POPULATION DYNAMICS OF INSECT PESTS AND POLLINATORS ASSOCIATED WITH *Litchi chinensis* Sonn.

Thesis

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By

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CERTIFICATE

This is to certify that the thesis entitled **"Population dynamics of insect pests and pollinators associated with *Litchi chinensis* Sonn."** submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** with major in **Entomology** and minor in **Plant Pathology** of the College of Post Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Sanjay Kumar Joshi, Id. No. 35472,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Pantnagar
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CERTIFICATE

We, the undersigned, members of the advisory committee of **Mr. Sanjay Kumar Joshi, Id. No. 35472** a candidate for the degree of **Doctor of Philosophy**, with major in **Entomology** and minor in **Plant Pathology**, agree that the thesis entitled **"Population dynamics of insect pests and pollinators associated with *Litchi chinensis* Sonn.",** may be submitted in partial fulfilment of the requirements for the degree.

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CONTENTS

Introduction

The litchi (*Litchi chinensis* Sonn.) an important sub-tropical evergreen fruit crop belonging to family *Sapindaceae,* is believed to have originated in China, where it has been grown in Southern Guangdong state for thousand of years. It is highly specific to climatic requirements and probably due to this reason its cultivation is restricted to few countries in the world. In India, litchi was introduced in the 18th century through Burma. India and China account for 91 percent of the world litchi production **(Anonymous, 2004)**. In India, 497,000 metric tones of litchi is produced from 78,000 hectares. The average productivity in the country is reported to be 6.4 tones per hectare **(Anonymous, 2011)**. Litchi is commercially grown in Bihar, Uttarakhand, West Bengal and Jharkhand. Due to its high economic returns and ever increasing demand in the domestic markets, the crop is also gaining momentum in Punjab, Himachal Pradesh, Assam, Tripura, and Orissa. The area under litchi production in Uttarakhand is 9,300 hectares with a production figure of 18,700 metric tones. The average productivity in the state is 2.0 tones per hectare **(Anonymous, 2011).** In Uttarakhand, the litchi is cultivated in Dehradun, Nainital, Udham Singh Nagar and parts of Pauri, Almora and Pithoragarh districts **(Singh and Dwivedi, 2007)**.

Litchi trees are attacked by a number of insect pests. Insects attack all parts of litchi trees. Some species cause severe damage by boring into and throughout the trunk, branches and fruits, while others distort leaves and reduce photosynthetic capacity **(Waite, 2005)**. Among these pests major ones are fruit borer, shoot borer, litchi bug, litchi erinose mite, leaf rollers, weevils and beetles.

Fruit borer caterpillar attacks the fruit causing direct crop loss. Two fruit borer species *Conopomorpha sinensis* and *Conopomorpha litchiella* are recorded from India and Southeast Asia to China and Taiwan. The creamy white larvae of litchi leafminer, *C. litchiella* bore into the shoots, but they may also mine the leaf blade. Although mature larvae prefer to feed on the midrib and veins of young leaves, they may also bore into fruit **(Waite, 2005)**.

Several bugs belonging to the Family Tessaritomidae attack litchi throughout China, South-east Asia and Australia. **Butani (1977)** reported that *Tessaritoma javanica* Thunberg and *T. quadrata* Distant are found feeding on younger shoots and fruits of litchi in India.

The litchi erinose mite, *Aceria litchii* (Keiffer), also known in China as litchi hairy mite, hairy spider or dog ear mite, attacks new vegetative growth throughout China and Taiwan **(Huang *et al*., 1990)**, India **(Prasad and Singh, 1981)**, Pakistan **(Alam and Wadud, 1963)**, Hawaii **(Nishida and Holdaway, 1945)** and Australia **(Waite, 1986)**.

Several species of leaf rollers attack litchi leaves. *Platypeplus aprobola* (Meyrick) has been recorded on litchi in China and India **(Butani, 1977)** and *Epiphyas postvittana* (Walker) was recorded attacking the crop in Australia.

Leaf cutting weevil, *Myllocerus undatus* (Marshall) is recently discovered from Indian subcontinent feeding on litchi leaves **(O'Brien *et al.*, 2006)**.

Low and irregular yields are reported worldwide in litchi, hampering its development as a major commercial crop (**Galan Sauco and Menini, 1989**). These problems are attributed either to a failure to initiate flowers or to a failure to set and retain fruit (**Batten, 1986**). In reviewing fruit set in litchi, several environmental and physiological factors could reduce fruit set. However, to determine the depression in yields due to pollination events, there is need to understand the response of pollination on fruit setting.

Litchi is a monoecious plant bearing separate male and hermaphrodite flowers on terminal panicles. Three different types of flowers usually bloom in succession on the same tree and even on the same panicles. These flowers include Male or Staminate flowers (M_1) with no functional ovaries bloom first; Hermaphrodite functioning as female (F) comprise the second stage and Imperfect hermaphrodite flowers (M_2), also lacking functional ovaries, bloom last**.** In case of litchi, self pollination can occur, however, litchi female flowers are generally recognized as self-sterile and require insects, usually honeybees, to transport pollen from anthers to stigmas for fruit set **(King *et al.,* 1989; Stern and Gazit, 1996).**

Studies on role of insect pollinators are very essential to improve the productivity of litchi. Several works have been reported on this aspect. **Chaturvedi (1965)** reported 43 percent fertilized flowers on open pollinated branches, zero percent on branches bagged with muslin, and 15.5 percent on branches bagged under mosquito cloth. **Abrol and Kitroo (1998)** reported *Apis dorsata* Fab., *A. mellifera* L. and *A. cerana indica* Fab. as the most important and efficient pollinators of litchi.

Besides honeybees, syrphids and non *Apis* bees also play very important role in pollination. Syrphids are one of the most important groups of pollinators. The most abundant syrphids are *Episyrphus balteatus*, *Melanostoma orientale*, *Syrphus corollae* and *Eristalis tenax*. Among non-*Apis* bees *Trigona* spp (Melliponinae) and *Xylocopa aestuans* (Xylocopinae) are also found very efficient insect pollinators **(Usha *et al.*, 2009)**.

Owing to the increasing population, it is very essential to protect the fruits from the heavy losses under field condition as well as increasing the yield by maximum fruit setting. To achieve this, there is an urgent need for integrated approach for enhancing fruit production by managing the pest with the use of economical and safer techniques that would also avoid negative impact on pollinators and other non-target organism.

Keeping this in view, a comprehensive study has been undertaken with following objectives:

1. Assessment of incidence and population dynamics of various insect pests on litchi leaves.
2. The diversity and relative abundance of insect pollinator species associated with litchi crop.

Review of Literature

The available literature on the present investigation and related aspects have been reviewed and presented below under following headings:

2.1. Insect pests associated with litchi crop

2.2. Insect pests under investigation

2.2.1. Leaf roller

2.2.2. Leaf folder

2.2.3. Mid rib borer

2.2.4. Beetle

2.2.5. Weevils

2.3. Diversity of major insect pollinator species associated with litchi

2.1 Insect pests associated with litchi crop

Insects and mites attack all parts of litchi trees. Some species cause severe damage by boring into and throughout the trunk and branches, while others devour or distort leaves and thus reduce photosynthetic capacity. Usually, the most economically important damage is that which is inflicted on the flowers and fruit. Even though other tree parts may be attacked and damaged by pests, it is the flowers and ultimately the fruit that provide an income for producers.

In China, **Tan *et al* (1995)** recorded 83 species of litchi pests belonging to 76 genera, 30 families and 7 orders, in which 14 species were dominant. The main factors affecting the dynamics of pests were the biological characteristics of the pests, age of litchi trees, climatic and ecological factors in the orchard.

Waite (2005) enlisted 73 species of arthropod pests of litchi (Table 1).

A survey has been taken in the orchard of litchi to study the lepidopterous pests on shoots, spikes of flowers, and fruits in Taiwan. It showed that 13 species of lepidopterous pests were found from litchi shoots which included two species of the Gracillariidae, *Conopomorpha sinensis* (Bradley) and *C. litchiella* (Bradley); six

Table 1: Arthropod pests of *Litchi chinensis* Sonn. (Waite, 2005)

Pest Species	Order	Family	Affected plant part	Geographical area
1. *Aceria litchii* (Keiffer)	Acari	Eriophyidae	Litchi leaves, flowers, fruit	India, China, Taiwan, Australia, Hawaii, Pakistan
2. *Oligonychus coffeae* (Nietner)	Acari	Tetranychidae	Litchi leaves	Australia
3. *Polyphagotarsonemus latus* (Banks)	Acari	Tarsonemidae	Litchi leaves, terminals	Australia, China, Hawaii
4. *Aristobia testudo* (Voet)	Coleoptera	Cerambycidae	Litchi branches	China
5. *Anoplophora maculata* (Thomson)	Coleoptera	Cerambycidae	Litchi branches	Taiwan
6. *Uracanthus cryptophagus* (Olliff)	Coleoptera	Cerambycidae	Litchi branches	Australia
7. *Rhyparida discopunctulata* (Blackburn)	Coleoptera	Chrysomelidae	Litchi leaves	Australia
8. *Monolepta australis* (Jacoby)	Coleoptera	Chrysomelidae	Litchi leaves	Australia
9. *Proctophana tomentosa* (Lacordaire)	Coleoptera	Chrysomelidae	Litchi leaves	Brazil
10. *Cratopus angustatus* (Boh.)	Coleoptera	Curculionidae	Litchi leaves, flowers, fruit, roots	Réunion
11. *Cratopus humeralis* (Boh.)	Coleoptera	Curculionidae	Litchi leaves, flowers, fruit, roots	Réunion
12. *Euthyrrhinus meditabundus* (Fab.)	Coleoptera	Curculionidae	Litchi twigs	Australia
13. *Orthorrhinus klugii* (Boh.)	Coleoptera	Curculionidae	Litchi twigs	Australia
14. *Xylotrupes gideon* (Linnaeus)	Coleoptera	Scarabaeidae	Litchi fruit	China, Australia
15. *Litchiomyia chinensis* (Yang and Luo)	Diptera	Cecidomyiidae	Litchi leaves	China
16. *Ceratitis capitata* (Weidemann)	Diptera	Tephritidae	Litchi fruit	South Africa, Réunion, Hawaii
17. *Ceratitis rosa* (Karsch)	Diptera	Tephritidae	Litchi fruit	South Africa, Réunion
18. *Bactrocera dorsalis* (Hendel)	Diptera	Tephritidae	Litchi fruit	Hawaii
19. *Bactrocera cucurbitae* (Coquillett)	Diptera	Tephritidae	Litchi fruit	Hawaii
20. *Bactrocera tryoni* (Froggatt)	Diptera	Tephritidae	Litchi fruit	Australia
21. *Tessaritoma javanica* (Thunberg)	Hemiptera	Tessaritomidae	Litchi flowers, fruit	India

Pest Species	Order	Family	Affected plant part	Geographical area
22. *Tessaritoma papillosa* (Drury)	Hemiptera	Tessaritomidae	Litchi flowers, fruit	India, China, Vietnam, Thailand, Myanmar, Philippines
23. *Tessaritoma quadrata* (Distant)	Hemiptera	Tessaritomidae	Litchi flowers, fruit	India
24. *Lyramorpha rosea* (Westw.)	Hemiptera	Tessaritomidae	Litchi fruit	Australia
25. *Amblypelta nitida* (Stal)	Hemiptera	Coreidae	Litchi fruit	Australia
26. *Amblypelta lutescens* (Distant)	Hemiptera	Coreidae	Litchi fruit	Australia
27. *Leptocoris rufomarginata* (Fabricius)	Hemiptera	Rhopalidae	Litchi fruit	Australia
28. Pulvinaria psidii (Maskell)	Hemiptera	Coccidae	Litchi and longan twigs, leaves, fruit	India, China, Taiwan, Australia, Florida
29. *Chloropulvinaria hesperidum* (Linnaeus)	Hemiptera	Coccidae	Litchi twigs	Australia
30. *Parasaissetia nigra* (Nietner)	Hemiptera	Coccidae	Litchi twigs	India
31. *Saissetia coffeae* (Walker)	Hemiptera	Coccidae	Litchi twigs	India
32. *Ceroplastes ceriferus* (Fabricius)	Hemiptera	Coccidae	Litchi leaves	Taiwan
33. *Nipaecoccus vastator* (Maskell)	Hemiptera	Coccidae	Litchi leaves	Taiwan
34. *Icerya seychellarum* (West.)	Hemiptera	Coccidae	Litchi twigs	Réunion
35. *Kerria lacca* (Kerr)	Hemiptera	Coccidae	Litchi twigs	Taiwan
36. *Hemiberlesia lataniae* (Signoret)	Hemiptera	Coccidae	Litchi branches, twigs	Australia
37. *Fiorinia nephelii* (Maskell)	Hemiptera	Coccidae	Litchi twigs	India
38. *Parlatoria pseudopyri* (Kuwana)	Hemiptera	Coccidae	Litchi twigs	India
39. *Parlatoria cinerea* (Danne and Hadden)	Hemiptera	Coccidae	Litchi twigs	India
40. *Planococcus citri* (Risso)	Hemiptera	Pseudococcidae	Litchi fruit	Taiwan
41. *Zeuzera coffeae* (Nietner)	Lepidoptera	Cossidae	Litchi and longan branches	China, Taiwan
42. *Conopomorpha sinensis* (Bradley)	Lepidoptera	Tortricidae	Litchi and longan fruit, leaves, shoots	China, Taiwan, Thailand
43. *Conopomorpha litchiella* (Bradley)	Lepidoptera	Tortricidae	Litchi and longan fruit, leaves, shoots	China, Taiwan, Thailand
44. *Cryptophlebia peltastica* (Meyr.)	Lepidoptera	Tortricidae	Litchi fruit	Mauritius, Seychelles, Réunion, South Africa, Madagascar
45. *Cryptophlebia leucotreta* (Meyr.)	Lepidoptera	Tortricidae	Litchi fruit	South Africa
46. *Cryptophlebia ombrodelta* (Lower)	Lepidoptera	Tortricidae	Litchi fruit	Thailand, China, Taiwan, Japan, Australia, Hawaii

Pest Species	Order	Family	Affected plant part	Geographical area
47. *Cryptophlebia illepida* (Butler)	Lepidoptera	Tortricidae	Litchi fruit	Hawaii
48. *Olethreutes praecedens* (Wals.)	Lepidoptera	Tortricidae	Litchi leaves	Réunion
49. *Olethreutes perdulata* (Meyr.)	Lepidoptera	Tortricidae	Litchi leaves	Australia
50. *Platypeplus aprobola* (Meyrick)	Lepidoptera	Tortricidae	Litchi leaves	India, China, Australia
51. *Epiphyas postvittana* (Walker)	Lepidoptera	Tortricidae	Litchi leaves	Australia, Hawaii
52. *Adoxophyes cyrtosema* (Meyr.)	Lepidoptera	Tortricidae	Litchi leaves	China
53. *Homona coffearia* (Nietner)	Lepidoptera	Tortricidae	Litchi leaves	China, Thailand
54. *Homona difficilis* (Meyrick)	Lepidoptera	Tortricidae	Litchi leaves	Thailand
55. Crocidosema litchivora	Lepidoptera	Tortricidae	Litchi flowers	Florida
56. *Deudorix epijarbas* (Moore)	Lepidoptera	Lycaenidae	Litchi fruit	India
57. Deudorix epijarbas amatius	Lepidoptera	Lycaenidae	Litchi fruit	China, Thailand
58. *Deudorix diovis* (Hewitson)	Lepidoptera	Lycaenidae	Litchi fruit	Australia
59. *Eudocima fullonia* (Clerck)	Lepidoptera	Noctuidae	Litchi fruit	Australia
60. *Eudocima salaminia* (Cramer)	Lepidoptera	Noctuidae	Litchi fruit	Australia
61. *Eudocima jordani* (Holland)	Lepidoptera	Noctuidae	Litchi fruit	Australia
62. *Oxyodes tricolor* (Guen.)	Lepidoptera	Noctuidae	Litchi leaves	Australia
63. *Oxyodes scrobiculata* (F.)	Lepidoptera	Noctuidae	Litchi leaves	Thailand
64. *Achaea janata* (L.)	Lepidoptera	Noctuidae	Litchi leaves	Australia
65. *Salagena* sp.	Lepidoptera	Metarbelidae	Litchi branches	South Africa
66. *Indarbela quadrinotata* (Walker)	Lepidoptera	Metarbelidae	Litchi branches	India
67. *Indarbela tetraonis* (Moore)	Lepidoptera	Metarbelidae	Litchi branches	India
68. *Arbela dea* (Swinhoe)	Lepidoptera	Metarbelidae	Litchi branches	China
69. *Comoritis albicapilla* (Moriuti)	Lepidoptera	Yponomeutidae	Litchi bark	China
70. *Dolichothrips indicus* (Hood)	Thysanoptera	Phlaeothripidae	Litchi flowers	India
71. *Megalurothrips distalis* (Karny)	Thysanoptera	Thripidae	Litchi leaves	India
72. *Scirtothrips dorsalis* (Hood)	Thysanoptera	Thripidae	Litchi and longan shoots	China
73. *Thrips imaginis* (Bagnall)	Thysanoptera	Thripidae	Litchi flowers	Australia

species of the Tortricidae, *Statherotis leucaspis* (Meyrick), *Dudua aprobola* (Meyrick), *Eboda celligera* (Meyrick), *Adoxophyes privatana* (Walker), *Lobesia sp.,* and *Cryptophlebia ombrodelta* (Lower); two species of the Pyralidae, *Diaphania indica* (Saunders) and *Conogethes evaxalis* (Walker); two species of the Noctuidae, *Sympis rufibasis* (Guenee) and *Oxyodes scrobiculata* (Fabricius); and one species of the Geometridae, *Thalassodes immissarius* (Walker). Five species of lepidopterous pests were observed on the spikes of flowers and fruits of litchi **(Hung *et al*., 2006).**

Surveys of insects and other pests on litchi were carried out from 2002 to 2007 in southern Taiwan. A total of 22 species of insects, one species of mite and one species of snail were found. Among them, the mango aphid *Greenidea mangiferae*, litchi fruit borer, *Conopomorpha sinensis*, leaf borer *C. litchiella*, cottony mealybug *Chloropulvinaria psidii*, leaf roller, *Ehola celligera* and oriental fruit fly, *Bactrocera dorsalis* were considered of economic importance **(Hung and Tsung, 2008)**.

2.2. Insect pests under investigation

2.2.1. Leaf roller

2.2.1. a. Biology

Several species of leaf rollers attack litchi leaves. Larvae of *Platypeplus aprobola* (Meyrick) were found infesting litchi at Muzaffarpur, Bihar, India, for the first time. The severe damage was done by the Tortricid. Population was highest during December to February. There were five larval instars, and the duration of the pupal stage was 7-10 days (**Singh, 1971**). *P. aprobola* (Meyrick) has been recorded on litchi in China and India **(Butani, 1977)** However in Australia, it causes significant loss of flowers **(Anonymous, 2004)**. *Epiphyas postvittana* (Walker) was also recorded attacking the crop in Australia.

Singh and Kumar (1997) studied the biology of litchi leaf roller, *S. leucaspis*. In the laboratory, adults of the pest mated 2-4 days after emergence, during the night. The pre-oviposition period was 1-2 days, the oviposition period was 4-6 days, fecundity was 37-127 eggs/female, percentage hatch was 80%, the incubation period was 2-6 days, the larval period was 10-18 days, the prepupal period was 1-3 days, and the pupal period was 8-10 and 8-13 days in males and females, respectively. Adult emergence was 90.07%, adult life span was 5-6 and 7-10 days in males and females, respectively, and the ratio of females to males was 1.5:1.

Citrus leaf roller *Adoxophyes cyrtosema* (Meyrick) is distributed throughout China. Litchi fruit, flower, leaf and new growth are also affected by this pest **(Menzel, 2002)**. The occurrence of *A. cyrtosema* in China was closely correlated with temperature, humidity, and precipitation. The infestation of the pest was divided into four stages. The first stage was from early June to last July. The population of the insect tended to reduce at this stage. The second stage was in August and the larvae were in overwintering stage. The third stage was early September to early October and the population began to increase and reached peaks in mid-October and mid-November, each beginning to reduce from the end of November. The fourth stage was from early December to the next May and the population began to increase again and reached peaks once in early January, middle February, middle April, and the last 10 days of May **(Liu *et al*., 2001)**.

In Guangzhou Province China, *A. cyrtosema* has about nine generations per year. The larvae overwinter in citrus nurseries or on grasses and pupate in March. Emerging moths then fly into litchi and citrus orchards where they mate and lay eggs on the leaves. Female moths lay up to three egg masses, each with about 140 eggs. They take an average of six days to hatch. The larvae web and roll leaves together to form a shelter in which they feed. This species has been recorded feeding externally on litchi fruit **(Waite and Hwang, 2002)**.

The orange fruit borer, *Isotenes miserana* (Walker), is an omnivorous leaf roller that also attacks litchi flowers and fruits in Queensland, Australia. In Florida, *Crocidosema litchivora* is reported for damaging litchi inflorescences **(Brown *et al*., 2002)**.

Nair and Sahoo (2006) studied the bionomics of the litchi leaf roller (*P. leucaspis*) on litchi cv. Bombai. Maximum pest population was observed during December and March-June. Larvae population was positively correlated with average temperature, average relative humidity and rainfall. The incubation period, larval period, prepupal period, pupal period and adult longevity were 3-5 days, 14-16 days, 1 day, 8-9 days and 5-6 days, respectively.

The community structure and fluctuation of leaf roller population in litchi and longan orchards was observed in Guangxi, China. Twenty species of leaf rollers belonging to 3 families were observed, in which 9 species were not reported as pests of litchi or longan in the past. Sixteen species belonging to 3 families were observed on longan orchards, and 17 species from 2 families in the litchi orchard. The evenness indices of community on longan and litchi were 0.2982 and 0.4063, respectively. Species distributions were not uniform, and certain species have high density. The dominant species on longan were *Olethreutes leucaspis* (*Statherotis leucaspis*), while in litchi orchards the dominant species were *O. leucaspis* and *Dudua aprobola*. The main species in both orchards were *O. leucaspis*, *D. aprobola* and *Eboda celligera* **(Zhou and Deng, 2006)**.

2.2.1. b. Management

Sahoo and Maiti (1992) reported that the tortricid *P. aprobola* (*Dudua aprobola*) is a pest of litchi in the Gangetic alluvial zone of West Bengal, India. In field tests with the insecticides, monocrotophos, phosphamidon and demeton methyl were proved to be the most effective for the control of the tortricid.

Singh and Kumar (1994) reported cypermethrin (0.006%) and carbaryl (0.10%) were the most and least effective insecticides against litchi leaf roller *Statherotis leucaspis*, respectively.

Singh *et al.* (2003) reported that the leaf infestation by leaf roller (*P. aprobola*) in litchi trees was 11.31 to 29.08% in phosphamidon (0.05%) treated trees and in control respectively. The neem products and cartap hydrochloride were not effective.

More than 20 leaf rollers had been detected in some litchi and longan plantations in Guangxi Province, China. *Olethreutes leucaspis*, *Dudua aprobola*, *Eboda cellerigera* and *Homona coffearia* were the dominant species. The natural enemies of these leaf rollers were surveyed and 21 insect species belonging to 9 families had been recorded. The results showed that 12 species in 4 families were parasitic and 9 species were predaceous. Parasitic wasps had been found in both the eggs and the larvae of these 4 leaf rollers. *Trichogramma dendrolimi* was found to be the dominant parasitoids for eggs, while *Pristomerus* spp., *Plectochorus* sp., *Xanthopimpla punctata*, *Apanteles* spp. and *Phanerotoma orientalis* were the parasitoids for larvae. 28 species (9 families) of spiders were recorded, only one species of *Hasarius* was predator of the first instar larvae of *O. leucaspis*. Imagoes of *Labidura* sp. was found as a predator of larvae of *O. leucaspis* **(Zhou and Deng, 2006)**.

2.2.2. Leaf folder

Chemical control strategies were developed against larvae of *Dudua aprobola* (Meyrick) which were webbing the young shoots of litchi in the Punjab, India. A single application of 0.02% fenvalerate or deltamethrin (decamethrin) eradicated the larvae from the shoots within 2 weeks of treatment, and deltamethrin was also very effective at 0.01%. These treatments were significantly more effective than fenvalerate at 0.01%, permethrin at 0.02%, and quinalphos at 0.02% but on grounds of cost, quinalphos at 0.02% is recommended **(Mann and Singh, 1984)**.

2.2.3. Mid rib borer

2.2.3. a. Biology

Hwang and Hsieh (1989) studied bionomics of the gracillariid *C. cramerella*, an important pest of litchi trees in Taiwan. *C. cramerella* was active in litchi orchards during the fruit developing season (April to September). The adult was 4.4 mm long with a pair of antennae longer than the body length. The emergence, mating and oviposition of adults took place at night. During the day, adults rested under the branches of shaded fruit trees. Adult females laid eggs on the surface of fruits, new leaves and new shoots. The mean number of eggs deposited by females was 114.1 and the rate of egg hatchability was 97%. The mean duration of the egg, larval and pupal stages were 3.3, 8.8 and 7 days, respectively. The longevity of the adult was approximately 6-8 days. Two species of parasitoids, *Phanerotoma* sp. and *Apanteles* sp., were identified from pupae of *C. cramerella*. Two other parasitoids *Tetrastichus* sp. and *Elasmus* sp., were reared from *C. cramerella* larvae feeding on shoots or leaves.

Yao and Liu (1990) reported two gracillariids *C. sinensis* and *C. litchiella* for the first time in China infesting litchi in Guangdong and Fujian. These two closely related species have long been considered as a single species. *C. sinensis* damages the fruits and shoots of litchi while *C. litchiella* damages shoots only.

C. sinensis lays yellow, scale-like eggs that are 0.4 mm long by 0.2 mm wide on litchi fruit as well as on new leaves and shoots in China, Taiwan and Thailand.

They prefer orchards with shady, humid and closed conditions In Taiwan, this pest can complete 4-5 generations during the litchi season. In the Guangzhou district of China, there are 11 overlapping generations each year **(Zhang *et al*., 1997)**.

Kriengkrai *et al.* (2000) reported that the *C. sinensis* infestation occurred on the young fruits from twenty days after fruit setting. The infestation percentage of the fruit borer increased when the young green fruits developed to yellow and red mature fruits. Infestation percentage reached 50 percent when the fruits were at 50-60 days after fruit setting.

Waite and Hwang (2002) reported that the eggs of *C. sinensis* hatch in 3-5 days, with the larva immediately penetrating the fruit, leaf or shoot. One or more eggs may be laid on a fruit but generally only one larva per fruit survives. Larvae tunnel through the flesh of the fruit, which often falls from the tree as a result of the damage they sustain. During the off-season, when fruit is not available, the larvae can survive by feeding on young leaves and shoots. Mature larvae are 6-10 mm long and brownish in color or green if their diet has consisted predominantly of leaves. Pupation occurs 8-12 days later under mature leaves in crème colored oval cocoons. An adult moth emerges 5-7 days later after it has changed from a brownish/light green to a dark brown color. Adults are very small with long thin antennae and narrow fringed forewings that are 8-11 mm across when expanded. Adult lifespan is 5-8 days. The moths are attracted to leaf flushes that emerge during the rainy season from June to October.

In a study in Taiwan it was found that the fecundity of litchi fruit borer, *C. sinensis* feeding on litchi fruits was higher (160.3 eggs/female) compared to those feeding on young shoots (99.6 eggs/female). However the survival rate was higher on shoots than in fruit **(Xie *et al.,* 2005)**.

In West Bengal *C. cramerella* has been found to cause severe damage to both immature and ripe litchi fruits. Not only the fruits but also tender leaves and newly formed young shoots were observed to be severely damaged by this pest. Although the pest was active throughout the year, the peak period of activity was July to November (as leaf miner and shoot borer) and March to May (as fruit borer). 26-89% of the dropped fruits were found to be infested by this particular pest **(Nair and Sahoo, 2006)**.

Schulte *et al.* (2007) reported that the leaf shoot infestation rate by *C. sinensis,* decreased in the fruiting season (March to May) in the low elevation orchard but increased in the high elevation orchard, where no fruits were present within the same period of time. It was also observed that females of *C. sinensis* clearly prefer fruits than shoots for oviposition. If no fruits are available, they are constrained to lay their eggs on shoots.

Peng *et al.* (2007) studied the attracting effect of different parts of host plant, litchi on oviposition of litchi fruit borer, *C. sinensis*. The females selected and oviposited at the new sprigs when new and old sprigs were provided.

Ranjan and Mukherjee (2008) reported that activity of *C. cramerella* started on the litchi leaves from the month of July and continued till the month of November. The maximum leaf infestation was recorded during August with 69.8% and 62.60% in 2006-07 and 2007-08 respectively. The leaf infestation was minimum in the month of November in both the years. The abiotic factors *viz,* minimum temperature and relative humidity were significantly correlated with the leaf infestation individually. The pest started its activity on litchi fruits from the month of April to June in both the fruiting year. The maximum fruit infestation (53.40%) was recorded in June, 2007. Almost similar trend was observed in the June, 2006 (51.6%). The abiotic factors, maximum temperature and relative humidity were significantly correlated with the fruit infestation**.**

Wen and Lee (2009) conducted survey on the population of the litchi fruit borer (*C. sinensis*) in China. The first peak of litchi fruit borer population occurred in May and June, and the second peak occurred in November.

Li and Qiu (2009) conducted an experiment on the flying distance and hibernation habit of litchi fruit stalk borer (*C. sinensis*). It was observed that the adult could fly a distance from 4.97 m up to 12 m. 92.5% of the adults had their abdomen up when hibernating. Unless disturbed by something, they hibernate in the day time, when nearing the evening, they start to fly intermittently. All these observations indicated that for control purposes, spraying pesticides should be done in the evening.

2.2.3. b. Management

Lall and Sharma (1978) reported that the litchi crop is severely attacked by *Acrocercops cramerella* (Snellen). The pest mines leaves in August-February, migrates in March-April to alternative food-plants such as *Eugenia jambolana* (*Syzygium jambolanum*) and *Cassia tora* (which grow wild in litchi orchards), and in May returns to litchi to oviposit on the fruits; the ensuing larvae feed in the fruits, pupate on the leaves, and give rise to new leaf-mining and shoot-boring generations. The highest population densities were observed in September, when the females laid the largest numbers of eggs and adult life-span was longest; the lowest density was observed in December. Severely infested trees presented a drooping appearance, damaged shoots and leaves eventually withered and fell off. The results of chemical control tests with 7 different insecticides, which were evaluated 1-21 days after treatment, indicated that sprays containing 0.025% methyl-demeton, 0.045% dimethoate or 0.08% thiometon, all applied at 15 litres spray/tree, were the most effective in reducing the numbers of larvae or pupae per leaf.

Sharma and Agrwal (1988) reported *Conopomorpha cramerella* (Snellen) damaging the fruits of litchi in Bihar and Uttar Pradesh. The Field collected larvae were found to be parasitized by *Mesochorus* sp., *Chelonus* sp., *Bracon* sp. and *Apanteles* sp.

Huang *et al.* (1994) reported that the fruit drop caused by *C. sinensis* infestation was highest in early May and early June, and most larvae in the dropped fruits had reached the 3rd-4th instars. Five hymenopterous parasitoids were recorded, of which *Phanerotoma* sp. was the most important, causing up to 22% parasitism of the gracillariid in dropped fruit**.**

Supatra *et al.* (1998) reported that fruit shedding of litchi occurred 40-90 percent after fruit set throughout the season. Fruit drop of litchi was increased due to litchi fruit borer, fruit crack and fruit browning diseases which are main causes of yield reduction. Five species of larval parasitoids of *C. sinensis* were observed. Three species of braconid were *Phanerotoma* sp., *Colastes* sp. and *Pholestesor* sp. Another two ichneumonids were identified as *Goryphus* sp. and *Paraphylax* sp. There was 4.18 percent parasitism of *C. sinensis*.

Mukherjee and Ranjan (2005) reported that spraying of phosphamidon at 0.03% gave the best results in controlling fruit borer infestation, followed by carbaryl at 0.2%. Among the plant products, the application of karanj cake (4 kg) + castor cake (1 kg) at the root zone gave better results than spraying nimbicidine at 0.2% against the pest. The yield of litchi fruits revealed that spraying of phosphamidon at 0.03% and carbaryl at 0.2% recorded the highest fruit yield per tree.

During the survey of litchi orchards in Chiayi, **Hung *et al.* (2008)** reported that the damage caused by fruit borer *C. sinensis* was 7.5-47% and 88.5% for the areas of pesticide-spray and unsprayed control, respectively. Study showed that *C. sinensis* caused up to 35.3% of damages of litchi fruits which were ripened and fallen on the ground during the peak activity period of this insect in May and June.

Singh *et al.* (2009) reported that the treatment (endosulfan + Halt) was superior in suppressing infestation of *Acrocercops cramerella* and also increased the yield (95.99 kg/tree). It was concluded that the incidence of fruit borer can be kept below the economic threshold level by one application of endosulfan (0.07%) followed by and one application of Halt (0.03%) in the month of April-May at the intervals of 12-15 days.

2.2.4. Beetle

The Japanese beetle, *Popillia japonica* was earlier misidentified with a species from the same genus as *Popillia quadriguttata* **(Ku *et al*., 1999).** The Japanese beetle, *Popillia japonica* is a highly destructive pest. Adult beetles attack foliage of litchi. There is only one generation of *P. japonica* per year. In North America and Canada, adults appear in summer and very active for about 6 to 8 weeks. Their normal life span is from 30 to 45 days. Beetles begin flying when the temperature is about 21ºC. Their flight is aimless except in response to chemical stimuli of food plants or sex pheromone. Most flights are short distances, but the beetle is capable of flying up to 8 km with the wind. Beetles prefer to feed on plant parts exposed to the direct rays of the sun, beginning at the top, regardless of height, and working downward. They feed on the upper surface of the foliage of plants, chewing the tissue between the veins, leaving a lace-like skeleton. As leaves on trees become less attractive, the beetles leave the trees and become more abundant on flowers or in field crops such as, corn and clover. The female deposits up to 60 eggs about 8 cm deep in soil of lawns and other grassy areas. Eggs hatch in about two weeks and the small larvae begin to feed on grass roots. Feeding continues until the approach of cold weather. They spend the winter from 5-31 cm below the surface and resume feeding in the spring. There are three larval instars. Most pass the winter in the third instar. When full grown, they pupate and after a resting period of about two weeks emerge as adult beetles in late June or early July **(Wallace, 2001)**.

The females of Japanese beetle, *P. japonica* burrow about 3 inches into the ground, usually into turf and lay a few eggs. This cycle repeats until the female has laid 40–60 eggs. In late autumn, after hatching, the grubs burrow 4–8 inches into the soil and remain inactive all winter. This insect spends about 10 months a year in the ground in the larval stage. In early spring, the grubs return to the turf and feed on roots until late spring, then pupation takes place. In about 2 weeks, adult beetles emerge from the pupae in the ground. This life cycle takes a year (**USDA, 2007**).

2.2.5. Weevils

According to **Singh (1971)** *Myllocerus discolor* (Boh.) and *M. undecimpustulatus* (Faust) were found for the first time attacking litchi in India. Populations of the weevil were largest during November-February and smallest during April-July. Heavy infestations resulted in damage to most of the leaves and very low yields in the subsequent season.

The grey weevil, *M. undecimpustulatus*, is active from April to November and passes winter in the adult stage, hidden in debris. The life cycle of pest is completed in 6 to 8 weeks during the active period. The female lays 360 eggs over a period of 24 days. The eggs hatch in three to five days. The young grubs feed on the roots of plants. The grubs complete their development in one to two months. Pupation occurs in the soil inside earthen cells and takes about one week. The adult weevils feed on leaves and live for 8 to 11 days in the summer and four to five months in the winter **(Atwal, 1976)**.

The apple weevil, *M. discolor*, the almond weevil, *M. laetivirens* and the grey weevil, *M. undecimpustulatus* are polyphagus pests feeding on a variety of host plants. The adult weevils of *Myllocerus* species feed on leaves, nibbling the leaves from the margins and eating away small patches of leaf lamina **(Butani, 1979)**. All the species in the Genus *Myllocerus* are polyphagous **(Hill, 1987)**.

Thomas (2000) reported litchi as a host plant for the grey weevil, *M. undecimpustulatus.*

O'Brien *et al.* (2006) reported Leaf cutting weevil, *M.undatus* (Marshall) from Indian subcontinent feeding on litchi leaves. This weevil is a native of Sri Lanka. The subspecies of *M. undecimpustulatus* are among the most serious pest species of weevils in India and Pakistan, where they attack more than 20 crops. The nominate subspecies and *M. u. maculosus* are major pests of cotton in India and Pakistan.

The biology of ash weevils, *Myllocerus* sp. was studied as heavy defoliators. Four species of *Myllocerus* such as *M. viridis*, *M. discolor, M. subfaciatus* and *M. maculosus* were found damaging the leaves of neem, *Azadirachta indica* in Sri Lanka. Adults of *Myllocerus* sp were small and had a dense covering of greyish to green with black cuticular marks. Female weevils laid eggs in clusters of 35.16±7.13 on muslin cloth covered the rearing chamber. Fecundity of weevil was 237.5±30.4 eggs. The mean incubation period of egg was 4.57±0.53 days at 28.9±1°C. The percent hatchability of egg was 68.12±11.15 at 28.9±1°C. The neonate grubs were small, creamy white with brown head, but just prior to pupal formation they enlarged in size. They burrowed through the soil and fed on the rootlets of a weed *Vernonia cinerea*. The mean grub period was 50.6±1.51 days at 29.1±1°C. Pupation was observed in an earthen brown colored puparium. Mean pupal period was 7.83±0.75 days at 29.1±1°C. *V. cinerea* is the highly preferred weed host of *Myllocerus* sp. This dicot weed served as an identical breeding site by facilitating the survival and development of weevils through out the year. The leaves of *V. cinerea* were fed by adult weevils whilst grubs fed on its rootlets **(Kiyanthy and Mikunthan, 2009)**.

2.3. Diversity of major insect pollinator species associated with litchi

Pollination of crops by insects is an essential feature for the agriculture prosperity. There are many crops that do not set fruits or seeds without pollinators because these are self-incompatible and other compatible ones increase their production when pollinators are plentiful at a right moment the crop requires them.

Several horticultural crops cultivated in India derive benefit or are dependent on pollinating insects for effective qualitative and quantitative improvement in crops yield. Significant increases in yields are recorded in cross pollinated fruit crops like litchi, apple, mango, peach, pear, plum etc., due to bee pollination.

Butcher (1957) reported that screw worm fly, *Callitroga macellaria* F. representing the order Diptera and family Calliphoridae might be the most effective pollinator of litchi. The insect was quite active throughout the period, frequently moving from one panicle to another. It was suggested that reduced activity of insect pollinators could be major reason for low yield in some litchi orchards and recommended augmenting pollination with honey bees during flowering period for increasing yield.

The syrphid fly *Eristalis brousii* (Williston) and nectar collectors of *Apis mellifera* were rated equal for pollination by **Bohart and Nye (1960).**

Chaturvedi (1965) observed two hundred female flowers to determine the mode of pollination in litchi. He concluded that percentage of fertilization in unbagged flowers was 43 while percentage of fertilization in bagged flowers with muslin cloth was zero and that in the flowers bagged with mosquito curtain cloth it was 15.5 per cent.

Free and Nuttall (1968) observed that litchi plants caged with bees produced 25 percent more fruits than plants caged without bees.

Pandey and Yadav (1970) observed that *Apis* sp. and *Mellipona* sp. comprised 98-99% of the total insect visitors to the litchi flowers. Most visits were made during morning hours between 6:30 am to 11:00 am.

In litchi, flowers opened throughout the day and there is no fixed hour of opening. The flowers started opening from 6.00 AM and continued up to 6.00 PM. The peak period of opening of litchi flower being 8:00 am to 10:00 am (42.85%). This was the time of peak abundance of the Syrphid flies. The adult Syrphid species have been found to take nectar, pollen or both from a large variety of flowers of litchi. It was also observed that Syrphid fly adults showed a marked change in behavior between 9:00-11:00 am, the time when pollen was abundant. They devoted less time to flying, made shorter moves to cover a number of flowers and spent more time on feeding **(Hamm, 1934; Emmett, 1971; El Berry *et al*., 1974; Maier and Waldbaur, 1979).**

Phadke and Naim (1974) reported that Most of the insect visitors to litchi flowers were honeybees, particularly *A. florae*, fewer *A. cerana* and hardly any *A. dorsata* were counted. On the branches bagged to exclude insects, fruit set was one quarter (or less) than that obtained on open trees.

At Bihar, India bee forage was surveyed around an *A. cerana indica* apiary at distances up to 1.6 km from the hives, 44 species were listed with flowering periods. Colonies were most active from January to mid March when pollen and nectar were abundant. Surplus honey was stored up to the end of April because the major source was litchi flowers **(Naim and Phadke, 1976)**.

According to **Dhaliwal *et al.* (1977),** *A. florea* Fab. (50%) and *A. cerana indica* Fab. (26%) were the most abundant Hymenopterans visiting litchi crop in the valley areas of the Indian Himalayas.

Brahmachary *et al.* (1980) reported *A. florea* as an important pollinator of litchi. Other bees observed included stingless bee, *Trigona* sp.

Badiyala and Garg (1990) introduced hoverflies and four *A. mellifera* colonies to a litchi orchard in Himachal Pradesh, India, at the start of flowering. The insects visited the flowers, especially in the morning, 9:30 – 11:30 AM and less active from 3:00 – 5:00 PM.

Toit and Swart (1994) introduced 22 honey bee (*A. mellifera*) colonies in a 10 ha orchard of *Litchi chinensis* cv. 'Bengal' at the start of flowering period. Foraging activity was monitored by sampling returning foragers at the hive entrance and identifying their loads: nectar, water, pollen and propolis. During the whole flowering period, nectar and pollen were collected from litchi flowers throughout the day, although activity decreased during the afternoon; water was collected on some days only, mainly in the afternoons. No propolis was collected. When 400 panicles on 20 trees were bagged to exclude insects, 2 fruits were obtained per panicle (mean weight 17 g) compared with an average of 6 (range 0-35) on 400 open-pollinated panicles (mean weight 18 g).

Toit and Swart (1995) reported that the honey bee (*A. mellifera*) foragers remained active on litchi flowers throughout the day and during the entire flowering period. Foraging for nectar was highest in the morning whereas pollen foraging reached its peak at noon. Bees also collected pollen from the plant species in or around the orchard.

A study was carried out at Jachh in 1992-1993 to determine the relative abundance of insect visitors on litchi and other fruits. Of the 34 insect species recorded on the flowers, 15 were dipteran, 13 were hymenopteran, 4 coleopteran and one each of lepidoptera and hemiptera. The main pollinators of litchi included the hoverfly, *Episyrphus balteatus* and *A. florea*. Fruit set on bagged panicles was 0.88 percent and 0.98 percent. For unbagged panicles, corresponding fruit sets were 2.14 percent and 2.48 percent **(Bhatia *et al*., 1995).**

Floral biology and pollination by *A. mellifera* were studied in a litchi orchard cultivar 'Calcuttia' at Dehradun, India. All 3 types of flowers (male, female, imperfect hermaphrodite) produced nectar and sugar concentration in nectar ranged from 60% to 75%. Apoidea constituted 89.3% of insect visitors to flowers; *A. mellifera* was the most abundant (44.8% of total), followed by *A. dorsata* (20.7%) and *Trigona iridipennis* (18.9%). There were few *A. cerana* and *A. florea*. The average number of fruits/inflorescence was 1.4 on inflorescences caged to exclude insects, 8.9 on a tree caged with *A. mellifera* and 14.9 on open pollinated trees **(Kumar *et al*., 1996)**.

Pollination of *Litchi chinensis* by *A. mellifera* was studied in a mixed plot of Israel's 2 commercial cultivars, Mauritius and Floridian. Pollination rate followed a consistent pattern: it was low during the first male flowering (M1) of Mauritius and reached a high value when the pseudo hermaphrodite flowering (M2) of Mauritius started. Pollen density on bees collected from Mauritius inflorescences was very low during M1 flowering and increased to very high values during M2 flowering. These results indicate that the Mauritius M1 flowering does not play an important role as a source of pollen for pollination. Significant and consistent differences in nectar volume per flower and sugar concentration in the nectar were found between M1, M2 and female Mauritius (F) flowers. These values were very high in F flowers, medium in M2 flowers and low in M1 flowers. Accordingly, the density of bees found on inflorescences was high during F flowering, intermediate during M2 flowering and low during M1 flowering **(Stern and Gazit, 1996)**.

Kumar *et al.* (1996) studied the foraging activity of *A. cerana indica*, *A. mellifera*, *A. dorsata* and *A. florea* on *Litchi chinensis* flowers at Bihar, India, from 7th to 31st March. Observations recorded on alternate day from 0800 hours to 1600 hours revealed that *A. cerana indica* was the most dominant insect forager while the lowest foraging activity was shown by *A. mellifera*. The foraging rate of *A. cerana indica* was maximum on 15th March, when the temperature ranged from 16.0 to 34.4°C with a relative humidity of 58% at 0700 hours and 29% at 1400 hours. *A. dorsata* had the next best foraging rate followed by *A. florea*. The number of visits per minute of *A. cerana indica* was positively correlated with temperature.

The pollen load of bees, visiting litchi inflorescences was weighed. The weight of pollen carried by bees of four *Apis* species was correlated significantly and positively with body weight. The weight of the average pollen load was 14.2 mg for *A. dorsata*, 10.7 mg for *A. mellifera*, 8.3 mg for *A. cerana* and 4.2 mg for *A. florea* **(Kitroo and Abrol, 1996)**.

Mahanta and Rahman (1997) reported that bee pollination in litchi crop resulted in yield of 64.45 fruits per branch compared to 56.75 fruits in the case of open pollinated treatment and 26.49 fruits in self pollination. The percent fruit set, weight of fruits and yield per hectare also showed a similar increase. Thus, effective insect pollination is essential for increasing fruit set and yield in litchi crop.

Mishra and Yazdani (1997) have reported that *A. cerana* was the most dominant forager on litchi in Bihar followed by *A. dorsata.* Other visitors included insect species of diptera, hymenoptera and lepidoptera.

Jarlan *et al.* (1997) included the *Eristalis* flies (Syrphidae) among the most efficient pollinators in litchi crop.

Singh *et al.* (1998) observed that *A. florea* was the most abundant followed by *Episyrphus balteatus*, *Mellipona* sp., *A. cerana indica* and *A. mellifera* in litchi. The pollination indices on the basis of their population and foraging behavior were: *A. dorsata* < *A. mellifera* < *Mellipona* sp. < *A. cerana indica* < *Episyrphus balteatus* < *A. florae*. In litchi open pollination increased the number of fruit set as well as yield over self pollination.

Heard (1999) observed the role of non *Apis* bees, *Trigona* sp. in crop pollination of litchi and found *Trigona* sp. as very efficient insect pollinators.

Abrol (1999) observed that *A. dorsata* was the most efficient pollinator of *Litchi chinensis* flowers in India with *A. mellifera*, *A. cerana* and *A. florea* of decreasing importance.

However, **Singh *et al.* (2002)** reported that the maximum number of bee foragers/minute/panicle was recorded in *A. mellifera* (46.51%) followed by *A. cerana indica* (40.28%), *A. dorsata* (9.05%) and *A. florea* (4.16%). The foraging rate (number of flowers visited by bees per minute) was maximum (10.74) in *A. mellifera* followed by *A. cerana indica* (9.30), *A. dorsata* (2.09), and *A. florea* (0.96). The maximum bee foragers/minute/panicle was recorded during 10.30-11.30 h followed by 11.30-12.30 h and the least was recorded at 15.30-16.30 h of the day.

The relative abundance of insect visitors on litchi cv. Shahi was surveyed in Bihar, India. The number of foragers was higher during the early flowering stage than during the mature flower stage of the crop. *A. mellifera* was the most dominant species (35.08%) of insect visitors on litchi followed by *A. cerana indica* (18.64%) and *A. dorsata* (13.38%). Lowest number of *A. florea* (6.20%) individuals was recorded visiting litchi flowers (**Singh *et al.,* 2006**).

Honeybee species *A. dorsata*, *A. mellifera*, *A. cerana indica* and *A. florea* were the most important and efficient pollinators of litchi flowers. They constituted more than 65% of the total pollinating insects **(Abrol, 2006).**

Usha *et al.* (2009) observed a total of 11 insect species visiting litchi flowers belonging to 5 species of diptera, *Melanostoma orientale*, *Syrphus corollae*, *Episyrphus balteatus*, *Eristalis tenax* and *Musca* sp. 5 of Hymenoptera *A. dorsata*, *A. mellifera*, *A. cerana indica*, *Trigona* sp. and *Xylocopa aestuans* and 1 of Coleoptera, *Coccinella septempunctata* The Hymenopterans constituted major group of insects (61.26%), visiting on litchi flowers.

Bhatnagar and Karnatak (2010) studied the impact of day hours and distance of bee hives on the foraging behavior of *A. mellifera*. There was a negative correlation between the distance of litchi tree and abundance of bees. Visitation of *A. mellifera* during morning hours was more than in the evening hours. The foraging rate decreased with the increase in temperature. The maximum foraging rate of *A. mellifera* was at 0900-1100 hr (14.92 flower/min/forager). The total time spent per flower per bee forager was highest (5.83 sec.) in the morning 0900-1100 hr.

Materials and Methods

Chapter 3 MATERIALS AND METHODS

The studies pertaining "Population dynamics of insect pests and pollinators associated with *Litchi chinensis* Sonn." were conducted at Horticulture Research Centre, Patharchatta, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during the period 2011-013.

3.1 Experimental site

3.2 Details of experiments

3.3 Observations

3.3.1 Assessment of incidence and population dynamics of various insect pests

3.3.1.1 Percent leaf infestation by various insect pests

3.3.1.2 Population of insect pests

3.3.2 The diversity and relative abundance of insect pollinators associated with litchi crop

3.4 Statistical analyses

3.1 Experimental site

Pantnagar is located in the sub-tropical zone at 29^0 N latitude and 79.3^0E longitude and at an altitude of 243.8m above the mean sea level in the "Tarai" region of Uttarakhand in Northern India. The location has sub humid tropical climate and is situated in the foot hills of "Shivalik" range of the Himalayas. The meteorological data indicate that the humid climate here is characterized by hot dry summer and cold winter. The temperature rises up to 40.0^0C in summer, while it falls to 2.0^0C in winter. Approximately, 1400 mm mean rainfall has been recorded and relative humidity fluctuate around 90 ± 5 percent during rainy season.

The detailed materials and methods employed for these studies are reported in this chapter objective wise.

3.2 Details of experiments

The experiment was carried out in Randomized Block Design (RBD) to assess leaf infestation and fluctuation in the population of insect pests. Three different orchards of litchi crop cv. Rose Scented were selected for observation. In each orchard three trees were selected randomly (replications) and observations were made at weekly interval by counting total leaves and leaves infested by various insect pests in a twig (30 cm length) in each of the four directions (East, West, North and South).

Characters of different orchards:

Orchards	Spacing of Trees (R×P) (Metre)	Age of trees (Years)	Mode of irrigation	Density
Orchard I	1.0×0.5	10	Flooding	High
Orchard II	8.0×8.0	12	Drip	Low
Orchard III	8.0×8.0	20	Drip	Low

To determine the spectrum of different insect pollinators visiting litchi blossom, systematic survey were carried out on daily basis during the flowering period at Horticulture Research Centre Patharchatta.

3.3 Observations

3.3.1 Assessment of incidence and population dynamics of various insect pests

3.3.1.1 Percent leaf infestation by various insect pests

The observations were recorded for leaf damage. The observations about healthy and infested leaves were taken to compute percentage of infested leaves on number basis. The presence of symptoms was the criterion for separating damaged leaves from healthy ones. The percentage of leaf infestation on the basis of number was calculated by following formula:

$$\text{Percent leaf infestation} = \frac{\text{Number of infested leaves}}{\text{Total leaves}} \times 100$$

3.3.1.2 Population of insect pests

Observations were made to find out fluctuation in the population and peak activity of various insect pests throughout the year. For this experiment, data on the population of various insect pests (adults and immature stages) were recorded at weekly interval. These observations were recorded in the same twigs in which percent infestation was recorded. All pest species were collected and preserved for further identification.

3.3.2 The diversity and relative abundance of insect pollinators associated with litchi crop

To assess the diversity of insect pollinators observations were made in two different directions (East & West) on five trees randomly selected in the orchard. In each direction an inflorescence with bloom was observed for three minutes and the population of different pollinators was counted visually. All pollinator species were collected and preserved for further identification.

The observations on relative abundance as well as weather parameters (temperature & relative humidity) were made at four different day hours (0800, 1100, 0200 and 1700) to evaluate the peak activity of pollinators during the day. The overall peak activity of pollinators during the flowering period was also evaluated by this data.

3.4 Statistical analyses

The data collected from various experiments were subjected to statistical analysis as prescribed for three factorial Randomized Block Design (RBD) at 5% level of significance. This data was also analyzed under multiple linear regression models to establish relationship between population and abiotic factors.

Results and Discussion

This chapter deals with the experimental finding obtained during course of investigation. The data has been analyzed statistically, dully supported by Tables and graphs. The result has been presented experiment wise, along with the discussion.

4.1 Assessment of incidence and population dynamics of various insect pests on litchi leaves

4.1.1a Population dynamics of litchi leaf roller, *Statherotis leucaspis* Meyrick (Lepidoptera: Tortricidae) during 2011-12 and 2012-13

4.1.1a.1 Annual appearing pattern of insect pest

4.1.1a.2 Impact of direction and month on population

4.1.1a.3 Impact of planting system, irrigation methods and plant's age of the orchard on population

4.1.1a.4 Impact of abiotic factors on population

4.1.1b Leaf infestation dynamics of litchi leaf roller, *Statherotis leucaspis* Meyrick (Lepidoptera: Tortricidae) during 2011-12 and 2012-13

4.1.1b.1 Annual appearing pattern of insect pest

4.1.1b.2 Impact of direction and month on leaf infestation

4.1.1b.3 Impact of planting system, irrigation methods and plant's age of the orchard on leaf infestation

4.1.1b.4 Impact of abiotic factors on leaf infestation

4.1.2a Population dynamics of litchi leaf folder, *Dudua aprobola* Meyrick (Lepidoptera: Tortricidae) during 2011-12 and 2012-13

4.1.2a.1 Annual appearing pattern of insect pest

4.1.2a.2 Impact of direction and month on population

4.1.2a.3 Impact of planting system, irrigation methods and plant's age of the orchard on population

4.1.2a.4 Impact of abiotic factors on population

4.1.2b Leaf infestation dynamics of litchi leaf folder, *Dudua aprobola* Meyrick (Lepidoptera: Tortricidae) during 2011-12 and 2012-13

4.1.2b.1 Annual appearing pattern of insect pest

4.1 Assessment of incidence and population dynamics of various insect pests on litchi leaves

4.1.1a Population dynamics of litchi leaf roller, *Statherotis leucaspis* Meyrick (Lepidoptera: Tortricidae) during 2011-12 and 2012-13

The observations on population of litchi leaf roller on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for population of the insect pest are presented in Table 2 and Table 3 for 2011-12 and 2012-13, respectively.

4.1.1a.1 Annual appearing pattern of insect pest

The perusal of the data revealed that population of the insect pest appeared twice during 2011-12 as well as 2012-13. During 2011-12 the population appeared in July (0.3 individuals) and reached to its maximum in September (2.5 individuals). The second appearance of the pest was observed in January (1.0 individual) and maximum population was observed in March (1.5 individuals) (Table 2). Similar pattern was observed during 2012-13, where the population appeared in July (0.8 individuals) and reached to its maximum in September (2.3 individuals). The second appearance of the pest was observed in January (1.5 individual) and maximum population was observed in March (1.9 individuals) (Table 3).

4.1.1a.2 Impact of direction and month on population

During 2011-12, in the first orchard, significantly higher population was recorded in East direction (0.9 individuals) and the minimum population was observed in North direction (0.4 individuals). Significantly higher population was recorded in the month of October (1.6 individuals) and the minimum population was observed in the month of July (0.4 individuals) (Table 2, Fig. 1).

During 2012-13, in the first orchard, significantly higher population was observed in East direction (0.9 individuals) and the minimum population was observed in North direction (0.5 individuals). The population recorded in the month of October (1.7 individuals) was significantly higher than all other months. The minimum population was observed in the month of July (0.3 individuals) (Table 3, Fig. 4).

During 2011-12, in the second orchard, significantly lower population was recorded in North direction (0.8 individuals) than in all other directions. The maximum population was recorded in south direction (1.1 individuals). The population was significantly higher in the month of September (2.9 individuals) which was found at par with the population observed in the month of October (2.8 individuals) and the minimum population was observed in the month of July (0.3 individuals) (Table 2, Fig. 2).

During 2012-13, in the second orchard, population was significantly lower in East direction (1.0 individual). The maximum population was recorded in North direction (1.3 individuals). Significantly higher population was recorded in the month of October (2.8 individuals) and minimum in the month of July (1.0 individuals) (Table 3, Fig. 5).

During 2011-12, in the third orchard, significantly higher population was recorded in the East direction (1.1 individuals). The minimum population was recorded in the West direction (1.0 individual), North direction (1.0 individual) and South direction (1.0 individual). Significantly higher population was recorded in the month of September (3.1 individuals) and it was found at par with the population observed in the month of October (3.0 individuals). The minimum population was observed in the month of July (0.3 individuals) (Table 2, Fig. 3).

During 2012-13, in the third orchard, significantly lower population was recorded in West direction (1.0 individual) and South direction (1.0 individual). The maximum population was recorded in the East direction (1.2 individuals). The population was significantly higher in the month of September (2.8 individuals) and

Table 2: Population of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.9	0.0	0.0	0.6	**0.4**	0.7	0.0	0.0	0.5	**0.3**	0.0	0.5	0.5	0.0	**0.3**	**0.3**	July
August	1.3	0.5	0.5	1.0	**0.8**	1.9	1.6	1.6	1.5	**1.7**	2.1	2.0	2.0	1.6	**1.9**	**1.5**	August
September	2.0	1.2	1.1	1.3	**1.4**	3.1	2.9	2.3	3.4	**2.9**	3.3	3.1	3.0	3.0	**3.1**	**2.5**	September
October	2.7	1.0	0.9	1.8	**1.6**	2.9	2.8	2.3	3.2	**2.8**	3.1	2.9	2.9	2.9	**3.0**	**2.5**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	1.2	0.6	0.5	0.9	**0.8**	1.0	0.9	1.1	0.9	**1.0**	1.2	1.2	1.3	1.2	**1.2**	**1.0**	January
February	1.4	1.1	0.8	1.0	**1.1**	1.4	1.4	1.3	1.5	**1.4**	1.4	1.3	1.4	1.3	**1.4**	**1.3**	February
March	1.7	1.3	1.0	1.4	**1.4**	1.3	1.6	1.5	1.8	**1.6**	1.6	1.5	1.4	1.5	**1.5**	**1.5**	March
Mean	**0.9**	**0.5**	**0.4**	**0.7**	**0.6**	**1.0**	**0.9**	**0.8**	**1.1**	**1.0**	**1.1**	**1.0**	**1.0**	**1.0**	**1.0**	**0.9**	
Sources of variation							CD at 5%						SEm±				
Orchard (O)							0.04						0.01				
Directions (D)							0.04						0.01				
Months (M)							0.08						0.02				
OxD							0.08						0.02				
OxM							0.14						0.05				
DxM							0.16						0.05				
OxDxM							0.28						0.10				

Table 3: Population of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.8	0.0	0.0	0.5	**0.3**	0.8	1.2	1.3	0.5	**1.0**	1.3	0.8	1.3	1.0	**1.1**	**0.8**	July
August	1.0	0.8	0.7	1.0	**0.9**	1.6	1.5	2.3	1.8	**1.8**	1.4	1.2	1.4	1.5	**1.4**	**1.4**	August
September	1.8	1.6	1.2	1.3	**1.5**	2.9	2.3	2.8	2.3	**2.6**	2.8	2.8	2.8	2.8	**2.8**	**2.3**	September
October	2.8	1.7	1.1	1.3	**1.7**	2.8	2.9	3.0	2.3	**2.8**	2.8	1.7	1.9	1.4	**2.0**	**2.1**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	1.6	1.3	0.9	1.2	**1.3**	1.4	1.6	1.6	1.6	**1.6**	1.7	1.5	1.5	1.5	**1.6**	**1.5**	January
February	1.6	1.4	1.2	1.3	**1.4**	1.4	2.2	2.3	2.2	**2.0**	2.2	1.7	2.1	1.7	**1.9**	**1.8**	February
March	1.7	1.5	1.2	1.6	**1.5**	1.5	2.3	2.3	2.2	**2.1**	2.2	2.1	2.3	2.2	**2.2**	**1.9**	March
Mean	**0.9**	**0.7**	**0.5**	**0.7**	**0.7**	**1.0**	**1.2**	**1.3**	**1.1**	**1.1**	**1.2**	**1.0**	**1.1**	**1.0**	**1.1**	**1.0**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.03	0.01
Directions (D)	0.03	0.01
Months (M)	0.06	0.02
OxD	0.06	0.02
OxM	0.10	0.03
DxM	0.12	0.04
OxDxM	0.20	0.07

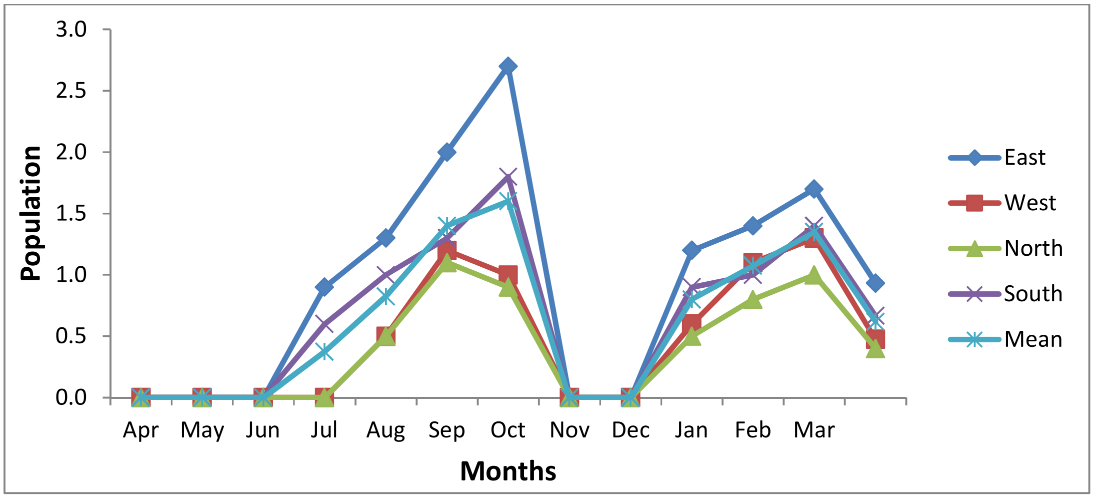

Fig. 1: Population of *Statherotis leucaspis* Meyrick in first orchard during 2011-012

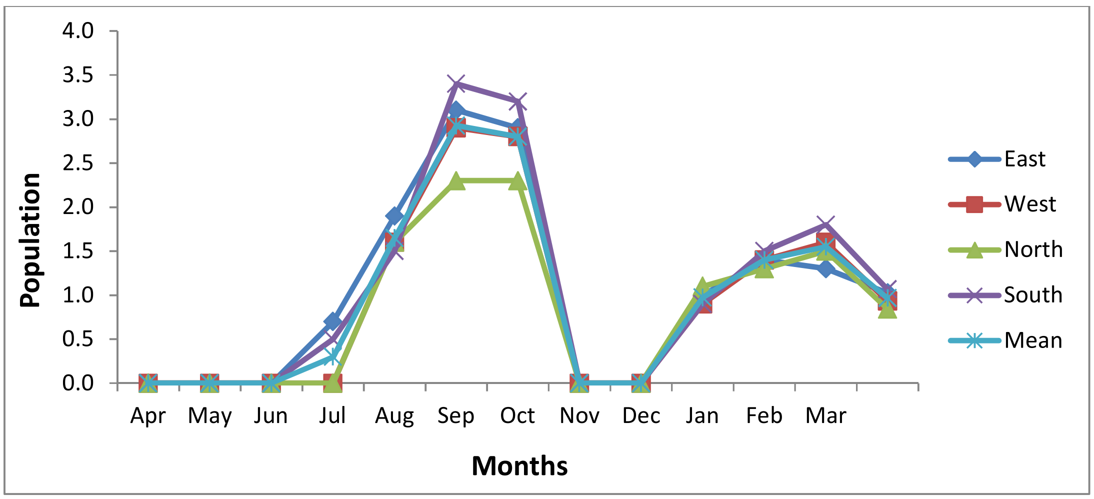

Fig. 2: Population of *Statherotis leucaspis* Meyrick in second orchard during 2011-012

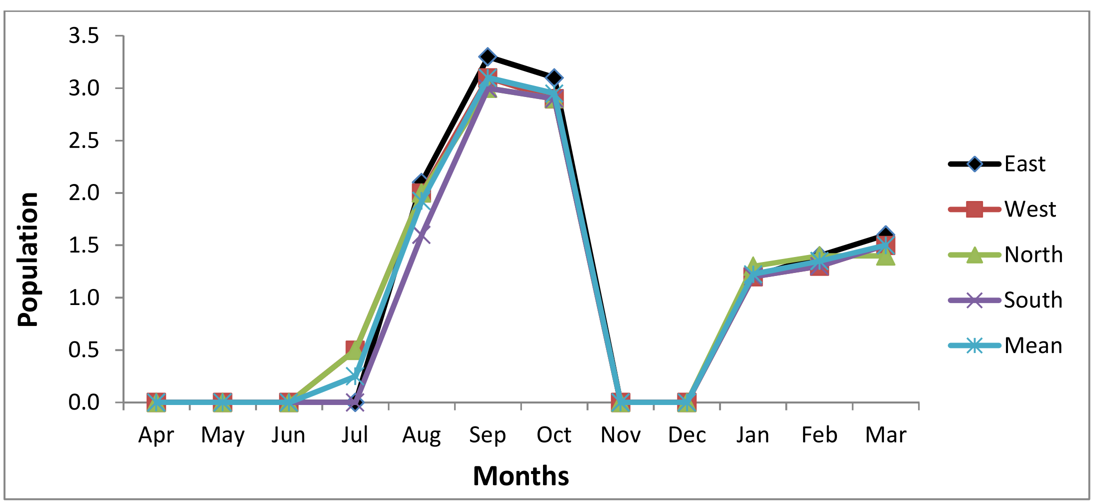

Fig. 3: Population of *Statherotis leucaspis* Meyrick in third orchard during 2011-012

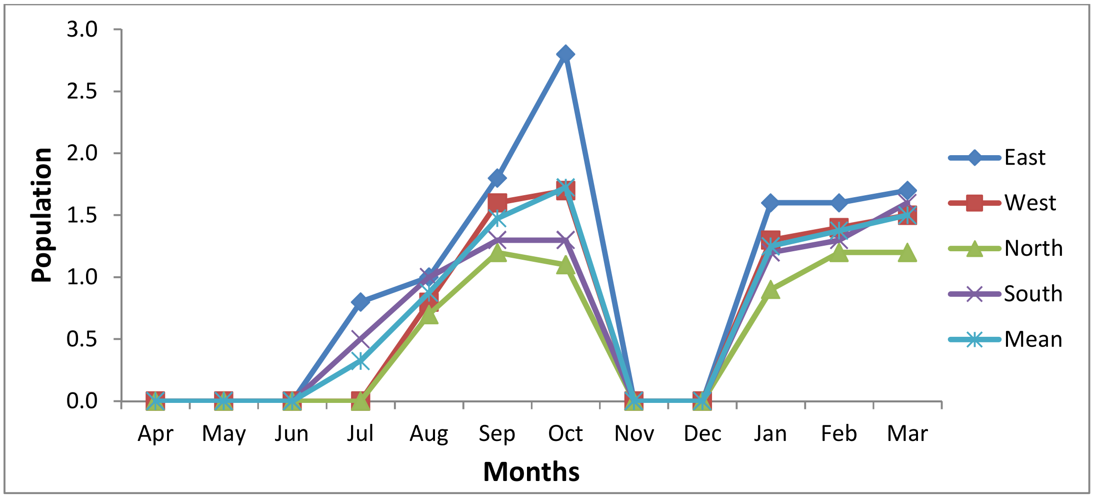

Fig. 4: Population of *Statherotis leucaspis* Meyrick in first orchard during 2012-013

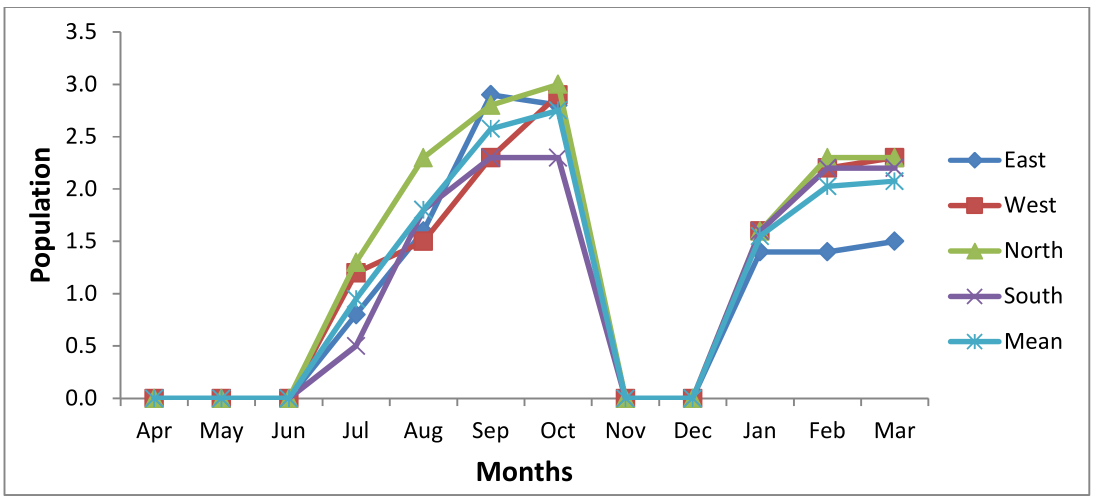

Fig. 5: Population of *Statherotis leucaspis* Meyrick in second orchard during 2012-013

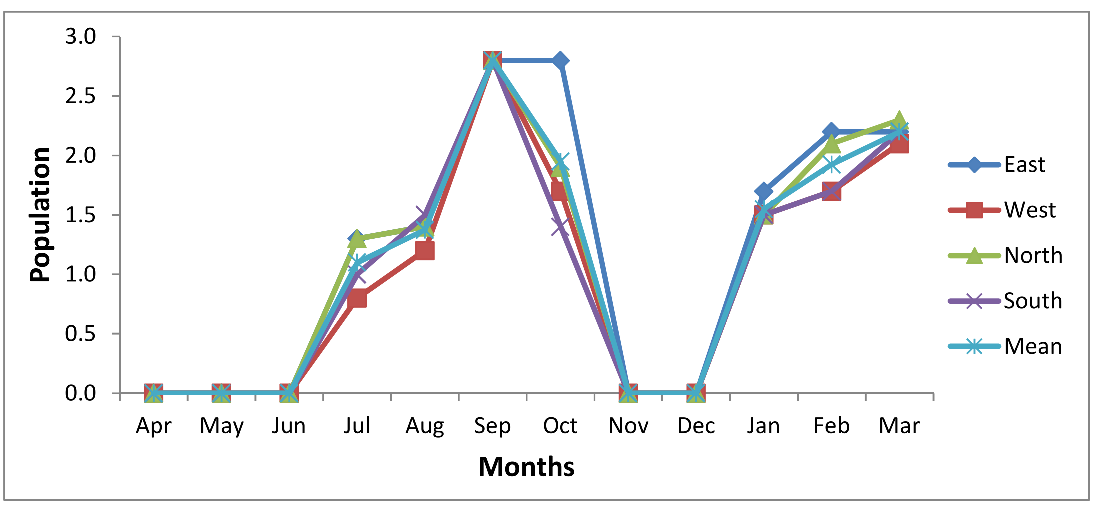

Fig. 6: Population of *Statherotis leucaspis* Meyrick in third orchard during 2012-013

minimum population was observed in the month of July (1.1 individuals) (Table 3, Fig. 6).

4.1.1a.3 Impact of planting system, irrigation methods and plant's age of the orchard on population

During 2011-12, the mean population among three orchards was observed significantly different. It was maximum in the second orchard (1.0 individual) and third orchard (1.0 individual) and minimum was recorded in first orchard (0.6 individuals) (Table 2). Similar pattern for the population among the orchards was observed during 2012-13. It was 1.1 individuals, 1.1 individuals and 0.7 individuals in second, third and first orchard, respectively (Table 3).

During 2011-12, irrespective of orchards, significantly higher population was recorded in East direction (1.0 individual) and it was recorded minimum in West direction (0.8 individuals) and North direction (0.8 individuals) (Table 4).

During 2012-13, irrespective of orchards, significantly higher population was recorded in East direction (1.1 individual) and it was recorded minimum in West direction (0.9 individuals) and South direction (0.9 individuals) (Table 6).

4.1.1a.4 Impact of abiotic factors on population

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on population, all factors were analyzed in the multiple linear regression models.

During 2011-12, the overall contribution of abiotic factors on leaf roller population was 53.4%. In the multiple regression equation the population decreased by 0.13 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 5).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.30 individuals increase in the population (Table 5).

The mean percent population increased by 0.19 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 5).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.07 individuals decrease in the population (Table 5).

The population decreased by 0.01 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 5).

During 2012-13, the overall contribution of abiotic factors on leaf roller population was 67.9%. In the multiple regression equation the population increased by 0.11 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 7).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.05 individuals increase in the population (Table 7).

The population increased by 0.08 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 7).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.05 individuals increase in the population (Table 7).

The mean percent population decreased by 0.03 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 7).

The leaf roller adult laid single egg on mid rib near the petiole of leaf in the ventral surface. When the larva emerged from the egg, it rolled the leaf from one margin towards inside with the help of white sticky secretion. Single larva developed within one rolled leaf. The larva feeds on the inside margin of rolled leaf and it dropped on the ground with the help of a fine thread for pupation.

4.1.1b Leaf infestation dynamics of litchi leaf roller, *Statherotis leucaspis* Meyrick (Lepidoptera: Tortricidae) during 2011-12 and 2012-13

The observations on incidence of litchi leaf roller, *Statherotis leucaspis* (Meyrick) on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for incidence of the insect pest are presented in Table 8 and Table 9 for 2011-12 and 2012-13, respectively.

Table 4: Population of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2011-12

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.5	0.2	0.2	0.4	**0.3**
August	1.8	1.4	1.4	1.4	**1.5**
September	2.8	2.4	2.1	2.6	**2.5**
October	2.9	2.2	2.0	2.6	**2.5**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	1.1	0.9	1.0	1.0	**1.0**
February	1.4	1.3	1.2	1.3	**1.3**
March	1.5	1.5	1.3	1.6	**1.5**
Mean	**1.0**	**0.8**	**0.8**	**0.9**	**0.9**
Sources of variation		CD at 5%		SEm±	
Directions (D)		0.04		0.01	
DxM		0.16		0.05	

Table 5: Impact of abiotic factors on population of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2011-12

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-12.154	-0.134	0.306	0.185	-0.066	-0.013
SE	13.461	0.680	0.650	0.098	0.148	0.015
T- value	-0.903	-0.198	0.471	1.879	-0.448	-0.859
R^2	53.4					

Population (Y) = $-12.154 - 0.134\ X_1 + 0.306\ X_2 + 0.185\ X_3 - 0.066\ X_4 - 0.013\ X_5$

Table 6: Population of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2012-13

Months	**East**	**West**	**North**	**South**	**Mean**
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	1.0	0.7	0.9	0.7	**0.8**
August	1.3	1.2	1.5	1.4	**1.4**
September	2.5	2.2	2.3	2.1	**2.3**
October	2.8	2.1	2.0	1.7	**2.1**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	1.6	1.5	1.3	1.4	**1.5**
February	1.7	1.8	1.9	1.7	**1.8**
March	1.8	2.0	1.9	2.0	**1.9**
Mean	**1.1**	**0.9**	**1.0**	**0.9**	**1.0**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.03	0.01
DxM	0.12	0.04

Table 7: Impact of abiotic factors on population of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2012-13

	Constant	**Temperature (˚C)**		**Relative humidity (%)**		**Rainfall (mm)**
		Maximum	**Minimum**	**0712 hrs**	**1412 hrs**	
		X_1	**X_2**	**X_3**	**X_4**	**X_5**
Co-efficient	-11.815	0.115	0.054	0.075	0.054	-0.031
SE	6.084	0.220	0.216	0.055	0.058	0.018
T- value	-1.942	0.520	0.248	1.365	0.939	-1.685
R^2	67.9					

Population (Y) = $-11.815 + 0.115\ X_1 + 0.054\ X_2 + 0.075\ X_3 + 0.054\ X_4 - 0.031\ X_5$

4.1.1b.1 Annual appearing pattern of insect pest

The perusal of the data revealed that incidence of the insect pest occurred twice during 2011-12 as well as 2012-13. During 2011-12 the incidence was started in July (0.6%) and reached to its maximum in September (11.2%) followed by reduction in incidence during October (10.6%). The second incidence of the pest was started in January (6.3%) and maximum leaf infestation was observed in March (7.4%) (Table 8) with subsequent reduction in infestation during April 2012. Similar pattern was observed during 2012-13, where the incidence was started in July (2.4%) and reached to its maximum in September (10.4%). The second incidence of the pest was started in January (7.7%) and maximum leaf infestation was observed in March (9.3%) (Table 9).

4.1.1b.2 Impact of direction and month on leaf infestation

During 2011-12, in the first orchard, the leaf infestation recorded in East direction (4.3%) was significantly higher than in all other directions (West, North and South). The minimum leaf infestation was observed in North direction (1.9%) which was found at par with the infestation occurred in West direction (2.4%) and South direction (2.6%). Significantly higher leaf infestation was recorded in the month of September (7.4%) which was found at par with the infestation occurred in the month of October (7.0%). Later on, the infestation started to reduce gradually due to decrease in temperature. The minimum leaf infestation was observed in the month of July (1.0%) (Table 8, Fig. 7).

During 2012-13, in the first orchard, significantly higher leaf infestation was recorded in East direction (4.6%) than in all other directions. The minimum leaf infestation was observed in North direction (1.9%). The leaf infestation recorded in the month of October (7.3%) and March (7.3%) was significantly higher which was found at par with the infestation occurred in the month of September (6.9%) and February (6.7%). The minimum leaf infestation was observed in the month of July (0.8%) (Table 9, Fig. 10).

During 2011-12, in the second orchard, significantly lower leaf infestation was recorded in North direction (4.0%) than in all other directions. The maximum leaf infestation was recorded in South direction (5.3%) which was found at par with the infestation occurred in the East direction (4.9%) and West direction (4.9%). The leaf infestation was significantly higher in the month of September (13.1%) which was found at par with the infestation recorded in the month of October (12.7%). The minimum leaf infestation was observed in the month of July (0.5%) (Table 8, Fig. 8).

During 2012-13, in the second orchard, leaf infestation was significantly lower in East direction (4.6%) than in all other directions. The maximum leaf infestation was recorded in North direction (5.9%) which was found at par with the infestation occurred in the West direction (5.6%) and South direction (5.4%). Significantly higher leaf infestation was recorded in the month of October (12.7%) and minimum in the month of July (3.4%) (Table 9, Fig.11).

During 2011-12, in the third orchard, maximum leaf infestation was recorded in the East direction (4.9%) and minimum leaf infestation was recorded in the south direction (4.2%). Significantly higher leaf infestation was recorded in the month of September (13.0%) which was found at par with the infestation occurred in the month of October (12.1%). The minimum leaf infestation was observed in the month of July (0.3%) (Table 8, Fig. 9).

During 2012-13, in the third orchard, significantly lower leaf infestation was recorded in West direction (4.8%) and South direction (4.8%) which was found at par with the infestation occurred in the North direction (5.2%). The maximum leaf infestation was recorded in the East direction (5.5%). The leaf infestation was significantly higher in the month of September (12.2%) which was found at par with the infestation recorded in the month of October (11.1%). The minimum leaf infestation was observed in the month of July (3.1%) (Table 9, Fig. 12).

4.1.1b.3 Impact of planting system, irrigation methods and plant's age of the orchard on leaf infestation

During 2011-12, the mean percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard (4.8%) which was found at par with the infestation recorded in third orchard (4.6%) and minimum was recorded in first orchard (2.8%) (Table 8). Similar pattern for the infestation among the orchards was observed during 2012-13. It was 5.4%, 5.1% and 3.2% in second, third and first orchard, respectively (Table 9).

Table 8: Incidence of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	2.8	0.0	0.0	1.2	**1.0**	1.5	0.0	0.0	0.6	**0.5**	0.0	0.7	0.6	0.0	**0.3**	**0.6**	July
August	4.8	2.3	2.0	4.1	**3.3**	6.9	5.2	6.4	6.6	**6.3**	7.8	7.2	7.7	6.1	**7.2**	**5.6**	August
September	9.8	7.6	5.7	6.5	**7.4**	13.7	13.2	10.8	14.9	**13.1**	14.3	13.2	12.3	12.3	**13.0**	**11.2**	September
October	10.2	5.3	5.7	6.6	**7.0**	12.7	13.1	10.9	13.9	**12.7**	13.3	12.1	11.0	12.0	**12.1**	**10.6**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	7.3	3.8	2.6	2.9	**4.2**	8.1	8.7	6.2	8.6	**7.9**	7.4	6.7	6.7	6.3	**6.8**	**6.3**	January
February	7.9	4.6	3.0	3.9	**4.9**	8.6	8.9	6.8	8.9	**8.3**	7.9	7.6	7.6	6.7	**7.4**	**6.9**	February
March	8.7	5.1	3.4	5.9	**5.8**	7.7	9.1	7.4	9.8	**8.5**	8.4	8.3	7.8	7.3	**7.9**	**7.4**	March
Mean	**4.3**	**2.4**	**1.9**	**2.6**	**2.8**	**4.9**	**4.9**	**4.0**	**5.3**	**4.8**	**4.9**	**4.7**	**4.5**	**4.2**	**4.6**	**4.0**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.40	0.14
Directions (D)	0.46	0.16
Months (M)	0.80	0.29
OxD	0.80	0.29
OxM	1.40	0.50
DxM	1.61	0.58
OxDxM	2.80	1.00

Table 9: Incidence of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	2.4	0.0	0.0	0.7	**0.8**	2.6	5.6	3.6	1.7	**3.4**	3.8	2.1	3.6	2.7	**3.1**	**2.4**	July
August	3.9	2.8	1.9	3.4	**3.0**	6.5	8.0	10.8	6.6	**8.0**	7.4	5.1	7.0	5.5	**6.3**	**5.8**	August
September	9.9	8.4	4.4	5.1	**6.9**	11.3	10.9	12.5	13.2	**12.0**	12.6	12.6	11.9	11.7	**12.2**	**10.4**	September
October	11.5	8.5	4.1	5.1	**7.3**	11.3	13.2	13.3	13.0	**12.7**	12.2	10.8	11.2	10.2	**11.1**	**10.4**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	9.0	6.8	3.7	4.7	**6.0**	7.3	9.0	9.3	9.1	**8.7**	9.3	8.0	8.5	8.1	**8.5**	**7.7**	January
February	9.0	7.6	4.3	5.9	**6.7**	7.9	10.0	10.1	10.0	**9.5**	10.0	9.2	9.7	9.1	**9.5**	**8.6**	February
March	9.5	8.4	4.7	6.5	**7.3**	8.6	10.7	11.0	10.7	**10.3**	10.6	9.9	10.8	10.2	**10.4**	**9.3**	March
Mean	**4.6**	**3.5**	**1.9**	**2.6**	**3.2**	**4.6**	**5.6**	**5.9**	**5.4**	**5.4**	**5.5**	**4.8**	**5.2**	**4.8**	**5.1**	**4.5**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.29	0.10
Directions (D)	0.33	0.11
Months (M)	0.58	0.20
OxD	0.58	0.20
OxM	1.00	0.35
DxM	1.15	0.41
OxDxM	1.99	0.71

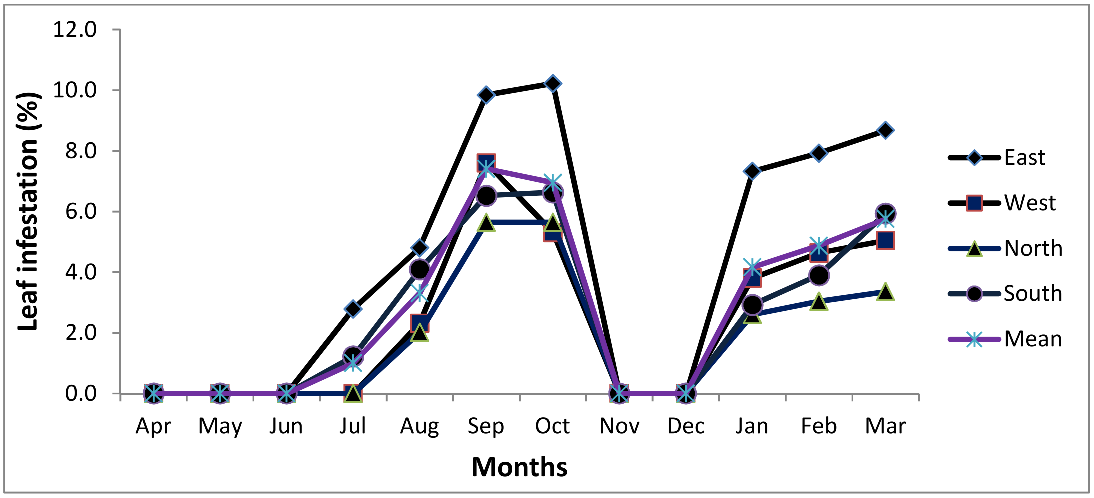

Fig. 7: Incidence of *Statherotis leucaspis* Meyrick in first orchard during 2011-012

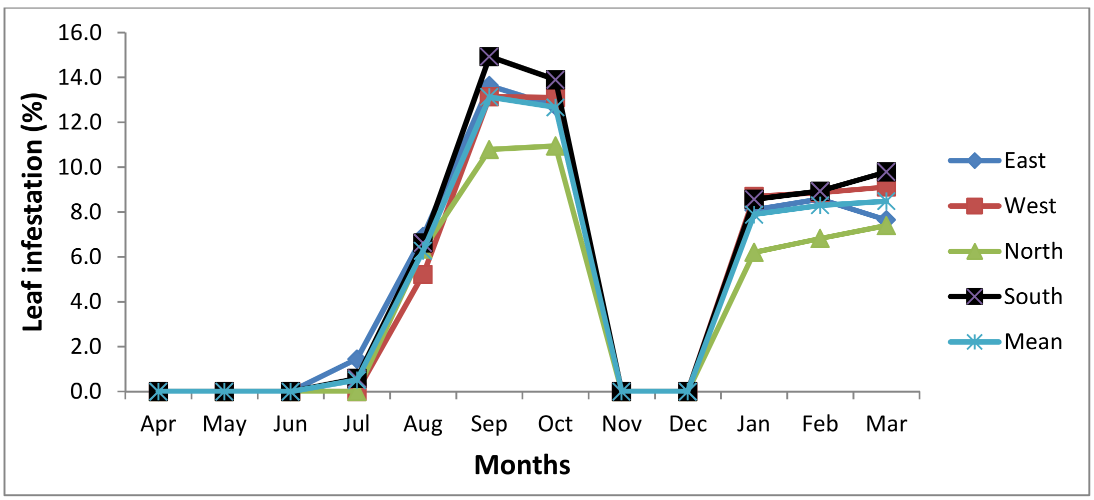

Fig. 8: Incidence of *Statherotis leucaspis* Meyrick in second orchard during 2011-012

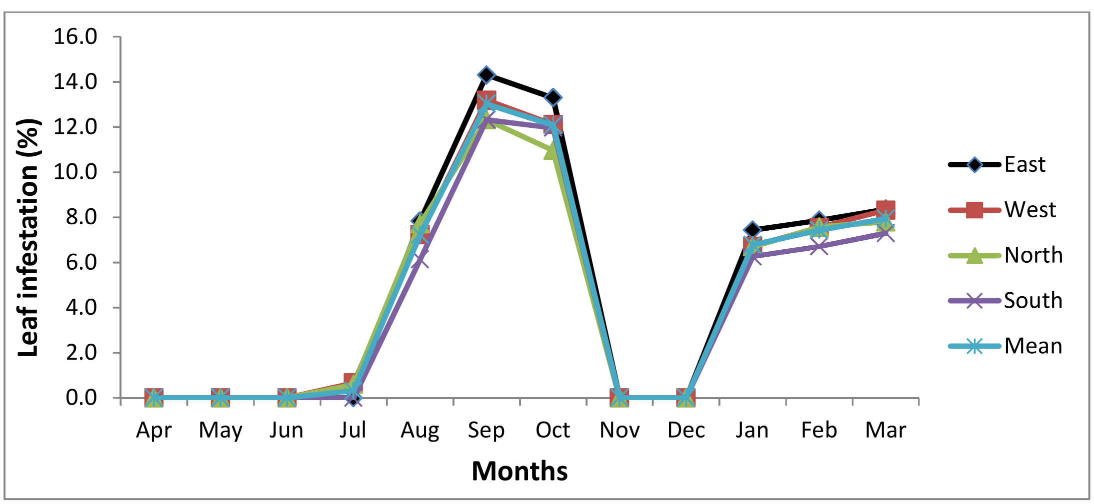

Fig. 9: Incidence of *Statherotis leucaspis* Meyrick in third orchard during 2011-012

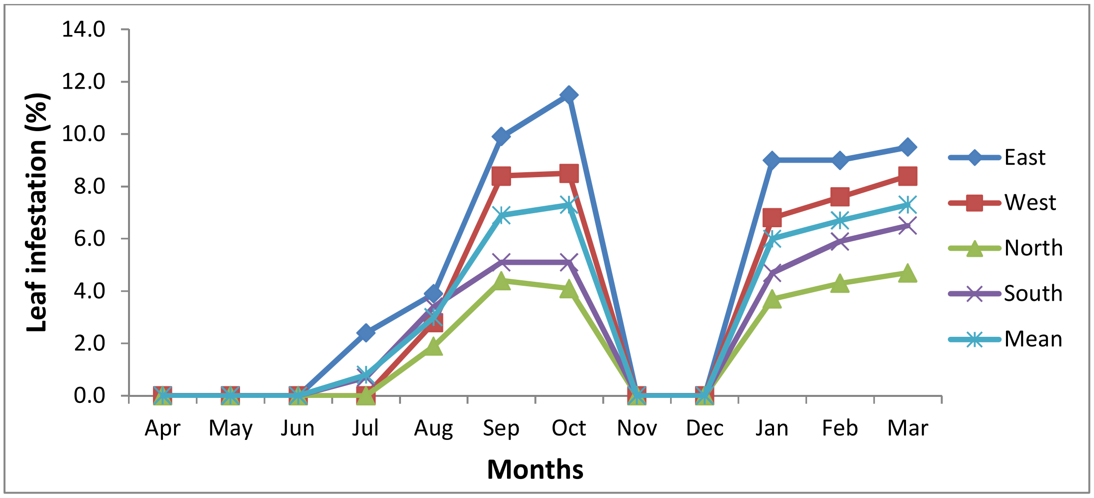

Fig. 10: Incidence of *Statherotis leucaspis* Meyrick in first orchard during 2012-013

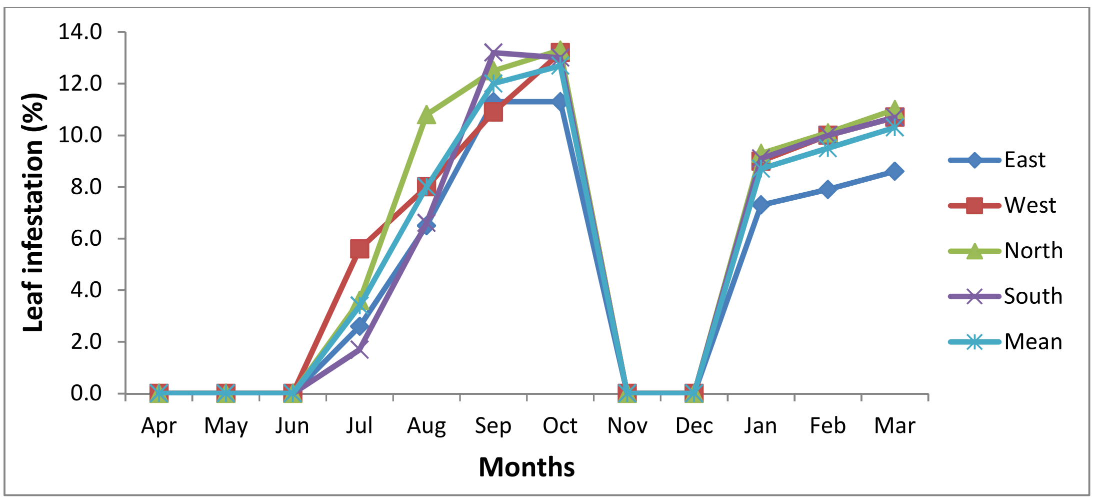

Fig. 11: Incidence of *Statherotis leucaspis* Meyrick in second orchard during 2012-013

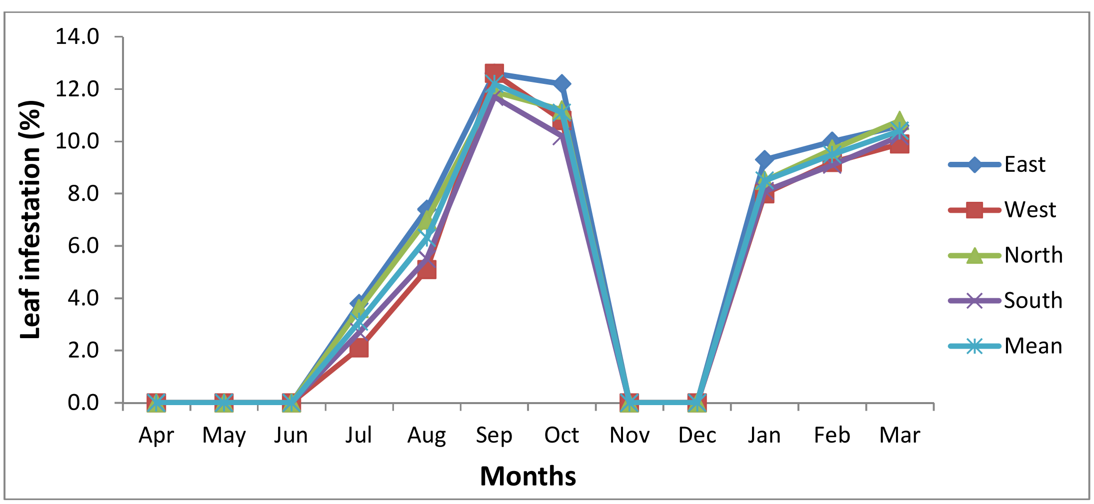

Fig. 12: Incidence of *Statherotis leucaspis* Meyrick in third orchard during 2012-013

During 2011-12, irrespective of orchards, significantly higher leaf infestation was recorded in East direction (4.7%) and it was recorded minimum in North direction (3.5%). Significantly higher leaf infestation was recorded in the month of September in all the four directions (East, West, North and South). It was found at par with infestation occurred in the month of October. The minimum leaf infestation was observed in the month of July (Table 10).

During 2012-13, leaf infestation was significantly lower in North direction (4.3%) and south direction (4.3%). The maximum leaf infestation was recorded in East direction (4.9%) which was found at par with infestation recorded in the West direction (4.7%). In the East direction, significantly higher leaf infestation was recorded in the month of October (11.7%) and minimum leaf infestation was recorded in the month of July (2.9%). In the West direction, leaf infestation recorded in the month of October (10.8%) was significantly higher and was found at par with the infestation occurred in the month of September (10.6%). The minimum leaf infestation was recorded in the month of July (2.6%). In the North direction, significantly lower leaf infestation was recorded in the month of July (2.4%). The maximum leaf infestation was recorded in the month of September (9.6%) which was found at par with the infestation occurred in the month of October (9.5%) and March (8.8%). In the South direction, significantly higher leaf infestation was recorded in the month of September (10.0%) which was found at par with the infestation occurred in the month of October (9.5%) and March (9.1%). The minimum leaf infestation was recorded in the month of July (1.7%) (Table 12).

4.1.1b.4 Impact of abiotic factors on leaf infestation

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on leaf infestation, all factors were analyzed in the multiple linear regression models.

During 2011-12, the value of coefficient of determination (R^2 = 48.1%) indicated the contribution of abiotic factors in leaf roller incidence. In the multiple regression equation the mean percent leaf infestation decreased by 1.07% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 11).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 1.69% increase in the mean percent leaf infestation (Table 11).

The mean percent leaf infestation increased by 0.81% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 11).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.37% decrease in the mean percent leaf infestation (Table 11).

The mean percent leaf infestation decreased by 0.07% with every unit increase (1mm) in rainfall, while other variables as constant (Table 11).

During 2012-13, the value of coefficient of determination (R^2 =66.0%) indicated the contribution of abiotic factors in leaf roller incidence. In the multiple regression equation the mean percent leaf infestation increased by 0.52% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 13).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.27% increase in the mean percent leaf infestation (Table 13).

The mean percent leaf infestation increased by 0.35% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 13).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.26% increase in the mean percent leaf infestation (Table 13).

The mean percent leaf infestation decreased by 0.16% with every unit increase (1mm) in rainfall, while other variables as constant (Table 13).

The probable reason for less infestation in the first orchard might be the high density of plants and irrigation pattern *i.e.* flooding mode of water application. Flooding might created unfavorable conditions for pupal development because the pupation site of larva was under the plant debris, no larva was observed pupating inside the rolled leaf.

Table 10: Incidence of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2011-12

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	1.4	0.2	0.2	0.6	**0.6**
August	6.5	4.9	5.4	5.6	**5.6**
September	12.6	11.3	9.6	11.3	**11.2**
October	12.1	10.2	9.2	10.8	**10.6**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	7.6	6.4	5.2	5.9	**6.3**
February	8.1	7.0	5.8	6.5	**6.9**
March	8.2	7.5	6.2	7.7	**7.4**
Mean	**4.7**	**4.0**	**3.5**	**4.0**	**4.0**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.46	0.16
DxM	1.61	0.58

Table 11: Impact of abiotic factors on litchi leaf roller, *Statherotis leucaspis* Meyrick incidence during 2011-12

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-40.662	-1.070	1.698	0.815	-0.372	-0.069
SE	64.336	3.248	3.106	0.470	0.706	0.074
T- value	-0.632	-0.329	0.546	1.735	-0.527	-0.926
R^2	48.1					

Mean percent leaf infestation (Y) = $-40.662 - 1.070 X_1 + 1.698 X_2 + 0.815 X_3 - 0.372 X_4 - 0.069 X_5$

Table 12: Incidence of litchi leaf roller, *Statherotis leucaspis* Meyrick during 2012-13

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	2.9	2.6	2.4	1.7	**2.4**
August	5.9	5.3	6.6	5.2	**5.8**
September	11.3	10.6	9.6	10.0	**10.4**
October	11.7	10.8	9.5	9.5	**10.4**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	8.5	8.0	7.2	7.3	**7.7**
February	9.0	8.9	8.0	8.3	**8.6**
March	9.6	9.7	8.8	9.1	**9.3**
Mean	**4.9**	**4.7**	**4.3**	**4.3**	**4.5**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.33	0.11
DxM	1.15	0.41

Table 13: Impact of abiotic factors on litchi leaf roller, *Statherotis leucaspis* Meyrick incidence with abiotic factors (2012-13):

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-56.261	0.525	0.279	0.358	0.261	-0.167
SE	30.109	1.090	1.067	0.270	0.285	0.090
T- value	-1.869	0.482	0.261	1.324	0.916	-1.855
R^2	66.0					
Mean percent leaf infestation (Y) = -56.261 +0.525 X_1 +0.279 X_2 +0.358 X_3 +0.261 X_4 -0.167 X_5						

Plate 1: Symptoms of *Statherotis leucaspis* infestation on litchi leaves

Plate 2: Egg laying site of *S. leucaspis*

Plate 3: Larva of *S. leucaspis*

Plate 4: Adult of *S. leucaspis*

4.1.2a Population dynamics of litchi leaf folder, *Dudua aprobola* Meyrick (Lepidoptera: Tortricidae) during 2011-12 and 2012-13

The observations on population of litchi leaf folder on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for population of the insect pest are presented in Table 14 and Table 15 for 2011-12 and 2012-13, respectively.

4.1.2a.1 Annual appearing pattern of insect pest

The perusal of the data revealed that population of the insect pest appeared once during 2011-12 as well as 2012-13. During 2011-12 the population appeared in August (0.3 individuals) and reached to its maximum in October (0.7 individuals) (Table 14). Similar pattern was observed during 2012-13, where the population appeared in August (0.4 individuals) and reached to its maximum in October (1.0 individuals) (Table 15).

4.1.2a.2 Impact of direction and month on population

During 2011-12, in the first orchard, significantly higher population was recorded in East direction (0.2 individuals) and it was found at par with the population observed in West direction (0.1 individuals) and South direction (0.1 individuals). Population was not observed in North direction. The maximum population was recorded in the month of September (0.4 individuals) and October (0.4 individuals) and minimum population was observed in the month of August (0.3 individuals) (Table 14, Fig.13).

During 2012-13, in the first orchard, maximum population was observed in West direction (0.2 individuals) and South direction (0.2 individuals) and minimum population was observed in East direction (0.1 individuals) and North direction (0.1 individuals). The population recorded in the month of October (0.8 individuals) was significantly higher than all other months. The minimum population was observed in the month of August (0.3 individuals) (Table 15, Fig.16).

During 2011-12, in the second orchard, significantly lower population was recorded in North direction (0.1 individuals) and South direction (0.1 individuals) which was found at par with the population observed in West direction (0.2 individuals). The maximum population was recorded in East direction

(0.3 individuals). The population was significantly higher in the month of October (0.8 individuals) and the minimum population was observed in the month of August (0.4 individuals) (Table 14, Fig. 14).

During 2012-13, in the second orchard, population was significantly lower in North direction (0.1 individuals) which was found at par with the population observed in West direction (0.2 individuals) and South direction (0.2 individuals). The maximum population was recorded in East direction (0.3 individuals). Significantly higher population was recorded in the month of October (1.1 individuals) and minimum in the month of August (0.4 individuals) (Table 15, Fig. 17).

During 2011-12, in the third orchard, maximum population was recorded in the East direction (0.2 individual), West direction (0.2 individual) and South direction (0.2 individuals) and minimum population was recorded in the North direction (0.1 individuals). Significantly higher population was recorded in the month of October (0.9 individuals) and minimum population was observed in the month of August (0.3 individuals) (Table 14, Fig.15).

During 2012-13, in the third orchard, maximum population was recorded in the East direction (0.2 individual), West direction (0.2 individual) and South direction (0.2 individuals) and minimum population was recorded in the North direction (0.1 individuals). The population was significantly higher in the month of October (1.0 individuals) and minimum population was observed in the month of August (0.4 individuals) (Table 15, Fig. 18).

4.1.2a.3 Impact of planting system, irrigation methods and plant's age of the orchard on population

During 2011-12, the mean population among three orchards was observed significantly different. It was maximum in the second orchard (0.2 individuals) and third orchard (0.2 individuals) and minimum was recorded in first orchard (0.1 individual) (Table 14). Similar pattern for the population among the orchards was observed during 2012-13 (Table 15).

During 2011-12, irrespective of orchards, significantly higher population was recorded in East direction (0.2 individuals) and it was recorded minimum in West direction (0.1 individual), South direction (0.1 individuals) and North direction (0.1

Table 14: Population of litchi leaf folder, *Dudua aprobola* Meyrick during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.6	0.3	0.0	0.2	**0.3**	0.8	0.4	0.2	0.3	**0.4**	0.3	0.5	0.2	0.3	**0.3**	**0.3**	August
September	0.8	0.4	0.0	0.2	**0.4**	1.0	0.7	0.3	0.4	**0.6**	0.6	0.7	0.5	0.7	**0.6**	**0.5**	September
October	0.8	0.5	0.0	0.4	**0.4**	1.2	0.8	0.3	0.9	**0.8**	1.1	0.8	0.6	0.9	**0.9**	**0.7**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.2**	**0.1**	**0.0**	**0.1**	**0.1**	**0.3**	**0.2**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.1**	**0.2**	**0.2**	**0.1**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.05	0.01
Directions (D)	0.06	0.02
Months (M)	0.10	0.03
OxD	0.10	0.03
OxM	0.18	0.06
DxM	0.21	0.07
OxDxM	0.37	0.13

Table 15: Population of litchi leaf folder, *Dudua aprobola* Meyrick during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.2	0.4	0.2	0.3	**0.3**	0.7	0.4	0.1	0.5	**0.4**	0.6	0.5	0.2	0.4	**0.4**	**0.4**	August
September	0.5	0.7	0.4	0.8	**0.6**	1.0	0.6	0.3	0.6	**0.6**	0.9	0.9	0.5	0.9	**0.8**	**0.7**	September
October	1.0	0.9	0.6	0.8	**0.8**	1.3	1.1	0.7	1.1	**1.1**	1.2	1.2	0.6	1.1	**1.0**	**1.0**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.1**	**0.2**	**0.1**	**0.2**	**0.1**	**0.3**	**0.2**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.1**	**0.2**	**0.2**	**0.2**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.04	0.01
Directions (D)	0.05	0.01
Months (M)	0.10	0.03
OxD	0.10	0.03
OxM	0.15	0.05
DxM	0.17	0.06
OxDxM	0.30	0.11

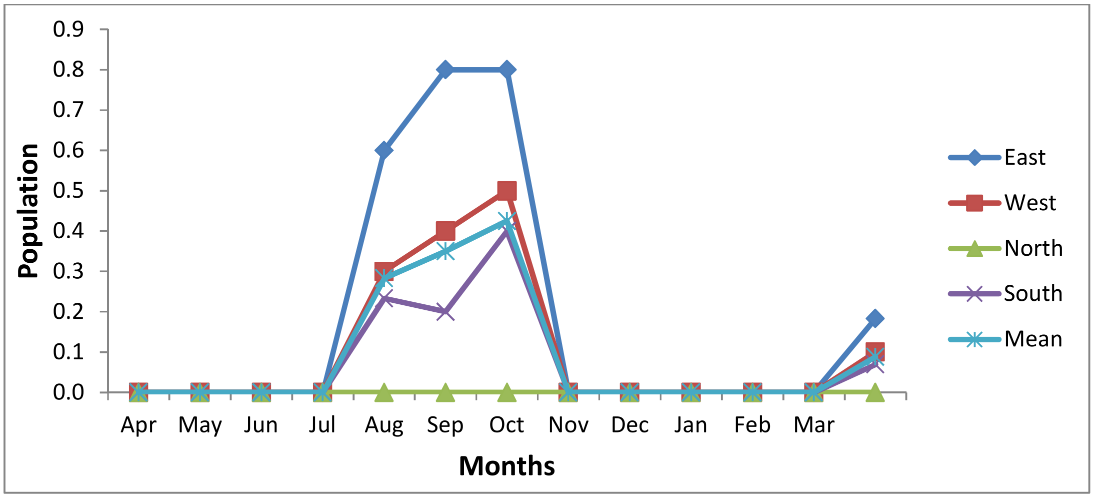

Fig. 13: Population of *Dudua aprobola* Meyrick in first orchard during 2011-012

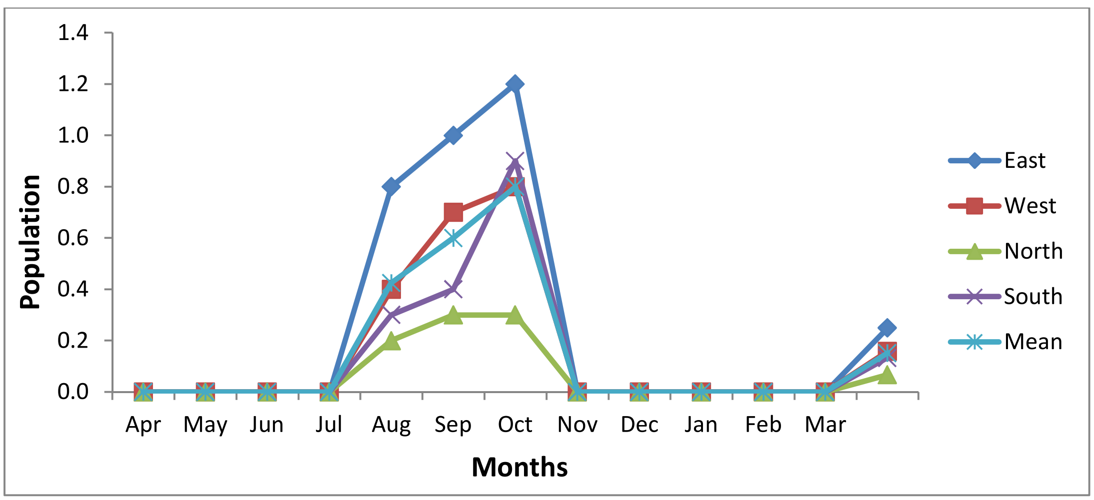

Fig. 14: Population of *Dudua aprobola* Meyrick in second orchard during 2011-012

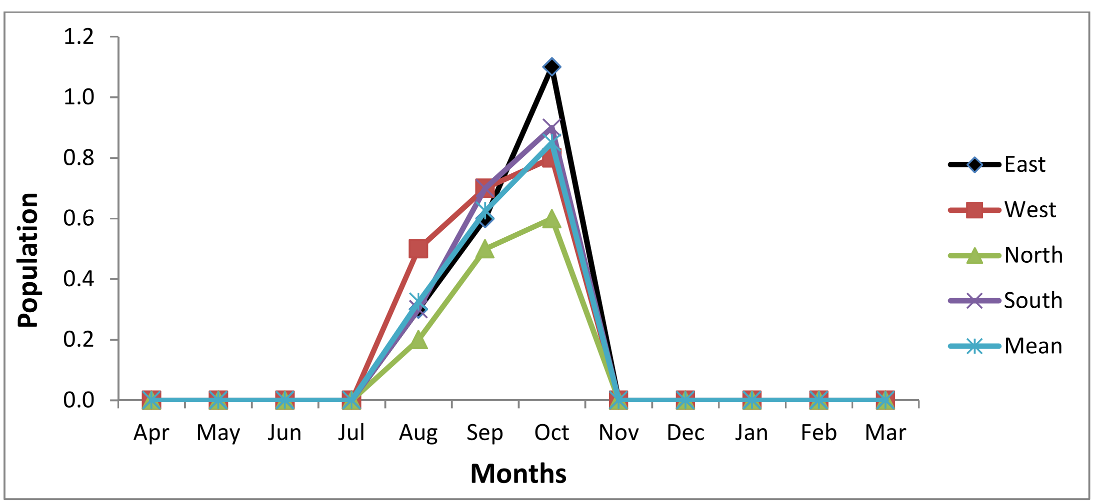

Fig. 15: Population of *Dudua aprobola* Meyrick in third orchard during 2011-012

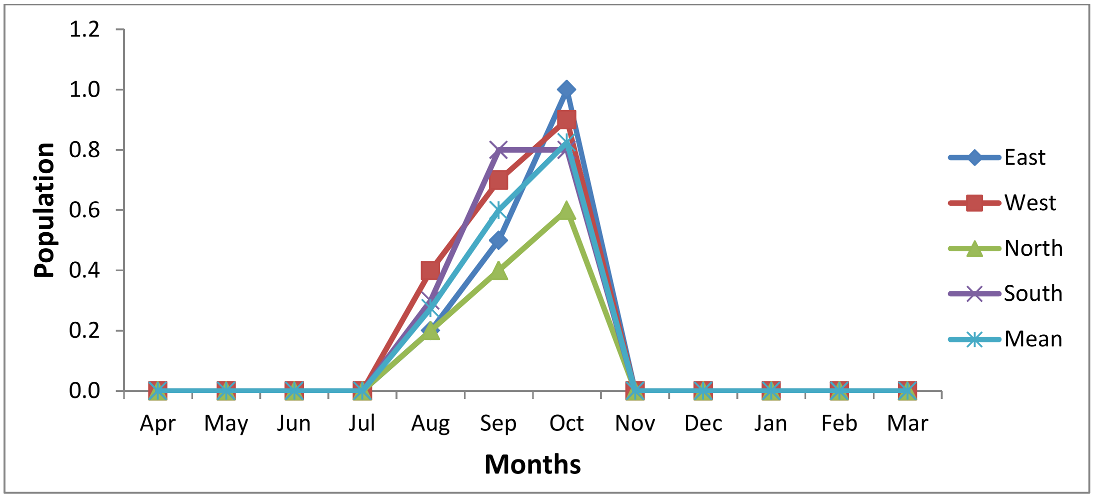

Fig. 16: Population of *Dudua aprobola* Meyrick in first orchard during 2012-013

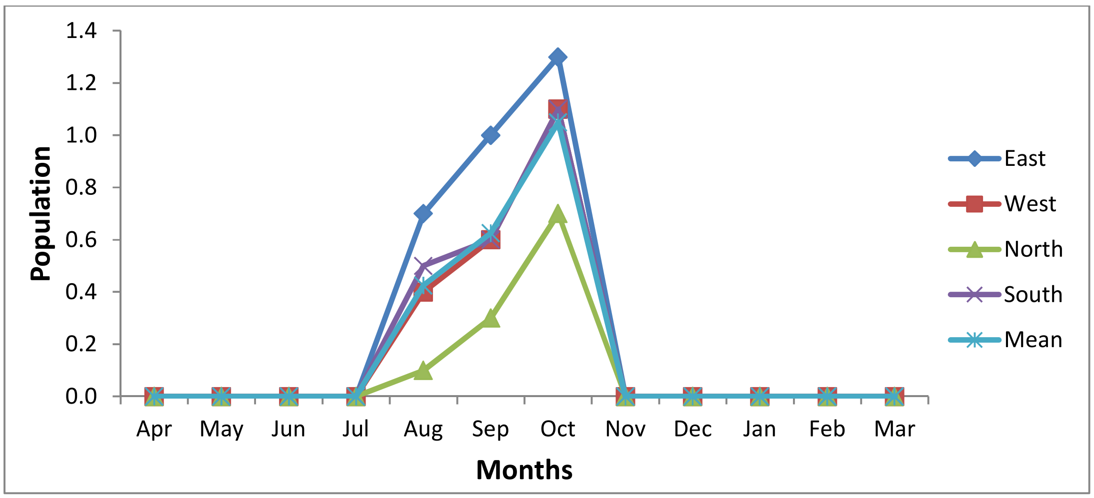

Fig. 17: Population of *Dudua aprobola* Meyrick in second orchard during 2012-013

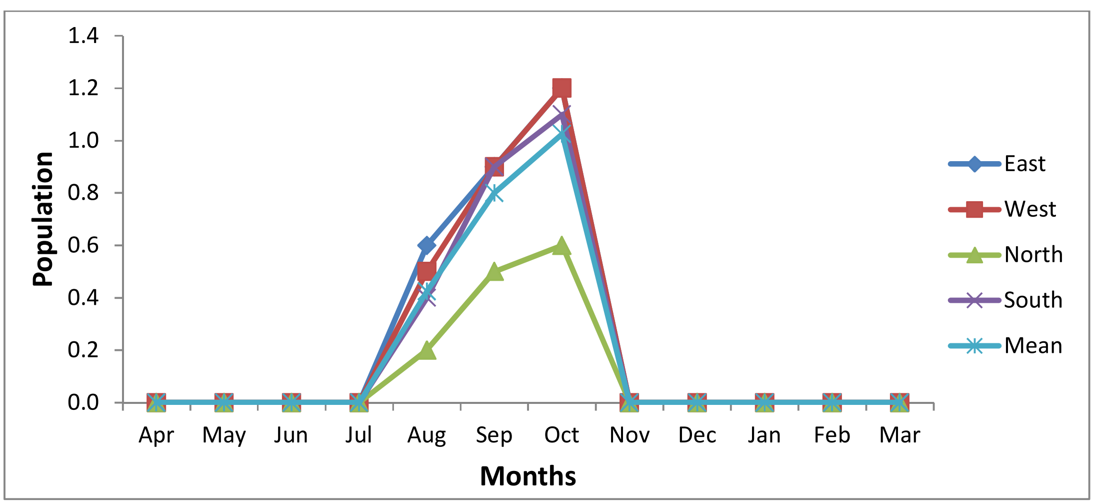

Fig. 18: Population of *Dudua aprobola* Meyrick in third orchard during 2012-013

individual). Significantly higher population was recorded in the month of October in all the four directions (East, West, North and South). The minimum population was observed in the month of August (Table 16).

During 2012-13, irrespective of orchards, significantly higher population was recorded in East direction (0.2 individuals), West direction (0.2 individual) and South direction (0.2 individuals) and it was recorded minimum in North direction (0.1 individual). Significantly higher population was recorded in the month of October in all the four directions (East, West, North and South). The minimum population was observed in the month of August (Table 18).

4.1.2a.4 Impact of abiotic factors on population

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on population, all factors were analyzed in the multiple linear regression models.

During 2011-12, the overall contribution of abiotic factors on leaf folder population was 61.8%. In the multiple regression equation the population increased by 0.08 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 17).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.02 individuals decrease in the population (Table 17).

The mean percent population increased by 0.02 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 17).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.02 individuals increase in the population (Table 17).

The population decreased by 0.003 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 17).

During 2012-13, the overall contribution of abiotic factors on leaf folder population was 60.3%. In the multiple regression equation the population decreased by 0.05 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 19).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.13 individuals increase in the population (Table 19).

The population increased by 0.06 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 19).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.02 individuals decrease in the population (Table 19).

The mean percent population decreased by 0.01 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 19).

The leaf folder adult laid single egg on mid rib or near the mid rib of leaf towards leaf tip in the ventral surface. When the larva emerged from the egg, it folded the leaf from one margin towards mid rib with the help of white sticky secretion. The half of leaf was folded and larva feeds by scrapping the green matter (chlorophyll) in ventral side. Single larva developed within one folded leaf. The pupation site of larva was under the plant debris.

4.1.2b Leaf infestation dynamics of litchi leaf folder, *Dudua aprobola* Meyrick (Lepidoptera: Tortricidae) during 2011-12 and 2012-13

The observations on incidence of litchi leaf folder on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for incidence of the insect pest are presented in Table 20 and Table 21 for 2011-12 and 2012-13, respectively.

4.1.2b.1 Annual appearing pattern of insect pest

The perusal of the data revealed that incidence of the insect pest occurred once during 2011-12 as well as 2012-13. During 2011-12 the incidence was started in August (0.9%) and reached to its maximum in October (1.7%) with subsequent reduction in infestation during November (Table 20). Similar pattern was observed during 2012-13, where the incidence was started in August (0.8%) and reached to its maximum in October (2.2%) (Table 21).

Table 16: Population of litchi leaf folder, *Dudua aprobola* Meyrick during 2011-12

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	0.6	0.4	0.1	0.3	**0.3**
September	0.8	0.6	0.3	0.4	**0.5**
October	1.0	0.7	0.3	0.7	**0.7**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.06	0.02
DxM	0.21	0.07

Table 17: Impact of abiotic factors on litchi leaf folder, *Dudua aprobola* Meyrick population during 2011-12

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-4.547	0.078	-0.023	0.023	0.017	-0.003
SE	3.027	0.153	0.146	0.022	0.033	0.003
T- value	-1.502	0.513	-0.156	1.035	0.504	-0.896
R^2	61.8					

Population (Y) = $-4.547 + 0.078 X_1 - 0.023 X_2 + 0.023 X_3 + 0.017 X_4 - 0.003 X_5$

Table 18: Population of litchi leaf folder, *Dudua aprobola* Meyrick during 2012-13

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	0.5	0.4	0.2	0.4	**0.4**
September	0.8	0.7	0.4	0.8	**0.7**
October	1.2	1.1	0.6	1.0	**1.0**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.2**	**0.2**	**0.1**	**0.2**	**0.2**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.05	0.01
DxM	0.17	0.06

Table 19: Impact of abiotic factors on litchi leaf folder, *Dudua aprobola* Meyrick population during 2012-13

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-3.910	-0.052	0.132	0.057	-0.022	-0.013
SE	2.448	0.089	0.087	0.022	0.023	0.007
T- value	-1.597	-0.587	1.521	2.592	-0.961	-1.764
R^2	60.3					

Population (Y) = $-3.910 - 0.052 X_1 + 0.132 X_2 + 0.057 X_3 - 0.022 X_4 - 0.013 X_5$

4.1.2b.2 Impact of direction and month on leaf infestation

During 2011-12, in the first orchard, the leaf infestation recorded in East direction (0.5%) was significantly higher than in all other directions (West, North and South). Leaf infestation was not occurred in North direction. Significantly higher leaf infestation was recorded in the month of October (1.2%). Later on, the infestation started to reduce gradually due to decrease in temperature. The minimum leaf infestation was observed in the month of August (0.7%) which was found at par with the infestation occurred in the month of September (0.9%) (Table 20, Fig. 19).

During 2012-13, in the first orchard, significantly higher leaf infestation was recorded in West direction (0.4%) which was found at par with the infestation occurred in the East direction (0.3%) and South direction (0.3%). The minimum leaf infestation was observed in North direction (0.2%). Significantly higher leaf infestation was recorded in the month of October (1.8%) and it was minimum in the month of August (0.6%) (Table 21, Fig. 22).

During 2011-12, in the second orchard, significantly lower leaf infestation was recorded in North direction (0.2%) which was found at par with the infestation occurred in the South direction (0.3%). The maximum leaf infestation was recorded in East direction (0.6%) which was found at par with the infestation occurred in the West direction (0.5%). The leaf infestation was significantly higher in the month of October (2.0%) which was found at par with the infestation occurred in the month of September (1.6%) and it was recorded minimum in the month of August (1.1%) (Table 20, Fig. 20).

During 2012-13, in the second orchard, leaf infestation was significantly lower in North direction (0.2%) than in all other directions. The maximum leaf infestation was recorded in East direction (0.6%) which was found at par with the infestation occurred in the South direction (0.5%). Significantly higher leaf infestation was recorded in the month of October (2.5%) and minimum in the month of August (1.0%) (Table 21, Fig. 23).

During 2011-12, in the third orchard, significantly higher leaf infestation was recorded in the East direction (0.5%) which was found at par with the infestation occurred in the West direction (0.4%) and South direction (0.3%). Leaf infestation was minimum in the North direction (0.9%). Significantly higher leaf infestation was recorded in the month of October (1.9%) which was found at par with the infestation occurred in the month of September (1.6%). The minimum leaf infestation was observed in the month of August (0.9%) (Table 20, Fig. 21).

During 2012-13, in the third orchard, significantly lower leaf infestation was recorded in North direction (0.3%) and it was recorded maximum in the East direction (0.5%), West direction (0.5%) and South direction (0.5%). The leaf infestation was significantly higher in the month of October (2.4%) and it was minimum in the month of August (0.9%) (Table 21, Fig. 24).

4.1.2b.3 Impact of planting system, irrigation methods and plant's age of the orchard on leaf infestation

During 2011-12, the mean percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard (0.4%) and third orchard (0.4%) and minimum in the first orchard (0.2%) (Table 20). Similar pattern for the infestation among the orchards was observed during 2012-13. It was 0.4 %, 0.4% and 0.3% in second, third and first orchard, respectively (Table 21).

During 2011-12, irrespective of orchards, significantly higher leaf infestation was recorded in East direction (0.5%) which was found at par with the infestation occurred in the West direction (0.4%) and it was recorded minimum in North direction (0.1%). Significantly higher leaf infestation was recorded in the month of October which was found at par with the infestation occurred in the month of September, in all the four directions (East, West, North and South). The minimum leaf infestation was observed in the month of August (Table 22).

During 2012-13, leaf infestation was significantly lower in North direction (0.2%). The maximum leaf infestation was recorded in East direction (0.5%) which was found at par with the infestation occurred in the West direction (0.4%) and South direction (0.4%). In the East direction, significantly higher leaf infestation was recorded in the month of October (2.8%) and minimum leaf infestation was recorded in the month of August (1.1%). In the West direction, leaf infestation recorded in the month of October (2.5%) was significantly higher and it was minimum in the month of August (1.0%). In the North direction, significantly lower leaf infestation was recorded in the month of August (0.4%) The maximum leaf infestation was recorded

Table 20: Incidence of litchi leaf folder, *Dudua aprobola* Meyrick during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	1.6	0.6	0.0	0.5	**0.7**	1.7	1.3	0.6	0.6	**1.1**	0.8	1.4	0.5	0.7	**0.9**	**0.9**	August
September	2.2	0.8	0.0	0.7	**0.9**	2.4	1.9	0.9	1.1	**1.6**	2.2	1.5	0.9	1.6	**1.6**	**1.4**	September
October	2.4	1.2	0.0	1.2	**1.2**	2.7	2.4	1.1	1.7	**2.0**	2.8	2.0	1.2	1.7	**1.9**	**1.7**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.5**	**0.2**	**0.0**	**0.2**	**0.2**	**0.6**	**0.5**	**0.2**	**0.3**	**0.4**	**0.5**	**0.4**	**0.2**	**0.3**	**0.4**	**0.3**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.13	0.04
Directions (D)	0.16	0.05
Months (M)	0.27	0.09
OxD	0.27	0.09
OxM	0.47	0.16
DxM	0.54	0.19
OxDxM	0.93	0.33

Table 21: Incidence of litchi leaf folder, *Dudua aprobola* Meyrick during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.5	0.9	0.4	0.5	**0.6**	1.5	1.0	0.4	1.1	**1.0**	1.2	1.0	0.5	1.0	**0.9**	**0.8**	August
September	1.1	1.7	1.0	1.3	**1.3**	2.2	1.3	0.9	1.5	**1.5**	1.8	1.9	1.1	2.0	**1.7**	**1.5**	September
October	2.3	2.1	1.3	1.6	**1.8**	3.4	2.6	1.2	2.8	**2.5**	2.7	2.9	1.5	2.5	**2.4**	**2.2**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.3**	**0.4**	**0.2**	**0.3**	**0.3**	**0.6**	**0.4**	**0.2**	**0.5**	**0.4**	**0.5**	**0.5**	**0.3**	**0.5**	**0.4**	**0.4**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.10	0.03
Directions (D)	0.11	0.04
Months (M)	0.19	0.07
OxD	0.19	0.07
OxM	0.33	0.12
DxM	0.38	0.14
OxDxM	0.67	0.24

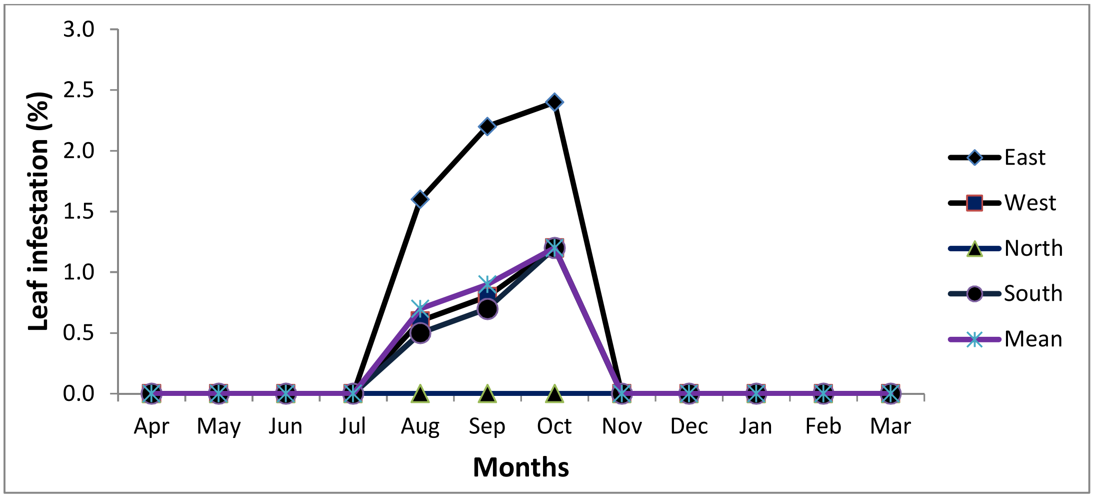

Fig. 19: Incidence of *Dudua aprobola* Meyrick in first orchard during 2011-012

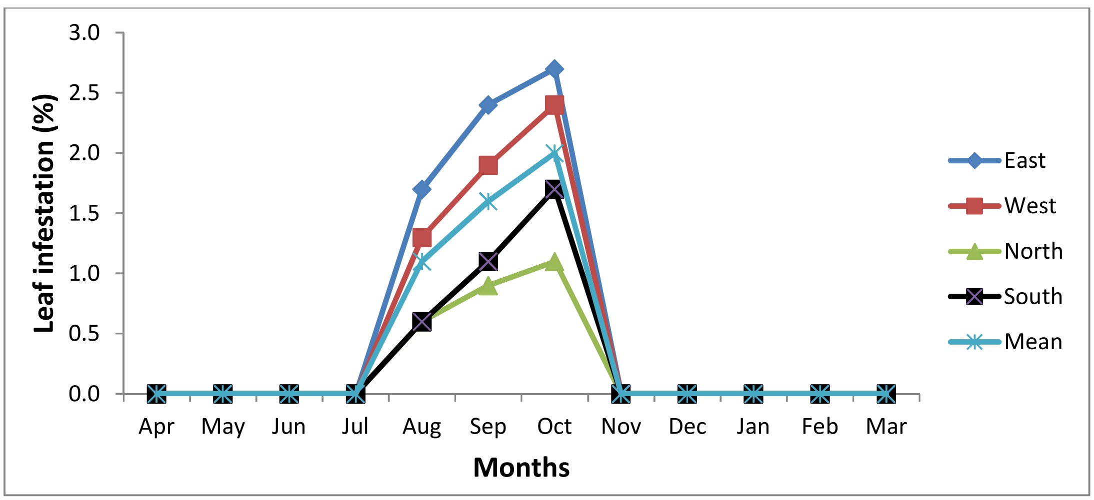

Fig. 20: Incidence of *Dudua aprobola* Meyrick in second orchard during 2011-012

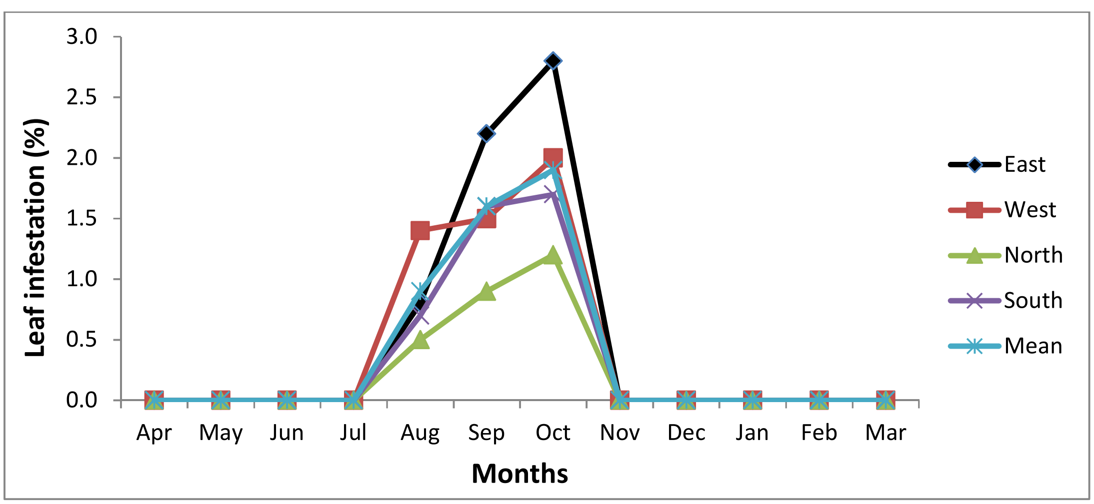

Fig. 21: Incidence of *Dudua aprobola* Meyrick in third orchard during 2011-012

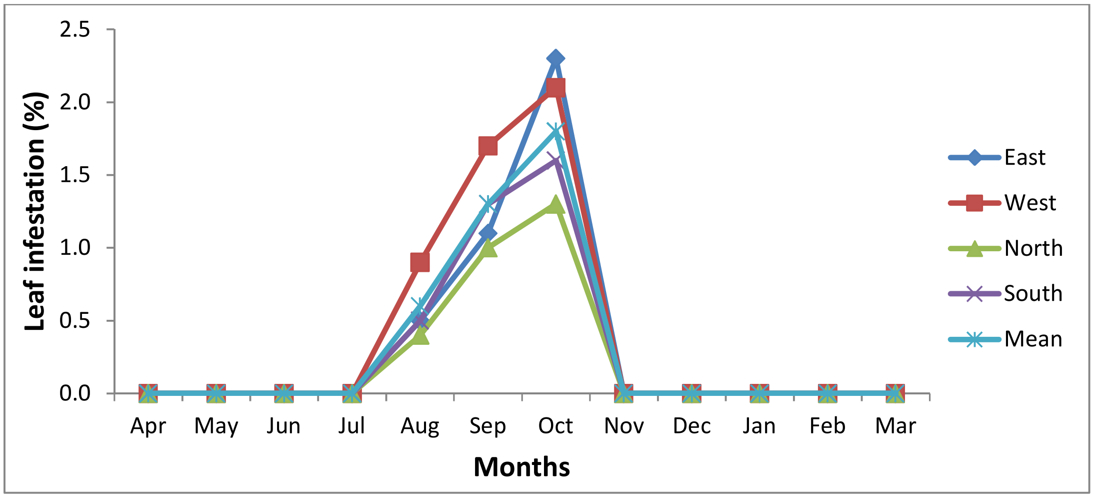

Fig. 22: Incidence of *Dudua aprobola* Meyrick in first orchard during 2012-013

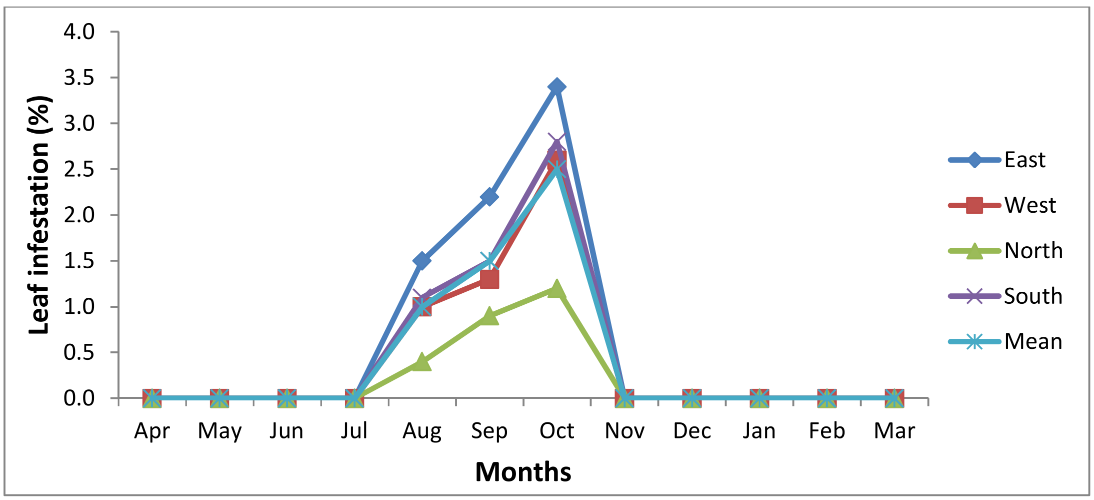

Fig. 23: Incidence of *Dudua aprobola* Meyrick in second orchard during 2012-013

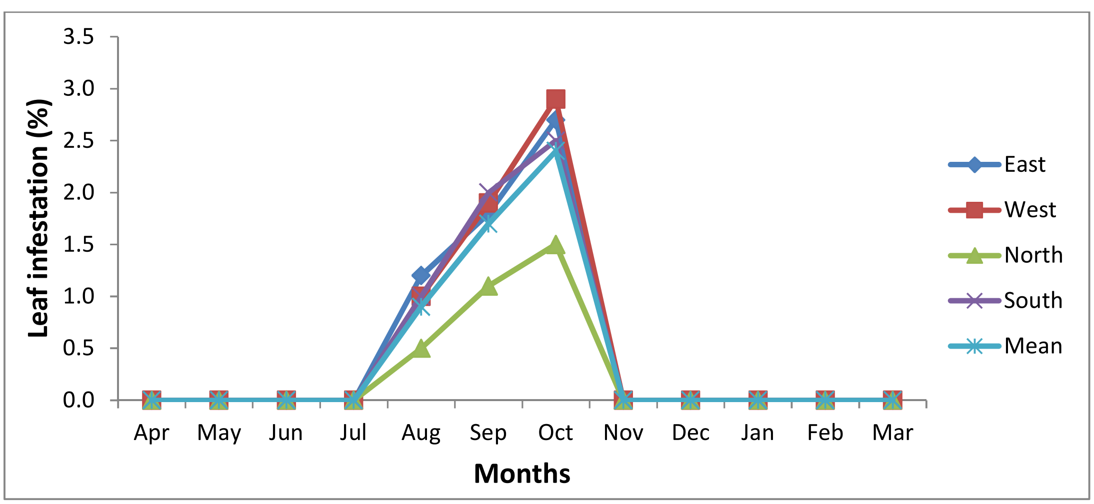

Fig. 24: Incidence of *Dudua aprobola* Meyrick in third orchard during 2012-013

Table 22: Incidence of litchi leaf folder, *Dudua aprobola* Meyrick during 2011-12

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	1.4	1.1	0.4	0.6	**0.9**
September	2.3	1.4	0.6	1.1	**1.4**
October	2.6	1.9	0.8	1.5	**1.7**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.5**	**0.4**	**0.1**	**0.3**	**0.3**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.16	0.05
DxM	0.54	0.19

Table 23: Impact of abiotic factors on litchi leaf folder, *Dudua aprobola* Meyrick incidence with abiotic factors (2011-12):

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-10.922	0.162	-0.024	0.062	0.035	-0.008
SE	7.670	0.387	0.370	0.056	0.084	0.009
T- value	-1.424	0.419	-0.064	1.099	0.417	-0.932
R^2	62.0					

Mean percent leaf infestation (Y) = $-10.922 + 0.162\ X_1 - 0.024\ X_2 + 0.062\ X_3 + 0.035\ X_4 - 0.008\ X_5$

Table 24: Incidence of litchi leaf folder, *Dudua aprobola* Meyrick during 2012-13

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	1.1	1.0	0.4	0.9	**0.8**
September	1.7	1.6	1.0	1.6	**1.5**
October	2.8	2.5	1.3	2.3	**2.2**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.5**	**0.4**	**0.2**	**0.4**	**0.4**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.11	0.04
DxM	0.38	0.14

Table 25: Impact of abiotic factors on litchi leaf folder, *Dudua aprobola* Meyrick incidence with abiotic factors (2012-13)

	Constant	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-8.558	-0.113	0.287	0.125	-0.050	-0.028
SE	5.451	0.197	0.193	0.049	0.052	0.016
T- value	-1.570	-0.572	1.484	2.561	-0.967	-1.721
R^2	59.1					

Mean percent leaf infestation (Y) = $-8.558 -0.113 X_1 +0.287 X_2 +0.125 X_3 -0.050 X_4 -0.028 X_5$

Plate 5 & 6: Symptoms of *Dudua aprobola* infestation on litchi leaves

Plate 7: Larva of *D. aprobola*

Plate 8: Adult of *D. aprobola*

in the month of October (1.3%) which was found at par with the infestation occurred in the month of September (1.0%). In the South direction, significantly higher leaf infestation was recorded in the month of October (2.3%). The minimum leaf infestation was recorded in the month of August (0.9%) (Table 24).

4.1.2b.4 Impact of abiotic factors on leaf infestation

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on leaf infestation, all factors were analyzed in the multiple linear regression models.

During 2011-12, the value of coefficient of determination (R^2 =62.0%) indicated the contribution of abiotic factors in leaf folder incidence. In the multiple regression equation the mean percent leaf infestation increased by 0.16% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 23).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.02% decrease in the mean percent leaf infestation (Table 23).

The mean percent leaf infestation increased by 0.06% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 23).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.03% increase in the mean percent leaf infestation (Table 23).

The mean percent leaf infestation decreased by 0.008% with every unit increase (1mm) in rainfall, while other variables as constant (Table 23).

During 2012-13, the value of coefficient of determination (R^2 =59.1%) indicated the contribution of abiotic factors in leaf folder incidence. In the multiple regression equation the mean percent leaf infestation decreased by 0.11% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 25).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.28% increase in the mean percent leaf infestation (Table 25).

The mean percent leaf infestation increased by 0.12% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 25).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.05% decrease in the mean percent leaf infestation (Table 25).

The mean percent leaf infestation decreased by 0.02% with every unit increase (1mm) in rainfall, while other variables as constant (Table 25).

The probable reason for more infestation in East direction, West direction and South direction might be the availability of comparatively higher number of young leaves than North direction.

4.1.3a Population dynamics of litchi mid rib borer, *Acrocercops cramerella* Snellen (Lepidoptera: Gracillariidae) during 2011-12 and 2012-13

The observations on population of litchi mid rib borer on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for population of the insect pest are presented in Table 26 and Table 27 for 2011-12 and 2012-13, respectively.

4.1.3a.1 Annual appearing pattern of insect pest

The perusal of the data revealed that population of the insect pest appeared once during 2011-12 as well as 2012-13. During 2011-12 the population appeared in August (0.6 individuals) and reached to its maximum in October (1.5 individuals) (Table 26). Similar pattern was observed during 2012-13, where the population appeared in August (0.5 individuals) and reached to its maximum in October (1.0 individuals) (Table 27).

4.1.3a.2 Impact of direction and month on population

Pest population was not observed in the first orchard during 2011-12 and 2012-13 (Table 26, Fig. 25 & 27, Fig. 28).

During 2011-12, in the second orchard, significantly lower population was recorded in North direction (0.3 individuals) and maximum population was recorded in East direction (0.6 individuals). The population was significantly higher in the

Table 26: Population of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.0	0.0	0.0	0.0	**0.0**	1.0	0.9	0.4	1.1	**0.9**	1.4	0.7	0.5	0.9	**0.9**	**0.6**	August
September	0.0	0.0	0.0	0.0	**0.0**	2.6	1.6	1.0	2.3	**1.9**	2.1	1.8	1.2	1.8	**1.7**	**1.2**	September
October	0.0	0.0	0.0	0.0	**0.0**	3.1	2.0	1.6	2.5	**2.3**	2.4	2.2	1.7	2.2	**2.1**	**1.5**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.6**	**0.4**	**0.3**	**0.5**	**0.4**	**0.5**	**0.4**	**0.3**	**0.4**	**0.4**	**0.3**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.04	0.01
Directions (D)	0.04	0.01
Months (M)	0.07	0.02
OxD	0.07	0.02
OxM	0.12	0.04
DxM	0.14	0.05
OxDxM	0.24	0.08

Table 27: Population of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.0	0.0	0.0	0.0	**0.0**	1.2	0.8	0.2	0.5	**0.7**	1.3	0.8	0.3	0.5	**0.7**	**0.5**	August
September	0.0	0.0	0.0	0.0	**0.0**	1.8	1.4	0.3	1.6	**1.3**	1.6	1.2	0.5	1.1	**1.1**	**0.8**	September
October	0.0	0.0	0.0	0.0	**0.0**	2.1	1.7	0.6	2.0	**1.6**	2.0	1.6	0.9	1.3	**1.5**	**1.0**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.4**	**0.3**	**0.1**	**0.3**	**0.3**	**0.4**	**0.3**	**0.1**	**0.2**	**0.3**	**0.19**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.04	0.01
Directions (D)	0.04	0.01
Months (M)	0.07	0.02
OxD	0.07	0.02
OxM	0.13	0.04
DxM	0.15	0.05
OxDxM	0.25	0.09

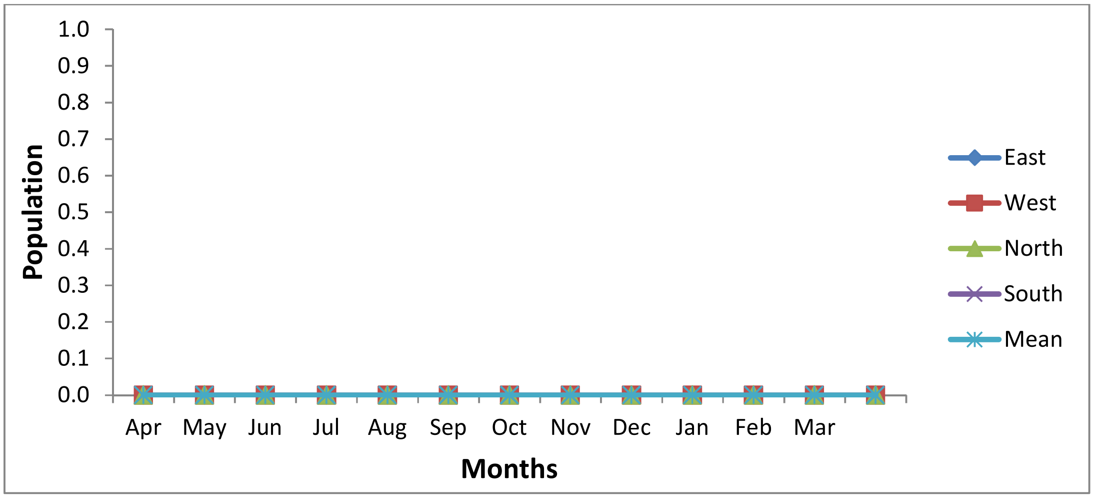

Fig. 25: Population of *Acrocercops cramerella* Snellen in first orchard during 2011-012

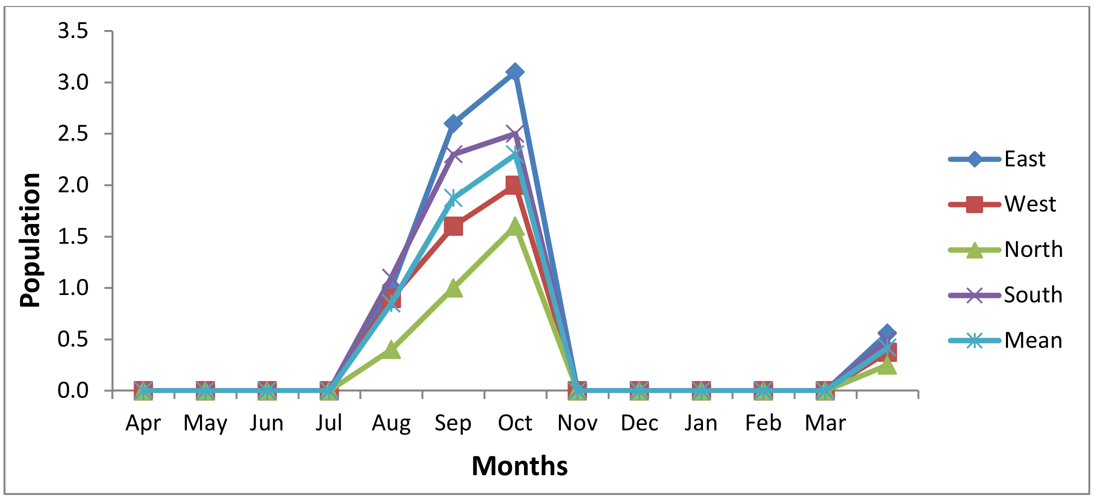

Fig. 26: Population of *Acrocercops cramerella* Snellen in second orchard during 2011-012

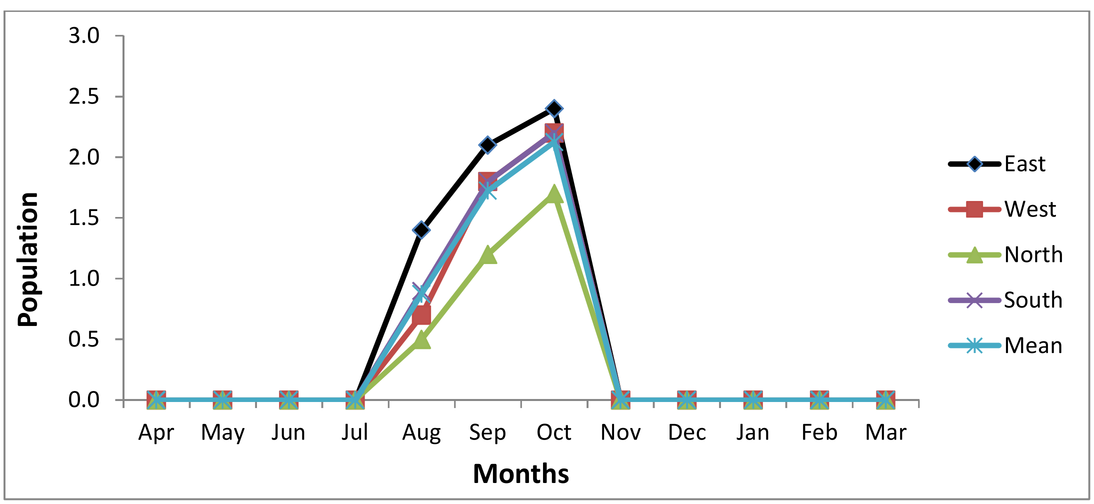

Fig. 27: Population of *Acrocercops cramerella* Snellen in third orchard during 2011-012

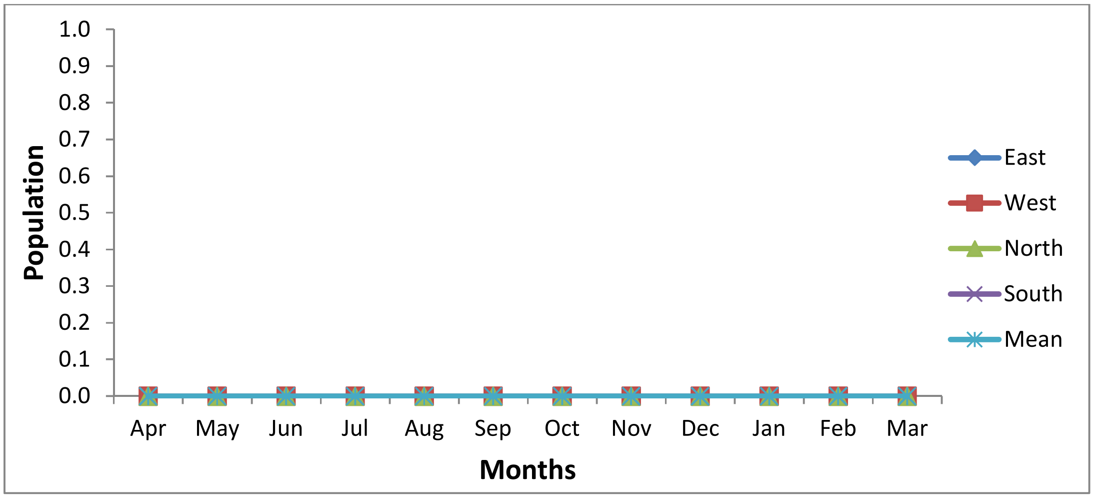

Fig. 28: Population of *Acrocercops cramerella* Snellen in first orchard during 2012-013

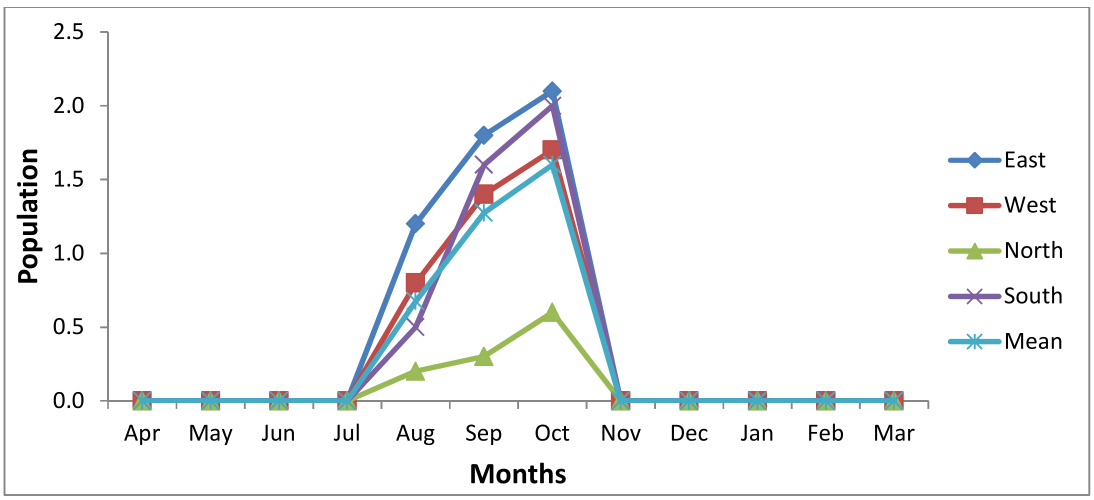

Fig. 29: Population of *Acrocercops cramerella* Snellen in second orchard during 2012-013

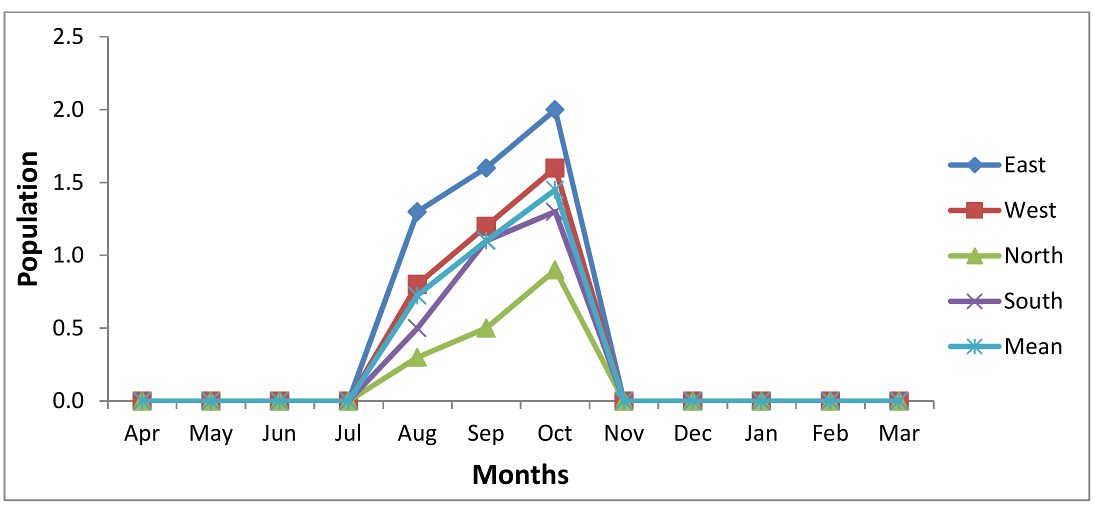

Fig. 30: Population of *Acrocercops cramerella* Snellen in third orchard during 2012-013

month of October (2.3 individuals) and the minimum population was observed in the month of August (0.9 individuals) (Table 26, Fig.26).

During 2012-13, in the second orchard, population was significantly lower in North direction (0.1 individuals) and the maximum population was recorded in East direction (0.4 individuals). Significantly higher population was recorded in the month of October (1.6 individuals) and minimum in the month of August (0.7 individuals) (Table 27, Fig. 29).

During 2011-12, in the third orchard, maximum population was recorded in the East direction (0.5 individual) and minimum population was recorded in the North direction (0.3 individuals). Significantly higher population was recorded in the month of October (2.1 individuals) and minimum population was observed in the month of August (0.9 individuals) (Table 26, Fig. 27).

During 2012-13, in the third orchard, maximum population was recorded in the East direction (0.4 individual) and minimum population was recorded in the North direction (0.1 individuals). The population was significantly higher in the month of October (1.5 individuals) and minimum population was observed in the month of August (0.7 individuals) (Table 27, Fig. 30).

4.1.3a.3 Impact of planting system, irrigation methods and plant's age of the orchard on population

During 2011-12, the mean population among three orchards was observed significantly different. It was maximum in the second orchard (0.4 individuals) and third orchard (0.4 individuals) and population was not observed in first orchard (Table 26). Similar pattern for the population among the orchards was observed during 2012-13. It was 0.3 individuals and 0.3 individuals in second and third orchard (Table 27).

During 2011-12, irrespective of orchards, significantly higher population was recorded in East direction (0.4 individuals) and it was recorded minimum in North direction (0.2 individuals). Significantly higher population was recorded in the month of October in all the four directions (East, West, North and South). The minimum population was observed in the month of August (Table 28). Similar pattern for the population irrespective of the orchards was observed during 2012-13. Where the population was 0.3 individuals and 0.1 individual in East direction and North direction respectively (Table 30).

4.1.3a.4 Impact of abiotic factors on population

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on population, all factors were analyzed in the multiple linear regression models.

During 2011-12, the overall contribution of abiotic factors on mid rib borer population was 64.7%. In the multiple regression equation the population increased by 0.10 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 29).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.02 individuals increase in the population (Table 29).

The mean percent population increased by 0.06 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 29).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.02 individuals increase in the population (Table 29).

The population decreased by 0.009 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 29).

During 2012-13, the overall contribution of abiotic factors on mid rib borer population was 62.5%. In the multiple regression equation the population decreased by 0.06 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 31).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.14 individuals increase in the population (Table 31).

The population increased by 0.06 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 31).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.02 individuals decrease in the population (Table 31).

Table 28: Population of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2011-12

Months	**East**	**West**	**North**	**South**	**Mean**
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	0.8	0.5	0.3	0.7	**0.6**
September	1.6	1.1	0.7	1.4	**1.2**
October	1.8	1.4	1.1	1.6	**1.5**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.4**	**0.3**	**0.2**	**0.3**	**0.3**
Sources of variation		CD at 5%		SEm±	
Directions (D)		0.04		0.01	
DxM		0.14		0.05	

Table 29: Impact of abiotic factors on population of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2011-12

	Constant	**Temperature (˚C)**		**Relative humidity (%)**		**Rainfall (mm)**
		Maximum	**Minimum**	**0712 hrs**	**1412 hrs**	
		X_1	**X_2**	**X_3**	**X_4**	**X_5**
Co-efficient	-8.890	0.104	0.018	0.057	0.024	-0.009
SE	6.372	0.322	0.308	0.047	0.070	0.007
T- value	-1.395	0.322	0.058	1.214	0.341	-1.185
R^2	64.7					

Population (Y) = $-8.890 + 0.104\ X_1 + 0.018\ X_2 + 0.057\ X_3 + 0.024\ X_4 - 0.009\ X_5$

Table 30: Population of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2012-13

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	0.8	0.5	0.2	0.3	**0.5**
September	1.1	0.9	0.3	0.9	**0.8**
October	1.4	1.1	0.5	1.1	**1.0**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.3**	**0.2**	**0.1**	**0.2**	**0.2**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.04	0.01
DxM	0.15	0.05

Table 31: Impact of abiotic factors on population of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2012-13

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-4.170	-0.056	0.143	0.060	-0.023	-0.014
SE	2.531	0.092	0.090	0.023	0.024	0.008
T- value	-1.648	-0.615	1.591	2.645	-0.947	-1.846
R^2	62.5					

Population (Y) = $-4.170 - 0.056 X_1 + 0.143 X_2 + 0.060 X_3 - 0.023 X_4 - 0.014 X_5$

The mean percent population decreased by 0.01 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 31).

The mid rib borer adult laid single egg on mid rib of leaf near the petiole in the ventral surface. When the larva emerged from the egg, it started mining the mid rib and another exit hole was made near the tip of leaf. Single larva developed within one mined mid rib. The pupation site of larva was on the dorsal side of leaf in a fine transparent web like structure.

4.1.3b Leaf infestation dynamics of litchi mid rib borer, *Acrocercops cramerella* Snellen (Lepidoptera: Gracillariidae) during 2011-12 and 2012-13:

The observations on incidence of litchi mid rib borer on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for incidence of the insect pest are presented in Table 32 and Table 33 for 2011-12 and 2012-13, respectively.

4.1.3b.1 Annual appearing pattern of insect pest

The perusal of the data revealed that incidence of the insect pest occurred once during 2011-12 as well as 2012-13. During 2011-12 the incidence was started in August (1.6%) and reached to its maximum in October (4.9%) with subsequent reduction in infestation during November (Table 32). Similar pattern was observed during 2012-13, where the incidence was started in August (1.7%) and reached to its maximum in October (3.0%) (Table 33).

These findings were also in accordance with **Ranjan and Mukherjee (2008)** who reported that the litchi shoot borer activity started on litchi leaves from the month of July and continued till the month of November.

4.1.3b.2 Impact of direction and month on leaf infestation

During 2011-12 as well as 2012-13, leaf infestation was not occurred in the first orchard (Table 32, Fig. 31 & 33, Fig. 34).

During 2011-12, in the second orchard, significantly lower leaf infestation was recorded in North direction (0.7%) than in all other directions. The maximum leaf infestation was recorded in East direction (2.0%). The leaf infestation was significantly higher in the month of October (7.3%) and it was recorded minimum in the month of August (2.3%) (Table 32, Fig. 32).

During 2012-13, in the second orchard, leaf infestation was significantly lower in North direction (0.2%) than in all other directions. The maximum leaf infestation was recorded in East direction (1.7%). Significantly higher leaf infestation was recorded in the month of October (5.2%) and minimum in the month of August (2.8%) (Table 33 , Fig.35).

During 2011-12, in the third orchard, maximum leaf infestation was recorded in the East direction (1.7%) and minimum leaf infestation was recorded in the North direction (0.8%). Significantly higher leaf infestation was recorded in the month of October (7.0%). The minimum leaf infestation was observed in the month of August (2.4%) (Table 32, Fig. 33).

During 2012-13, in the third orchard, significantly lower leaf infestation was recorded in North direction (0.3%) and it was recorded maximum in the East direction (1.3%). The leaf infestation was significantly higher in the month of October (3.9%). The minimum leaf infestation was observed in the month of August (2.2%) (Table 33, Fig. 36).

4.1.3b.3 Impact of planting system, irrigation methods and plant's age of the orchard on leaf infestation

During 2011-12, the mean percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard (1.4%) which was found at par with the infestation recorded in third orchard (1.3%) and no infestation was recorded in first orchard (Table 32). Similar pattern for the infestation among the orchards was observed during 2012-13. It was 1.0 %, 0.8% and 0.0% in second, third and first orchard, respectively (Table 33).

During 2011-12, irrespective of orchards, significantly higher leaf infestation was recorded in East direction (1.3%) and it was recorded minimum in North direction (0.5%). Significantly higher leaf infestation was recorded in the month of October in all the four directions (East, West, North and South). The minimum leaf infestation was observed in the month of August (Table 34).

During 2012-13, leaf infestation was significantly lower in North direction (0.2%). The maximum leaf infestation was recorded in East direction (1.0%). In the East direction, significantly higher leaf infestation was recorded in the month of

Table 32: Incidence of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.0	0.0	0.0	0.0	**0.0**	3.5	2.1	1.0	2.7	**2.3**	3.7	1.9	1.3	2.8	**2.4**	**1.6**	August
September	0.0	0.0	0.0	0.0	**0.0**	9.8	4.6	2.9	7.9	**6.3**	7.9	6.0	3.9	6.4	**6.1**	**4.1**	September
October	0.0	0.0	0.0	0.0	**0.0**	11.2	7.6	4.0	8.6	**7.3**	9.3	6.8	4.4	7.4	**7.0**	**4.9**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.0**	**1.2**	**0.7**	**1.6**	**1.4**	**1.7**	**1.2**	**0.8**	**1.4**	**1.3**	**0.9**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.10	0.03
Directions (D)	0.11	0.04
Months (M)	0.20	0.07
OxD	0.20	0.07
OxM	0.34	0.12
DxM	0.40	0.14
OxDxM	0.69	0.25

Table 33: Incidence of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.0	0.0	0.0	0.0	**0.0**	5.1	4.3	0.5	1.2	**2.8**	4.2	2.8	0.5	1.2	**2.2**	**1.7**	August
September	0.0	0.0	0.0	0.0	**0.0**	7.2	5.6	0.9	3.8	**4.4**	5.1	3.5	1.1	3.5	**3.3**	**2.6**	September
October	0.0	0.0	0.0	0.0	**0.0**	7.9	6.4	1.2	5.1	**5.2**	5.9	4.0	1.8	3.8	**3.9**	**3.0**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.7**	**1.4**	**0.2**	**0.8**	**1.0**	**1.3**	**0.9**	**0.3**	**0.7**	**0.8**	**0.6**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.10	0.03
Directions (D)	0.11	0.04
Months (M)	0.20	0.07
OxD	0.20	0.07
OxM	0.35	0.12
DxM	0.41	0.14
OxDxM	0.71	0.25

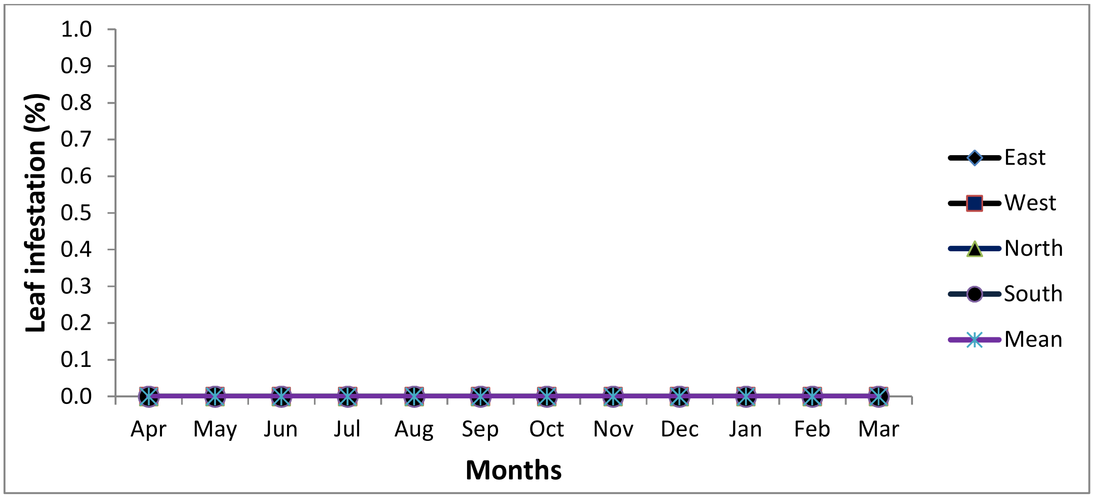

Fig. 31: Incidence of *Acrocercops cramerella* Snellen in first orchard during 2011-012

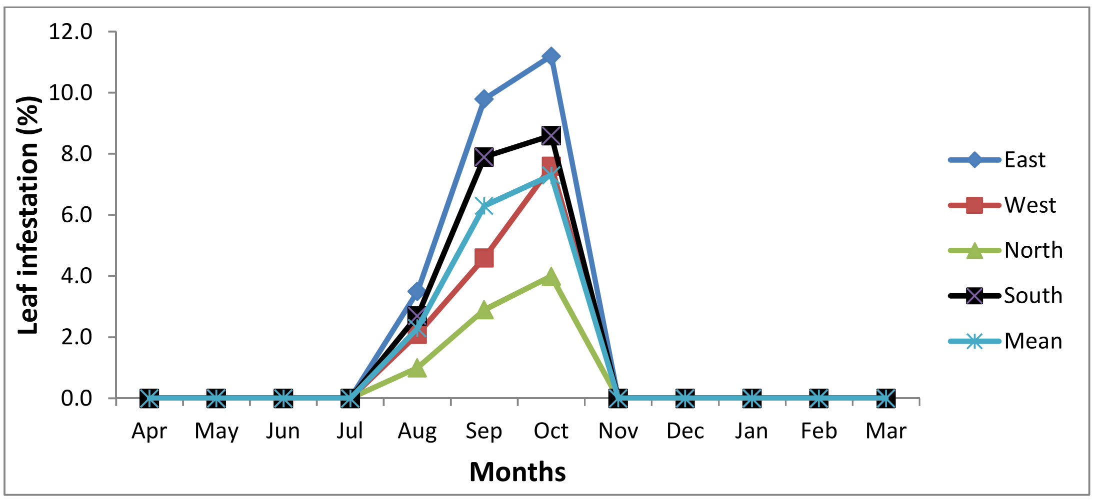

Fig. 32: Incidence of *Acrocercops cramerella* Snellen in second orchard during 2011-012

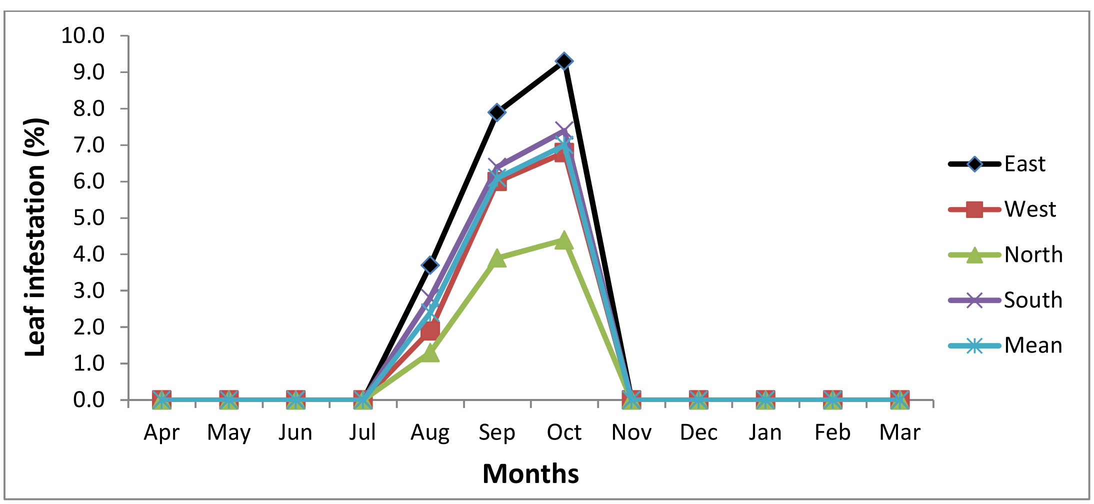

Fig. 33: Incidence of *Acrocercops cramerella* Snellen in third orchard during 2011-012

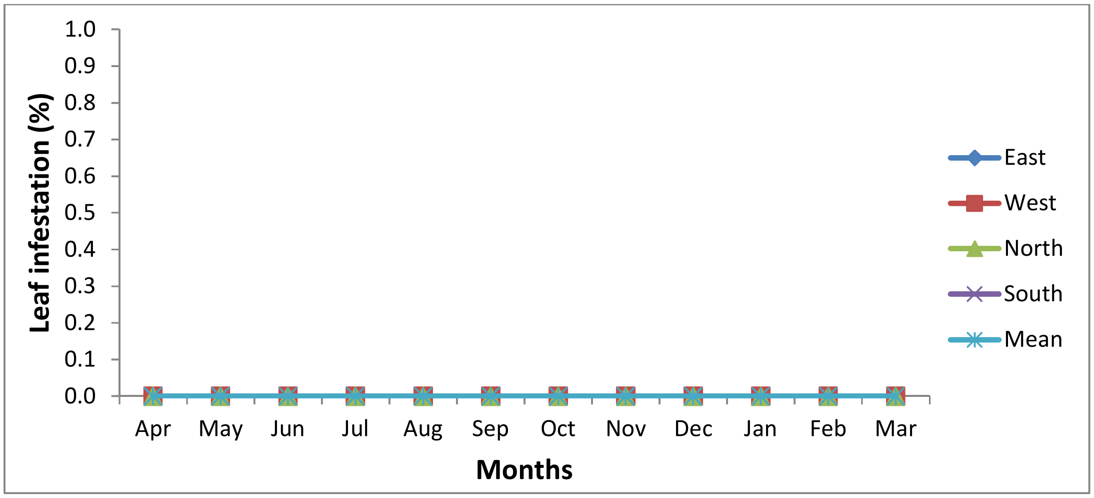

Fig. 34: Incidence of *Acrocercops cramerella* Snellen in first orchard during 2012-013

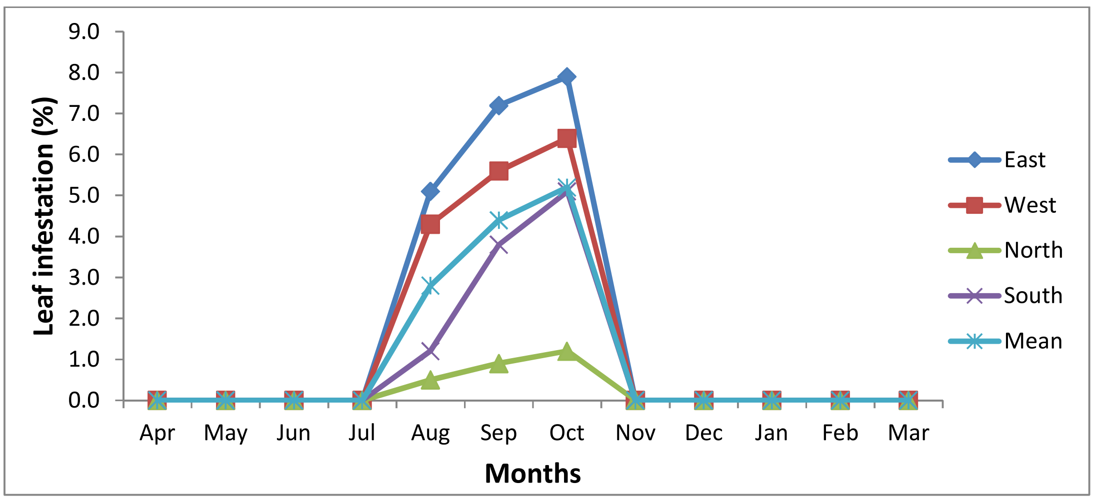

Fig. 35: Incidence of *Acrocercops cramerella* Snellen in second orchard during 2012-013

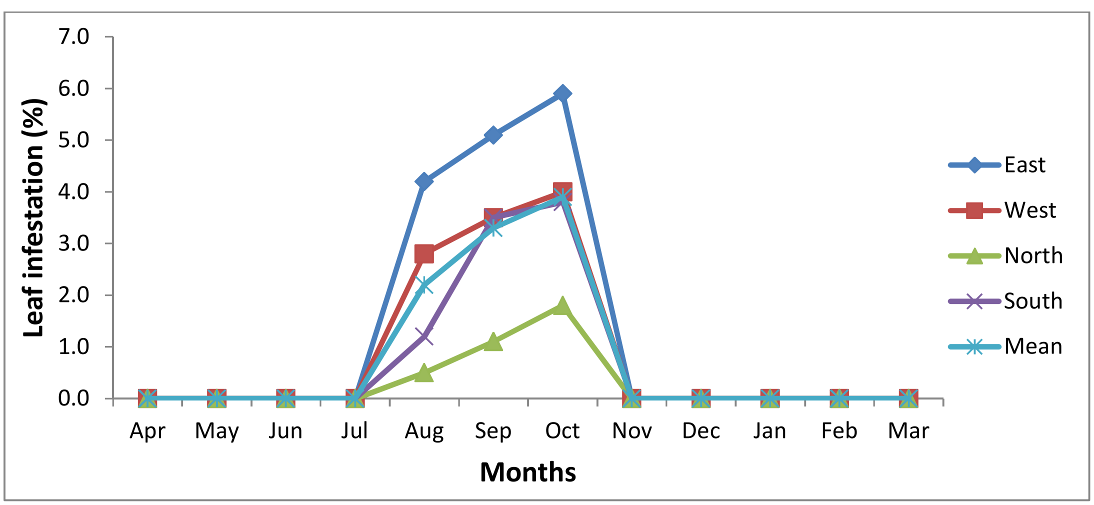

Fig. 36: Incidence of *Acrocercops cramerella* Snellen in third orchard during 2012-013

Table 34: Incidence of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2011-12

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	2.4	1.3	0.8	1.8	**1.6**
September	5.9	3.5	2.3	4.8	**4.1**
October	6.8	4.8	2.8	5.3	**4.9**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**1.3**	**0.8**	**0.5**	**1.0**	**0.9**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.11	0.04
DxM	0.40	0.14

Table 35: Impact of abiotic factors on litchi mid rib borer, *Acrocercops cramerella* Snellen incidence during 2011-12

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-28.355	0.255	0.154	0.197	0.064	-0.033
SE	20.574	1.039	0.993	0.150	0.226	0.024
T- value	-1.378	0.245	0.155	1.314	0.282	-1.387
R^2	67.0					

Mean percent leaf infestation (Y) = $-28.355 + 0.255 X_1 + 0.154 X_2 + 0.197 X_3 + 0.064 X_4 - 0.033 X_5$

Table 36: Incidence of litchi mid rib borer, *Acrocercops cramerella* Snellen during 2012-13

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	3.1	2.4	0.3	0.8	**1.7**
September	4.1	3.0	0.7	2.4	**2.6**
October	4.6	3.5	1.0	3.0	**3.0**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**1.0**	**0.7**	**0.2**	**0.5**	**0.6**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.11	0.04
DxM	0.41	0.14

Table 37: Impact of abiotic factors on litchi mid rib borer, *Acrocercops cramerella* Snellen incidence during 2012-13

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-12.974	-0.178	0.450	0.185	-0.067	-0.044
SE	7.552	0.273	0.268	0.068	0.071	0.023
T- value	-1.718	-0.651	1.682	2.721	-0.931	-1.960
R^2	65.4					

Mean percent leaf infestation (Y) = $-12.974 - 0.178 X_1 + 0.450 X_2 + 0.185 X_3 - 0.067 X_4 - 0.044 X_5$

Plate 9 & 10: Symptoms of *Acrocercops cramerella* infestation on litchi leaves

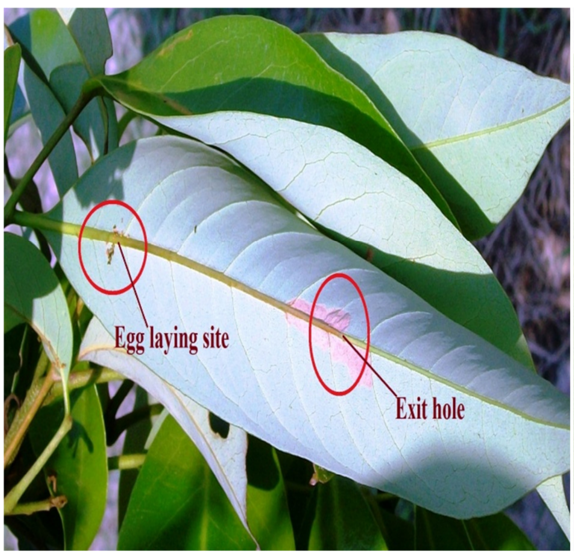

Plate 11: Mid rib of infested leaf

Plate 12: Larva of *A. cramerella*

Plate 13 & 14: Pupation site of *A. cramerella*

Plate 15: Larva of *A. cramerella* (as fruit borer)

Plate 16: Entry hole of larva near peduncle

October (4.6%) and minimum leaf infestation was recorded in the month of August (3.1%). In the West direction, leaf infestation recorded in the month of October (3.5%) was significantly higher and it was minimum in the month of August (2.4%). In the North direction, significantly lower leaf infestation was recorded in the month of August (0.3%) which was found at par with the infestation occurred in the month of September (0.7%). The maximum leaf infestation was recorded in the month of October (1.0%). In the South direction, significantly higher leaf infestation was recorded in the month of October (3.0%). The minimum leaf infestation was recorded in the month of August (0.8%) (Table 36).

4.1.3b.4 Impact of abiotic factors on leaf infestation

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on leaf infestation, all factors were analyzed in the multiple linear regression models.

During 2011-12, the value of coefficient of determination (R^2 =67.0%) indicated the contribution of abiotic factors in mid rib borer incidence. In the multiple regression equation the mean percent leaf infestation increased by 0.25% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 35).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.15% increase in the mean percent leaf infestation (Table 35).

The mean percent leaf infestation increased by 0.19% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 35).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.06% increase in the mean percent leaf infestation (Table 35).

The mean percent leaf infestation decreased by 0.03% with every unit increase (1mm) in rainfall, while other variables as constant (Table 35).

During 2012-13, the value of coefficient of determination (R^2 =65.4%) indicated the contribution of abiotic factors in mid rib borer incidence. In the multiple regression equation the mean percent leaf infestation decreased by 0.17% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 37).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.45% increase in the mean percent leaf infestation (Table 37).

The mean percent leaf infestation increased by 0.18% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 37).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.06% decrease in the mean percent leaf infestation (Table 37).

The mean percent leaf infestation decreased by 0.04% with every unit increase (1mm) in rainfall, while other variables as constant (Table 37).

These findings were also in accordance with **Ranjan and Mukherjee (2008)** who reported that the abiotic factors *viz.* temperature and relative humidity were significantly related with the leaf infestation caused by litchi shoot borer.

4.1.4a Population dynamics of Japanese beetle, *Popillia japonica* Newman (Coleoptera: Scarabaeidae) during 2011-12 and 2012-13

The observations on population of litchi beetle on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for population of the insect pest are presented in Table 38 and Table 39 for 2011-12 and 2012-13, respectively.

4.1.4a.1 Annual appearing pattern of insect pest

The perusal of the data revealed that population of the insect pest appeared once during 2011-12 as well as 2012-13. During 2011-12 the population appeared in July (0.4 individuals) and reached to its maximum in October (2.4 individuals) followed by reduction in population during November (1.9 individuals) (Table 38). Similar pattern was observed during 2012-13, where the population appeared in July (0.7 individuals) and reached to its maximum in October (2.3 individuals) (Table 39).

Table 38: Population of Japanese beetle during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.4	0.3	0.0	0.0	**0.2**	1.4	0.9	0.0	0.3	**0.7**	0.9	0.0	0.0	0.8	**0.4**	**0.4**	July
August	0.8	0.7	0.0	0.0	**0.4**	2.2	1.7	0.0	1.5	**1.4**	1.7	0.3	0.7	1.5	**1.1**	**0.9**	August
September	2.0	2.1	1.2	2.1	**1.9**	2.7	2.2	0.5	2.0	**1.9**	2.5	1.1	1.2	2.3	**1.8**	**1.8**	September
October	2.4	2.3	1.4	3.0	**2.3**	3.0	2.8	1.6	2.7	**2.5**	3.1	1.6	2.0	2.9	**2.4**	**2.4**	October
November	0.0	0.0	0.0	0.0	**0.0**	3.3	2.6	2.1	3.1	**2.8**	3.5	2.4	2.3	3.3	**2.9**	**1.9**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.5**	**0.5**	**0.2**	**0.4**	**0.4**	**1.1**	**0.9**	**0.4**	**0.8**	**0.8**	**1.0**	**0.5**	**0.5**	**0.9**	**0.7**	**0.6**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.08	0.03
Directions (D)	0.10	0.04
Months (M)	0.17	0.06
OxD	0.17	0.06
OxM	0.29	0.10
DxM	0.34	0.12
OxDxM	0.59	0.21

Table 39: Population of Japanese beetle during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	1.2	0.5	0.0	0.0	**0.4**	1.1	0.8	0.0	1.3	**0.8**	1.2	0.9	0.0	1.2	**0.8**	**0.7**	July
August	1.7	1.1	0.0	0.0	**0.7**	1.8	1.3	1.1	1.7	**1.5**	1.7	1.4	0.7	1.6	**1.4**	**1.2**	August
September	2.2	1.7	0.9	1.8	**1.7**	2.5	1.8	1.7	2.2	**2.1**	2.1	1.9	1.1	2.1	**1.8**	**1.8**	September
October	2.6	2.1	1.3	2.4	**2.1**	3.1	2.2	2.1	2.6	**2.5**	2.6	2.2	1.5	2.4	**2.2**	**2.3**	October
November	0.0	0.0	0.0	0.0	**0.0**	3.4	2.5	2.4	2.9	**2.8**	3.0	2.6	1.8	2.9	**2.6**	**1.8**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**0.6**	**0.5**	**0.2**	**0.4**	**0.4**	**1.0**	**0.7**	**0.6**	**0.9**	**0.8**	**0.9**	**0.8**	**0.4**	**0.9**	**0.7**	**0.6**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.05	0.01
Directions (D)	0.06	0.01
Months (M)	0.10	0.03
OxD	0.10	0.03
OxM	0.17	0.05
DxM	0.19	0.06
OxDxM	0.33	0.11

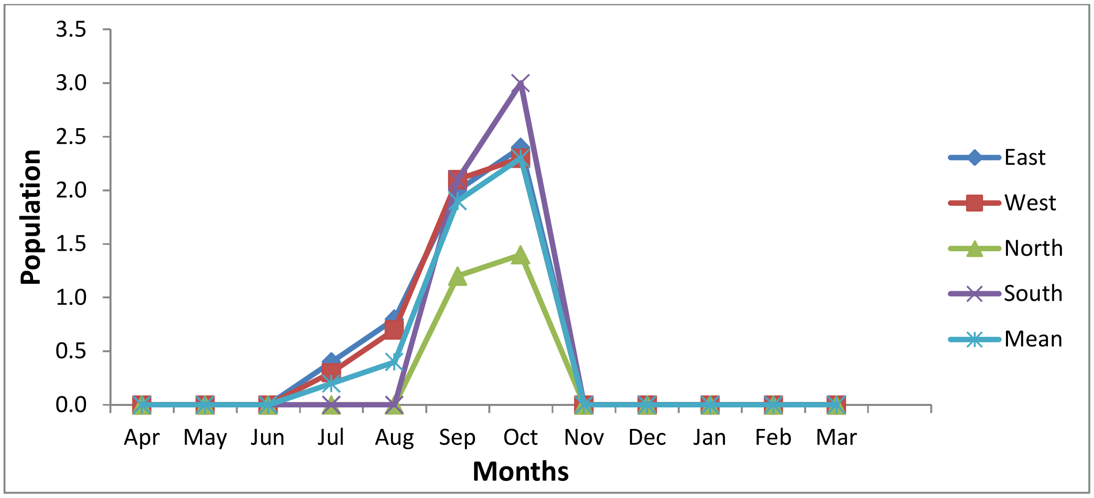

Fig. 37: Population of Japanese beetle in first orchard during 2011-012

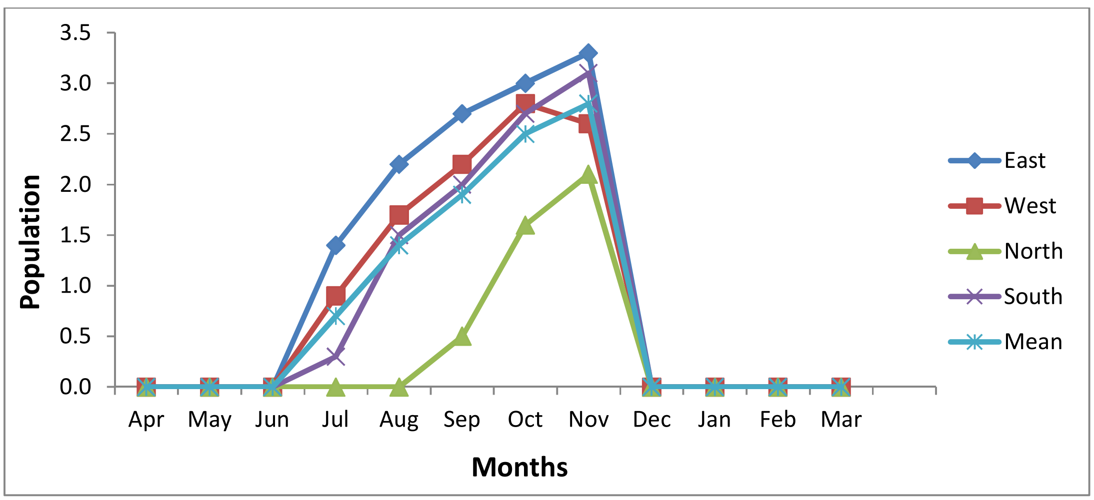

Fig. 38: Population of Japanese beetle in second orchard during 2011-012

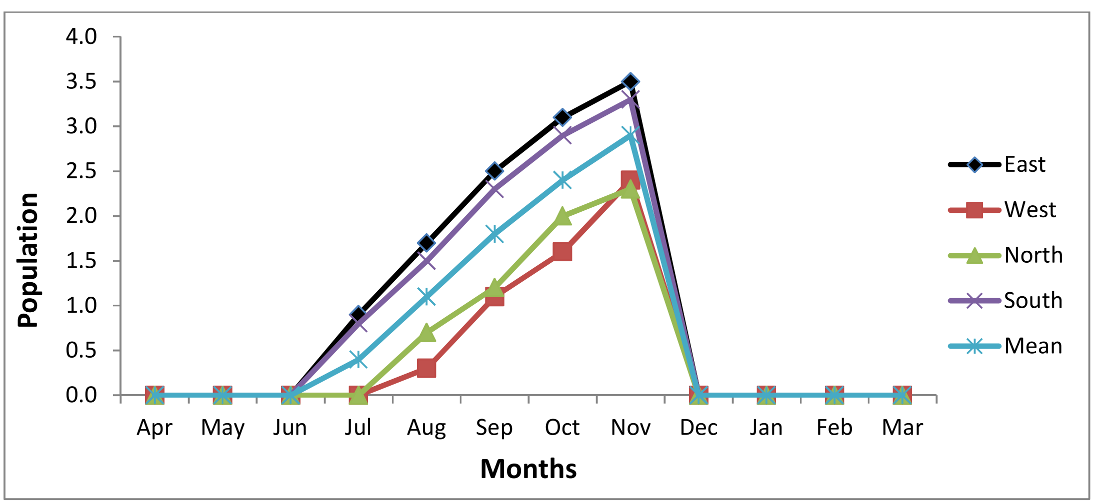

Fig. 39: Population of Japanese beetle in third orchard during 2011-012

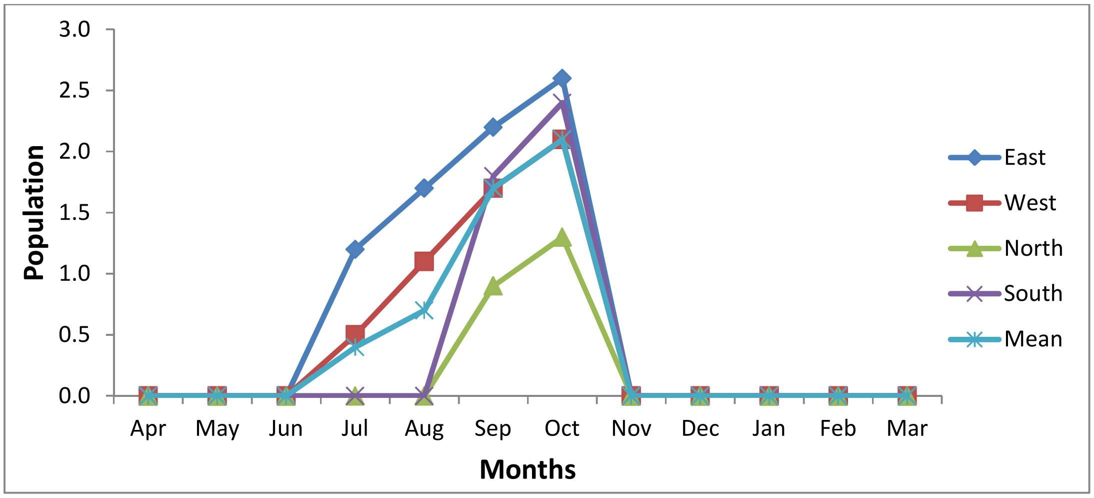

Fig. 40: Population of Japanese beetle in first orchard during 2012-013

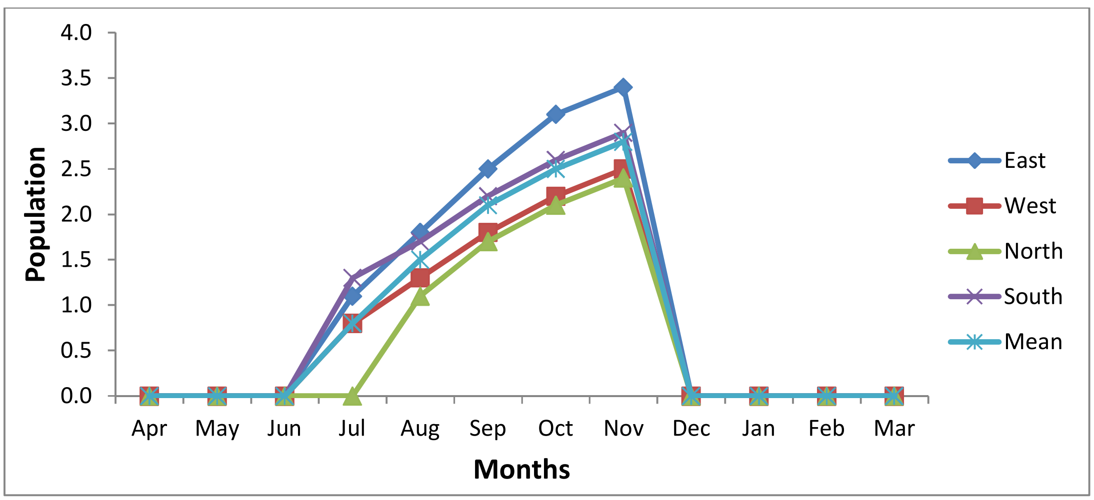

Fig. 41: Population of Japanese beetle in second orchard during 2012-013

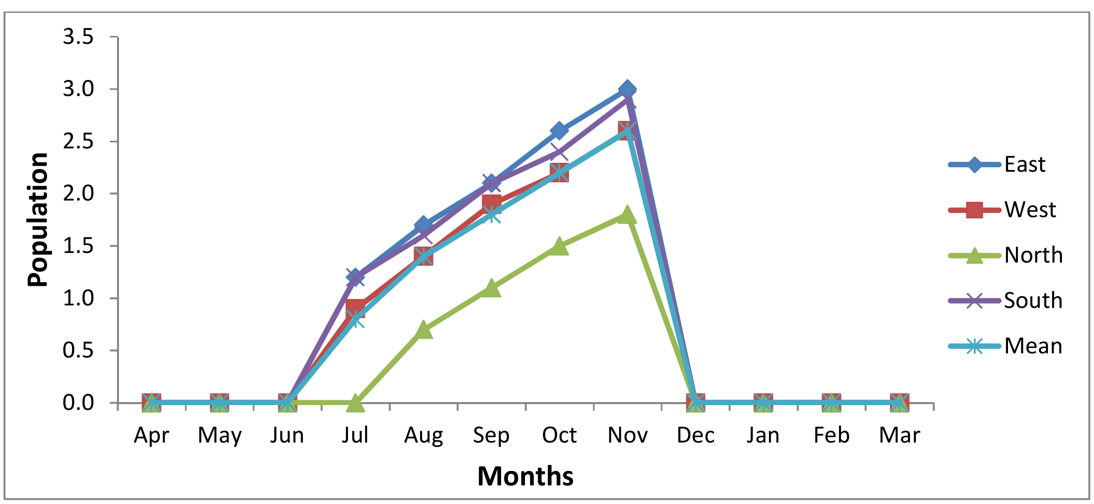

Fig. 42: Population of Japanese beetle in third orchard during 2012-013

4.1.4a.2 Impact of direction and month on population

During 2011-12, in the first orchard, significantly higher population was recorded in East direction (0.5 individuals) and West direction (0.5 individuals) and it was found at par with the population observed in South direction (0.4 individuals). The minimum population was observed in North direction (0.2 individuals). Significantly higher population was recorded in the month of October (2.3 individuals). The minimum population was observed in the month of July (0.2 individuals) which was found at par with the population recorded during August (0.4 individuals) (Table 38, Fig. 37).

During 2012-13, in the first orchard, significantly higher population was observed in East direction (0.6 individuals) and it was found at par with the population recorded in West direction (0.5 individuals). The minimum population was observed in North direction (0.2 individuals). The population recorded in the month of October (2.1 individuals) was significantly higher than all other months. The minimum population was observed in the month of July (0.4 individuals) (Table 39, Fig. 40).

During 2011-12, in the second orchard, significantly lower population was recorded in North direction (0.4 individuals) than in all other directions. The maximum population was recorded in East direction (1.1 individuals). The population was significantly higher in the month of November (2.8 individuals) and the minimum population was observed in the month of July (0.7 individuals) (Table 38, Fig. 38).

During 2012-13, in the second orchard, population was significantly lower in North direction (0.6 individuals) which was found at par with the population observed in West direction (0.7 individuals). The maximum population was recorded in East direction (1.0 individuals) and it was found at par with the population occurred in the South direction (0.9 individuals). Significantly higher population was recorded in the month of November (2.8 individuals) and minimum in the month of July (0.8 individuals) (Table 39, Fig. 41).

During 2011-12, in the third orchard, significantly higher population was recorded in the East direction (1.0 individuals) and it was found at par with the population observed in South direction (0.9 individuals). The minimum population was recorded in the West direction (0.5 individuals) and North direction (0.5 individuals). Significantly higher population was recorded in the month of November (2.9 individuals) and minimum population was observed in the month of July (0.4 individuals) (Table 38, Fig. 39).

During 2012-13, in the third orchard, significantly lower population was recorded in North direction (0.4 individuals). The maximum population was recorded in the East direction (0.9 individuals) and South direction (0.9 individuals) which was found at par with the population recorded in West direction (0.8 individuals). The population was significantly higher in the month of November (2.6 individuals) and minimum population was observed in the month of July (0.8 individuals) (Table 39, Fig. 42).

4.1.4a.3 Impact of planting system, irrigation methods and plant's age of the orchard on population

During 2011-12, the mean population among three orchards was observed significantly different. It was maximum in the second orchard (0.8 individuals) and minimum was recorded in first orchard (0.4 individuals) (Table 38). Similar pattern for the population among the orchards was observed during 2012-13. It was 0.8 individuals, 0.7 individuals and 0.4 individuals in second, third and first orchard, respectively (Table 39).

During 2011-12, irrespective of orchards, significantly higher population was recorded in East direction (0.8 individuals) and it was recorded minimum in North direction (0.4 individuals). Significantly higher population was recorded in the month of October in all the four directions (East, West, North and South). The minimum population was observed in the month of July (Table 40). Similar pattern for the population was observed during 2012-13 (Table 42).

4.1.4a.4 Impact of abiotic factors on population

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on population, all factors were analyzed in the multiple linear regression models.

Table 40: Population of Japanese beetle during 2011-12

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.9	0.4	0.0	0.4	**0.4**
August	1.6	0.9	0.2	1.0	**0.9**
September	2.4	1.8	1.0	2.1	**1.8**
October	2.8	2.2	1.7	2.9	**2.4**
November	2.3	1.7	1.5	2.1	**1.9**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.8**	**0.6**	**0.4**	**0.7**	**0.6**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.10	0.04
DxM	0.34	0.12

Table 41: Impact of abiotic factors on population of Japanese beetle during 2011-12

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-23.581	0.628	-0.405	0.067	0.131	-0.007
SE	9.899	0.500	0.478	0.072	0.109	0.011
T- value	-2.382	1.257	-0.848	0.923	1.208	-0.582
R^2	70.9					

Population (Y) = $-23.581 + 0.628\ X_1 - 0.405\ X_2 + 0.067\ X_3 + 0.131\ X_4 - 0.007\ X_5$

Table 42: Population of Japanese beetle during 2012-13

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	1.2	0.7	0.0	0.8	**0.7**
August	1.7	1.3	0.6	1.1	**1.2**
September	2.3	1.8	1.2	2.0	**1.8**
October	2.8	2.2	1.6	2.5	**2.3**
November	2.1	1.7	1.4	1.9	**1.8**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.8**	**0.6**	**0.4**	**0.7**	**0.6**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.06	0.01
DxM	0.19	0.06

Table 43: Impact of abiotic factors on population of litchi beetle during 2012-13

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-9.964	-0.174	0.341	0.195	-0.120	-0.011
SE	3.541	0.128	0.126	0.032	0.033	0.011
T- value	-2.814	-1.359	2.720	6.146	-3.572	-1.067
R^2	87.7					

Population (Y) = $-9.964 - 0.174 X_1 + 0.341 X_2 + 0.195 X_3 - 0.120 X_4 - 0.011 X_5$

During 2011-12, the overall contribution of abiotic factors on beetle population was 70.9%. In the multiple regression equation the population increased by 0.63 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 41).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.40 individuals decrease in the population (Table 41).

The mean percent population increased by 0.07 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 41).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.13 individuals decrease in the population (Table 41).

The population decreased by 0.007 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 41).

During 2012-13, the overall contribution of abiotic factors on beetle population was 87.7%. In the multiple regression equation the population decreased by 0.17 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 43).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.34 individuals increase in the population (Table 43).

The population increased by 0.19 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 43).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.12 individuals decrease in the population (Table 43).

The mean percent population decreased by 0.01 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 43).

4.1.4b Leaf infestation dynamics of Japanese beetle, *Popillia japonica* Newman (Coleoptera: Scarabaeidae) during 2011-12 and 2012-13

The observations on incidence of litchi beetles on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for incidence of the insect pest are presented in Table 44 and Table 45 for 2011-12 and 2012-13, respectively.

4.1.4b.1 Annual appearing pattern of insect pest

The perusal of the data revealed that incidence of the insect pest occurred once during 2011-12 as well as 2012-13. During 2011-12 the incidence was started in July (2.4%) and reached to its maximum in November (8.5%) followed by reduction in incidence during December (Table 44). Similar pattern was observed during 2012-13, where the incidence was started in July (1.8%) and reached to its maximum in November (8.7%) (Table 45).

4.1.4b.2 Impact of direction and month on leaf infestation

During 2011-12, in the first orchard, significantly higher leaf infestation was recorded in West direction (2.1%) which was found at par with the infestation occurred in East direction (1.8%) and South direction (1.4%). The minimum leaf infestation was observed in North direction (1.0%). Significantly higher leaf infestation was recorded in the month of October (5.4%) which was found at par with the infestation occurred in the month of September (5.2%) and November (4.9%). Later on, the infestation started to reduce gradually due to decrease in temperature. The minimum leaf infestation was observed in the month of July (1.5%) which was found at par with the infestation occurred in the month of August (1.9%) (Table 44, Fig. 43).

During 2012-13, in the first orchard, significantly higher leaf infestation was recorded in East direction (2.1%) which was found at par with the infestation occurred in West direction (1.9%). The minimum leaf infestation was observed in North direction (0.9%). The leaf infestation recorded in the month of October (6.9%) was significantly higher than in all other months and it was minimum in the month of July (0.8%) which was found at par with the infestation occurred in the month of August (1.3%) (Table 45, Fig. 46).

Table 44: Incidence of Japanese beetle during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	2.1	1.9	0.0	2.0	**1.5**	4.0	2.7	3.1	4.4	**3.6**	3.3	0.0	1.6	3.1	**2.0**	**2.4**	July
August	2.6	2.8	0.1	2.0	**1.9**	4.4	5.8	5.1	5.0	**5.1**	3.8	0.3	2.0	3.1	**2.3**	**3.1**	August
September	5.5	7.0	3.9	4.2	**5.2**	8.5	6.9	5.6	6.7	**6.9**	7.4	5.4	4.3	3.7	**5.2**	**5.8**	September
October	5.7	7.4	4.0	4.3	**5.4**	8.9	10.8	7.2	8.9	**9.0**	8.9	8.8	5.6	7.5	**7.7**	**7.3**	October
November	5.4	6.5	3.6	4.0	**4.9**	12.9	12.5	7.5	13.1	**11.5**	9.4	11.4	6.3	9.3	**9.1**	**8.5**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**1.8**	**2.1**	**1.0**	**1.4**	**1.6**	**3.2**	**3.2**	**2.4**	**3.2**	**3.0**	**2.7**	**2.2**	**1.7**	**2.2**	**2.2**	**2.3**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.38	0.13
Directions (D)	0.44	0.15
Months (M)	0.76	0.27
OxD	0.76	0.27
OxM	1.31	0.47
DxM	1.51	0.54
OxDxM	2.62	0.94

Table 45: Incidence of Japanese beetle during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
May	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	1.5	1.5	0.0	0.0	**0.8**	3.6	3.3	1.4	4.8	**3.3**	3.5	1.1	0.0	0.8	**1.4**	**1.8**	July
August	3.5	1.5	0.0	0.0	**1.3**	5.7	4.5	5.8	5.4	**5.4**	6.4	3.4	1.3	2.3	**3.4**	**3.3**	August
September	5.9	4.9	3.0	4.6	**4.6**	9.8	8.9	7.0	9.6	**8.8**	9.7	7.8	4.0	5.5	**6.8**	**6.7**	September
October	7.1	8.1	4.4	8.0	**6.9**	11.1	10.0	8.2	10.7	**10.0**	10.3	8.9	4.7	6.0	**7.5**	**8.1**	October
November	6.7	7.0	3.1	6.4	**5.8**	13.6	11.7	9.4	11.5	**11.6**	11.3	10.4	5.3	8.1	**8.8**	**8.7**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	February
March	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	March
Mean	**2.1**	**1.9**	**0.9**	**1.6**	**1.6**	**3.7**	**3.2**	**2.7**	**3.5**	**3.3**	**3.4**	**2.6**	**1.3**	**1.9**	**2.3**	**2.4**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.21	0.07
Directions (D)	0.25	0.08
Months (M)	0.43	0.15
OxD	0.43	0.15
OxM	0.74	0.26
DxM	0.85	0.30
OxDxM	1.48	0.53

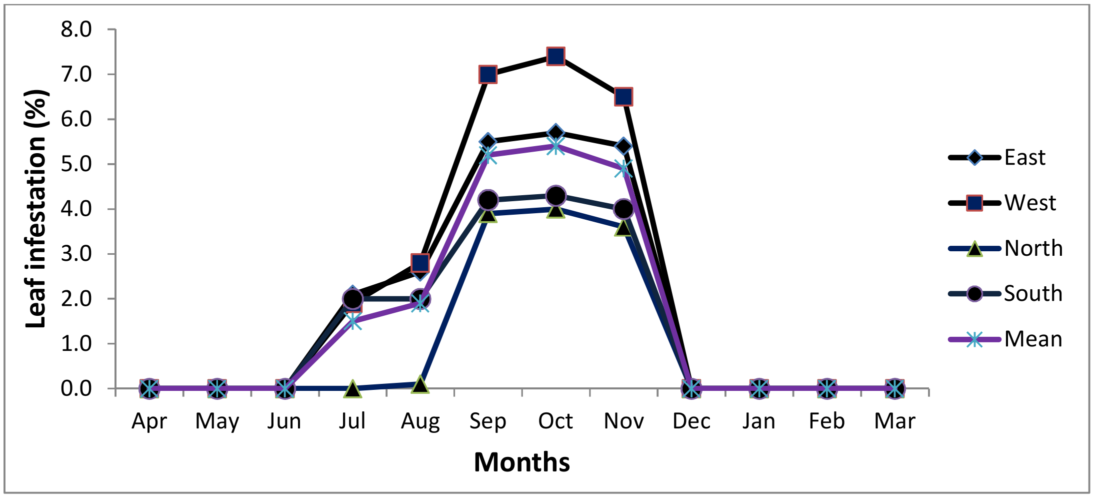

Fig. 43: Incidence of Japanese beetle in first orchard during 2011-012

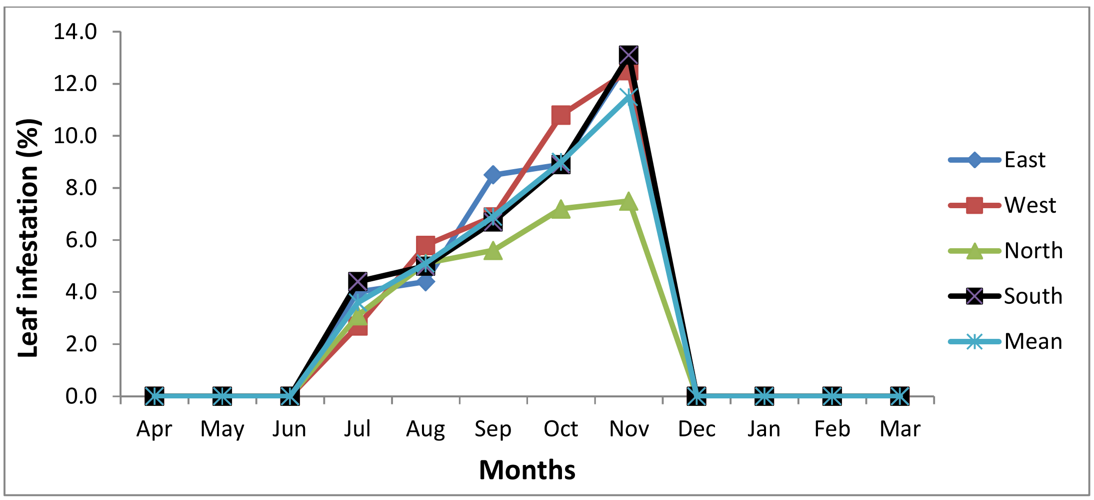

Fig. 44: Incidence of Japanese beetle in second orchard during 2011-012

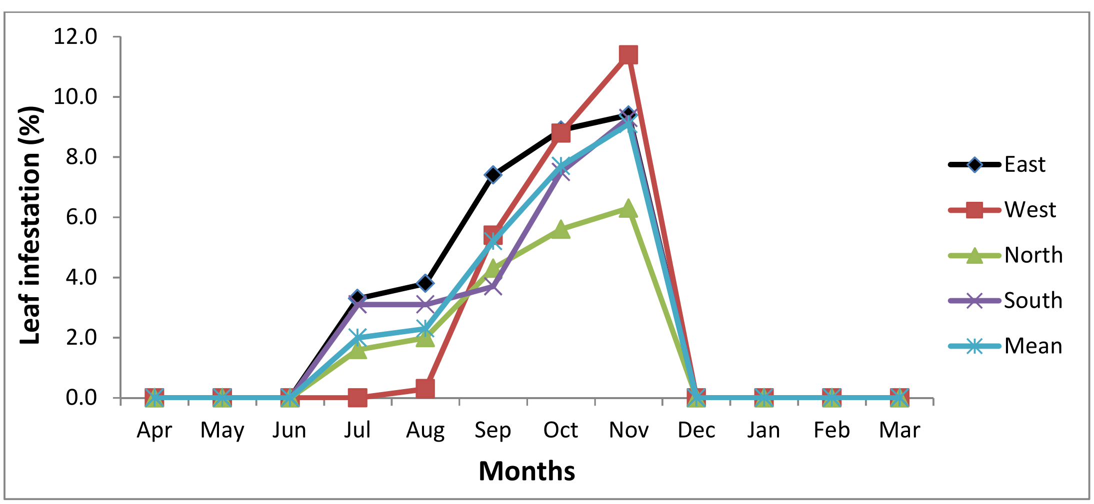

Fig. 45: Incidence of Japanese beetle in third orchard during 2011-012

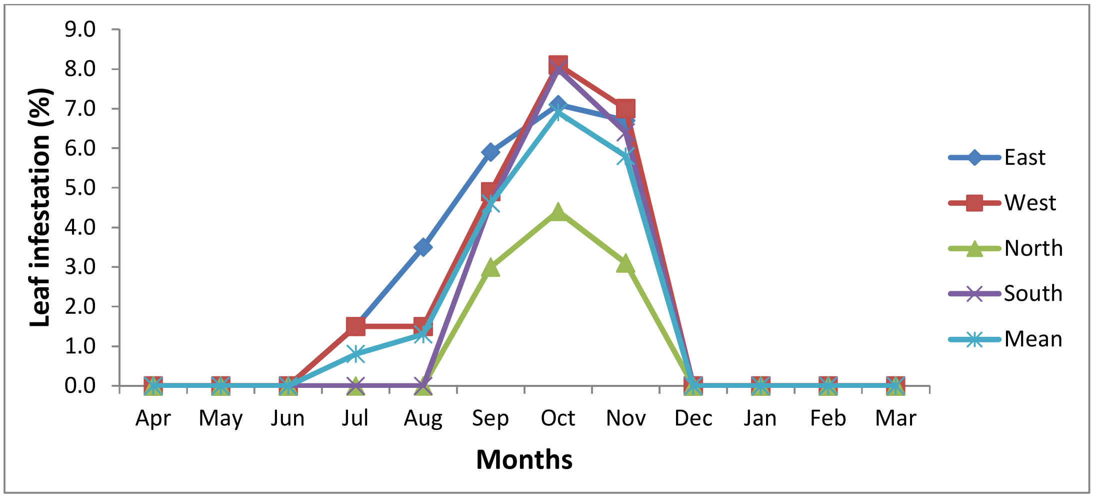

Fig. 46: Incidence of Japanese beetle in first orchard during 2012-013

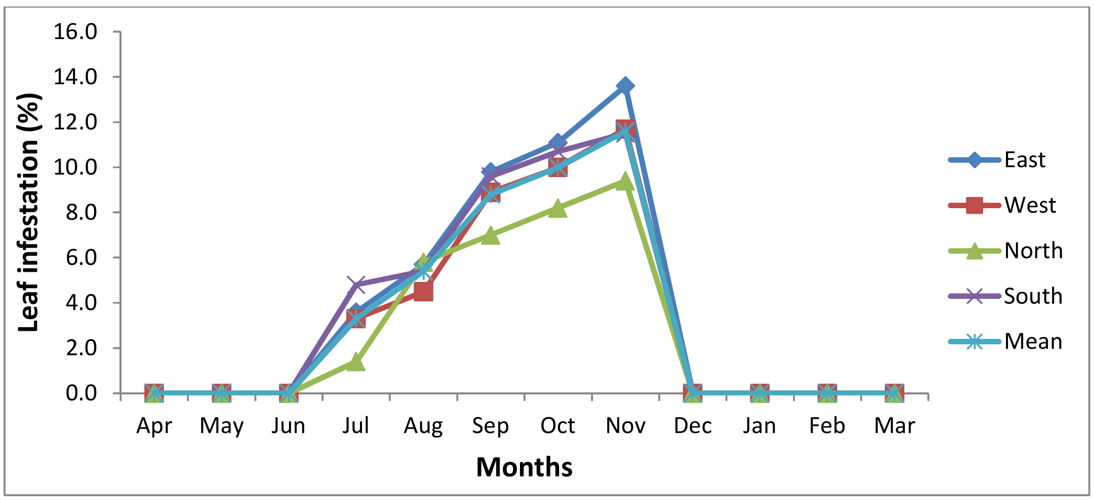

Fig. 47: Incidence of Japanese beetle in second orchard during 2012-013

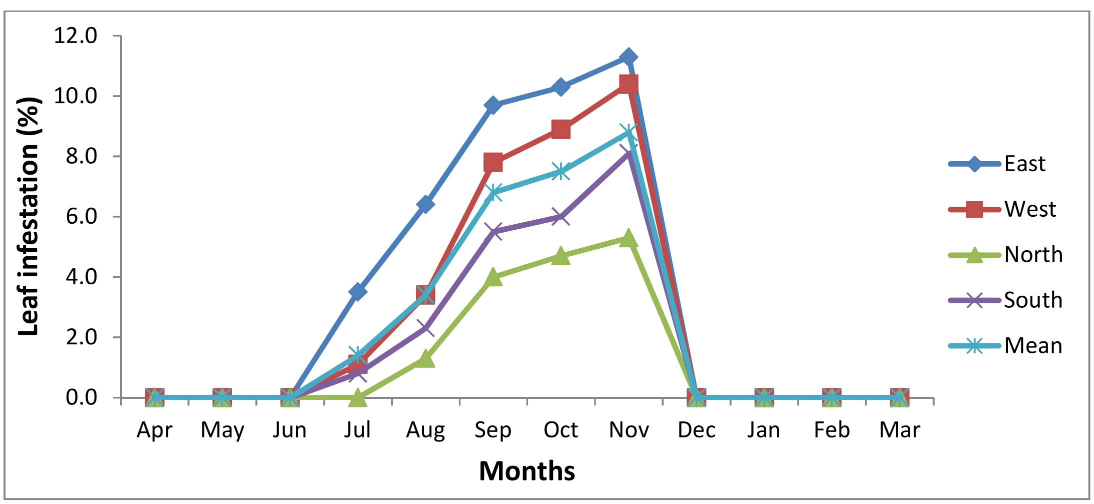

Fig. 48: Incidence of Japanese beetle in third orchard during 2012-013

During 2011-12, in the second orchard, significantly lower leaf infestation was recorded in North direction (2.4%) than in all other directions. The maximum leaf infestation was recorded in East direction (3.2%), West direction (3.2%) and South direction (3.2%). The leaf infestation was significantly higher in the month of November (11.5%) and it was recorded minimum in the month of July (3.6%) (Table 44, Fig. 44).

During 2012-13, in the second orchard, leaf infestation was significantly lower in North direction (2.7%) than in all other directions. The maximum leaf infestation was recorded in East direction (3.7%). Significantly higher leaf infestation was recorded in the month of November (11.6%) and minimum in the month of July (3.3%) (Table 45, Fig. 47).

During 2011-12, in the third orchard, maximum leaf infestation was recorded in the East direction (2.7%) which was found at par with the infestation occurred in the West direction (2.2%) and South direction (2.2%). The minimum leaf infestation was recorded in the North direction (1.7%). Significantly higher leaf infestation was recorded in the month of November (9.1%) and it was recorded minimum in the month of July (2.0%) which was found at par with the infestation occurred in the month of August (2.3%) (Table 44, Fig. 45).

During 2012-13, in the third orchard, significantly lower leaf infestation was recorded in North direction (1.3%) and it was recorded maximum in the East direction (3.4%). The leaf infestation was significantly higher in the month of November (8.8%). The minimum leaf infestation was observed in the month of July (1.4%) (Table 45, Fig. 48).

4.1.4b.3 Impact of planting system, irrigation methods and plant's age of the orchard on leaf infestation

During 2011-12, the mean percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard (3.0%) and minimum was recorded in first orchard (1.6%) (Table 44). Similar pattern for the infestation among the orchards was observed during 2012-13. It was 3.3%, 2.3% and 1.6% in second, third and first orchard, respectively (Table 45).

During 2011-12, irrespective of orchards, significantly higher leaf infestation was recorded in East direction (2.6%) which was found at par with the infestation occurred in the West direction (2.5%) and South direction (2.3%). It was recorded minimum in North direction (1.7%). In the East direction, significantly higher leaf infestation was recorded in the month of November (9.2%) which was found at par with the infestation occurred in the month of October (7.7%) and minimum leaf infestation was recorded in the month of July (3.1%) which was found at par with the infestation occurred in the month of August (3.6%). In the West direction, leaf infestation recorded in the month of November (10.1%) was significantly higher and was found at par with the infestation occurred in the month of October (9.0%). The minimum leaf infestation was recorded in the month of July (1.5%) which was found at par with the infestation occurred in the month of August (3.0%). In the North direction, significantly lower leaf infestation was recorded in the month of July (1.6%) which was found at par with the infestation occurred in the month of August (2.4%). The maximum leaf infestation was recorded in the month of November (5.8%) which was found at par with the infestation occurred in the month of September (4.6%) and October (5.6%). In the South direction, significantly higher leaf infestation was recorded in the month of October (8.8%) and the minimum was recorded in the month of July (3.2%) which was found at par with the infestation occurred in the month of August (3.4%) (Table 46).

During 2012-13, leaf infestation was significantly lower in North direction (1.6%) and it was recorded maximum in East direction (3.0%). In the East direction, significantly higher leaf infestation was recorded in the month of November (10.5%) and minimum leaf infestation was recorded in the month of July (2.9%). In the West direction, leaf infestation recorded in the month of November (9.7%) was significantly higher and was found at par with the infestation occurred in the month of October (9.0%). The minimum leaf infestation was recorded in the month of July (2.0%). In the North direction, significantly lower leaf infestation was recorded in the month of July (0.5%). The maximum leaf infestation was recorded in the month of November (5.9%) which was found at par with the infestation occurred in the month of October (5.8%). In the South direction, significantly higher leaf infestation was recorded in the month of November (8.7%) which was found at par with the

Table 46: Incidence of Japanese beetle during 2011-12

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	3.1	1.5	1.6	3.2	**2.4**
August	3.6	3.0	2.4	3.4	**3.1**
September	7.1	6.4	4.6	4.9	**5.8**
October	7.8	9.0	5.6	6.9	**7.3**
November	9.2	10.1	5.8	8.8	**8.5**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**2.6**	**2.5**	**1.7**	**2.3**	**2.3**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.44	0.15
DxM	1.51	0.54

Table 47: Impact of abiotic factors on Japanese beetle incidence during 2011-12:

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-83.229	2.390	-1.665	0.200	0.492	-0.011
SE	40.414	2.040	1.951	0.295	0.444	0.046
T- value	-2.059	1.172	-0.853	0.678	1.108	-0.233
R^2	61.4					

Mean percent leaf infestation (Y) = $-83.229 + 2.390 X_1 - 1.665 X_2 + 0.200 X_3 + 0.492 X_4 - 0.011 X_5$

Table 48: Incidence of Japanese beetle during 2012-13

Months	East	West	North	South	Mean
April	0.0	0.0	0.0	0.0	**0.0**
May	0.0	0.0	0.0	0.0	**0.0**
June	0.0	0.0	0.0	0.0	**0.0**
July	2.9	2.0	0.5	1.9	**1.8**
August	5.2	3.1	2.4	2.6	**3.3**
September	8.5	7.2	4.7	6.6	**6.7**
October	9.5	9.0	5.8	8.2	**8.1**
November	10.5	9.7	5.9	8.7	**8.7**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	0.0	0.0	0.0	0.0	**0.0**
March	0.0	0.0	0.0	0.0	**0.0**
Mean	**3.0**	**2.6**	**1.6**	**2.3**	**2.4**
Sources of variation		CD at 5%		SEm±	
Directions (D)		0.25		0.08	
DxM		0.85		0.30	

Table 49: Impact of abiotic factors on Japanese beetle incidence during 2012-13

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-36.695	-0.713	1.295	0.784	-0.518	-0.035
SE	13.523	0.490	0.479	0.121	0.128	0.041
T- value	-2.714	-1.457	2.701	6.455	-4.051	-0.858
R^2	88.3					

Mean percent leaf infestation (Y) = -36.695 -0.713 X_1 +1.295 X_2 +0.784 X_3 -0.518 X_4 -0.035 X_5


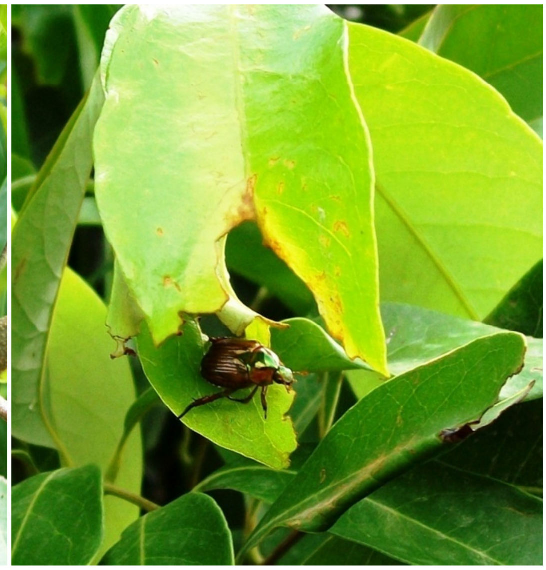

Plate 17 **Plate 18**


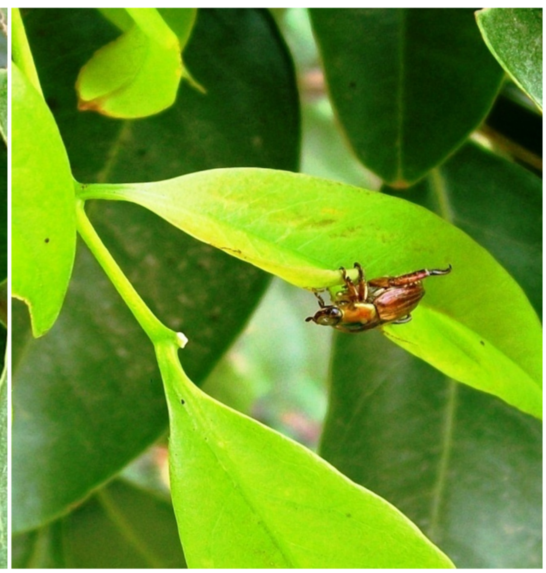

Plate 19 **Plate 20**

***Popillia japonica* adults feeding on litchi leaves**

Plate 21 **Plate 22**

Plate 23 **Plate 24**

Symptoms of *P. japonica* infestation on litchi leaves

infestation occurred in the month of October (8.2%). The minimum leaf infestation was recorded in the month of July (1.9%) which was found at par with the infestation occurred in the month of August (2.6%) (Table 48).

4.1.4b.4 Impact of abiotic factors on leaf infestation

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on leaf infestation, all factors were analyzed in the multiple linear regression models.

During 2011-12, the value of coefficient of determination (R^2 =61.4%) indicated the contribution of abiotic factors in beetles incidence. In the multiple regression equation the mean percent leaf infestation increased by 2.39% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 47).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 1.66% decrease in the mean percent leaf infestation (Table 47).

The mean percent leaf infestation increased by 0.20% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 47).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.49% increase in the mean percent leaf infestation (Table 47).

The mean percent leaf infestation decreased by 0.01% with every unit increase (1mm) in rainfall, while other variables as constant (Table 47).

During 2012-13, the value of coefficient of determination (R^2 =88.3%) indicated the contribution of abiotic factors in beetles incidence. In the multiple regression equation the mean percent leaf infestation decreased by 0.71% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 49).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 1.29% increase in the mean percent leaf infestation (Table 49).

The mean percent leaf infestation increased by 0.78% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 49).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.51% decrease in the mean percent leaf infestation (Table 49).

The mean percent leaf infestation decreased by 0.03% with every unit increase (1mm) in rainfall, while other variables as constant (Table 49).

The probable reason for less infestation in the first orchard may be the high density of plants and irrigation pattern, flooding mode of water applicaion. Flooding may create unfavorable conditions for larval and pupal development because the egg laying site for adult is in the soil. The larval and pupal development also takes place in the soil. These findings were also in accordance with the report of **USDA (2007)** which stated that females of Japanese beetle, *Popillia japonica* burrow about 3 inches into the ground, usually into turf and lay a few eggs. This cycle repeats until the female has laid 40–60 eggs. In late autumn, the grubs burrow 4–8 inches into the soil and remain inactive all winter. This insect spends about 10 months a year in the ground in the larval stage. In early spring, the grubs return to the turf and feed on roots until late spring, then pupation takes place. In about 2 weeks, adult beetles emerge from the pupae in the ground. This life cycle takes a year.

4.1.5a Population dynamics of weevils, *Hypomeces squamosus* Faust, *Lepropus aurovittatus* Heller, *L. lateralis* Faust, *Peltotrachelus pupes* Faust, *Amblyrrhinus poricollis* Schoenherr, *Myllocerus dentifer* Guerin, *M. curvicornis* Marshall, *M. laetivirens* Marshall, *M. discolor* Boheman (Coleoptera: Curculionidae) during 2011-12 and 2012-13

The observations on population of litchi weevils on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for population of the insect pest are presented in Table 50 and Table 51 for 2011-12 and 2012-13, respectively.

4.1.5a.1 Annual appearing pattern of insect pest

The perusal of the data revealed that population of the insect pest appeared once during 2011-12 as well as 2012-13. During 2011-12 the population appeared in February (1.6 individuals) and reached to its maximum in May (4.5 individuals) (Table 50). Similar pattern was observed during 2012-13, where the population appeared in February (1.5 individuals) and reached to its maximum in May (4.2 individuals) (Table 51).

Table 50: Population of litchi weevils during 2011-12

Months	**Orchard I**					**Orchard II**					**Orchard III**					**Grand Mean**	**Leaf emergence pattern**
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	4.7	3.9	2.8	4.1	**3.9**	4.1	3.6	2.4	3.9	**3.5**	4.5	3.6	3.0	4.1	**3.8**	**3.7**	-
May	5.8	4.3	3.3	5.0	**4.6**	5.4	4.3	3.1	4.8	**4.4**	5.3	4.2	3.6	4.9	**4.5**	**4.5**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	August
September	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	September
October	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	1.7	1.9	1.2	1.4	**1.6**	1.9	1.7	1.4	2.2	**1.8**	2.6	1.1	0.8	1.2	**1.4**	**1.6**	February
March	2.8	2.3	1.8	2.5	**2.4**	3.1	3.0	2.7	3.8	**3.2**	3.9	2.0	2.0	2.5	**2.6**	**2.7**	March
Mean	**1.3**	**1.0**	**0.8**	**1.1**	**1.0**	**1.2**	**1.1**	**0.8**	**1.2**	**1.1**	**1.4**	**0.9**	**0.8**	**1.1**	**1.0**	**1.0**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.10	0.03
Directions (D)	0.11	0.04
Months (M)	0.19	0.07
OxD	0.19	0.07
OxM	0.34	0.12
DxM	0.40	0.14
OxDxM	0.68	0.24

Table 51: Population of litchi weevils during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**	**East**	**West**	**North**	**South**	**Mean**		
April	3.5	3.2	2.2	3.1	**3.0**	4.2	3.5	2.9	4.3	**3.7**	5.1	2.8	2.9	3.4	**3.6**	**3.4**	-
May	3.9	3.8	2.9	4.2	**3.7**	5.3	4.2	3.4	5.2	**4.5**	6.3	3.7	3.3	4.5	**4.5**	**4.2**	-
June	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	August
September	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	September
October	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	1.9	1.6	0.9	1.2	**1.4**	2.0	1.1	0.8	1.6	**1.4**	2.3	1.9	0.9	1.4	**1.6**	**1.5**	February
March	2.3	2.1	1.2	1.8	**1.9**	3.1	2.3	1.5	2.8	**2.4**	3.0	2.4	1.3	2.1	**2.2**	**2.2**	March
Mean	**1.0**	**0.9**	**0.6**	**0.9**	**0.8**	**1.2**	**0.9**	**0.7**	**1.2**	**1.0**	**1.4**	**0.9**	**0.7**	**1.0**	**1.0**	**0.9**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.07	0.02
Directions (D)	0.08	0.02
Months (M)	0.14	0.05
OxD	0.14	0.05
OxM	0.24	0.08
DxM	0.28	0.10
OxDxM	0.48	0.17

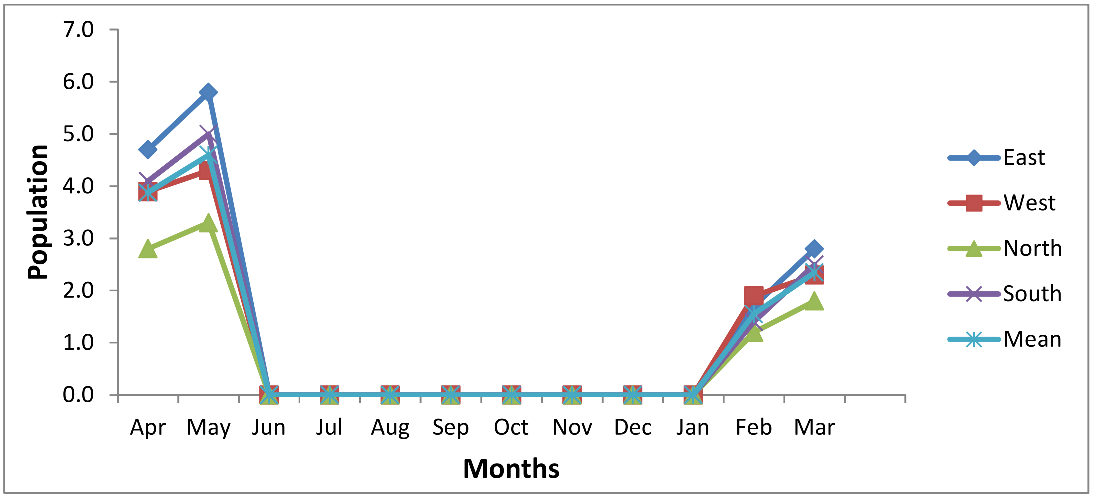

Fig. 49: Population of litchi weevils in first orchard during 2011-012

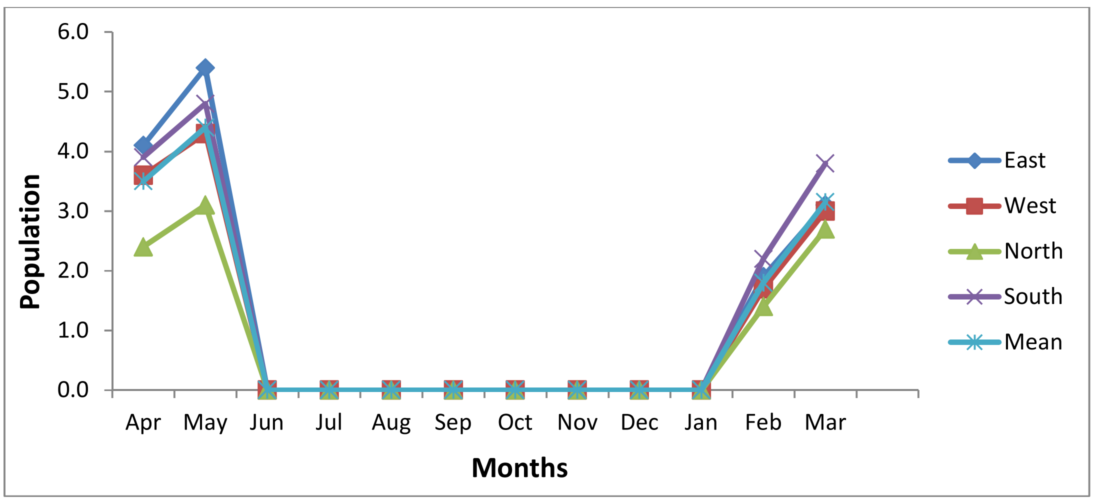

Fig. 50: Population of litchi weevils in second orchard during 2011-012

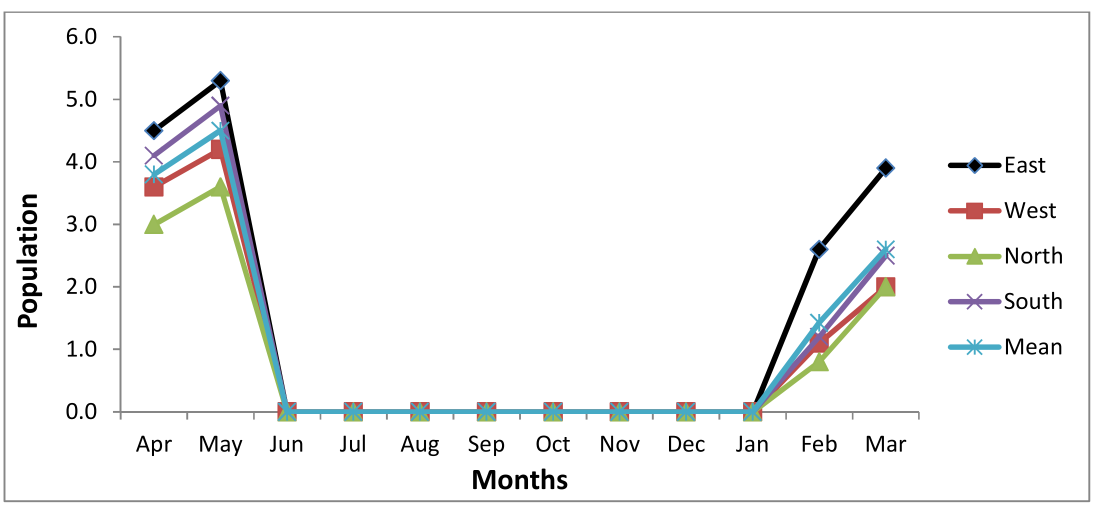

Fig. 51: Population of litchi weevils in third orchard during 2011-012

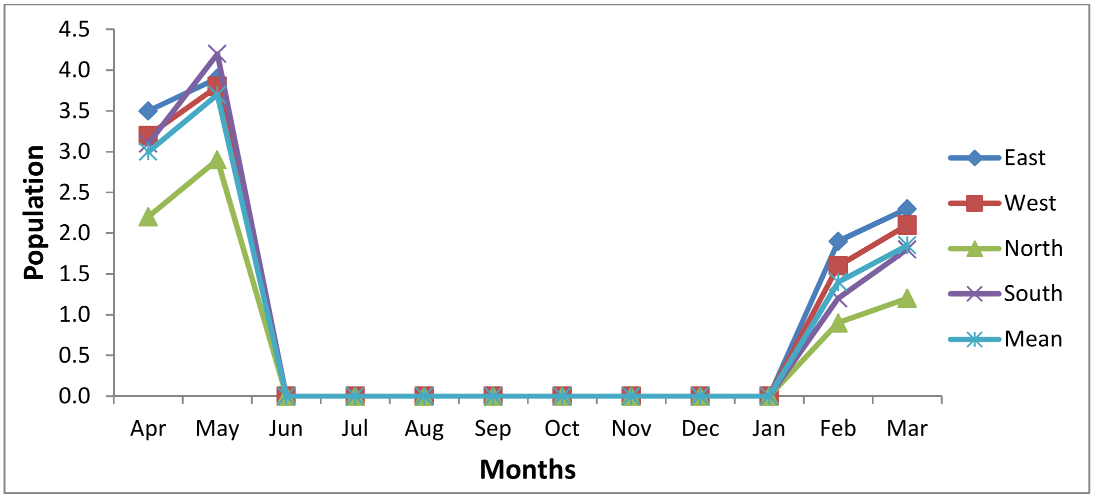

Fig. 52: Population of litchi weevils in first orchard during 2012-013

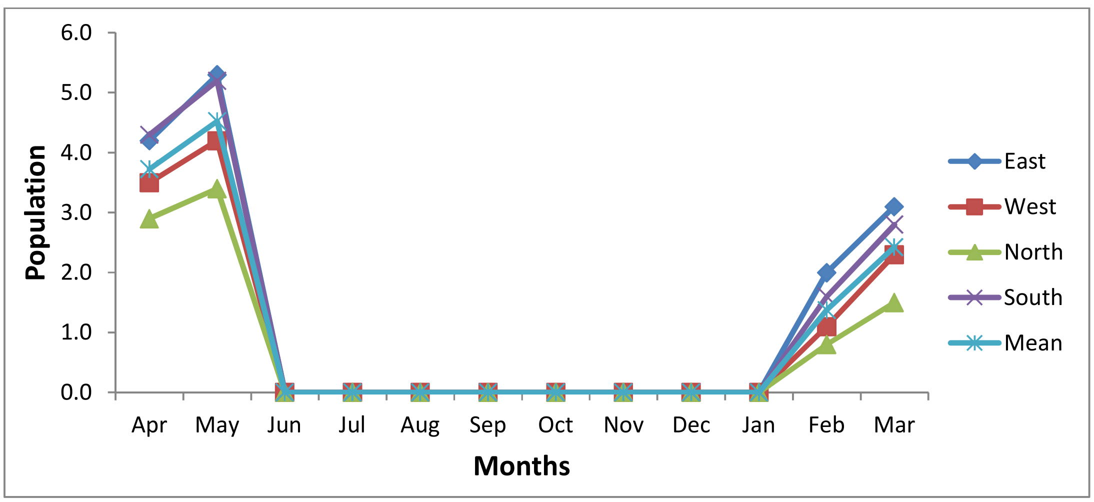

Fig. 53: Population of litchi weevils in second orchard during 2012-013

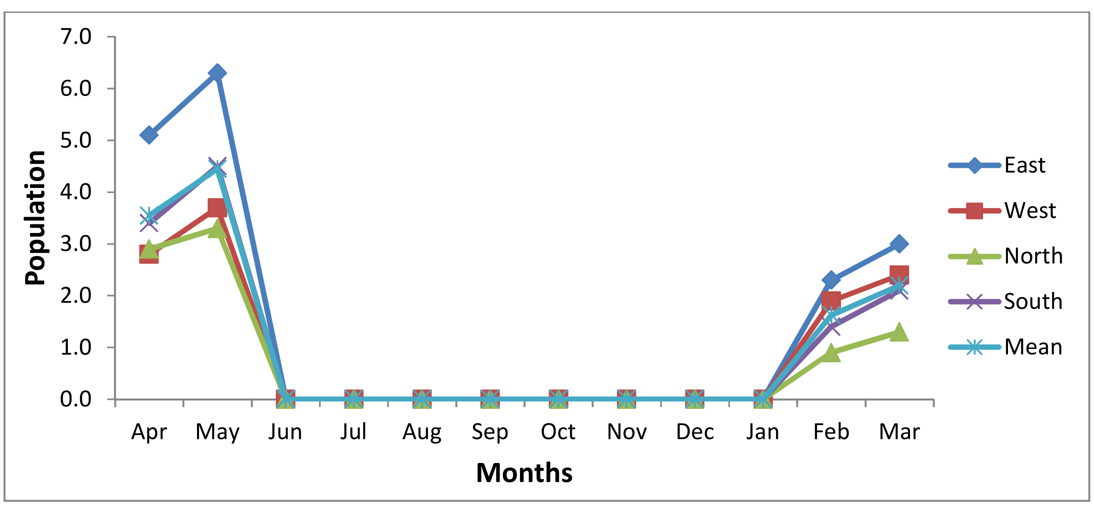

Fig. 54: Population of litchi weevils in third orchard during 2012-013

4.1.5a.2 Impact of direction and month on population

During 2011-12, in the first orchard, significantly higher population was recorded in East direction (1.3 individuals) and the minimum population was observed in North direction (0.8 individuals). Significantly higher population was recorded in the month of May (4.6 individuals) and the minimum population was observed in the month of February (1.6 individuals) (Table 50, Fig. 49).

During 2012-13, in the first orchard, significantly higher population was observed in East direction (1.0 individuals) and it was found at par with the population recorded in West direction (0.9 individuals) and South direction (0.9 individuals). The minimum population was observed in North direction (0.6 individuals). The population recorded in the month of May (3.7 individuals) was significantly higher than all other months. The minimum population was observed in the month of February (1.4 individuals) (Table 51, Fig. 52).

During 2011-12, in the second orchard, significantly lower population was recorded in North direction (0.8 individuals) than in all other directions. The maximum population was recorded in East direction (1.2 individuals) and South direction (1.2 individuals) and it was found at par with the population recorded in West direction (1.1 individuals). The population was significantly higher in the month of May (4.4 individuals) and the minimum population was observed in the month of February (1.8 individuals) (Table 50, Fig. 50).

During 2012-13, in the second orchard, population was significantly lower in North direction (0.7 individuals) than in all other directions. The maximum population was recorded in East direction (1.2 individuals) and South direction (1.2 individuals). Significantly higher population was recorded in the month of May (4.5 individuals) and minimum in the month of February (1.4 individuals) (Table 51, Fig. 53).

During 2011-12, in the third orchard, significantly higher population was recorded in the East direction (1.4 individuals). The minimum population was recorded in the North direction (0.8 individuals) which was found at par with the population recorded in West direction (0.9 individuals). Significantly higher population was recorded in the month of May (4.5 individuals) and minimum population was observed in the month of February (1.4 individuals) (Table 50, Fig. 51).

During 2012-13, in the third orchard, significantly lower population was recorded in North direction (0.7 individuals) and the maximum population was recorded in the East direction (1.4 individuals). The population was significantly higher in the month of May (4.5 individuals) and minimum population was observed in the month of February (1.6 individuals) (Table 51, Fig. 54).

4.1.5a.3 Impact of planting system, irrigation methods and plant's age of the orchard on population

During 2011-12, the mean population among three orchards was different. It was maximum in the second orchard (1.1 individuals) and minimum was recorded in first orchard (1.0 individuals) and second orchard (1.0 individuals) (Table 50).

During 2012-13, the mean population among three orchards was significantly different. It was maximum in the second orchard (1.0 individuals) and third orchard (1.0 individuals) and minimum was recorded in first orchard (0.8 individuals) (Table 51).

During 2011-12, irrespective of orchards, significantly higher population was recorded in East direction (1.3 individuals) and it was recorded minimum in North direction (0.8 individuals). Significantly higher population was recorded in the month of May in all the four directions (East, West, North and South). The minimum population was observed in the month of February (Table 52). Similar pattern for the population was observed during 2012-13 (Table 54).

4.1.5a.4 Impact of abiotic factors on population

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on population, all factors were analyzed in the multiple linear regression models.

During 2011-12, the overall contribution of abiotic factors on weevils population was 89.0%. In the multiple regression equation the population decreased by 0.96 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 53).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.95 individuals increase in the population (Table 53).

Table 52: Population of litchi weevils during 2011-12

Months	East	West	North	South	Mean
April	4.4	3.7	2.7	4.0	**3.7**
May	5.5	4.3	3.3	4.9	**4.5**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	0.0	0.0	0.0	0.0	**0.0**
September	0.0	0.0	0.0	0.0	**0.0**
October	0.0	0.0	0.0	0.0	**0.0**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	2.1	1.6	1.1	1.6	**1.6**
March	3.3	2.4	2.2	2.9	**2.7**
Mean	**1.3**	**1.0**	**0.8**	**1.1**	**1.0**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.11	0.04
DxM	0.40	0.14

Table 53: Impact of abiotic factors on population of litchi weevils during 2011-12

	Constant	**Temperature (˚C)**		**Relative humidity (%)**		**Rainfall (mm)**
		Maximum	**Minimum**	**0712 hrs**	**1412 hrs**	
		X_1	**X_2**	**X_3**	**X_4**	**X_5**
Co-efficient	27.438	-0.960	0.947	0.027	-0.295	-0.014
SE	11.219	0.566	0.542	0.082	0.123	0.013
T- value	2.446	-1.696	1.749	0.329	-2.399	-1.117
R^2	89.0					

Population (Y) = 27.438 -0.960 X_1 +0.947 X_2 +0.027 X_3 -0.295 X_4 -0.014 X_5

Table 54: Population of litchi weevils during 2012-13

Months	East	West	North	South	Mean
April	4.3	3.2	2.7	3.6	**3.4**
May	5.2	3.9	3.2	4.6	**4.2**
June	0.0	0.0	0.0	0.0	**0.0**
July	0.0	0.0	0.0	0.0	**0.0**
August	0.0	0.0	0.0	0.0	**0.0**
September	0.0	0.0	0.0	0.0	**0.0**
October	0.0	0.0	0.0	0.0	**0.0**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	2.1	1.5	0.9	1.4	**1.5**
March	2.8	2.3	1.3	2.2	**2.2**
Mean	**1.2**	**0.9**	**0.7**	**1.0**	**0.9**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.08	0.02
DxM	0.28	0.10

Table 55: Impact of abiotic factors on population of litchi weevils during 2012-13

	Constant	Temperature (˚C)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	0712 hrs	1412 hrs	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	-1.131	0.787	-0.840	-0.212	0.196	0.026
SE	8.644	0.313	0.306	0.078	0.082	0.026
T- value	-0.131	2.514	-2.741	-2.727	2.404	0.999
R^2	75.3					

Population (Y) = $-1.131 + 0.787 X_1 - 0.840 X_2 - 0.212 X_3 + 0.196 X_4 + 0.026 X_5$

The mean percent population increased by 0.03 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 53).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.30 individuals decrease in the population (Table 53).

The population decreased by 0.01 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 53).

During 2012-13, the overall contribution of abiotic factors on weevils population was 75.3%. In the multiple regression equation the population increased by 0.79 individuals with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 55).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 0.84 individuals decrease in the population (Table 55).

The population decreased by 0.21 individuals with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 55).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.20 individuals increase in the population (Table 55).

The mean percent population decreased by 0.03 individuals with every unit increase (1mm) in rainfall, while other variables as constant (Table 55).

4.1.5b Leaf infestation dynamics of weevils, *Hypomeces squamosus* Faust, *Lepropus aurovittatus* Heller, *L. lateralis* Faust, *Peltotrachelus pupes* Faust, *Amblyrrhinus poricollis* Schoenherr, *Myllocerus dentifer* Guerin, *M. curvicornis* Marshall, *M. laetivirens* Marshall, *M. discolor* Boheman (Coleoptera: Curculionidae) during 2011-12 and 2012-13

The observations on incidence of litchi weevils on the crop plants were made in four major directions (East, West, North and South) in three orchards during 2011-12 and 2012-13. The data for incidence of the insect pest are presented in Table 56 and Table 57 for 2011-12 and 2012-13, respectively.

The leaf infestation pattern of litchi weevil is quite different from other insect pests of litchi. The symptoms of feeding include small irregular cuts throughout leaf margins. The pest is able to consume all kind of leaves (soft and succulent to hard). The soft and succulent leaves appear from the second fortnight of February till end of March and acquire hardness as the pest population increases with increasing temperature in successive months. However, the pest continues feeding on hard and mature leaves. At extreme temperatures (last week of May to June) the pest population gradually declines, as a result, leaf infestation also decreases.

4.1.5b.1 Annual appearing pattern of insect pest

The perusal of the data revealed that incidence of the insect pest occurred once during 2011-12 as well as 2012-13. During 2011-12 the incidence was started in February (7.9%) and reached to its maximum in May (28.2%) followed by reduction in incidence during June (22.6%) (Table 56). Similar pattern was observed during 2012-13, where the incidence was started in February (6.9%) and reached to its maximum in May (22.5%) (Table 57).

4.1.5b.2 Impact of direction and month on leaf infestation

During 2011-12, in the first orchard, significantly higher leaf infestation was recorded in East direction (8.9%) which was found at par with the infestation occurred in West direction (8.5%). The minimum leaf infestation was observed in North direction (6.2%) which was found at par with the infestation occurred in South direction (7.0%). The leaf infestation recorded in the month of September (7.4%) was significantly higher than all other months. Later on, the infestation started to reduce gradually due to reduction in pest population. The minimum leaf infestation was observed in the month of February (8.4%) (Table 56, Fig. 55).

During 2012-13, in the first orchard, significantly higher leaf infestation was recorded in West direction (5.8%) which was found at par with the infestation occurred in East direction (5.3%) and South direction (5.0%). The minimum leaf infestation was observed in North direction (4.4%). significantly higher leaf infestation was observed in the month of May (18.1%) and it was recorded minimum in he month of February (6.9%) (Table 57, Fig. 58).

Table 56: Incidence of litchi weevils during 2011-12

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	29.6	28.2	16.4	22.4	**24.2**	19.5	21.3	22.3	25.3	**22.1**	23.5	25.1	18.9	21.8	**22.3**	**22.9**	-
May	31.6	29.9	21.4	24.6	**26.9**	29.3	27.9	26.5	34.4	**29.5**	29.8	29.4	25.1	28.1	**28.1**	**28.2**	-
June	25.4	21.9	16.6	20.1	**21.0**	25.4	20.3	21.2	29.6	**24.1**	24.6	22.7	19.1	24.4	**22.7**	**22.6**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	August
September	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	September
October	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	9.3	10.3	7.5	6.4	**8.4**	9.9	8.3	10.0	7.7	**9.0**	7.0	5.4	6.7	6.3	**6.4**	**7.9**	February
March	10.3	11.3	11.9	10.5	**11.0**	17.6	18.0	16.4	17.5	**17.4**	15.0	12.7	13.6	13.7	**13.8**	**14.0**	March
Mean	**8.9**	**8.5**	**6.2**	**7.0**	**7.6**	**8.5**	**8.0**	**8.0**	**9.5**	**8.5**	**8.3**	**7.9**	**7.0**	**7.9**	**7.8**	**8.0**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.70	0.24
Directions (D)	0.80	0.28
Months (M)	1.38	0.49
OxD	1.38	0.49
OxM	2.40	0.86
DxM	2.77	0.99
OxDxM	4.80	1.72

Table 57: Incidence of litchi weevils during 2012-13

Months	Orchard I					Orchard II					Orchard III					Grand Mean	Leaf emergence pattern
	East	West	North	South	Mean	East	West	North	South	Mean	East	West	North	South	Mean		
April	14.1	15.0	11.0	12.8	**13.2**	19.1	19.6	17.6	19.5	**19.0**	21.8	18.2	15.7	17.7	**18.4**	**16.8**	-
May	18.0	19.9	16.6	18.0	**18.1**	26.1	24.5	23.4	29.0	**25.8**	31.5	22.2	19.6	20.9	**23.6**	**22.5**	-
June	12.9	17.7	12.6	15.3	**14.6**	21.7	20.0	18.2	24.7	**21.2**	24.1	16.9	14.4	15.5	**17.7**	**17.8**	-
July	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	July
August	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	August
September	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	September
October	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	October
November	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
December	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	-
January	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**	January
February	8.3	7.9	5.2	6.2	**6.9**	8.8	6.7	7.3	7.6	**7.6**	9.0	5.9	5.8	3.6	**6.1**	**6.9**	February
March	10.0	9.3	7.0	7.4	**8.4**	13.9	11.7	12.1	12.9	**12.7**	14.1	9.9	9.2	6.1	**9.8**	**10.3**	March
Mean	**5.3**	**5.8**	**4.4**	**5.0**	**5.1**	**7.5**	**6.9**	**6.6**	**7.8**	**7.2**	**8.4**	**6.1**	**5.4**	**5.3**	**6.3**	**6.2**	

Sources of variation	CD at 5%	SEm±
Orchard (O)	0.41	0.14
Directions (D)	0.48	0.17
Months (M)	0.83	0.29
OxD	0.83	0.29
OxM	1.43	0.51
DxM	1.65	0.59
OxDxM	2.87	1.03

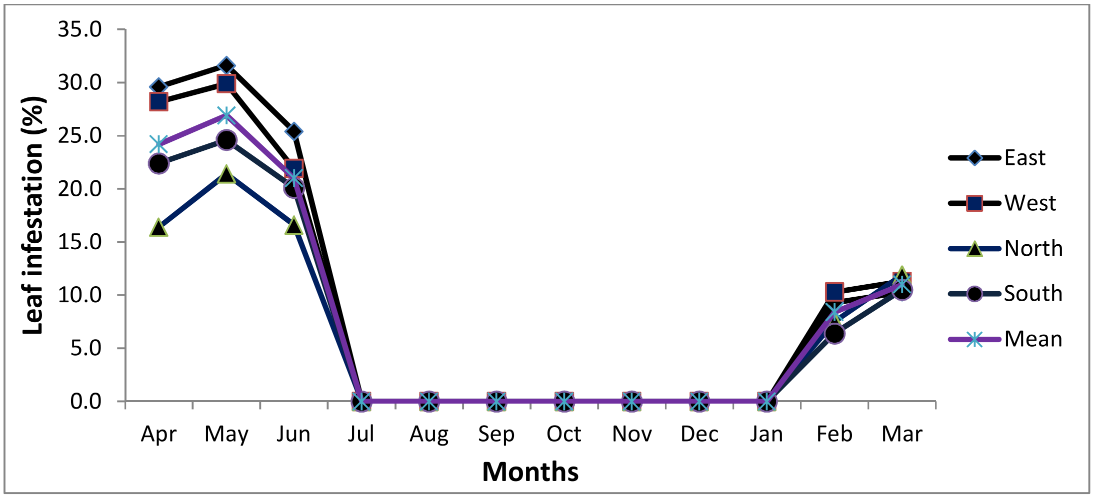

Fig. 55: Incidence of litchi weevils in first orchard during 2011-012

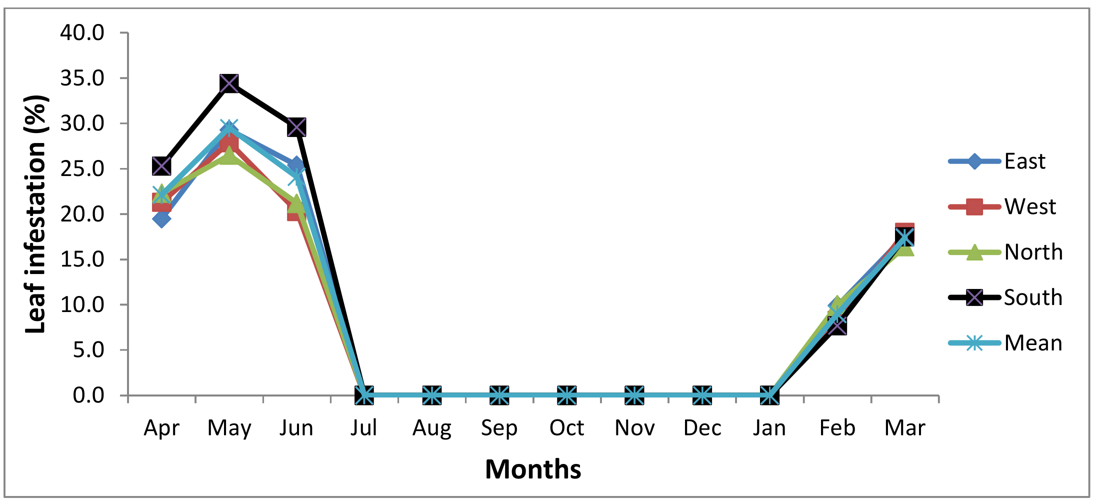

Fig. 56: Incidence of litchi weevils in second orchard during 2011-012

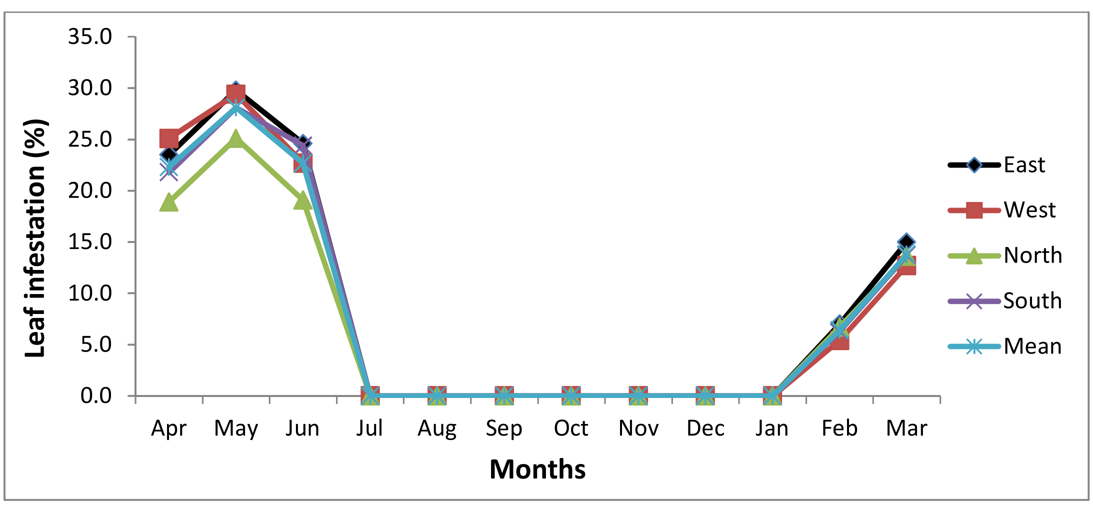

Fig. 57: Incidence of litchi weevils in third orchard during 2011-012

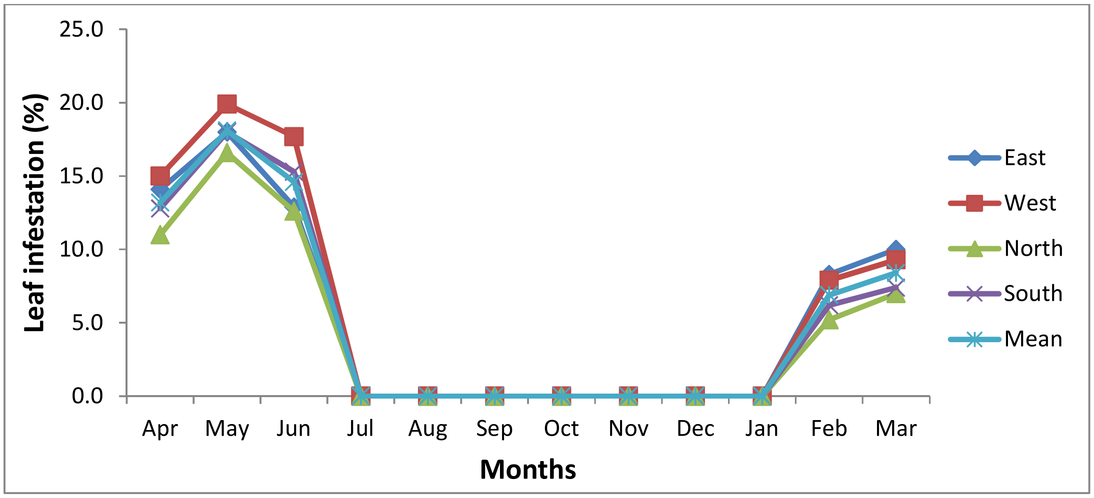

Fig. 58: Incidence of litchi weevils in first orchard during 2012-013

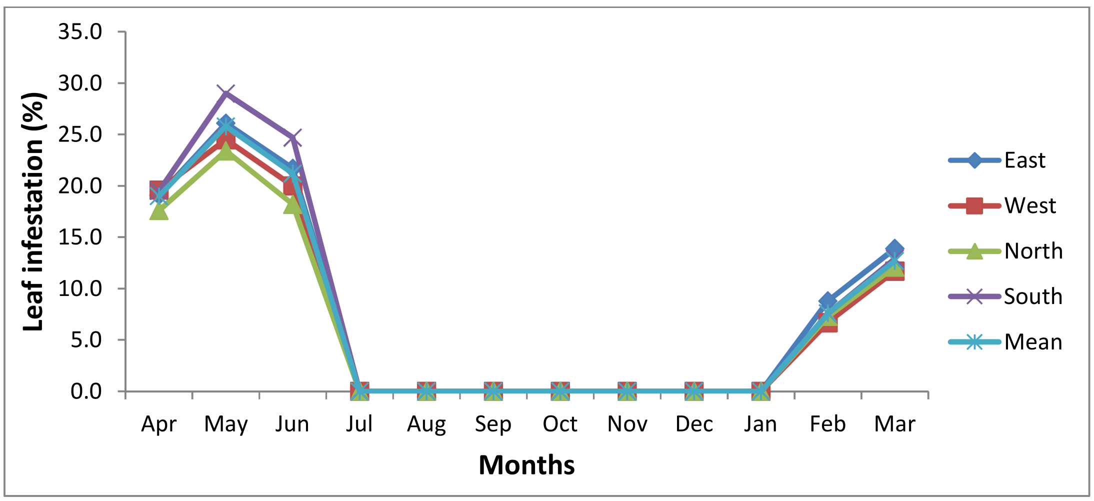

Fig. 59: Incidence of litchi weevils in second orchard during 2012-013

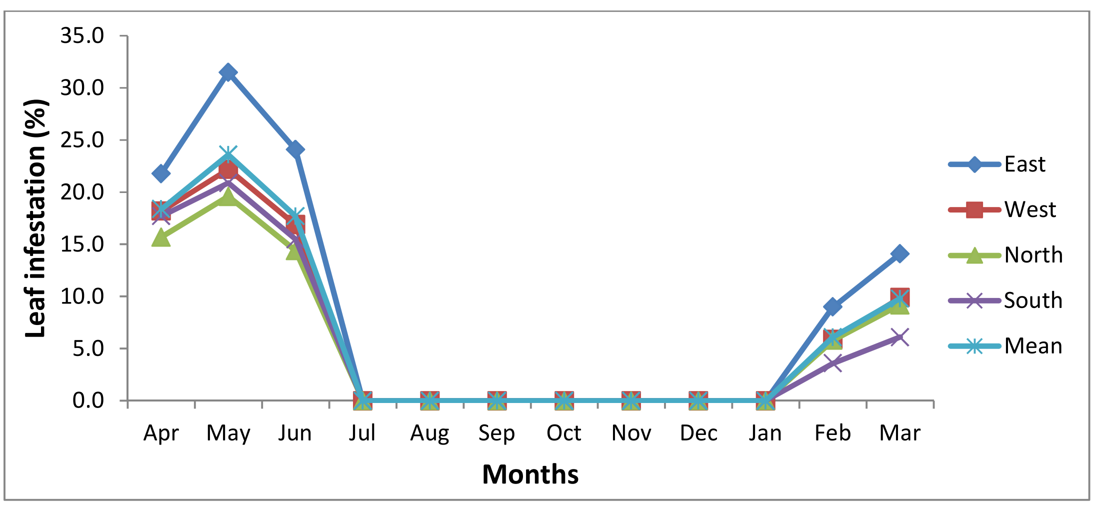

Fig. 60: Incidence of litchi weevils in third orchard during 2012-013

During 2011-12, in the second orchard, significantly lower leaf infestation was recorded in West direction (8.0%) and North direction (8.0%) which was found at par with the infestation occurred in the East direction (8.5%). The maximum leaf infestation was recorded in South direction (9.5%). The leaf infestation was significantly higher in the month of May (29.5%) and it was recorded minimum in the month of February (9.0%) (Table 56, Fig. 56).

During 2012-13, in the second orchard, leaf infestation was significantly lower in North direction (6.6%) which was found at par with the infestation occurred in the West direction (6.9%). The maximum leaf infestation was recorded in South direction (7.8%) which was found at par with the infestation occurred in the East direction (7.5%). Significantly higher leaf infestation was recorded in the month of May (25.8%) and minimum in the month of February (7.6%) (Table 57, Fig. 59).

During 2011-12, in the third orchard, maximum leaf infestation was observed in the East direction (8.3%) and it was recorded minimum in the North direction (7.0%). Significantly higher leaf infestation was recorded in the month of May (28.1%) and minimum was observed in the month of February (6.4%) (Table 56, Fig. 57).

During 2012-13, in the third orchard, significantly lower leaf infestation was recorded in South direction (5.3%) which was found at par with the infestation occurred in the West direction (6.1%) and North direction (5.4%). The maximum leaf infestation was recorded in the East direction (8.4%). The leaf infestation was significantly higher in the month of May (23.6%) and it was recorded minimum in the month of February (6.1%) (Table 57, Fig. 60).

4.1.5b.3 Impact of planting system, irrigation methods and plant's age of the orchard on leaf infestation

During 2011-12, the mean percent leaf infestation among three orchards was observed significantly different. It was minimum in the first orchard (7.6%) which was found at par with the infestation recorded in third orchard (7.8%) and maximum was recorded in second orchard (8.5%) (Table 56). Similar pattern for the infestation among the orchards was observed during 2012-13. It was 5.1 %, 6.3% and 7.2% in first, third and second orchard, respectively (Table 57).

During 2011-12, irrespective of orchards, significantly higher leaf infestation was recorded in East direction (8.6%) which was found at par with the infestation occurred in the West direction (8.1%) and South direction (8.1%). it was recorded minimum in North direction (7.0%). Significantly higher leaf infestation was recorded in the month of May in all the four directions (East, West, North and South) and it was observed minimum in the month of February (Table 58).

During 2012-13, leaf infestation was significantly lower in North direction (5.4%) and it was recorded maximum in East direction (7.0%). Significantly higher leaf infestation was observed in the month of May in all the four directions (East, West, North and South) and it was recorded minimum in the month of February (Table 60).

4.1.5b.4 Impact of abiotic factors on leaf infestation

In order to study the combined effect of abiotic factors (temperature, relative humidity and rainfall) on leaf infestation, all factors were analyzed in the multiple linear regression models.

During 2011-12, the value of coefficient of determination (R^2 =80.6%) indicated the contribution of abiotic factors in weevils incidence. In the multiple regression equation the mean percent leaf infestation decreased by 1.76% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 59).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 1.73% increase in the mean percent leaf infestation (Table 59).

The mean percent leaf infestation decreased by 0.96% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 59).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.49% decrease in the mean percent leaf infestation (Table 59).

The mean percent leaf infestation decreased by 0.04% with every unit increase (1mm) in rainfall, while other variables as constant (Table 59).

Table 58: Incidence of litchi weevils during 2011-12

Months	East	West	North	South	Mean
April	24.2	24.9	19.2	23.2	**22.9**
May	30.2	29.1	24.3	29.0	**28.2**
June	25.1	21.6	19.0	24.7	**22.6**
July	0.0	0.0	0.0	0.0	**0.0**
August	0.0	0.0	0.0	0.0	**0.0**
September	0.0	0.0	0.0	0.0	**0.0**
October	0.0	0.0	0.0	0.0	**0.0**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	8.7	8.0	8.1	6.8	**7.9**
March	14.3	14.0	14.0	13.9	**14.0**
Mean	**8.6**	**8.1**	**7.0**	**8.1**	**8.0**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.80	0.28
DxM	2.77	0.99

Table 59: Impact of abiotic factors on litchi weevils incidence during 2011-12

	Constant	**Temperature (˚C)**		**Relative humidity (%)**		**Rainfall (mm)**
		Maximum	**Minimum**	**0712 hrs**	**1412 hrs**	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	140.629	-1.757	1.734	-0.956	-0.488	-0.042
SE	98.065	4.950	4.735	0.716	1.076	0.113
T- value	1.434	-0.355	0.366	-1.335	-0.454	-0.368
R^2	80.6					

Mean percent leaf infestation (Y) = $140.629 - 1.757 X_1 + 1.734 X_2 - 0.956 X_3 - 0.488 X_4 - 0.042 X_5$

Table 60: Incidence of litchi weevils during 2012-13

Months	East	West	North	South	Mean
April	18.3	17.6	14.8	16.7	**16.8**
May	25.2	22.2	19.9	22.6	**22.5**
June	19.6	18.2	15.1	18.5	**17.8**
July	0.0	0.0	0.0	0.0	**0.0**
August	0.0	0.0	0.0	0.0	**0.0**
September	0.0	0.0	0.0	0.0	**0.0**
October	0.0	0.0	0.0	0.0	**0.0**
November	0.0	0.0	0.0	0.0	**0.0**
December	0.0	0.0	0.0	0.0	**0.0**
January	0.0	0.0	0.0	0.0	**0.0**
February	8.7	6.8	6.1	5.8	**6.9**
March	12.7	10.3	9.4	8.8	**10.3**
Mean	**7.0**	**6.3**	**5.4**	**6.0**	**6.2**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.48	0.17
DxM	1.65	0.59

Table 61: Impact of abiotic factors on litchi weevils incidence during 2011-12

	Constant	**Temperature (˚C)**		**Relative humidity (%)**		**Rainfall (mm)**
		Maximum	**Minimum**	**0712 hrs**	**1412 hrs**	
		X_1	X_2	X_3	X_4	X_5
Co-efficient	39.237	1.819	-1.854	-1.031	0.602	-0.033
SE	23.309	0.844	0.826	0.209	0.220	0.070
T- value	1.683	2.155	-2.243	-4.924	2.732	-0.466
R^2	94.2					

Mean percent leaf infestation (Y) = 39.237 +1.819 X_1 -1.854 X_2 -1.031 X_3 +0.602 X_4 -0.033 X_5

Plate 25 **Plate 26**

Plate 27 **Plate 28**

Adult weevils on litchi leaves

Plate 29

Plate 30

Plate 31

Plate 32

Symptoms of weevils infestation on litchi leaves

Lepropus aurovittatus

L. lateralis

Hypomeces squamosus

Amblyrrhinus poricollis

Peltotrachelus pupes

Myllocerus discolor

M. dentifer

M. laetivirens

M. curvicornis

Plate 33: Different species of weevils infesting litchi leaves

Table 62: Leaf infestation pattern of insect pests during 2011-12 and 2012-13

Pest	Infestation	Orchard I				Orchard II				Orchard III			
		2011-12		2012-13		2011-12		2012-13		2011-12		2012-13	
		Direction	Month	Direction	Month	Direction	Month	Direction	Month	Direction	Month	Direction	Month
1.Leaf roller	Min	North	Jul	North	Jul	North	Jul	East	Jul	South	Jul	West, South	Jul
	Max	East	Sep	East	Oct	South	Sep	North	Oct	East	Sep	East	Sep
2.Leaf folder	Min	North	Aug	North	Aug	North	Aug	North	Aug	North	Aug	North	Aug
	Max	East	Oct	West	Oct	East	Oct	East	Oct	East	Oct	East, West, South	Oct
3.Mid rib borer	Min	-	-	-	-	North	Aug	North	Aug	North	Aug	North	Aug
	Max	-	-	-	-	East	Oct	East	Oct	East	Oct	East	Oct
4.Beetle	Min	North	Jul	North	Jul	North	Jul	North	Jul	North	Jul	North	Jul
	Max	West	Oct	East	Oct	East, West, South	Nov	East	Nov	East	Nov	East	Nov
5.Weevils	Min	North	Feb	North	Feb	West, North	Feb	North	Feb	North	Feb	South	Feb
	Max	East	May	West	May	South	May	South	May	East	May	East	May

During 2012-13, the value of coefficient of determination (R^2 =94.2%) indicated the contribution of abiotic factors in weevils incidence. In the multiple regression equation the mean percent leaf infestation increased by 1.82% with every unit increase (1˚C) in maximum temperature, while other variables as constant (Table 61).

The regression values of minimum temperature showed that for other variables as constant, every unit increase (1˚C) in minimum temperature resulted in 1.86% decrease in the mean percent leaf infestation (Table 61).

The mean percent leaf infestation decreased by 1.03% with every unit increase (1%) in maximum relative humidity, while other variables as constant (Table 61).

The regression values of minimum relative humidity showed that for other variables as constant, every unit increase (1%) in minimum relative humidity resulted in 0.60% increase in the mean percent leaf infestation (Table 61).

The mean percent leaf infestation decreased by 0.03% with every unit increase (1mm) in rainfall, while other variables as constant (Table 61).

4.2 The diversity and relative abundance of insect pollinator species associated with litchi crop

4.2.1 Relative abundance of Honey bee, *Apis mellifera* on litchi inflorescence during 2011 and 2012

The observations on relative abundance (average population) of honey bee, *Apis mellifera* on litchi inflorescence were made in two directions (East and West) at four different day hours (0800, 1100, 1400 and 1700 hours) during 2011 and 2012. The data for relative abundance of pollinator are presented in Table 63 and Table 64 as well as Fig. 61 and 62 for 2011and 2012, respectively.

4.2.1.1 Relative abundance of pollinator during flowering period

The perusal of the data revealed that the pollinator population was higher at initiation of flowering period and gradually the population declined in successive days. During 2011 significantly higher population was observed on April 11 (4.3 foragers/inflorescence/3min). It was recorded minimum on April 15 (0.2 foragers/inflorescence/3min) and it was at par with the population observed on April 08 (0.4 foragers/inflorescence/3min), April 13 (0.6 foragers/inflorescence/3min) and

April 14 (0.5 foragers/inflorescence/3min). In the evening of April 10, honeybee hives were placed in the orchard so maximum population was observed on April 11 (4.3 foragers/inflorescence/3min) (Table 63). During 2012, the population observed on March 26 (3.8 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded on March 24 (3.3 foragers/inflorescence/3min), March 25 (3.1 foragers/inflorescence/3min), March 27 (2.6 foragers/inflorescence/3min), March 29 (2.6 foragers/inflorescence/3min), March 30 (2.6 foragers/inflorescence/ 3min), March 31 (2.8 foragers/inflorescence/3min) and April 01 (2.5 foragers/ inflorescence/3min), April 02 (2.4 foragers/inflorescence/3min), April 03 (2.7 foragers/inflorescence/3min). The minimum population was recorded on April 10 (1.5 foragers/inflorescence/3min) which was found at par with the population observed on April 05 (1.7 foragers/inflorescence/3min), April 08 (1.8 foragers/inflorescence/3min) and April 09 (1.6 foragers/inflorescence/3min) (Table 64).

4.2.1.2 Impact of day hours and days on relative abundance

During 2011, in the East direction, pollinator population recorded at 1100 hours (4.4 foragers/inflorescence/3min) was significantly higher than all other day hours (0800, 1400 and 1700 hours). The minimum population was observed at 1400 hours (0.3 foragers/inflorescence/3min) and was at par with the population recorded at 1700 hours (0.5 foragers/inflorescence/3min). Significantly higher population was recorded on April 11 (6.0 foragers/inflorescence/3min) and minimum population was observed on April 15 (0.3 foragers/inflorescence/3min) which was found at par with the population recorded on April 08 (0.6 foragers/inflorescence/3min) (Table 63).

During 2012, in the East direction, significantly higher population was observed at 1100 hours (5.2 foragers/inflorescence/3min) and it was recorded minimum at 1700 hours (1.9 foragers/inflorescence/3min). The population observed on March 26 (4.2 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded on March 24 (3.9 foragers/inflorescence/3min), March 25 (3.8 foragers/inflorescence/3min), March 30 (3.7 foragers/inflorescence/ 3min) and March 31 (3.8 foragers/inflorescence/3min). The minimum population was observed on April 10 (1.9 foragers/inflorescence/3min) which was found at par with the population recorded on April 05 (2.4 foragers/inflorescence/3min), April 08 (2.3 foragers/inflorescence/3min) and April 09 (2.1 foragers/inflorescence/3min) (Table 64).

Table 63: Relative abundance of *Apis mellifera* on litchi inflorescence during 2011

Days	East (D_1)					West (D_2)					Grand Mean
	0800	1100	1400	1700	Mean	0800	1100	1400	1700	Mean	
March 24	7.8	4.2	0.4	0.6	**3.3**	1.8	2.8	0.2	0.4	**1.3**	**2.3**
March 25	7.4	6.0	0.4	0.4	**3.6**	2.0	2.8	0.2	0.2	**1.3**	**2.4**
March 26	7.4	6.6	0.2	0.6	**3.7**	2.2	2.4	0.4	0.4	**1.4**	**2.5**
March 27	6.4	6.4	0.6	0.4	**3.5**	2.0	2.4	0.2	0.2	**1.2**	**2.3**
March 28	6.6	7.0	0.0	0.6	**3.6**	2.2	2.8	0.2	0.4	**1.4**	**2.5**
March 29	7.4	6.6	0.2	0.4	**3.7**	2.2	2.6	0.2	0.4	**1.4**	**2.5**
March 30	0.0	2.8	0.2	0.6	**0.9**	0.0	2.8	1.6	1.8	**1.6**	**1.2**
March 31	3.8	7.2	0.0	0.6	**2.9**	0.4	1.2	0.6	1.6	**1.0**	**1.9**
April 01	5.0	4.2	0.2	0.2	**2.4**	1.6	2.4	0.0	0.4	**1.1**	**1.8**
April 02	2.8	3.6	0.0	0.4	**1.7**	2.4	2.0	0.2	0.0	**1.2**	**1.4**
April 03	2.8	3.2	0.0	0.4	**1.6**	2.6	1.4	0.4	0.2	**1.2**	**1.4**
April 04	2.8	3.0	0.0	0.4	**1.6**	2.6	2.0	0.0	0.2	**1.2**	**1.4**
April 05	2.8	2.0	0.0	0.0	**1.2**	2.8	2.2	0.0	0.2	**1.3**	**1.3**
April 06	3.2	5.2	0.0	0.6	**2.3**	2.8	2.0	0.0	0.0	**1.2**	**1.7**
April 07	3.8	4.0	0.0	0.0	**2.0**	1.2	0.8	0.0	0.0	**0.5**	**1.2**
April 08	0.2	2.2	0.0	0.0	**0.6**	0.0	0.8	0.0	0.0	**0.2**	**0.4**
April 09	3.0	5.6	0.0	0.0	**2.2**	0.0	0.8	0.0	0.0	**0.2**	**1.2**
April 10	2.8	4.8	0.0	0.2	**2.0**	0.0	0.8	0.0	0.0	**0.2**	**1.1**
April 11	10.2	10.0	2.6	1.0	**6.0**	2.0	2.2	4.4	2.2	**2.7**	**4.3**
April 12	5.0	3.2	1.8	2.0	**3.0**	1.6	1.0	2.6	2.6	**2.0**	**2.5**
April 13	0.2	1.8	0.6	0.8	**0.9**	0.0	0.8	0.6	0.0	**0.4**	**0.6**
April 14	0.8	1.8	0.6	0.2	**0.9**	0.0	0.4	0.0	0.4	**0.2**	**0.5**
April 15	0.6	0.4	0.0	0.0	**0.3**	0.0	0.4	0.0	0.0	**0.1**	**0.2**
Mean	**4.0**	**4.4**	**0.3**	**0.5**	**2.3**	**1.4**	**1.7**	**0.5**	**0.5**	**1.0**	**1.7**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.12	0.04
Day hours (H)	0.17	0.06
Days (Y)	0.40	0.14
DxH	0.24	0.08
DxY	0.57	0.20
HxY	0.81	0.29
DxHxY	1.14	0.41

Table 64: Relative abundance of *Apis mellifera* on litchi inflorescence during 2012

Days	East (D_1)					West (D_2)					Grand Mean
	0800	1100	1400	1700	Mean	0800	1100	1400	1700	Mean	
March 24	2.4	9.8	2.2	1.0	**3.9**	0.6	7.6	0.8	1.8	**2.7**	**3.3**
March 25	2.4	9.0	2.6	1.0	**3.8**	1.0	6.4	0.8	1.8	**2.5**	**3.1**
March 26	0.0	12.6	1.8	2.2	**4.2**	0.0	8.0	2.4	3.0	**3.4**	**3.8**
March 27	2.8	4.4	4.6	0.6	**3.1**	0.4	1.4	4.0	2.2	**2.0**	**2.6**
March 28	3.6	4.4	3.0	1.6	**3.2**	0.8	2.2	1.4	0.6	**1.3**	**2.2**
March 29	2.6	5.6	3.2	2.4	**3.5**	1.0	3.0	1.4	1.2	**1.7**	**2.6**
March 30	2.6	6.2	3.4	2.4	**3.7**	0.8	3.2	1.4	0.6	**1.5**	**2.6**
March 31	2.8	6.0	3.4	3.0	**3.8**	0.6	3.6	1.4	1.4	**1.8**	**2.8**
April 01	2.8	5.6	3.0	3.0	**3.6**	1.2	2.2	1.0	1.2	**1.4**	**2.5**
April 02	3.8	4.2	1.8	3.2	**3.3**	1.6	3.0	0.4	1.4	**1.6**	**2.4**
April 03	4.2	3.6	3.8	2.6	**3.6**	1.8	3.0	1.6	1.2	**1.9**	**2.7**
April 04	4.2	4.2	3.0	2.0	**3.4**	1.6	2.0	0.6	0.6	**1.2**	**2.3**
April 05	3.2	1.8	2.8	1.6	**2.4**	1.4	2.0	0.6	0.4	**1.1**	**1.7**
April 06	3.8	5.0	1.2	2.0	**3.0**	2.4	2.4	0.6	0.4	**1.5**	**2.2**
April 07	3.2	4.0	2.2	1.4	**2.7**	1.6	2.6	1.0	0.6	**1.5**	**2.1**
April 08	2.8	3.0	2.0	1.2	**2.3**	1.6	1.8	0.8	0.8	**1.3**	**1.8**
April 09	2.4	2.8	2.4	0.8	**2.1**	1.4	1.4	1.2	0.4	**1.1**	**1.6**
April 10	2.0	1.6	2.0	1.8	**1.9**	0.6	1.0	1.4	1.6	**1.2**	**1.5**
Mean	**2.9**	**5.2**	**2.7**	**1.9**	**3.2**	**1.1**	**3.2**	**1.3**	**1.2**	**1.7**	**2.4**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.12	0.04
Day hours (H)	0.18	0.06
Days (Y)	0.37	0.13
DxH	0.25	0.09
DxY	0.53	0.19
HxY	0.75	0.27
DxHxY	1.06	0.38

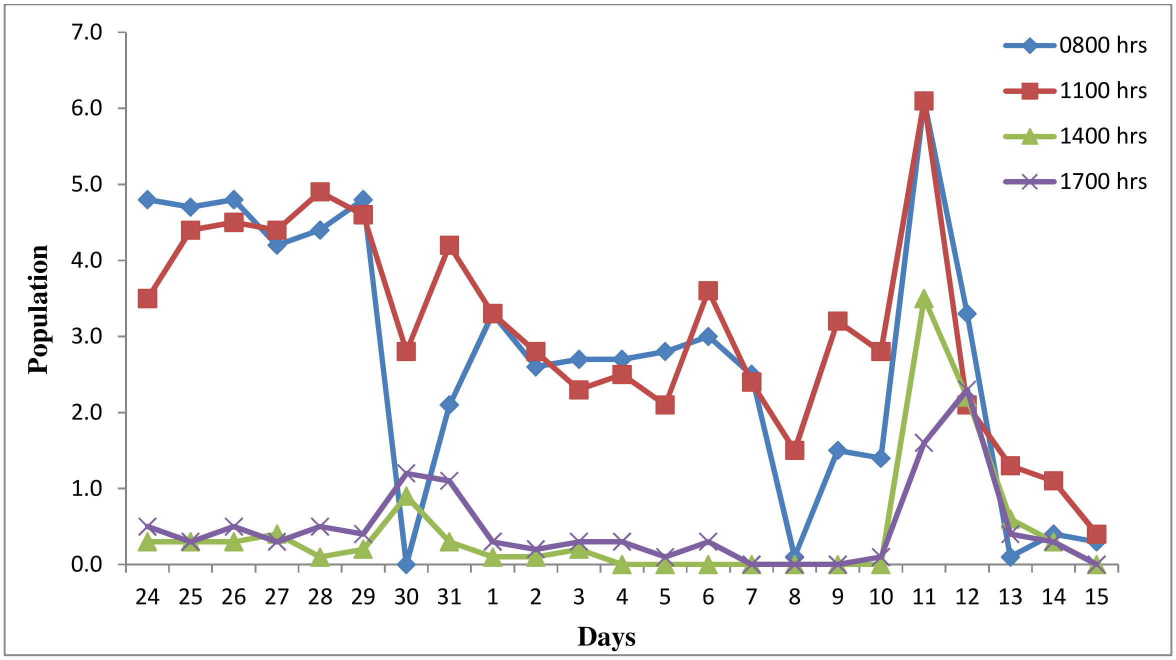

Fig. 61: Relative abundance of *Apis mellifera* on litchi inflorescence during 2011

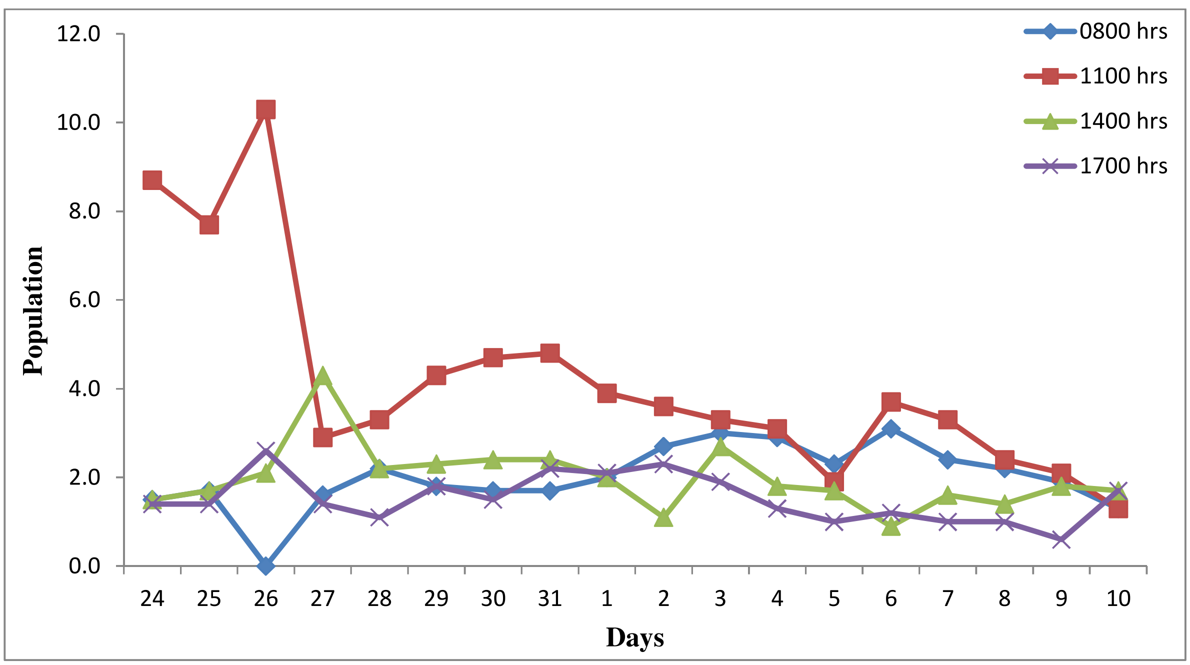

Fig. 62: Relative abundance of *Apis mellifera* on litchi inflorescence during 2012

During 2011, in West direction, significantly lower population was recorded at 1400 hours (0.5 foragers/inflorescence/3min) and 1700 hours (0.5 foragers/ inflorescence/3min). The maximum population was recoded at 1100 hours (1.7 foragers/inflorescence/3min). The population was significantly lower on April 15 (0.1 foragers/inflorescence/3min) and was found at par with the population observed on April 07 (0.5 foragers/inflorescence/3min), April 08 (0.2 foragers/inflorescence/ 3min), 09 (0.2 foragers/inflorescence/3min), April 10 (0.2 foragers/inflorescence/ 3min), April 13 (0.4 foragers/inflorescence/3min) and April 14 (0.2 foragers/ inflorescence/3min). The maximum population was observed on April 11 (2.7 foragers/inflorescence/3min) (Table 63).

During 2012, in the West direction, pollinator population was significantly lower at 0800 hours (1.1 foragers/inflorescence/3min) and was found at par with the population at 1700 hours (1.2 foragers/inflorescence/3min). The maximum population was recorded at 1100 hours (3.2 foragers/inflorescence/3min). Significantly higher population was observed on March 26 (3.4 foragers/inflorescence/3min). Population was minimum on April 05 (1.1 foragers/inflorescence/3min) and April 09 (1.1 foragers/inflorescence/3min) which was found at par with the population observed on March 28 (1.3 foragers/inflorescence/3min), March 30 (1.5 foragers/inflorescence/ 3min), April 01 (1.4 foragers/inflorescence/3min), April 02 (1.6 foragers/ inflorescence/3min), April 04 (1.2 foragers/inflorescence/3min), April 05 (1.1 foragers/inflorescence/3min), April 06 (1.5 foragers/inflorescence/3min), April 07 (1.5 foragers/inflorescence/3min), April 08 (1.3 foragers/inflorescence/3min) and April 09 (1.1 foragers/inflorescence/3min) (Table 64).

4.2.1.3 Impact of direction on relative abundance of pollinator

During 2011, the relative abundance of pollinator between East and West directions was significantly different. It was maximum in East direction (2.3 foragers/inflorescence/3min) and minimum in West direction (1.0 foragers/inflorescence/3min) (Table 63). Similar pattern for the relative abundance was observed during 2012. It was 3.2% and 1.7% in East direction and West direction respectively (Table 64).

During 2011, irrespective of directions, significantly higher population was observed at 1100 hours (3.1 foragers/inflorescence/3min) and it was recorded minimum at 1400 hours (0.4 foragers/inflorescence/3min) and found at par with the population at 1700 hours (0.5 foragers/inflorescence/3min). At 0800 hours, significantly higher population was observed on April 11 (6.1 foragers/ inflorescence/3min). The minimum population was observed on April 08 (0.1 foragers/inflorescence/3min) and April 13 (0.1 foragers/inflorescence/3min) and it was at par with the population recorded on April 14 (0.4 foragers/inflorescence/3min) and April 15 (0.3 foragers/inflorescence/3min). At 1100 hours, significantly lower population was recorded on April 15 (0.4 foragers/inflorescence/3min) which was found at par with the population observed on April 14 (1.1 foragers/ inflorescence/3min). The maximum population was recorded on April 11 (6.1 foragers/inflorescence/3min). At 1400 hours, pollinator population was not observed during April 04 to April 10 and on April 15. Maximum population was observed on April 11 (3.5 foragers/inflorescence/3min). At 1700 hours, significantly higher population was observed on April 12 (2.3 foragers/inflorescence/3min) and it was at par with the population observed on April 11 (1.6 foragers/inflorescence/3min). Population was not observed during April 07 to April 09 and on April 15 (Table 65).

During 2012, irrespective of directions, significantly lower population was observed at 1700 hours (1.5 foragers/inflorescence/3min) and it was recorded maximum at 1100 hours (4.2 foragers/inflorescence/3min). At 0800 hours, population was not observed on March 26. Significantly higher population was recorded on April 06 (3.1 foragers/inflorescence/3min) and it was found at par with the population recorded on April 02 (2.7 foragers/inflorescence/3min), April 03 (3.0 foragers/ inflorescence/3min), April 04 (2.9 foragers/inflorescence/3min) and April 07 (2.4 foragers/inflorescence/3min). At 1100 hours, population recorded on March 26 (10.3 foragers/inflorescence/3min) was significantly higher and minimum population was recorded on April 10 (1.3 foragers/inflorescence/3min) which was found at par with the population observed on April 05 (1.9 foragers/inflorescence/3min). At 1400 hours, significantly lower population was observed on April 06 (0.9 foragers/ inflorescence/3min) and it was found at par with the population recorded on March 24 (1.5 foragers/inflorescence/3min), April 02 (1.1 foragers/inflorescence/3min), April

Table 65: Relative abundance of *Apis mellifera* on litchi inflorescence during 2011

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	4.8	3.5	0.3	0.5	**2.3**
March 25	4.7	4.4	0.3	0.3	**2.4**
March 26	4.8	4.5	0.3	0.5	**2.5**
March 27	4.2	4.4	0.4	0.3	**2.3**
March 28	4.4	4.9	0.1	0.5	**2.5**
March 29	4.8	4.6	0.2	0.4	**2.5**
March 30	0.0	2.8	0.9	1.2	**1.2**
March 31	2.1	4.2	0.3	1.1	**1.9**
April 01	3.3	3.3	0.1	0.3	**1.8**
April 02	2.6	2.8	0.1	0.2	**1.4**
April 03	2.7	2.3	0.2	0.3	**1.4**
April 04	2.7	2.5	0.0	0.3	**1.4**
April 05	2.8	2.1	0.0	0.1	**1.3**
April 06	3.0	3.6	0.0	0.3	**1.7**
April 07	2.5	2.4	0.0	0.0	**1.2**
April 08	0.1	1.5	0.0	0.0	**0.4**
April 09	1.5	3.2	0.0	0.0	**1.2**
April 10	1.4	2.8	0.0	0.1	**1.1**
April 11	6.1	6.1	3.5	1.6	**4.3**
April 12	3.3	2.1	2.2	2.3	**2.5**
April 13	0.1	1.3	0.6	0.4	**0.6**
April 14	0.4	1.1	0.3	0.3	**0.5**
April 15	0.3	0.4	0.0	0.0	**0.2**
Mean	**2.7**	**3.1**	**0.4**	**0.5**	**1.7**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.17	0.06
HxY	0.81	0.29

Table 66: Relative abundance of *Apis mellifera* on litchi inflorescence during 2012

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	1.5	8.7	1.5	1.4	**3.3**
March 25	1.7	7.7	1.7	1.4	**3.1**
March 26	0.0	10.3	2.1	2.6	**3.8**
March 27	1.6	2.9	4.3	1.4	**2.6**
March 28	2.2	3.3	2.2	1.1	**2.2**
March 29	1.8	4.3	2.3	1.8	**2.6**
March 30	1.7	4.7	2.4	1.5	**2.6**
March 31	1.7	4.8	2.4	2.2	**2.8**
April 01	2.0	3.9	2.0	2.1	**2.5**
April 02	2.7	3.6	1.1	2.3	**2.4**
April 03	3.0	3.3	2.7	1.9	**2.7**
April 04	2.9	3.1	1.8	1.3	**2.3**
April 05	2.3	1.9	1.7	1.0	**1.7**
April 06	3.1	3.7	0.9	1.2	**2.2**
April 07	2.4	3.3	1.6	1.0	**2.1**
April 08	2.2	2.4	1.4	1.0	**1.8**
April 09	1.9	2.1	1.8	0.6	**1.6**
April 10	1.3	1.3	1.7	1.7	**1.5**
Mean	**2.0**	**4.2**	**2.0**	**1.5**	**2.4**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.18	0.06
HxY	0.75	0.27

07 (1.6 foragers/inflorescence/3min) and April 08 (1.4 foragers/inflorescence/3min). At 1700 hours, population observed on April 09 (0.6 foragers/inflorescence/3min) was significantly lower and it was found at par with the population recorded on March 28 (1.1 foragers/inflorescence/3min), April 04 (1.3 foragers/inflorescence/3min), April 05 (1.0 foragers/inflorescence/3min), April 06 (1.2 foragers/inflorescence/ 3min), April 07 (1.0 foragers/inflorescence/3min) and April 08 (1.0 foragers/inflorescence/3min). The maximum population was observed on March 26 (2.6 foragers/inflorescence/3min) which was found at par with the population recorded on March 31 (2.2 foragers/inflorescence/3min), April 01 (2.1 foragers/inflorescence/3min), April 02 (2.3 foragers/inflorescence/3min) and April 03 (1.9 foragers/inflorescence/3min) (Table 66).

These findings were in accordance with the studies carried out by **Pandey and Yadav (1970)** who reported that *Apis spp*. and *Mellipona spp*. visited litchi flowers mostly during morning hours between 6:30 am to 11:00 am. **Badiyala and Garg (1990)** also reported that *Apis mellifera* visited the flowers, especially in the morning (9:30–11:30 AM) and was less active from 3:00–5:00 PM. Similarly **Singh *et al.* (2002)** reported that the maximum bee foragers/minute/panicle was recorded during 10.30-11.30 hours followed by 11.30-12.30 hours and the least was recorded at 15.30-16.30 hours of the day.

4.2.1.4 Impact of abiotic factors on population of pollinator

In order to study the combined effect of abiotic factors (temperature and relative humidity) on population of pollinator, both factors were analyzed in the multiple linear regression models.

4.2.1.4a Impact of abiotic factors on population of pollinator in East direction

The temperature and relative humidity in the surrounding of inflorescence (up to 10 cm from inflorescence) had more impact on population of pollinator than the temperature and relative humidity of the location.

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 10.5%. The population increased by 0.11 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 67).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.07 individuals in the population.

The minimum temperature of the location had positive impact on population and it was decreased by 0.06 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population decreased by 0.02 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.02 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 71.8%. The population decreased by 0.01 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 70).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.14 individuals in the population.

The population was increased by 0.02 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.18 individuals in the population.

The population decreased by 0.06 individuals with every unit increase (1%) in minimum relative humidity and the maximum relative humidity of the location had positive impact on population.

4.2.1.4b Impact of abiotic factors on population of pollinator in West direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 32.9%. The population increased by 0.20 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 68).

Table 67: Impact of temperature and relative humidity on population of *Apis mellifera* in East direction during 2011

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-2.929	0.110	0.069	0.003	-0.056	-0.023	0.020
SE	23.562	0.449	0.078	0.146	0.364	0.078	0.051
T- value	-0.124	0.245	0.878	0.023	-0.153	-0.290	0.403
R^2	10.5						
Population (Y) = -2.929 +0.110 X_1 +0.069 X_2 +0.003 X_3 -0.056 X_4 -0.023 X_5 +0.020X_6							

Table 68: Impact of temperature and relative humidity on population of *Apis mellifera* in West direction during 2011

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-8.431	0.201	0.032	-0.022	0.002	0.034	0.016
SE	8.850	0.159	0.030	0.061	0.151	0.032	0.021
T- value	-0.953	1.260	1.048	-0.361	0.014	1.057	0.759
R^2	32.9						
Population (Y) = -8.431 +0.201 X_1 +0.032 X_2 -0.022 X_3 +0.002 X_4 +0.034 X_5 +0.016X_6							

Table 69: Impact of temperature and relative humidity on mean population of *Apis mellifera* during 2011

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-8.563	0.222	0.061	-0.016	-0.016	0.005	0.020
SE	14.966	0.277	0.050	0.097	0.241	0.051	0.033
T- value	-0.572	0.802	1.203	-0.168	-0.068	-0.100	0.591
R^2	16.5						
Population (Y) = -2.929 +0.110 X_1 +0.069 X_2 +0.003 X_3 -0.056 X_4 -0.023 X_5 +0.020X_6							

Table 70: Impact of temperature and relative humidity on population of *Apis mellifera* in East direction during 2012

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	6.268	-0.011	0.144	0.024	-0.181	-0.063	0.002
SE	14.528	0.378	0.122	0.067	0.121	0.030	0.019
T- value	0.675	-0.029	1.181	0.361	-1.494	-2.122	0.102
R^2	71.8						

Population (Y) = 6.268 -0.011 X_1 +0.144 X_2 +0.024 X_3 -0.181 X_4 -0.063 X_5 +0.002X_6

Table 71: Impact of temperature and relative humidity on population of *Apis mellifera* in West direction during 2012

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	7.419	-0.116	0.100	0.017	-0.111	-0.015	-0.018
SE	12.307	0.276	0.122	0.069	0.125	0.034	0.021
T- value	0.603	-0.421	0.820	0.251	-0.890	-0.449	-0.832
R^2	59.1						

Population (Y) = 7.419 -0.116 X_1 +0.100 X_2 +0.017 X_3 -0.111 X_4 -0.015 X_5 -0.018X_6

Table 72: Impact of temperature and relative humidity on mean population of *Apis mellifera* during 2012

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	0.116	0.080	0.192	0.008	-0.162	-0.035	-0.005
SE	11.208	0.267	0.104	0.054	0.095	0.025	0.016
T- value	0.010	0.300	1.849	0.146	-1.704	-1.398	-0.329
R^2	76.2						

Population (Y) = 0.116 +0.080 X_1 +0.192 X_2 +0.008 X_3 -0.162 X_4 -0.035 X_5 -0.005X_6

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.03 individuals in the population.

The population was decreased by 0.02 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant and the maximum temperature of the location had positive impact on population.

The population increased by 0.03 individuals and 0.02 individuals with every unit increase (1%) in minimum relative humidity and maximum relative humidity of the location, respectively while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 59.1%. The population decreased by 0.12 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 71).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.10 individuals in the population.

The population was increased by 0.02 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.11 individuals in the population.

The population decreased by 0.01 individuals and 0.02 individuals with every unit increase (1%) in minimum relative humidity and maximum relative humidity of the location, respectively while other variables as constant.

4.2.1.4c Impact of abiotic factors on overall population of pollinator

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 16.5%. The population increased by 0.22 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 69).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.06 individuals in the population.

The population decreased by 0.02 individuals and 0.02 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The minimum relative humidity of the location had positive impact on population and it was increased by 0.02 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 76.2%. The population increased by 0.08 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 72).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.19 individuals in the population.

The minimum temperature of the location had positive impact on population and it was decreased by 0.16 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population was decreased by 0.03 individuals with every unit increase (1˚C) in minimum relative humidity of the location, while other variables as constant and the maximum relative humidity of the location also had negative impact on the population.

4.2.1 Relative abundance of *Apis dorsata* on litchi inflorescence during 2011 and 2012

The observations on relative abundance of *Apis dorsata* on litchi inflorescence were made in two directions (East and West) at four different day hours (0800, 1100, 1400 and 1700 hours) during 2011 and 2012. The data for relative abundance of pollinator are presented in Table 73 and Table 74 as well as Fig. 63 and 64 for 2011and 2012, respectively.

Plate 34 & 35: ***Apis mellifera*** **foraging on litchi flowers**

Plate 36 & 37: ***Apis dorsata*** **foraging on litchi flowers**

Table 73: Relative abundance of *Apis dorsata* on litchi inflorescence during 2011

Days	East (D_1)					West (D_2)					Grand
	0800	**1100**	**1400**	**1700**	**Mean**	**0800**	**1100**	**1400**	**1700**	**Mean**	**Mean**
March 24	2.2	2.0	0.0	1.2	**1.4**	1.8	1.2	0.8	0.8	**1.2**	**1.3**
March 25	2.4	1.6	1.2	1.0	**1.6**	0.8	0.8	0.4	0.6	**0.7**	**1.1**
March 26	4.0	2.4	0.8	1.6	**2.2**	1.2	0.6	1.0	0.6	**0.9**	**1.5**
March 27	2.0	3.0	1.4	1.4	**2.0**	1.0	1.4	0.6	1.0	**1.0**	**1.5**
March 28	2.6	2.6	0.2	0.6	**1.5**	0.6	1.8	0.8	0.8	**1.0**	**1.3**
March 29	2.2	2.4	0.6	1.0	**1.6**	1.0	1.6	1.4	1.2	**1.3**	**1.4**
March 30	0.0	3.0	1.6	1.0	**1.4**	0.0	3.0	0.8	0.6	**1.1**	**1.3**
March 31	3.4	3.6	0.6	0.8	**2.1**	0.6	1.4	0.4	1.4	**1.0**	**1.5**
April 01	3.4	3.2	0.2	0.0	**1.7**	0.4	1.4	0.0	0.4	**0.6**	**1.1**
April 02	2.6	3.0	0.4	0.4	**1.6**	2.8	0.8	0.2	0.0	**1.0**	**1.3**
April 03	2.2	2.4	0.8	0.6	**1.5**	2.0	1.0	0.2	0.4	**0.9**	**1.2**
April 04	2.0	1.8	0.4	0.4	**1.2**	1.6	1.0	0.4	0.4	**0.9**	**1.0**
April 05	2.0	1.4	0.0	0.0	**0.9**	1.8	1.0	0.0	0.6	**0.9**	**0.9**
April 06	2.0	3.0	0.0	0.4	**1.4**	1.6	0.4	0.0	0.4	**0.6**	**1.0**
April 07	1.8	1.0	0.0	0.4	**0.8**	0.8	0.0	0.0	0.0	**0.2**	**0.5**
April 08	1.4	1.0	0.0	0.0	**0.6**	0.2	0.8	0.0	0.0	**0.3**	**0.4**
April 09	2.2	1.2	0.0	0.4	**1.0**	0.0	1.2	0.0	0.0	**0.3**	**0.6**
April 10	2.0	2.2	0.4	0.0	**1.2**	0.4	0.4	0.6	0.6	**0.5**	**0.8**
April 11	2.0	2.8	0.4	0.2	**1.4**	0.4	0.4	1.2	0.8	**0.7**	**1.0**
April 12	0.8	0.4	0.4	0.2	**0.5**	0.2	0.0	0.2	0.2	**0.2**	**0.3**
April 13	0.2	0.2	0.2	0.8	**0.4**	0.0	0.4	0.2	0.0	**0.2**	**0.3**
April 14	0.0	0.0	0.4	0.2	**0.2**	0.0	0.0	0.0	0.0	**0.0**	**0.1**
April 15	0.2	0.2	0.2	0.0	**0.2**	0.0	0.0	0.2	0.0	**0.1**	**0.1**
Mean	**1.9**	**1.9**	**0.4**	**0.5**	**1.2**	**0.8**	**0.9**	**0.4**	**0.5**	**0.7**	**0.9**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.09	0.03
Day hours (H)	0.12	0.04
Days (Y)	0.30	0.10
DxH	0.18	0.06
DxY	0.43	0.15
HxY	0.60	0.21
DxHxY	0.86	0.31

Table 74: Relative abundance of *Apis dorsata* on litchi inflorescence during 2012

Days	East (D_1)					West (D_2)					Grand
	0800	1100	1400	1700	Mean	0800	1100	1400	1700	Mean	Mean
March 24	0.8	2.0	0.4	0.0	**0.8**	0.0	1.4	0.6	0.2	**0.6**	**0.7**
March 25	0.4	2.0	0.4	0.0	**0.7**	0.0	1.4	1.6	0.0	**0.8**	**0.7**
March 26	0.0	1.4	0.0	0.0	**0.4**	0.0	0.8	0.0	0.0	**0.2**	**0.3**
March 27	0.6	1.2	0.2	0.0	**0.5**	0.0	0.0	0.4	0.4	**0.2**	**0.4**
March 28	2.6	1.2	0.4	0.0	**1.1**	0.8	0.8	0.2	0.0	**0.5**	**0.8**
March 29	1.6	1.4	0.4	0.0	**0.9**	0.2	0.2	0.0	0.4	**0.2**	**0.5**
March 30	0.6	1.6	0.0	0.0	**0.6**	0.0	0.4	0.4	0.2	**0.3**	**0.4**
March 31	0.4	1.4	0.2	0.0	**0.5**	0.0	0.0	0.6	0.2	**0.2**	**0.4**
April 01	1.4	3.8	0.2	0.0	**1.4**	0.6	0.8	0.4	0.4	**0.6**	**1.0**
April 02	1.0	1.8	0.2	0.0	**0.8**	0.2	1.2	0.2	0.2	**0.5**	**0.6**
April 03	0.6	0.6	0.2	0.0	**0.4**	0.0	0.2	0.6	0.0	**0.2**	**0.3**
April 04	0.4	0.2	0.2	0.0	**0.2**	0.0	0.0	0.8	0.0	**0.2**	**0.2**
April 05	0.6	0.8	0.0	0.0	**0.4**	0.0	0.2	0.6	0.0	**0.2**	**0.3**
April 06	0.4	0.0	0.0	0.0	**0.1**	0.2	0.0	0.4	0.0	**0.2**	**0.1**
April 07	0.4	0.0	0.2	0.0	**0.2**	0.0	0.0	0.0	0.0	**0.0**	**0.1**
April 08	0.0	0.6	0.0	0.0	**0.2**	0.0	0.0	0.0	0.0	**0.0**	**0.1**
April 09	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 10	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
Mean	**0.7**	**1.1**	**0.2**	**0.0**	**0.5**	**0.1**	**0.4**	**0.4**	**0.1**	**0.3**	**0.4**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.07	0.02
Day hours (H)	0.10	0.03
Days (Y)	0.22	0.07
DxH	0.15	0.05
DxY	0.31	0.11
HxY	0.44	0.15
DxHxY	0.62	0.22

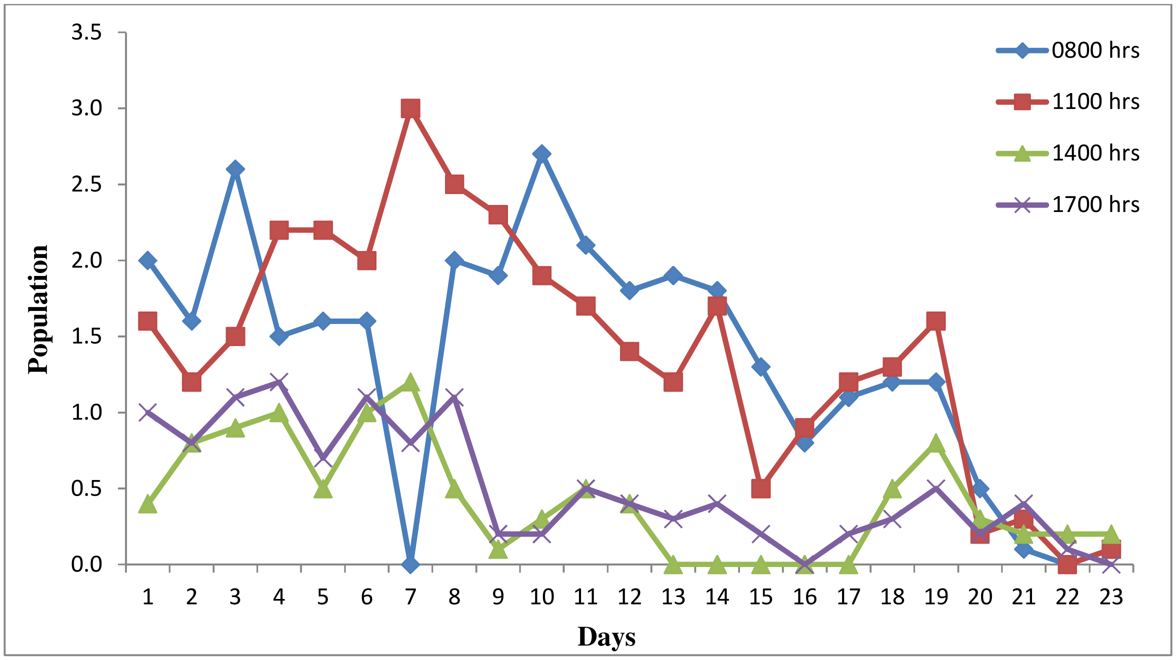

Fig. 63: Relative abundance of *Apis dorsata* on litchi inflorescence during 2011

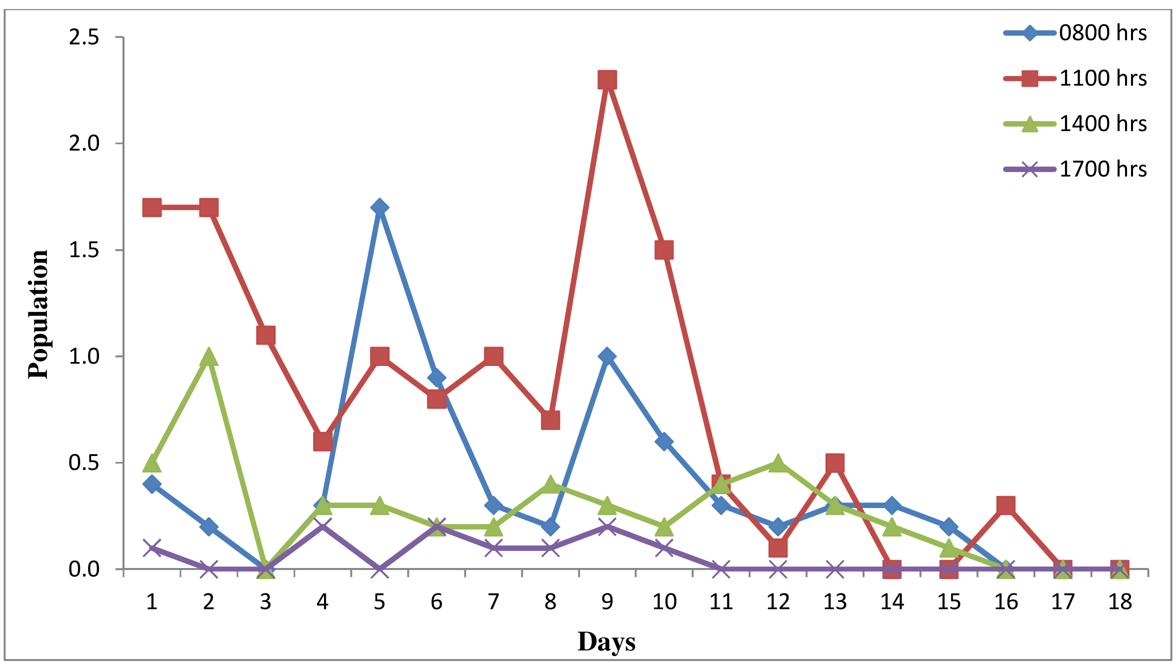

Fig. 64: Relative abundance of *Apis dorsata* on litchi inflorescence during 2012

4.2.1.1 Relative abundance of pollinator during flowering period

During 2011 significantly higher population was observed on March 26 and March 27 (1.5 foragers/inflorescence/3min) and it was at par with the population observed on March 24 (1.3 foragers/inflorescence/3min), March 28 (1.3 foragers/inflorescence/3min), March 30 (1.3 foragers/inflorescence/3min), April 02 (1.3 foragers/inflorescence/3min), April 03 (1.2 foragers/inflorescence/3min) and March 29 (1.4 foragers/inflorescence/3min). It was recorded minimum on April 14 and April 15 (0.1 foragers/inflorescence/3min) and it was at par with the population observed on April 08 (0.4 foragers/inflorescence/3min), April 12 and April 13 (0.3 foragers/inflorescence/3min) (Table 73). During 2012, the population observed on April 01 (1.0 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded on March 28 (0.8 foragers/inflorescence/3min). The minimum population was recorded on April 9 and April 10 (0.0 foragers/inflorescence/3min) which was found at par with the population observed on April 04 (0.2 foragers/inflorescence/3min), April 06 (0.1 foragers/inflorescence/3min) and April 07 (0.1 foragers/inflorescence/3min) and April 08 (0.1 foragers /inflorescence/3min) (Table 74).

4.2.1.2 Impact of day hours and days on relative abundance

During 2011, in the East direction, pollinator population recorded at 0800 and 1100 hours (1.9 foragers/inflorescence/3min) was significantly higher than all other day hours (1400 and 1700 hours). The minimum population was observed at 1400 hours (0.4 foragers/inflorescence/3min) and was at par with the population recorded at 1700 hours (0.5 foragers/inflorescence/3min). Significantly higher population was recorded on March 26 (2.2 foragers/inflorescence/3min) which was found at par with the population recorded on March 27 (2.0 foragers/inflorescence/3min) and March 31 (2.1 foragers/inflorescence/3min). Minimum population was observed on April 14 and April 15 (0.2 foragers/inflorescence/3min) which was found at par with the population recorded on April 08 (0.6 foragers/inflorescence/3min), April 12 (0.5 foragers/ inflorescence/3min) and April 13 (0.4 foragers/inflorescence/3min) (Table 73).

During 2012, in the East direction, significantly higher population was observed at 1100 hours (1.1 foragers/inflorescence/3min) and population was not observed at 1700 hours. The population observed on April 01 (1.4 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded on March 28 (1.1 foragers/inflorescence/3min). The minimum population was observed on April 9 and April 10 (0.0 foragers/inflorescence/3min) which was found at par with the population recorded on April 04 (0.2 foragers/inflorescence/3min), April 06 (0.1 foragers/inflorescence/3min), April 07 (0.2 foragers/inflorescence/3min) and April 08 (0.2 foragers/inflorescence/3min) (Table 74).

During 2011, in West direction, significantly lower population was recorded at 1400 hours (0.4 foragers/inflorescence/3min). The maximum population was recorded at 1100 hours (0.9 foragers/inflorescence/3min). The population was not observed on April 14 (0.0 foragers/inflorescence/3min) and was found at par with the population observed on April 07 (0.2 foragers/inflorescence/3min), April 08 (0.3 foragers/inflorescence/3min), 09 (0.3 foragers/inflorescence/3min), April 12 (0.2 foragers/inflorescence/3min), April 13 (0.2 foragers/inflorescence/3min) and April 15 (0.1 foragers/inflorescence/3min). The maximum population was observed on March 29 (2.7 foragers/inflorescence/3min) and found at par with the population observed on March 24 (1.2 foragers/inflorescence/3min), March 26 (0.9 foragers/inflorescence/ 3min), March 27 (1.0 foragers/inflorescence/3min), March 28 (1.0 foragers/inflorescence/3min), March 30 (1.1 foragers/inflorescence/3min), March 31 (1.0 foragers/inflorescence/3min), April 02 (1.0 foragers/inflorescence/3min), April 03 (0.9 foragers/inflorescence/3min), April 04 (0.9 foragers/inflorescence/3min) and April 05 (0.9 foragers/inflorescence/3min) (Table 73).

During 2012, in the West direction, pollinator population was significantly lower at 0800 hours and 1700 hours (0.1 foragers/inflorescence/3min). The maximum population was recorded at 1100 hours and 1400 hours (0.4 foragers/inflorescence/3min). Significantly higher population was observed on March 25 (0.8 foragers/inflorescence/3min) which was found at par with population observed on March 24 (0.6 foragers/inflorescence/3min), March 28 (0.5 foragers/inflorescence/3min), April 01 (0.6 foragers/inflorescence/3min) and April 02 (0.5 foragers/inflorescence/3min). Population was minimum on April 07 (0.0 foragers/inflorescence/3min), April 08 (0.0 foragers/inflorescence/3min), April 09

Table 75: Relative abundance of *Apis dorsata* on litchi inflorescence during 2011

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	2.0	1.6	0.4	1.0	**1.3**
March 25	1.6	1.2	0.8	0.8	**1.1**
March 26	2.6	1.5	0.9	1.1	**1.5**
March 27	1.5	2.2	1.0	1.2	**1.5**
March 28	1.6	2.2	0.5	0.7	**1.3**
March 29	1.6	2.0	1.0	1.1	**1.4**
March 30	0.0	3.0	1.2	0.8	**1.3**
March 31	2.0	2.5	0.5	1.1	**1.5**
April 01	1.9	2.3	0.1	0.2	**1.1**
April 02	2.7	1.9	0.3	0.2	**1.3**
April 03	2.1	1.7	0.5	0.5	**1.2**
April 04	1.8	1.4	0.4	0.4	**1.0**
April 05	1.9	1.2	0.0	0.3	**0.9**
April 06	1.8	1.7	0.0	0.4	**1.0**
April 07	1.3	0.5	0.0	0.2	**0.5**
April 08	0.8	0.9	0.0	0.0	**0.4**
April 09	1.1	1.2	0.0	0.2	**0.6**
April 10	1.2	1.3	0.5	0.3	**0.8**
April 11	1.2	1.6	0.8	0.5	**1.0**
April 12	0.5	0.2	0.3	0.2	**0.3**
April 13	0.1	0.3	0.2	0.4	**0.3**
April 14	0.0	0.0	0.2	0.1	**0.1**
April 15	0.1	0.1	0.2	0.0	**0.1**
Mean	**1.4**	**1.4**	**0.4**	**0.5**	**0.9**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.12	0.04
HxY	0.60	0.21

Table 76: Relative abundance of *Apis dorsata* on litchi inflorescence during 2012

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	0.4	1.7	0.5	0.1	**0.7**
March 25	0.2	1.7	1.0	0.0	**0.7**
March 26	0.0	1.1	0.0	0.0	**0.3**
March 27	0.3	0.6	0.3	0.2	**0.4**
March 28	1.7	1.0	0.3	0.0	**0.8**
March 29	0.9	0.8	0.2	0.2	**0.5**
March 30	0.3	1.0	0.2	0.1	**0.4**
March 31	0.2	0.7	0.4	0.1	**0.4**
April 01	1.0	2.3	0.3	0.2	**1.0**
April 02	0.6	1.5	0.2	0.1	**0.6**
April 03	0.3	0.4	0.4	0.0	**0.3**
April 04	0.2	0.1	0.5	0.0	**0.2**
April 05	0.3	0.5	0.3	0.0	**0.3**
April 06	0.3	0.0	0.2	0.0	**0.1**
April 07	0.2	0.0	0.1	0.0	**0.1**
April 08	0.0	0.3	0.0	0.0	**0.1**
April 09	0.0	0.0	0.0	0.0	**0.0**
April 10	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.4**	**0.8**	**0.3**	**0.1**	**0.4**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.10	0.03
HxY	0.44	0.15

(0.0 foragers/inflorescence/3min) and April 10 (0.0 foragers/inflorescence/3min) which was found at par with the population observed on March 26 (0.2 foragers/inflorescence/3min), March 27 (0.2 foragers/inflorescence/3min), March 29 (0.2 foragers/inflorescence/3min), March 30 (0.3 foragers/inflorescence/3min), March 31 (0.2 foragers/inflorescence/3min), April 03 (0.2 foragers/inflorescence/3min), April 04 (0.2 foragers/inflorescence/3min), April 05 (0.2 foragers/inflorescence/3min) and April 06 (0.2 foragers/inflorescence/3min) (Table 74).

4.2.1.3 Impact of direction on relative abundance of pollinator

During 2011, the relative abundance of pollinator between East and West directions was significantly different. It was maximum in East direction (1.2 foragers/inflorescence/3min) and minimum in West direction (0.7 foragers/inflorescence/3min) (Table 73). Similar pattern for the relative abundance was observed during 2012. It was 0.5% and 0.3% in East direction and West direction respectively (Table 74).

During 2011, irrespective of directions, significantly higher population was observed at 0800 hours and 1100 hours (1.4 foragers/inflorescence/3min) and it was recorded minimum at 1400 hours (0.4 foragers/inflorescence/3min) and found at par with the population at 1700 hours (0.5 foragers/inflorescence/3min). At 0800 hours, significantly higher population was observed on April 02 (2.7 foragers/inflorescence/3min) and it was at par with population recorded on March 26 (2.6 foragers/inflorescence/3min) and April 03 (2.1 foragers/inflorescence/3min). The minimum population was observed on March 30 and April 14 (0.0 foragers/inflorescence/3min) and it was at par with the population recorded on April 12 (0.5 foragers/inflorescence/3min) April 13 (0.1 foragers/inflorescence/3min) and April 15 (0.1 foragers/inflorescence/3min). At 1100 hours, significantly lower population was recorded on April 14 (0.0 foragers/inflorescence/3min) which was found at par with the population observed on April 07 (0.5 foragers/inflorescence/3min), April 12 (0.2 foragers/inflorescence/3min), April 13 (0.3 foragers/inflorescence/3min) and April 15 (0.1 foragers/inflorescence/3min). The maximum population was recorded on March 30 (3.0 foragers/inflorescence/3min) which was found at par with the population observed on March 31 (2.5

foragers/inflorescence/3min). At 1400 hours, pollinator population was not observed during April 05 to April 09. Maximum population was observed on March 30 (1.2 foragers/inflorescence/3min) which was found at par with the population observed on March 25 (0.8 foragers/inflorescence/3min), March 26 (0.9 foragers/inflorescence/ 3min), March 27 (1.0 foragers/inflorescence/3min), March 29 (1.0 foragers/inflorescence/3min) and April 11 (0.8 foragers/inflorescence/3min). At 1700 hours, significantly higher population was observed on March 28 (1.2 foragers/inflorescence/3min) and it was at par with the population observed on March 24 (1.0 foragers/inflorescence/3min), March 25 (0.8 foragers/inflorescence/3min), March 26 (1.1 foragers/inflorescence/3min), March 28 (0.7 foragers/inflorescence/ 3min), March 29 (1.1 foragers/inflorescence/3min), March 30 (0.8 foragers/ inflorescence/3min) and March 31 (1.1 foragers/inflorescence/3min). Population was not observed during April 08 and on April 15 (Table 75).

During 2012, irrespective of directions, significantly lower population was observed at 1700 hours (0.1 foragers/inflorescence/3min) and it was recorded maximum at 1100 hours (0.8 foragers/inflorescence/3min). At 0800 hours, population was not observed on March 26 and from April 08 to April 10. Significantly higher population was recorded on March 28 (1.7 foragers/inflorescence/3min). At 1100 hours, population recorded on April 01 (2.3 foragers/inflorescence/3min) was significantly higher and no population was recorded on April 06, April 07, April 09 and April 10. At 1400 hours, population was not observed on March 26 and from April 08 to April 10 and significantly higher population was observed on March 25 (1.0 foragers/inflorescence/3min). At 1700 hours, population was not observed on March 25, March 26, March 28 and from April 03 to April 10. The maximum population was observed on March 27 (0.2 foragers/inflorescence/3min), March 29 (0.2 foragers/inflorescence/3min) and April 01 (0.2 foragers/inflorescence/3min) (Table 76).

4.2.1.4 Impact of abiotic factors on population of pollinator

In order to study the combined effect of abiotic factors (temperature and relative humidity) on population of pollinator, both factors were analyzed in the multiple linear regression models.

4.2.1.4a Impact of abiotic factors on population of pollinator in East direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 54.3%. The population decreased by 0.10 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant. The surrounding relative humidity of inflorescence had negative impact on pollinator population (Table 77).

The population decreased by 0.09 individuals with every unit increase (1˚C) in minimum temperature and it was decreased by 0.09 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population increased by 0.03 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.01 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 39.7%. The population increased by 0.11 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 80).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.04 individuals in the population.

The population was decreased by 0.05 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.06 individuals in the population.

The minimum and maximum relative humidity of the location had positive impact on population.

4.2.1.4b Impact of abiotic factors on population of pollinator in West direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 76.9%. The population decreased by 0.07 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant. The surrounding relative humidity of inflorescence had negative impact on population of pollinator (Table 78).

The population was decreased by 0.06 individuals with every unit increase (1˚C) in minimum temperature, while other variables as constant and the population was decreased by 0.10 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population increased by 0.03 individuals with every unit increase (1%) in minimum relative humidity while other variables as constant and maximum relative humidity of the location had negative impact on population.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 59.8%. The population decreased by 0.16 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 81).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.06 individuals in the population.

The population was decreased by 0.04 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in increase of 0.01 individuals in the population.

The population decreased by 0.01 individuals with every unit increase (1%) in minimum relative humidity, while other variables as constant and maximum relative humidity of the location had positive impact on population.

4.2.1.4c Impact of abiotic factors on overall population of pollinator

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 70.8%. The population decreased by 0.08 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 79).

Table 77: Impact of temperature and relative humidity on population of *Apis dorsata* in East direction during 2011

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	7.471	-0.106	-0.007	-0.088	-0.087	0.028	0.012
SE	7.203	0.137	0.024	0.045	0.111	0.024	0.015
T- value	1.037	-0.776	-0.303	-1.973	-0.780	1.194	0.746
R^2	54.3						
Population (Y) = 7.471 -0.106 X_1 -0.007 X_2 -0.088 X_3 -0.087 X_4 +0.028 X_5 +0.012X_6							

Table 78: Impact of temperature and relative humidity on population of *Apis dorsata* in West direction during 2011

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	6.507	-0.070	-0.005	-0.063	-0.096	0.032	-0.002
SE	3.105	0.056	0.011	0.021	0.053	0.011	0.007
T- value	2.096	-1.247	-0.487	-2.979	-1.807	2.841	-0.234
R^2	76.9						
Population (Y) = 6.507 -0.070 X_1 -0.005 X_2 -0.063 X_3 -0.096 X_4 +0.032 X_5 -0.002X_6							

Table 79: Impact of temperature and relative humidity on mean population of *Apis dorsata* during 2011

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	6.567	-0.083	-0.005	-0.077	-0.088	0.032	0.005
SE	4.416	0.082	0.015	0.029	0.071	0.015	0.010
T- value	1.487	-1.018	-0.305	-2.705	-1.230	2.106	0.541
R^2	70.8						
Population (Y) = 6.567 -0.083 X_1 -0.005 X_2 -0.077 X_3 -0.088 X_4 +0.032 X_5 +0.005X_6							

Table 80: Impact of temperature and relative humidity on population of *Apis dorsata* in East direction during 2012

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-2.225	0.114	0.041	-0.052	-0.062	0.000	0.008
SE	14.544	0.347	0.114	0.059	0.087	0.026	0.016
T- value	-0.153	0.329	0.359	-0.878	-0.717	-0.007	0.493
R^2	39.7						
Population (Y) = -2.225 +0.114 X_1 +0.041 X_2 -0.052 X_3 -0.062 X_4 +0.000 X_5 +0.008X_6							

Table 81: Impact of temperature and relative humidity on population of *Apis dorsata* in West direction during 2012

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	8.012	-0.161	-0.059	-0.040	0.011	-0.012	0.003
SE	4.553	0.100	0.045	0.026	0.044	0.012	0.008
T- value	1.760	-1.605	-1.330	-1.534	0.263	-0.940	0.337
R^2	59.8						
Population (Y) = 8.012 -0.161 X_1 -0.059 X_2 -0.040 X_3 +0.011 X_4 -0.012 X_5 +0.003X_6							

Table 82: Impact of temperature and relative humidity on mean population of *Apis dorsata* during 2012

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	3.947	-0.056	-0.013	-0.038	-0.026	-0.002	0.003
SE	7.849	0.181	0.068	0.038	0.061	0.018	0.011
T- value	0.503	-0.309	-0.188	-0.990	-0.419	-0.123	0.284
R^2	47.7						
Population (Y) = 3.947 -0.056 X_1 -0.013 X_2 -0.038 X_3 -0.026 X_4 -0.002 X_5 +0.003 X_6							

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.005 individuals in the population.

The population decreased by 0.08 individuals and 0.09 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The population increased by 0.03 individuals with every unit increase (1%) in minimum relative humidity, while other variables as constant. The maximum relative humidity of the location had positive impact on population.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 47.7%. The population decreased by 0.06 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 82).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.01 individuals in the population.

The population decreased by 0.04 individuals and 0.03 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The minimum relative humidity had negative impact on the population while maximum relative humidity of the location had positive impact on the population.

4.2.1 Relative abundance of syrphids, *Eristalis tenax* L., *E. tabanoides* Jennicke, *Ischiodon scutellaris* F., *Sphaerophoria Indiana* Bigot on litchi inflorescence during 2011 and 2012

The observations on relative abundance of Syrphids on litchi inflorescence were made in two directions (East and West) at four different day hours (0800, 1100, 1400 and 1700 hours) during 2011 and 2012. The data for relative abundance of pollinator are presented in Table 83 and Table 84 as well as Fig. 65 and 66 for 2011and 2012, respectively.

4.2.1.1 Relative abundance of pollinator during flowering period

The perusal of the data revealed that the pollinator population was higher at initiation of flowering period and gradually the population declined in successive days. During 2011 significantly higher population was observed on March 29 (11.5 foragers/inflorescence/3min) which was found at par with the population recorded on March 28 (11.4 foragers/inflorescence/3min). It was recorded minimum on April 15 (1.2 foragers/inflorescence/3min) (Table 83). During 2012, the population observed on March 28 (1.6 foragers/inflorescence/3min) and March 30 (1.6 foragers/inflorescence/ 3min) was significantly higher. The population was not observed during April 08 to April 10 (Table 84).

4.2.1.2 Impact of day hours and days on relative abundance

During 2011, in the East direction, pollinator population recorded at 0800 hours (14.5 foragers/inflorescence/3min) was significantly higher than all other day hours (0800, 1400 and 1700 hours). The minimum population was observed at 1400 hours (5.8 foragers/inflorescence/3min). Significantly higher population was recorded on March 29 (15.0 foragers/inflorescence/3min) which was found at par with the population recorded on March 26 (14.7 foragers/inflorescence/3min), March 27 (14.0 foragers/inflorescence/3min) and March 28 (14.6 foragers/inflorescence/3min). Minimum population was observed on April 15 (2.0 foragers/inflorescence/3min) (Table 83).

During 2012, in the East direction, significantly higher population was observed at 1700 hours (0.8 foragers/inflorescence/3min) and it was recorded minimum at 0800 hours, 1100 hours and 1400 hours (0.7 foragers/ inflorescence/3min). The population observed on March 28 and March 30 (2.0 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded on March 29 (1.6 foragers/inflorescence/3min). The population was not observed during April 05, April 06 and from April 08 to April 10 (Table 84).

During 2011, in West direction, significantly lower population was recorded at 1400 hours (1.9 foragers/inflorescence/3min) which was found at par with population recorded at 1700 hours (2.2 foragers/inflorescence/3min). The maximum population was recoded at 1100 hours (11.6 foragers/inflorescence/3min). The population was

Table 83: Relative abundance of Syrphids on litchi inflorescence during 2011

Days	East (D_1)					West (D_2)					Grand
	0800	**1100**	**1400**	**1700**	**Mean**	**0800**	**1100**	**1400**	**1700**	**Mean**	**Mean**
March 24	12.6	10.0	9.0	10.2	**10.5**	3.6	10.6	0.8	1.8	**4.2**	**7.3**
March 25	17.6	11.6	10.6	12.4	**13.1**	4.8	13.4	1.4	3.0	**5.7**	**9.4**
March 26	20.8	13.2	11.2	13.6	**14.7**	5.4	15.6	2.6	2.4	**6.5**	**10.6**
March 27	16.6	16.6	9.8	12.8	**14.0**	3.8	14.8	4.0	3.2	**6.5**	**10.2**
March 28	21.0	13.6	11.6	12.0	**14.6**	5.2	20.8	3.2	4.0	**8.3**	**11.4**
March 29	20.0	14.0	13.0	13.0	**15.0**	3.8	19.4	5.0	3.6	**8.0**	**11.5**
March 30	0.0	17.4	11.2	12.0	**10.2**	0.0	21.6	6.4	4.8	**8.2**	**9.2**
March 31	22.8	10.8	4.2	7.8	**11.4**	6.0	15.6	1.0	3.6	**6.6**	**9.0**
April 01	22.0	9.8	4.8	10.4	**11.8**	5.8	24.4	0.8	3.6	**8.7**	**10.2**
April 02	20.4	11.8	3.8	9.4	**11.4**	7.0	17.8	1.4	2.2	**7.1**	**9.2**
April 03	18.0	10.6	4.0	8.4	**10.3**	6.6	16.2	1.6	1.8	**6.6**	**8.4**
April 04	20.6	10.0	3.6	8.8	**10.8**	8.4	19.8	1.8	1.6	**7.9**	**9.3**
April 05	21.2	9.0	4.2	8.8	**10.8**	8.8	22.0	1.4	2.2	**8.6**	**9.7**
April 06	22.2	5.2	5.0	8.6	**10.3**	7.8	4.2	1.8	2.2	**4.0**	**7.1**
April 07	20.2	4.4	1.8	2.2	**7.2**	5.8	2.0	1.2	1.0	**2.5**	**4.8**
April 08	6.8	5.2	1.8	0.2	**3.5**	4.6	2.8	0.4	0.0	**2.0**	**2.7**
April 09	5.0	4.6	3.0	2.4	**3.8**	0.8	3.2	0.8	1.4	**1.6**	**2.7**
April 10	11.2	4.4	3.6	2.8	**5.5**	1.6	3.4	2.0	1.2	**2.1**	**3.8**
April 11	12.4	4.2	5.0	4.4	**6.5**	3.4	6.2	2.8	2.8	**3.8**	**5.2**
April 12	11.4	3.0	4.0	4.4	**5.7**	4.0	4.2	1.8	1.8	**3.0**	**4.3**
April 13	2.2	10.2	4.0	3.8	**5.1**	0.0	3.6	1.0	0.8	**1.4**	**3.2**
April 14	5.8	12.4	3.8	4.4	**6.6**	0.0	4.6	0.4	1.0	**1.5**	**4.1**
April 15	3.8	1.6	1.0	1.4	**2.0**	0.0	0.6	0.0	0.8	**0.4**	**1.2**
Mean	**14.5**	**9.3**	**5.8**	**7.6**	**9.3**	**4.2**	**11.6**	**1.9**	**2.2**	**5.0**	**7.1**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.20	0.07
Day hours (H)	0.28	0.10
Days (Y)	0.67	0.24
DxH	0.34	0.14
DxY	0.94	0.33
HxY	1.33	0.48
DxHxY	1.89	0.67

Table 84: Relative abundance of Syrphids on litchi inflorescence during 2012

Days	East (D_1)					West (D_2)					Grand
	0800	1100	1400	1700	Mean	0800	1100	1400	1700	Mean	Mean
March 24	0.6	1.0	1.6	1.8	**1.3**	0.0	3.0	0.8	0.2	**1.0**	**1.1**
March 25	0.4	1.2	0.8	2.0	**1.1**	0.2	2.0	0.4	0.4	**0.8**	**0.9**
March 26	0.0	0.8	1.8	1.4	**1.0**	0.0	2.0	0.6	0.2	**0.7**	**0.9**
March 27	0.8	0.4	0.4	1.0	**0.7**	0.8	1.4	0.4	0.0	**0.7**	**0.7**
March 28	1.0	2.0	1.4	3.6	**2.0**	0.2	1.4	1.0	2.4	**1.3**	**1.6**
March 29	1.2	1.8	1.2	2.0	**1.6**	1.2	1.6	0.0	0.4	**0.8**	**1.2**
March 30	0.8	3.2	1.6	2.2	**2.0**	0.8	2.4	0.2	1.2	**1.2**	**1.6**
March 31	1.8	0.8	1.2	0.8	**1.2**	0.2	3.2	0.0	0.0	**0.9**	**1.0**
April 01	1.8	0.8	0.8	0.0	**0.9**	0.8	1.4	0.2	0.0	**0.6**	**0.7**
April 02	0.4	0.0	0.0	0.0	**0.1**	0.8	0.0	0.0	0.0	**0.2**	**0.2**
April 03	2.2	0.6	1.6	0.4	**1.2**	1.2	0.8	0.0	0.2	**0.6**	**0.9**
April 04	1.4	0.0	0.2	0.0	**0.4**	0.6	0.4	0.0	0.0	**0.3**	**0.3**
April 05	0.0	0.0	0.0	0.0	**0.0**	0.4	0.0	0.0	0.0	**0.1**	**0.1**
April 06	0.0	0.0	0.0	0.0	**0.0**	0.4	0.0	0.0	0.0	**0.1**	**0.1**
April 07	0.2	0.0	0.0	0.0	**0.1**	0.8	0.0	0.0	0.0	**0.2**	**0.1**
April 08	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 09	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 10	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
Mean	**0.7**	**0.7**	**0.7**	**0.8**	**0.7**	**0.5**	**1.1**	**0.2**	**0.3**	**0.5**	**0.6**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.10	0.03
Day hours (H)	0.14	0.05
Days (Y)	0.30	0.11
DxH	0.20	0.07
DxY	0.43	0.15
HxY	0.61	0.22
DxHxY	0.87	0.31

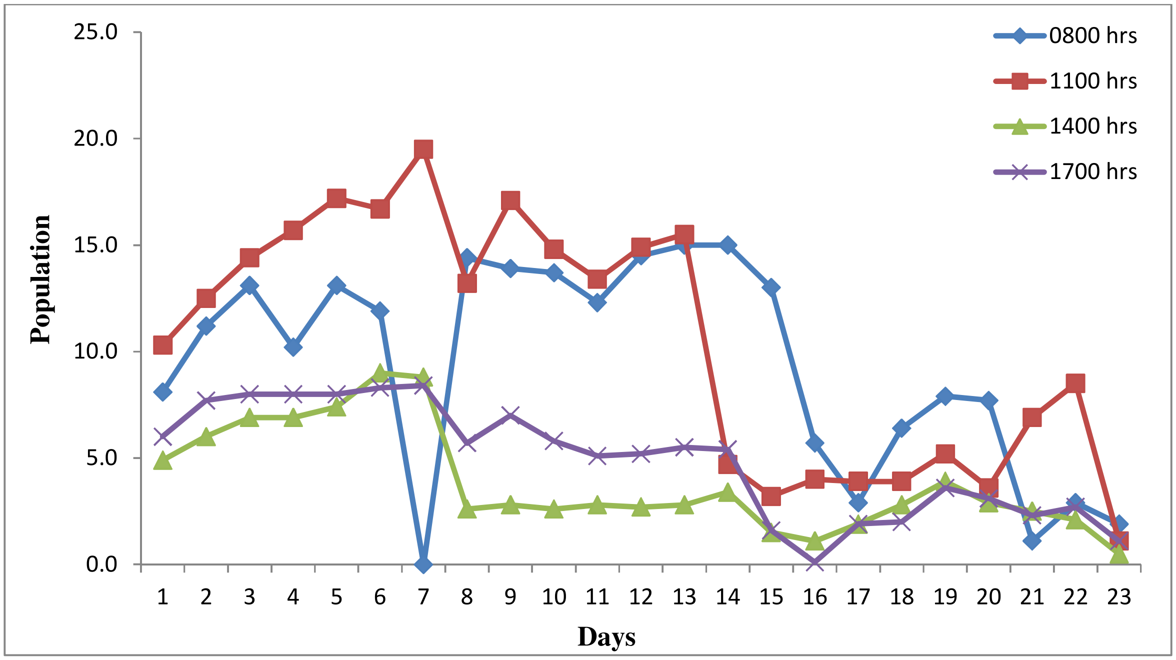

Fig. 65: Relative abundance of Syrphids on litchi inflorescence during 2011

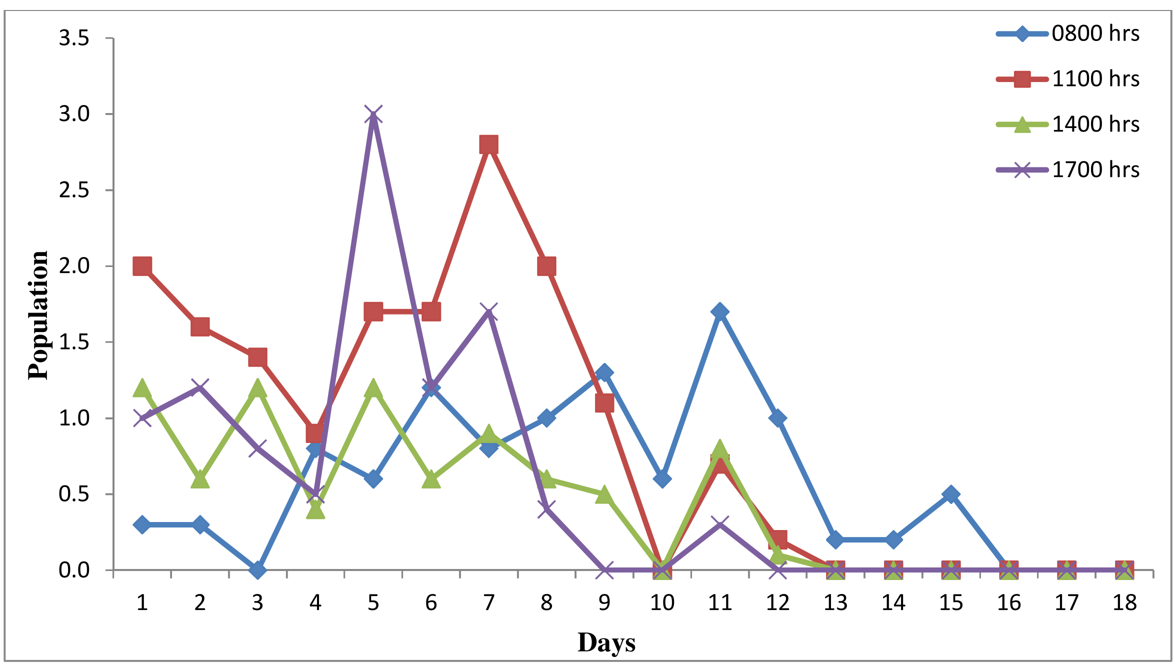

Fig. 66: Relative abundance of Syrphids on litchi inflorescence during 2012

significantly lower on April 15 (0.4 foragers/inflorescence/3min). The maximum population was observed on April 01 (8.7 foragers/inflorescence/3min) and was found at par with population recorded during March 28 (8.3 foragers/inflorescence/3min), March 29 (8.0 foragers/inflorescence/3min), March 30 (8.2 foragers/inflorescence/3min), April 04 (7.9 foragers/inflorescence/3min) and April 05 (8.6 foragers/inflorescence/3min) (Table 83).

During 2012, in the West direction, pollinators population was significantly lower at 1400 hours (0.2 foragers/inflorescence/3min) and was found at par with the population at 1700 hours (0.3 foragers/inflorescence/3min). The maximum population was recorded at 1100 hours (1.1 foragers/inflorescence/3min). Significantly higher population was observed on March 28 (1.3 foragers/inflorescence/3min) which was found at par with population recorded on March 24 (1.0 foragers/inflorescence/3min) and March 31 (0.9 foragers/inflorescence/3min). Population was not observed during April 08 to April 10 (Table 84).

4.2.1.3 Impact of direction on relative abundance of pollinator

During 2011, the relative abundance of pollinator between East and West directions was significantly different. It was maximum in East direction (9.3 foragers/inflorescence/3min) and minimum in West direction (5.0 foragers/inflorescence/3min) (Table 83). Similar pattern for the relative abundance was observed during 2012. It was 0.7% and 0.5% in East direction and West direction respectively (Table 84).

During 2011, irrespective of directions, significantly higher population was observed at 1100 hours (10.4 foragers/inflorescence/3min) and it was recorded minimum at 1400 hours (3.9 foragers/inflorescence/3min). At 0800 hours, significantly higher population was observed on April 05 and April 06 (15.0 foragers/inflorescence/3min) which was found at par with the population recorded on March 31 (14.4 foragers/inflorescence/3min), April 01 (13.9 foragers/inflorescence/3min), April 02 (13.7 foragers/inflorescence/3min) and April 04 (14.5 foragers/inflorescence/3min). The population was not observed on March 30. At 1100 hours, significantly lower population was recorded on April 15 (1.1 foragers/inflorescence/3min). The maximum population was recorded on March 30

(19.5 foragers/inflorescence/3min). At 1400 hours, maximum population was observed on March 29 (9.0 foragers/inflorescence/3min) which was found at par with the population recorded on March 30 (8.8 foragers/inflorescence/3min). Minimum population was recorded on April 15 (0.5 foragers/inflorescence/3min) which was found at par with the population recorded on April 07 (1.5 foragers/inflorescence/3min) and April 08 (1.1 foragers/inflorescence/3min). At 1700 hours, significantly higher population was observed on March 30 (8.4 foragers/inflorescence/3min) and it was at par with the population observed on March 25 (7.7 foragers/inflorescence/3min), March 26 (8.0 foragers/inflorescence/3min), March 27 (8.0 foragers/inflorescence/3min), March 28 (8.0 foragers/inflorescence/ 3min), March 29 (8.3) and April 01 (7.0 foragers/inflorescence/3min). Minimum population was recorded on April 08 (0.1 foragers/inflorescence/3min) which was found at par with the population recorded on April 15 (Table 85).

During 2012, irrespective of directions, significantly lower population was observed at 1400 hours (0.5 foragers/inflorescence/3min) which was found at par with the population recorded at 0800 hours and 1700 hours. It was recorded maximum at 1100 hours (0.9 foragers/inflorescence/3min). At 0800 hours, population was not observed on March 26 and from April 08 to April 10. Significantly higher population was recorded on April 03 (1.7 foragers/inflorescence/3min). At 1100 hours, population recorded on March 30 (2.8 foragers/inflorescence/3min) was significantly higher and population was not recorded on April 02 and from April 05 to April 10. At 1400 hours, significantly higher population was observed on March 24, March 26 and March 28 (1.2 foragers/inflorescence/3min). No population was recorded during April 05 to April 10. At 1700 hours, population observed on March 28 (3.0 foragers/inflorescence/3min) was significantly higher. Population was not observed during April 04 to April 10 (Table 86).

These findings were in accordance with the studies carried out by **Badiyala and Garg (1990)** who introduced hoverflies to a litchi orchard in Himachal Pradesh, India, at the start of flowering. The insects visited the flowers, especially in the morning (9:30 – 11:30AM) and less active from 3:00 – 5:00 PM. **Jarlan *et al.* (1997)** have also included the *Eristalis* flies (Syrphidae) among the most efficient pollinators in litchi crop.

Table 85: Relative abundance of Syrphids on litchi inflorescence during 2011

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	8.1	10.3	4.9	6.0	**7.3**
March 25	11.2	12.5	6.0	7.7	**9.4**
March 26	13.1	14.4	6.9	8.0	**10.6**
March 27	10.2	15.7	6.9	8.0	**10.2**
March 28	13.1	17.2	7.4	8.0	**11.4**
March 29	11.9	16.7	9.0	8.3	**11.5**
March 30	0.0	19.5	8.8	8.4	**9.2**
March 31	14.4	13.2	2.6	5.7	**9.0**
April 01	13.9	17.1	2.8	7.0	**10.2**
April 02	13.7	14.8	2.6	5.8	**9.2**
April 03	12.3	13.4	2.8	5.1	**8.4**
April 04	14.5	14.9	2.7	5.2	**9.3**
April 05	15.0	15.5	2.8	5.5	**9.7**
April 06	15.0	4.7	3.4	5.4	**7.1**
April 07	13.0	3.2	1.5	1.6	**4.8**
April 08	5.7	4.0	1.1	0.1	**2.7**
April 09	2.9	3.9	1.9	1.9	**2.7**
April 10	6.4	3.9	2.8	2.0	**3.8**
April 11	7.9	5.2	3.9	3.6	**5.2**
April 12	7.7	3.6	2.9	3.1	**4.3**
April 13	1.1	6.9	2.5	2.3	**3.2**
April 14	2.9	8.5	2.1	2.7	**4.1**
April 15	1.9	1.1	0.5	1.1	**1.2**
Mean	**9.4**	**10.4**	**3.9**	**4.9**	**7.1**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.28	0.10
HxY	1.33	0.48

Table 86: Relative abundance of Syrphids on litchi inflorescence during 2012

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	0.3	2.0	1.2	1.0	**1.1**
March 25	0.3	1.6	0.6	1.2	**0.9**
March 26	0.0	1.4	1.2	0.8	**0.9**
March 27	0.8	0.9	0.4	0.5	**0.7**
March 28	0.6	1.7	1.2	3.0	**1.6**
March 29	1.2	1.7	0.6	1.2	**1.2**
March 30	0.8	2.8	0.9	1.7	**1.6**
March 31	1.0	2.0	0.6	0.4	**1.0**
April 01	1.3	1.1	0.5	0.0	**0.7**
April 02	0.6	0.0	0.0	0.0	**0.2**
April 03	1.7	0.7	0.8	0.3	**0.9**
April 04	1.0	0.2	0.1	0.0	**0.3**
April 05	0.2	0.0	0.0	0.0	**0.1**
April 06	0.2	0.0	0.0	0.0	**0.1**
April 07	0.5	0.0	0.0	0.0	**0.1**
April 08	0.0	0.0	0.0	0.0	**0.0**
April 09	0.0	0.0	0.0	0.0	**0.0**
April 10	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.6**	**0.9**	**0.5**	**0.6**	**0.6**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.14	0.05
HxY	0.61	0.22

4.2.1.4 Impact of abiotic factors on population of pollinator

In order to study the combined effect of abiotic factors (temperature and relative humidity) on population of pollinator, both factors were analyzed in the multiple linear regression models.

4.2.1.4a Impact of abiotic factors on population of pollinator in East direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 76.8%. The population decreased by 1.53 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 87).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.11 individuals in the population.

The population decreased by 0.50 individuals with every unit increase (1˚C) in minimum temperature and it was decreased by 0.50 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population increased by 0.33 individuals with every unit increase (1%) in minimum relative humidity and decreased by 0.003 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 68.7%. The population increased by 0.52 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 90).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.25 individuals in the population.

The population was decreased by 0.07 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.20 individuals in the population.

The population decreased by 0.01 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.01 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

4.2.1.4b Impact of abiotic factors on population of pollinator in West direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 84.5%. The population decreased by 0.14 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 88).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.08 individuals in the population.

The population was decreased by 0.46 individuals with every unit increase (1˚C) in minimum temperature, while other variables as constant and the population was decreased by 0.59 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population increased by 0.29 individuals with every unit increase (1%) in minimum relative humidity while increased by 0.01 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 75.1%. The population increased by 0.03 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 91).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.06 individuals in the population.

The population was decreased by 0.01 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The

Table 87: Impact of temperature and relative humidity on population of Syrphids in East direction during 2011

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	77.895	-1.532	-0.111	-0.504	-0.502	0.330	-0.003
SE	34.681	0.660	0.116	0.216	0.536	0.114	0.074
T- value	2.246	-2.319	-0.958	-2.335	-0.935	2.891	-0.034
R^2	76.8						
Population (Y) = 77.895 -1.532 X_1 -0.111 X_2 -0.504 X_3 -0.502 X_4 +0.330 X_5 -0.003X_6							

Table 88: Impact of temperature and relative humidity on population of Syrphids in West direction during 2011

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	30.282	-0.143	-0.081	-0.464	-0.591	0.294	0.014
SE	18.257	0.329	0.063	0.125	0.311	0.066	0.043
T- value	1.658	-0.436	-1.289	-3.713	-1.897	4.437	0.318
R^2	84.5						
Population (Y) = 30.282 -0.143 X_1 -0.081 X_2 -0.464 X_3 -0.591 X_4 +0.294 X_5 +0.014X_6							

Table 89: Impact of temperature and relative humidity on mean population of Syrphids during 2011

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	48.681	-0.695	-0.076	-0.501	-0.538	0.319	0.005
SE	24.928	0.461	0.084	0.161	0.402	0.086	0.056
T- value	1.953	-1.507	-0.906	-3.108	-1.337	3.724	0.085
R^2	80.8						
Population (Y) = 48.681 -0.695 X_1 -0.076 X_2 -0.501 X_3 -0.538 X_4 +0.319 X_5 +0.005X_6							

Table 90: Impact of temperature and relative humidity on population of Syrphids in East direction during 2012

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-17.389	0.528	0.256	-0.074	-0.203	-0.011	0.010
SE	19.302	0.460	0.151	0.078	0.115	0.035	0.022
T- value	-0.901	1.147	1.692	-0.952	-1.760	-0.304	0.487
R^2	68.7						
Population (Y) = -17.389 +0.528 X_1 +0.256 X_2 -0.074 X_3 -0.203 X_4 -0.011 X_5 +0.010X_6							

Table 91: Impact of temperature and relative humidity on population of Syrphids in West direction during 2012

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	1.636	0.031	0.064	-0.014	-0.127	-0.010	0.007
SE	6.524	0.143	0.064	0.038	0.062	0.018	0.011
T- value	0.251	0.217	0.997	-0.378	-2.029	-0.586	0.600
R^2	75.1						
Population (Y) = 1.636 +0.031 X_1 +0.064 X_2 -0.014 X_3 -0.127 X_4 -0.010 X_5 +0.007X_6							

Table 92: Impact of temperature and relative humidity on mean population of Syrphids during 2012

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-6.249	0.236	0.152	-0.040	-0.165	-0.012	0.008
SE	11.067	0.256	0.096	0.054	0.086	0.026	0.016
T- value	-0.565	0.924	1.582	-0.750	-1.913	-0.453	0.499
R^2	71.5						
Population (Y) = -6.249 +0.236 X_1 +0.152 X_2 -0.040 X_3 -0.165 X_4 -0.012 X_5 +0.008 X_6							

Plate 38 & 39: Syrphids foraging on litchi flowers

Sphaerophoria Indiana

***Eristalis* sp.**

E. tabanoides

E. tenax

Plate 40: Different species of syrphids foraging on litchi flowers

regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.12 individuals in the population.

The population decreased by 0.01 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.007 individuals with every unit increase (1%) in maximum relative humidity of the location, while other variables as constant.

4.2.1.4c Impact of abiotic factors on overall population of pollinator

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 80.8%. The population decreased by 0.67 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 89).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.08 individuals in the population.

The population decreased by 0.50 individuals and 0.53 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The population increased by 0.32 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.005 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 71.5%. The population increased by 0.24 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 92).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.15 individuals in the population.

The population decreased by 0.04 individuals and decreased by 0.17 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The population decreased by 0.01 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.008 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

4.2.1 Relative abundance of Stingless bee, *Trigona laeviceps* Smith on litchi inflorescence during 2011 and 2012

The observations on relative abundance of Stingless bee, *Trigona laeviceps* on litchi inflorescence were made in two directions (East and West) at four different day hours (0800, 1100, 1400 and 1700 hours) during 2011 and 2012. The data for relative abundance of pollinator are presented in Table 93 and Table 94 as well as Fig. 67 and 68 for 2011and 2012, respectively.

4.2.1.1 Relative abundance of pollinator during flowering period

During 2011 significantly higher population was observed on March 28 (7.9 foragers/inflorescence/3min) which was found at par with the population recorded on March 29 (7.4 foragers/inflorescence/3min). No population was recorded during April 03 to April 15 (Table 93). During 2012, the population observed on March 26 (3.5 foragers/inflorescence/3min) was significantly higher which was found at par with the population recorded on March 31 (3.3 foragers/inflorescence/3min). The minimum population was recorded on April 05 (1.7 foragers/inflorescence/3min) (Table 94).

4.2.1.2 Impact of day hours and days on relative abundance

During 2011, in the East direction, pollinator population recorded at 1100 hours (2.8 foragers/inflorescence/3min) was significantly higher than all other day hours (0800, 1400 and 1700 hours). The minimum population was observed at 0800 hours (0.7 foragers/inflorescence/3min). Significantly higher population was recorded on March 29 (6.5 foragers/inflorescence/3min) which was found at par with the population recorded on March 28 (6.4 foragers/inflorescence/3min). Population was not observed during April 03 to April 15 (Table 93).

Table 93: Relative abundance of *Trigona laeviceps* on litchi inflorescence during 2011

Days	East (D_1)					West (D_2)					Grand
	0800	1100	1400	1700	Mean	0800	1100	1400	1700	Mean	Mean
March 24	1.2	3.8	2.2	3.8	**2.8**	1.4	2.8	2.8	3.6	**2.7**	**2.7**
March 25	2.6	2.6	3.6	5.4	**3.6**	1.0	3.6	4.6	5.4	**3.7**	**3.6**
March 26	3.6	4.6	4.0	7.4	**4.9**	2.6	3.4	6.8	10.2	**5.8**	**5.3**
March 27	3.8	8.6	3.0	6.0	**5.4**	2.0	5.0	11.4	14.8	**8.3**	**6.8**
March 28	2.2	11.0	5.6	6.6	**6.4**	2.8	4.2	14.6	16.4	**9.5**	**7.9**
March 29	1.6	11.6	5.0	7.6	**6.5**	1.8	4.0	13.4	14.4	**8.4**	**7.4**
March 30	0.0	0.0	5.4	5.2	**2.7**	0.0	0.0	15.8	16.8	**8.2**	**5.4**
March 31	0.0	15.2	1.4	4.8	**5.4**	0.2	2.8	6.6	7.4	**4.3**	**4.8**
April 01	1.4	5.8	1.2	1.4	**2.5**	0.0	0.2	4.6	3.8	**2.2**	**2.3**
April 02	0.6	2.0	0.6	0.4	**0.9**	0.0	0.0	0.6	1.2	**0.5**	**0.7**
April 03	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 04	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 05	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 06	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 07	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 08	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 09	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 10	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 11	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 12	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 13	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 14	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 15	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
Mean	**0.7**	**2.8**	**1.4**	**2.1**	**1.8**	**0.5**	**1.1**	**3.5**	**4.1**	**2.3**	**2.0**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.15	0.05
Day hours (H)	0.20	0.07
Days (Y)	0.50	0.17
DxH	0.29	0.10
DxY	0.70	0.25
HxY	1.00	0.35
DxHxY	1.40	0.50

Table 94: Relative abundance of *Trigona laeviceps* on litchi inflorescence during 2012

Days	East (D_1)					West (D_2)					Grand
	0800	**1100**	**1400**	**1700**	**Mean**	**0800**	**1100**	**1400**	**1700**	**Mean**	**Mean**
March 24	0.0	3.0	3.0	3.4	**2.4**	0.0	1.8	2.2	3.6	**1.9**	**2.1**
March 25	0.0	3.2	2.4	2.4	**2.0**	0.0	1.8	3.4	3.2	**2.1**	**2.1**
March 26	0.0	5.6	5.0	4.6	**3.8**	0.0	4.0	3.8	5.0	**3.2**	**3.5**
March 27	0.0	3.0	5.6	3.4	**3.0**	0.0	1.4	4.2	3.6	**2.3**	**2.7**
March 28	0.0	3.2	3.4	4.2	**2.7**	0.0	1.4	1.4	3.4	**1.6**	**2.1**
March 29	0.0	5.6	3.4	4.8	**3.5**	0.0	3.0	1.6	2.8	**1.9**	**2.7**
March 30	0.4	6.0	4.2	5.6	**4.1**	0.0	3.2	2.2	3.4	**2.2**	**3.1**
March 31	1.0	6.4	5.0	4.4	**4.2**	0.0	3.8	2.4	3.0	**2.3**	**3.3**
April 01	1.6	4.4	4.8	4.8	**3.9**	0.6	2.2	2.2	2.2	**1.8**	**2.9**
April 02	1.8	3.8	3.6	3.4	**3.2**	1.2	3.2	2.2	2.2	**2.2**	**2.7**
April 03	2.6	4.2	2.4	1.6	**2.7**	1.2	2.2	4.4	3.8	**2.9**	**2.8**
April 04	1.6	2.8	2.4	2.0	**2.2**	1.2	1.8	3.4	2.8	**2.3**	**2.3**
April 05	2.0	2.8	3.2	2.4	**2.6**	0.4	0.8	0.8	1.4	**0.9**	**1.7**
April 06	2.8	5.6	2.0	2.6	**3.3**	2.0	3.0	1.2	2.0	**2.1**	**2.7**
April 07	2.8	4.4	2.2	3.0	**3.1**	1.6	2.6	2.6	2.0	**2.2**	**2.7**
April 08	3.0	4.4	2.6	1.8	**3.0**	1.6	3.0	2.8	2.6	**2.5**	**2.7**
April 09	2.8	2.8	2.4	1.4	**2.4**	2.0	2.0	2.6	2.0	**2.2**	**2.3**
April 10	2.8	4.6	2.2	2.0	**2.9**	1.8	2.4	3.0	2.4	**2.4**	**2.7**
Mean	**1.4**	**4.2**	**3.3**	**3.2**	**3.0**	**0.8**	**2.4**	**2.6**	**2.9**	**2.2**	**2.6**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.12	0.04
Day hours (H)	0.17	0.05
Days (Y)	0.36	0.12
DxH	0.23	0.08
DxY	0.50	0.17
HxY	0.70	0.25
DxHxY	1.00	0.35

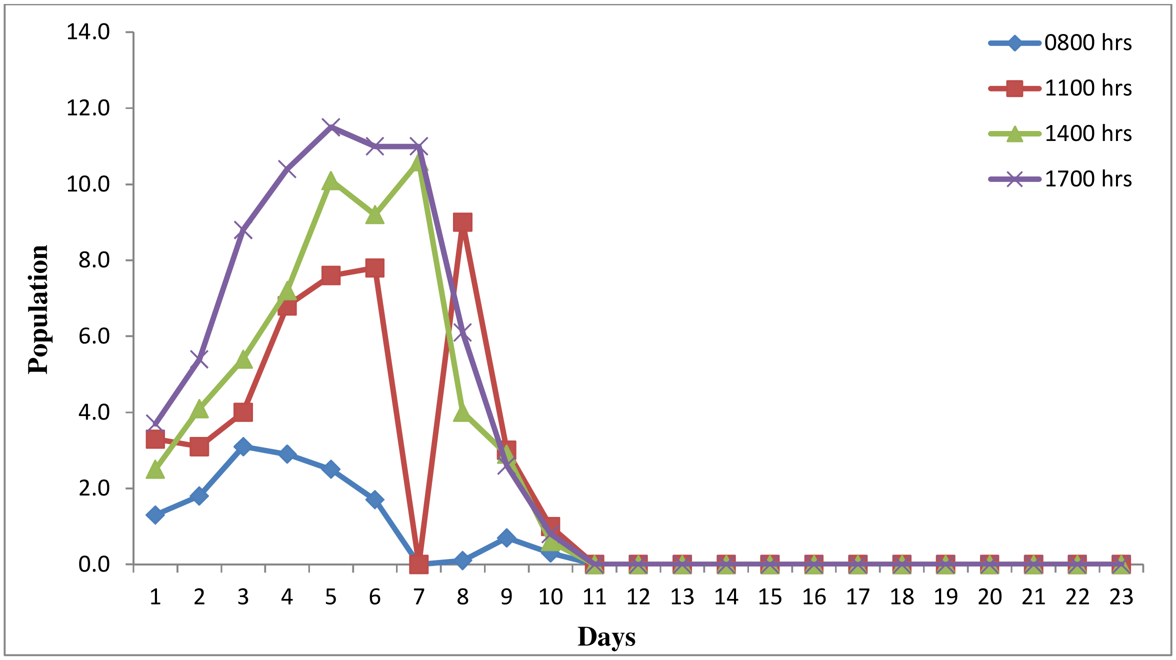

Fig. 67: Relative abundance of *Trigona laeviceps* on litchi inflorescence during 2011

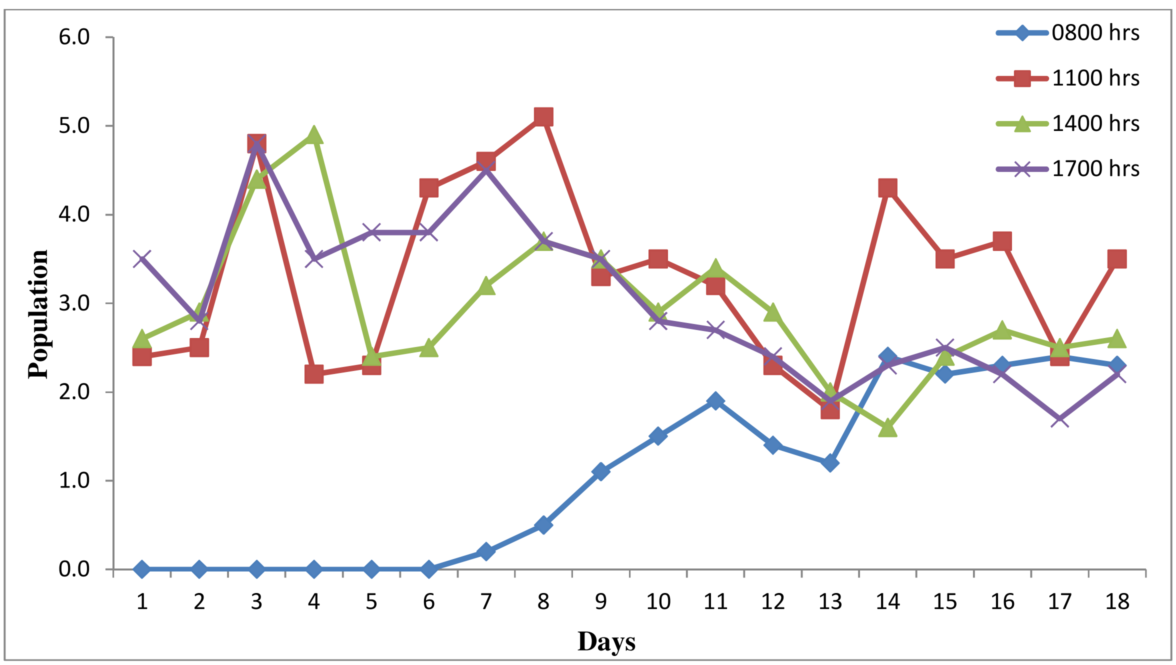

Fig. 68: Relative abundance of *Trigona laeviceps* on litchi inflorescence during 2012

During 2012, in the East direction, significantly higher population was observed at 1100 hours (4.2 foragers/inflorescence/3min) and it was recorded minimum at 0800 hours (1.4 foragers/inflorescence/3min). The population observed on March 31 (4.2 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded on March 26 (3.8 foragers/inflorescence/3min). The population was observed minimum during March 25 (2.0 foragers/inflorescence/3min) which was found at par with the population observed during March 24 (2.4 foragers/ inflorescence/3min), April 04 (2.2 foragers/inflorescence/3min) and April 09 (2.4 foragers/inflorescence/3min) (Table 94).

During 2011, in West direction, significantly lower population was recorded at 0800 hours (0.5 foragers/inflorescence/3min). The maximum population was recorded at 1700 hours (4.1 foragers/inflorescence/3min). The population was not observed during April 03 to April 15. The maximum population was observed on March 28 (9.5 foragers/inflorescence/3min) (Table 93).

During 2012, in the West direction, pollinator population was significantly lower at 0800 hours (0.8 foragers/inflorescence/3min). The maximum population was recorded at 1700 hours (2.9 foragers/inflorescence/3min). Significantly higher population was observed on March 26 (3.2 foragers/inflorescence/3min) which was found at par with population recorded on April 03 (2.9 foragers/inflorescence/3min). Minimum population was observed during April 05(0.9 foragers/inflorescence/3min) (Table 94).

4.2.1.3 Impact of direction on relative abundance of pollinator

During 2011, the relative abundance of pollinator between East and West directions was significantly different. It was maximum in West direction (2.3 foragers/inflorescence/3min) and minimum in East direction (1.8 foragers/ inflorescence/3min) (Table 93). Variation in pattern for the relative abundance was observed during 2012. It was 2.2% and 3.0% in West direction and East direction respectively (Table 94).

During 2011, irrespective of directions, significantly higher population was observed at 1700 hours (3.1 foragers/inflorescence/3min) and it was recorded minimum at 0800 hours (0.6 foragers/inflorescence/3min). At 0800 hours, significantly higher population was observed on March 26 (3.1 foragers/ inflorescence/3min) which was found at par with the population recorded on March 27 (2.9 foragers/inflorescence/3min) and March 28 (2.5 foragers/inflorescence/3min). The population was not observed on March 30 and from April 03 to April 15. At 1100 hours, significantly higher population was recorded on March 31 (9.0 foragers/inflorescence/3min). The population was not recorded on March 30 and from April 03 to April 15. At 1400 hours, maximum population was observed on March 30 (10.6 foragers/inflorescence/3min) which was found at par with the population recorded on March 28 (10.1 foragers/inflorescence/3min). No population was recorded during April 03 to April 15. At 1700 hours, significantly higher population was observed on March 28 (11.5 foragers/inflorescence/3min) and it was at par with the population observed on March 29 (11.0 foragers/inflorescence/3min) and March 30 (11.0 foragers/inflorescence/3min). Population was not observed during April 03 to April 15 (Table 95).

During 2012, irrespective of directions, significantly lower population was observed at 0800 hours (1.1 foragers/inflorescence/3min). It was recorded maximum at 1100 hours (3.3 foragers/inflorescence/3min). At 0800 hours, population was not observed during March 24 to March 29. Significantly higher population was recorded on April 06 and April 09 (2.4 foragers/inflorescence/3min) which was found at par with the population recorded on April 03 (1.9 foragers/inflorescence/3min), April 07 (2.2 foragers/inflorescence/3min), April 08 (2.3 foragers/inflorescence/3min) and April 10 (2.3 foragers/inflorescence/3min). At 1100 hours, population recorded on March 31 (5.1 foragers/inflorescence/3min) was significantly higher which was found at par with the population recorded during March 26 (4.8 foragers/ inflorescence/3min) and March 30 (4.6 foragers/inflorescence/3min). Minimum population was recorded during April 05 (1.8 foragers/inflorescence/3min) which was found at par with the population recorded during March 24 (2.4 foragers/ inflorescence/3min), March 25 (2.5 foragers/inflorescence/3min), March 27 (2.2 foragers/inflorescence/3min), March 28 (2.3 foragers/inflorescence/3min), April 04 (2.3 foragers/inflorescence/3min) and April 09 (2.4 foragers/inflorescence/3min). At 1400 hours, significantly higher population was observed on March 27 (4.9 foragers/inflorescence/3min) which was found at par with the population recorded

Table 95: Relative abundance of *Trigona laeviceps* on litchi inflorescence during 2011

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	1.3	3.3	2.5	3.7	**2.7**
March 25	1.8	3.1	4.1	5.4	**3.6**
March 26	3.1	4.0	5.4	8.8	**5.3**
March 27	2.9	6.8	7.2	10.4	**6.8**
March 28	2.5	7.6	10.1	11.5	**7.9**
March 29	1.7	7.8	9.2	11.0	**7.4**
March 30	0.0	0.0	10.6	11.0	**5.4**
March 31	0.1	9.0	4.0	6.1	**4.8**
April 01	0.7	3.0	2.9	2.6	**2.3**
April 02	0.3	1.0	0.6	0.8	**0.7**
April 03	0.0	0.0	0.0	0.0	**0.0**
April 04	0.0	0.0	0.0	0.0	**0.0**
April 05	0.0	0.0	0.0	0.0	**0.0**
April 06	0.0	0.0	0.0	0.0	**0.0**
April 07	0.0	0.0	0.0	0.0	**0.0**
April 08	0.0	0.0	0.0	0.0	**0.0**
April 09	0.0	0.0	0.0	0.0	**0.0**
April 10	0.0	0.0	0.0	0.0	**0.0**
April 11	0.0	0.0	0.0	0.0	**0.0**
April 12	0.0	0.0	0.0	0.0	**0.0**
April 13	0.0	0.0	0.0	0.0	**0.0**
April 14	0.0	0.0	0.0	0.0	**0.0**
April 15	0.0	0.0	0.0	0.0	**0.0**
Mean	**0.6**	**2.0**	**2.5**	**3.1**	**2.0**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.20	0.07
HxY	1.00	0.35

Table 96: Relative abundance of *Trigona laeviceps* on litchi inflorescence during 2012

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	0.0	2.4	2.6	3.5	**2.1**
March 25	0.0	2.5	2.9	2.8	**2.1**
March 26	0.0	4.8	4.4	4.8	**3.5**
March 27	0.0	2.2	4.9	3.5	**2.7**
March 28	0.0	2.3	2.4	3.8	**2.1**
March 29	0.0	4.3	2.5	3.8	**2.7**
March 30	0.2	4.6	3.2	4.5	**3.1**
March 31	0.5	5.1	3.7	3.7	**3.3**
April 01	1.1	3.3	3.5	3.5	**2.9**
April 02	1.5	3.5	2.9	2.8	**2.7**
April 03	1.9	3.2	3.4	2.7	**2.8**
April 04	1.4	2.3	2.9	2.4	**2.3**
April 05	1.2	1.8	2.0	1.9	**1.7**
April 06	2.4	4.3	1.6	2.3	**2.7**
April 07	2.2	3.5	2.4	2.5	**2.7**
April 08	2.3	3.7	2.7	2.2	**2.7**
April 09	2.4	2.4	2.5	1.7	**2.3**
April 10	2.3	3.5	2.6	2.2	**2.7**
Mean	**1.1**	**3.3**	**3.0**	**3.0**	**2.6**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.17	0.05
HxY	0.70	0.25

during March 26 (4.4 foragers/inflorescence/3min). Minimum population was recorded during April 06 (1.6 foragers/inflorescence/3min) which was found at par with the population recorded during April 05 (2.0 foragers/inflorescence/3min). At 1700 hours, population observed on March 26 (4.8 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded during March 30. Minimum population was observed during April 09 (1.7 foragers/inflorescence/3min) which was found at par with the population recorded during April 04 (2.4 foragers/inflorescence/3min), April 05 (1.9 foragers/inflorescence/3min), April 06 (2.3 foragers/inflorescence/3min), April 08 (2.2 foragers/inflorescence/3min) and April 10 (2.2 foragers/inflorescence/3min) (Table 96).

4.2.1.4 Impact of abiotic factors on population of pollinator

In order to study the combined effect of abiotic factors (temperature and relative humidity) on population of pollinator, both factors were analyzed in the multiple linear regression models.

4.2.1.4a Impact of abiotic factors on population of pollinator in East direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 66.3%. The population decreased by 0.71 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 97).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.71 individuals in the population.

The population decreased by 0.07 individuals with every unit increase (1˚C) in minimum temperature and it was decreased by 0.74 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population increased by 0.02 individuals with every unit increase (1%) in minimum relative humidity and decreased by 0.03 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 41.5%. The population increased by 0.94 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 100).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.31 individuals in the population.

The population was increased by 0.06 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.23 individuals in the population.

The population increased by 0.01 individuals with every unit increase (1%) in minimum relative humidity and decreased by 0.04 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

4.2.1.4b Impact of abiotic factors on population of pollinator in West direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 73.1%. The population decreased by 0.69 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant. (Table 98).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.11 individuals in the population.

The population was decreased by 0.03 individuals with every unit increase (1˚C) in minimum temperature, while other variables as constant and the population was decreased by 1.21 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population increased by 0.05 individuals with every unit increase (1%) in minimum relative humidity while decreased by 0.05 individuals with every unit

Table 97: Impact of temperature and relative humidity on population of *Trigona laeviceps* in East direction during 2011

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	49.666	-0.715	0.071	-0.065	-0.748	0.017	-0.030
SE	25.861	0.492	0.086	0.161	0.400	0.085	0.055
T- value	1.920	-1.452	0.821	-0.402	-1.871	0.194	-0.539
R^2	66.3						
Population (Y) = 49.666 -0.715 X_1 +0.071 X_2 -0.065 X_3 -0.748 X_4 +0.017 X_5 -0.030X_6							

Table 98: Impact of temperature and relative humidity on population of *Trigona laeviceps* in West direction during 2011

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	63.375	-0.688	0.110	-0.025	-1.217	0.046	-0.045
SE	29.363	0.528	0.101	0.201	0.501	0.107	0.069
T- value	2.158	-1.302	1.087	-0.126	-2.431	-0.427	-0.650
R^2	73.1						
Population (Y) = 63.375 -0.688 X_1 +0.110 X_2 -0.025 X_3 -1.217 X_4 +0.046 X_5 -0.045X_6							

Table 99: Impact of temperature and relative humidity on mean population of *Trigona laeviceps* during 2011

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	52.747	-0.618	0.103	-0.051	-0.963	0.029	-0.036
SE	26.202	0.485	0.088	0.169	0.423	0.090	0.059
T- value	2.013	-1.276	1.168	-0.299	-2.279	0.320	-0.616
R^2	72.5						
Population (Y) = 52.747 -0.618 X_1 +0.103 X_2 -0.051 X_3 -0.963 X_4 +0.029 X_5 -0.036X_6							

Table100: Impact of temperature and relative humidity on population of *Trigona laeviceps* in East direction during 2012

Constant		Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-34.419	0.940	0.310	0.063	-0.234	0.013	0.038
SE	24.129	0.575	0.189	0.098	0.144	0.044	0.027
T- value	-1.426	1.634	1.641	0.641	-1.627	0.307	1.412
R^2	41.5						
Population (Y) = -34.419 +0.940 X_1 +0.310 X_2 +0.063 X_3 -0.234 X_4 +0.013 X_5 +0.038X_6							

Table 101: Impact of temperature and relative humidity on population of *Trigona laeviceps* in West direction during 2012

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-1.134	0.143	0.154	0.090	-0.150	-0.010	-0.033
SE	12.002	0.264	0.118	0.069	0.115	0.033	0.021
T- value	-0.094	0.542	1.309	1.297	-1.306	-0.313	-1.606
R^2	35.3						
Population (Y) = -1.134 +0.143 X_1 +0.154 X_2 +0.090 X_3 -0.150 X_4 -0.010 X_5 -0.033X_6							

Table 102: Impact of temperature and relative humidity on mean population of *Trigona laeviceps* during 2012

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-16.675	0.502	0.229	0.093	-0.199	0.008	0.002
SE	13.113	0.303	0.114	0.064	0.102	0.030	0.019
T- value	-1.272	1.656	2.014	1.454	-1.955	0.250	0.090
R^2	41.2						
Population (Y) = -16.675 +0.502 X_1 +0.229 X_2 +0.093 X_3 -0.199 X_4 +0.008 X_5 +0.002 X_6							

increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 35.3%. The population increased by 0.14 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 101).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.15 individuals in the population.

The population was increased by 0.09 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.15 individuals in the population.

The population decreased by 0.01 individuals with every unit increase (1%) in minimum relative humidity and decreased by 0.03 individuals with every unit increase (1%) in maximum relative humidity of the location, while other variables as constant.

4.2.1.4c Impact of abiotic factors on overall population of pollinator

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 72.5%. The population decreased by 0.61 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 99).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.10 individuals in the population.

The population decreased by 0.05 individuals and 0.96 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The population increased by 0.03 individuals with every unit increase (1%) in minimum relative humidity and decreased by 0.04 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 41.2%. The population increased by 0.50 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 102).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in increase of 0.23 individuals in the population.

The population increased by 0.09 individuals and decreased by 0.20 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The population increased by 0.008 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.002 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

4.2.1 Relative abundance of *Coccinella septempunctata* L. on litchi inflorescence during 2011 and 2012

The observations on relative abundance of *Coccinella septempunctata* on litchi inflorescence were made in two directions (East and West) at four different day hours (0800, 1100, 1400 and 1700 hours) during 2011 and 2012. The data for relative abundance of pollinator are presented in Table 103 and Table 104 as well as Fig. 69 and 70 for 2011and 2012, respectively.

4.2.1.1 Relative abundance of pollinator during flowering period

The perusal of the data revealed that the population gradually increases during flowering period. During 2011 significantly higher population was observed on April 12 (10.8 foragers/inflorescence/3min). No population was recorded from March 24 to March 29 (Table 103). During 2012, the population observed on April 02

Plate 41 & 42: ***Trigona laeviceps*** **foraging on litchi flowers**

Plate 43 & 44: ***Coccinella septempunctata*** **foraging on litchi flowers**

Table 103: Relative abundance of *Coccinella* on litchi inflorescence during 2011

Days	East (D_1)					West (D_2)					Grand Mean
	0800	**1100**	**1400**	**1700**	**Mean**	**0800**	**1100**	**1400**	**1700**	**Mean**	
March 24	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
March 25	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
March 26	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
March 27	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
March 28	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
March 29	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
March 30	0.0	1.8	1.4	1.0	**1.1**	0.0	1.8	1.0	0.6	**0.9**	**1.0**
March 31	1.6	2.0	2.2	1.0	**1.7**	0.4	0.6	3.0	1.0	**1.3**	**1.5**
April 01	0.8	3.2	2.2	2.0	**2.1**	0.4	2.4	3.2	3.6	**2.4**	**2.2**
April 02	2.6	4.0	2.4	2.8	**3.0**	2.2	2.6	3.0	3.2	**2.8**	**2.9**
April 03	3.4	3.8	2.6	3.0	**3.2**	2.4	2.4	3.0	2.8	**2.7**	**2.9**
April 04	3.0	3.4	2.6	2.6	**2.9**	2.4	2.8	2.6	2.8	**2.7**	**2.8**
April 05	3.2	3.8	3.2	3.6	**3.5**	2.6	3.2	3.2	3.4	**3.1**	**3.3**
April 06	3.2	4.0	3.6	4.4	**3.8**	3.4	3.2	3.6	4.0	**3.6**	**3.7**
April 07	3.2	4.4	2.4	4.8	**3.7**	1.8	3.8	2.2	4.2	**3.0**	**3.4**
April 08	4.6	4.0	3.6	3.0	**3.8**	4.2	4.8	4.6	4.8	**4.6**	**4.2**
April 09	5.0	4.2	2.8	2.4	**3.6**	2.6	3.0	10.8	12.8	**7.3**	**5.5**
April 10	7.8	3.8	2.8	2.6	**4.3**	2.4	3.0	13.2	13.0	**7.9**	**6.1**
April 11	14.4	15.0	3.4	3.6	**9.1**	2.2	1.8	15.4	15.2	**8.7**	**8.9**
April 12	16.2	18.6	4.0	3.4	**10.6**	3.6	4.2	17.6	18.8	**11.1**	**10.8**
April 13	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 14	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
April 15	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.0**	**0.0**
Mean	**3.0**	**3.3**	**1.7**	**1.7**	**2.4**	**1.3**	**1.7**	**3.8**	**3.9**	**2.7**	**2.6**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.10	0.03
Day hours (H)	0.15	0.05
Days (Y)	0.37	0.13
DxH	0.21	0.07
DxY	0.52	0.18
HxY	0.74	0.26
DxHxY	1.04	0.37

Table 104: Relative abundance of *Coccinella* on litchi inflorescence during 2012

Days	East (D_1)					West (D_2)					Grand Mean
	0800	**1100**	**1400**	**1700**	**Mean**	**0800**	**1100**	**1400**	**1700**	**Mean**	
March 24	0.2	1.2	0.2	0.0	**0.4**	0.0	0.6	0.8	0.2	**0.4**	**0.4**
March 25	0.2	1.2	0.6	0.0	**0.5**	0.0	0.8	1.2	0.4	**0.6**	**0.6**
March 26	0.0	0.2	0.4	0.0	**0.2**	0.0	0.0	0.8	0.0	**0.2**	**0.2**
March 27	0.0	0.6	0.6	0.2	**0.4**	0.0	0.2	1.0	0.8	**0.5**	**0.4**
March 28	0.0	1.2	0.0	2.0	**0.8**	0.0	0.4	0.2	2.0	**0.7**	**0.7**
March 29	0.0	1.0	0.0	0.6	**0.4**	0.0	0.0	0.2	0.8	**0.3**	**0.3**
March 30	0.4	2.0	0.8	0.8	**1.0**	0.0	0.6	0.2	2.0	**0.7**	**0.9**
March 31	0.6	3.4	1.0	0.8	**1.5**	0.0	1.4	2.4	1.2	**1.3**	**1.4**
April 01	1.2	5.6	1.0	0.2	**2.0**	0.2	2.6	3.0	0.8	**1.7**	**1.8**
April 02	0.6	4.6	4.4	1.4	**2.8**	0.6	4.2	5.0	2.4	**3.1**	**2.9**
April 03	0.8	1.2	0.2	0.2	**0.6**	0.4	0.0	1.2	0.6	**0.6**	**0.6**
April 04	0.8	2.2	1.0	0.4	**1.1**	0.0	0.4	2.2	1.4	**1.0**	**1.1**
April 05	0.6	2.4	1.6	1.8	**1.6**	0.0	1.4	1.8	2.2	**1.4**	**1.5**
April 06	1.6	3.2	1.8	2.4	**2.3**	0.8	1.4	1.6	2.0	**1.5**	**1.9**
April 07	0.6	3.0	1.8	2.4	**2.0**	0.2	1.6	3.0	3.0	**2.0**	**2.0**
April 08	1.6	3.0	2.8	2.8	**2.6**	0.8	2.4	3.8	3.2	**2.6**	**2.6**
April 09	2.6	2.8	2.4	1.6	**2.4**	1.2	2.2	2.8	2.2	**2.1**	**2.2**
April 10	1.6	3.0	3.0	2.8	**2.6**	1.4	2.0	4.4	3.4	**2.8**	**2.7**
Mean	**0.7**	**2.3**	**1.3**	**1.1**	**1.4**	**0.3**	**1.2**	**2.0**	**1.6**	**1.3**	**1.3**

Sources of variation	CD at 5%	SEm±
Directions (D)	0.10	0.03
Day hours (H)	0.15	0.05
Days (Y)	0.32	0.11
DxH	0.21	0.07
DxY	0.45	0.16
HxY	0.63	0.22
DxHxY	0.90	0.32

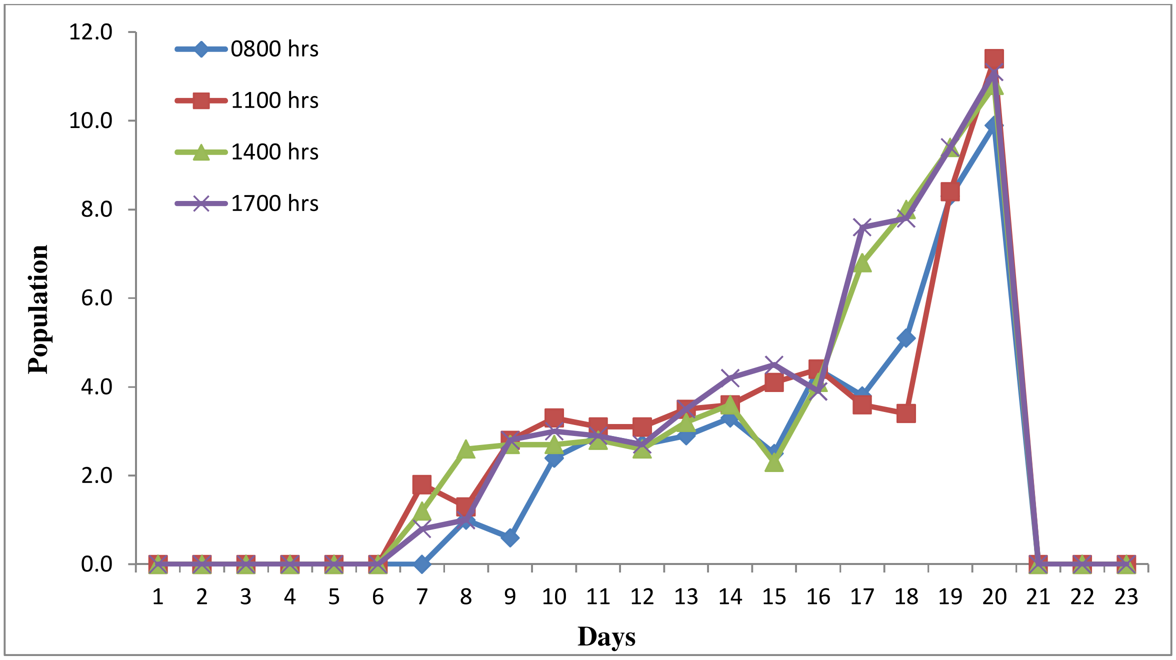

Fig. 69: Relative abundance of *Coccinella* on litchi inflorescence during 2011

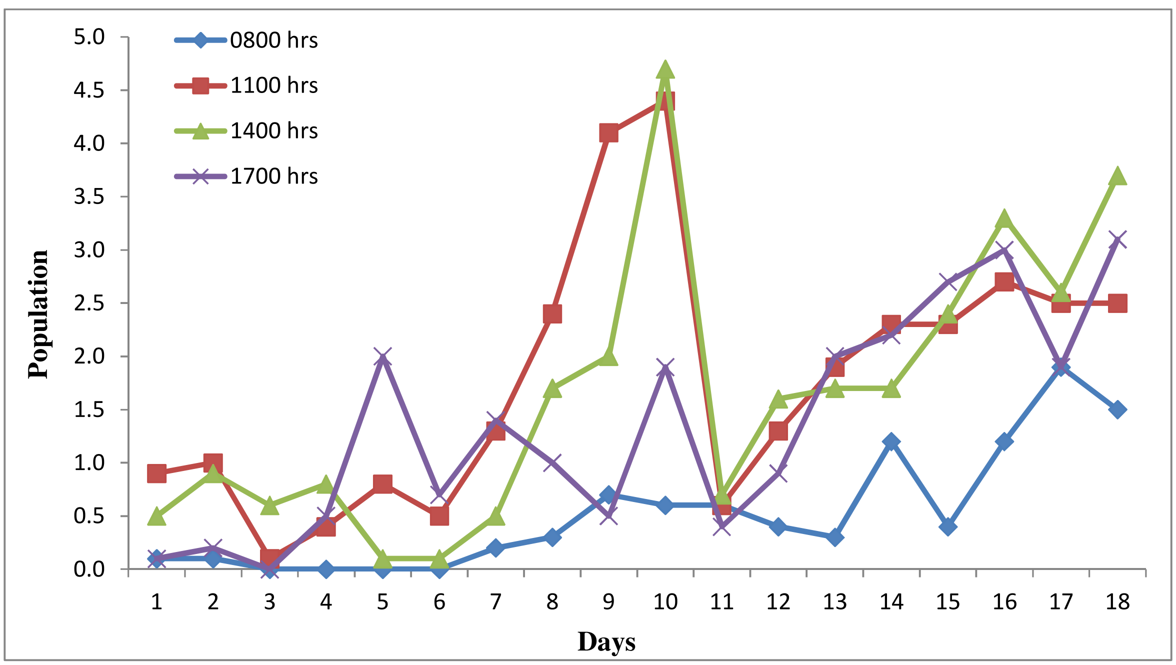

Fig. 70: Relative abundance of *Coccinella* on litchi inflorescence during 2012

(2.9 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded on April 08 (2.6 foragers/inflorescence/3min) and April 10 (2.7 foragers/inflorescence/3min). The minimum population was recorded on March 26 (0.2 foragers/inflorescence/3min) which was found at par with the population observed on March 24 (0.4 foragers/inflorescence/3min), March 27 (0.4 foragers/inflorescence/3min) and March 29 (0.3 foragers/inflorescence/3min) (Table 104).

4.2.1.2 Impact of day hours and days on relative abundance

During 2011, in the East direction, pollinator population recorded at 1100 hours (3.3 foragers/inflorescence/3min) was significantly higher than all other day hours (0800, 1400 and 1700 hours). The minimum population was observed at 1400 hours and 1700 hours (1.7 foragers/inflorescence/3min). Significantly higher population was recorded on April 12 (10.6 foragers/inflorescence/3min) and no population was observed from March 24 to March 29 and from April 13 to April 15 (Table 103).

During 2012, in the East direction, significantly higher population was observed at 1100 hours (2.3 foragers/inflorescence/3min) and it was recorded minimum at 0800 hours (0.7 foragers/inflorescence/3min). The population observed on April 02 (2.8 foragers/inflorescence/3min) was significantly higher and found at par with the population recorded on April 08 (2.6 foragers/inflorescence/3min), April 09 (2.4 foragers/inflorescence/3min) and April 10 (2.6 foragers/inflorescence/3min). The minimum population was observed on March 26 (0.2 foragers/ inflorescence/3min) which was found at par with the population recorded on March 24 (0.4 foragers/inflorescence/3min), March 25 (0.5 foragers/inflorescence/3min), March 27 (0.4 foragers/inflorescence/3min), March 29 (0.4 foragers/inflorescence/ 3min) and April 03 (0.6 foragers/inflorescence/3min) (Table 104).

During 2011, in West direction, significantly lower population was recorded at 0800 hours (1.3 foragers/inflorescence/3min). The maximum population was recorded at 1700 hours (3.9 foragers/inflorescence/3min) which was at par with the population recorded at 1400 hours. The population was not observed from March 24 to March 29 and from April 13 to April 15. The maximum population was observed on April 12 (11.1 foragers/inflorescence/3min) (Table 103).

During 2012, in the West direction, pollinator population was significantly lower at 0800 hours (0.3 foragers/inflorescence/3min). The maximum population was recorded at 1400 hours (2.0 foragers/inflorescence/3min). Significantly higher population was observed on April 02 (3.1 foragers/inflorescence/3min) which was found at par with the population observed on April 10 (2.8 foragers/ inflorescence/3min). Population was minimum on March 26 (0.2 foragers/ inflorescence/3min) which was found at par with the population observed on March 24 (0.4 foragers/inflorescence/3min), March 25 (0.6 foragers/inflorescence/3min), March 27 (0.5 foragers/inflorescence/3min), March 29 (0.3 foragers/inflorescence/ 3min) and April 03 (0.6 foragers/inflorescence/3min) (Table 104).

4.2.1.3 Impact of direction on relative abundance of pollinator

During 2011, the relative abundance of pollinator between East and West directions was significantly different. It was maximum in West direction (2.7 foragers/inflorescence/3min) and minimum in East direction (2.4 foragers/inflorescence/3min) (Table 103). A slight variation in the pattern for the relative abundance was observed during 2012. It was 1.3% and 1.4% in West direction and East direction respectively (Table 104).

During 2011, irrespective of directions, significantly higher population was observed at 1700 hours (2.8 foragers/inflorescence/3min) which was found at par with the population recorded at 1400 hours (2.7 foragers/inflorescence/3min) and it was recorded minimum at 0800 hours (2.2 foragers/inflorescence/3min). At 0800 hours, significantly higher population was observed on April 12 (9.9 foragers/inflorescence/3min). The population was not observed during March 24 to March 30 and during April 13 to April 15. At 1100 hours, significantly no population was recorded from March 24 to March 30 and from April 13 to April 15. The maximum population was recorded on April 12 (11.4 foragers/inflorescence/3min). At 1400 hours, pollinator population was not observed during March 24 to March 30 and during April 13 to April 15. Maximum population was observed on April 12 (10.8 foragers/inflorescence/3min). At 1700 hours, significantly higher population was observed on April 12 (11.1 foragers/inflorescence/3min. Population was not observed during March 24 to March 30 and during April 13 to April 15 (Table 105).

Table 105: Relative abundance of *Coccinella* on litchi inflorescence during 2011

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	0.0	0.0	0.0	0.0	**0.0**
March 25	0.0	0.0	0.0	0.0	**0.0**
March 26	0.0	0.0	0.0	0.0	**0.0**
March 27	0.0	0.0	0.0	0.0	**0.0**
March 28	0.0	0.0	0.0	0.0	**0.0**
March 29	0.0	0.0	0.0	0.0	**0.0**
March 30	0.0	1.8	1.2	0.8	**1.0**
March 31	1.0	1.3	2.6	1.0	**1.5**
April 01	0.6	2.8	2.7	2.8	**2.2**
April 02	2.4	3.3	2.7	3.0	**2.9**
April 03	2.9	3.1	2.8	2.9	**2.9**
April 04	2.7	3.1	2.6	2.7	**2.8**
April 05	2.9	3.5	3.2	3.5	**3.3**
April 06	3.3	3.6	3.6	4.2	**3.7**
April 07	2.5	4.1	2.3	4.5	**3.4**
April 08	4.4	4.4	4.1	3.9	**4.2**
April 09	3.8	3.6	6.8	7.6	**5.5**
April 10	5.1	3.4	8.0	7.8	**6.1**
April 11	8.3	8.4	9.4	9.4	**8.9**
April 12	9.9	11.4	10.8	11.1	**10.8**
April 13	0.0	0.0	0.0	0.0	**0.0**
April 14	0.0	0.0	0.0	0.0	**0.0**
April 15	0.0	0.0	0.0	0.0	**0.0**
Mean	**2.2**	**2.5**	**2.7**	**2.8**	**2.6**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.15	0.05
HxY	0.74	0.26

Table 106: Relative abundance of *Coccinella* on litchi inflorescence during 2012

Months	0800 hrs	1100 hrs	1400 hrs	1700 hrs	Mean
March 24	0.1	0.9	0.5	0.1	**0.4**
March 25	0.1	1.0	0.9	0.2	**0.6**
March 26	0.0	0.1	0.6	0.0	**0.2**
March 27	0.0	0.4	0.8	0.5	**0.4**
March 28	0.0	0.8	0.1	2.0	**0.7**
March 29	0.0	0.5	0.1	0.7	**0.3**
March 30	0.2	1.3	0.5	1.4	**0.9**
March 31	0.3	2.4	1.7	1.0	**1.4**
April 01	0.7	4.1	2.0	0.5	**1.8**
April 02	0.6	4.4	4.7	1.9	**2.9**
April 03	0.6	0.6	0.7	0.4	**0.6**
April 04	0.4	1.3	1.6	0.9	**1.1**
April 05	0.3	1.9	1.7	2.0	**1.5**
April 06	1.2	2.3	1.7	2.2	**1.9**
April 07	0.4	2.3	2.4	2.7	**2.0**
April 08	1.2	2.7	3.3	3.0	**2.6**
April 09	1.9	2.5	2.6	1.9	**2.2**
April 10	1.5	2.5	3.7	3.1	**2.7**
Mean	**0.5**	**1.8**	**1.6**	**1.4**	**1.3**

Sources of variation	CD at 5%	SEm±
Day hours (H)	0.15	0.05
HxY	0.63	0.22

During 2012, irrespective of directions, significantly lower population was observed at 0800 hours (0.5 foragers/inflorescence/3min) and it was recorded maximum at 1100 hours (1.8 foragers/inflorescence/3min). At 0800 hours, population was not observed during March 26 to March 29. Significantly higher population was recorded on April 09 (1.9 foragers/inflorescence/3min) and it was found at par with the population recorded on April 10 (1.5 foragers/inflorescence/3min). At 1100 hours, population recorded on April 02 (4.4 foragers/inflorescence/3min) was significantly higher and minimum population was recorded on March 26 (0.1 foragers/inflorescence/3min) which was found at par with the population observed on March 27 (0.4 foragers/inflorescence/3min), March 29 (0.5 foragers/inflorescence/3min) and April 03 (0.6 foragers/inflorescence/3min). At 1400 hours, significantly lower population was observed on March 28 and March 29 (0.1 foragers/inflorescence/3min) and it was found at par with the population recorded on March 24 (0.5 foragers/inflorescence/3min), March 26 (0.6 foragers/inflorescence/3min), March 30 (0.5 foragers/inflorescence/3min) and April 03 (0.7 foragers/inflorescence/3min). At 1700 hours, no population was observed on March 26. The maximum population was observed on April 10 (3.1 foragers/inflorescence/ 3min) which was found at par with the population recorded on April 07 (2.7 foragers/inflorescence/3min) and April 08 (3.0 foragers/inflorescence/3min) (Table 106).

4.2.1.4 Impact of abiotic factors on population of pollinator

In order to study the combined effect of abiotic factors (temperature and relative humidity) on population of pollinator, both factors were analyzed in the multiple linear regression models.

4.2.1.4a Impact of abiotic factors on population of pollinator in East direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 54.7%. The population increased by 1.43 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 107).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.04 individuals in the population.

The population increased by 0.15 individuals with every unit increase (1˚C) in minimum temperature and it was increased by 0.24 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population decreased by 0.02 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.06 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 87.7%. The population decreased by 0.25 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 110).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.36 individuals in the population.

The population was increased by 0.04 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.04 individuals in the population.

The minimum relative humidity had negative impact on population while maximum relative humidity of the location had positive impact on population.

4.2.1.4b Impact of abiotic factors on population of pollinator in West direction

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 56.9%. The population increased by 0.72 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 108).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.16 individuals in the population.

Table 107: Impact of temperature and relative humidity on population of *Coccinella* in East direction during 2011

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-56.010	1.431	-0.042	0.153	0.239	-0.018	0.061
SE	35.591	0.678	0.119	0.221	0.550	0.117	0.076
T- value	-1.574	2.111	-0.355	0.692	0.434	-0.157	0.794
R^2	54.7						
Population (Y) = -56.010 +1.431 X_1 -0.042 X_2 +0.153 X_3 +0.239 X_4 -0.018 X_5 +0.061X_6							

Table 108: Impact of temperature and relative humidity on population of *Coccinella* in West direction during 2011

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-12.205	0.725	-0.158	0.252	-0.134	-0.148	0.030
SE	35.667	0.642	0.122	0.244	0.608	0.130	0.084
T- value	-0.342	1.129	-1.294	1.032	-0.220	-1.141	0.357
R^2	56.9						
Population (Y) = -12.205 +0.725 X_1 -0.158 X_2 +0.252 X_3 -0.134 X_4 -0.148 X_5 +0.030X_6							

Table 109: Impact of temperature and relative humidity on mean population of *Coccinella* during 2011

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	-34.440	1.092	-0.086	0.209	0.038	-0.092	0.044
SE	35.901	0.664	0.121	0.232	0.579	0.123	0.080
T- value	-0.959	1.644	-0.706	0.901	0.066	-0.748	0.554
R^2	54.5						
Population (Y) = -34.440 +1.092 X_1 -0.086 X_2 +0.209 X_3 +0.038 X_4 -0.092 X_5 +0.044X_6							

Table 110: Impact of temperature and relative humidity on population of *Coccinella* in East direction during 2012

	Constant	Surrounding environment of inflorescence (East)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	22.603	-0.249	-0.358	0.043	-0.042	-0.006	0.004
SE	15.419	0.368	0.121	0.062	0.092	0.028	0.017
T- value	1.466	-0.677	-2.969	0.685	-0.455	-0.198	0.208
R^2	87.7						
Population (Y) = 22.603 -0.249 X_1 -0.358 X_2 +0.043 X_3 -0.042 X_4 -0.006 X_5 +0.004X_6							

Table 111: Impact of temperature and relative humidity on population of *Coccinella* in West direction during 2012:

	Constant	Surrounding environment of inflorescence (West)		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	21.631	-0.185	-0.334	0.051	-0.054	0.007	-0.021
SE	13.532	0.298	0.133	0.078	0.129	0.037	0.024
T- value	1.598	-0.620	-2.522	0.645	-0.420	0.183	-0.901
R^2	76.2						
Population (Y) = 21.631 -0.185 X_1 -0.334 X_2 +0.051 X_3 -0.054 X_4 +0.007 X_5 -0.021X_6							

Table 112: Impact of temperature and relative humidity on mean population of *Coccinella* during 2012

	Constant	Surrounding environment of inflorescence		Open environment of location			
		Temperature (˚C)	Relative humidity (%)	Temperature		Relative humidity	
				Min	Max	Min	Max
		X_1	X_2	X_3	X_4	X_5	X_6
Co-efficient	24.679	-0.282	-0.371	0.045	-0.032	-0.006	-0.008
SE	13.157	0.304	0.114	0.064	0.102	0.030	0.019
T- value	1.876	-0.927	-3.246	0.707	-0.311	-0.210	-0.412
R^2	84.7						
Population (Y) = 24.679 -0.282 X_1 -0.371 X_2 +0.045 X_3 -0.032 X_4 -0.006 X_5 -0.008 X_6							

The population was increased by 0.25 individuals with every unit increase (1˚C) in minimum temperature, while other variables as constant and the population was decreased by 0.13 individuals with every unit increase (1˚C) in maximum temperature of the location, while other variables as constant.

The population decreased by 0.15 individuals with every unit increase (1%) in minimum relative humidity while increased by 0.03 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 76.0%. The population decreased by 0.19 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 111).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.33 individuals in the population.

The population was increased by 0.05 individuals with every unit increase (1˚C) in minimum temperature of the location, while other variables as constant. The regression values of maximum temperature of the location showed that for other variables as constant, every unit increase (1%) in maximum temperature resulted in decrease of 0.05 individuals in the population.

The population increased by 0.007 individuals with every unit increase (1%) in minimum relative humidity and decreased by 0.02 individuals with every unit increase (1%) in maximum relative humidity of the location, while other variables as constant.

4.2.1.4c Impact of abiotic factors on overall population of pollinator

During 2011, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 54.5%. The population increased by 1.09 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 109).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.09 individuals in the population.

The population increased by 0.21 individuals and 0.04 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The population decreased by 0.09 individuals with every unit increase (1%) in minimum relative humidity and increased by 0.04 individuals with every unit increase (1%) in maximum relative humidity of the location while other variables as constant.

During 2012, the overall contribution of temperature and relative humidity in the surrounding of inflorescence and location on population was 84.7%. The population decreased by 0.28 individuals with every unit increase (1˚C) in the surrounding temperature of inflorescence while other variables as constant (Table 112).

The regression values of surrounding relative humidity of inflorescence showed that for other variables as constant, every unit increase (1%) in relative humidity resulted in decrease of 0.37 individuals in the population.

The population increased by 0.04 individuals and decreased by 0.03 individuals with every unit increase (1%) in minimum temperature and maximum temperature of the location, respectively while other variables as constant.

The minimum and maximum relative humidity of the location had negative impact on the population.

Summary and Conclusion

This chapter includes the summery of the experimental findings as well as the conclusion of the experimental results.

5.1 Assessment of incidence and population dynamics of various insect pests on litchi leaves

5.2 The diversity and relative abundance of insect pollinator species associated with litchi crop

5.1 Assessment of incidence and population dynamics of various insect pests on litchi leaves

Studies on incidence as well as population dynamics of insect pests were undertaken in three different orchards, on the litchi trees selected randomly for observation at Horticulture Research Centre, Patharchatta. The observations on the crop plants were made in four major directions (East, West, North and South). During the studies, five insect pests (Litchi leaf roller, leaf folder, mid rib borer, beetle and weevils) were observed for assessment of incidence (percent leaf infestation) and their population dynamics.

The experiment on incidence of leaf roller indicated that the incidence of insect pest occurred twice in a year. The incidence was started in the month of July and reached to its maximum in September followed by reduction in incidence during October. The second incidence of the pest was started in January and maximum leaf infestation was observed in March with subsequent reduction in infestation during April. The maximum leaf infestation was recorded in the East direction and it was minimum in the North direction. The percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard and minimum was recorded in the first orchard. During 2011-012, the percent leaf infestation was increased with increase in minimum temperature and maximum relative humidity while it was decreased with increase in the maximum temperature, minimum relative humidity and rainfall. During 2012-013, the percent leaf infestation was decreased with increase in rainfall and it was increased with increase in maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity.

The population of leaf roller appeared twice in a year. The population appeared in the month of July and reached to its maximum in September. The second appearance of the pest was observed in the month of January and maximum population was observed in March. During 2011-012, the maximum population was recorded in the East direction and it was minimum in the West direction and North direction. The population was increased with increase in minimum temperature and maximum relative humidity while it was decreased with increase in maximum temperature, minimum relative humidity and rainfall. During 2012-013, the maximum population was recorded in the East direction and it was minimum in the West direction and South direction. The population was decreased with increase in rainfall and it was increased with increase in maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity. The population of pest among three orchards was observed significantly different. It was maximum in the second and third orchard and minimum was recorded in the first orchard.

The observations on incidence of leaf folder indicated that the incidence of insect pest occurred once in a year. The incidence was started in the month of August and reached to its maximum in October with subsequent reduction in infestation during November. The maximum leaf infestation was recorded in the East direction and it was minimum in the North direction. The percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard and minimum was recorded in the first orchard. During 2011-012, the percent leaf infestation was increased with increase in maximum temperature, maximum relative humidity and minimum relative humidity while it was decreased with increase in the minimum temperature, and rainfall. During 2012-013, the percent leaf infestation was decreased with increase in maximum temperature, minimum relative humidity and rainfall and it was increased with increase in minimum temperature and maximum relative humidity.

The population of leaf folder appeared once in a year. The population appeared in the month of August and reached to its maximum in October. During 2011-012, the maximum population was recorded in the East direction and it was minimum in the West direction, North direction and South direction. The population was increased with increase in maximum temperature, maximum relative humidity and minimum relative humidity while it was decreased with increase in minimum temperature and rainfall. During 2012-013, the maximum population was recorded in the East direction West direction and South direction and it was minimum in the North direction. The population was decreased with increase in maximum temperature, minimum relative humidity and rainfall and it was increased with increase in minimum temperature and maximum relative humidity. The population of pest among three orchards was observed significantly different. It was maximum in the second and third orchard and minimum was recorded in the first orchard.

The experiment on incidence of mid rib borer indicated that the incidence of insect pest occurred once in a year. The incidence was started in the month of August and reached to its maximum in October with subsequent reduction in infestation during November. The maximum leaf infestation was recorded in the East direction and it was minimum in the North direction. The percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard and infestation was not recorded in the first orchard. During 2011-012, the percent leaf infestation was increased with increase in maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity while it was decreased with increase in the rainfall. During 2012-013, the percent leaf infestation was decreased with increase in maximum temperature, minimum relative humidity and rainfall and it was increased with increase in minimum temperature and maximum relative humidity.

The population of mid rib borer appeared once in a year. The population appeared in the month of August and reached to its maximum in October. The maximum population was recorded in the East direction and it was minimum in the North direction. The population of pest among three orchards was observed significantly different. It was maximum in the second and third orchard and population was not recorded in the first orchard. During 2011-012, the population was increased with increase in maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity while it was decreased with increase in rainfall. During 2012-013, the population was decreased with increase in maximum temperature, minimum relative humidity and rainfall and it was increased with increase in minimum temperature and maximum relative humidity.

The observations on incidence of beetle indicated that the incidence of insect pest occurred once in a year. The incidence was started in the month of July and reached to its maximum in November followed by reduction in incidence during December. The maximum leaf infestation was recorded in the East direction and it was minimum in the North direction. The percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard and minimum infestation was recorded in the first orchard. During 2011-012, the percent leaf infestation was increased with increase in maximum temperature, maximum relative humidity and minimum relative humidity while it was decreased with increase in the minimum temperature and rainfall. During 2012-013, the percent leaf infestation was decreased with increase in maximum temperature, minimum relative humidity and rainfall and it was increased with increase in minimum temperature and maximum relative humidity.

The population of beetle appeared once in a year. The population appeared in the month of July and reached to its maximum in November. The maximum population was recorded in the East direction and it was minimum in the North direction. The population of pest among three orchards was observed significantly different. It was maximum in the second orchard and minimum population was recorded in the first orchard. During 2011-012, the population was increased with increase in maximum temperature, maximum relative humidity and minimum relative humidity while it was decreased with increase in minimum temperature, and rainfall. During 2012-013, the population was decreased with increase in maximum temperature, minimum relative humidity and rainfall and it was increased with increase in minimum temperature and maximum relative humidity.

The observations on incidence of weevils indicated that the incidence of insect pest occurred once in a year. The incidence was started in the month of February and reached to its maximum in May followed by reduction in incidence during June. The maximum leaf infestation was recorded in the East direction and it was minimum in the North direction. The percent leaf infestation among three orchards was observed significantly different. It was maximum in the second orchard and minimum infestation was recorded in the first orchard. During 2011-012, the percent leaf infestation was increased with increase in minimum temperature while it was decreased with increase in the maximum temperature, maximum relative humidity, minimum relative humidity and rainfall. During 2012-013, the percent leaf infestation was decreased with increase in minimum temperature, maximum relative humidity and rainfall and it was increased with increase in maximum temperature and minimum relative humidity.

The population of weevils appeared once in a year. The population appeared in the month of February and reached to its maximum in May. The maximum population was recorded in the East direction and it was minimum in the North direction. The population of pest among three orchards was observed different. It was maximum in the second orchard and minimum population was recorded in the first orchard. During 2011-012, the population was increased with increase in minimum temperature and maximum relative humidity while it was decreased with increase in maximum temperature, minimum relative humidity and rainfall. During 2012-013, the population was decreased with increase in minimum temperature and maximum relative humidity and it was increased with increase in maximum temperature, minimum relative humidity and rainfall.

5.2 The diversity and relative abundance of insect pollinator species associated with litchi crop

Studies on the diversity of insect pollinators in litchi crop were undertaken at Horticulture Research Centre Patharchatta. To assess the diversity of insect pollinators systematic survey were carried out during the flowering period. Observations were made in two different directions (East & West) on five trees randomly selected in the orchard. In each direction an inflorescence with bloom was observed for three minutes and the population of different pollinators was counted visually.

The observations on relative abundance as well as weather parameters (temperature & relative humidity) were made at four different day hours (0800, 1100, 0200 and 1700) to evaluate the peak activity of pollinators during the day.

The initiation of pollinators visit on litchi flowers started just after opening of flowers in the last week of March. The maximum abundance of *Apis mellifera*, *Apis dorsata*, *Trigona laeviceps* and syrphids was observed in the end of March while the peak abundance of *Coccinella septempunctata* was recorded in the second week of April, during both years.

During whole flowering period, significantly higher population of *Apis mellifera* was observed in East direction than West direction. The population was higher in East direction at all four day hours (0800, 1100, 0200 and 1700) than West direction. In both the directions, the population of pollinator increased with increase in the surrounding temperature and relative humidity of inflorescence.

The population of *Apis dorsata* was significantly higher in East direction than West direction. The population was higher in East direction at the morning day hours (0800 and 1100) and it was higher in West direction at 1400 hours and 1700 hours. In both the directions, the population of pollinator decreased with increase in the surrounding temperature and relative humidity of inflorescence.

The population of syrphids was significantly higher in East direction than West direction. The population was higher in East direction at 0800 hours and as the temperature increases in East direction at 1100 hours the population was higher in West direction. The population of pollinator was lower in West direction at 1400 hours and 1700 hours due to comparatively higher temperature than East direction. During 2011, the population of pollinator decreased with increase in the surrounding temperature and relative humidity of inflorescence while during 2012, the population of pollinator increased with increase in the surrounding temperature and relative humidity of inflorescence.

During 2011, the population of *Trigona laeviceps* was significantly higher in West direction than East direction and during 2012, it was significantly higher in East direction than West direction. The population of pollinator increased with increase in the surrounding relative humidity of inflorescence. During 2011, the population of pollinator decreased with increase in the surrounding temperature of inflorescence and during 2012, the population of pollinator increased with increase in the surrounding temperature of inflorescence.

During 2011, the population of *Coccinella septempunctata* was significantly higher in West direction than East direction and during 2012, it was higher in East direction than West direction. The population was higher in East direction at the morning day hours (0800 and 1100) and it was higher in West direction at 1400 hours and 1700 hours. The population of pollinator decreased with increase in the surrounding relative humidity of inflorescence. During 2011, the population of pollinator increased with increase in the surrounding temperature of inflorescence and during 2012, the population of pollinator decreased with increase in the surrounding temperature of inflorescence.

On the basis of the results summarized above, it can be concluded that the litchi crop has a rich biodiversity of insect fauna including insect-pests and pollinators which affect the production of litchi. The study of preferred direction for leaf infestation by insect pest is helpful in deciding the spraying direction in the tree to avoid excess and wasteful use of pesticides. The study of peak foraging time (day hour) as well as direction is also very important as it is helpful in deciding the spray schedule of different insecticides during flowering period. Thus, efforts for conservation and management of the diversified group of insect pollinators should seriously be made to utilize their potential as crop pollinators. Knowledge of pollinators in terms of their species number, abundance, and potential as pollinators and other biological attributes play an important role to improve the productivity and quality of the crop. Thus, the integrated approach is essential for enhancing fruit production by managing the pest with the use of economical and safer techniques that would also avoid negative impact of pesticides on pollinators and other non target organisms.

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Appendix

Appendix-I

Monthly weather data

Station name : PANTNAGAR | **Longitude** : 79 deg. 30' E

Latitude : 29 deg. N | **Altitude** : 243.84 m. AMSL

Months	Year	Temperature (˚C)		Relative Humidity (%)		Rainfall (mm)
		Maximum	Minimum	0700 hrs	1400 hrs	
April	2011	35.6	18.2	69.8	27.2	1.2
May	2011	35.9	22.5	72.3	41.8	20.0
June	2011	33.7	24.4	81.0	62.8	86.1
July	2011	32.2	25.5	88.6	70.4	156.6
August	2011	32.1	25.3	88.5	71.0	159.7
September	2011	32.0	23.6	90.3	68.8	60.4
October	2011	31.0	17.0	89.8	54.6	0.0
November	2011	26.9	12.3	90.0	52.0	0.0
December	2011	21.4	8.1	93.3	57.5	2.6
January	2012	19.7	6.7	91.2	59.8	5.0
February	2012	24.6	8.2	90.0	39.8	0.2
March	2012	29.6	13.0	88.5	40.5	1.0
April	2012	35.2	18.5	67.8	31.0	1.5
May	2012	39.8	22.3	61.0	24.3	0.0
June	2012	39.9	26.0	63.0	31.3	5.3
July	2012	32.8	26.0	86.4	68.6	93.3
August	2012	32.3	25.5	89.3	72.3	53.0
September	2012	31.7	23.8	89.3	68.0	51.8
October	2012	31.1	15.7	87.4	42.8	0.0
November	2012	26.7	9.4	91.3	37.5	0.0
December	2012	21.2	7.2	91.3	55.8	0.0
January	2013	16.0	5.7	96.6	69.7	0.0
February	2013	22.8	9.8	91.1	56.1	3.0
March	2013	29.0	13.4	89.3	56.7	0.4

VITA

The author of this manuscript Sanjay Kumar Joshi was born on July 02, 1988 at Garagar, Uttarakhand. He passed his High School examination from Government Inter College, Bardakhan and Intermediate examination from Vivekanand Vidya Mandir Inter College, Pithoragarh in the year 2002 and 2004, respectively. He graduated from Government Post Graduate College Pithoragarh in 2007. In the same year, he joined College of Post Graduate Studies of G.B. Pant University of Agri. & Tech., Pantnagar for the degree of Master of Science with major in Entomology. Later he joined the Ph. D. from the same department with major in Entomology and minor in Plant Pathology.

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ABSTRACT

The leaf infestation pattern as well as population dynamics of five different foliage feeders (*Statherotis leucaspis* Meyrick, *Dudua aprobola* Meyrick, *Acrocercops cramerella* Snellen, *Popillia japonica* Newman and Weevils) was observed in litchi crop at Horticulture Research Centre Pattharchatta during 2011-013. The incidence of all insect pests once in a year except in leaf roller where it was twice in a year. The incidence of all the pests was maximum in East direction and minimum incidence was recorded in North direction. The population as well as leaf infestation was minimum in high density orchard (1.0 × 0.5 Metre). Low density orchard (8.0 × 8.0 Metre) was preferred for maximum infestation by all pests. The abiotic factors (Temperature and Relative humidity) had significant impact on pest incidence. Rainfall was a limiting factor for all the insect pests.

The relative abundance of different insect pollinators during the flowering season was found maximum in the end of March in East direction. The maximum abundance of *Apis mellifera* (3.1 and 4.2 foragers/inflorescence/3minute), *Apis dorsata* (1.4 and 0.8 foragers/inflorescence/3minute) and Syrphid flies (10.4 and 0.9 foragers/inflorescence/ 3minute) was recorded at 1100 hours during the year 2011 and 2012 respectively. The maximum abundance of *Trigona laeviceps* Smith and *Coccinella septempunctata* was in the evening hours (1400 and 1700 hours). The surrounding environment of inflorescence had more impact on the relative abundance of pollinators than the open environment of location.

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गौण विषय	: **पादप रोग विज्ञान**		
शोध शीर्षक	: **"*लीची चाइनेन्सिस* सोन. से संबंधित कीटों एवं परागकरताओं की सांख्य गतिकी"**		
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सारांश

उद्यान अनुसंधान केन्द्र, पत्तथर चट्टा में लीची की फसल पर वर्ष 2011–13 के दौरान पांच अलग–अलग पत्ती खाने वाले कीटों (*स्टेथिरोटीस ल्यूकासपिस* मैरिक, *डुडुआ एपरोबोला* मैरिक, *ऐक्रोसरकोप्स क्रेमिरैला* स्नैलेन, *पोपिलिया जेपोनिका* न्यूमैन एवं वीविल्स) के पत्ती खाने के तरीके एवं सांख्य गतिकी का अध्ययन किया गया। सभी कीटों का आक्रमण वर्ष में एक बार पाया गया जबकि पत्ती लपेटक का आक्रमण वर्ष में दो बार पाया गया। सभी कीटों का सर्वाधिक आक्रमण पूर्व दिशा में एवं न्यूनतम आक्रमण उत्तर दिशा में पाया गया। अत्यधिकी सघनता वाले बाग (1×0.5 मीटर) में जीव संख्या एवं आक्रमण न्यून्तम पाया गया। सभी कीटों के द्वारा आक्रमण के लिए न्यून सघनता वाले बाग (8×8 मीटर) को वरीयता दी गयी। कीटों के आक्रमण पर अजैविक कारकों (तापमान एवं नमी) का महत्वपूर्ण असर पाया गया। वर्षा सभी कीटों के आक्रमण के लिए सीमित करने का कारक थी।

पुष्पन अवधि के दौरान विभन्न परागण कीटों की आवागमन गतिविधि मार्च माह के अन्त में पूर्व दिशा में सर्वाधिक पायी गयी। क्रमशः वर्ष 2011 एवं 2012 के दौरान एपिस मैलिफेरा (3.1 एवं 4.2 भ्रमणकारी/पुष्प गुच्छ/3 मिनट), एपिस डौरसाटा (1.4 एवं 0.8 भ्रमणकारी/पुष्प गुच्छ/3 मिनट) एवं शिरफिड (10.4 एवं 0.9 भ्रमणकारी/पुष्प गुच्छ/3 मिनट) की सर्वाधिक आवागमन गतिविधि दिन में 11 बजे पायी गयी। *ट्रिगोना लेबिसेप्स* स्मिथ एवं *कॉक्सिनेला सेप्टमपंकटेटा* की सर्वाधिक आवागमन गतिविधि दोपहर बाद के घंटो (14 तथा 17 बजे) में पायी गयी। जगह के खुले वातावरण की अपेक्षा पुष्प गुछ के निकट चारों ओर के वातावरण का परागकर्ताओं की गतिविधि पर ज्यादा असर पाया गया।

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