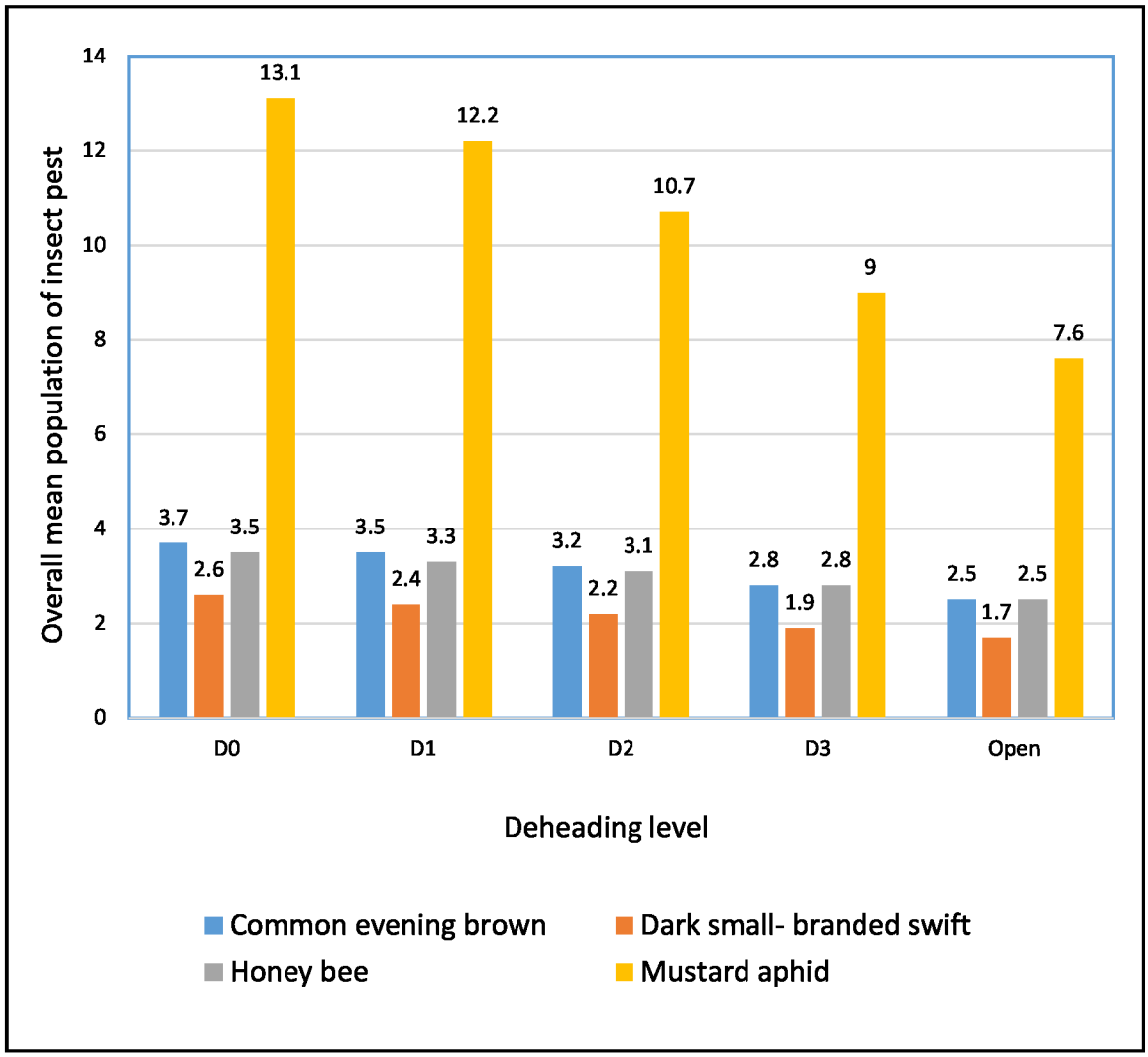


Figure.17 Overall mean population of Common evening brown, Dark small-branded swift, Honey bee and Mustard aphid on mustard at different deheading level.

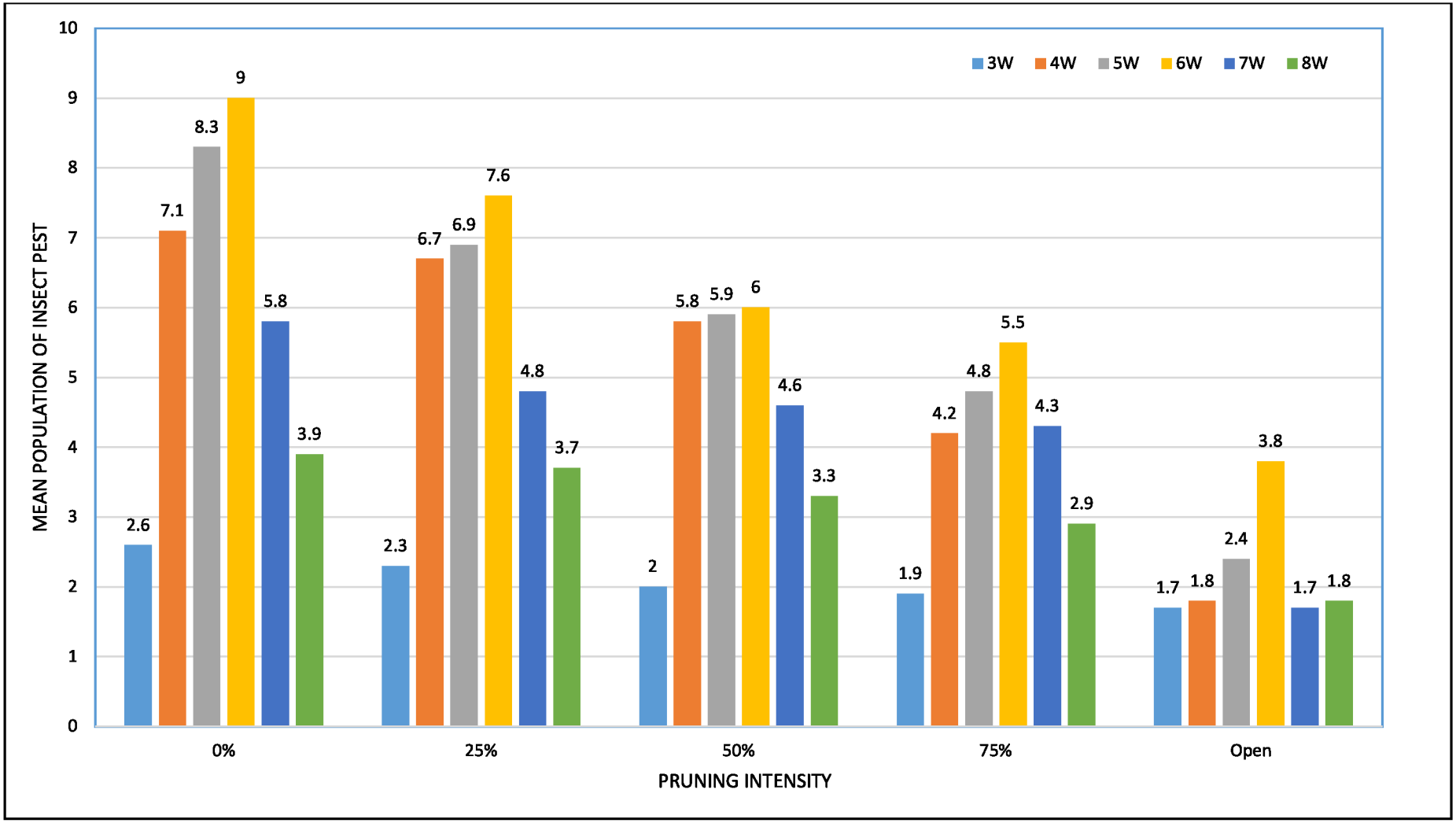


Figure.2 Population dynamics and prevalence of Six-spotted zigzag ladybird.

Plate 1. Over view of the experimental field (agrisilviculture system).

Plate 3. Handling & Collection of insect-pest under agrisilviculture system.

Collection from field crop

Collection from tree

Plate 5. Various insect-pest of *Dalbergia sissoo* and mustard under agrisilviculture system.

Six-spotted zigzag ladybird (*Cheilomenes sexmaculata)*

Larva *(Illeis cincta)*

Adult (*Illeis cincta)*

Mustard aphid (*Lipaphis erysimi)*

Honey bee (*Apis indica)*

Plate 2. Over view of the experimental field (agrihorticulture system).

Plate 4. Handling & Collection of insect-pest under agrihorticulture system.

Collection from field crop

Collection from tree

Plate 6. Various insect-pest of guava and mustard under agrihorticulture system

Zelus bug (*Zelus luridus*)

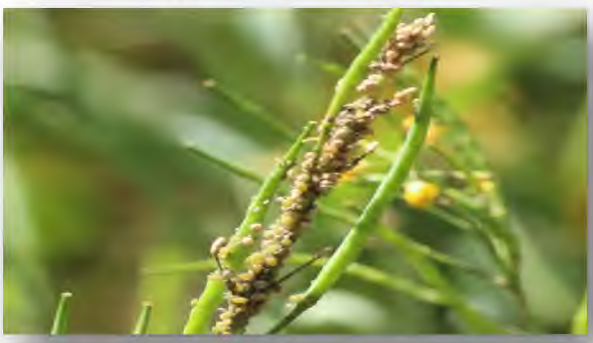
Leaf-footed bug
(*Aschistocoris brevicornis*)

Stink bug (*Erthesina fullo*)

Jewel Bug (*Chrysocoris purpureus*)

Common evening brown
(*Melanitis leda*)

Dark small-branded swift
(*Pelopidas mathias*)



Mustard aphid (*Lipaphis erysimi*)

Honey bee (*Apis indica*)

DISCUSSION

The study was conducted on the **"Assessment of insect-pest dynamics and their management in agroforestry systems of semi-arid tropics"** was carried out during the year 2018-19 in Rabi season at Forestry research farm, New Dusty Acre area, Department of Forestry, College of Agriculture, J.N.K.V.V, Jabalpur. discussion refers to the seasonal incidence, nature of damage and population dynamics of insect pest under agrisilviculture and agrihorticulture system.

Insect-pests are the most important group of organisms causing injury to plants in agroforestry systems. Therefore, the management of insect-pests in these systems is crucial to sustained production, and even farmers have recognized this as a priority issue for agroforestry research.

The insect-pests of an agroforestry system are essentially the pests of its components the crops and woody perennials. The dynamics of insect pests and their natural enemies are governed by the complexity and composition of the agroforestry system. The pest situation in these systems will be influenced by the degree of interaction between the components.

Research involving agricultural and horticultural cropping system, however, suggests that vegetation diversity frequently result in significant reduction of insect-pest problem. Trees also affect pest infestations by acting as barriers to movement of insects, masking the odours emitted by other components of the system and sheltering herbivores and natural enemies.

5.1 Population dynamics of insect-pest communities in agrisilviculture system during 2018-19.

On *Dalbergia sissoo*

- Six-spotted zigzag ladybird *Cheilomenes sexmaculata* (Coleoptera :Coccinellidae)
- *Illeis cincta* (Coleoptera :Coccinellidae).

On Mustard *Brassica juncea* (L.)

- Mustard aphid *Lipaphis erysimi* (Hemiptera : Aphididae).
- Honey bee *Apis indica* (Hymenoptera : Apidae).

5.2 Population dynamics of insect-pest communities in agrihorticulture system during 2018 –19.

On Guava

- Zelus bug *Zelus luridus* (Heteroptera : Reduviidae).
- Leaf-footed bug /Squash bug *Aschistocoris brevicornis* (Heteroptera : Coreidae).
- Stink bug *Erthesina fullo* (Heteroptera : Pentatomidae).
- Jewel bug *Chrysocoris purpureus* (Heteroptera : Scutelleridae).

On Mustard

- Common evening brown *Melanitis leda* (Lepidoptera : Satyridae).
- Dark small-branded swift *Pelopidas mathias,* (Lepidoptera : Hesperiidae).
- Honey bee *Apis indica* (Hymenoptera : Apidae).
- Mustard aphid *Lipaphis erysimi* (Hemiptera : Aphididae).

5.1.1 Seasonal Incidence and Population Dynamics of insect-pest under agrisilvicuture system.

Population dynamics and prevalence of Six-spotted zigzag ladybird on mustard aphid (*Lipaphis erysimi)* which started from 3rd week of January to last week of February. The minimum and maximum temperature was 8.4^{0}C, 28.8^{0}C and relative humidity was 75.8% in the morning and 31.4% in the evening. Similar results were also reported by Y.P. Singh et al. (2008). The biology and feeding potential of *Cheilomenes sexmaculala* was studied in the laboratory at 27±2°C and 70±5% relative humidity on mustard aphid. Kulkarni and Patel (2001) from Gujarat, who reported that aphid incidence occurred between the first week of January and the fourth week of February with high incidence during the first week of February. The population of ladybird beetle which appeared during the last week of January (0.67 beetles/plant) reached the peak level (2.90 beetles/plant) during the third week of February.

Illeis cincta which appeared from fourth week of January to last week of February. Maximum population was recorded on the 2nd week of February. Average population of *I. cincta* in all treatments and replications at different pruning intensities. It was identified as a mycophagous insect. It was found on

powdery mildew disease of *D. sissoo*. In this context similar work was conducted by Thite S.V (et al. 2013). *I. cincta* belongs to family – Coccilinidae and shows mycophagous behaviour on powdery mildew disease of *D. sissoo* and *X. strumarium*. It was observed that the micophagous insect was identified and confirmed as *I. cinacta*.

Lipaphis erysimi which started from second week of January. Maximum population was recorded on the first week of February. The minimum and maximum temperature was 26.20C and 9.90C and the relative humidity was 69% in the morning and 36.42% in the evening. Similar results were also carried out by Sarkar et al. (2008) revealed that aphid was active during mid of December to February and most abundant during 3rd and 4th week of January when the temperature ranged from 7.9 to 25.5 °C. Takar et al. (2005) observed the *L. erysimi* appeared on Mustard in the first week of January (16.3 aphids/plant) and reached its peak (764.2 aphids/plant) in second week of February.

5.2.1 Seasonal Incidence and Population Dynamics of insect-pest under agrihorticuture system.

Chrysocoris purpureus was observed as polyphagous bug with beautiful coloration (green blue with black spots). It attacked mainly the tender shoots, leaves and fruits of guava tree and observe on tender shoots of mustard. It was found as sucking type pest. Similar Incidence were recorded by Doman et al. (2018) The blue bug, *C. purpureus* attacked mainly the tender shoots and fruits of Jatropha. It was found sucking the sap from fruits, due to which the colour of fruits changed from green to yellow.

The population dynamics and prevalence of Zelus bug was find out from 3rd week of December to last week of January. *Zelus luridus* is a predator of other insects that occur on leaves of trees and shrubs. It has forelegs modified to help insect prey. For this, it uses sticky traps. However, they also use sticky substances to ensnare and hold insects. Similar observation conducted by Weirauch, C. (2006). The adult of this species, glandular units in the legs are the source for a sticky cover on the fore tibia, which also assists in prey capture. Thus, a functional replacement of extrinsic sticky substances derived from the mother's secretion on the egg mass of *Z. luridus*.

Leaf-footed bug appeared from 4th week of December to last week of January. This bugs inject their sharp, sucking mouthparts into the plant and suck the sap from the leaves and fruits. Maximum population was recorded on the 2nd week of January during this week the minimum and maximum temperature was 6.0^{0}C, 23.9^{0}C and the relative humidity was 84.5% in the morning and 42.8% in the evening. Average mean population of Leaf-footed bug in all treatments and replications at different deheading level was 3.6, 3.2, 2.9, 2.6, and 2.3, in D_0, D_1, D_2, D_3 and Open condition respectively.

The Stink Bug (*Erthesina fullo*) is a pest which observed on guava tree. it has dark brown and grey colour. It has an impact on timber trees and horticultural crops. It feed upon bark and trunk of the tree and sucks sap. Similar host incidence report was conducted by MPI (2014), there is limited information on the host range of *E. fullo*, but it is known to feed on various plants. Hosts include Citrus (Li et al., 1997), *Mangifera indica, Diospyros kaki, Cinnamomum camphora, Hibiscus rosa-sinensis, Eucalyptus, Psidium guajava, Averrhoa carambola, Zea mays, Punica granatum, Ziziphus jujube, Prunus armeniaca, Prunus persica, Prunus pseudocerasus, Prunus salicina, Pyrus bretschneideri, Pyrus calleryana, Salix, Ailanthus altissima* (Rider, 2015).

Population dynamics and prevalence of Common evening brown (*Melanitis leda)* which started from 4th week of December. Average mean population of Common evening brown in all treatments and replications at different deheading level was 3.7, 3.5 3.2, 2.8 and 2.5, in D_0, D_1, D_2, D_3 and open condition respectively. It wings are dark brown with a large sub-apical patch which is black with two white spots. It's have polyphagous nature. The caterpillars of *Melanitis leda* feed on leaves and young shoots of the host plant, and hide underside of crops. Adult butterflies of *Melanitis leda* are nectar feeders and occasionally pollen feeders. The similar finding was reported by Anita Singh and Amarjit Lal Sharma (2014). also reveals that *Myzus persicae, Bemisia tabaci; Pyrilla perpusilla* and *Melanitis leda* are common insect pest on Mustard, Wheat and Chick pea which persist throughout the year. This is due to their polyphagous nature and ability to migrate from one host to other.

Dark small-branded swift observed from 3rd week of December the minimum and maximum temperature was 8.4^{0}C, 22.3^{0}C and the relative humidity was 77.4% in the morning and 36.6% in the evening. It observed as

floral visitor insect and act as a pollinator on the flowering of the mustard crop. The larvae affect to the margin of leaves and backward rolling of the leaves are symptoms of damage. Average mean population of Dark small-branded swift in all treatments and replications at different deheading level was 2.6, 2.4, 2.2, 1.9 and 1.7, in D_0, D_1, D_2, D_3 and open condition respectively. Similar behaviour were recorded by Yuna Ikeuchi (2015). Report that the diurnal skipper *Pelopidas mathias* can act as a pollinator for the population of *Habenaria radiata* in Nara Prefecture, Japan.

Population dynamics and prevalence of *Apis indica* which started from fourth week of January. *A. indica* is a floral visitor beneficial insect. It plays a major role in honey production and crop pollination in flowering plants. Maximum population was recorded on the 2nd week of February minimum and maximum temperature was 10.7^{0}C, 26.2^{0}C and the relative humidity was 77.5% in the morning and 47.71% in the evening where the insect population was 3.7, 4.1, 4.4, 4.5 and 4.6 in open condition, under the D_3, D_2, D_1 and no deheaded tree respectively. Average mean population of *A. indica* in all treatments and replications at different deheading level was 3.5, 3.3, 3.1, 2.8 and 2.5, in D_0, D_1, D_2, D_3 and open condition respectively.

Population dynamics and prevalence of *Lipaphis erysimi* which started from second week of January and it was found upto last week of February. Apis indica is a floral visitor beneficial insect. It plays a major role in honey production and crop pollination in flowering plants. Maximum population was recorded on the 1st week of February the minimum and maximum temperature was 11.6^{0}C and 23.5^{0}C and the relative humidity was 85.3% in the morning and 55.7% in the evening. Minimum population of *L. erysimi* was recorded in 4th week of February. It was observed 2.0, 4.4, 4.5, 4.8 and 5.8 in open condition and under D_3, D_2, D_1 and no deheaded tree, respectively. After this week *L. erysimi* was not found. The minimum and maximum temperature was 9.9^{0}C, 26.2^{0}C and the relative humidity was 69% in the morning and 36.42% in the evening. Similar incidence period reported by Kulkarni and Patel (2001) from Gujarat conducted experiments during winter 1998-99 and they reported that aphid incidence occurred between the first week of January and the fourth week of February with high incidence during the first week of February.

SUMMARY, CONCLUTSION AND SUGGESTION FOR FURTHER WORK

Present investigations on **"Assessment of insect-pest dynamics and their management in agroforestry systems of semi-arid tropics"** was carried out during the year 2018-19 in Rabi season at Forestry research farm, New Dusty Acre area, Department of Forestry, College of Agriculture, J.N.K.V.V, Jabalpur. The results obtained in the present study are presented in this chapter under following heads.

1. Dynamics of insect-pest communities in agrisilviculture and agrihorticulture system.
2. Insect-pest prevalence and its effect in intercropping system.
3. Effect of tree component on pest population.

6.1 Summary

The present study revealed total twelve insects of five order under agrisilviculture and agrihorticulture system which are two insects of Coleoptera eg. Six-spotted zigzag ladybird (*Cheilomenes sexmaculata)*, and *Illeis cincta* on *Dalbergia sissoo,* one insect of Hemiptera eg. mustard aphid (*Lipaphis erysimi*), and one insect of Hymenoptera eg. Honey bee (*Apis indica)* on mustard under agrisilviculture system.

Four insect was observed of Heteroptera eg. Zelus bug (*Zelus luridus)* Leaf-footed bug /Squash Bugs (*Aschistocoris brevicornis*), stink bug (*Erthesina fullo),* and Jewel Bug (*Chrysocoris purpureus)* on guava, two insect of Lepidoptera eg. Common evening brown (*Melanitis leda),* Dark small-branded swift (*Pelopidas mathias),* one insect of Hemiptera eg. mustard aphid (*Lipaphis erysimi*), and one insect of Hymenoptera eg. Honey bee (*Apis indica)* on mustard under agrohorticulture system.

6.2 Conclusion

Based on the results the following conclusions are drawn from the present investigation.

1. Various species of insect pests observed on *Dalbergia sissoo* and mustard were Six-spotted zigzag ladybird (*Cheilomenes sexmaculata)*, *Illeis cincta* and mustard aphid (*Lipaphis erysimi*), Honey bee (*Apis indica)* under agrisilviculture system respectively.

2. In agrohorticulture system Zelus bug (*Zelus luridus)* Leaf-footed bug /Squash Bugs (*Aschistocoris brevicornis*), stink bug (*Erthesina fullo),* Jewel Bug (*Chrysocoris purpureus)* and Common evening brown (*Melanitis leda),* Dark small-branded swift (*Pelopidas mathias),* Honey bee (*Apis indica),* mustard aphid (*Lipaphis erysimi*) were observed on guava and mustard respectively.

3. The number of insects varied from block to block due to shade of tree component. The number of insects in open was less because of more sunlight as compare to the block of 75%, 50%, 25% and no pruned tree and the block of D_3, D_2, D_1 and no deheaded tree in agrisilviculture and agrihorticulture system respectively.

4. Maximum mean population of insect-pest was found under no pruned tree in agrisilviculture system and no deheaded tree in agrihorticulture system.

6.3 Suggestion for further work

During the course of investigation, some important question came through, which needs further research and detailed investigation need to be done. Some importance suggestions are:

- Present investigation also gives the knowledge about different shade effect on insect-pest population. The result shows the maximum population in higher shed and less population in open condition.
- A detail study should be carried out on control measures of the insect-pest of agrisilviculture and agrihorticulture system.
- Studies on predators, parasites and parasitoids should be done more intensively.
- The trial may be repeated on farmer's fields on large scale to confirm the results.
- This work should be further continued so as to study the impact of shade on yield loss, infestation and damage per cent due to insect-pest.

Bibliography

Agriculture at a Glance. 2015. Indian agriculture database, Published in India by Oxford University Press. New Delhi. 109 p.

Ahuja D. B. 1990. Population dynamics of mustard aphid, *Lipaphis erysimi* (Kalt.) on Indian mustard, *Brassica juncea* (Sub. Sp. *juncea*). J. Pit. Protection. 18 (2): pp 233-235.

Ali M.S. Azam F. and chaturvedi O.P. 2006. Population Fluctuation of Shisham Tree Hopper, *Gargara mixtra*. Indian journal of Agroforestry. Vol. 8 No. 1; 74-76.

Ali M.S. Azam F. and chaturvedi O.P. 2007. Studies on Seasonal Occurrence, Incidence and Population Fluctuation of Shisham Leaf Blinder, *Dichomeries eridantis* Mey. Indian journal of Agroforestry Vol.9 No. 2; pp 121-124.

Anita Singh and Amarjit Lal Sharma 2014. Agriculturally Important Insects Diversity in Kharif and Rabi crops of Talwandi sabo, Punjab. International Journal of Scientific and Research Publications, Volume 4, Issue 8, August 2014 1 ISSN 2250-3153.

Anonymous, 2013. Rapeseed mustard production technology for different agro-ecological systems in India. Directorate of Rapeseed mustard Research, Bharatpur, 321 303, India, p. 54.

Anonymous, 2015. Area, production and productivity of mustard. associated bioagents in Indian mustard (*Brassica juncea*) crop. Indian J. agric.

Bakhetia, D. R. C. and Brar K. S. 1982. Pest control in rapeseed and mustard. Indian fmg. 11: 60-63.

Beeson, C.F.C. 1941. The ecology and control of the forest insects of Indian and the neighbouring countries, Vasant press, Dehra Dun, 1007pp.

Bharat Lal, Nayak MK, Srivastava AK and Tomar DS. 2018. Seasonal incidence of major insect pests of mustard and their natural enemies. International Journal of Chemical Studies, 6(3): 3658-3661.

Bharat Lal, Nayak MK, Tomar DS and Thakur SR, 2018. Efficacy of newer insecticides against mustard aphid, *Lipaphis erysimi* (Kalt.) in Indian mustard under Bundelkhand Agro climatic zone of Madhya Pradesh Journal of Entomology and Zoology Studies 6(6): 400-403.

Bhatt, P. D. and Bapodra, J. G. 2004. Population dynamics of mustard sawfly, *Athalia lugens proxima* (Klug) on mustard in relation to weather parameters. Indian J. Ent., 66(3): 284-285.

Black, C.A. 1965. Method of plant and soil analysis part 11. Publ. Amencan soc1ety Agronomy, Madison Wiscorsin USA pp. 13671373.

Browne, F.G. 1968. Pest and disease of forest plantation trees. An annotated list of the principal special occurring in the British common wealth. *Clasrandon press,* Oxford, 1330pp.

Chapman, H.D. and Pratt. P.P. 1961. Soil water and plant analysis. University California Agriculture Dir. Publication.

Cochran WC and Cox GM 1950. Experimental design John willy and sons, New York, U.S.A., pp. 298-300.

Devi and S. Jha. (2017) Incidence and Screening of guava (*Psidium guajava* L.) Varieties against Fruit Borer (*Deudorix isocrates* F.) in Eastern Gangetic Plains of West Bengal. India International Journal of Current Microbiology and Applied Sciences. Volume 6 Number 10. pp 1689-1698.

Dhakal, L.P. and Kjaer, E.D. 2005. Mortality in *Dalbergia sissoo* (Roxb.) Heavy Infection by *Aristobia horridula Bettles*: Will Genetic Variation in Susceptibility Play a Role in Combating Declining Health. Forest Ecology and Management. Vol. 218.

Dhyani, S.K., Handa, A.K. and Uma. 2013. Area under Agroforestry in India: An Assessment for Present Status and Future Perspective. Indian J. Agroforrstry., 15(1).

Dogra Indira; Nirmala Devi and Desh Raj 2003. J. Ent. Res. 27(2): 145- 149. Indian fmg. 11:6063.

Doman Singh Tekam, Birendra Tigga and Yogesh Kumar Upadhyay 2018. Study on morphometric parameters of the blue bug, *Chrysocoris purpureus* International Journal of Fauna and Biological Studies 5(1): 37-38.

FAO. 2000. Forest resources assessment report.

Firake D. M., Behere G. T., Deshmukh N. A., Firake P. D., Azad Thakur N. S. 2013. Recent Scenario of Insect-pests of guava in North East India and Their Eco-friendly Management Indian Journal of Hill Farming 26(1):55-57.

Haseeb M. 2007 current status of insect-pest problems in guava ISHS Acta Horticulturae 735: ISHI International Guava Symposium.

Haseeb M. and Sharma S.,2007. studies on incidence and crop losses by fruit borer *Deudorix isocrates* (lep: lycaenidae) on guava ishs acta horticulturae 735: international guava symposium.

Joshi RB and Baral SR. 2000. A report on die-back of *Dalbergia sissoo* in Nepal. Field Document - FORSPA 2000 No. 18 pp.

Kalia S and Lal RR. 1999. Insect-pests of *Dalbergia sissoo* Roxb. at and around Jabalpur. Advances in Forestry Research in India. 20, 190-202.

Khedkar, A. A. 2011. Population dynamics and impact of nitrogenous fertilizer on major insect-pests and management of aphid, *L. erysimi* in mustard. M. Sc. (Agri.) thesis submitted to Anand Agricultural University, AAU, Anand.

King, K.F.S. and Chandlar, M.T. 1978. The wasteland. ICRAF. Nairobi, 85 pp

Kulkarni, A.V. and Patel, I.S. 2001. Seasonal abundance of mustard aphid and associated bioagents in Indian mustard (*Brassica juncea*) crop. Indian J. agric. Sci., 71(10): 681-682.

Kumar A. 2017. The study of insect-pests of *Dalbergia sissoo* Roxb. and Their Seasonal Incidence in Jharkhand, India. American Journal of Agriculture and Forestry. Vol. 5, pp. 137-144.

Kumar A. 2017. The study of insect-pests of *Dalbergia sissoo Roxb*. and their seasonal incidence in Jharkhand, India. American Journal of Agriculture and Forestry. Vol. 5, No. 5, 2017, pp. 137-144.

Kumar A., Premi O.P. and Thomas L. 2008 Rapeseed-mustard cultivation in India- An Overview National Research Centre on Rapeseed-mustard, Bharatpur – 321 303.

Lalji Prasad; Ansari, I.A.; Subhash Chandra 1999. Outbreak of shisham (*Dalbergia sissoo*) defoliator, *Plecoptera reflexa* (Guen.) (Lepidoptera: Noctuidae) in Doon Valley, India Annals of Forestry 7(2): 297-298.

Li L, Wang R, Waterhouse DF. 1997. The Distribution and Importance of Arthropod Pests and Weeds of Agriculture and Forestry Plantations in Southern China. ACIAR, Canberra, Australia.

Lundgren, B.O. 1982. Cited in Editorial: What is Agroforestry? Agroforestry Systems 1: 7-12.

Mahmood, N.M. 1994. Horticultural Fruit Crops. National Book Foundation, Islamabad, Pakistan. 633p.

Mathur RN, Singh B.1959. A list of insect-pests of forest plantations in India and the adjacent countries. Indian For. Bull (N.S.): Entomology, 171 (6).

Meenakshi Devi, Naveen Singh, GS Yadav, Jeet Ram Sharma and Jayant Yadav 2018 Screening of guava cultivars against different insect-pests in agroclimatic condition of Haryana. Journal of Entomology and Zoology Studies. 6(2): 857-859.

Mohsen, A.M.A. 2018. Survey of insect-pests infested guava orchards and infestation of main and offseasons guava crops a year round by fruit fly *Ceratitis capitat* (wiedemann). Middle East Journal of Applied Sciences Volume: 08 Pages: 1264-1272.

MPI. 2014. Yellow spotted stink bug - *Erthesina fullo*. Data sheet. Ministry for primary industries, New Zealand.

Muhammad Sarwar 2006. Occurrence of insect-pests on guava (*s*) Tree. Pakistan J. Zool., vol. 38(3), pp. 197-200.

Nair K.S.S., Mathew G. Mohanadas K., and Menon A.R.R. 1986 study of insect-pest incidence in natural forests KFRI Research Report 44 Pages: 23.

Nair, P.K.R. and Garrity, D. 2012. Agroforestry-The future of global land use. Adv. Agrofor., 9: 531.

National Horticulture Mission (NHM), (2012) Annual Report. pp. 74.

National Horticulture Mission (NHM), (2012). IPM Schedule for guava pests. Ministry of Agriculture Department of Agriculture & Cooperation Krishi Bhawan, New Delhi. New York, U.S.A., pp. 298-300.

Olsen, S.P. Cole, C.V., Watanable, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soil by extraction with sodium bi-carbonate. Publ., U.S. Deptt. Agric. circular, 939: 1-19.

Pawan, K. 2012. Scenario of insect-pests and diseases of paddy in Himachal Pradesh. Agricultural Science Digest. Vol. 32; No 1; 71-74.

Pawar KR, Giri AN, Kattar KD and Nadrc KR.1976. Effect of sowing dates on yield of promising varieties of cotton under irrigated conditions in Marathwada region. Journal of Maharashtra Agricultural Universities, 1(I): 75- 77.

Piper, C.S. 1967. Soil and plant analysis. Publ., Asia Publication House, Bombay, pp. 157-176.

Prasad, L., Pandey R., Ansari L. A. and Chandra S. 2002. Population dynamics of *Dalbergia sissoo* defoliators, *Plecoptera reflexa* and *Dichomeris eridantis*. Indian Forester, 128(7): 800-813.

Prinsley RT. 1991. Australian agroforestry: setting the scene for future research. Canberra: RIRDC, insect-pest in agroforestry ICRAF, page no. 2.

Qureshi N. A., Qureshi M. Z., Ali N, Athar M, and Ullah A. 2012. Protozoidal activities of *Eucalyptus cammeldulensis, Dalbergia sissoo* and *Acacia arabica* woods and their different parts on the entozoic flagellates of *Heterotermes indicola* and *Coptotermes heimi*. African Journal of Biotechnology Vol. 11(57), pp. 12094-12102

Rahman M. S., Wadud M. A.,Hasan M. K., Chakma A. and Ahmad M. 2008. Prevalence of insect-pests and their effects on growth and yield of mungbean grown under multipurpose trees, J. Agrofor. Environ. 2(1): 69-72.

Rahman MS, Wadud MA, Hasan MK, Chakma A and Ahmad M. 2008. Prevalence of insect-pests and their effects on growth and yield of mungbean grown under multipurpose trees. *J. Agrofor.* Environ. 2(1): 69-72.

Rao M. R., Singh. M. P. and Day R. 2000. Insect-pest problems in tropical agroforestry systems: Contributory factors and strategies for management Agroforestry Systems, Volume 50, Issue 3, pp 243–277.

Rathore MP. Singh 1995. Insect-pests in Agroforestry. ICRAF Nairobi, Kenya Working Paper No. 70.

Rider DA. 2015. Plant Host Records. Pentatomidae: Pentatominae. North Dakota State University.

Sah SB., Ali MS. 2005. Population dynamics of *Oxyrachis tarandus Fab.* on sapling of *Dalbergia sissoo.* Journal of Applied Biology. 15 (2), 47-50.

Sahu CM, Ganguli JL, Kerketta A and Penkra KL. 2016. Screening of mixed species plantation. against various insect-pests under agro-silvi pattern of cropping system at Raipur. International Journal of Plant Protection 9(2):570-577.

Sarkar A, Konar A, Hazra S and Choudhuri S. 2008. Incidence and chemical control of mustard aphid, *Lipaphis erysimi* (Kalt.) on mustard in new alluvial zone of West Bengal. J. Ent. Res., 32(1): 41-43

Sarwar M. 2006. Occurrence of insect-pests on guava (*Psidium guajava*) Tree. Pakistan J. Zool., vol. 38(3), pp. 197-200. Sci., 71(10): 681-682.

Shekhawat K, Rathore SS, Premi OP, Kandpa BK, and Chauhan JS. 2012. Advances in Agronomic Management of Indian mustard (*Brassica juncea* (L.) *Czernj.Cosson*): An Overview, Hindawi Publishing Corporation International Journal of Agronomy Volume 2012, Article ID 408284, 14 pages.

Shrivastava , A., Harvir Singh and Thakur H.I. 1995. Impact of abiotic factors on the population dynamics of mustard aphid, *Lipaphis erysimi.* J. Oilseeds .Res. 12(2):197-202.

Sing S. 1986. Management of diseases in agro forestry nurseries national agro forestry workshop, Karanak, Haryana.

Singh AP, Bhandari RS and Verma TD. 2004 Important insect-pests of poplars in agroforestry and strategies for their management in north western India. Agroforestry Systems 63: 15–26.

Singh Y.P., Meghwal H.P. and Singh S.P. 2008. Biology and Feeding Potential of *Cheilomenes sexmaculata* Fabricius (Coleoptera: Coccinellidae) on mustard aphid. National Research Centre on Rapeseed-Mustard. Annals of Arid Zone 47(2): 185-190.

Singh, C.; Lal, M. N. and Singh, P. S. 2012. Occurrence of insect-pests on rapeseed, *Brassica rapa* (var. YST-151) and its association with weather variables in eastern Uttar Pradesh. Indian J. Ent., 74(2): 183-185.

Singh, O. P. and R. R. Rawat 1983. Seasonal incidence and toxological studies on *L. erysimi* and its parasite *Aphidius sp*. In Madhya Pradesh, India, Pranikee 4 :259-267. (RAE, 73(2):860).

Sinha, R. P., Yazani S. S and Verma G. D. 1990. Population dynamics of mustard aphid, *Lipaphis erysimi* (kalt) in relation to ecological parameters. Indian J. Ent. 52(3):387-392.

Subbiah, B.V. and Asija, C.L. (1956). A rapid method for the estimator of available nitrogen in soil. Current Science, 25: 259-260.

Takar BL, Jat KL, Kanwat PM and Sharma JK. 2005. Efficacy of some insecticides against *Lipaphis erysimi* (Kalt.) on mustard, Agri. Sci. Digest, 25(3): 14-18.

Thite S.V., Chavan Y.R., Aparadh V.T. and Kore B.A. 2013. Incidence of *Illeis cincta* (Fabricius) on Powdery Mildew of *Dalbergia sissoo* and *Xanthium strumarium* International Journal of Advanced Research, Volume 1, Issue 5, 20-23.

Umesh, Dr. Rajesh Kumar and Gaurav Kant 2018. To study seasonal incidence of guava fruit fly, *Bactrocera spp*. and its impact on yield international journal of chemical studies; 6(6): 1018-1020.

Utami S, Triwidodo H, Pudjianto, Rauf A, Haneda NF. 2018. Population dynamics of *Arthroschista hilaralis* pest and its parasitoid diversity in various jabon (*Anthocephalus cadamba*) cropping patterns in South Sumatra, Indonesia. Biodiversitas 19(1) 239-245.

Weirauch, C. 2006. Observations on the sticky trap predator *Zelus luridus* Stål (Heteroptera, Reduviidae, Harpactorinae), with the description of a novel gland associated with the female genitalia. *Denisia* 19, zugleich Kataloge . Landesmuseen Neue Serie 50:1169–1180

Yuna Ikeuchi, 2 Kenji Suetsugu, 3 and Huyuhiko Sumikawa 2015. Diurnal skipper *pelopidas mathias* (lepidoptera: hesperiidae) pollinates *habenaria radiata* (orchidaceae) 1 Article in Entomological News Volume 125. PP 7-9.

Zomer, R.J., Bossio, D.A., Trabucco, A., Yuanjie, L., Gupta, D.C., and Singh, V.P. 2007. "Trees and Water: Smallholder Agroforestry on Irrigated Lands in Northern India." International Water Management Institute, Colombo, Sri Lanka (Series: IWMI Research Reports, no. 122).

Appendix

Appendix – I Population dynamics of insect-pest communities in agrisilviculture system during 2018-19.

S. No	Common Name	Scientific Name	Order	Family
Dalbergia sissoo				
1.	Six-spotted zigzag ladybird	*Cheilomenes sexmaculata*	Coleoptera	Coccinellidae
2.	Illeis cincta	*Illeis cincta*	Coleoptera	Coccinellidae
Mustard				
1.	Mustard aphid	*Lipaphis erysimi*	Hemiptera	Aphididae
2.	Honey bee	*Apis indica*	Hymenoptera	Apidae

Appendix – II Population dynamics of insect-pest communities in agrihorticulture system during 2018 – 19.

S. No	Common Name	Scientific Name	Order	Family
Guava				
1.	Zelus bug	*Zelus luridus*	Heteroptera	*Reduviidae*
2.	Leaf-footed bug /Squash bug	*Aschistocoris brevicornis*	Heteroptera	Coreidae
3.	Stink bug	*Erthesina fullo*	Heteroptera	Pentatomidae
4.	Jewel bug	*Chrysocoris purpureus*	Heteroptera	Scutelleridae
Mustard				
1.	Common evening brown	*Melanitis leda*	Lepidoptera	satyridae
2.	Dark small-branded swift	*Pelopidas mathias,*	Lepidoptera	Hesperiidae
3.	Honey bee	*Apis indica*	Hymenoptera	Apidae
4.	Mustard aphid	*Lipaphis erysimi*	Hemiptera	Aphididae

Appendix – III Overall mean population of insect-pest at different pruning intensities in agrisilviculture system.

Appendix – III(a)

S.No.	Insect	Overall mean population of insect-pest at different pruning intensities				
		0%	25%	50%	75%	Open
Dalbergia sissoo						
1.	*Cheilomenes sexmaculata*	6.1	5.3	4.6	3.9	2.2
2.	*Illeis cincta*	2.6	2.1	1.9	1.5	1.3

Appendix – III(b)

S.No.	Insect	Overall mean population of insect-pest at different pruning intensities				
		0%	25%	50%	75%	Open
Mustard						
1.	*Lipaphis erysimi.*	7.8	7.2	6.5	5.8	4.9
2.	*Apis indica*	6.0	4.8	4.4	3.9	3.7

Appendix – IV Overall mean population of insect-pest at different deheading level in agrihorticulture system.

Appendix – IV(a)

S.No.	Insect	Overall mean population of insect-pest at different deheading leve				
		D_0	D_1	D_2	D_3	Open
Guava						
1.	Zelus bug	4.3	4.0	3.0	3.4	3.1
2.	Leaf-footed bug	3.6	3.9	2.9	2.6	2.3
3.	Stink bug	1.8	1.6	1.5	1.3	1.1
4.	Jewel Bugs	4.0	3.7	3.1	2.9	2.4

Appendix – IV(b)

S.No.	Insect	Overall mean population of insect-pest at different deheading leve				
		D_0	D_1	D_2	D_3	Open
Mustard						
1.	Common evening brown	3.7	3.5	3.2	2.8	2.5
2.	Dark small-branded swift	2.6	2.4	2.2	1.9	1.7
3.	Honey bee	3.5	3.3	3.1	2.8	2.5
4.	Mustard aphid	13.1	12.2	10.7	9.0	7.6

Appendix – V ANOVA for maximum population of Six-spotted zigzag ladybird under agrisilviculture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	5.1	1.7	1.4	3.5	5.0
MT	4.0	193.8	48.4	40.5	3.3	5.4
Error A.	12.0	14.4	1.2			
ST	2.0	2.1	1.1	0.9	5.1	10.9
Error B.	6.0	7.1	1.2			
Interaction	8.0	4.5	0.6	0.1	2.4	3.4
Error C	24.0	128.9	5.4			
Total	59.0	355.9				

Appendix – VI ANOVA for maximum population of *Illeis cincta*. under agrisilviculture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	0.4	0.1	0.3	3.5	5.0
MT	4.0	11.8	2.9	5.3	3.3	5.4
Error A.	12.0	6.6	0.6			
ST	2.0	0.9	0.5	1.0	5.1	10.9
Error B.	6.0	2.8	0.5			
Interaction	8.0	2.7	0.3	0.3	2.4	3.4
Error C	24.0	31.9	1.3			
Total	59.0	57.2				

Appendix – VII ANOVA for maximum population of mustard aphid *Lipaphis erysimi* under agrisilviculture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	9.4	3.1	0.7	3.5	5.0
MT	4.0	230.4	57.6	13.2	3.3	5.4
Error A.	12.0	52.4	4.4			
ST	2.0	11.1	5.6	1.3	5.1	10.9
Error B.	6.0	26.4	4.4			
Interaction	8.0	11.1	1.4	0.1	2.4	3.4
Error C	24.0	410.1	17.1			
Total	59.0	750.9				

Appendix – VIII ANOVA for maximum population of *Apis indica* under agrisilviculture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	3.3	1.1	1.9	3.5	5.0
MT	4.0	43.2	10.8	18.1	3.3	5.4
Error A.	12.0	7.2	0.6			
ST	2.0	1.0	0.5	1.2	5.1	10.9
Error B.	6.0	2.6	0.4			
Interaction	8.0	4.0	0.5	0.1	2.4	3.4
Error C	24.0	106.4	4.4			
Total	59.0	167.7				

Appendix – IX ANOVA for maximum population of Zelus bug under agrihorticulture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	5.0	1.7	2.0	3.5	5.0
MT	4.0	15.8	4.0	4.9	3.3	5.4
Error A.	12.0	9.8	0.8			
ST	2.0	4.4	2.2	1.6	5.1	10.9
Error B.	6.0	8.4	1.4			
Interaction	8.0	8.1	1.0	0.2	2.4	3.4
Error C	24.0	135.1	5.6			
Total	59.0	186.6				

Appendix – X ANOVA for maximum population of Leaf-footed bug under agrihorticulture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	4.9	1.6	2.9	3.5	5.0
MT	4.0	26.3	6.6	11.6	3.3	5.4
Error A.	12.0	6.8	0.6			
ST	2.0	2.0	1.0	2.3	5.1	10.9
Error B.	6.0	2.6	0.4			
Interaction	8.0	4.1	0.5	0.1	2.4	3.4
Error C	24.0	103.2	4.3			
Total	59.0	149.9				

Appendix – XI ANOVA for maximum population of Stink bug under agrihorticulture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	1.8	0.6	1.7	3.5	5.0
MT	4.0	4.6	1.2	3.3	3.3	5.4
Error A.	12.0	4.2	0.4			
ST	2.0	0.2	0.1	0.5	5.1	10.9
Error B.	6.0	1.5	0.3			
Interaction	8.0	0.6	0.1	0.1	2.4	3.4
Error C	24.0	15.0	0.6			
Total	59.0	27.9				

Appendix – XII ANOVA for maximum population of Jewel bug under agrihorticulture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	1.1	0.4	0.6	3.5	5.0
MT	4.0	28.3	7.1	10.8	3.3	5.4
Error A.	12.0	7.9	0.7			
ST	2.0	2.2	1.1	0.8	5.1	10.9
Error B.	6.0	8.6	1.4			
Interaction	8.0	3.9	0.5	0.2	2.4	3.4
Error C	24.0	73.9	3.1			
Total	59.0	125.9				

Appendix – XI ANOVA for maximum population of Common evening brown under agrihorticulture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	3.5	1.2	1.9	3.5	5.0
MT	4.0	20.2	5.1	8.0	3.3	5.4
Error A.	12.0	7.6	0.6			
ST	2.0	1.4	0.7	0.5	5.1	10.9
Error B.	6.0	8.6	1.4			
Interaction	8.0	3.1	0.4	0.1	2.4	3.4
Error C	24.0	67.3	2.8			
Total	59.0	111.7				

Appendix – XIV ANOVA for maximum population of Dark small-branded swift under agrihorticulture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	6.6	2.2	5.1	3.5	5.0
MT	4.0	7.8	1.9	4.5	3.3	5.4
Error A.	12.0	5.2	0.4			
ST	2.0	8.1	4.1	17.8	5.1	10.9
Error B.	6.0	1.4	0.2			
Interaction	8.0	2.7	0.3	0.1	2.4	3.4
Error C	24.0	61.1	2.5			
Total	59.0	92.9				

Appendix – XV ANOVA for maximum population of *Apis indica* under agrihorticulture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	0.7	0.2	0.2	3.5	5.0
MT	4.0	6.8	1.7	1.8	3.3	5.4
Error A.	12.0	11.7	1.0			
ST	2.0	0.7	0.4	0.3	5.1	10.9
Error B.	6.0	8.2	1.4			
Interaction	8.0	1.5	0.2	0.1	2.4	3.4
Error C	24.0	53.6	2.2			
Total	59.0	83.3				

Appendix – XVI ANOVA for maximum population of mustard aphid *Lipaphis erysimi* under agrihorticulture system.

Source	DF	SS	MS	F Cal	at 5%	at 1%
Replication	3.0	10.9	3.6	0.8	3.5	5.0
MT	4.0	677.5	169.4	35.3	3.3	5.4
Error A.	12.0	57.6	4.8			
ST	2.0	30.9	15.4	3.5	5.1	10.9
Error B.	6.0	26.3	4.4			
Interaction	8.0	22.6	2.8	0.1	2.4	3.4
Error C	24.0	717.5	29.9			
Total	59.0	1543.3				

CURRICULUM VITAE

Name of the author- Kailash Kumar

Place: Devthana, Balaghat, MP.

Date of Birth- 15 May 1992

The author of this thesis Kailash Kumar S/o Shri Chhattelal Mashram and Late Mrs. Purnta Devi was born on 15 May 1992 at Devthana Balaghat (Madhya Pradesh). He has joined the following institutions and successfully completed the degree of M.Sc. (Forestry) during the year 2018 -19 with 8.1 OGPA with 10 point scale.

He has got the following degrees:

S.No.	Degrees granted	Institution	University/ Board	Percentage	Year
1.	M.Sc.(Forestry)	College of Agriculture, Jabalpur	JNKVV, Jabalpur	81.00	2019
2.	B.Sc.(Forestry)	College of Agriculture, Jabalpur	JNKVV, Jabalpur	73.10	2017
3.	H.S.S.C	Govt. Boys H.S.School Katangi	MP Board	69.20	2011
4.	H.S.C	Govt. Boys H.S.School Katangi	MP Board	58.50	2009

He has following scientific interests:

Scientific interests

- Forestry
- Nursery Management
- Plantation

For the partial fulfillment of the master's degree programme he was allotted a research problem "Assessment of insect-pest dynamics and their management in Agroforestry Systems of semi-arid tropics" which was successfully conducted by his and being submitted in the form of the thesis.