BIO-INTENSIVE INTEGRATED PEST MANAGEMENT OF MAJOR INSECT PESTS OF BRINJAL (Solanum melongena Guen.)

BY

Amit Kumar

(J-12-D-153-A)

A Thesis submitted to Faculty of Postgraduate Studies
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IN

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Ph.D

BIO-INTENSIVE INTEGRATED PEST MANAGEMENT OF MAJOR INSECT PESTS OF BRINJAL (Solanum melongena)

Amit Kumar

2017

Certificate – I

This is to certify that the thesis entitled **"Bio-intensive Integrated Pest Management of Major Insect Pests of Brinjal, (*Solanum melongena* Guen.)"**, submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Entomology** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu is a record of bonafide research, carried out by **Mr. Amit Kumar**, Registration Number **J-12-D-153-A** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of thesis investigation have been duly acknowledged.

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Place: Jammu.
Date: 12.1.2017

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Date: 16.1.2017

Certificate – II

We, the members of Advisory Committee of **Mr. Amit Kumar,** Registration No. **J-12-D-153-A,** a candidate for the degree of **Doctor of Philosophy in Entomology** have gone through the manuscript of the thesis entitled **"Bio-intensive Integrated Pest Management of Major Insect Pests of Brinjal, (*Solanum melongena* Guen.)"**, and recommend that it may be submitted by the student in partial fulfillment of the requirements for the degree.

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This is to certify that the thesis entitled **"Bio-intensive Integrated Pest Management of Major Insect Pests of Brinjal, (*Solanum melongena* Guen.)"**, submitted by **Mr. Amit Kumar,** Registration No. **J-12-D-153-A** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, in partial fulfillment of the requirement for the degree of **Doctor of Philosophy in Entomology** was examined and approved by the Advisory Committee and External Examiner(s) on 20/3/2017

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ABSTARCT

Title of the Thesis	:	**BIO-INTENSIVE INTEGRATED PEST MANAGEMENT OF MAJOR INSECT PESTS OF BRINJAL (*Solanum melongena* Guen.)**
Name of Student	:	**Amit Kumar**
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Name of Major Advisor	:	Dr. V. Koul
Year of Award of degree	:	2017
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Study on bio-intensive integrated pest management of major insect pests of brinjal (*Solanum melongena* Guen.) was carried out at Entomological field, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha for two consecutive year during 2014 and 2015.

The studies revealed that the more than 29 insect pests specie were associated with brinjal crop in the Jammu region. Out of fourteen (14) insect pests, five (5) insect pests were categorized as major insect on the basis of economic losses caused in brinjal ecosystem. Apart from insect pest, a large number of natural enemy fauna (12 species of predators and 3 species of parasitoids) were recorded. The observations on seasonal natural fluctuation of Brinjal Shoot and Fruit Borer (BSFB) larval and adult population and Red Spider Mite (RSM) on brinjal were recorded at weekly intervals starting from 15^{th} to 36^{th} standard week during 2014 and 17^{th} to 37^{th} standard weeks during 2015. The two peak of BSFB larval population build-up observed during 24^{th} (14.33 larvae per plant) and 32^{nd} standard weeks (11.66 mean larval population per plant) on brinjal crop during 2014 while in 2015, peak larval number of 14.00 larvae per brinjal plant was recorded during 30^{th} standard week. The two peaks of adult male trap catch population were noticed during 20^{th} (5.33 moths per trap per week) and in 30^{th} (4.66) standard week in pheromone traps and 22^{nd} (22.33 moths per trap per week) and 30^{th} (19.66 moths per trap per week) in wota trap during 2014 which constituted the two overlapping generations of BSFB pest in Jammu region. The trap catches of BFSB (adult) population in pheromone trap during 2015 showed that the peak trap catches of 11.33 moths per trap per week in 30^{th} standard week while, in Wota trap, the peak activity of 19.67 moths per trap per week in 31^{st} standard week. The maximum of 51.81 mean number of red spider mite (RSM), *T. neocalidonicus* per 4 cm^2 on brinjal were recorded in 25^{th} standard week during 2014. Whereas, during 2015, two peaks of adult mite populations were recorded *i.e.*, in 26^{th} SW with 36.02 red mite per $4cm^2$ leaf area and in 35^{th} SW with 24.37 mite per $4cm^2$ leaf area, respectively.

The correlation studies indicated the BSFB (larvae) populations were found positively correlated with relative humidity (morning, evening) and rainfall and negatively correlated with maximum temperature. The overall impact of weather factors on population build up of BSFB larval population was 57.3 per cent 83.8% during 2014 and 2015, respectively. The pooled data on BSFB (adult) populations in pheromone trap catches were observed to be positively correlated with temperature (minimum), relative humidity (morning). Wheareas, in case of wota trap catches, it was recorded to be positively correlated with temperature (minimum). The overall impact of weather factor was found to be 58.0 and 64.3 %. per cent in Wota trap catches during 2014 and 2015, respectively. The correlation studies showed that the adult population of the red mite was recorded to be negatively correlated with relative humidity (morning) and rainfall, and positively

correlated with relative humidity (morning) and rainfall, and positively correlated with temperature (Maximum and Minimum) and overall impact of weather factors on population build up of red mite was recorded to be 42.2 per cent.

Screening of twenty five brinjal varieties against brinjal shoot and fruit borer for resistance response revealed that ten varieties RCMBL-01, PLP-1, IBH-3, IBL-116, Rajindra brinjal, KS-356, JB-24, JBH-8, IBH-02 and CHBR-1were showed tolerant response, five varieties Arka Sree, DRNKU-03-26, JB-6, BCB-464 and JB-64 had found moderately tolerant, eight varieties JB-18, HIC-13311, Ramnagar Giant, MDV-01, Swarn Pratibha, Brinjal Round Green, KS-331 and PBL-24 were susceptible and the two varieties DBR-31and Kashmiri brinjal were found to be highly susceptible. The screening of twenty five commonly grown brinjal varieties against red spider mite during 2015 showed that the three varieties RCMBL-01, Ramnagar Giant, and Swarn Pratibha were recorded as moderately resistant, four varieties CHBR-1, MDV-01, Arka Sree and JB-24 were found as moderately resistant, five varieties, IBH-3, JB-18, Rajindra Brinjal, DBR-31and BCB-464 were found to be susceptible and thirteen varieties PLP-1, KS-331, HIC-13311, IBL-116, PBL-24, Brinjal Round Green, JBH-8, DRNKU-03-26, IBH -02, KS-356, JB-06, JB-64 and Kahmiri Brinjal were recorded as highly susceptible.

Among the three modules tested during 2014, the overall impact of Module-III (4.63) was found to be the best and superior treatment combination than Module-I (5.71) and Module-II (7.98) in suppressing the BSFB larval population. The descending order of performance of modules as: Module-III >Module-I>Module-II. Similar trend was also noticed during 2015 wherein, overall impact of Module-III (5.60) was found to be the best and superior treatment combination, although Module-II was at par with Module-I (6.08) in suppressing the BSFB larval population on shoots. Module-III was found to be superior in obtaining the healthy fruits (47.20 /5 plants) and reduction in infested fruits (17.60 /5 plants) on the basis of number whereas, and on weight basis, 3.60 kg/5 plants healthy fruits and 1.07 kg/5 plants infested fruits were obtained, respectively. Similar findings were also recorded during 2015 in Module-III which was found to be superior in obtaining the healthy fruits on number basis (46.46 /5 plants) and reducing the infested fruits (19.20 /5 plants) and on weight basis (3.22 kg/5 plants healthy fruits) and 0.94 kg/5 plants infested fruits, respectively. The mean population of *T. flavo-orbitalis* was found to be superior in IIIrd module with the highest overall mean population of 4.60 adult/20 infested fruits and maximum parasitisation with 22.99±7.60 per cent during 2014. Similar trend was also recorded during 2015 in IIIrd module with the overall mean population of 5.86 adult/20 infested fruits and percentage parasitization was recorded to be 29.33±6.62.

The perusal of the data during 2014 revealed that all modules were found to be cost effective but the highest yield (250 q/ha) and highest cost benefit ratio (1:2.33) were obtained in case of module-III (BIPM). The module-III was found in giving the highest benefit of Rs. 146850.00 than the Module-I which obtained the benefits of Rs. 75550.00. While during 2015, highest yield was found in case of module-III (BIPM) 230 q/ha with highest cost benefit ratio (1:1.96).

Signature of Major Advisor **Signature of Student**

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HEARTLY

DEDICATED TO

My grand father

Late Munshi Lal

Respected principal

Chapter 1

Introduction

Chapter-1

INTRODUCTION

India has been bestowed with the diverse types of agro-climatic conditions, which encourages and favours a wide range of vegetables crop production. In the recent years, the country has witnessed tremendous changes in both the production and productivity of several vegetable crops which has increased manifold. India has emerged as one of the leading vegetable producers of the world with a total annual production of 162.18 million tonnes with 17.6 MT/ha productivity from an area of 8.99 million hectares (NHB, 2015). Jammu and Kashmir State accounts for 1395.5 MT total vegetable production from 631 ha land with 22.1 MT/ha productivity (NHB, 2015).

Vegetables constitute the most important food next only to cereals and pulses as they are the important source of antioxidants, vitamins, minerals and fibre contributing a significant role in a nutritionally balanced diet of vegetarian population. Due to increasing health consciousness, the demand and consumption pattern of fresh vegetables have increased, but the per capita consumption of vegetables is still much lower (130g/person/day) than the recommended *i.e.*, 300g/person/day.

Among the vegetable crops, Brinjal (*Solanum melongena* Guen.) is an important vegetable crop grown throughout the world and cultivated in all the tropical, sub-tropical and temperate zones. India and Indo-china are considered the centres of origin for eggplant (Vavilov, 1951). Eggplant is well adapted to high rainfall and high temperatures, and is among the few vegetables capable of high yields in hot-wet environments (Hanson *et al*., 2006).

Brinjal is one of the most common and popular vegetable crops grown in India. Presently it is cultivated in approximate 7.11 lakh hectare area with the annual production of 13.56 mt with productivity of 19.1 t/ha (NHB, 2013). In terms of area, West Bengal ranks first and maximum production has been reported from West Bengal followed by Odisha, Andhra Pradesh, Bihar and others in the country. Besides India, it is commonly grown in Bangladesh, Pakistan, China and the Philippines.

Brinjal is highly productive and usually finds its place as the poor man's crop. It is rich source of minerals (calcium, magnesium, phosphorus, sodium, potassium, chlorine, iron etc.), vitamins and also has some medicinal importance (Choudhary, 1967). Eggplant contains nutrients such as dietary fiber, folate, ascorbic acid, vitamin K, niacin, vitamin B6, pantothenic acid, potassium, iron, magnesium, manganese, phosphorus, and copper (USDA, 2009); the nutrients that it contributes to the diets of the poor are especially important during times when other vegetables are in short supply.

Insect pest and disease infestation is one of the major constraints in increasing the yield potential in major vegetable crops such as brinjal, tomato, okra, cucurbitaceous and cole crops (Dhandapani *et al.*, 2003). In Asia, it is the most important and the first ranked pest of India, Pakistan, Sri lanka, Nepal, Bangladesh, Thailand, Philippines, Cambodia, Laos and Vietnam (AVRDC, 1994). The pest is reported from regions of eggplant cultivation in Africa, South of the Sahara and South-East Asia, including China and the Philippines (CABI, 2007). However, in recent years the production of brinjal has been seriously affected due to a steady increase in insect pest infestation, especially the Brinjal Shoot and Fruit Borer (BSFB), *Leucinodes orbaonalis* Guenn. (Pyralidae: Lepidoptera) which reduce the productivity as well as quality of the fruits.

BSFB is practically monophagous but other plants belonging to family Solanaceae are reported to be the hosts of this pest. Due to concealed mode of life, BSFB is the most serious pest of brinjal (Sardana *et al.*, 2004) and hard to control with the repeated application of insecticides. The propensity of BSFB infestation on brinjal crops assumed serious proportions due to monoculture crop production, off season cultivation, summer hybrids and other newly introduced varieties. The yield losses caused by *L. orbonalis* have been estimated up to 70-92 per cent (Islam and Karim, 1991; Dhandapani *et al.*, 2003; Chakraborti and Sarkar, 2011). Further, Shukla (1989) observed that *Leucinodes* causes losses varying between 25 and 45 per cent whereas, Raju *et al.* (2007) reported fruit losses varying from 20.70 to 88.89 per cent and the infestation on shoots was as high as 73.33 per cent during August and reached up to 86.66 per cent in the end of September.

Besides BSFB attack, brinjal crops are susceptible to a large magnitude of insect pests and non insect pest such as Red Spider Mites (*Tetranychus cinnabarinus*) who also pose a great threat to brinjal cultivation inflicting losses ranging from 30 to 40 per cent (Srinivasan, 1993) and in many cases, there is 100 per cent yield loss due to viral diseases vectored by insects (Shivalingswami *et al.*, 2002). During last decade, the red spider mite, *Tetranychus urticae* has emerged as a serious pest of vegetables causing serious economic loss. The outbreak of this pest in our country assumed to be the consequence of frequent and indiscriminate use of toxic chemicals, especially pyrethroid insecticides by the vegetable growers (Dobson *et al*., 2002). Moreover, warm and dry weather is favourable for the multiplication and spread of this pest (Jeppson *et al.,* 1975). In India, it has been reported as one of the important pests of vegetable crops (Gupta, 1985 and Singh *et al.*, 1987) and is known to attack about 150 host plants of economically important species (Zhang, 2003 and Xie *et al*., 2006). *T. urticae* is the most notorious pest responsible for significant yield losses in many economic crops, vegetables, fruits (Salman, 2007) and in ornamental and agronomic crops worldwide (James and Price, 2002). It has a very rapid population growth, short developmental time, high birth rate and long adult survival (Clotuche *et al*., 2011). The mite infests the under surface of the leaves, where it produces profuse webbing and suck chlorophyll contents of the plant which leads to appearance of chlorotic spots, leaf drop and even death (Helle and Sabelis, 1985; Martinez- Ferrer *et al.*, 2006).

To combat the pest problem, it has been observed that farmers applied 12-18 sprays in a cropping season or on almost every alternative day to suppress the pest population where large scale commercial cultivation of brinjal is adopted. Such indiscriminate and excessive use of insecticides leads to development of resistance and elimination of beneficial natural enemies (Simmons and Jackson, 2000) of the pest which in turn accentuated the BSFB and mites problem. Further, the situation becomes more aggravated and alarming due to irrational and persistent use of chemical pesticides in the form of pollution in the agro-ecosystem, disturbance of ecological balance, pest resurgence, secondary pest outbreaks and bio-magnification of residue (Rangam, 1991) in brinjal crop ecosystem.

Keeping in view the present crisis ushered by the unregulated use of pesticides and its alarming effects on the environment, there is a dire need to explore some alternative methods which could be able to sufficiently manage the pest below Economic Injury Level.

The present investigations are aimed to study major insect pest, natural enemy fauna and their management with following objectives:

1. To monitor the occurrence of red mites, Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* and natural enemy fauna in brinjal ecosystem
2. Screening of twenty five (25) brinjal varieties against Red Mites and Brinjal Shoot and Fruit Borer
3. To develop an eco-friendly Integrated Pest management programme for *Leucinodes orbonalis*

Chapter 2

Review of Literature

Chapter-2

REVIEW OF LITERATURE

This chapter deals with the work done in the past emphasizing on the objectives decided for the present investigation. The major thrust has been given to the bio-intensive integrated approach which comprises cultural, physical, mechanical, biological and eco-friendly insecticidal methods for the management of Brinjal Shoot and Fruit Borer (BSFB), *Leucinodes orbonalis*. Efforts were made to cite some important and pertinent references on monitoring the occurrence of red mites, brinjal Shoot and Fruit Borer (BSFB) and their natural enemy fauna in brinjal ecosystem, screening of 25 brinjal varieties against red mites and Brinjal Shoot and Fruit Borer and development eco-friendly Integrated Pest management programme for *Leucinodes orbonalis.*

2.1 Insect pests and natural enemy fauna of brinjal

Vevai (1970) reported 26 insect pests species and few non insect pest species infesting brinjal of which the Brinjal Shoot and Fruit Borer, *L. orbonalis,* whitefly, *Bemisia tabaci* (Genn.); leafhopper, *Amarasca devastans* (Distant); epilachna beetle, *Henosepilachna vigintioctopunctata* (Fab.); aphid, *Aphis gossypii* (Glover.); mealybug, *Centroccocus insolitus* (Guen.); lace wing bug, *Urentius hystricellus* (Richt.) and non insect pest, red spider mite, *Tetranichus macfurlanei* (Andre) cause severe damage, necessitating initiation of control measures quite frequently.

Ho (2000) suggested avoiding spraying of broad-spectrum pesticides as they may kill predators and lead to outbreaks of spider mites on brinjal. Further, he recorded predators of spider mites like *Stethorus* spp., *Oligota* spp., *Anthrocnodax occidentalis* Felt, *Feltiella minuta* Felt, etc. from Taiwan.

Hazarika *et al*. (2001) reported that the Green lacewings (*Mallada basalis* Walker and *Chrysoperla carnea* Stephens) are effective generalist predators of spider mites. They observed that the third instar grub of *C. carnea* could consume 25–30 spider mite adults per day however, it needs supplemental food for their long-term survival.

Singh and Singh (2002) recorded the three parasites *i.e.*, *Trathala flavo-orbitalis*, a dipteran fly and a mermethid nematode as natural enemies of *L. orbonalis*. The parasitization by *Trathala flavo-orbitails* to shoot and fruit borer ranged from 1.59 to 5.79 per cent (average 5.14%) during 1994 with highest parasitization in September, however, during 1995 the parasitization ranged from 2.30 to 6.81 per cent (average 5.56%) with highest in September. The parasitization by unidentified dipteran fly ranged from 1.65 to 2.35 per cent (average 1.94%) during 1994 and from 1.23 to 2.51 per cent (average 1.87%) during 1995. Mermathid nematode parasitized the larvae of shoot and fruit borer to the extent of 9.39 per cent during 1994 and 9.49 per cent during 1995.

Das (2006) recorded twenty seven species of insects and one species of mite besides 23 natural enemies from the brinjal crop ecosystem in Bangladesh. Of these, BSFB, leafhopper and *Epilachna* beetles are considered to be the major / key pests while the rests are minor in importance. The major/key pests are observed almost every year wherever, brinjal is grown and they cause a significant damage to the crop, while the minor pests are observed in small numbers in the field and they do not make any significant damage to the crop. Therefore, it is evident that the brinjal ecosystem has a great diversity of insect and mite pests which is likely to maintain a stable environment in the brinjal ecosystem.

Latif *et al.* (2009) revealed that twenty species of harmful arthropods were found under seventeen families belonging to eight orders and seven families of predators. The Brinjal Shoot and Fruit Borer, aphid, jassid, epilachna beetle and whitefly were observed as common and major insect pest in brinjal ecosystem.

Yasodha and Natarajan (2009) conducted a survey and recorded twelve parasitoids belonging to two super families viz., Ichneumonoidea and Chalcidoidea emerged from field collected *L. orbonalis* larvae. The parasitoids identified were; *Trathala flavoorbitalis* Cameroon, *Phaneratoma* sp. *Chelonus* sp., *Vaepellinae* sp. *Bracon hebetor* Say, *Antrocephalus mitys* Walker, *Brachymeria lasus* Walker, *Spalangia irregularis* Walker, *Spalangia endius* Walker, *Endius* sp. *Spalangia* sp. and *Trichogramma* sp. *Trichogramma* sp. was found to parasitize the field exposed eggs of *L. orbonalis* for six days.

Sankari (2010) observed eight species of spiders *viz., Argiope luzona* (Walckenaer) (Argiopidae), *Cyrtophora cicatrosa* (Doleschall) (Arneidae), C*hrysso argyrodiformis*

(Yaginuma) (Theridiidae), *Hipossa pantherina* (Thorell) (Lycosidae), *Oxyopes lineatipes* (C.L.Koch) (Oxyopidae), *Oxyopes javanus* (Thorell) (Oxyopidae), *Peucetia viridana* (Thorell) (Oxyopidae) and *Lycosa pseudoannulata* (Boescriberg and Strand) (Lycosidae) were recorded in both the plants in two selected areas. The population of spiders did not show significant difference between areas, plants and number of species of spiders. The predatory potency of web building spiders were estimated in the fields against insects found in the crop fields *viz., Camponotus compressus* (black ant), *Occophylla smaragdina* (tree ant), *Apis florae* (honey bee), *Kallima inachus* (butterfly), *Plusia orichalcia* (catterpiller), *Leuanodes orbonalis* (moth), *Aphis gossypii* (cotton aphids), *Bemisia tabaci* (whitefly), *Culex quina* (mosquitoe), *Drosophila melanogaster* (fruitfly), *Musca nebulo* (housefly), *Amritodus alkinsoni* (mango leaf hopper), *Macromia magnifica* (dragonfly) and *Epilachna vigintioctopunctata* (beetle).

Dar *et al.* (2015) investigated the arthropod biodiversity on the brinjal in Kashmir. Total 13 species of plant harmful arthropods belonging to 6 different orders, including 12 species of foliage feeders. The Brinjal Shoot and Fruit Borer (*L. orbonalis*), Epilachna beetle (*Epilachna* sp.), whitefly (*Bemisia tabaci*), jassid (*Amerasca biguttula biguttula*) and aphids were dominant and major insect pests of the brinjal. Coleoptera had higher diversity index of 0.186 followed by ants with diversity index of 0.762. Predaceous arthropods belonged to eight orders, occupied by ten families. Spiders mainly Lycosidae family contributed higher frequency and ranked as second most important arthropods with relative abundance of 0.230 followed by family formicidae

2.2 Seasonal incidence of Brinjal Shoot and Fruit Borer (BSFB) and red spider mites (RSM)

2.2.1 Seasonal incidence of larval population of Brinjal Shoot and Fruit Borer (BSFB)

Mall *et al.* (1992) reported that the infestation of BSFB, *L. orbonalis* on shoots started in the third week of August and assumed a serious proportions during September (76.66 to 93.33%). Fruit infestation was maximum (62.79 %) in the initial stage of fruiting which declined slowly with the advent of winter during December. They further reported that the infestation of the pest on shoots did not seem to be influenced by any of the environmental factors. Though, it was maximum at 28^0C temperature with 80 per cent relative humidity, whereas, infestation of pest on fruits has significant positive correlation with maximum temperature (r = 0.61) and significant negative with morning relative humidity (r = -0.60).

Dhamdhere *et al.* (1995) found that pest commenced from 45 and 55 days after transplanting of brinjal seedlings in summer and kharif season, respectively and continued up to harvest. The infestation in summer and kharif season ranged from 7.56 to 23.55 and 17.24 to 30.87 on shoots and 10.06 to 25.27 and 23.34 to 47.75 per cent fruits number and weight basis, respectively.

Tripathi *et al.* (1996) revealed that highest incidence of the BSFB on shoots was noticed in 46th standard week (8.05 %) and lowest in 31st standard week (0.98 %). The highest fruit damage occurred at low mean temperature of 19.4 °C and 61 per cent relative humidity. The extent of damage on weight basis ranged between 4.03 and 57.01 per cent and followed a similar trend as on number basis.

Kumar *et al.* (1997) observed that infestation of Brinjal Shoot and Fruit Borer was significantly affected by temperature than other environmental factors. The peak shoot (15.71%) and fruit infestation (71.09% by weight) were recorded during the last week of June and first week of July, respectively.

Prasad and Logiswaran (1997) determined the influence of weather factors on the population of insect pests of brinjal. The incidence of shoot damage by *L. orbonalis* revealed significant positive correlation with maximum temperature, relative humidity and rainfall and a negative correlation with minimum temperature.

Tripathy and Senaptati (1998) studied the seasonal incidence of *L. orbonalis* on brinjal in relation to weather parameters. The study indicated that this pest counted for up to 15.71 per cent shoot and 25.38-75.21 per cent and 23.29-71.09 per cent of fruit infestation on number and weight basis, respectively. The peak infestation on shoots (15.71%) and fruits (71.09 by weight) were recorded during the last week of June and the first week of July, respectively. A moderate range of temperature coupled with high humidity was found to be favourable.

Tripathy *et al*. (1998) also reported that the pest remained active throughout the year. The peak infestation of pest on shoots (8.05%) was recorded during 15th-21st November and on fruits 13th-19th December. The mean fruit infestation on the basis of number and weight was 4.45-62.5 per cent and 4.03-57.01 per cent, respectively.

Singh *et al.* (2000) reported that the top shoots of brinjal were infested by *L. orbonalis* in the end of August (73.33 %), which peaked in the third week of September (86.6%). on initiation of the flowering, the pest infestation continuously declined on the shoots and reached to zero level in the end of October, but at critical stage, the pest infestation shifted over to flowers and fruits and reached to peak within a week. There was a positive role of temperature on the multiplication of this pest whereas, relative humidity responded negatively.

Murthy (2001) found that the infestation of *L. orbonalis* in brinjal shoots started in the first week of August and remained up to second week of October, with peak in second week of September in both the years. Infestation in shoots decreased after fruit setting and completely disappeared thereafter. The infestation in fruits was recorded in the second week of September and remained up to third week of October. The infestation increased gradually and reached maximum in the first week of October (63.09% on number basis and 51.45% on weight basis). The infestation of fruit borer started declining and persisted only up to third week of October.

Oommen and Kumar (2004) reported that the infestation of *L. orbonalis* on fruits commenced from the last week of September (10.0 %). The incidence started increasing and reached to the maximum during the third week of October (75.08 %), thereafter, declined. Both the average relative humidity and temperature had a negative association with the fruit infestation.

Bharadiya and Patel (2005) reported that the activity of shoot and fruit borer, *L. orbonalis*, on shoots started in the first week of September (4.9% incidence) and reached the peak level (17.1%) before migrating to fruits by fourth week of October.

Singh *et al.* (2006) reported that the incidence of *L. orbonalis* on brinjal occurred from the second week of September to the second week of October, when 76.66-93.33 per cent plants were found to be infested with an intensity of 1.16-2.90 damaged shoots per plant. Maximum intensity (2.90 shoots per plant) and incidence (93.33% infested shoots) were recorded in the fourth week of September, when average temperature was 28^0C with 75 per cent relative humidity. The infestation on fruits was recorded in the first week of October. Initially the intensity and infestation were high with 1.66 fruit per plant and 66.7 per cent damaged fruits, respectively. The average temperature above 21^0C and relative humidity above 65 per cent were found to be more favourable for the pest multiplication.

The average loss due to shoot and fruit borer on brinjal fruits were calculated as 13.30 per cent.

Mahesh and Men (2007) reported that the incidence of *L. orbonalis* on brinjal commenced from August (21.2%) and reached its first peak during the mid of October (35.3%) with 21.4-33.0 ^{0}C temperature, 45-86 per cent relative humidity, 2.5 mm rainfall and 7 h of sunshine. There was an increase in activity of pest that reached 37.7 per cent during mid of November with 18.3-31.8^{0}C temperature, 49-86 per cent relative humidity, 41 mm rainfall and 8 h of sunshine.

Patial and Mehta (2008) who reported from Palampur (Himachal Pradesh) that during rainy season BSFB reached its peak on 22nd September during the first year of investigation (2003) and during 2004 the pest attained its peak on 11th August.

Naqvi *et al.* (2009) reported that the effect of abiotic factors on *L. orbonalis* revealed that maximum temperature had positive significant effect on fruit infestation; whereas, negative significant correlation was computed between borer infestation and minimum temperature. Relative humidity had positive significant effect on shoot and fruit borer. Rainfall had no effect on shoot and fruit borer infestation.

Varma *et al*. (2009), maximum population of Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* in Allahabad, U.P. was observed in 5th and 2nd week of December during 1st and 2nd year respectively. The Brinjal Shoot and Fruit Borer incidence showed positive correlation with maximum relative humidity, rainfall and wind speed during 1st year and with maximum relative humidity and sunshine hours in 2nd year. The damaged fruit and fruit weight loss varied from 3.76 to 45.45 per cent and 3.00 to 67.71 per cent in 1st year and 5.71 to 44.26 per cent and 3.00 to 51.33 per cent in 2nd year.

Shukla and Khatri (2010) who reported from Kanpur that the adults population of Brinjal Shoot and Fruit Borer *Leucinodes orbonalis* Guenee fluctuated to a great deal not only from year to year but also in different months. Adult increased considerably in the month of October and November and decreased in subsequent weeks of December. The maximum temperature and abundance of moth showed a positive correlation (r = 0.319) during both the years. The correlation coefficient of minimum temperature and moth trapping also came out was positive (r = 0.3893) indicating the minimum temperature plays an important role in building up of moth population.

Singh *et al*. (2011) observed that incidence of shoot and fruit borer was started in the month of April and continued till the end of the June. The peak period of the pest on shoot was recorded in the first week of June (29.45%) and fourth week of May (25.24%) during the first and second cropping seasons respectively. However, the incidence of the pest on fruit was highest during the second week of June, 2003 (67.16%) and third week of June, 2004 (72.25%). The correlation study revealed that average temperature and relative humidity showed significant positive association while average sunshine observed significant negative association with the infestation of the pest on brinjal.

Mathur, *et al*. (2012b) reported that effect of abiotic factors on the seasonal incidence of major insect pests was observed on brinjal crop during rabi 2009. The incidence of leaf hopper (*Amrasca biguttula biguttula*) was maximum during December, 52^{nd} Standard Week (SW) and minimum during March (12^{th} SW). The incidence of white fly (*Bemisia tabaci*) was maximum during January (2^{nd} SW) and lowest in March (12^{th} SW). Both these insects showed significant negative correlation with both maximum and minimum temperature and wind speed while a positive correlation was revealed with mean relative humidity and total rainfall. The incidence of shoot and fruit borer, *Leucinodes orbonalis* Guenee was observed during Nov.– Dec. with peak infestation during Feb. (6^{th} and 7^{th} SW). The per cent shoot damage was positively correlated with both maximum and minimum temperature, rainfall and wind speed while negatively correlated with mean relative humidity. While percent fruit infestation revealed a non significant positive correlation with maximum and minimum temperature, rainfall and wind speed exhibited negative correlation with mean relative humidity. The statistically significant values indicated that occurrence of insect pests population was due to the prevailing ecological conditions. Thus the management of brinjal pest complex during rabi sown brinjal should therefore be promoted and tailored from November onwards using an integrated approach.

Kaur *et al*. (2014) revealed that the larval population was recorded feeding on shoots up to 41^{st} standard week and thereafter these larvae were observed feeding on fruits. Maximum number of larvae *i.e.,* 10 larvae/90 plants were recorded from shoots as well as fruits in the 39^{th} and 40^{th} standard weeks (third and last week of September, 2009). On an average, 7 larvae/90 plants were observed in the 38^{th} standard week (second week of September, 2009) when the average temperature and RH per cent were 28.8 ºC and 72 %, respectively. In the 40^{th} standard week, the larval population increased up to 10 larvae/90 plants when the average temperature was 30.5 ºC and average RH was 56 %. Interestingly, the average population drastically declined after 41^{st} standard week *i.e.,* from 4 larvae/90 plants to 0.5 larvae/ 90 plants in the 47^{th} standard week. However, no larva was observed in 48^{th} standard week.

Nayak *et al.* (2014) observed the first peak of BSFB larval activity (2.5 larvae plant^{-1} week^{-1}) during 32^{nd} SMW (2^{nd} week of August) while the second peak (2.9 larvae plant^{-1} week^{-1}) was noticed during 38^{th} SMW (3^{rd} week of September) in rainy season 2009. However, in 2010, the larval population attained its first highest number (2.4 larvae plant^{-1} week^{-1}) during 33^{rd} SMW (3^{rd} week of August) and the subsequent higher density (2.7 larvae plant^{-1} week^{-1}) was noticed at 40^{th} SMW (first week of October). In winter season, during 2009-10, the larval intensity attained its first peak (2.1 larvae plant^{-1} week^{-1}) during 51^{st} SMW (3^{rd} week of December) and the second peak (2.3 larvae plant^{-1} week^{-1}) was observed during 8^{th} SMW (3^{rd} week of February). In the second year the first peak of larval population (1.9 larvae plant^{-1} week^{1}) was at 49^{th} SMW (first week of December) while the second peak (2.6 larvae plant^{-1} week^{-1}) was attained at 8^{th} SMW (3^{rd} week of February). In Summer season, in 2010, the first peak larval population was observed during 15^{th} SMW (2^{nd} week of April) with significantly higher larval intensity (3.4 larvae plant^{-1} week^{-1}) followed by the second peak (3.2 larvae plant^{-1} week^{-1}) during 20^{th} SMW. However, during 2011, the first peak larval intensity (3.2 larvae plant^{-1} week^{-1}) was attained at 14^{th} SMW (1^{st} week of April) followed by second peak (2.9 larvae plant^{-1} week^{-1}) at 20^{th} SMW (3^{rd} week of May).

2.2.2 Seasonal incidence of adult population of Brinjal Shoot and Fruit Borer (BSFB)

Viraktamath and Kumar (2004) conducted field experiment to evaluate the efficacy of Fine (India) light trap, which emitted bluish light, and ICRISAT-modified light trap, which emitted white light, in monitoring insect pests in agricultural and horticultural ecosystems and reported that both traps were equally efficient in attracting moths of *L. orbonalis.*

Jhala *et al.* (2005) assessed the three types of traps (*viz.,* delta sticky trap, phero-trap and nomate trap) for trapping *L. orbonalis* and reported that nomate trap installed at a height of one metre from the ground level was found to be ideal in catching maximum moths during the cropping season.

Rath and Maity (2005) conducted a field experiments in farmers' fields in Orissa, India during the *summer* and *kharif* season of 2004 with 4 integrated pest management (IPM) components and reported that application of neem (*Azadirachta indica*) oil cake at 100 kg/acre at transplanting, installation of pheromone traps at 25/acre at flower bud initiation stage (45 days old crop), mechanical clipping of infested shoots at weekly interval following spraying of neem oil (Multineem) at 10-12 days interval, significantly reduced the shoot and fruit borer (*Leucinodes orbonalis*) infestation on brinjal (aubergine) cultivars Teishpur local and Desi Bada when compared with the non-IPM plots (farmers practice). This eco-friendly approach increased the yield of marketable fruits and cost:benefit ratio in the IPM plots over the non-IPM plots during both seasons.

Rahman, *et al*. (2009) reported that the efficiency of different traps setting positions varied significantly. Trapping efficiency observed the T1 ensured the minimum shoot and fruit infestation 10.02% and 20.95%, respectively, minimum infested fruit yield (4.75 ton/ha), maximum healthy and total fruit yield (26.72 and 31.47 ton/ha) and the maximum BCR (1.70), which was followed by T2 and T4. The minimum trapping efficiency of T9 treatment led the maximum shoot and fruit infestation 13.89% and 29.26%, respectively, maximum infested fruit yield (7.59 ton/ha), minimum healthy and total fruit yield (17.74 and 25.32 ton/ha) and the minimum BCR (1.00). A correlation between the number of BSFB adults trapped from the most efficient trap setting and the shoot and fruit infestation recorded and found a linear positive correlation between number of BSFB adults trapped and shoot infestation (r = 0.781) and fruit infestation (r = 0.810). The effect of pheromone trap positions observed in this study may be attributed to the easy accessibility of the lures and traps, when they are placed at the canopy.

Cork *et al*. (2001) analysed the female pheromone gland extracts prepared from insects of Indian and Taiwanese origin confirmed (*E*)- 11-hexadecenyl acetate (E11-16:Ac) as the major pheromone component with 0.8 to 2.8% of the related (*E*)-11-hexadecen-1-ol (E11-16:OH), as previously reported from Sri Lanka. The average quantity of E11-16:Ac extracted per female was estimated to be 33 ng, with a range of 18.9 to 46.4 ng when collected 2 to 3 hr into the scotophase. In field trials conducted in India, blends containing between 1 and 10% E11-16:OH caught more male *L. orbonalis* than E11-16:Ac alone. At the 1000 *¹*g dose, on white rubber septa, addition of 1% E11-16:OH to E11-16:Ac was found to be more attractive to male *L. orbonalis* than either 0.1 or 10% E11-16:OH. Trap catch was found to be positively correlated with pheromone release rate, with the highest dose tested, 3000 ^{1}g, on white rubber septa catching more male moths than lower doses. Field and wind tunnel release rate studies confirmed that E11-16:OH released from white rubber septa and polyethylene vials at approximately twice the rate of E11-16:Ac and that the release rate of both compounds was doubled in polyethylene vials compared to white rubber septa. This difference in release rate was reflected in field trials conducted in Bangladesh where polyethylene vial dispensers caught more male moths than either black or white rubber septa, each loaded with the same 100 : 1 blend of E11-16:Ac and E11-16:OH in a 3000 ^{1}g loading.

Srinivasan and Babu (2000) in a field experiment evaluated the synthetic sex pheromone components A (IIZ)-hexadecenyl acetate) and B (IIZ)-hexadecen-1-ol), at 10, 50, 100, 200, 300, 400 and 500 mg alone, or in combination (A:B), at 100:5, 100:10, 100:20, 100:30, 100:50, 100:75, 100:100, 75:100, 50:100, 30:100, 20:100, 10:100, and 5:100 mg, using water trough traps for moth (*L. orbonalis*) attraction and for use in monitoring pest incidence in brinjal and reported that component A at 300 mg resulted in the highest number of moths (86) trapped, while component B showed no attraction at any concentration. Among the A:B combinations, 100:50 mg showed the highest number of moths trapped (33). Cork *et al.* (2001, 2003, 2005) observed that trap catch was positively correlated with pheromone release rate and reported that blends containing between 1 and 10% E 11-16: OH caught more male than E 11-16: Ac alone. They reported that Delta and Wing traps baited with synthetic female sex pheromone of *Leucinodes orbonalis* caught and retained ten times more moths than with either *Spodoptera* or Uni-trap designs. Trap catch was proportional to the radius of sticky disc traps with a range of 5-20 cm radius while discs with 2.5 cm radius caught no moths. Wing traps placed at crop height caught significantly more moths than traps placed 0.5 cm above or below the crop canopy. They also tested locally produced clear plastic water traps (12cm x 14cm x 21cm) for the control of Brinjal Shoot and Fruit Borer *L. orbonalis* and reported that significantly more male moths were caught in traps treated with water containing powdered detergent, light gear oil or insecticide. All water traps tested caught significantly higher number of moths than sticky delta traps with open sides under farmer's field conditions. Trap catches per 100 m^2 were found to increase with increasing number of traps from 3 to 6.

2.2.3 Seasonal incidence of Red Spider Mite (RSM)

Pande and Yadava (1975) reported that the population of *T. cinnabarinus* on brinjal reached peak from May to June in Udaipur. The maximum day temperature and minimum night temperatures were positively correlated with mite population.

Pillai and Palanoswami (1983) worked out on cassava and found that a complex of four species of mite *viz.*, *Eutetranychus orientalis*, *Oligonychus biharensis*, *Tetranychus cinnabarinus* and *T. neocaladonicus* caused significant yield reduction of 17.33 %.

Gupta and Gupta (1985) recorded that *T. cinnabarinus* appeared in severe form during May-middle of July and again during November -December in West Bengal.

Pande and Sharma (1985) observed that the incidence of *T. neocaledonicus* on brinjal at Udaipur was low from October to January. Thereafter with increase in temperature the pest population also showed increasing trend and reached its peak in May. Besides temperatures and relative humidity, plant vigor and availability of more matured leaves also play a significant role in population buildup of mites.

According to Pal *et al.* (1989), *Tetranychus cinnabarinus* reached peak during May-June. Increase in population was directly related with the air temperature while, high humidity (78.42 to 80.93%) and rainfall (164.96 to 551.62 mm) adversely affected the mite population.

Mishra *et al.* (1990) reported that various accessions of brinjal were attacked by *T. cinnabarinus* mites throughout the crop period. Being maximum during May when the mean temperature was 30.45°C. They also found positive correlation between mite population and temperature.

Rai *et al.* (1995) revealed that temperature, relative humidity and wind velocity were positively correlated while, rainfall adversely affected the mite population on brinjal. But, sunshine hours did not show any effect. Joint contribution of abiotic and biotic factors on buildup of phytophagous mite was significant explaining 72 per cent variation by these factors at Ludhiana.

Incidence of *T. macfarlanei* on cotton occurred from October to February and carried over to brinjal and okra from March to June and on some weed plants from July to December in Gujarat (Jose and Shah, 1989). *T. macfarlanei* was abundant during summer season from 45 to 90 days after planting (DAP) of brinjal variety MHB 10 with a peak at 75 DAP (Eswarareddy, 2000).

Roopa (2005) reported that spider mites (*T. macfarlanei*) appeared much earlier on summer crop (45 DAT) as compared to *kharif* and *rabi* in brinjal. The population reached peak twice *i.e.*, on 28th standard week, July 9-15 (14.20 individuals/4 cm^2 leaf) and 46th standard week, November 12-18 (28.73 individuals/4 cm^2 leaf). The population of phytoseiids was low throughout the observation period. The correlation studies on population of *T. macfarlanei* with biotic and abiotic factors were non-significant but the joint contribution of above parameters explained about 34 per cent variation.

Rajkumar *et al*. (2005) observed the mite incidence was maximum during 19th standard week (first week of May) with 9.36 mites per leaf and which was followed by 8.50 mites per leaf during the 18th standard week (last week of April). There was no mite population during 47th (third week of November) to 5th (last week of January) standard weeks due to non-availability of foliage because of pruning of the crop. Population appeared again during 6th standard week and increased as summer progressed. The higher mite population was noticed in March to May which may be due to absence of rain and dry weather. Further, the continuous application of synthetic pyrethroid to suppress bud borer, which must have induced the mite population build up. The population of mite showed an increasing trend from 6th standard week (1st week of February) and increased with the advancement of summer and reaches up to 6.56 mites per leaf and then sudden decrease in mite population in 14th (1st week of April) standard week due to application of acaricides for the control of mite and once again it started increasing as the summer progressed. Only maximum and minimum temperatures recorded positive and significant relationship with mite population, while rainfall, morning and evening relative humidity recorded negative and significant relationship. Among the weather parameters maximum and minimum temperatures influence the mite population to the tune of 60.30 and 34.00 per cent. While the rainfall, morning and evening relative humidity influenced the mite population to tune of 30.64, 27.61, 22.61 per cent, respectively. Maximum temperature was positively correlated and an increase in one degree Celsius increased the mite population by 0.60 percent.

Mandal *et al*. (2006) reported the activity of the red spider mite showed non-significant negative correlation with maximum temperature and positive correlation with minimum temperature. Morning and afternoon relative humidity showed a significant positive association with the activity of mites on the okra. Regression analysis explained 78-85 per cent variability due to meteorological parameters in the population of red spider mite.

Ismail *et al***.** (2007) reported the mean abundance of *T. urticae* was the lowest in summer followed by autumn, winter reaching its peak in spring (DF= 3; P<0.000). On the other hand, mean abundance of *S. gilvifrons* was the highest in spring followed by winter, autumn and was the lowest in the summer (DF= 3; P<0.000). Mean abundance of *S. longicornis* was the highest in summer followed by spring, winter and autumn (DF= 3; P<0.000). No significant correlation was found between numbers of *T. urticae* and *S. gilvifrons* (R= -0.005, P<0.881). While a negative correlation was found between numbers of *T. urticae* and *S. longicornis* (R= -0.069, P<033). On the other hand, positive correlation was found between numbers of the two predators (R= -0.157, P< 0.000). Mean total abundance of TSSM in the absence of its predators was 35.70±1.60, which was significantly higher compared to the presence of *S. gilvifrons* (24.95±2.60; DF= 780; P<0.048), *S. longicornis* (26.19±2.68; DF= 858; P<0.012) and both predators (22.23±3.32; DF= 750; P<0.04). On the other hand, no significant differences were found between mean abundance of TSSM in case of presence of only one or both predators. The presence of *S. gilvifrons*, although mean abundance of TSSM varied according to the life stages of the predator showing 20.64±3.56, 22.09±3.009 & 29.69±3.88 during presence of adult, larval and pupal stages of the predator, respectively, also no significant differences were recorded. In the presence of *S. longicornis*, mean abundance of TSSM significantly varied according to the life stages of the predator showing 23.32±3.02 (DF= 80; P<0.030) & 21.58±3.46 (DF= 124; P<0.042) during presence of adult and larval stages of the predator, respectively).

Anitha and Nandihali (2008) reported that incidence of red spider mite on summer crop okra commenced from 16^{th} standard week (2.12 mites/3leaves) and peak infestation was on 2^{nd} week of May (14.61 mites/3leaves) and on *kharif* crop peaked during 4^{th} week of October (29.25 mites/3 leaves).

Fitzgerald *et. al*. (2008) observed results while studying spatial distribution on different mite species in strawberry plants and reported that *T. urticae* was most abundant on older leaves i.e., lower canopy. This variation in result can be explained by the fact that mite population usually moves from lower canopy towards upper canopy and when food reserve in the lower canopy becomes scanty the population moves towards upper. Correlation between mite infestations with important weather parameters showed that population had non-significant positive correlation with temperature (maximum, minimum and average), maximum relative humidity and weekly total rainfall where as significant positive correlation with minimum and average relative humidity. The population had a non-significant negative correlation with temperature gradient. The mite population showed a tendency to increase with the increase of high temperature and relative humidity.

Prasanna and Prasad (2008) recorded the incidence of the tetranychid mites and their natural enemies (predatory mites and insects) prevailing on brinjal [aubergine] during the rabi and summer months of 2006-07 in selected districts/taluks of northern Karnataka (Dharwad, Belgaum and Uttara Kannada), India. The results clearly signify the importance of Phytoseiids in the natural control of tetranychid mites in brinjal ecosystem.

Chinniah *et al*. (2009) reported that the maximum temperature had significant positive correlation (r = + 0.701) with two spotted spider mite population dynamics whereas, the relative humidity (r = - 0.471) and rainfall (r = - 0.398) had a significant negative correlation with two spotted spider mite population. The minimum temperature, wind velocity and sunshine hours had no significant effect on the population dynamics of two spotted spider mite. In the first season (October 2008 to January 2009), the incidence of two spotted spider mite, *T. urticae* was moderate due to the prevalence of medium temperature and slightly higher relative humidity. The mite population density was 7 to 10 per 2 cm^2 of leaf. From the linear regression equations fit, it could be inferred that an increase in maximum temperature by 1^oC there was a proportionate increase of two spotted spider mite population by 1.184 per cent. Nevertheless for an increase in relative humidity by one per cent there was a decrease in mite population by 0.218 per cent, and for every 1 mm increase in rainfall, the mite population declined by 0.195 per cent. Simple correlation worked out with other abiotic factors *viz.*, minimum temperature, sunshine hours and wind velocity with two spotted spider mite population revealed no significant impact of these three abiotic factors on the population dynamics of spider mite in brinjal ecosystem.

Patil and Nandihalli (2009) reported that spider mites *Tetranychus macfarlanei* Baker and Pritchard on brinjal appeared at 45 days after transplanting and attained its peak in 28^{th} standard week with 14.2 individuals per 4 cm^2 leaf area in summer. Afterwards population declined steadily up to 30^{th} standard week and later it reached a minimum of 1.67 individuals per 4 cm^2 leaf area. The activity of phytoseiids started from 23^{rd} standard week with 0.07 mites per leaf and reached peak of 1.20 mite per leaf on 28^{th} standard week coinciding with peak population of prey mite (14.2 / 4 cm^2 leaf area). On *kharif* crop, spider mites appeared much later than summer crop *i. e*., at 90 days after transplanting (1^{st} week of

November). During rabi, spider mite population attained two peaks on brinjal. The first peak incidence occurred in 46^{th} standard week (November 12-18) with 28.73 individuals per 4 cm^2 leaf area and the second peak, 23.8 individuals per 4 cm^2 leaf area was attained during January 1-7, 2005.

Rachana *et al*. (2009) reported that the high mite population was observed from March first fortnight and this trend continued up to second fortnight of April. The mite incidence was almost same on basal, middle and top leaves (16.59, 14.21, 12.31 per cm^2) during first fortnight of April. During May, the mite number reduced on the top and middle leaves gradually, the trend continued during June-July with subsequent decrease in population on basal leaf. The lower population was recorded from June to February. It was seen that the incidence of *T. neocaledonicus* had significant positive correlation with mean temperature (Y=1.3307 x -31.517, R^2=0.6177), a significant negative correlation with mean relative humidity (Y=0.6289 X +51.27, R^2 =0.1071). A non-significant negative correlation of mite population with rainfall may be due to the scanty rainfall received during the period of study.

Mallik (2010) recorded significant defoliation in tomato plants infested by mites for longer duration (12 or 9 weeks) and under higher mite population (400 mites per plants initially released) during early growth stages. Leaf chlorophyll content in mite infested tomato plants had significantly lower total chlorophyll (1.592, 1.597 mg/g) than other feeding durations at 11^{th} week as compared to 1.04 mg/g after 60 days *T. urticae* feeding on cucumber leaves during present investigation.

Dutta *et al.* (2011) studied the spatial distribution of mites in brinjal plant and reported that mite was most densely populated in the upper canopy (44.24%) followed by middle (30.57%) and lower canopy (25.19%). This variation in result can be explained by the fact that mite population usually moves from lower canopy towards upper canopy when food reserve in the lower canopy becomes scanty.

Mohanasundaram and Sharma (2011) reported the infestation of okra fruit borer was observed during middle of August, whereas, the red spider mite appeared during 1^{st} week of September. Peak incidence of leafhopper (217.00 nymphs/15 leaves), whitefly (28.90/15 leaves), red spider mite (231.10 mites/cm^2) and fruit borer (56. 6%) during last week of August, 1^{st} week of August, 3^{rd} week of September and 3^{rd} week of September, respectively.

Prasad and Singh (2011) studied the qualitative and quantitative composition of phytophagous mites infesting brinjal and revealed that brinjal was infested with six mite pest species, viz. *T. urticae*, *T. macfarlanei*, *T. ludeni*, *Brevipalpus phoenicis*, *Polyphagotarsonemus latus* and *Aceria lycopersici*. Out of these mite species, *T. urticae* appeared as major pest during post-rainy season, as minor pest in rainy season and as mild pest in autumn. *A. lycopersici* infestation was mild to severe pest during spring and extremely severe during summer season. *T. urticae* remained almost absent in presence of heavy incidence of *A. lycopersici* in spring and summer seasons on brinjal. The findings indicated that displacement of *T. urticae* from brinjal by heavy occurrence of *A. lycopersici* on the same host plant indicated the changing scenario of mite pest spectrum on brinjal in the present studies. As such, *T. urticae* remained the major mite pest during post-rainy and autumn and *A. lycopersici* emerged as severe pest during spring and summer season in brinjal agro-ecosystem in the agro-climatic conditions of Varanasi region.

Duttai *at al.* (2012) reported that all the surveyed vegetables except bitter gourd were attacked by the mite with varying levels of infestation. However, the highest mite population per leaf was observed in brinjal (32.27) which was followed by cucumber (16.08) and teasle gourd (7.2). Mites were most densely populated in the lower canopy region in the brinjal plant. Among the tested acaricides, Lakad 1.8 EC (Abamectin) provided the highest (83.4%) reduction of mite population over control, although the other acaricides also gave good control of this pest.

Ghosh (2013) reported the red spider mite was active throughout the growing period with a peak population (6.18 mites/leaf) during 23rd SMW (last week of May) in the pre-*kharif* crop. Highest population (7.56/leaf) was found on the 42nd SMW (first week of October) in the post *kharif* crop. Sudden fall of population was found in last week of June because of heavy rains. The incidence of mite population always remained higher on the upper canopy of the plant. Weekly population counts on mites showed non-significant positive correlation (p=0.05) with temperature, maximum relative humidity, total rainfall and significant positive correlation with minimum and average relative humidity. Eight treatments *viz.,* microbial insecticide (toxin), avermectin (Vertimec 1.9 EC) @ 1.0 ml/ L; botanical insecticide azadirachtin (neemactin 0.15 EC) @ 2.5 ml/L,; botanical extracts, *Spilanthes paniculata* flower extracted in methanol @ 1.0% and 5.0% and mixed formulation like neem and floral extract of *Spilanthes* 5% (@ 2.5 ml and 50 ml/L were evaluated and compared with the ability of Sulphur (Sulfex 80 WP) @ 5g/ L and Fenazaquin (Magister 10EC) @ 2ml/L for the management of the mite pest. Fenazaquin resulted in the best suppression of mite population (79.24 % suppression), closely followed by avermectin (76.40 % suppression). Among bio-pesticides, avermectin and combination of neem with *Spilanthes* gave better results recording more than 70 % suppression. Neem and *Spilanthes* individually did not produce good results but when used as a mixture they recorded better results (70.66 % suppression).

Meena *et al*. (2013) observed the incidence the mite population in January, was very low (1.0 mite/10 cm^2 leaf area). The population gradually increased and peaked to 22.98 mites/10 cm^2 leaf area in the first fortnight of May along with the rise in temperature and sunshine. Then, the population declined to a low level of 3.43 mites/10 cm^2 leaf area in the first fortnight of December. Maximum and minimum temperatures had a significant positive correlation and sunshine had a non-significant positive correlation, whereas relative humidity and rainfall had a non-significant negative correlation with the mite population. Infestation of the two spotted spider mite was more severe in untreated conditions in comparison to the treated ones. The difference was due to various abiotic factors and natural pest infestation occurrence which drastically affected the flower quality and yield. In protected conditions, flower quality and yield were superior than in unprotected conditions *i.e.* number of flower spike/plant (2.92±0.57 spikes), number of flowers/spike (11.78±1.16 flowers), spike length (57.59±7.35 cm), diameter of flower spikes (9.09±1.01 mm), and flower size (6.73±1.16 cm).

Tripathi *et al*. (2013) reported the maximum population of *Tetranychus urticae* in the month of June 1^{st} fortnight (352.50) on okra and *T. ludeni* (308.60) on brinjal when average atmospheric temperature was 35.53, relative humidity 33.0 % and rainfall nil while minimum population of *T. urticae* (7.20) on okra and *T. ludeni* (4.20) on brinjal was recorded in 1^{st} fortnight of March when average atmospheric temperature was 21.7, relative humidity 61.7 % and rainfall 6.40 mm. A positive correlation was found between temperature and mite population and negative with humidity and rainfall.

Singh and Singh (2014) reported positive correlation of the fortnightly population count of *T. neocaledonicus* with maximum temperature (r = +0.161), negative correlation with minimum temperature (r = -0.247), significant negative correlation with morning relative humidity (r= -0.581) and evening relative humidity (r = -0.717). Mite population was significantly negatively correlated with rainfall (r= -0.576).

Kumar *et al*. (2015) reported the population fluctuation of phytophagous mite (*T. urticae*) in okra and its relation with different weather variables during 2010 and 2011 under unprotected conditions at Varanasi region. The results revealed that the mite population commenced from 9^{th} and 10^{th} standard week in 2010 and 2011 respectively. The highest population mites per 2.5 cm^2 leaf area was recorded on 21^{st} standard week (47.75) in 2010 while the maximum population was recorded in 18^{th} standard week (45.99) during 2011. It was found that the mite infestation was heavy during May in both the years. The maximum number of predatory mites was recorded on 15^{th} standard week (11.86) in 2010 while in 2011 population of predatory mite was highest in 18^{th} standard week (15.98). The population of predatory mites, mean temperature, sunshine hours and wind velocity showed a significant positive correlation with the mite pest whereas, a negative correlation was established with relative humidity and rainfall.

Mazid *et al*. (2015) reported the red spider mites as active in the summer season. Highest population of the mite was recorded in 2^{nd} fortnight of June whereas, least number of mites were recorded in December. Mite numbers were considerably low in the winter months. Sudden decline in mite population was observed in July and August with the onset of heavy rainfall. Correlation studies of pest population with weather parameters revealed that there was a significant positive correlation of the population of mites with the increasing temperature and rainfall whereas moderate positive correlation was observed with relative humidity.

Shukla and Radadia (2015) reported the red spider mite population as active throughout the crop season under the polyhouse conditions with the peak activities during first week of April. A significant positive correlation exists between spider mite population and average temperature whereas a significant negative correlation existed between mite population and average relative humidity under polyhouse conditions on carnation.

Veerendra *et al*. (2015) reported the seasonal mean incidence of mites as 13.7 and 14.6 per square inch of leaf in these two villages, respectively, with higher incidence between January to April months. The correlation studies on population of *T. urticae* was significantly and positively correlated with maximum and minimum temperature, whereas negatively correlated with relative humidity and non-significant with rainfall.

2.3 Screening of brinjal varieties/cultivars

2.3.1 Brinjal Shoot and Fruit Borer (BSFB)

Mishra *et al.* (1988) screened 46 brinjal varieties for resistance to *L. orbonalis* and observed that fruit damage ranged from 1.74 per cent in the long fruited variety, Katrain-4 to 53.24 per cent in the round fruited variety, T-3. Leaf colour and phyllotaxy were not related to pest resistance but tightly arranged seeds in mesocarp, thick fruit skin and closely packed vascular bundles in the pulp were possible causes of resistance in long fruited varieties. However, long fruited varieties, S-5 and Pusa Purple Long were susceptible despite having these characteristics.

Dash and Singh (1990) tested the comparative susceptibility of nine aubergine cultivars to *L. orbonalis* and observed that none of the cultivars was free from attack by this pest. Pusa Purple Cluster was the least susceptible variety, with 18.76 per cent of fruit being attacked. The cultivar Muktakeshi had the highest mean number of holes per fruit.

Darekar *et al.* (1991) screened nine varieties of brinjal for resistance to *L. orbonalis*, out of them, PBR-129-5, Arka Kusumakar and wild brinjal were found resistant. Biochemicals, *viz.*, total sugar and free amino acids were found positively correlated with fruit infestation, whereas, polyphenol content was negatively correlated.

Singh *et al*. (1991) studied the effect of morphological characters on the incidence of *L. orbonalis* on different aubergine lines. Out of 150 lines tested, SM17-4, RBR 129-5 and Punjab Barsati were the most resistant and Punjab Chamkila the least resistant to damage by the pyralid. Resistance was attributed to a large number of small sized fruits per plant with shorter inter / intracluster distance, late fruiting and longer fruiting period.

Patil and Ajri (1993) studied the biophysical factors associated with resistance to shoot and fruit borer in brinjal. Out of 17 varieties of brinjal screened for resistance to *L. orbonalis*, PBR-129-5, ARU-2-C and PBR-91-1 were found least susceptible. Days to first bloom, shoot thickness, calyx girth, pedical length, number of holes per infested fruit, number of larvae per fruit and percentage infested plants showed a strong positive correlation with susceptibility to the pests. Number of seeds per fruit, yield per plant and fruit skin thickness exhibited a strong negative correlation with susceptibility.

Grewal and Singh (1995) tested the susceptibility of 12 aubergine cultivars to *L. orbonalis* and observed that the infestation on fruits by the pest was in the range of 27-61 per cent. The cv. SM-17-4, Pusa Purple Cluster and Brinjal Green Long were least susceptible to the pest, have narrow pericarp and oblong fruits with green, purple or light purple colour, in addition to long peripheral seedring and less seedless area.

Sah *et al*. (1995) screened eight brinjal cultivars for their relative susceptibility to *L. orbonalis.* The varieties exhibited varying degree of damage to shoot and fruits, with differences in larval population. MBH had the lowest infestation of shoots (1.66%), while, the highest infestation (2.57%) was observed on Kochbachia (Local). None of the varieties were resistant to fruit infestation, but the lowest infestation on the basis of number (25.29%) was recorded on Kochbachia and on the basis of weight (25.34%) on Anpurna.

Gangopadhyay *et al*. (1996) tested the comparative susceptibility of 27 germplasms and two wild species of brinjal to *L. orbonalis*. The cultivars Arka Kusumakar, Nischintapur, Brinjal Long Green, Altapti Arka Shirish, Manipur, Makra and Chikon long proved relative resistant to the pest, whereas, Green Brinjal Round, Suphal, Gourkaj-1, Brinjal No.-3 and Light Purple Round were highly susceptible. Physical characters of the germplasms indicated that resistance is not conferred by any single character like spininess, shape and size of fruits or arrangement of seeds.

Panda (1999) screened 174 brinjal cultivars for resistance to *L. orbonalis* and reported that none of the brinjal entries was immune to larval attack of shoots and fruits. The early fruiting are more liable to fruit attack by the pest. The leaf hair density and shoots per plant played an important role in restricting shoot damage whereas, tight calyx, long fruits, tightly packed seeds in the mesocarp restricted the fruit damage. The fruit attack was also restricted by low percentage of moisture, nitrogen and potash and high phosphorus content.

Javed *et al*. (2001) reported response of different aubergine cultivars against Brinjal Shoot and Fruit Borer (*L. orbonalis)* was evaluated at National Agriculture Research Centre, Islamabad during 2007-08 and 2008-09. The results reflected different levels of infestation in all cultivars by the pest. Cultivar Neelam showed maximum fruit infestation (58.60 and 48.09%) followed by Black long (47.93 and 33.31%), while minimum was observed in Nirala with 24.75 and 21.57% fruit infestation during 2007-08 and 2008-09, respectively.

Similarly, shoot infestation was found maximum in Neelam (43.15 and 33.75%) followed by Kanha-091 (37.72 and 28.73 %) and Nirala was found to be least attacked by the pest showing 19.27 and 15.81% shoot infestation during 2007-08 and 2008-09, respectively. The correlation of different morphological plant characters with fruit infestation indicated very strong and negative correlation between fruit infestation and leaf trichomes, stem thickness and stem hair density. A negatively significant correlation was found between fruit infestation and plant height (r = – 0.716), crown hair density (r = – 0.672) while the correlations of leaf hair density (r = – 0.623), and leaf area (r = – 0.613), was also significant and negative but not so strong. There was positive correlation with fruit yield (q/acre) and positive and non significant correlation with number of primary branches/plant with r-value 0.661and 0.319, respectively.

Jat and Pareek (2003) studied the biophysical and biochemical factors associated with *L. orbonalis* resistance in the brinjal cultivars and observed that shoots of less susceptible cultivars had more lignified hypodermis with compact vascular bundles and narrow shoot pith. The varieties having narrow pericarp and mesocarp with compact seedrings and closely arranged seeds in mesocarp were less infested to shoot and fruit borer. The biochemical characters, *viz*., total sugar, free amino acids and crude protein were positively correlated with fruit infestation, while, total phenols had negative correlation.

Jat *et al.* (2003) screened 10 aubergine cultivars of brinjal for resistance to *L. orbonalis* and observed lowest infestation on shoots in Arka Kusumakar (3.28%) and on fruits in Arka Kusumakar (18.33%) and SM-10 (20.23%). Neelam Long (30.72%) and Pusa Purple Long (31.60%) were found moderately susceptible. Fruit infestation was highest in Pusa Purple Round (46.51%). Pant Ritruaj and Arka Kusumakar had the highest fruit yield (23.74 and 22.94 t ha^{-1}, respectively). Arka Kusumakar and SM-10 were resistant to shoot and fruit borer.

Senapati (2003) tested the comparative susceptibility of 12 aubergine cultivars to *L. orbonalis* and observed the lowest percentage of shoot infestation in Pusa Purple Long (4.0%), while, the lowest percentage of fruit infestation by weight (16.24%) and number (27.4%) basis were recorded in Hissar shyamal and Milky White. The highest infestation on shoots (11.11%) was recorded in HYK, while, the highest percentage of fruit infestation by weight (45.67%) and number (47.53%) basis was in KB-13. The highest total fruit yield per plant by weight (1.996 kg) and number (40.13 fruits per plant) were recorded for Hissar shyamal followed by Pusa Purple Long (1.64 kg; 21.8 fruits).

Mandal *et al*. (2005) screened 31 brinjal cultivars for resistance to *L. orbonalis* and observed that none of the cultivars was resistant. Only three cultivars *i.e.* BBS 103, BB-112 and Pusa Purple Culuster were moderately resistant, recording 11.28, 12.98 and 13.33 per cent fruit damage on number basis and 12.13, 13.36 and 13.86 per cent on weight basis, respectively. These moderately resistant cultivars produced comparatively high yield of 23.60, 16.19 and 17.51 t ha^{-1}, respectively.

Rajkumar *et al.* (2005) who point out plant species and varieties differ greatly in their levels of susceptibility or resistance to specific pests which is measured in terms of survival, development and reproductive rates. Shorter development time and greater reproduction in the susceptible varieties indicate susceptibility of the variety.

Yadav and Sharma (2005) screened 11 aubergine cultivars for their resistance to *L. orbonalis*. The varieties, brinjal Green Long, selection Puja and Pusa Purple Long were found relatively less susceptible (< 25% infestation); Pusa Hybird-5, Pusa Kranti, Kokila, Pusa Upkar and Aarti were moderately susceptible (25-35% infestation) and Navkiran, Pusa Uttam and Pusa Hybrid-6 were susceptible (> 35% infestation) to the infestation of shoot and fruit borer.

Arvind *et al.* (2007) evaluated 20 cultivars of brinjal against *L. orbonalis* on the basis of per cent shoot and fruit infestation and observed that none of the variety escaped infestation of pest. On the basis of grade index, the local cultivar was tolerant to shoot infestation whereas, Pusa Kranti, compostie-2, Pusa Purple Cluster, Pusa Purple Long, CH-249, GC-7, GC-2, SM-141, BB-60-C, Arka Nidhi, Arka Neelkanth, BR-116 and Arka Keshav had moderate infestation. Pusa Purple Round, CH-309, Nisha Improved, Safal, Kashmiri and Hissar Shyamal were categorized as susceptible. On the basis of per cent infestation of fruits, Pusa Purple Long, Pusa Purple Cluster, GC-7, GC-2, Arka Neel Kanth, Arka Nidhi, Composite-2 and Local were graded as moderately tolerant and cultivars, CH-309, Hissar Shyamal, Nisha Improved and Safal were categorized as highly susceptible.

Shinde (2007) was observed that fruit infestation by *L. orbonalis* on brinjal was positively correlated with total fruit weight, fruit length, calyx length and fruit girth and shoot infestation with total number of shoots and shoot thickness. Fruit infestation was also positively correlated with total sugar, potassium and zinc content and negatively correlated with total phenol, iron, copper, manganese, calcium, ash, curde fibre and silica contents. Whereas, shoot infestation has positive correlation with phosphorus, potassium and zinc contents and negative with iron, copper, manganese, calcium, crude fibre, ash and silica contents.

Ahmad *et al*. (2008) reported the twenty brinjal varieties/lines during the period from October 2007 to May 2008 were identified for their characteristics of susceptibility/resistance against *L. orbonalis* infestation. In case of shoot infestation, the varieties/lines Katabegun WS, and Marich begun S were found to be tolerant while the varieties/lines Amjuri, Borka, Dharola, Deembegun, ISD 006, Kajla, Khatkhatia BAU, Laffa S, Singnath, Thamba and Uttara were found to be moderately tolerant; BL-118, Eye red, Islampuri BADC, Irribegun and Nayantara were found to be susceptible; Bijoy and Kaikka N were found to be highly susceptible. In case of fruit infestation, the varieties/lines Thamba and Katabegun WS were found to be tolerant while the varieties/lines Amjuri, BL-118, ISD 006, Islampuri BADC, Irribegun, Marich begun S, Kajla, Khatkhatia BAU, Laffa S and Singnath were found to be moderately tolerant; Borka, Dharola, Deembegun, Eye red, Kaikka N, Nayantara and Uttara were found to be susceptible and the variety Bijoy was found to be highly susceptible.

Elanchezhyan *et al*. (2008a) screened cultivars/ hybrids/ germplasm of brinjal to major insect pests and their natural enemies. The study revealed that the hybrid, Sweta was the best in reducing the shoot and fruit damage by *L. orbonalis* recording the mean shoot and fruit damage of 8.0 and 8.7 per cent (number basis) and population of spotted leaf beetle, *H. vigintioctopunctata* Fab., ash weevil, *Myllocerus* spp. Guerin, mealybug, *C. insolitus*, aphid, *A. gossypii* Glover, leafhopper, *A. devastans* Ishida and whitefly, *B. tabaci* recording 8.0, 0.0, 6.5, 6.3, 0.0 and 0.0 nos./ three leaves, respectively. The hybrids, Bejo Sheetal and Pusa hybrid-6 recorded high population of coccinellids, syrphids and spiders. The biochemical characters such as total sugars, total chlorophyll and moisture content were positively correlated with shoot damage while total phenols and ash content have negative correlation.

Elanchezhyan *et al*. (2008b) studied the responses of 25 aubergine cultivars to *L. orbonalis*. Sweta and Ravaiya varieties recorded the lowest levels of shoot and fruit damage (1-10%), thus, these cultivars were considerable resistant to *L. orbonalis*. Pusa Purple Cluster and Black Beauty were resistant, whereas, Apsara, Brinjal-925, Kirti, ARBH-555, MEBH-11 and Shubham (02) were moderately resistant (11-20% fruit damage). The tolerant cultivars (21-30% fruit damage) consisted of Annamali, Green Super Usha, MEBH-9 and Vijay ARBH-905, Sarukuvalayapatti Local and Soorakundu Local were susceptible (31-40% fruit damage), whereas, Beejo Sheetal and Pusa hynrid-6 were highly susceptible (> 41%).

Kumawat and Kumawat (2009) studied the varietal susceptibility in brinjal against *L. orbonalis* and found that none of the variety was immune from the infestation of pest. The infestation started in the last week of August and reached to its peak in the fourth week of October and continued upto second week of December. The varieties, Arka Kusumakar (18.74%) and SM-10 (20.78% infestation) were found least susceptible; Neelum Long, Pusa Purple Long, Pusa Kranti, Baingan Ritruraj and Daftari as moderately susceptible, whereas, Unnati (41.24%), Black Round (41.35%) and Pusa Purple Round (47%) as highly susceptible to the infestation of shoot and fruit borer.

Amin *et al*. (2014) screened morphological characteristics of leaves, shoots and fruits of 5 brinjal varieties/lines viz., BL 099, BARI Brinjal-6, BL 117, BL 072 , BARI Brinjal-1 and wild *Solanum torvum* at the experimental farm and laboratories of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the period from September 2004 to April 2005 in a randomized block design with three replications. Higher number of leaves (195.50 plant-1) invites higher shoot and fruit infestation which was found positively correlated (r^2= 0.55). Higher leaf area (63.53cm2/leaf) and leaf trichom (256.7/25 mm2) had lower shoot and fruit infestation which was found negatively correlated (R^2 =0.65). Among the morphological characteristics of shoots viz., number of shoot, daimeter and length of top inter node have a positive correlation (R^2=0.69, 0.85, 0.44) and number of prickles and trichome on shoot have a negative correlation (R^2 =0.22,0.70) with BSFB infestation on brinjal shoot. The morphological characters of fruits like fruit per plant, calyx length, fruit length, diameter, shape and color have significant effect on BSFB infestation. Diameter of fruit, weight of fruit has a positive correlation (R2=0.14, 0.10) and length of fruit (R2=0.36) and calyx (R2=0.79) have a negative effect on BSFB attacking brinjal fruit.

Khan and Singh (2014) reported response of different brinjal genotypes against Brinjal Shoot and Fruit Borer (*L. orbonalis)* was evaluated at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) in kharif (rainy season) 2011- 2012. 192 eggplant entries/accessions and were evaluated for resistance to shoot and fruit borer. Minimum mean infestation in fruits was found in genotype EC305163 (0.0%) and IC090132 (0.0%) while maximum mean infestation in fruits was recorded in IC261792 (100%) and IC420406 (100%). Among 192 genotypes of brinjal tested, two of them EC305163 and IC090132 was found immune to shoot and fruit borer, three genotype namely IC545256, IC433625 and IC264470 found resistance, 21 fairly resistance, 38 tolerant, 52 susceptible and rest 76 genotypes were found highly susceptible to Brinjal Shoot and Fruit Borer.

Devi *et al*. (2015) screened different brinjal genotypes against Brinjal Shoot and Fruit Borer (*L. orbonalis*) at evaluated Indira Gandhi Krishi Viswavidyalaya, Raipur (Chhattisgarh) in Rabi summer season 2013. 18 eggplant entries/accessions which were evaluated for resistance to shoot and fruit borer. Minimum mean infestation in fruits was found in genotype Punjab Sadabahar, 2010/ BRLVAR-3, 2010/BRLVAR-1, 2010/BRLVAR- 4 while maximum mean infestation in fruits was recorded in Swarnamani. The calyx diameter and fruit diameter was significantly positive association with fruit infestation. Greenish purple colour variety was the least preferred by fruit borers with fruit damage of 5.21 per cent and highest fruit damage (28.27%) was noticed on infested fruits in the variety of dark purple with white colour.

Habib *et al.* (2015) screened brinjal genotypes at the New Developmental Farm (NDF) of The University of Agriculture, Peshawar (UAP) in 2014. Three Brinjal genotypes Shamli, pearl long and black beauty were used in the study. Pest infestation started in the first week of May. Overall mean density of *A. gossypii* was non-significantly higher (0.71 individuals leaf-1) on Black Beauty and lower (0.66 *A. gossypii* leaf-1) on Pearl Long. Overall mean density of *A. biguttula biguttula* was non-significantly higher (each 0.47 individuals leaf-1) on Shamli and Black Beauty and lower (0.44 individuals leaf-1) on Pearl Long. Fruit infestation by *L. orbonalis* was significantly lower (35 infested fruits/100) for Shamli and higher (53 infested fruits/100 fruits) for Black Beauty. *L. orbonalis* produced significantly higher number of holes (7.7 holes/fruit/week) on Black Beauty and lower number (2.6 holes/fruit/week) on Shamli. Overall mean yield of the brinjal genotypes was significantly higher for Shamli with 4923.1 kg/ha and lower for Pearl Long with 1230.8 kg/ac. Density of the three pests was comparatively lower on Shamli and its yield was significantly higher than the other two genotypes. Based on the above mentioned results Shamli brinjal genotype is recommended to the growers in Peshawar.

Rameash *et al*. (2015) screened of 52 brinjal (*S. melongena*) genotypes, sourced from different regions of India covering 14 states, to evaluate their reaction to the shoot and fruit borer, *L. orbonalis* Among the genotypes screened, four accessions viz., IC136347, IC127021, IC111077 and IC013332 were identified as resistant by recording a lower (<10 %) fruit damage, while seven genotypes as fairly resistant; 11 as tolerant; 20 as susceptible and 13 as highly susceptible to *L. orbonalis*. The correlation between morphological attributes and the shoot infestation showed that, the plant spread ($r = 0.592$ at $P < 0.01$)and number of primary branches ($r = 0.404$ at $P < 0.01$) had a significant positive correlation with the infestation of shoot and fruit borer. The DIVA-GIS analysis revealed that the germplasm collected from the states of Andhra Pradesh, Haryana, Jharkhand and Tripura were found to be having a higher Shannon diversity index (1.109 - 0.832) and coefficient of variation (35% - 60%) indicating a presence of wider range in sources of resistance for *L. orbonalis* in those regions. Targeted germplasm exploration in the identified areas would provide good sources of resistance in brinjal for *L. orbonalis*.

2.3.2 Red Spider Mite (RSM)

Soans *at el* (1973) screened seven varieties of the eggplant *Solanum melongena* L. against two-spotted spider mite T. urticae. The Sinompiro variety which was observed in the field to be highly resistant to mites did not exhibit a high level of resistance when tested in the laboratory. The Black Beauty and Sinompiro varieties exhibited some resistance to the mites. The Dingras No.1 and No. 3 varieties showed a lower level of resistance than the Black Beauty and Sinompiro varieties.

Parker et al. (1995) reported resistant or moderately resistant cultivars against red spider mite available in the region. For instance, accessions or varieties such as EG058, Pusa Purple Long, Pusa Purple Cluster, Pusa Purple Round, H- 128, H-129, Aushey, Thorn Pendy, Black Pendy, H- 165, H-407, Dorley, PPC-17-4, PVR-195, Shyamla Dhepa, Banaras Long Purple, Arka Kesav, Arka Kusmakar, Punjab Barsati, Punjab Chamkila, Kalyanpur-2 and Gote-2 have been tolerant or resistant.

Munoz *et al*. (2000) Screened and reported the (‘TO-937’) that appeared to resist attack by the two-spotted spider mite (*T. urticae*). *L. pimpinellifolium* is a very close relative of the cultivated tomato (*Lycopersicon esculentum* Mill.) and thereby a potential source of desirable traits that could be introgressed to the crop species. The objective of this study was to investigate the genetics of the resistance present in ‘TO-937’. Resistance to infestation by the spider mite was quantified in 24-plant plots of *L. pimpinellifolium* accessions ‘TO-937’ and ‘PE-10’, *L. pennellii* accession ‘PE-45’, *L. esculentum* cultivars ‘Moneymaker’, ‘Roma’ and ‘Kalohi’ (reported to be partially resistant: Stoner & Stringfellow, 1967), and the interspecific F1 cross, *L. esculentum* ‘Moneymaker’ *L. pimpinellifolium* ‘TO-937’. Only ‘TO-937’, the F1, and ‘PE-45’ were found to be resistant.

Hafiz and Damarany (2006) evaluated the 7 cowpea cultivars on development time, longevity and fecundity of *T. urticae* at 25^0C. Ch-Reds and IT82 D889 had the shorter life cycle of *T. urticae* than the other cultivars. Mites reared on Tvu-21, Pinkeye and IT 82 D889 had the highest fecundity (17.22, 16.22, and 15.75 eggs/female, respectively). The mites reared on Ch-Reds had the shorter life span (16.13 days). Based on the obtained results we concluded that the Tvu-21 and Pinkeye cowpea Cultivars were the most suitable hosts for the tested pests and Six-Weeks and B-Crowder were the least suitable.

Roseleen and Ramaraju (2011) evaluated the okra germplasm and identify the potential sources of two spotted spider mite resistance that can be exploited for the improvement of commercial okra. Based on the mean mite population and damage score six entries out of the 58 entries namely Kasturi bhendi, (R), Dharmapuri local (MR), Parbani Kranti (MR), Pusa Sawani (MR), COBhH1 (MR) and Mahyco 10 (S) with varied levels of resistance were identified.

Atalay and Kumaral (2013) Leaflets from four tomato varieties (Swanson, Super Red, Dante and Alsancak) were assayed with the spider mite to detect the mite’s the egg hatching, development duration, survival, sex rates, intrinsic rate (rm), reproductive rate (Ro), mean generation time (To) and gross reproduction rate (GRR). The study showed that when *T. urticae* fed on different tomato varieties, there is no statistically difference among the total developmental time of the mite, although the differences among varieties were shown in terms of egg hatching and juvenile stages. Whereas, Ro (112,80 and 130,89), To (16,75 and 16,81) and GRR (115,7 and 131,02) of Alsancak and Dante varieties, respectively, were significantly higher than the mite feds on Super Red (Ro =60,4; To = 26,7; GRR = 66,9) and Swanson (Ro =49,4; To = 25,3; GRR = 56,9). The mite population level during 15 days on Alsancak varieties was significantly higher compared with that on other tomato varieties. Thus, the findings indicate a possible susceptible of the Alsancak, which is plant parasitic nematodes resistance variety, against *T. urticae.* Thus, the results indicate that Swanson variety is more resistant to *T. urticae* compared with the other tomato varieties.

Kumar *et al*. (2013) screened twenty one brinjal varieties against spider mite and found that three varieties namely Pechiparai, Pusa - 5, Pusa Purple Cluster as low resistance. The other entries viz., Palur – 2, Arka Kusumakar, Elavambady, MBH-114, Round Beauty Black, Pusa –6, Pusa Kranti, Pusa Anmol fall under the category susceptible. Rest of the varieties were observed under the category of highly susceptible. Hence, there was no variety found properly resistant.

Dutta (2015) screened morphological attributes of tea leaf varieties TV1, TV6 and TV10 to understand their resistance against the red spider mite *Oligonychus coffeae* Nietner which acts as a decap towards the tea economy of India. Varietal studies revealed that TV1 the resistant variety is highly palatable by the mite in comparison to TV6 and TV10. Life parameters of *O. coffeae* viz., fecundity showed significant positive correlation with length of leaf axil (r = 0.71169**) and % leaf area damage (r = 0.83574**). Similarly, hatching of *O. coffeae* also showed significant positive correlation with % leaf area damage (r = 0.69839**).

Keskina and Kumral (2015) screened seven varieties one variety, Beaufort, derived from a cross between the wild tomato *Solanum habrochaites* Knapp & Spooner and the cultivated tomato *Solanum lycopersicum* L., and six cultivated varieties: Beril, Bt-236, Impala, Simena, Troy and Y-67. The study revealed that when *T. urticae* fed on the Beaufort tomato variety, the demographic parameters [rm (0.121), Ro (5.79) and GRR (5.79)] were lower than when the mite fed on the other varieties. Additionally, the mite population level on the Beaufort variety was significantly lower compared with those on other tomato varieties. Moreover, the lowest mite survival rate was observed on the Beaufort variety. The densities of non-glandular (Type V) and glandular trichomes (Types IV, VI) on this variety were significantly higher than on the others. The variety's tolerance to mite damage was also found to be higher compared to other varieties. According to the life table parameters, population levels and rates of damage from *T. urticae*, the tomato variety Y-67 was found to be very susceptible to the mite. Also, the densities of non-glandular (Type V) and glandular (Type VI) trichomes in the susceptible variety were determined to be lower than in the Beaufort and some cultivated varieties. Variety Bt-236 was very similar to Beaufort in terms of the survival rates, damage rates and the density of Type VI glandular trichome on the leaf surface. The damage rate per female mite was highest on Y-67, intermediate on Simena, Troy and Beril, and lowest on the Beaufort, Impala and Bt-236 varieties.

2.4 Management of Brinjal Shoot and Fruit Borer

Temrude *et al.* (1992) evaluated fenvalerate (0.2%), cypermethrin (0.01%), endosulfan (0.05%) and carbaryl (0.02%) alone and at half concentration mixed with neemark (0.05%) and found that mixing of neemark with cypermethrin or fenvalerate gave better control of the pest than did neemark alone.

Chitra *et al.* (1993) evaluated the efficacy of six plant products against *L. orbonalis* and reported that petroleum ether extract (0.1%) of the leaves of *Argemone mexicana* was more effective (76.18% control) than monocrotophos (78.82% control). An extract of *Azadirachta indica* leaves (0.1%) and 0.1% neknool gave 69.55% and 69.02% control, respectively.

Kumar and Babu (1998) evaluated the ovipositional deterrent effects of two commercial neem formulations against *L. orbonalis* and found that Neem Azal-F @1ml/litre was the most effective treatment and the repellency was found to be dose dependent.

Qureshi, (1998) reported that use of *Bacillus thuringiensis* (Bt): in a field experiment in 1995 in Rajasthan, India, treatment with 2 ml/liter of Dipel 8 significantly reduced fruit damage caused by FSB compared with the untreated control (8.78 vs. 12.34%) and produced higher fruit yield than the control (12.07 v/s. 9.98 t/ha).

Sasikala *et al*. (1999) found that neem oil (0.2%) and neem oil (0.1%) + Bt (0.075%) gave higher fruit yield *viz.*, 40.76 and 33.80 kg per plot, respectively compared to control which yielded 17.5 kg per plot.

Jat and Pareek (2001) evaluated the efficacy of eco-friendly insecticides against *L. orbonalis* in aubergine cv. Purple Round. The treatments were endosulfan 35 EC at 0.07%, malathion 50 EC at 0.05%, carbaryl 50 WP at 0.2%, neemgold 0.15 EC at 1.21 l/ha, nimbecidine 0.03 EC at 1.5l/ha, *Bacillua thuringiensis* (Bt) at 0.02%, Bt + endosulfan (0.012 +0.035%), Bt + carbaryl (0.012 + 0.10%), cypermethrin 25 EC at 0.007% and control. Nimbecidine was the least effective while all other treatments provided better control of the pest.

Krishna *et al.* (2002) reported that phorate application at transplanting followed by foliar spray of *Bt kurstaki* + carbaryl reduced the shoot infestation ranging from 6.71 to

9.365. The application of 500g *Bacillus thuringiensis* var. *kurstaki* (Btk)/ha + 126g monocrotophos /ha recorded minimum shoot borer infestation with a maximum yield of 169.10 q/ha with highest cost-benefit ratio (1:9.95) among different insecticide mixtures and natural enemies (Naitam and Mali, 2001).

Puranik *et al.* (2002) showed that five sprays of Dipel (Bt *kurstaki*) 8L at 0.2% at 10 day intervals resulted in minimum shoot (9.56%) as well as fruit (11.78%) infestation and maximum yield of marketable fruits (196.96 Q/ha) in brinjal crop. Dipel (Bt *kurstaki*) was proved to be the most effective treatment and was at par with Delfin WG, Halt WP and Biolep WP all at 0.2% concentrations and were superior to cypermethrin and endosulfan.

Mote and Shivu (2003) evaluated the efficacy of *B. thuringiensis* (0.04%) and *T. chilonis* (60,000/ha) and insecticides azadirachtin (0.0006%), lufenuron (0.005%), avermectin (0.0004%), monocrotophos 36 SL (0.05%), deltamethrin + triazophos (0.05%), beta-cyfluthrin 12.5+chlorpyrifos 250 (0.05%) and cypermethrin 5+chlorpyrifos 50 (0.05%) against pest complex of brinjal and reported that Bt was highly effective against the fruit borer (*L. orbonalis*) and increased fruit yield.

Singh (2003) evaluated the combination of insecticides and plant extracts, *viz*., neem cake (20 q ha^{-1}), karanj cake (20 q ha^{-1}), neem oil (3%) and karanj oil (3%) against *L. orbonalis* on brinjal. The foliar application of quinolphos 20 EC with basal application of neem cake reduced the incidence of borer and increased the yield of brinjal. The incidence and yield recorded in basal application of neem cake with foliar spray of neem oil was at par with combination of conventional insecticides. From environmental pollution point of view, neem products alone or in combination with conventional insecticide were advocated.

Kaur (2004) evaluated the efficacy of IPM modules against, *L. orbonalis* on brinjal cv. Punjab Barsati. The treatments were composed of single or combined application of NSKE, profenofos and cypermethrin. Twice application of NSKE and profenofos + cypermethrin resulted in the lowest fruit damage (23.88%). Application of NSKE in combination with two applications of profenofos and cypermethrin resulted in the highest total marketable yield (250 qha^{-1}), whereas, single application of profenofos resulted in the highest total fruit yield (388 qha^{-1}).

Bajpai *et al.* (2005) studied on the development of IPM modules for *L. orbonalis* on brinjal and recorded the lowest infestation (9.8 %) with highest fruit yield (288 qha^{-1}) in (M_8) when recommended plant spacing, potassic fertilizers, destruction of infested plant parts and insecticides at 15 day interval was utilized. The use of insecticides after the destruction of infested plant parts (M_3) was found superior over other remaining modules giving 16.19 per cent fruit damage and 251 q ha^{-1} fruit yield. Potassic fertilizers with insecticides (M_7) giving 20.4 per cent damage and 226 q ha^{-1} fruit yield was also found effective.

Satpathy *et al.* (2005) reported that *Trichogramma chilonis* + endosulfan and *T. chilonis* +NSKE (4%)+shoot clipping recorded less fruit infestation (58 and 60%, respectively) compared to control (84.32%). During harvest at 50 and 140 days after transplanting, the average fruit damage in *T. chilonis* + endosulfan, T. *chilonis* + NSKE (4%) + shoot clipping and control was 46.34, 45.15 and 59.47 per cent, respectively.

Rath and Dash (2005) evaluated the non chemical IPM modules against *L. orbonalis* on brinjal and observed lower infestation in IPM plots (1.83 and 1.79% during the summer and *kharif* season) than in non-IPM plots (12.67and 9.52%). Fruit infestation on number basis was also lower in IPM plots (13.07 and 6.56%) than in non-IPM plots (43.34 and 27.30%). The IPM system also resulted in high average yield (12.20 and 13.10 t ha^{-1}) and cost benefit ratio (1:1.81 and 1:2.95) than the conventional system with fruit yield of 13.10 and 11.37 t ha^{-1} and cost benefit ratio of 1:1.03 and 1:1.80, respectively during the summer and *kharif* season.

Alam *et al*. (2006) reported that weekly releases of egg parasitoid, *T. chilonis* @ 1g parasitized eggs/ha/week and larval parasitoid, *Bracon habetor* Say @ 800-1000 adults/ha/week could be decrease the population of Brinjal Shoot and Fruit Borer.

Srinivasan (2008) highlighted about the different strategies like resistant cultivars, sex pheromone, cultural, mechanical and biological control methods in integrated pest management (IPM) programme in controlling the eggplant fruit and shoot borer (BFSB) via pilot project demonstrations in selected areas of Bangladesh and India. Eggplant accessions EG058, BL009, ISD006 and a commercial hybrid, Turbo possess appreciable levels of resistance to EFSB. Use of BFSB sex pheromone traps based on (E)-11-hexadecenyl acetate and (E)-11-hexadecen-1-ol to continuously trap the adult males significantly reduced the pest damage on eggplant in South Asia. In addition, prompt destruction of pest damaged eggplant shoots and fruits at regular intervals, and withholding of pesticide use to allow proliferation of local natural enemies especially the parasitoid, *Trathala flavo-orbitalis* reduced the BFSB population. The profit margins and production area significantly increased whereas pesticide use and labour requirement decreased for those farmers who adopted this IPM technology.

Gautam *et al.* (2008) reported that the insecticides endosulfan, malathion and quinalphos proved to be the most effective in reducing shoot infestation on brinjal by 90, 87.6 and 80 per cent, respectively. Among botanicals, Neemarin and Achook were significantly at par and reduced 78.8 and 77.6 per cent shoot infestation, respectively followed by Bioneem (69.6%), in reducing shoot infestation over control. Biopesticides, Dipel and Diolep registered 60.8 and 59.6 per cent reduction in shoot infestation, respectively. The maximum fruit yield (21.7 t ha^{-1}) was obtained in endosulfan treated plot followed by malathion (19.2 ha^{-1}) and quinalphos (17.7 t ha^{-1}).

Adiroubane and Raghuraman (2008) laid out an experiment with nine treatments such as *Pongamia pinnata* (L) (PPO) (2%), *Madhuca indica* (J.F.Gonel) oil (MIO) (2%), PPO +MIO in 1:1 (2%), oxymatrine 1.2 EC (0.2%) (M/S. Jasmine Biological Pvt. Ltd., Hyderabad), spinosad 45 SC (225 g.a.i. ha-1), acephate 75 SP (750 g.a.i. ha-1), carbaryl 50 WP + wettable sulphur 50 WP (1:1), neem seed kernel extract (NSKE 5%) along with untreated check in a Randomized Block Design (RBD) and three replications during 2005 and 2006 and recorded the borer infestation on shoot and fruits (number basis) on randomly selected five plants from each treatment per plot. Oxymatrine (1.2 EC @ 0.2 per cent) and spinosad (45 SC @ 225 g a.i. ha^{-1}) were found to be effective against Brinjal Shoot and Fruit Borer, *L. orbonalis*. Oxymatrine was effective at early vegetative stage. Highest per cent reduction of shoot damage was observed in oxymatrine and it is on par with spinosad. Spinosad was effective at fruiting stage. Maximum per cent reduction of fruit damage was recorded in spinosad and it was on par with oxymatrine.

Chatterjee (2009) formulated a realistic sustainable management module for Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis*) at four villages near Sriniketan. The module with three components i.e. pheromone trap, timely mechanical control and application of azadex (neem based insecticides) was found most effective in reduction of shoot damage (76.59%) followed by the farmer's practice (*i.e.* twenty times application of insecticides) (76.36%). Whereas highest protection in fruit damage (48.26%) and yield increment (53.19%) were obtained from the practices of setting trap+timely mechanical control and trap+application of azadex, respectively. The module having all three components was found next best, which provided 45.91 per cent less fruit damage coupled with 52.29 per cent more production. Moreover, setting of only pheromone trap @ 75 numbers per hectare gave quite substantial protection in shoot damage (58.35%), fruit damage (33.73%) and yield (28.67%) while simultaneous use of trap+azadex afforded 71.72 and 39.06 per cent protection against shoot and fruit damage, respectively.

Ghatak *et al*. (2009) assessed the bio-efficacy of two indigenous plant products *viz*., seed extracts of *Annona squamosa* (Annonaceae) and *Strychnos nuxvomica* (Loganeaceae) using methanol as solvent and an entomopathogenic fungus, *Verticillium lecanii*, in controlling Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* of brinjal. Both the botanicals were used at 2.0 ml, 3.0 ml and 4.0 ml lit^{-1} of water, while for *V. lecanii*, these were 1.5 g, 2.0 g and 3.0 g lit^{-1} of water. Besides untreated control, emamectin benzoate 5% SG was used at 0.22 g, 0.28 g and 0.56 g lit^{-1} of water, for comparison. The results indicated a reduction in fruit damage in the range of 71.98% to 76.94%, 65.99% to 66.79% and 58.67% to 66.79% respectively, over control, in treatments with *A. squamosa, S. nuxvomica* and *V. lecanii,* while in case of emamectin benzoate, it was 69.93% to 73.04%.

Dutta *et al*. (2011) observed that the module with three different component, *viz*., pheromone trap, mechanical control and application of peak neem (neem based insecticide) was found best in reduction of shoot damage (86.69%), fruit damage (59.36%) and yield increment (96.94%). This was followed by Pheromone trap+Peak neem in terms of shoot damage (79.24%), Farmers practices in terms of fruit damage (54.13%) and Pheromone trap+Peak neem in terms of yield increment (68.64%). Installation of pheromone trap at 65 number per hactare, starting from 15 after transplanting till final harvest and changing the lure at monthly interval gave quite substantial protection in shoot damage (58.39%), fruit damage (38.17%) and increase in yield (49.71%) over control. While simultaneous application of Trap and peak neem afforded 79.24% and 47.70 per cent protection against shoot and fruit damage respectively. Comparative efficacy of different treatment where trap was used showed that the pooled data on the male moth catches over time revealed that lure used in the present study was effective with a recorded 53.56 numbers of moth catches per trap in the module of Mechanical removal of infested fruits and shoots + Pheromone trap + peak neem. A total of 46.92, 26.47 and 20.99 moth was captured in the module Pheromone trap+Peak neem, installation of pheromone trap and mechanical removal of infested fruits and shoots + pheromone trap respectively.

Kumar *et al*. (2012) evaluated the potential two botanicals viz; ozoneem and neem seed kernel extract (NSKE) and three chemical insecticides viz; imidacloprid, alphamathrin, chlorpyriphos 50% EC+cypermethrin 5% EC against *Leucinodes orbonalis*. Botanicals were tested alone and in combination with cultural practices. On the basis of the pooled means, the results revealed that three sprays of chlorpyriphos+cypermethrin @ 0.01% active substance (a.s.) in 15 days intervals was found to be the most economical, resulting in minimum shoot (2.15%) and fruit (12.95%) infestation respectively, followed by alphamathrin @ 0.01% a.s. with a highest marketable yield of 87.77 q/ha. Maximum marketable yield was received from the treatment with alphamathrin, but due to high costs involved in the use of this chemical, it took second place. Three sprays of NSKE @ 5 ml/lt. recorded a maximum of shoot (3.91%) and fruit (24.49%) infestation, respectively. It is therefore, suggested that the combination of chlorpyriphos 50% EC+cypermethrin 5% EC, being the most effective and economically viable insecticide, can be utilized as a valuable chemical component in Integrated Pest Management to manage the *L. orbonalis* in eggplant crop.

Mathur *et al*. (2012a) evaluated different IPM modules for the management of *Leucinodes orbonalis*. Local brinjal cultivars of semi arid region of Rajasthan like Pusa purple long-74 and Navkiran were found to be promising varieties with low shoot and fruit infestation. Newer botanical oils of Pungam (*Pongamia pinnata* L.) and Iluppai (*Madhuca indica*) in IPM modules proved to be quite effective in lowering both shoot and fruit infestation and can thus be utilized in resistance management strategy. In addition, use of female sex pheromone for BSFB resulted in significant number of moth traps. Thus the efforts to expand the use of IPM technology can be beneficial in holistic manner. The current scenario of *Bt* brinjal can have a great scope if incorporated as part of IPM technology.

Mainali *et al*. (2013) observed that fruit infestation per cent on number and weight basis was the lowest in abamectin treated plots (17.42 and 16.13) followed by cypermethrin (29.13 and 27.80), *Bt*k (31.26 and 29.17), nimbecidine (35.66 and 33.79), anosom (42.22 and 39.66), CFE (62.94 and 60.02) and untreated check (75.84 and 73.58), respectively. The highest marketable fruit yield (28.75 mt/ha) was obtained in abamectin treated plots followed by cypermethrin (23.91 mt/ha), *Bt*k (22.10 mt/ha), nimbecidine (21.19 mt/ha), anosom (18.59 mt/ha), CFE (12.23 mt/ha) and untreated check (7.67 mt/ha), respectively.

The marketable yield increment over untreated control was the highest in Abamectin (275%) followed by cypermetrhirn (212%), Btk (188%), nimbecidine (176%), anosom (142%), CFE (59%), respectively. Similarly, the highest yield loss reduced by the use of abamectin (74%), Btk (60%), cypermethrin (58%), nimbecidine (50%), anosom (43%), CFE (16%) respectively. From this study, it was concluded that Abamectin and *Bt*k is the most viable bio-rational options for *L. orbonalis* management.

Ghosh and Chakraborty (2014) reported the control of Brinjal Shoot and Fruit Borer pest by using chemical insecticides that could lead to human health hazards arising from toxic residues in the fruit. One botanical insecticide azadirachtin *i.e.*, neem (neemactin 0.15 EC) @ 2.5 ml/L, and four botanical extracts, tulsi (*Ocimum tenuiflorum*) leaf extract @ 5.0%, *Polygonum hydropiper* floral part extract @ 10.0%, *Pongamia pinnata* fruit extracts @ 10.0%, and garlic (*Allium sativum*) extract @ 5.0%, and one treatment containing mixture of neem and dicofol (@ 2.5 ml + 1 ml/L were evaluated and compared with the ability of Dicofol, a chemical insecticide (Kelthane 18.50 EC) @ 3ml/ L to control the mite pest, *Tetranychus sp.*. Dicofol treatment resulted in the best suppression of mite population (83.16 % suppression), closely followed by mixed formulation of botanical pesticide, azadirachtin and chemical pesticide, dicofol (71.41 % suppression). However, among the bio-pesticides including plant extracts *Polygonum* flower extract (at 10 % concentration) was the most effective providing moderate to higher control (51.04 % suppression). Neem individually did not produce good results (moderate mite suppression) but when used as a mixture with lower dose (1 ml/L) of chemical insecticide, dicofol provided better results recording more than 70 % suppression.

Kumar and Raghuraman (2014) reported that the strategy of IPM for the control of Brinjal Shoot and Fruit Borer (*L. orbonalis*) consists of resistant cultivar, sex pheromone, cultural, mechanical and biological control methods. Brinjal cultivars such as Krishna, Pusa anmol, Pusa purple cluster, Navkiran and Pusa purple long-74 possess appreciable levels of resistance to *L. orbonalis*. For the control of *L. orbonalis*, the use of sex pheromone traps based on (E)-11-hexadecenyl acetate and (E)-11-hexadecen-1-ol to continuously trap the adult males significantly reduced the pest damage on brinjal. In addition, prompt destruction of pest damaged brinjal shoots and fruits at regular intervals and withholding of pesticide use to allow proliferation of local natural enemies especially the parasitoid, *Trathala flavoorbitalis* reduced the *L. orbonalis* population. The IPM strategy was profit margins and production area significantly increased whereas, pesticide use and labour requirement decreased for those farmers, who adopted this IPM technology. The effort also made to expand the *L. orbonalis* management with the help of production and management practices such as the remove the infected parts.

Mamun *et al*. (2014) evaluated the bioefficacy of spinosad and pheromone trap (Jhilik) alone or their combined effects against BSFB infestation. The spraying of spinosad (Libsen 45 SC) in combination with pheromone trap found to be the most effective treatment to reduce shoot (1.16%) and fruit damage (5.95%) in comparison with that in the water-treated control (shoot damage; 26.37% while fruit damage 46.35% respectively). On the other hand, pheromone trap was much effective than spinosad when these treatments were applied individually. Moreover, the loss of brinjal was significantly reduced when the plots were treated with spinosad (24.14%) or pheromone (18.42%) compared to the untreated plot (60%) while minimum loss (7.81%) was estimated in the treatment with spinosad + pheromone trap.

Elanchezhyan and Baskaran (2008) conducted a field experiments during July-December 2006 in Tamil Nadu, India and observed that IPM based module consisting of brinjal [aubergine] (PKM 1)+cluster bean (4:1)+six releases of *Trichogramma chilonis* at 2.5 cc/acre on 15, 22, 29, 36 43 and 50 days after transplanting (DAT)+two releases of *Chrysoperla* eggs (20 000 eggs/acre) on 60 and 70 DAT+yellow sticky trap at 25/acre+*Leucinodes orbonalis* pheromone trap at 5/acre (intercropping system based module I) was found to be the best in managing major pests (*L. orbonalis*) of brinjal.

Samota et al. (2014) studied the different IPM modules against shoot and fruit borer, *L. orbonalis* on brinjai crop during 2009-10 at Jaipur and revealed that the module-3 comprising of neem cake+clipping of affected shoots+Btk was found most effective against *L. orbonalis* however, next to standard check endosulfan and both were found statistically at par in their efficacy. The next most effective modules were M-2 (neem cake+clipping of affected shoots+neem gold) and M-1 (neem cake+clipping of affected shoots+NSKE). The other treatments viz., application of neem gold and NSKE were found moderately effective however, neem cake and clipping of affected shoots were found least effective against the pest.

2.6 Economics of different IPM modules for management of BSFB in brinjal

Islam *et al*. (2004) evaluated the pest management practices against the Brinjal Shoot and Fruit Borer, *L. orbonalis* infesting aubergine. They observed that fenvalerate (0.02%) was the best treatment followed by carbofuran 3 G at 0.5 kg ai ha^{-1}, removal and destruction of infested plant parts, neem oil (0.2%) conc., neem leaf extract at 1:1 ratio and Dipel (0.15%). The highest healthy yield of 320 q ha^{-1} was obtained in the plot treated with fenvalerate. The treatment fenvalerate gave the highest B:C ratio of 1:16.41 followed by the removal and destruction of infested plant parts (1:5.66).

Chiranjeevi *et al*. (2005) reported spraying of 0.005 per cent cypermethrin or 0.1 per cent profenofos or alternate spraying of NSKE–profenofos–cypermethrin starting from flower initiation stage at 15 days interval along with the adoption of IPM module was effective in management of Brinjal Shoot and Fruit Borer. Highest yield of 213.87 q/ha, 208.25 q/ha and 203. 98 q/ha were recorded with the lowest incidence of shoot borer (5.46, 5.40 and 5.83%) and fruit borer (17.16, 16.87 and 17.72%) with spraying of cypermethrin, profenofos or alternate spraying of NSKE–profenofos–cypermethrin along with IPM module, respectively. The highest C:B ratio (1.96) was recorded with cypermethrin along with IPM module followed by profenofos (1.91) and a CB ratio of 1.87 was obtained with alternate sprays of NSKE–profenofos and cypermethrin. Maximum incidence of fruit borer (20.77%) and shoot borer (14.80%) was recorded with the treatment where stem application was done with imidacloprid @ 1 ml/lit of water, showing the inefficacy of the treatment in management of the pest.

Singh *et al.* (2008) evaluated the IPM tools against shoot and fruit borer on brinjal and reported that neem based product such as neem kernel solution, neem oil, multineem and neem cake were ineffective against the pest. Mass trapping + Neem oil spray + shoot clipping gave significantly higher protection over untreated plots. The most effective treatment was cypermethrin @ 30 g a.i. ha^{-1} against the pest, which was found superior to any of the tools. Chemical treatment recorded highest protected yield and cost benefit ratio (1:5.3). Mass trapping supplemented with neem spray and clipping was second in order to fetch higher protected yield and cost benefit ratio (1:4) than other less effective treatment.

Suradkar *et al*. (2008) evaluated the different integrated pest management (IPM) modules with one insecticidal schedule against Brinjal Shoot and Fruit Borer, *L. orbonalis*, in Akola, Maharashtra, India. Spinosad + *Metazhizium anisopliae* + chelating agent + cartap hydrochloride module was the most effective in reducing shoot infestation (7.47%), number of fruit damage (25.59%) and damage to fruits on weight basis (25.83%), and in giving maximum yield (81.82 q/ha) and benefit:cost ratio.

Mandal *et al*. (2009) evaluated suitable integrated pest management (IPM) modules against the Brinjal Shoot and Fruit Borer (BSFB) in farmers' fields at Birauli, Samastipur, Bihar. The modules consisted of use of pheromone traps along with clipping of infested shoots, removal of infested fruits at each harvest and sprays of biorational insecticides, like spinosad (Success 45EC; 0.4 ml/L) and azadirachtin 0.15% (Rakshak; 2 ml/L) in different combinations. These modules were compared with the farmers' practice of alternate sprays of endosulfan (Thiodan 35EC; 2 ml/L) and dimethoate (Rogor 30EC; 2 ml/L), 3-4 times per week, and an untreated control. The results revealed that the mean shoot and fruit damage was the lowest in IPM module in which spinosad spray was followed by azadirachtin spray along with clipping of infested shoots and removal of infested fruits at each harvesting, resulting in the highest yield of marketable fruits (160.24 q/ha). The cost-benefit analysis also showed the highest C:B ratio of 1:10.14, which in other modules varied between 1:7.12 and 1:8.55. In contrast, in farmers' practice the increase in yield over control as a result of insecticidal sprays was not commensurate with the cost of treatment, and therefore, resulted in monetary loss.

Nagesh *et al*. (2009) conducted a field study and developed the cost effective IPM modules for the management of Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* Linnaeus at Regional Agricultural Research Station, Lam, Guntur (Andhra Pradesh) during 2006-08. The IPM module with integrated plant protection components like application of FYM, neem cake, seedling dip with imidacloprid before transplanting, maize as border crop, monitoring through pheromone traps, mechanical destruction of damaged shoots and fruits and need based application of insecticides proved to be the best module in managing *L. orbonalis* and also resulted in low shoot and fruit damage, higher marketable fruits with high C:B ratio compared with BIPM and farmers' practice modules.

Rahman *et al*. (2009) portrayed that the all combined treatments, T1 comprised spraying of Marshal® at 2 days interval, mechanical control and using pheromone trap placed at plant canopy and in the centre of the plot, performed the best in all respects ensuring the lowest shoot (6.27%) and fruit (3.19 % by number and 2.83% by weight) infestation, the highest reduction of shoot (79.65%) and fruit (89.03% by number and 90.72% by weight) infestation to compare with control rather than using any single option such as sole mechanical control, schedule spray of Marshal at 7 days interval or sole sex pheromone trap. As a result, the maximum fruit yield (32.71 tons/ha) was produced in T1, which contributed the highest yield of healthy fruits (30.42 t ha^{-1}) as well as gave maximum BCR (2.05). The sex pheromone confused the male adult for mating and thus preventing fertilized egg production *vis-à-vis* reduces larval and adult population build–up. Marshal® was applied, when adult population reached at alarming phase indicated by monitoring results i.e., 10 to 15 adults caught per pheromone trap. Thus Marshal® killed the BSFB larvae as well as adults by its systemic and contact action. These treatments altogether significantly reduced the BSFB population and its infestation level, which ultimately increased the yield of brinjal.

Bhushan *et al*. (2011) evaluated the efficacy of pest management modules against Brinjal Shoot and Fruit Borer (*L. orbonalis*) during Rabi season of 2009-10 and 2010-11 and revealed that minimum shoot and fruit damage (9.32 and 14.83 per cent, respectively) was observed in module having shoot clipping with alternate spraying of Multineem (1500 ppm) and Triazophos (35%) plus deltamethrin (1%). Maximum yield (210.5 q/ha) was also recorded in the same module. Minimum shoot and fruit damage was recorded in 3rd week of December.

Shah *et al*. (2011) evaluated the effectiveness of 3 different modules such as Module-1 includes mass trapping through sex pheromone traps (40 traps/ha)+clipping of infested shoot at weekly interval starting from 20 days after transplanting (DAT)+spray application of neem seed kernel extract (NSKE) @ 4% at 20 days interval starting from flowering stage. Module-2 contains clipping of infested shoots+application of potash @ 100 kg/ha+field sanitation+spray application of spinosad @ 0.0135% alternated with azadirachtin @ 0.0006% at 20 days interval; and Module-3 comprises schedule based application of spinosad @ 0.0135%, flubendiamide @ 0.01% and Novaluron @ 0.01% at 20 days interval for the management of Brinjal Shoot and Fruit Borer (BSFB). They showed that the Module-2 and 3 recording 6.20 and 5.99% damaged shoots and 61.70 and 63.00% reduction over control, respectively and were at par and significantly superior to Module-1. Module-1 recorded lowest damage to fruits (7.88%) and highest reduction over control (67.00), was at par with module-2 (9.10% fruit damage and 61.89% reduction over control), but significantly superior to module-3 (14.11% fruit damage and 40.91% reduction over control). Module-1 recorded highest fruit yield (32.79 quintals/ha) and highest increase over control (41.99%), was at par with module-2 (31.66 quintals and 39.92% increase over control), but significantly superior to module- 3 (26.73 quintals and 28.84% increase over control). Mass trapping of male moths caused appreciable mating disruption resulting into reduction in damage to shoot during growth period and fruits during fruiting period. There was significant negative correlation of moth catches with damage to shoot (r=-0.6189) and fruits (r=-0.8008). Module-1 recording less than 45% reduction in predatory spider's population over control was found comparatively safer to spiders as compared to module-2 and 3, both of which recorded more than 85% reduction over control. The highest gross (Rs 49,185/ha) and net (Rs 20,655/ha), realization was obtained in IPM module-1 followed by module-2 (with gross and net realization of Rs 47,490 and Rs 18,630/ha, respectively) and module-3 (with gross and net realization of Rs 40,095 and Rs 11,565/ha, respectively). The highest net ICBR was in module-2 (1:2.21), which was almost same to module-1 (1:2.20). Module-3 recorded lowest NICBR (1:0.15) and proved to be least economical due to the involvement of high cost of synthetic insecticides and lower fruits yield. Thus module-1 was most effective against BSFB, increased marketable yield and gave higher ICBR. This module was also found comparatively safe to predatory spiders in brinjal ecosystem. The next best strategy was Module-2.

Javed (2012) evaluated the integration of *T. chilonis*, hoeing and clipping of infested plant parts reduced fruit infestation to the maximum level (5.61, 6.14 and 6.66%) and maximum increase in yield (q acre^{-1}) (42.58, 35.99 and 39.29) at research farm PMAS Arid Agriculture University Rawalpindi, Vegetable Research Farm NARC, Islamabad and Usman Khattar Vegetable Farm Taxila, Rawalpindi, respectively against *L. orbonalis* fruit infestation. Conclusively, the resistant cultivar “Nirala” and integration of different non chemical techniques (*T. chilonis* + hoeing + clipping) were recommended for the management of *L. orbonalis* in brinjal fields.

Mathur *et al*. (2012c) evaluated the efficacy of plant products *viz*., Neem oil (2%), Iluppai (*Madhuca indica*) oil (2%), Pungam oil (2%), combination of Iluppai and Pungam (1: 1) and microbial formulations *viz*., entomopathogenic fungi, *Beauveria bassiana* and *Verticillium lecanii* against the Brinjal Shoot and Fruit Borer (BSFB), *L. orbonalis*. The results revealed that newer plant products i.e., oils of Iluppai and Pungam were at par with standard check endosulfan and were found to be significantly superior than microbial formulations and also showed better efficiency than Neem oil in the suppression of BSFB infestation with significant insecticidal property. The yield data also revealed that the maximum yield of marketable fruits was obtained using Iluppai oil (202.75 q ha^{-1}); the per cent gain over control was least with *V. lecanii* followed by *B. bassiana*, neem oil, combination of Iluppai and Pungam oil, Pungam oil, Iluppai oil (77.8%), and maximum with endosulfan (83.3%). The results thus suggest that newer plant products such as oils of Iluppai and Pungum are promising botanicals in the integrated pest management strategy against BSFB.

Ashadul *et al*. (2014) evaluated eight treatments *viz.* T1: Tamarind fruit extract, T2: Bon kolmi leaf extract, T3: Ata leaf extract, T4: Neem leaf extract, T5: Tobacco leaf extract, T6: Mahogony seed extract, T7: Aktara 25 WG and T8: Control for the management of Brinjal Shoot and Fruit Borer. They showed that T4 had higher on total shoots (16.0 $plant^{-1}$), healthy shoots (15.7 $plant^{-1}$), total fruits (25.3 $plant^{-1}$), healthy fruits (23.0 plant ^{1}), fruits weight (2.7 kg plant 1), healthy fruits weight (2.7 kg $plant^{-1}$) and fruit yield (36.2 t ha^{-1}). Protection of shoot and fruit borer had higher over control (92.5 and 91.3%, respectively) and fruit yield increment over control had higher (61.7%) in T4. Among the all characters control treatment produced lower results in this study. Use of neem leaf extract was highly effective to reduce the shoot and fruit infestation as well as to get higher yield.

Chapter 3

Materials and Methods

Chapter-3

MATERIALS AND METHODS

The materials employed and methodology adopted during the entire course of investigation to study various objectives for the development of an effective, economical and ecological pest management programme, the knowledge regarding occurrence and seasonality of red mites and Brinjal Shoot and Fruit Borer (BSFB) and their associated natural enemy fauna, screening of varieties against against red mites and Brinjal Shoot and Fruit Borer and development of an eco-friendly IPM modules for *Leucinodes orbonalis* are of prime importance in formulating the IPM programme for the brinjal growers in Jammu region.

3.1 Details of the experiments

3.1.1 Location and site of the experimental plots for studying seasonal incidence

The site located at the research farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha was selected for laying out the experimental field trial (Plate-1). The plot size of 5×5 m^2 was selected to study the seasonal activity of BSFB and red spider mite and natural enemies of brinjal during 2014 and 2015. The meteorological data for the period of experimentation *i.e.*, 2014 and 2015 was obtained from the Agro-meteorological observatory, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu.

3.1.2 Layout of the Experiment

Crop	:	Brinjal (*Solanum melongena* L.)
Design	:	Randomised Block Design (RBD)
Spacing	:	100 × 100 cms
Replications	:	3

3.1.3 Crop Variety

The variety “Kashmiri brinjal” was used in the experiments. This variety is good for fresh consumption in the local market. The leaves are broad and medium lobed. The first

Plate-1

Lay-out of the experimental field at SKUAST-J Chatha Farm

(A) Experimental View of lay-out at Chatha Farm SKUAST-J during 2014

(B) Experimental view of brinjal crops during 2015

(C)Field ploughing by tractors at Chatha Farm

(D) Cultural operation in the experimental field

(E) Irrigation of brinjal crop

(F) monitoring of insect pest incidence at Chatha Farm fruit picking commences at 40-60 days after transplanting; the fruits are attractive and yellowish in color, 20-35 cm long, having excellent shelf life.

3.1.4 Cultural Operations

Cultural operations were done according to the package of practices (2012) SKUAST-Jammu.

3.1.5 Harvesting

The fruits were harvested at frequent intervals in the early morning hours by hand picking. Hand gloves were used to protect fingers. The fruits were harvested by bending the pedicel with a jerk or by using sharp knife.

3.2 Insect pests and natural enemy fauna of brinjal

The experiment was conducted at Research Farm, Chatha, SKUAST-J for consecutive two years *i.e*., 2014 and 2015. The activity on the basis of regular occurrence of insect- pests and natural enemy fauna were recorded at weekly intervals during the entire course of investigation in brinjal crop ecosystem.

3.2.1 Seasonal incidence of Brinjal Shoot and Fruit Borer (BSFB) and Red Spider mites (RSM)

The experiment was conducted at Research Farm, Chatha, SKUAST-J. In each replication, 5 plants were selected randomly and tagged.

3.2.1 Seasonal incidence of larval population of Brinjal Shoot and Fruit Borer (BSFB)

The seasonal incidence of larval population of BFSB was recorded from infested twigs and fruits at weekly intervals during morning hours and mean population were calculated and correlated with weather factors.

3.2.2 Seasonal incidence of adult population of Brinjal Shoot and Fruit Borer (BSFB)

Incidence of insect pests was examined throughout the season by placing pheromone traps (@ 10 traps /ha) and water traps (@ 100 trap/ha) placed in the field at a height of one foot from the crop canopy and direct count the adult BSFB population trap catches in every replication. Observations were recorded on weekly interval throughout the cropping season.

3.2.3 Seasonal incidence of Red Spider Mite (RSM)

In case of red spider mite, three leaves were selected (bottom, middle and upper) from tagged plants and 4cm^2 area cut from selected each leaf and adult of red spider mite were counted with the help of microscope.

3.3 Screening of brinjal varieties/cultivars

The experiment was laid out in randomized block design with three replication to evaluate the response of twenty five varieties of brinjal against fruit and shoot borer (*L. orbonalis*) and red spider mite (Table 1). For conducting this experiment, no plant protection measures were given against BSFB and mite pest during the entire cropping season.

3.3.1 Brinjal Shoot and Fruit Borer (BSFB)

In every observation, five plants was selected randomly and tagged. The incidence of larval population of BFSB was recorded from infested twigs and fruits at weekly intervals. Relative tolerance for Brinjal Shoot and Fruit Borer was determined on the basis of grade index, suggested by Mukhopadhyay and Mandal (1994) who classified the brinjal varieties on the basis of number of larvae per five plants and made four grades *i.e*.,

1. Tolerant (< 2.0 larvae)
2. Moderately tolerant (2.1–3.0)
3. Susceptible (3.1-5.0)
4. Highly susceptible (> 5.0 larvae)

3.3.2 Red Spider Mite (RSM)

Observations on red spider mite incidence were recorded at weekly interval on different varieties (Table 1). In every observation, five plants was selected randomly and tagged. The number of mites was counted on three leaves from each plant on top, middle and bottom portions of the plants. The adult population per 4 cm^2 leaf area was recorded and finally the mean population was worked out. The brinjal varieties were screened against red spider mites (adult population per 4 cm^2 leaf area) on the basis of scale given below:

1. Resistant (0.00)
2. Moderately Resistant (1-5.00)
3. Low Resistant (5.1-10.00)
4. Susceptible (10.1-15.00)
5. Highly Susceptible (> 15.00)

The scale has been developed keeping in view the damage caused to crops at different levels of population.

Table 1. List of screened brinjal varieties against BSFB and Red Spider Mite

S. No.	Varieties	S. No.	Varieties
1	JB-18	14	Brinjal round green
2	RCMBL-01	15	JBH-8
3	PLP-1	16	Ramnagar Gaint
4	IBH-3	17	Rajindra brinjal
5	KS-331	18	KS-356
6	MDV-01	19	JB-24
7	CHBR-1	20	Swarn Pratibha
8	DBR-31	21	DRNKU-03-26
9	HIC-13311	22	IBH-02
10	IBL-116	23	BCB-464
11	PBL-24	24	JB-6
12	Arka Sree	25	Kashmiri Brinjal (Control)
13	JB-64		

3.4 Management of Brinjal Shoot and Fruit Borer

Three modules were formulated and tested for the management of *Leucinodes orbonalis*. The modules are as follows-

Module I: Recommended practice of SKUAST-Jammu

1. Regular clipping of the infested shoots and fruits and destroy them or buried in a pit
2. Installation of pheromone traps and wota traps @ 100 per ha at 10 m spacing after 15days of transplantation.
3. Plant two lines of border row of coriander for encouragement of natural enemy fauna for natural control
4. Spraying the crops alternatively with Profenophos 50 EC @ 2ml/litre of water and flubendiamide (1g/lit of water) at 15 days interval starting from 20 days after transplantation to control the Brinjal Shoot and Fruit Borer.

Module II: Farmers' Practice

The commonly used insecticides by farmers have been evaluated for management of Brinjal Shoot and Fruit Borer.

Module III: BIPM (Bio-intensive Integrated Pest Management)

The module III include the following treatments-

1. Use of net as mechanical barrier
2. Pheromone and wota traps @ 1 trap/100m^2
3. Neem oil 5% (spray)
4. Clipping-off infested shoots
5. Foliar spray of *Beauvaria bassiana*@750 ml/ha (Biorin 1ml/l)
6. Foliar spray of *Pongamia pinnata* oil (2%)
7. Spray of Bt @ 500g per hectare (Biolep 1g/l)

Recording observations in each modules

Different treatments in modules were applied as scheduled or twenty days after transplanting. In each replication, the five plants were randomly selected and tagged. Observations were recorded at weekly intervals during morning hours and the infested shoot and fruit (number and weight basis) were recorded.

3.5 Parasitization of larval parasitoid, *Trathala flavo-orbitalis*

The natural enemies were recorded at the weekly intervals during survey the research trial field at Research Farm, Chatha, Division of Entomology, SKUAST-J. For recording the activity and occurrence of parasitoids in brinjal, 20 BFSB infested fruits were collected and brought to laboratory for parasitoids emergence. The number of pest and natural enemies that emerge from these fruits were recorded and mean percent parasitism were calculated.

3.6 Economics of different IPM modules for management of BSFB in brinjal

The yield of markeTable brinjal fruits in kilogram was recorded from five selected plants in each plot. In total 7-8 picking of fruits from each plot and cumulative yield (kg/ 5plants) was obtained by adding the weight of fruit from different harvests. The cumulative yield from each (5plants/ plot) was converted into yield on quintal/hectare basis.

The cost benefit ratio were also computed by using the total cost of module and net return obtained in term of increased yield (Rs./ha) over control. For each modules, increase in fruit yield over control plots was worked out and monetary value of additional quantity of brinjal for each module was estimated at the prevailing market rate of Rs. 1500/q during 2014 and 2015. The net benefit due to each module was calculated after deducting the expenditure incurred on implementing various control methods under modules and labour charges. Finally, the cost benefit ratio for each modules during each year separately was worked out according to method suggested by Ramasubbaiah *et al.* (1980).

The experiment was conducted in randomized block design. Observations have been taken at weekly intervals starting from 20 days after transplanting till the harvesting of the crop. The data was analyzed by using SPSS-16 package.

Chapter 4

Experimental Results

RESULTS

The results obtained on the seasonal incidence of Brinjal Shoot and Fruit Borer (BSFB) and Red Spider Mites (RSM), screening of 25 brinjal varieties for resistance reaction against BSFB and RSM and evaluation of three different Modules for BSFB on brinjal crop at research farm Chatha, Division of Entomology SKUAST- Jammu during 2014 and 2015 are presented under the following sub-heads-

4.1 Insect pests and natural enamies fauna of brinjal

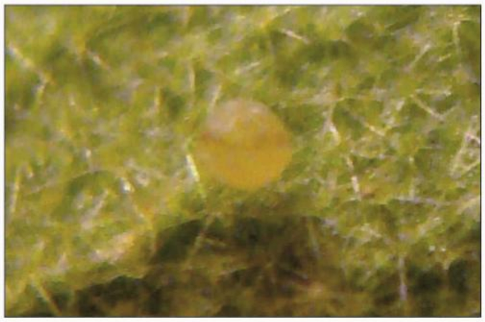
A wide array of insect pest and natural enemy fauna (predators and parasitoids) were recorded in brinjal crop during two years of experimentation *i.e*., 2014 and 2015. Out of fourteen (14) insect pests, five (5) insect pests were categorized as major insect pest such as Brinjal Shoot and Fruit Borer (Plate-2), Red Spider Mites (Plate-3), white fly, Jassid and Hadda beetle on the basis of economic losses caused in brinjal ecosystem. Survey of natural enemy fauna (especially parasitoids and predators) was observed and their prevalence with their respective specified hosts is presented in Table 2. Apart from insect pest, a large number of natural enemy fauna (12 species of predators and 3 species of parasitoids) such as lady bird beetles, ground beetles, rove beetles, reduviid bug, big eyed bug, pentatomid bug, earwigs, praying mantis, green lacewing, european wasp, and predatory mites along with the three parasitoid namely *Trathala flavo-orbitalis*, *Goryphus nursei* and *Campoletes chlorideae* were recorded during both the years of experimentation (Plate-4). *In toto*, twenty nine (29) insect pests and natural enemy fauna were observed in the brinjal ecosystem (Table 2).

4.2 Seasonal Incidence of Brinjal Shoot and Fruit Borer (BSFB) and Red Spider Mites (RSM) during 2014, 2015 and pooled

The seasonal incidence of BSFB and RSM was observed for the consecutive two years *i.e.*, 2014 and 2015 on brinjal crop. The observations on natural infestation of BSFB and RSM on brinjal were recorded at weekly intervals starting from 15th standard week i.e.,

Plate-2

Brinjal shoot and fruit borer (BSFB) infestation



(A) Egg of brinjal shoot and fruit borer (BSFB)

(B) BSFB larva infesting the twig of brinjal crop

(C) Drooping of brinjal twig due to infestation of BSFB larvae

(D) Larva of BSFB inside the fruit

(E) Pupa of BSFB larva

(F) Adult of BSFB

Plate-3

Mites infestation on brinjal

(A) Nursery seedlings infested with webs of red mite, *Tetranychus urticae*

(B) Complete yellowing and crinckling of nursery seedling leaves

(C) Red mite infestation on brinjal leaf

(D) Magnified View of Red spider mite

(E) Web formation by mites in main field

(F) Reduction of chlorophyll area due to mite infestation

Plate-4

Natural enemy fauna in brinjal ecosystem

(A) Larval parasitoid, *Trathala flavo-orbitalis* probing for parasitization

(B) *Goryphus nursei* searching for prey on brinjal

(C) Ladybird beetles *C. septumpunctata* and *C. sexmaculata* on brinjal

(D) *Reduviid bug, Rhynocoris marginatus* predating upon BSFB larva

(E) Pentatomid bug, *Eocanthecona furcellata*

(F) Green lacewing adult on brinjal crop

Table 2: List of insect-pests and natural enemy fauna recorded in brinjal ecosystem during 2014 and 2015

S.N.	Common Names	Scientific Names	Family: Order	Status
1	Brinjal Shoot and Fruit Borer	*Leucinodes orbaonalis* Guenn.	Pyralidae: Lepidoptera	Major
2	Red Spider Mite	*Tetranychus macfarlanei* Baker	Tetranychidae: Trombidiformes	Major
3	Aphid	*Myzus persicae* Sulzar	Aphididae: Hemiptera	Minor
4	Thrips	*Thrips palmi* Karny	Thripidae: Thysanoptera	Minor
5	Whitefly	*Bemisia tabaci* Gennadius	Aleyrodidae: Hemiptera	Major
6	Jassid	*Amrasca biguttula biguttula* Ishida	Cicadellidae: Homoptera	Major
7	Hadda beetle	*Epilachna vigintioctopunctata* Fabricius	Coccinellidae: Coleoptera	Major
8	Mealy Bug	*Phenacoccus solenopsis* Tinsley	Pseudococcidae: Hemiptera	Minor
9	Termite	*Odontotermes obesus*	Isoptera: Termitidae	Minor
10	Brinjal Leaf Roller	*Eublemma olivacea* Walker	Noctuidae: Lepidoptera	Minor
11	Brinjal Lace Bug	*Urentiushys tericellus* Richter	Tingidae: Hemiptera	Minor
12	Tobacco cut worm	*Spodoptera litura* Fabricius	Noctuidae: Lepidoptera	Minor
13	Brinjal fruit borer	*Helicoverpa armigera* Hubner	Noctuidae: Lepidoptera	Minor
14	Ash weevil	*Myllocerussub fasciatus* Guerin Meneville	Cucurlionidae: Coleoptera	Minor
Predators fauna recorded in brinjal ecosystem during 2014 and 2015				
15	Lady bird beetles	*Coccinella septempunctata*	Coccinellidae: Coleoptera	
16	Lady bird beetles	*Coccinella sexmaculata*	Coccinellidae: Coleoptera	
17	Ground beetles	*Ophionea sp.*	Carabidae: Coleoptera	
18	Rove beetles	*Paederus sp.*	Staphylinidae: Coleoptera	
19	Reduviid bug	Phynocoris merginatus F.	Reduviidae: Hemiptera	
20	Big eyed bug	*Geocori* sp.	Geocoridae: Hemiptera	
21	Pentatomid bug	*Eocanthecona furcellata*	Pentatomidae: Hemiptera	
22	Earwigs	*Forficula auricularia*	Forficulidae: Dermiptera	
23	Praying mantis	Mantis religiosa	Mantidae: Mantodea	
24	Green lacewing	*Chrysoperla carnea*	Chysopidae: Neuroptera	
25	European wasp	*Vespula germanica*	Vespidae: Hymenoptera	
26	Predatory mites	*Amblyseius tetranuchivorus Gupta*	Phytoseiidae: Mesostigmata	
Parasitoid fauna				
27	Trathala	*Trathala flavo-orbitalis*	Ichneumonidae: Hymenoptera	
28	Goryphus	*Goryphus nursei*	Ichneumonoide: Hymenoptera	
29	Campoletes	*Campoletes chlorideae*	Ichneumonoidea: Hymenoptera	

soon after the appearance of larval population with twigs dropping symptoms, till 36th standard week during 2014 and 17th standard week to 37th standard weeks during 2015. The relationship of seasonal incidence of BSFB larval population per plant and RSM mean number of adult population per 4cm^2 leaf area with weekly mean maximum and minimum temperature and morning and evening relative humidity during 2014 and 2015 were studied and presented here under.

4.2.1 Seasonal incidence of larval population of Brinjal Shoot and Fruit Borer (BSFB)

During 2014, BSFB mean larval population per plant on brinjal ranged from 0.33 to 14.33 (Table 3). Infestation was first observed nearly 30 days after transplanting i.e., from 16th standard week with an initial population of 0.33 larvae per plant. The population was observed to be increasing gradually till 24th SW recording a maximum of 14.33 larvae per plant. The mean weekly temperature, relative humidity and rainfall during the period were recorded to be 28.6°C, 65.8 per cent and 95.2 mm, respectively. The larval population of BSFB then decreased till 30th standard week on the same crop up to 6.00 larvae per plant. During this period, the weekly mean temperature, relative humidity and rainfall were observed 85.1°C, 76.25 per cent and 30.6 mm, respectively. Again, the population was observed to increasing up to 32nd SW, recording a maximum density of 11.66 mean larval population per plant. Thereafter, its population declined and minimum mean number of larvae per plant (1.33 larvae / plant) was recorded in 36th SW (Table 3, Fig.1). Thus, there was two peak of BSFB larval population build-up observed during 24th and 32nd standard weeks on brinjal crop during 2014.

Like the first year, the seasonal incidence of BSFB larval population was recorded on 2nd year brinjal crop from the 17th SW up to 37th standard week, 2015. A weekly interval survey on incidence of this pest revealed that the mean BSFB larval population per plant in brinjal were ranged from 1.0 to 14.00. The population was quite fluctuating and observed to be low up to 22nd SW when the mean weekly maximum and minimum temperature, morning and evening relative humidity and rainfall were observed to be 37.2°C, 21.5 °C, 59.0, 29 per cent and 1.8mm, respectively. Thereafter, the population was observed to be increasing gradually till 30th standard week recording a peak larval number with maximum of 14.00 larvae per brinjal plant. However, the population decreased up to 2.33 larvae per plant by 37th standard week. During this period the weekly mean maximum and minimum

Fig. 1: Seasonal incidence of BSFB larval/plants in relation to abiotic factors on brinjal during 2014

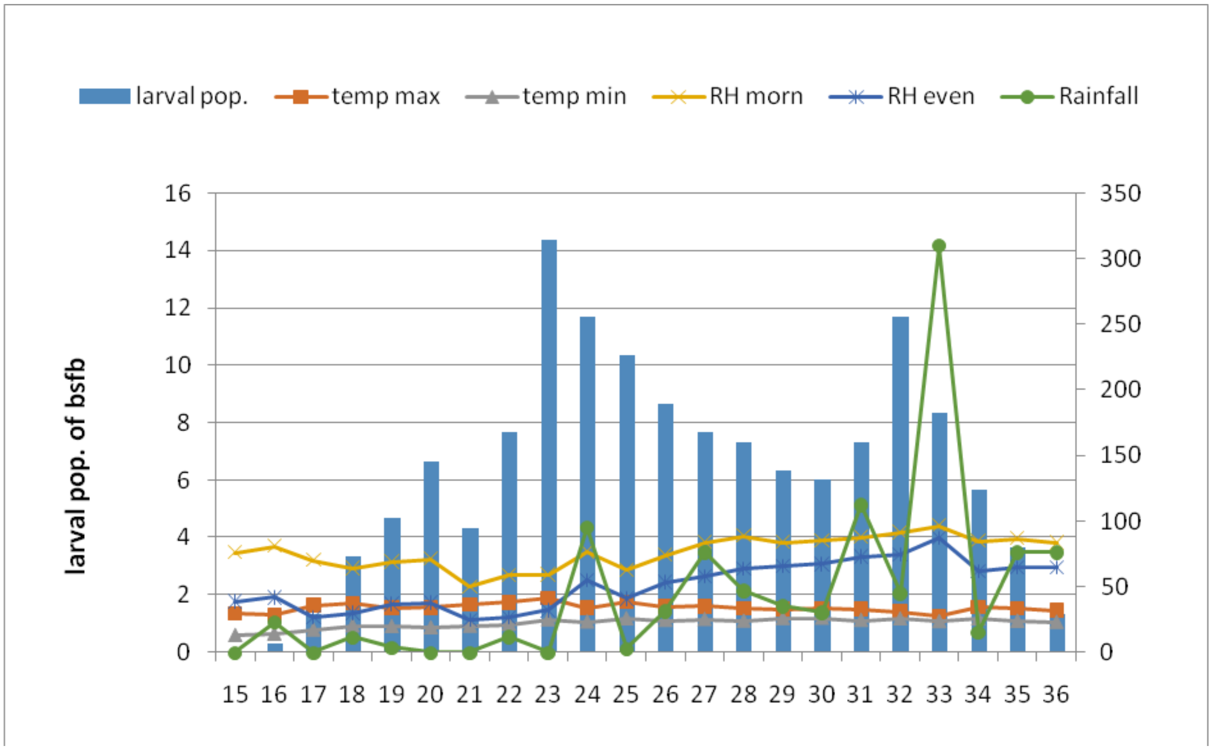


Fig. 2: Trap catches of BSFB male adult population by Pheromone trap and Wota trap on brinjal during 2014

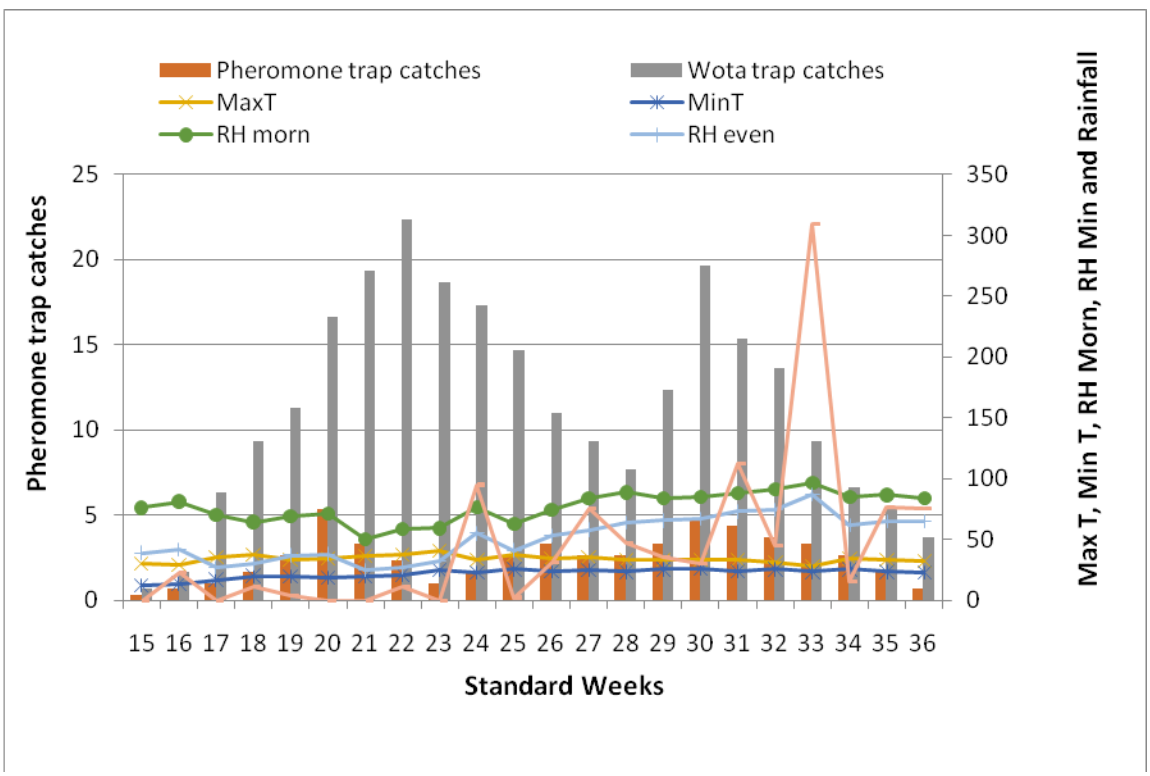


Table 3: Seasonal incidence of Brinjal Shoot and Fruit Borer (BSFB) larval population on brinjal during 2014

Standard weeks	Mean number of BSFB larval population per plant	Temp. (Max.) C°	Temp. (Min.) C°	R. H. (Morning) %	R. H. (Evening) %	Rainfall (mm)
15	0.00	29.7	12.9	76	39	0
16	0.33	28.6	14.1	81	42	23.0
17	1.33	35.8	17.2	70	27	0
18	3.33	37.3	20.4	64	30	11.5
19	4.66	33.9	19.8	69	37	3.8
20	6.66	34.1	18.9	71	38	0
21	4.33	36.6	20.0	50	25	0
22	7.66	37.9	21.5	58.4	26.7	12.0
23	11.66	41.1	25.0	59.0	32.3	0.0
24	14.33	33.9	23.3	76.6	55.0	95.2
25	10.33	38.3	25.8	62.6	41.0	2.6
26	8.66	34.9	24.4	74.1	53.4	31.6
27	7.66	35.2	25.1	83.7	58.0	76.2
28	7.33	33.4	23.9	88.6	64.0	47.2
29	6.33	33.1	25.9	84.0	65.7	35.4
30	6.00	33.6	26.1	85.1	67.4	30.6
31	7.33	33.0	24.5	87.9	72.9	112.5
32	11.66	31.1	25.6	91.1	74.6	45.2
33	8.33	28.0	23.6	96.4	87.0	309.4
34	5.66	34.7	25.6	84.9	62.0	15.6
35	3.66	33.5	23.8	86.6	64.9	76.4
36	1.33	32.2	23.0	83.6	64.7	76.1

temperature, morning and evening relative humidity and rainfall were observed to be 35.1°C, 23.6 °C, 80.0, 53 per cent and 0.0 mm, respectively (Table 4, Fig. 2).

4.2.2 Seasonal incidence of adult population of Brinjal Shoot and Fruit Borer (BSFB) during 2014, 2015 and pooled.

The data on incidence of BSFB male adult population by trap catches showed that initial moth catch in pheromone trap was observed in 15^{th} standard week with 0.33 mean number of BSFB adults. As the environmental variables showed the gradually increasing trend, a gradual increase of trap catches was recorded up to 20^{th} standard week with peak catches of 5.33 moths per trap per week. The mean weekly temperature and relative humidity during the period were recorded to be 26.5°C and 54.5 per cent, respectively. The moth activity was observed in pheromone traps up to the harvest of crop i.e., 36^{th} standard week. The adult population fluctuated between 20^{th} and 30^{th} standard week, exhibiting one 'V' shaped oscillations between 22^{nd} and 30^{th} standard week (Table 5, Fig. 3). Thereafter, a sharp decline was noticed up to the harvest of crop during 36^{th} SW with 0.66 mean numbers of moths per trap. Thus, there were two peaks of adult trap catch population noticed during 20^{th} standard week and in 30^{th} standard week. Similarly, the initial population of BSFB adult moth catches (0.66) was recorded in Wota trap during 15^{th} standard week. A gradual increase was recorded up to 22^{th} standard week with the peak catches of 22.33 moths per trap (Table 5). During this period, the maximum temperature, minimum temperature, morning humidity, evening humidity and rainfall were observed to be 37.9°C, 21.5°C, 58.4, 26.7 per cent, and 12.00 mm, respectively. The adult trap population fluctuated between 22^{th} to 30^{th} standard week, exhibiting two 'V' shaped oscillations between 22^{th} to 28^{th} standard week and 28^{th} to 30^{th} standard week. Thereafter, a sharp decline was noticed up to 36^{th} SW. Thus, the two peaks were noticed during the year *viz*., first one on 22^{nd} standard week and second during 30^{th} standard week which constituted the two overlapping generations of BSFB pest in Jammu region (Fig. 3).

The trap catches of BSFB (adult) population data during 2015 showed that the early moth catch trap in pheromone trap was obtained during 17^{th} standard week (0.33 mean number of BSFB trap catches in pheromone trap), immediately after appearance of over wintered moths. A gradual increase was noticed up to 30^{th} standard week with the peak trap catches of 11.33 moths per trap per week (Table 6). The moth activity through trap catches

Fig 3: Seasonal incidence of red spider mites (RSM) on brinjal (per 4 cm^2 leaf area) in relation to abiotic factors on brinjal during 2014

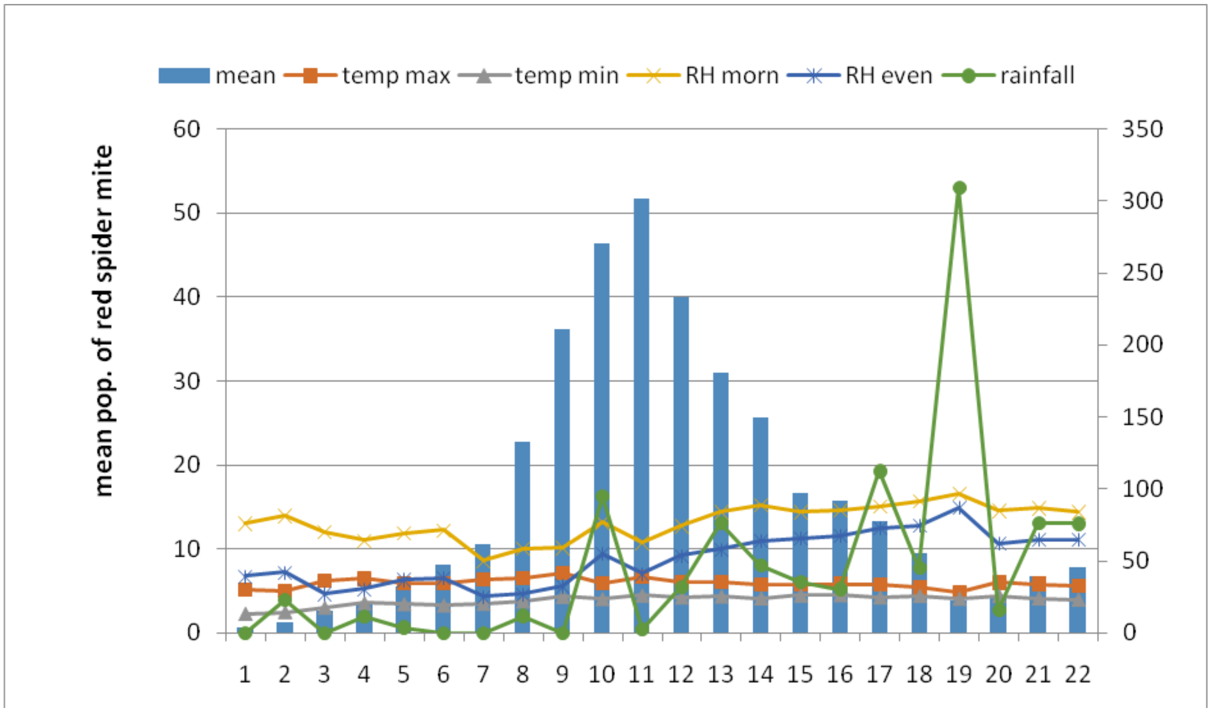


Fig. 4: Seasonal incidence of BSFB larval/plants in relation to abiotic factors on brinjal during 2015

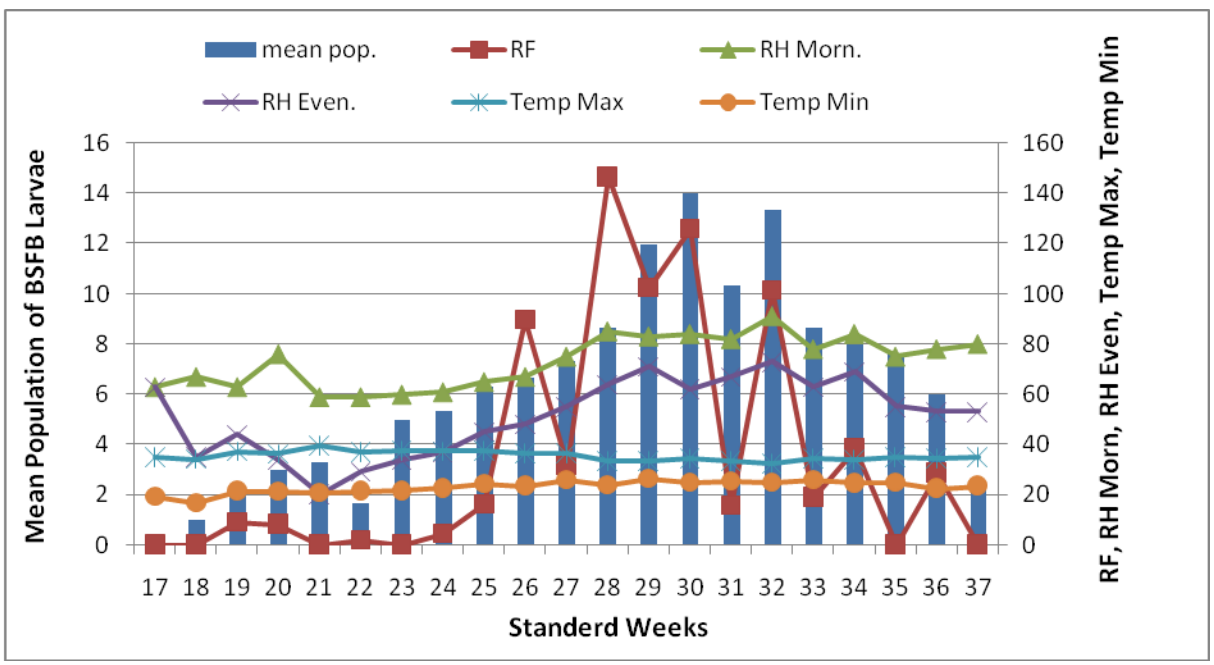


Table 4: Seasonal incidence of Brinjal Shoot and Fruit Borer (BSFB) larval population on brinjal during 2015

Standard weeks	mean number of (BSFB) larval population per plant	Temp. (max.) C^o	Temp. (min.) C^o	R. H. (morning) %	R. H. (evening) %	Rainfall (mm)
17	0.00	35.1	19.2	63	63	0
18	1.00	34.3	16.8	67	35	0
19	2.33	37.3	21.5	63	44	9.1
20	3.00	36.4	21.4	76	34	8.4
21	3.33	39.7	20.8	59	20	0
22	1.67	37.2	21.5	59	29	1.8
23	5.00	37.6	21.6	60	34	0
24	5.33	37.4	22.7	61	37	4.4
25	6.33	37.7	24.5	65	45	16.3
26	6.67	36.7	23.6	67	48	89.8
27	7.33	36.5	26	75	55	31.8
28	8.67	33.5	24	85	64	146.9
29	12.00	33.5	26.4	83	71	102.6
30	14.00	34.5	24.9	84	62	126.2
31	10.33	33.4	25.5	82	67	15.8
32	13.33	32.5	25	91	73	101.6
33	8.67	34.5	25.9	78	63	19
34	8.00	34	24.7	84	69	38.4
35	7.67	35.2	24.9	75	55	0
36	6.00	34.6	22.6	78	53	28.8
37	2.33	35.1	23.6	80	53	0

Table 5: Trap catches of BSFB male adult population by Pheromone trap and Wota trap on brinjal during 2014

Standard weeks	Mean no. of BSFB trap catches in Pheromone traps	Mean no. of BSFB trap catches in Wota traps	Temp. (Max.) C°	Temp. (Min.) C°	R. H. (Morn) %	R. H. (Even) %	Rainfall (mm)
15	0.33	0.66	29.7	12.9	76	39	0
16	0.66	1.66	28.6	14.1	81	42	23.0
17	1.00	6.33	35.8	17.2	70	27	0
18	1.66	9.33	37.3	20.4	64	30	11.5
19	2.66	11.33	33.9	19.8	69	37	3.8
20	5.33	16.66	34.1	18.9	71	38	0
21	3.33	19.33	36.6	20.0	50	25	0
22	2.33	22.33	37.9	21.5	58.4	26.7	12.0
23	1.00	18.66	41.1	25.0	59.0	32.3	0.0
24	1.66	17.33	33.9	23.3	76.6	55.0	95.2
25	2.66	14.66	38.3	25.8	62.6	41.0	2.6
26	3.33	11.00	34.9	24.4	74.1	53.4	31.6
27	2.66	09.33	35.2	25.1	83.7	58.0	76.2
28	2.66	7.66	33.4	23.9	88.6	64.0	47.2
29	3.33	12.33	33.1	25.9	84.0	65.7	35.4
30	4.66	19.66	33.6	26.1	85.1	67.4	30.6
31	4.33	15.33	33.0	24.5	87.9	72.9	112.5
32	3.66	13.66	31.1	25.6	91.1	74.6	45.2
33	3.33	9.33	28.0	23.6	96.4	87.0	309.4
34	2.66	6.66	34.7	25.6	84.9	62.0	15.6
35	1.66	5.33	33.5	23.8	86.6	64.9	76.4
36	0.66	3.66	32.2	23.0	83.6	64.7	76.1

Table 6: Trap catches of BSFB male adult population by Pheromone trap and Wota trap on brinjal during 2015

Standard weeks	Mean no. of BSFB trap catches in Pheromone traps	Mean no. of BSFB trap catches in Wota traps	Temp. (Max.) C°	Temp. (Min.) C°	R. H. (Morn) %	R. H. (Even) %	Rainfall (mm)
17	0.33	0.33	35.1	19.2	63	63	0
18	0.67	1.00	34.3	16.8	67	35	0
19	1.00	1.67	37.3	21.5	63	44	9.1
20	2.00	1.33	36.4	21.4	76	34	8.4
21	2.67	2.33	39.7	20.8	59	20	0
22	4.67	2.67	37.2	21.5	59	29	1.8
23	3.33	3.67	37.6	21.6	60	34	0
24	2.67	4.00	37.4	22.7	61	37	4.4
25	1.33	4.33	37.7	24.5	65	45	16.3
26	2.00	5.67	36.7	23.6	67	48	89.8
27	2.67	6.33	36.5	26	75	55	31.8
28	3.67	8.33	33.5	24	85	64	146.9
29	8.67	13.67	33.5	26.4	83	71	102.6
30	11.33	17.33	34.5	24.9	84	62	126.2
31	9.00	19.67	33.4	25.5	82	67	15.8
32	4.67	11.33	32.5	25	91	73	101.6
33	7.67	15.33	34.5	25.9	78	63	19
34	3.33	16.33	34	24.7	84	69	38.4
35	2.00	4.00	35.2	24.9	75	55	0
36	1.67	2.67	34.6	22.6	78	53	28.8
37	0.67	1.67	35.1	23.6	80	53	0

continued to be noticed up to 37th standard week (0.6733 mean number of BSFB trap catches) at the time of harvesting. While in Wota trap, the initial BSFB adult moth catch was recorded during 17th standard week and a gradual increase in trap catches were noticed up to 31st standard week with the peak activity of 19.67 moths per trap per week. During this period, the weekly mean temperature (maximum and minimum), relative humidity (morning and evening) and rainfall, were recorded to be 33.4°C, 25.5°C, 82, 67 per cent and 15.8 mm, respectively. The trap catches was recorded up to 37th standard week at the time of harvesting with 1.67 moths per trap per week (Fig. 4).

4.2.3 Seasonal incidence of Red Spider Mite (RSM) during 2014, 2015 and pooled.

The sucking non-insect pest such as Red Spider Mites (RSM) was found damaging the crop by sucking the cell sap from the leaves surface and thus the affected leaves turned yellowish, curled upward and gave the shriveled appearance. During the two years of experimentation, there were two types of red spider *viz*., *Tetranychus neocalidonicus* Andre and *Tetranychus urticae* Koch was found infesting the brinjal crop. The seasonal incidence of Red Spider Mites observed at experimental sites indicated that *T. neocalidonicus* was found damaging and remain active on the brinjal crop during the different stages of crop growth whereas, *T. urticae* was confined only to nursery seedlings. The observations on natural infestation of Red Spider Mites (RSM), *T. neocalidonicus* in the main field of brinjal crop were recorded at weekly intervals starting from 15th SW to 36th SW during the year 2014. The mean number of Red Spider Mites population/ 4 cm^2 on brinjal ranged from 0.67 to 51.81. Infestation was first observed nearly a month after transplantation of seedlings in the main field *i.e*., from 15th standard week with an initial population of 0.67 mites per 4 cm^2. From there, the population was observed to be increasing gradually till 25th standard week recording a maximum of 51.81 mean number of mites per 4 cm^2 on brinjal. During this period, the mean maximum and minimum temperature, morning and evening relative humidity and rainfall in 25th standard week were observed to be 38.3°C, 25.8°C, 62.6, 41.0 per cent and 2.6 mm, respectively. Thereafter, the Red Mites population was observed to be declining up to 7.84 mean number of adult mite population per 4 cm^2 leaf area in 36th SW (Table 7, fig. 5).

The initial appearance of Red Spider Mites (RSM) was observed during 18th standard week with 0.68 mean number of adult mite population per 4 cm^2 leaf area. There were two

Table 7: Seasonal incidence of Red Spider Mites on brinjal (per 4 cm^2 leaf area) during 2014

Standard weeks	Red mites (mean no. of adult population)	Temp. (max.) C^o	Temp. (min.) C^o	R. H. (morning) %	R. H. (evening) %	Rainfall (mm)
15	0.67	29.7	12.9	76	39	0
16	1.22	28.6	14.1	81	42	23.0
17	2.67	35.8	17.2	70	27	0
18	3.33	37.3	20.4	64	30	11.5
19	5.55	33.9	19.8	69	37	3.8
20	8.11	34.1	18.9	71	38	0
21	10.56	36.6	20.0	50	25	0
22	22.81	37.9	21.5	58.4	26.7	12.0
23	36.22	41.1	25.0	59.0	32.3	0.0
24	46.48	33.9	23.3	76.6	55.0	95.2
25	51.81	38.3	25.8	62.6	41.0	2.6
26	40.00	34.9	24.4	74.1	53.4	31.6
27	31.33	35.2	25.1	83.7	58.0	76.2
28	25.22	33.4	23.9	88.6	64.0	47.2
29	16.67	33.1	25.9	84.0	65.7	35.4
30	15.78	33.6	26.1	85.1	67.4	30.6
31	13.22	33.0	24.5	87.9	72.9	112.5
32	9.55	31.1	25.6	91.1	74.6	45.2
33	3.89	28.0	23.6	96.4	87.0	309.4
34	4.11	34.7	25.6	84.9	62.0	15.6
35	6.78	33.5	23.8	86.6	64.9	76.4
36	7.84	32.2	23.0	83.6	64.7	76.1

peaks of adult mite populations were recorded during 2015 *i.e*., in 26th SW with 36.02 red mite per 4cm^2 leaf area and in 35th SW with 24.37 mite per 4cm^2 leaf area, respectively. The corresponding maximum and minimum temperatures, morning and evening relative humidity and rainfall was recorded to be 36.7°C, 23.6°C,67,48 per cent and 89.9 mm during 26th SW whereas, 35.2°C, 24.9°C, 75, 55 per cent and 0.0 mm during 35th SW, respectively. Thereafter its population declined and minimum population was recorded in 37th SW with 1.51 mean number of red mite per 4cm^2 leaf area (Table 8, Fig. 6).

Correlation Studies

The correlation studies indicated that weather parameters played an important role in population build up of BSFB, its trap catches and Red Spider Mites on brinjal. The pest incidence data of BSFB, trap catches and Red Spider Mites were correlated with the weather data obtained from Meteorology Division SKUAST-Jammu, Chatha for both the years of experimentation *i.e*., 2014 and 2015, respectively.

The relationship between mean maximum and minimum temperatures, mean morning and evening relative humidity, rainfall and incidence of BSFB larval population when worked out during 2014, it was observed that BSFB larval populations was found significantly correlated with temperature (minimum and maximum) and non significantly correlated with relative humidity (morning and evening) and rainfall (Table 9). However, during 2015, a highly positive correlation between BSFB larval incidences with mean maximum temperature, mean relative humidity (morning and evening) and rainfall existed which was found to be statistically significant even at 5% level except minimum temperature which existed the highly negative correlation. The Pooled data correlation studies showed that the BSFB (larvae) populations were found positively correlated with relative humidity (morning, evening) and rainfall and negatively correlated with maximum temperature (Table 10).

The relationship between abiotic factors and trap catches of adult population of BSFB in pheromone trap showed that BSFB (adult) populations in pheromone trap catches was found significantly correlated with minimum temperature and non significantly correlated with relative humidity (morning and evening), maximum temperature and rainfall while it was found positively correlated with temperature (minimum), relative humidity (morning), negatively correlated with rainfall and maximum temperature during 2015.The

Fig. 5: Trap catches of BSFB male adult population by Pheromone trap and Wota trap on brinjal during 2015

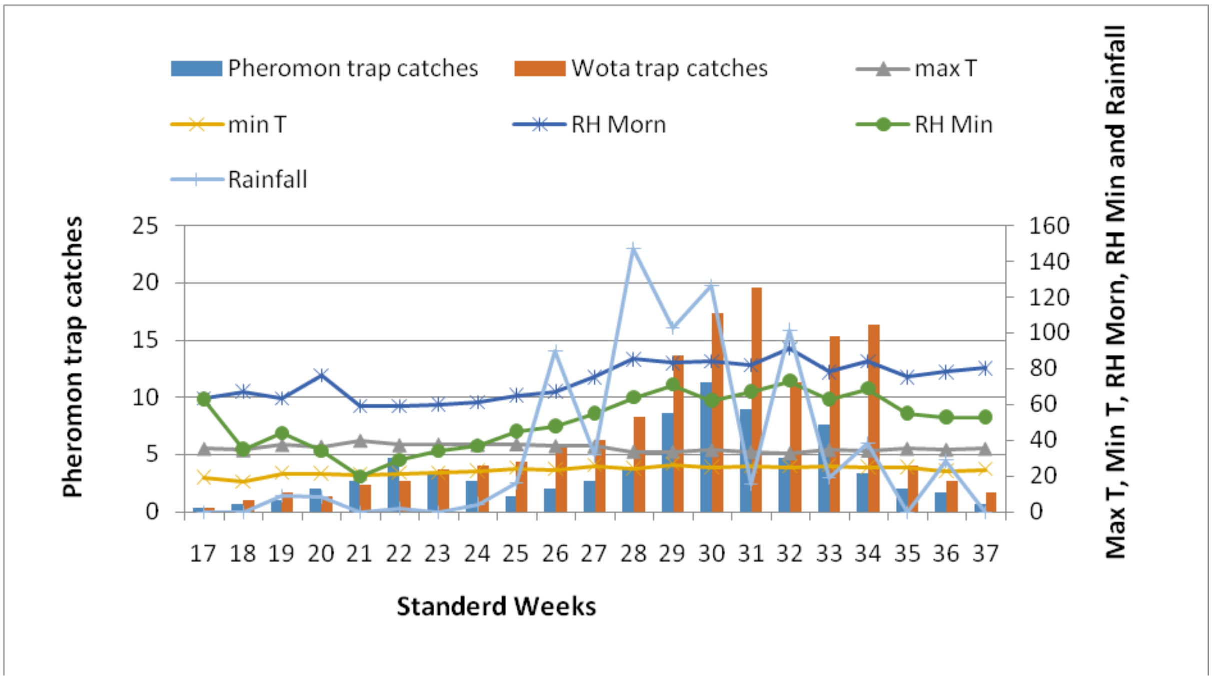


Fig 6: Seasonal incidence of red spider mites (RSM) on brinjal (per 4 cm^2 leaf area) in relation to abiotic factors on brinjal during 2015

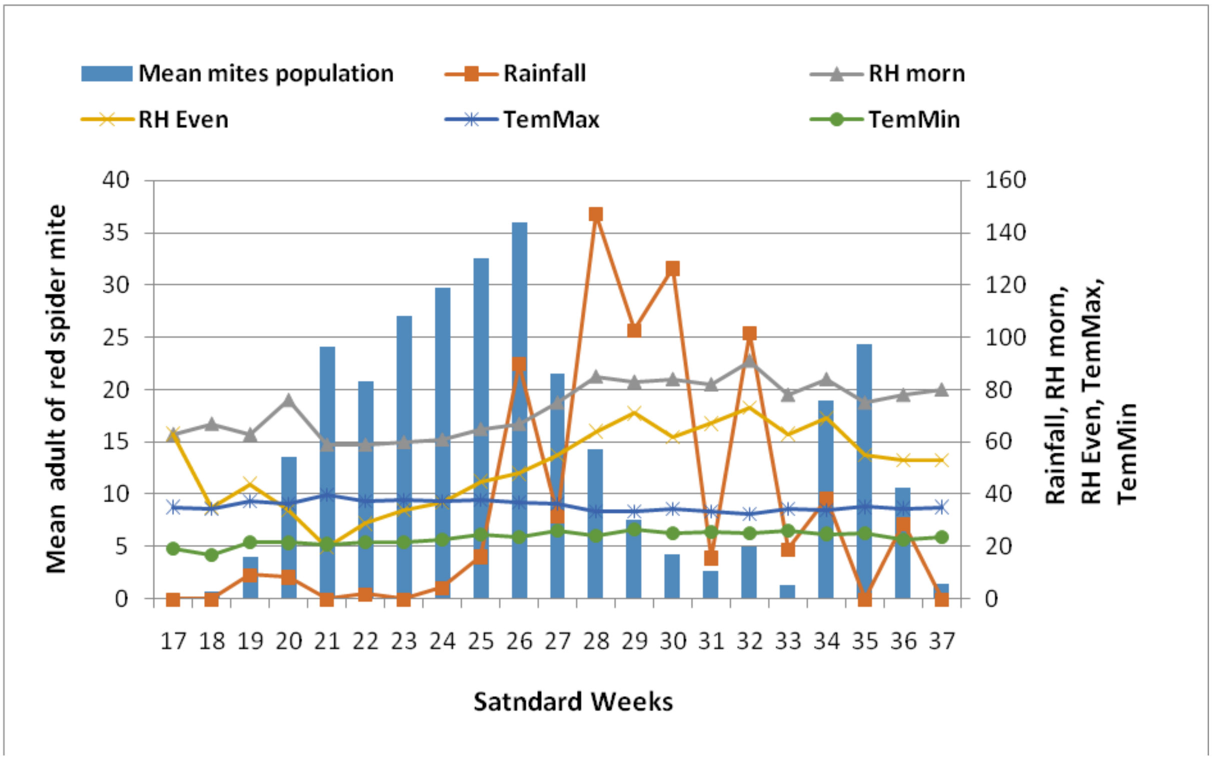


Table 8: Seasonal incidence of Red Spider Mites on brinjal (per 4 cm^2 leaf area) during 2015

Standard weeks	**Red mites (mean no. of adult population)**	**Temp. (max.) C^o**	**Temp. (min.) C^o**	**R. H. (morning) %**	**R. H. (evening) %**	**Rainfall (mm)**
17	0.0	35.1	19.2	63	63	0
18	0.68	34.3	16.8	67	35	0
19	4.03	37.3	21.5	63	44	9.1
20	13.57	36.4	21.4	76	34	8.4
21	24.13	39.7	20.8	59	20	0
22	20.80	37.2	21.5	59	29	1.8
23	27.09	37.6	21.6	60	34	0
24	29.69	37.4	22.7	61	37	4.4
25	32.52	37.7	24.5	65	45	16.3
26	36.02	36.7	23.6	67	48	89.8
27	21.53	36.5	26	75	55	31.8
28	14.29	33.5	24	85	64	146.9
29	7.61	33.5	26.4	83	71	102.6
30	4.31	34.5	24.9	84	62	126.2
31	2.68	33.4	25.5	82	67	15.8
32	4.96	32.5	25	91	73	101.6
33	1.39	34.5	25.9	78	63	19
34	18.99	34	24.7	84	69	38.4
35	24.37	35.2	24.9	75	55	0
36	10.67	34.6	22.6	78	53	28.8
37	1.51	35.1	23.6	80	53	0

Table 9: Correlation matrix of Brinjal Shoot and Fruit Borer (BSFB) and Red Mite in relation to abiotic factors on brinjal

S. No.	Insect Pests	During 2014					During 2015				
		Temperature (C^o)		Relative Humidity (%)		Rainfall (mm)	Temperature (C^o)		Relative Humidity (%)		Rainfall (mm)
		Maximum	Minimum	Morning	Evening		Maximum	Minimum	Morning	Evening	
1	BSFB larval population	-0.398*	0.692**	-0.036	0.217	0.180	0.808**	-0.554**	0.739**	0.683**	0.730**
2	Pheromone trap catches (BSFB) adults population	-0.017	0.456*	0.177	0.346	0.530	-0.404	0.552**	0.481*	0.432	-0.533*
3	Water trap catches of BSFB adults population	0.428*	0.555**	-0.440*	0-0.171	-0.102	-0.590**	0.708**	0.675**	0.696**	-0.522*
4	Red Mite	0.516*	0.514*	-0.244	-0.037	-0.067	0.631**	0.101	-0.451*	-0.448*	-0.074

** $p < 0.01$
* $p < 0.05$

Table 10: Pooled data on correlation matrix of Brinjal Shoot and Fruit Borer (BSFB) and Red Spider Mites in relation to abiotic factors on brinjal

S. No.	Insect Pests	Temperature (C^o)		Relative Humidity (%)		Rainfall (mm)
		Maximum	Minimum	Morning	Evening	
1	BSFB larval population	-0.372*	0.701**	0.335*	0.450**	0.422**
2	Pheromone trap catches (BSFB) adults population	-0.115	0.454**	0.284	0.357*	0.277
3	Water trap catches of BSFB adults population	0.021	0.431**	0.105	0.203	0.167
4	Red Mite	0.500**	0.366*	-0.304*	-0.191	-0.371*

** $p < 0.01$
* $p < 0.05$

correlation study showed that BSFB (adult) populations in Wota trap catches was found significantly positive correlation with temperature (minimum and maximum) and negative with morning relative humidity and non significantly correlated with relative humidity (evening), and rainfall during 2014. While during 2015, Wota/Water trap catches of BSFB (adult) were found positively correlated with relative humidity (morning, evening), temperature (minimum) and negatively correlated with maximum temperature, and rainfall. The pooled data of correlation studies showed that the BSFB (adult) populations in pheromone trap catches were observed to be positively correlated with temperature (minimum), relative humidity (morning) (Table 10).

The correlation studies showed that the Red Spider Mites populations was found significantly and positively correlated with temperature (minimum and maximum) and non significantly correlated with relative humidity (morning and evening) and rainfall during 2014 whereas, it was found negatively correlated with relative humidity (morning and evening), rainfall and positively correlated with temperature (maximum) and no correlation was found with minimum temperature (Table 9). The pooled data on correlation studies showed that the adult population of the red mite was recorded to be negatively correlated with relative humidity (morning) and rainfall, and positively correlated with temperature (Maximum and Minimum) (Table 10).

The linear regression equations for BSFB larval population was calculated to be Y= –1.612– 0.310 X1 +1.097 X2 -0.038 X3 – 0.137 X4 +0.016 X5. The multiple determination (R^2) values was worked out to be 0.573 which indicated that the overall impact of weather factors on population build up of BSFB larval population was 57.3 per cent. While during 2015, the overall impact of weather factors on the Brinjal Shoot and Fruit Borer (BSFB) larval population was 83.80 % (Table 11). The pooled data on linear regression equations for BSFB larval population was calculated to be Y= 7.478–0.600X1+1.210X2 -0.035X3 -0.115X4 +0.018 with the corresponding correlation co-efficient of multiple determination (R^2) values worked out to be 0.567. The overall impact of weather on the Brinjal Shoot and Fruit Borer larval population was 56.70 % (Table 12).

The corresponding value of linear regression equations for pheromone trap catches of BSFB adults population was calculated to be Y= –12.144– 0.331X1 +0.303X2 -0.073X3+ 0.008X4 -0.003X5. The multiple determination (R^2) values was worked out to be 0.302 for

Table 11: Regression equation and co-efficient of determination (R^2) of BSFB and Red Mite in relation to abotic factors on brinjal

S. No	Insect pests	During 2014			During 2015		
		Regression equation	**Coefficient of determination (R^2)**	**Coefficient of variation (%)**	**Regression equation**	**Coefficient of determination (R^2)**	**Coefficient of variation (%)**
1	BSFB larval population	Y= –1.612–0.310X1 +1.097X2 -0.038X3 –0.137X4 +0.016X5	0.573	57.30	Y= 12.800– 0.033X1 -0.022X2 -0.068X3 -0.812X4 +1.134X5	0.838	83.80
2	Pheromone trap catches of BSFB adults population	Y= –12.144–0.331X1 +0.303X2 -0.073X3+ 0.008X4 -0.003X5	0.302	30.20	Y= 55.295+0.020X1-0.168X2 -0.136X3+ -1.642X41+0.089X5	0.493	49.30
3	Water trap catches of BSFB adults population	Y= –51.762–0.893X1 +1.387X2 -0.532X3 –0.009X4 +0.009X5	0.580	58.00	Y= –42.750+0.014X1 -0.118X2 -0.030X3-1.788X4+1.607X5	0.643	64.30
4	Red Mite	Y= 4.805–1.056X1 +3.997X2 –0.156X3 –0.600X4 +0.029X5	0.441	44.10	Y= -33.803– 0.075X1 -0.627X2 -0.357X3 +1.027X4+3.149X5	0.600	60.00

Where,

Y = Constant, X1 = Temperature (Maximum), X2 = Temperature (Minimum)
X3 = Relative Humidity (Morning), X4 = Relative Humidity (Evening), X5 = Rainfall

Table 12. Pooled data on regression equation and coefficient of determination (R^2) of BSFB and Red Spider mite in relation to a-biotic factors on brinjal

S. No.	Insect pests	Regression equation	Coefficient of determination (R^2)	Coefficient of variation (%)
1	**BSFB larval population**	Y= 7.478–0.600X1+1.210X2 -0.035X3 - 0.115X4 +0.018X5	0.567	56.70
2	**BSFB adult catches in Pheromone traps**	Y= 15.420 -0.587X1+0.644X2 -0.048X3 - 0.061X41+0 .003X5	0.275	27.50
3	**BSFB adult catches in water trap**	Y= 72.030 -2.305X1 +2.315X2 -0.295X3 - 0.263X4+0 .0087X5	0.294	29.40
4	**Red Mite**	Y= 25.299 -1.037X1+ 3.603X2 -0.391X3 - 0.553X4+ 0.048X5	0.442	44.20

Where,

Y = Constant, X1 = Temperature (Maximum), X2 = Temperature (Minimum), X3 = Relative Humidity (Morning),
X4 = Relative Humidity (Evening), X5 = Rainfall

pheromone trap catches of BSFB adults population which revealed the overall weather impact was 30.2 per cent during 2014 whereas, overall impact of weather factors for population catches in pheromone trap was 49.3% during 2015. The linear regression equations for Wota trap catches of BSFB adults population was calculated to be Y= – 51.762– 0.893X1 +1.387X2 -0.532X3 – 0.009X4 +0.009X5. The overall impact of weather factor was found to be 58.0 per cent in Wota trap catches. While during 2015, weather factors regulated the trap catches in Wota traps was found to be 64.3 %. The linear regression equations for Pheromone trap catches of BSFB adults population was calculated to be Y= 15.420 -0.587X1+0.644X2 -0.048X3 -0.061X41+0 .003X5, and the R^2 Value was 0.275. The overall impact of weather for population build up was 27.5%. while in case of wota trap catches, it was recorded to be positively correlated with temperature (minimum). The corresponding value of linear regression equations for wota trap catches of BSFB adults population was calculated to be Y= 72.030 -2.305X1 +2.315X2 -0.295X3 -0.263X4+0 .0087X5, with the multiple determination was worked out to be 0.294. The overall impact of weather was 29.4%.

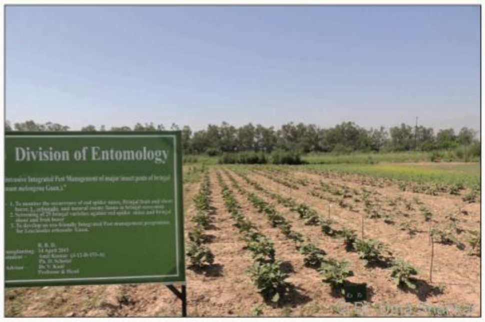
The value of linear regression equations for red mite population were calculated to be Y= 4.805– 1.056X1 +3.997X2 –0.156X3 –0.600X4 +0.029X5. These equations showed the increasing trend of red mite incidence due to increase in temperature, preferably to some extent. The corresponding multiple determination (R^2) values worked out to 0.441 for Red Mites, and was found statistically significant at 5% level of significance. The overall impact of weather factors on population build up was 44.1 per cent on Red Mites during 2014. The overall impact of weather factors on population build up of red mite was found to be 60.0 per cent during 2015 (Table 11). The corresponding value of R^2 in case of red mite was found to be 0.442. The overall impact of weather factors on population build up of red mite was 44.2 per cent (Table 12).

4.3 Screening of brinjal varieties/cultivars during 2014, 2015 and pooled

Screening of twenty five varieties of brinjal for resistance response against Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis*) and Red Spider Mites (*Tetranychus*) (Plate-5) are given below-

Plate-5

Screening of 25 brinjal varieties against BSFB and red mites



(A) Field view of Screening experiment at Chatha Farm, SKUAST-J

(B) Monitoring of BSFB infestation for screeing in brinjal

(C) Replication 1 for screening of brinjal varieties

(D) Replication 2 for screening of brinjal varieties

(E) Screening of 25 varieties of brinjal against BSFB infestation

4.3.1 Brinjal Fruit and Shoot Borer (BSFB)

Screening of twenty five brinjal varieties (Table 13) against Brinjal Shoot and Fruit Borer (BSFB) for resistance response revealed that the ten varieties RCMBL- 01, PLP-1, IBH-3, IBL-116, JBH-8, Rajindra brinjal, KS-356, JB-24, IBH-02 and BCB-464 were found in showing the tolerance between the score of 0.0-2.0 (larvae/5plants), the four varieties CHBR-1, Arka Sree, DRNKU-03-26 and JB-64 were found to be moderately tolerant with score of 2.1-3.0, the nine varieties JB-18, KS-331, MDV-01, HIC-13311, PBL-24, Brinjal Round Green, Ramnagar Giant, Swarn Pratibha and JB-6 were observed to be susceptible with score of 3.1-5.0 and the two varieties DBR-31 and Keshmiri Brinjal were recorded to be highly susceptible with score of 5.1- above 5.1 during 2014.

Similarly during 2015, screening of twenty five brinjal varieties against Brinjal Shoot and Fruit Borer (BSFB) for resistance response showed that the ten varieties RCMBL- 01, PLP-1, IBH-3, IBL-116, JBH-8, Rajindra brinjal, KS-356, JB-24, IBH-02 and CHBR-1 were found to be tolerant and fallen in the score of 0.0-2.0 (larvae/5plants), ten varieties such as HIC-13311, Arka Sree, MDV-01, Ramnagar Giant, DRNKU-03-26, Swarn Pratibha, Brinjal Round Green, JB-6, BCB-464 and JB-64 were observed to be moderately tolerant with score of 2.1-3.0, three varieties like JB-18, KS-331 and PBL-24 and were susceptible with score of 3.1-5.0 and the two varieties DBR-31 and Keshmiri Brinjal were highly susceptible with score of 5.1- above (Table-14).

Pooled data on Screening of 25 brinjal varieties for the resistance against BSFB revealed that the ten varieties RCMBL- 01, PLP-1, IBH-3, IBL-116, Rajindra brinjal, KS-356, JB-24, JBH-8, IBH-02 and CHBR-1 showed tolerance between the score of 0-2.0 (larvae/5plants), the five varieties Arka Sree, DRNKU-03-26, JB-6, BCB-464 and JB-64 were found moderately tolerant with score of 2.1-3.0, the eight varieties JB-18, HIC-13311, Ramnagar Giant, MDV-01, Swarn Pratibha, Brinjal Round Green, KS-331 and PBL-24 and were susceptible with score of 3.1-5.0 and the two varieties DBR-31and Keshmiri Brinjal were highly susceptible with score of 5.1- above (Table-15).

4.3.2 Red Spider Mites (RSM)

The screening of twenty five commonly grown brinjal varieties against Red Spider Mites showed that the two varieties RCMBL-01 and Swarn Pratibha were recorded moderately tolerant with score of 0-5.00, three varieties CHBR-1, Arka Sree and Ramnagar

Table 13: Larval population of Brinjal Shoot and Fruit Borer (BSFB) on brinjal varieties per 5 plants during 2014

Brinjal Varieties	Vegetative Stage								Fruiting Stage															
	Standard Weeks																							
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Over All Mean	Response
JB-18	0.06	0.53	1.06	1.60	1.73	2.00	2.53	3.06	3.60	5.53	5.80	3.20	2.86	3.46	8.73	10.20	8.80	8.66	6.53	5.03	4.26	1.06	4.10	**Susceptible**
RCMBL-01	0.00	0.30	0.46	0.80	1.00	1.06	1.20	1.46	1.53	1.80	1.66	0.93	1.00	1.26	1.66	1.73	1.60	1.06	0.73	0.66	0.40	0.00	1.01	**Tolerant**
PLP-1	0.00	0.06	0.33	0.60	0.93	1.06	1.26	1.40	1.46	2.53	2.80	1.53	1.53	2.13	2.53	2.60	2.73	1.80	1.06	0.66	0.40	0.00	1.34	**Tolerant**
IBH-3	0.00	0.20	0.53	1.26	1.73	1.86	2.13	2.53	2.66	2.86	1.73	1.33	2.20	2.33	2.46	2.66	2.06	1.26	0.73	0.40	0.33	0.00	1.51	**Tolerant**
KS-331	0.00	0.20	0.46	1.26	1.86	2.26	2.86	4.86	10.13	13.26	6.06	2.20	1.93	2.73	3.60	8.46	5.93	4.13	3.06	2.00	1.46	0.00	3.58	**Susceptible**
MDV-01	0.06	0.46	1.33	1.60	2.06	2.26	3.73	4.93	5.80	8.00	9.06	4.26	2.46	3.26	5.86	7.53	4.40	3.20	2.06	1.93	1.33	0.13	3.44	**Susceptible**
CHBR-1	0.00	0.20	0.80	0.80	1.26	1.80	2.20	2.53	2.86	3.33	4.13	3.13	2.60	3.73	3.86	4.60	4.06	3.93	2.86	1.93	1.06	0.00	2.34	**Moderately Tolerant**
DBR-31	0.13	0.46	1.40	2.13	2.40	3.20	3.80	8.26	7.60	10.33	11.20	6.80	5.20	8.53	12.46	10.00	9.86	8.26	7.60	3.86	2.40	0.06	5.72	**Highly Susceptible**
HIC-13311	0.06	0.33	0.60	1.20	1.53	1.60	4.46	6.00	8.20	13.86	15.06	5.40	4.26	2.40	6.60	10.40	5.73	3.53	2.46	1.20	0.60	0.41	4.36	**Susceptible**
IBL-116	0.00	0.20	0.46	0.73	1.13	1.53	2.06	2.13	2.60	2.73	2.86	1.53	1.73	1.80	2.06	2.46	2.13	1.40	1.00	0.53	0.40	0.00	1.43	**Tolerant**
PBL-24	0.06	0.40	0.93	1.40	2.20	2.93	3.20	4.06	5.06	11.66	12.66	4.53	2.93	3.86	6.00	10.60	11.20	6.40	5.00	4.46	2.66	1.93	4.74	**Susceptible**
Arka Sree	0.00	0.26	0.46	1.00	1.60	2.13	2.93	3.06	3.40	4.06	4.93	2.46	1.86	2.13	3.80	4.46	4.86	3.86	3.40	1.93	1.20	0.00	2.45	**Moderately Tolerant**
Brinjal Round Green	0.06	0.46	1.00	1.46	1.93	2.33	4.93	6.20	8.13	8.26	10.00	11.6	6.26	6.06	5.60	4.13	2.86	2.06	1.13	1.00	0.60	0.58	3.94	**Susceptible**
JBH-8	0.00	0.40	0.73	1.20	1.33	1.80	1.93	2.33	2.40	2.60	2.73	1.60	1.93	2.20	2.06	2.13	2.66	1.46	1.20	0.8	0.60	0.00	1.55	**Tolerant**
Ramnagar Gaint	0.00	0.13	0.26	0.33	2.20	3.93	6.00	9.73	10.06	11.86	14.33	7.46	5.46	3.40	1.46	1.60	2.13	1.06	0.86	0.73	0.26	0.00	3.78	**Susceptible**
Rajindra brinjal	0.00	0.13	0.33	0.86	0.93	1.33	1.40	1.53	1.13	1.06	1.60	1.73	1.60	1.73	1.86	1.93	1.40	1.13	0.93	0.6	0.33	0.00	1.07	**Tolerant**
KS-356	0.00	0.20	0.66	0.80	1.20	1.26	1.33	1.53	1.66	1.73	1.86	1.06	1.26	1.33	1.53	1.80	1.93	1.26	0.73	0.46	0.46	0.00	1.09	**Tolerant**
JB-24	0.00	0.13	0.26	0.33	0.46	0.93	1.26	1.60	1.60	1.80	1.93	1.13	1.00	1.20	1.86	1.66	1.46	1.00	0.86	0.66	0.26	0.00	0.97	**Tolerant**
Swarn Pratibha	0.00	0.06	0.33	0.53	1.66	3.73	5.73	7.06	7.93	13.20	10.06	6.60	4.80	1.73	2.40	2.53	1.73	0.86	0.73	0.60	0.40	0.00	3.30	**Susceptible**
DRNKU-03-26	0.06	0.40	0.66	1.40	2.40	2.73	3.26	3.60	4.20	4.66	2.80	3.53	3.66	3.86	4.06	4.46	3.26	1.86	1.20	1.00	0.53	0.26	2.44	**Moderately Tolerant**
IBH-02	0.00	0.20	0.40	0.66	0.86	1.06	1.20	1.33	1.53	1.73	1.93	1.20	1.40	1.53	1.60	1.66	1.80	1.13	0.93	0.40	0.26	0.00	1.04	**Tolerant**
BCB-464	0.00	0.26	0.40	0.86	0.93	1.00	3.40	3.86	4.13	4.26	4.60	2.20	1.53	1.80	2.60	2.73	2.46	2.26	1.46	0.80	0.60	0.00	1.92	**Tolerant**
JB-6	0.06	0.40	0.60	1.06	1.40	1.86	2.53	5.26	5.13	12.00	13.73	5.53	3.60	1.86	2.33	3.13	3.53	2.46	1.80	1.40	0.80	1.46	3.27	**Susceptible**
JB-64	0.06	0.20	0.40	0.86	1.26	2.13	2.86	3.40	4.53	4.73	4.80	1.86	1.93	2.80	3.06	3.60	3.73	1.86	1.26	0.93	0.80	0.73	2.17	**Moderately Tolerant**
Kashmiri Brinjal (Control)	0.33	1.53	1.80	2.20	3.13	3.73	4.60	5.60	9.20	10.07	14.20	7.40	11.50	11.73	12.46	13.66	15.86	9.73	6.06	5.00	3.46	2.21	7.07	**Highly Susceptible**

Table 14: Larval Population of Brinjal Shoot and Fruit Borer (BSFB) on brinjal varieties per 5 plants during 2015

Brinjal Varieties	**Vegetative Stage**								**Fruiting Stage**														
	Standard Weeks																						
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**Over all mean**	**Response**
JB-18	0.00	0.60	0.93	1.46	1.73	2.20	2.60	3.20	3.80	4.46	5.73	2.80	2.73	3.26	6.00	6.66	8.80	8.13	6.93	5.66	4.60	3.92	**Susceptible**
RCMBL-01	0.00	0.26	0.40	0.80	1.20	1.06	0.80	1.40	1.60	1.66	1.86	0.86	0.80	1.33	1.66	1.80	1.20	0.93	0.73	0.66	0.40	1.02	**Tolerant**
PLp-1	0.00	0.13	0.26	0.66	0.93	0.93	1.26	1.20	1.33	1.80	2.40	1.40	1.50	2.06	2.53	2.60	2.86	1.73	1.06	0.80	0.60	1.34	**Tolerant**
IBH-3	0.00	0.06	0.60	1.06	1.60	1.80	2.00	2.46	2.80	2.93	3.00	1.26	1.46	2.06	2.13	2.26	2.40	1.40	0.86	0.46	0.40	1.57	**Tolerant**
KS-331	0.00	1.34	0.33	1.00	1.80	2.26	2.86	3.13	5.26	7.40	8.73	4.46	1.86	2.40	3.46	4.20	4.86	4.00	2.86	1.73	1.13	3.10	**Susceptible**
MDV-01	0.00	0.46	1.06	1.53	1.86	2.13	2.40	2.86	5.53	7.20	7.66	4.33	2.20	3.26	3.73	4.26	3.86	3.53	3.26	2.13	1.26	3.07	**Moderately Tolerant**
CHBR-1	0.00	0.06	0.33	0.26	0.20	0.86	1.26	1.66	1.73	1.93	2.00	1.20	1.13	1.20	1.80	1.86	1.73	1.20	1.00	0.93	0.46	1.09	**Tolerant**
DBR-31	0.00	0.46	0.80	1.60	2.00	2.53	2.86	5.60	7.60	8.26	5.86	5.26	4.73	7.46	12.2	8.80	8.13	7.93	6.46	4.40	3.46	5.07	**Highly Susceptible**
HIC-13311	0.00	0.40	0.53	1.00	1.46	1.80	2.26	3.93	7.26	8.53	8.86	4.93	1.86	2.06	2.66	3.60	2.86	2.20	1.60	1.06	0.80	2.84	**Moderately Tolerant**
IBL-116	0.00	0.20	0.60	1.00	1.40	1.73	2.40	2.60	2.60	2.80	2.93	1.66	1.80	1.93	2.13	2.40	2.06	1.13	0.80	0.53	0.46	1.58	**Tolerant**
PBL-24	0.06	0.53	0.86	1.33	2.06	3.06	3.43	4.53	5.20	5.80	6.46	1.80	2.00	4.26	6.40	9.53	13.20	7.20	6.60	5.20	4.93	4.50	**Susceptible**
Arka Sree	0.00	0.13	0.46	0.86	1.60	2.26	2.86	3.00	3.53	4.00	4.20	1.93	1.80	2.26	4.33	4.46	4.93	3.86	3.40	1.86	1.13	2.52	**Moderately Tolerant**
Brinjal round green	0.00	0.60	1.06	1.53	1.86	2.20	2.46	2.80	5.53	7.4	7.86	4.13	1.13	2.53	3.20	4.53	2.86	1.86	1.73	1.60	0.80	2.75	**Moderately Tolerant**
JBH-8	0.00	0.46	0.86	1.13	1.33	1.66	1.80	1.93	1.02	2.13	2.53	0.93	1.13	1.66	2.13	2.26	2.60	1.76	1.60	1.13	0.73	1.47	**Tolerant**
Rampur Gaint	0.00	0.06	0.20	0.40	0.60	1.13	1.20	4.40	6.93	7.66	8.93	5.06	4.73	1.26	1.40	1.60	1.80	1.40	1.20	0.46	0.33	2.42	**Moderately Tolerant**
Rajindra brinjal	0.00	0.06	0.46	0.93	0.94	1.06	1.13	1.06	1.20	1.00	1.67	1.67	1.93	1.60	1.66	1.86	1.53	1.46	1.26	0.66	0.46	1.12	**Tolerant**
KS-356	0.00	0.26	0.60	0.73	1.26	1.20	0.73	1.33	1.73	1.80	1.93	0.80	0.80	1.46	1.53	1.73	1.93	1.80	1.53	1.13	0.86	1.20	**Tolerant**
JB-24	0.00	0.06	0.33	0.26	0.20	0.86	1.26	1.66	1.73	1.93	2.00	1.20	1.13	1.20	1.80	1.86	1.73	1.20	1.00	0.93	0.46	1.09	**Tolerant**
Swarn Pratibha	0.00	0.13	0.33	0.53	0.86	1.13	3.86	6.00	7.40	8.40	2.80	1.13	1.26	1.66	2.40	2.73	1.86	1.26	1.06	0.86	0.66	2.21	**Moderately Tolerant**
DRNKU-03-26	0.00	0.20	0.66	1.20	2.20	2.26	2.86	3.20	3.66	4.86	4.20	3.26	2.40	3.46	3.53	4.30	3.26	2.93	2.66	1.20	0.80	2.53	**Moderately Tolerant**
IBH-02	0.00	0.26	0.60	0.80	1.00	1.26	1.33	1.40	1.66	1.86	1.86	0.73	0.80	1.26	1.53	1.60	1.86	1.33	1.20	1.00	0.60	1.14	**Tolerant**
BCB-464	0.00	0.06	0.27	0.60	0.87	0.80	0.73	0.93	4.46	6.46	7.73	5.53	1.46	1.80	2.80	2.93	2.46	2.13	1.53	1.00	0.73	2.17	**Moderately Tolerant**
JB-6	0.06	0.46	0.80	1.00	1.43	2.13	2.60	3.40	4.20	6.33	7.46	0.86	1.06	1.73	2.20	2.53	2.33	2.53	2.20	1.86	1.06	2.30	**Moderately Tolerant**
JB-64	0.00	0.26	0.60	0.93	1.60	2.20	2.60	3.46	4.20	4.33	4.93	1.86	2.00	3.26	3.46	3.53	3.93	2.10	1.73	1.33	1.20	2.36	**Moderately Tolerant**
Kashmiri Brinjal (Control)	0.86	1.00	1.40	2.26	3.00	3.73	4.46	5.20	5.80	6.73	9.06	15.20	12.86	10.26	13.20	15.93	17.80	11.26	7.86	6.86	6.20	7.67	**Highly Susceptible**

Table 15: Pooled data on larval Population of Brinjal Shoot and Fruit Borer (BSFB) on brinjal varieties per 5 plants

Brinjal varieties	Vegetative Stage								Fruiting Stage														
	Standard Weeks																						
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Over all Mean	Response
JB-18	0.03	0.57	1.00	1.53	1.73	2.10	2.57	3.13	3.70	4.99	5.77	3.00	2.79	3.36	7.37	8.43	8.80	8.39	6.73	5.35	4.43	4.08	**Susceptible**
RCMBL-01	0.00	0.28	0.43	0.80	1.10	1.06	1.00	1.43	1.56	1.73	1.76	0.89	0.90	1.30	1.66	1.77	1.40	0.99	0.73	0.66	0.40	1.04	**Tolerant**
PLp-1	0.00	0.09	0.29	0.63	0.93	0.99	1.26	1.30	1.39	2.16	2.60	1.47	1.52	2.09	2.53	2.60	2.79	1.76	1.06	0.73	0.50	1.37	**Tolerant**
IBH-3	0.00	0.13	0.56	1.16	1.67	1.83	2.07	2.49	2.73	2.89	2.36	1.29	1.83	2.19	2.29	2.46	2.23	1.33	0.79	0.43	0.365	1.58	**Tolerant**
KS-331	0.00	0.77	0.39	1.13	1.83	2.26	2.86	3.99	7.69	10.33	7.39	3.33	1.89	2.56	3.53	6.33	5.39	4.07	2.96	1.86	1.29	3.42	**Susceptible**
MDV-01	0.03	0.46	1.19	1.56	1.96	2.19	3.06	3.89	5.66	7.60	8.36	4.29	2.33	3.26	4.79	5.89	4.13	3.36	2.66	2.03	1.29	3.34	**Susceptible**
CHBR-1	0.00	0.13	0.57	0.53	0.73	1.33	1.73	2.09	2.29	2.63	3.06	2.16	1.86	2.46	2.83	3.23	2.89	2.56	1.93	1.43	0.76	1.77	**Tolerant**
DBR-31	0.06	0.46	1.10	1.86	2.20	2.86	3.33	6.93	7.60	9.29	8.53	6.03	4.96	7.99	12.33	9.4	8.99	8.09	7.03	4.13	2.93	5.53	**Highly Susceptible**
HIC-13311	0.03	0.36	0.56	1.10	1.49	1.70	3.36	4.96	7.73	11.19	11.96	5.16	3.06	2.23	4.63	7.00	4.29	2.86	2.03	1.13	0.70	3.69	**Susceptible**
IBL-116	0.00	0.20	0.53	0.86	1.26	1.63	2.23	2.36	2.60	2.76	2.89	1.59	1.76	1.86	2.09	2.43	2.09	1.26	0.90	0.53	0.43	1.54	**Tolerant**
PBL-24	0.06	0.46	0.89	1.36	2.13	2.99	3.31	4.29	5.13	8.73	9.56	3.16	2.46	4.06	6.20	10.06	12.20	6.80	5.80	4.83	3.79	4.68	**Susceptible**
Arka Sree	0.00	0.19	0.46	0.93	1.60	2.19	2.89	3.03	3.46	4.03	4.56	2.19	1.83	2.19	4.06	4.46	4.89	3.86	3.40	1.89	1.16	2.54	**Moderately Tolerant**
Brinjal round green	0.03	0.53	1.03	1.49	1.89	2.26	3.69	4.50	6.83	7.83	8.93	7.86	3.69	4.29	4.40	4.33	2.86	1.96	1.43	1.30	0.70	3.42	**Susceptible**
JBH-8	0.00	0.43	0.79	1.16	1.33	1.73	1.86	2.13	1.71	2.36	2.63	1.26	1.53	1.93	2.09	2.19	2.63	1.61	1.40	0.96	0.66	1.54	**Tolerant**
Rampur Gaint	0.00	0.09	0.23	0.36	1.40	2.53	3.60	7.06	8.49	9.76	11.63	6.26	5.09	2.33	1.43	1.60	1.96	1.23	1.03	0.59	0.29	3.19	**Susceptible**
Rajindra brinjal	0.00	0.09	0.26	0.63	0.76	1.23	1.30	2.96	4.03	4.36	5.26	3.39	3.16	1.49	1.63	1.76	1.60	1.26	1.06	0.53	0.33	1.77	**Tolerant**
KS-356	0.00	0.09	0.39	0.89	0.93	1.19	1.26	1.29	1.16	1.03	1.63	1.70	1.76	1.66	1.76	1.89	1.46	1.29	1.09	0.63	0.39	1.12	**Tolerant**
JB-24	0.00	0.09	0.29	0.29	0.33	0.89	1.26	1.63	1.66	1.86	1.96	1.16	1.06	1.20	1.83	1.76	1.59	1.10	0.93	0.79	0.36	1.05	**Tolerant**
Swarn Pratibha	0.00	0.03	0.27	1.26	1.98	3.83	4.90	6.09	7.07	10.51	9.09	7.97	4.24	2.02	2.28	2.07	1.45	0.71	1.86	2.15	1.87	3.41	**Susceptible**
DRNKU-03-26	0.03	0.30	0.66	1.30	2.30	2.49	3.06	3.40	3.93	4.76	3.50	3.39	3.03	3.66	3.79	4.38	3.26	2.39	1.93	1.10	0.66	2.54	**Moderately Tolerant**
IBH-02	0.00	0.23	0.50	0.73	0.93	1.16	1.26	1.36	1.59	1.79	1.89	0.96	1.10	1.39	1.56	1.63	1.83	1.23	1.06	0.70	0.43	1.11	**Tolerant**
BCB-464	0.00	0.16	0.33	0.73	0.90	0.90	2.06	2.39	4.29	5.36	6.16	3.86	1.49	1.80	2.70	2.83	2.46	2.19	1.49	0.90	0.66	2.08	**Moderately Tolerant**
JB-6	0.06	0.43	0.70	1.03	1.41	1.99	2.56	4.33	4.66	9.16	10.59	3.19	2.33	1.795	2.26	2.83	2.93	2.49	2.00	1.63	0.93	2.83	**Moderately Tolerant**
JB-64	0.03	0.23	0.50	0.89	1.43	2.16	2.73	3.43	4.36	4.53	4.86	1.86	1.96	3.03	3.26	3.56	3.83	1.98	1.49	1.13	1.00	2.23	**Moderately Tolerant**
Kashmiri Brinjal (Control)	0.59	1.26	1.60	2.23	3.06	3.73	4.53	5.40	7.50	8.40	11.63	11.30	12.18	10.99	12.83	14.79	16.83	10.49	6.96	5.93	4.83	7.48	**Highly Susceptible**

Giant were found to be low in resistance with score of 5.10-10.00, the six varieties MDV-01, DBR-31, Arka Shree, PBL-24, JB-24 and BCB-464 were observed to be susceptible with score of 10.10-15.00 and fourteen varieties JB-18, PLP-1, IBH-3, KS-331, HIC-13311, IBL-116, Brinjal Round Green, JBH-8, Rajindra brinjal, KS-356, DRNKU-03-26, IBH -02, JB-06, JB-64 and Kahmiri Brinjal were found highly susceptible with score of 15.10 – above (Table 16).

The results obtained during 2015 experimental period were more or less similar to that of previous year. Screening of brinjal varieties against red mite showed that the seven varieties *viz*., RCMBL-01, PLP-1, MDV-01, Rajindra brinjal, Ramnagar Giant, DBR-31and Swarn Pratibha were moderately tolerant with score of 0-5.00, the seven varieties like CHBR-1, JB-18, KS-356, Arka Sree, BCB-464, JB-24 and JB-64 were found to be low in resistance with score of 5.10-10.00, four varieties *i.e*., IBH-3, KS-331, Brinjal Round Green, and JBH-8 were found susceptible with score of 10.10-15.00 and seven varieties such as HIC-13311, IBL-116, PBL-24, DRNKU-03-26, IBH -02, JB-06, and Kahmiri Brinjal were observed to be highly susceptible with score of 15.10 – above (Table 17).

Pooled data on screening of brinjal varieties against red mite revealed that the three varieties RCMBL-01, Ramnagar Giant, and Swarn Pratibha were moderately tolerant with score of 0-5.00, the four varieties CHBR-1, MDV-01, Arka Sree and JB-24 were Low Resistance with score of 5.10-10.00, the five varieties, IBH-3, JB-18, Rajindra brinjal, DBR-31and BCB-464 were susceptible with score of 10.10-15.00 and thirteen varieties PLP-1, KS-331, HIC-13311, IBL-116, PBL-24, Brinjal Round Green, JBH-8 DRNKU-03-26, IBH -02, KS-356, JB-06, JB-64 and Kahmiri Brinjal were highly susceptible with score of 15.10 - above (Table 18).

4.4 Management of Brinjal Shoot and Fruit Borer

Three different Modules were formulated to evaluate the impact of eco-friendly Integrated Pest Management of BSFB larval population reduction on brinjal (Plate-6). For comparing the data sets, Post-hoc data analysis (Tukey-HSD test) was used. The performance of different IPM Modules in term of reduction of BSFB larval population are presented as follows-

Among the three Modules tested during 2014, Module-I was found to be superior in reducing the BSFB larval population (1.33 larvae/5plants) on shoots during the month of

Plate-6

Different modules for the management of BSFB infestation

(A) Field view of different modules during 2014 at Chatha Farm

(B) Field View of different modules during 2015 at Chatha Farm

© Use of net barrier and pheromone traps to reduce the BSFB infestation

(D) Installation of Wota trap inside the net barrier

(E) Spraying of botanicals in BIPM module

(F) Field view during 2015

Table 16: Population of Red Mite on brinjal varieties (4 cm^2 per leaf area) during 2014

Brinjal Varieties	Vegetative Stage								Fruiting Stage															
	Standard Weeks																							
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Overall Mean	Response
JB-18	0.00	0.00	0.17	0.59	2.24	5.35	2.86	4.88	5.59	30.90	44.48	32.48	30.12	41.62	50.04	44.53	36.24	39.64	27.22	13.90	10.10	3.42	19.38	**Highly Susceptible**
RCMBL-01	0.00	0.00	0.04	0.30	0.64	2.55	4.13	2.59	2.44	3.33	1.84	5.72	2.55	4.21	6.95	9.57	3.46	4.66	2.46	2.50	2.39	1.95	2.92	**Moderately Resistance**
PLP-1	0.00	3.15	4.24	3.26	6.57	5.44	6.51	12.68	15.06	31.99	37.11	12.68	23.21	51.46	59.19	54.28	40.64	44.21	26.57	17.75	18.95	13.13	22.18	**Highly Susceptible**
IBH-3	0.00	1.81	0.79	2.86	3.75	8.01	10.77	13.35	14.68	21.66	28.28	42.30	28.70	42.64	36.86	31.21	19.35	23.35	25.39	12.26	4.99	2.17	17.05	**Highly Susceptible**
KS-331	0.04	0.48	2.41	6.02	8.33	11.84	16.73	20.15	26.57	35.33	32.44	26.21	43.17	35.28	60.93	39.97	12.68	15.06	31.99	37.11	12.68	4.10	21.79	**Highly Susceptible**
MDV-01	0.04	0.81	2.57	3.95	3.50	4.57	4.62	5.82	8.08	10.61	15.99	13.57	6.17	14.28	22.63	27.57	16.28	9.70	21.37	18.04	6.42	2.46	10.43	**Susceptible**
CHBR-1	0.00	0.00	0.28	1.99	2.55	3.01	4.57	5.93	5.90	5.39	5.17	4.37	9.13	16.06	19.06	12.06	6.17	13.39	3.84	9.50	2.75	1.53	6.32	**Low Resistance**
DBR-31	0.38	0.64	2.30	4.66	3.81	4.10	4.88	5.86	8.44	14.04	15.99	14.97	9.28	17.44	26.28	29.22	19.64	13.84	23.48	18.19	8.66	3.08	11.85	**Susceptible**
HIC-13311	0.50	0.70	2.62	5.75	10.55	12.86	18.32	24.26	28.32	37.97	34.84	30.06	43.88	35.88	59.09	43.48	14.13	16.68	35.22	35.50	12.48	2.61	22.99	**Highly Susceptible**
IBL-116	0.17	3.10	4.54	4.75	7.74	5.64	8.53	12.68	17.31	34.2	40.88	14.28	25.04	52.06	60.06	55.13	44.35	48.10	27.82	19.61	20.93	14.17	23.68	**Highly Susceptible**
PBL-24	0.24	0.77	2.93	5.66	6.26	4.81	5.88	12.55	11.22	17.55	17.88	16.81	12.20	17.99	28.46	31.57	23.97	15.47	20.42	20.06	9.86	3.95	13.03	**Susceptible**
Arka Sree	0.00	0.086	0.93	2.33	3.65	4.24	5.24	5.75	7.39	5.98	5.33	4.81	9.35	18.09	20.84	12.05	6.53	13.74	3.30	10.89	5.67	2.09	6.74	**Low Resistance**
Brinjal Round Green	0.24	4.41	4.99	5.22	10.15	10.19	8.02	14.02	17.06	35.88	32.04	14.02	26.82	52.31	51.48	55.68	41.68	47.30	29.39	18.64	20.97	11.15	23.26	**Highly Susceptible**
JBH-8	0.33	0.75	1.55	3.02	4.22	7.33	5.52	4.88	12.04	35.39	47.4	38.02	44.75	45.44	60.08	52.46	40.68	39.64	30.97	15.77	11.93	4.97	23.05	**Highly Susceptible**
Ramnagar Gaint	0.04	0.53	0.97	2.24	3.17	4.39	4.95	6.86	6.77	5.93	5.84	5.48	10.39	17.06	20.06	12.73	7.95	14.39	6.59	9.50	2.88	1.17	6.81	**Low Resistance**
Rajindra brinjal	0.39	4.10	5.75	5.73	7.47	5.86	9.26	11.57	17.64	34.95	45.26	17.97	26.17	52.88	62.37	56.84	43.72	48.28	27.55	21.52	18.62	14.61	24.48	**Highly Susceptible**
KS-356	0.59	1.06	4.27	5.99	11.08	15.06	20.13	26.48	28.95	37.97	35.84	31.81	44.44	37.62	60.05	42.88	16.73	17.82	36.97	36.61	12.84	2.83	24.00	**Highly Susceptible**
JB-24	0.196	0.90	3.31	4.79	4.50	5.30	7.13	6.15	9.77	12.24	17.04	18.20	11.84	16.97	23.31	29.39	18.24	12.79	22.17	17.97	9.88	4.62	11.67	**Susceptible**
Swarn Pratibha	0.00	0.19	0.97	0.93	1.06	2.15	4.75	2.93	3.79	3.18	2.08	6.64	3.28	2.41	5.70	7.48	3.57	3.57	1.48	1.22	1.04	0.51	2.68	**Moderately Resistance**
DRNKU-03-26	0.48	2.01	3.62	5.75	6.35	6.62	8.11	14.94	18.4	34.93	40.30	14.97	26.53	51.73	58.01	54.75	46.24	47.98	28.68	20.08	21.48	14.44	23.93	**Highly Susceptible**
IBH-02	0.53	1.57	3.73	5.55	11.84	14.51	19.53	25.37	29.81	38.53	34.8	32.59	44.15	38.57	60.18	41.81	15.42	16.93	36.08	37.35	11.68	3.02	23.80	**Highly Susceptible**
BCB-464	0.35	0.84	3.48	5.90	6.66	4.55	6.24	12.93	9.93	16.59	16.28	17.44	13.15	17.24	30.01	32.64	24.82	16.66	18.24	19.10	10.04	5.53	13.12	**Susceptible**
JB-6	0.51	0.92	3.10	4.75	4.77	8.55	10.46	5.64	11.95	25.59	36.06	41.44	41.04	45.17	32.35	49.02	27.35	38.77	19.77	13.59	9.77	6.31	19.86	**Highly Susceptible**
JB-64	0.37	2.17	3.33	3.70	5.68	5.64	6.68	10.70	15.57	22.81	30.73	14.15	23.46	42.82	50.82	44.30	46.31	45.90	23.04	17.17	17.90	10.53	20.17	**Highly Susceptible**
Kashmiri Brinjal (Control)	0.31	0.04	1.88	3.48	3.59	4.53	5.64	4.88	7.70	11.68	14.84	27.04	46.04	63.17	45.9	29.62	34.75	26.77	20.21	16.21	10.48	5.77	17.48	**Highly Susceptible**

Table 17: Population of Red Mite on brinjal varieties ($4cm^2$ per leaf area) during 2015

Brinjal Varieties	Vegetative Stage								Fruiting Stage														
	Standard Weeks																						
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**Overall Mean**	**Response**
JB-18	0.00	0.19	2.10	2.26	3.08	4.61	4.26	6.66	4.88	6.39	5.84	5.88	10.13	12.42	18.62	12.90	7.73	13.37	6.02	8.90	3.91	6.67	**Low Resistance**
RCMBL-01	0.00	0.02	0.19	1.28	1.83	2.46	3.78	3.37	3.35	4.57	2.82	5.38	4.58	5.46	8.24	10.15	5.06	6.55	4.18	5.06	2.39	3.84	**Moderately Resistance**
PLp-1	0.10	0.82	2.48	4.44	4.61	6.12	5.86	6.79	8.82	11.04	14.79	13.35	10.30	14.81	22.24	31.10	14.06	5.70	12.04	13.35	5.86	9.94	**Moderately Resistance**
IBH-3	0.04	0.70	1.95	4.10	4.44	5.37	5.91	6.39	9.04	15.26	17.39	16.30	10.22	17.35	27.02	29.24	19.70	13.88	22.88	16.13	5.95	11.87	**Susceptible**
KS-331	0.08	0.77	2.48	6.44	6.51	6.64	7.35	14.15	14.02	20.02	16.66	19.97	14.59	18.12	27.37	34.19	24.93	15.94	21.28	10.84	3.80	13.62	**Susceptible**
MDV-01	0.02	0.19	1.73	2.46	4.96	5.90	6.10	7.53	8.75	7.81	7.37	6.15	11.62	21.83	22.28	12.46	8.24	14.27	4.66	8.35	4.19	7.94	**Moderately Resistance**
CHBR-1	0.00	0.00	0.44	2.15	3.52	3.66	4.17	6.13	5.57	5.93	5.04	4.75	7.57	12.95	6.99	6.57	7.53	4.32	6.59	3.93	0.70	4.69	**Low Resistance**
DBR-31	0.00	0.55	2.82	5.41	5.15	4.55	6.24	10.04	8.59	13.19	14.97	15.73	10.04	12.70	23.13	22.48	20.15	12.59	8.55	3.77	1.48	9.62	**Moderately Resistance**
HIC-13311	0.30	2.41	4.33	3.26	5.57	6.19	6.51	11.3	12.72	22.51	33.08	16.53	22.32	48.99	45.56	46.75	37.97	41.49	18.10	6.44	2.66	18.81	**Highly Susceptible**
IBL-116	0.30	2.06	3.30	4.30	4.88	8.59	12.33	14.81	15.68	22.63	34.64	40.59	32.08	45.77	39.24	31.21	20.93	16.64	9.73	6.02	1.62	17.49	**Highly Susceptible**
PBL-24	0.53	2.04	2.02	5.64	6.63	6.92	4.19	11.87	10.72	30.90	44.48	32.48	30.12	41.62	50.04	44.53	42.70	22.73	13.13	6.57	2.59	19.64	**Highly Resistance**
Arka Sree	0.00	0.36	2.57	3.95	3.50	4.57	4.62	5.82	8.08	10.61	9.97	9.66	6.17	10.81	8.84	12.44	11.04	9.70	13.53	8.59	2.86	7.03	**Low Resistance**
Brinjal round green	0.24	0.81	2.35	5.24	8.01	8.99	11.95	13.28	16.61	22.84	26.47	30.06	25.06	25.57	20.08	16.75	14.13	7.42	7.77	6.35	2.50	12.97	**Susceptible**
JBH-8	0.19	1.79	1.84	2.81	4.28	5.99	7.98	11.79	13.77	18.19	24.02	14.02	26.82	32.39	24.38	22.90	22.22	9.53	6.19	5.71	1.97	12.32	**Susceptible**
Rampur Gaint	0.00	0.00	0.21	0.68	1.01	1.86	2.2	2.39	3.10	4.79	4.68	4.08	7.79	4.33	5.77	4.53	5.46	3.88	2.50	1.17	0.28	2.89	**Moderately Resistance**
Rajindra brinjal	0.00	0.04	1.08	1.10	58.57	1.88	3.37	2.93	2.46	1.74	2.33	4.573	3.28	2.13	4.10	2.97	2.17	3.55	1.75	1.61	1.17	4.89	**Moderately Resistance**
KS-356	0.04	0.88	2.06	4.50	3.81	4.30	6.34	9.91	8.17	11.90	13.86	12.34	9.13	10.44	17.82	16.70	17.73	9.24	7.88	1.99	1.22	8.11	**Low resistance**
JB-24	0.00	0.00	0.44	1.28	2.83	2.90	4.37	6.81	8.75	7.15	7.37	6.15	9.57	16.24	15.19	9.73	5.93	9.15	4.66	3.68	0.88	5.86	**Low Resistance**
Swarn Pratibha	0.00	0.31	0.93	1.48	2.42	2.46	3.23	2.84	2.57	3.84	2.70	4.67	5.28	5.06	6.30	7.75	3.90	3.59	2.34	1.52	0.50	3.03	**Moderately Resistance**
DRNKU-03-26	0.79	2.57	3.41	4.22	8.55	8.90	6.84	12.33	12.30	26.68	30.79	14.02	25.64	41.24	39.30	41.17	35.85	38.17	27.77	14.44	3.90	18.99	**Highly Susceptible**
IBH-02	0.46	1.30	1.55	3.02	4.22	7.33	5.52	4.88	12.04	30.28	44.02	32.68	34.43	45.44	46.19	42.17	40.68	35.99	23.26	14.17	3.64	20.63	**Highly Susceptible**
BCB-464	0.00	0.00	0.59	1.41	2.79	3.55	5.39	7.42	8.59	10.84	13.19	16.40	6.43	13.88	15.24	20.08	20.93	12.86	8.33	2.73	0.70	8.16	**Low Resistance**
JB-6	0.35	1.15	4.27	5.99	11.30	3.02	18.79	23.71	28.33	36.44	36.91	35.70	39.99	38.48	44.68	41.13	16.73	16.59	35.84	11.99	4.79	22.20	**sceptible**
JB-64	.043	0.37	2.48	4.13	4.33	4.84	6.10	6.42	9.50	11.35	14.97	16.73	9.84	15.93	22.08	24.90	15.75	10.24	15.93	4.70	0.84	9.59	**tance**
Kashmiri Brinjal (Control)	0.99	1.41	3.39	4.26	9.77	2.64	16.95	18.77	28.70	35.67	34.02	29.44	39.52	38.57	47.91	39.37	15.42	15.90	35.28	15.39	2.73	21.24	**sceptible**

Table 18: Pooled data on population of Red Mite (adult) on brinjal varieties (4 cm^2 per leaf area)

Brinjal varieties	Vegetative Stage								Fruiting Stage														
	Standard Weeks																						
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Over all Mean	Response
JB-18	0.00	0.09	1.135	1.425	2.66	4.98	3.56	5.77	5.23	18.64	25.16	19.18	20.12	27.02	34.33	28.71	21.98	26.50	16.62	11.4	7.00	13.40	**Susceptible**
RCMBL-01	0.00	0.01	0.11	0.79	1.23	2.50	3.95	2.98	2.89	3.95	2.33	5.55	3.56	4.83	7.59	9.86	4.26	5.60	3.32	3.78	2.39	3.40	**Moderately Resistance**
PLp-1	0.05	1.98	3.36	3.85	5.59	5.78	6.18	9.73	11.94	21.51	25.95	13.01	16.75	33.13	40.71	42.69	27.35	24.95	19.30	15.55	12.40	16.27	**Highly Susceptible**
IBH-3	0.02	1.25	1.37	3.48	4.09	6.69	8.34	9.87	11.86	18.46	22.83	29.3	19.46	29.99	31.94	30.22	19.52	18.61	24.13	14.19	5.47	14.81	**Susceptible**
KS-331	0.06	0.62	2.44	6.23	7.42	9.24	12.04	17.15	20.29	27.67	24.55	23.09	28.88	26.7	44.15	37.08	18.80	15.5	26.63	23.97	8.24	18.13	**Highly Susceptible**
MDV-01	0.03	0.5	2.15	3.20	4.23	5.23	5.36	6.67	8.41	9.21	11.68	9.86	8.89	18.05	22.45	20.01	12.26	11.98	13.01	13.19	5.30	9.13	**Low Resistance**
CHBR-1	0.00	0.00	0.36	2.07	3.03	3.33	4.37	6.03	5.73	5.66	5.10	4.56	8.35	14.50	13.02	9.31	6.85	8.85	5.21	6.71	1.72	5.46	**Low Resistance**
DBR-31	0.19	0.59	2.56	5.03	4.48	4.32	5.56	7.95	8.51	13.61	15.48	15.35	9.66	15.07	24.70	25.85	19.89	13.21	16.01	10.98	5.07	10.67	**Susceptible**
HIC-13311	0.40	1.55	3.47	4.50	8.06	9.52	12.41	17.78	20.52	30.24	33.96	23.29	33.1	42.43	52.32	45.11	26.05	29.08	26.66	20.97	7.57	21.38	**Highly Susceptible**
IBL-116	0.23	2.58	3.92	4.52	6.31	7.115	10.43	13.74	16.49	28.41	37.76	27.43	28.56	48.91	49.65	43.17	32.64	32.37	18.77	12.81	11.27	20.81	**Highly Susceptible**
PBL-24	0.38	1.40	2.47	5.65	6.44	5.86	5.03	12.21	10.97	24.22	31.18	24.64	21.16	29.80	39.25	38.05	33.33	19.1	16.77	13.31	6.22	16.54	**Highly Susceptible**
Arka Sree	0.00	0.22	1.75	3.14	3.57	4.40	4.93	5.78	7.73	8.29	7.65	7.23	7.76	14.45	14.84	12.24	8.78	11.72	8.41	9.74	4.26	6.99	**Low Resistance**
Brinjal round green	0.24	2.61	3.67	5.23	9.08	9.59	9.98	13.65	16.83	29.36	29.25	22.04	25.94	38.94	35.78	36.21	27.90	27.36	18.58	12.49	11.73	18.40	**Highly Susceptible**
JBH-8	0.26	1.27	1.69	2.91	4.25	6.66	6.75	8.33	12.90	26.79	35.71	26.02	35.78	38.91	42.23	37.68	31.45	24.58	18.58	10.74	6.95	18.11	**Highly Susceptible**
Rampur Gaint	0.02	0.26	0.59	1.46	2.09	3.12	3.57	4.62	4.93	5.36	5.26	4.78	9.09	10.69	12.91	8.63	6.70	9.13	4.54	5.33	1.58	4.98	**Moderately Resistance**
Rajindra brinjal	0.19	2.07	3.41	3.41	33.02	3.87	6.31	7.25	10.05	18.34	23.79	11.27	14.72	27.50	33.23	29.90	22.94	25.91	14.65	11.56	9.89	14.92	**Susceptible**
KS-356	0.31	0.97	3.16	5.24	7.44	9.68	13.23	18.19	18.56	24.93	24.85	22.07	26.78	24.03	38.93	29.79	17.23	13.53	22.42	19.30	7.03	16.55	**Highly Susceptible**
JB-24	0.45	1.65	2.61	2.89	4.06	5.01	5.26	8.29	10.49	12.09	12.78	8.99	13.27	19.77	22.29	13.98	9.36	15.66	11.31	6.78	2.75	9.03	**Low Resistance**
Swarn Pratibha	0.00	0.25	0.95	1.20	1.74	2.30	3.99	2.88	3.18	3.51	2.39	5.65	4.28	3.73	6.00	7.61	3.73	3.58	1.91	1.37	0.77	2.90	**Moderately Resistance**
DRNKU-03-26	0.63	2.29	3.51	4.98	7.45	7.76	7.47	13.63	15.35	30.80	35.54	14.49	26.08	46.48	48.65	47.96	41.04	43.07	28.22	17.26	12.69	21.68	**Highly Susceptible**
IBH-02	0.49	1.43	2.64	4.28	8.03	10.92	12.52	15.12	20.92	34.40	39.41	32.63	39.29	42.00	53.18	41.99	28.05	26.46	29.67	25.76	7.66	22.70	**Highly Susceptible**
BCB-464	0.17	0.42	2.03	3.65	4.72	4.05	5.81	10.17	9.26	13.71	14.73	16.92	9.79	15.56	22.62	26.36	22.87	14.76	13.28	10.91	5.37	10.82	**Susceptible**
JB-6	0.43	1.035	3.68	5.37	8.03	10.78	14.62	14.67	20.14	31.01	36.48	38.57	40.51	41.82	38.51	45.07	22.04	27.68	27.80	12.79	7.28	21.35	**Highly Susceptible**
JB-64	0.20	1.27	2.90	3.91	5.00	5.24	6.39	8.56	12.53	17.08	22.85	15.44	16.65	29.37	36.45	34.6	31.03	28.07	19.48	10.93	9.37	15.11	**Highly Susceptible**
Kashmiri Brinjal (Control)	0.65	0.72	2.63	3.87	6.68	8.58	11.29	11.82	18.2	23.67	24.43	28.24	42.78	50.87	46.90	34.49	25.08	21.33	27.74	15.80	6.60	19.63	**Highly Susceptible**

April 2014 and found at par with Module-III. During the May month, the Module-III and Module-I were found at par in reducing the BSFB pest population (2.58 and 3.83 larvae/5plants) than the Module-II (5.83). Similar trend was also noticed during June month 2014. Module-III was found to be superior in reducing the larval population on brinjal shoots during the months of July (6.41) and found significantly different from Module-I and Module-II. During August, Module-III (3.11) and Module-I (3.88) were found to be at par in reducing the BSFB larval population. Overall, the impact of Module-III (4.63) was found to be the best and superior treatment combination than Module-I (5.71) and Module-II (7.98) in suppressing the BSFB larval population (Table 19). The descending order of performance of Modules were as follows: Module-III >Module-I>Module-II.

Module-I was found to be superior in reducing the BSFB larval population (2.00 and 4.11 larvae/5 plants) on shoots during the month of May and September 2015, respectively. During the June month, the Module-III and Module-I were found at par in reducing the BSFB pest population (3.53 and 4.66 larvae/5 plants) than the Module-II (7.33). Module-III was found to be superior in reducing the larval population on brinjal shoots during the months of July (6.00) and August (7.41) and found statistically significant with other two Modules. Whereas, Module-I (9.16 and 10.33) and Module-II (9.91 and 12.25) were found to be at par in reducing the BSFB larval population during July and August month, respectively. Overall, the impact of Module-III (5.60) was found to be the best and superior treatment combination, although Module-II was at par with Module-I (6.08) in suppressing the BSFB larval population on shoots (Table 20). The descending order of performance of three different Modules were as follows: Module-III >Module-I>Module-II.

Among the entire period of investigation, Module-III was found to be superior in obtaining the healthy fruits (47.20 /5 plants) and reduction in infested fruits (17.60 /5 plants) on the basis of number whereas, and on weight basis, 3.60 kg/5 plants healthy fruits and 1.07 kg/5 plants infested fruits were obtained, respectively. In Module-I, the total number of the healthy fruits obtained on number basis were 39.26 /5 plants and reduction in infested fruits were found to be 32.33/5 plants whereas, on weight basis, 2.28 kg/5 plants healthy fruits and 1.58 kg/5 plants infested fruits were obtained. Similarly, in Module-II, the healthy fruits on number basis was found to be 23.60/5 plants and on weight basis 1.66 kg/5 plants were recorded, respectively. Whereas, the total number of infested fruits 38.66 /5 plants and on weight basis 2.37 kg/5 plants were recorded (Table 21).

Table 19: Evaluation of eco-friendly Integrated Pest management modules on the basis of shoot infestation by BSFB larval population during 2014

Treatments	April, 2014	May, 2014	June, 2014	July, 2014	August, 2014	Cumulative
Module-I	1.33^{a}	3.83^{a}	7.66^{a}	10.25^{b}	3.88^{a}	5.71^{b}
Module-II	4.66^{b}	5.83^{b}	10.66^{b}	10.08^{b}	7.55^{b}	7.98^{c}
Module-III	2.11^{a}	2.58^{a}	5.86^{a}	6.41^{a}	3.11^{a}	4.63^{a}
F-value (P-value)	**14.00 (0.000)**	**8.85 (0.002)**	**10.00 (0.001)**	**5.93 (0.009)**	**28.78 (0.000)**	**24.05 (0.000)**

Treatments with the same letters are not significantly different (P <0.05).

Table 20: Evaluation of eco-friendly Integrated Pest management modules on the basis of shoot infestation by BSFB larval population during 2015

Treatments	May, 2015	June, 2015	July, 2015	August, 2015	September, 2015	Cumulative
Module-I	2.00[a]	4.66 [a]	9.16 [b]	10.33[b]	4.11 [a]	6.08 [a]
Module-II	2.67[b]	7.33[b]	9.91 [b]	12.25 [b]	7.66 [b]	7.65 [b]
Module-III	2.67[b]	3.53 [a]	6.00 [a]	7.41 [a]	4.55 [b]	5.60 [a]
F-value (P-value)	**4.63 (0.021)**	**2.77 (0.000)**	**8.80 (0.002)**	**11.36 (0.000)**	**4.58 (0.027)**	**13.91 (0.000)**

Treatments with the same letter are not significantly different (P <0.05).

Table 21: Evaluation of eco-friendly Integrated Pest management modules on the basis of Fruits infestation by BSFB larval population during 2014

	Fruit numbers			Fruits Weight (Kg)		
Treatments	**Infested**	**Un-Infested**	**Total**	**Infested**	**Un-Infested**	**Total**
Module-I	32.33[b]	39.26[b]	71.33[b]	1.58[a]	2.28[a]	3.86[a]
Module-II	38.66[c]	23.60[a]	51.00[a]	2.37[b]	1.66[a]	4.04[a]
Module-III	17.60[a]	47.20[b]	65.46[b]	1.07[a]	3.60[b]	4.67[b]
F-value **(P-value)**	**32.37** **(0.000)**	**19.21** **(0.000)**	**16.43** **(0.000)**	**16.53** **(0.000)**	**26.22** **(0.000)**	**4.69** **(0.017)**

Treatments with the same letter are not significantly different ($P < 0.05$).

Module-III was found to be superior in obtaining the healthy fruits on number basis (46.46 /5 plants) and reducing the infested fruits (19.20 /5 plants) and on weight basis (3.22 kg/5 plants healthy fruits) and 0.94 kg/5 plants infested fruits, respectively. In Module-I, the total number of the healthy fruits obtained on number basis were 38.46 /5 plants and reduction of infested fruits were found to be 34.46 kg/5 plants whereas, on number basis (38.46 /5 plants healthy fruits) (34.46/5 plants infested fruits) and weight basis (healthy fruits 2.16 kg/5 plants) (infested fruits 1.46 kg/5 plants) were obtained, respectively. Similarly, in Module-II, the healthy fruits on number basis was found to be 26.00 kg/5 plants and on weight basis 1.74 kg/5 plants, respectively. Whereas, the total number of infested fruits 29.53 /5 plants and on weight basis 1.81 kg/5 plants were recorded (Table 22). Module-III was found to be superior in suppressing the larval pest population and increase in healthy fruits on the fruit number (72.86 /5 plants) and on weight basis (4.12 kg/5 plants) followed by Module-I (67.00 infested fruits/5 plants and 3.42 kg healthy fruits/5 plants) and Module-II (55.53 infested fruits/5 plants and 2.79 healthy fruits/5 plants) respectively. Module-II was found to be less effective in reducing the BSFB larval population during the entire course of investigation (Table 22). The descending order of performance of three Modules were found as follows- Module-III >Module-I>Module-II.

4.5 Parasitization of larval parasitoid, *Trathala flavo-orbitalis*

The data regarding Occurrence of *Trathala flavo-orbitalis* in terms of parasitization during 2014 and 2015 is given in Table 23. The larval and pupal parasitoid of BSFB, *Trathala flavo-orbitalis* was found abundantly in the field condition and recovered in enough numbers in different types of Modules used during both years of experimentation. The infested fruits were brought to the laboratory at different intervals throughout the experimentation for emergence of parasitoids for further calculation of parasitisation of BSFB larvae. The mean population of *T. flavo-orbitalis* was found to be superior in IIIrd Module with the highest overall mean population of 4.60 adult/20 infested fruits. Again, the maximum parasitisation was recorded in Module-IIIrd with 22.99±7.60 per cent followed by Module Ist with mean population 3.99 adult/20 infested fruits and parasitization per cent was found to be 19.98±6.14%. While in case of IInd Module, 1.80 adult population/20 infested fruits was recovered with 8.98% parasitization during 2014.

Table 22: Evaluation of eco-friendly Integrated Pest management modules on the basis of Fruits infestation by BSFB larval population during 2015

Fruit numbers				Fruits Weight (Kg)		
Treatments	**Infested**	**Un-Infested**	**Total**	**Infested**	**Un-Infested**	**Total**
Module-I	34.46^{b}	38.46^{b}	67.00^{b}	1.46^{ab}	2.16^{a}	3.42^{ab}
Module-II	29.53^{b}	26.00^{a}	55.53^{a}	1.81^{b}	1.74^{a}	2.79^{b}
Module-III	19.20^{a}	46.46^{b}	72.86^{b}	0.94^{a}	3.22^{b}	4.12^{a}
F-value **(P-value)**	**10.53** **(0.000)**	**11.25** **(0.000)**	**5.89** **(0.007)**	**6.26** **(0.006)**	**14.19** **(0.000)**	**5.42** **(0.010)**

Treatments with the same letter are not significantly different ($P < 0.05$).

Similar trend was also observed during 2015 experimentation. The larval parasitoid of BSFB, *T. flavo-orbitalis* was found to be superior in IIIrd Module with the overall mean population of 5.86 adult/20 infested fruits and percentage parasitization was recorded to be 29.33±6.62. Module IIIrd was followed by the Module Ist with the overall mean population 3.59 adult/20 infested fruits and parasitization per cent was 17.99±5.35. while in case of IInd Module, 1.66 adult population/20 infested fruits were recovered with 8.32±2.42 per cent parasitisation, respectively (Table 23, Fig. 7).

Pooled data on occurrence of larval parasitoid, *T. flavo-orbitalis* and its parasitization in different Modules revealed that Module IIIrd was found to be superior in overall mean population of 5.26 adult/20 infested fruits and overall parasitization which was recorded to be 26.31 per cent. Module Ist was found to be intermediate in terms of overall population 3.79 adult/20 infested fruits and parasitization 18.82 per cent. Module IInd was found to be inferior in terms of mean adult population recovery with 1.29 adult population/20 infested fruits and parasitisation was observed to 8.64 per cent (Table 24, Fig. 8).

4.6 Economics of different IPM Modules for management of BSFB in brinjal during 2014 and 2015

For each Modules, increase in fruit yield over control plots was worked out and monetary value of additional quantity of brinjal for each Module was estimated at the prevailing market rate of Rs. 1500/q. The net benefit due to each Module was calculated after deducting the expenditure incurred on implementing various control methods under Modules and labour charges for treatments.

The perusal of the data during 2014 revealed that all Modules were found to be cost effective (Table 25). The highest yield was found in case of Module-III (BIPM) 250 q/ha followed by Module-I (Recommended practices of SKUAST-J) 190 q/ha and Module-II (Farmer's practices) 110 q/ha. The Module-III was found in giving the highest benefit of Rs. 146850.00 than the Module-I which obtained the benefits of Rs. 75550.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III (1:2.33) than Module-I which showed (1:1.70) C: B ratio.

The perusal of the 2015 data showed that all Modules were found to be cost effective. The highest yield was found in case of Module-III (BIPM) 230 q/ha followed by Module-I (Recommended practices of SKUAST- J) 175 q/ha and Module-II (Farmer

Fig 7: Occurrence of BFSB larval parasitoid, *Trathala flavo-orbitalis* and its parasitization in different modules during 2014 and 2015

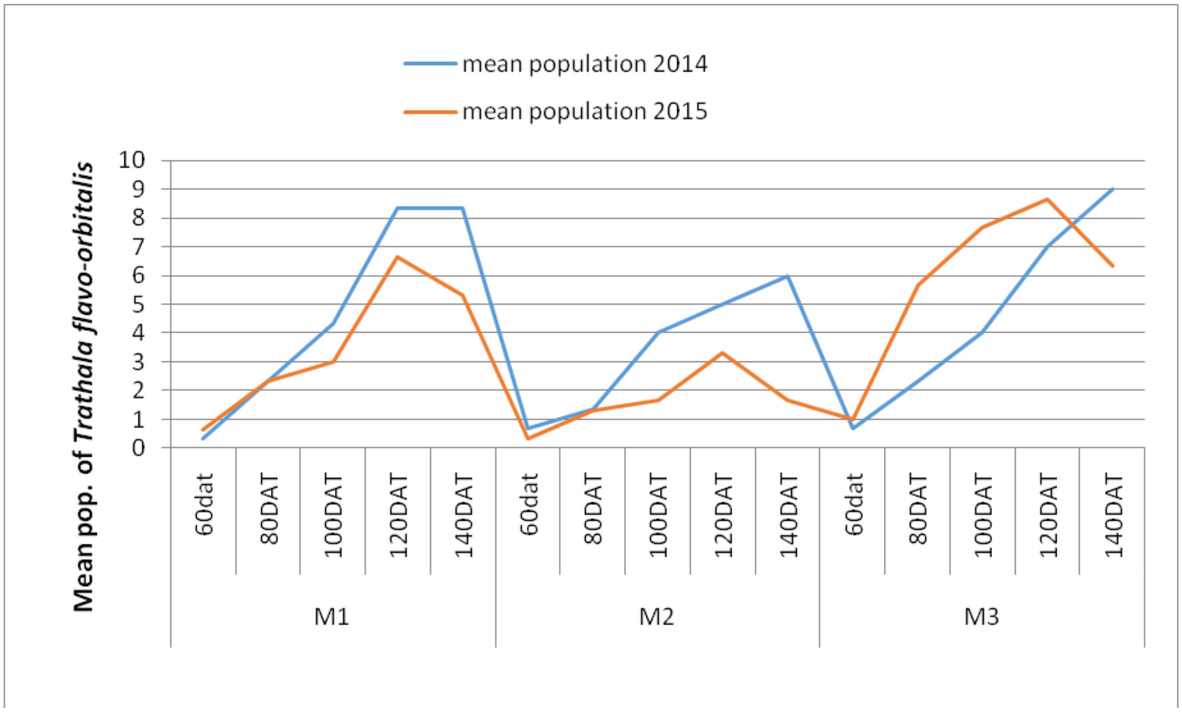


Fig 8: Pooled data of occurrence of BFSB larval parasitoid, *Trathala flavo-orbitalis* and its parasitization in different modules

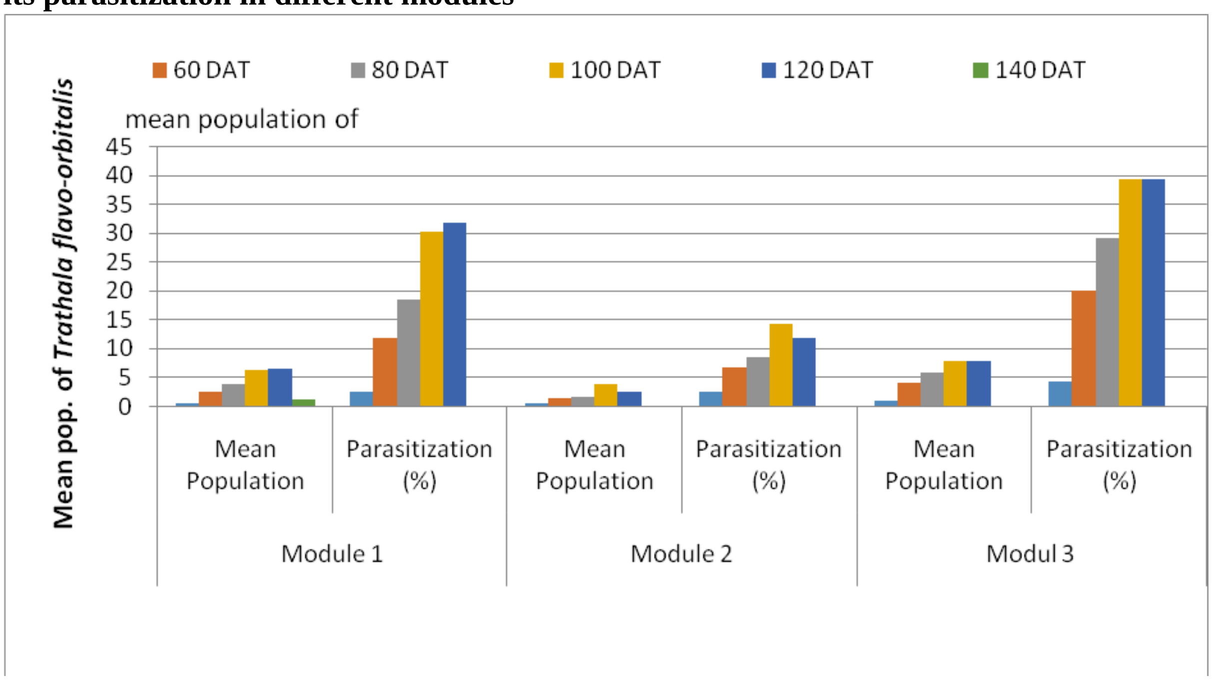


Table 23: Occurence and parasitization of BFSB larvae by parasitoid, *Trathala flavo-orbitalis* adult population per 20 infested fruits in different modules

Modules		During 2014						During 2015					
		Time (Days after transplantion)						Time (Days after transplantion)					
		40	60	80	100	120	Mean ± S.E.	40	60	80	100	120	Mean ± S.E.
Module I	**Mean Population**	0.33	2.33	4.33	5.66	7.33	3.99±1.22	0.66	2.33	3.00	6.66	5.33	3.59±1.07
	Parasitization (%)	1.65	11.65	21.65	28.3	36.65	19.98±6.14	3.33	11.65	15.00	33.33	26.65	17.99±5.35
Module II	**Mean Population**	0.66	1.33	1.66	2.33	3.00	1.80±0.40	0.33	1.33	1.66	3.33	1.66	1.66±0.48
	Parasitization (%)	3.30	6.65	8.00	11.65	15.00	8.92±2.02	1.65	6.65	8.33	16.65	8.33	8.32±2.42
Module III	**Mean Population**	0.66	2.33	4.00	7.00	9.00	4.60±1.52	1.00	5.66	7.66	8.66	6.33	5.86±1.32
	Parasitization (%)	3.30	11.65	20.00	35.00	45.00	22.99±7.60	5.00	28.33	38.33	43.33	31.65	29.33±6.62

Table 24: Pooled data on occurrence and parasitization of BFSB larvae by parasitoid, *Trathala flavo-orbitalis* adult population per 20 infested fruits in different modules

Modules		**Time (Date after transplanting)**					
		40	**60**	**80**	**100**	**120**	**Mean ± S.E.**
Module I	**Mean Population**	0.49	2.33	3.66	6.16	6.33	3.79±1.12
	Parasitization (%)	2.45	11.65	18.30	30.08	31.65	18.82±5.52
Module II	**Mean Population**	0.49	1.33	1.66	3.83	2.33	1.29±1.25
	Parasitization (%)	2.45	6.65	8.33	14.15	11.65	8.64±4.52
Module III	**Mean Population**	0.83	3.99	5.83	7.83	7.83	5.26±2.94
	Parasitization (%)	4.15	19.97	29.15	39.15	39.15	26.31±14.73

Table 25: Economic of different IPM modules for management of BSFB in brinjal

S. N.	Treatment	Average yield (q/ha)	Increase over control (q)	Value of additional yield (Rs.)	Cost of treatment (Rs.)	Net profit (Rs.)	Cost benefit ratio
During 2014							
1	Module III	250.00	140.00	210000.00	63150.00	146850.00	1:2.33
2	Module I	190.00	80.00	12000.00	44500.00	75500.00	1:1.70
3	Module II (Control)	110.00	-	-	-	-	-
During 2015							
1	Module III	230.00	125.00	187500.00	63150.00	124350.00	1:1.96
2	Module I	175.00	70.00	105000.00	44500.00	60500.00	1:1.35
3	Module II (Control)	105.00	-	-	-	-	-

Cost of brinjal fruits during 2014 was Rs. 1500/ quintal
Labour charges @ Rs. 250/ Labour /day

practices) 105 q/ha. The Module-III was found to be best in giving the highest benefit of Rs. 124350.00 than Module-I which gave the benefit of Rs. 60500.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III (1:1.96) while (1:1.35) cost: benefit ratio was obtained in Module-I.

The perusal of pooled data on Cost benefit ratio for different IPM Modules during both the years showed that all Modules were found to be cost effective. The highest yield was obtained in case of Module-III (BIPM) 240 q/ha followed by Module-I (Recommended practices of SKUAST- J) 182.5 q/ha and Module-II (Farmer's practices) 107.5 q/ha. The Module-III gave the highest benefit of Rs. 199350.00 than Module-I which received the benefits of Rs. 68000.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III with 1:3.15 than Module-I which showed 1:1.52 cost: benefit ratio (Table 26).

Table 26: Pooled data on economic of different IPM modules for management of BSFB in brinjal

S. N.	Treatment	Average yield (q/ha)	Increase over control (q)	Value of additional yield (Rs.)	Cost of treatment (Rs.)	Net profit (Rs.)	Cost benefit ratio
1	Module III	240.00	132.50	262500.00	63150.00	199350.00	1:3.15
2	Module I	182.50	75.00	112500.00	44500.00	68000.00	1:1.52
3	Module II (Control)	107.50	-	-	-	-	-

Cost of brinjal fruits during 2015 was Rs. 1500/ quintal
Labour charges @ Rs. 250/Labour/day

Chapter 5

Discussion

Chapter-5

DISCUSSION

The present investigation was carried out with an objective to study the Monitoring the occurrence of Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* (BSFB), Red Spider Mitess (RSM) and natural enemy fauna, screening of twenty five brinjal varieties against BSFB and Red Spider Mites and evaluation of an eco-friendly Integrated Pest management Modules for *L. orbonalis* in brinjal crops ecosystem. The results obtained in this study on bio-intensive integrated pest management of Brinjal Shoot and Fruit Borer and Red Spider Mites of brinjal (*Solanum melongena* L.) are discussed as under:

5.1 Insect pests and natural enamies fauna of brinjal

The monitoring of major insect pests revealed that shoot and fruit borer and red mite were found damaging the brinjal and remain active throughout the cropping season at various growth stages of crop. The observations on seasonal natural fluctuation of BSFB and RSM on brinjal were recorded at weekly intervals starting from 15^{th} standard week i.e., soon after the appearance of larval population with twigs dropping symptoms, till 36^{th} standard week during 2014 and 17^{th} standard week to 37^{th} standard weeks during 2015.

A large magnitude of insect pest and natural enemy fauna (predators and parasitoids) were recorded in brinjal crop during two years of experimentation *i.e.*, 2014 and 2015. Out of fourteen (14) insect pests, five (5) insect pests were categorized as major insect pest such as Brinjal Shoot and Fruit Borer, Red Spider Mites, white fly, jassid and hadda beetle on the basis of economic losses caused in brinjal ecosystem. Apart from insect pest, a large number of natural enemy fauna (12 species of predators and 3 species of parasitoids) such as lady bird beetles, ground beetles, rove beetles, reduviid bug, big eyed bug, pentatomid bug, earwigs, praying mantis, green lacewing, european wasp, and predatory mites along with the three parasitoid namely *Trathala flavo-orbitalis*, *Goryphus nursei* and *Campoletes chlorideae* were recorded during both the years of experimentation. *In toto*, twenty nine (29) insect pests and natural enemy fauna were observed in in the brinjal ecosystem.

The present results are supported by the studies conducted by Vevai (1970), Das (2006), Latif *et al.* (2009), Yasodha and Natarajan (2009), Sankari (2010) and Dar *et al.* (2015) who recorded several species of insect-pests, parasitoids and predators along with few non insect pest species infesting brinjal crop. It is evident from the studies that the brinjal ecosystem has a great diversity of arthropod pests and natural enemy fauna which is likely to maintain a stable environment in the brinjal ecosystem.

5.2 Seasonal Incidence of Brinjal Shoot and Fruit Borer (BSFB) and Red Spider Mitess (RSM)

5.2.1 Seasonal incidence of larval population of Brinjal Shoot and Fruit Borer (BSFB)

The seasonal incidence of BSFB mean larval population per plant on brinjal ranged from 0.33 to 14.33 during 2014. Infestation was first observed nearly 30 days after transplanting *i.e*., from 16th standard week with an initial population of 0.33 larvae per plant. The population was observed to be increasing gradually till 24th SW recording a maximum of 14.33 larvae per plant. The larval population of BSFB then decreased till 30th standard week on the same crop up to 6.00 larvae per plant. Again, the population was observed to increasing up to 32nd SW, recording a maximum density of 11.66 mean larval population per plant. Thereafter, its population declined and minimum mean number of larvae per plant (1.33 larvae / plant) was recorded in 36th SW. Thus, there was two peak of BSFB larval population build-up observed during 24th and 32nd standard weeks on brinjal crop during 2014.

The seasonal incidence of BSFB larval population was recorded on 2nd year brinjal crop from the 17th SW up to 37th standard week, 2015. Incidence of this pest revealed that the mean BSFB larval population per plant in brinjal was ranged from 1.0 to 14.00. The population was quite fluctuating and observed to be low up to 22nd SW and then the population was observed to be increasing gradually till 30th standard week recording a peak larval number of 14.00 larvae per brinjal plant.

These findings were in supportive with those reported from India by Mall *et al,* 1992; Kumar *et al.*, 1997; Tripathy and Senaptati, 1998; Singh *et al.,* 2011 while studying the seasonal incidence of this pest Kaur *et al*., 2014 also reported that the larval population was feeding on shoots up to 41st standard week and thereafter these larvae were observed feeding on fruits. Kumar *et al.* (1997) recorded the peak shoot (15.71%) and fruit infestation

(71.09% by weight) during the last week of June and first week of July, respectively. Singh (1984) observed that the adults of *L. orbonalis* appear in March and the larvae caused extensive damage to the crop from June to August which seems to be accordance with the present findings.

Tripathy and Senapati (1998) also observed that crops planted during March to September recorded a higher level of shoot infestation than crops transplanted during remaining months. In both the years of the present study, the crop was transplanted during March (12th SW and 14th SW) which recorded a higher mean larval incidence of shoot and fruit borer (14.33 larval population /plant and 14.00 larval population /plant for 20014-2015, respectively. Similar findings was also recorded by Nayak *et al.*, 2014 who observed the first peak of BSFB larval activity (2.5 larvae plant^{-1} week^{-1}) during 32nd SMW (2nd week of August) while the second peak (2.9 larvae plant^{-1} week^{-1}) was noticed during 38th SMW (3rd week of September) in rainy season 2009.

5.2.2 Seasonal incidence of adult population of Brinjal Shoot and Fruit Borer (BSFB)

The data on trap catches of BFSB male adult population showed that the trap catches was recorded up to 20th standard week with peak catches of 5.33 moths per trap per week. The moth activity was observed in pheromone traps up to the harvest of crop i.e., 36th standard week. The adult population fluctuated and exhibiting one ‘V’ shaped oscillations between 22nd to 30th standard week. Thus, there were two peaks of adult trap catch population noticed during 20th standard week and in 30th standard week.

Similarly, the initial population of BSFB adult moth catches (0.66) was recorded in Wota trap during 15th standard week. A gradual increase was recorded up to 22th standard week with the peak catches of 22.33 moths per trap. The adult trap population fluctuated between 22th to 30th standard week, exhibiting two ‘V’ shaped oscillations between 22th to 28th standard week and 28th to 30th standard week. Thus, the two peaks were noticed during the year *viz*., first one on 22nd standard week and second during 30th standard week which constituted the two overlapping generations of BSFB pest in Jammu region.

The trap catches of BFSB (adult) population data during 2015 showed that the peak trap catches of 11.33 moths per trap per week in 30th standard week. The moth activity through trap catches continued to be noticed up to 37th standard week (0.6733 mean number of BSFB trap catches) at the time of harvesting. While, in Wota trap, the initial BSFB adult moth catch was recorded during 17th standard week and a gradual increase in trap catches were noticed up to 31st standard week with the peak activity of 19.67 moths per trap per week.

The findings of the present study also draw support from the observations made by Jhala *et al.* (2005) who assessed the three different types of traps (*viz.*, delta sticky trap, phero-trap and nomate trap) for trapping *L. orbonalis* and reported that nomate trap installed at a height of one metre from the ground level was found to be ideal in catching maximum moths. The results of the present study get further impetus from the report of Srinivasan and Babu (2000) who also tested locally produced clear plastic water traps for the control of BSFB, *L. orbonalis* and reported that significantly more male moths were caught in traps treated with water containing powdered detergent, light gear oil or insecticide. The present investigation also established that fact that wota or water trap was found to be more efficient than pheromone trap in catching the male moths population. The probable reason for more number of catches in wota traps was due to more exposed area and reduced surface tension of water for the weak flier like BSFB borer adult population in the present result.

5.2.3 Seasonal incidence of Red Spider Mites (RSM)

The seasonal incidence of Red Spider Mites (RSM), *T. neocalidonicus* was found infesting the brinjal crop during the different stages of crop growth and recorded throughout the cropping season during 2014 whereas, *T. urticae* was confined only to seedlings grown in the nursery. The mean number of Red Spider Mites population/ 4 cm^2 on brinjal ranged from 0.67 to 51.81. Infestation was first observed from 15th standard week with an initial population of 0.67 mites per 4 cm^2. From there, the population was observed to be increasing gradually till 25th standard week recording a maximum of 51.81 mean number of mites per 4 cm^2 on brinjal. Thereafter, the red mites population was observed to be declining up to 7.84 mean number of adult mite population per 4 cm^2 leaf area in 36th SW.

The initial appearance of Red Spider Mites (RSM) was observed during 18th standard week with 0.68 mean number of adult mite population per 4 cm^2 leaf area during 2015. There were two peaks of adult mite populations were recorded during 2015 *i.e.*, in 26th SW with 36.02 red mite per 4cm^2 leaf area and in 35th SW with 24.37 mite per 4cm^2 leaf area, respectively. The corresponding maximum and minimum temperature, morning and evening relative humidity and rainfall was recorded to be 36.7°C, 23.6°C,67,48 per cent and 89.9

mm during 26th SW whereas, 35.2°C, 24.9°C, 75, 55 per cent and 0.0 mm during 35th SW, respectively.

The present findings were in conformity with Pande and Sharma, 1985; Rajkumar *et al*., 2005 who reported the mean abundance of *T. urticae* which was the lowest in summer followed by autumn who showed that the incidence of *Tetranychus neocaledonicus* increases with temperature and mite incidence was maximum during 19th standard week (first week of May) with 9.36 mites per leaf . Ismail *et al***.,** 2007 reported the mean abundance of *T. urticae* was the lowest in summer followed by autumn which also supports our findings for the *Tetranychus urticae* mite infestation in brinjal seedlings grown in nursery during autumn.

Correlation studies

The correlation studies indicated that weather parameters played an important role in population build up of BSFB, its trap catches and Red Spider Mites on brinjal.

The relationship between mean maximum and minimum temperature, mean morning and evening relative humidity, rainfall and incidence of BSFB larval population when worked out during 2014, it was observed that BSFB larval populations was found significantly correlated with temperature (minimum and maximum) and non significantly correlated with relative humidity (morning and evening) and rainfall. However, during 2015, a highly positive correlation between BSFB larval incidences with mean maximum temperature, mean relative humidity (morning and evening) and rainfall existed which was found to be statistically significant except minimum temperature which existed the highly negative correlation. The Pooled data on correlation studies showed that the BSFB (larvae) populations were found positively correlated with relative humidity (morning, evening) and rainfall and negatively correlated with maximum temperature.

The linear regression equations for BSFB larval population was calculated to be Y= –1.612– 0.310 X1 +1.097 X2 -0.038 X3 – 0.137 X4 +0.016 X5. The multiple determination (R^2) values indicated that the overall impact of weather factors on population build up of BSFB larval population was 57.3 per cent. While during 2015, the overall impact of weather factors on the Brinjal Shoot and Fruit Borer (BSFB) larval population was 83.8%. The linear regression equations for BSFB larval population were calculated to be Y= 7.478–

0.600X1+1.210X2 -0.035X3 - 0.115X4 +0.018 and overall impact of weather on the BSFB larval population was found to be 83.8%.

Our results on impact of temperature and relative humidity on BSFB larval build-up coincide with the studies reported earlier by Mall *et al.* (1992) reported that infestation on shoots by *L. orbonalis* was not influenced by any environmental factors. They further reported that the positive effect of maximum temperature (r = 0.61) on population build-up by *L. orbonalis* on brinjal fruits which is in conformity with the present findings. The opinion of Kumar *et al.*, 1997; Kumar *et al.*, 2000 and Singh *et al.*, 2000 in respect of BSFB infestation who showed that as temperature increases and humidity decreases, fecundity of *L. orbonalis* increases, thus resulting in more pest population and higher infestation in brinjal crop. The findings of the present study also draw support from the observations made by Singh *et al.* (2000) who reported a positive role of temperature in population build-up of the pest on brinjal fruits. Jat *et al.* (2002) had also recorded similar findings that there was a positive and significant effect of maximum temperature and rainfall on fruit borer infestation on brinjal. A positive role of temperature and negative correlation between relative humidity and infestation by the pest on brinjal shoots has also been reported by Singh *et al.* (2000) which is in line with the present findings.

The correlation studies of adult population of BSFB in pheromone trap showed that BSFB (adult) trap catches populations was found significantly correlated with minimum temperature and non significantly correlated with relative humidity (morning and evening), maximum temperature and rainfall during 2014 and 2015. The correlation study showed that BSFB (adult) populations in wota trap catches was found significantly positive with temperature (minimum and maximum) and negative with morning relative humidity during 2014. While during 2015, wota trap catches of BSFB (adult) were found positively correlated with relative humidity (morning, evening), temperature (minimum) and negatively correlated with maximum temperature, and rainfall. The perusal of pooled data on BSFB (adult) populations in pheromone trap catches were observed to be positively correlated with temperature (minimum), relative humidity (morning). The overall impact of weather for population build up was 27.5%. While, in case of wota trap catches, it was recorded to be positively correlated with temperature (minimum).

The corresponding value of linear regression equations for pheromone trap catches of BSFB adults population was calculated to be Y= –12.144– 0.331X1 +0.303X2 -0.073X3+ 0.008X4 -0.003X5. The multiple determination (R^2) values revealed the overall weather impact was 30.2 per cent pheromone trap catches during 2014 whereas, overall impact of weather factors for population catches in pheromone trap was 49.3% during 2015. The linear regression equations for Wota trap catches of BSFB adults population was calculated to be Y= –51.762– 0.893X1 +1.387X2 -0.532X3 – 0.009X4 +0.009X5. The overall impact of weather factor was found to be 58.0 per cent in Wota trap catches. While during 2015, weather factors regulated the trap catches in Wota traps was found to be 64.3 %. The linear regression equations for wota trap catches of BSFB adults population was calculated to be Y= 72.030 -2.305X1 +2.315X2 -0.295X3 -0.263X4+0 .0087X5, and the overall impact of weather was recorded to be 29.4%.

The correlation studies showed that the Red Spider Mitess populations was found significantly and positively correlated with temperature (minimum and maximum) during 2014 whereas, it was found negatively correlated with relative humidity (morning and evening), rainfall and positively correlated with temperature (maximum). The pooled data on correlation studies showed that the adult population of the red mite was recorded to be negatively correlated with relative humidity (morning) and rainfall, and positively correlated with temperature (Maximum and Minimum). The overall impact of weather factors on population build up of red mite was 42.2 per cent. The linear regression equations showed the increasing trend of red mite incidence due to increase in temperature, preferably to some extent. The corresponding multiple determination (R^2) value was found statistically significant at 5% level of significance. The overall impact of weather factors on population build up was 44.1 per cent on red mites. The overall impact of weather factors on population build up of red mite was found to be 60.0 per cent during 2015.

Red Spider Mites infestation was also in confirmity to Mishra *et al.* (1990) who reported that various accessions of brinjal were attacked by *T. cinnabarinus* mites throughout the crop period. Being maximum during May when the mean temperature was 30.45°C. They also found positive correlation between mite population and temperature. Further, Rai *et al.* (1995) also revealed that temperature, relative humidity and wind velocity were positively correlated while, rainfall adversely affected the mite population on brinjal. Similar findings was also observed by Roopa (2005) who reported that spider mites (*T.*

macfarlanei) appeared much earlier on summer crop (45 DAT) as compared to *kharif* and *rabi* in brinjal. The population reached peak twice *i.e*., on 28th standard week, July 9-15 (14.20 individuals/4 cm^2 leaf) and 46th standard week, November 12-18 (28.73 individuals/4 cm^2 leaf).

The results obtained by Chinniah *et al*., 2009 and Patil and Nandihalli, 2009 also confirmed the present findings who reported that spider mites *Tetranychus macfarlanei* on brinjal appeared at 45 days after transplanting and attained its peak in 28th standard week with 14.2 individuals per 4 cm^2 leaf area in summer. The maximum temperature had significant positive correlation (r = 0.701) with two spotted spider mite population dynamics whereas, the relative humidity (r = - 0.471) and rainfall (r = - 0.398) had a significant negative correlation with two spotted spider mite population. The minimum temperature, wind velocity and sunshine hours had no significant effect on the population dynamics of two spotted spider mite.

5.3 Screening of brinjal varieties/cultivars

Screening of twenty five varieties of brinjal for resistance response against fruit and shoot borer (*L. orbonalis*) and Red Spider Mites (*Tetranychus*) are presented below-

5.3.1 Brinjal Shoot and Fruit Borer (BSFB)

Screening of twenty five brinjal varieties against Brinjal Shoot and Fruit Borer for resistance response revealed that the ten varieties RCMBL- 01, PLP-1, IBH-3, IBL-116, JBH-8, Rajindra brinjal, KS-356, JB-24, IBH-02 and BCB-464 were found to be tolerant with score of 0.0-2.0 (larvae/5 plants), the four varieties CHBR-1, Arka Sree, DRNKU-03-26 and JB-64 were found to be moderately tolerant with score of 2.1-3.0, the nine varieties JB-18, KS-331, MDV-01, HIC-13311, PBL-24, Brinjal Round Green, Ramnagar Giant, Swarn Pratibha and JB-6 were observed to be susceptible with score of 3.1-5.0 and the two varieties DBR-31 and Keshmiri Brinjal were recorded to be highly susceptible with score of 5.1- above 5.1 during 2014.

Similar observations on screening of twenty five brinjal varieties against Brinjal Shoot and Fruit Borer (BSFB) for resistance response were also recorded during 2015. The perusal of data showed that the ten varieties RCMBL- 01, PLP-1, IBH-3, IBL-116, JBH-8, Rajindra brinjal, KS-356, JB-24, IBH-02 and CHBR-1 were found to be tolerant and fallen in the score of 0.0-2.0 (larvae/5plants), ten varieties such as HIC-13311, Arka Sree, MDV-

01, Ramnagar Giant, DRNKU-03-26, Swarn Pratibha, Brinjal Round Green, JB-6, BCB-464 and JB-64 were observed to be moderately tolerant with score of 2.1-3.0, three varieties like JB-18, KS-331 and PBL-24 and were susceptible with score of 3.1-5.0 and the two varieties DBR-31 and Kashmiri Brinjal were highly susceptible with score of 5.1- above found.

Pooled data on Screening of 25 brinjal varieties for the resistance against BSFB revealed that the ten varieties RCMBL- 01, PLP-1, IBH-3, IBL-116, Rajindra brinjal, KS-356, JB-24, JBH-8, IBH-02 and CHBR-1were showed tolerant response, five varieties Arka Sree, DRNKU-03-26, JB-6, BCB-464 and JB-64 were found moderately tolerant, eight varieties JB-18, HIC-13311, Ramnagar Giant, MDV-01, Swarn Pratibha, Brinjal Round Green, KS-331 and PBL-24 were susceptible and the two varieties DBR-31and Kashmiri brinjal were found to be highly susceptible.

Studies conducted by earlier workers (Dash and Singh, 1990; Mandal *et al*., 2005 had also testified that none of the brinjal varieties was completely free from infestation by *L. orbonalis*. Panda (1999) screened 174 brinjal cultivars for resistance to *L. orbonalis* and reported that none of the brinjal entries was immune to larval attack of shoots and fruits. The present findings are in conformity with the results obtained by Jat *et al*., 2003 who tested the comparative susceptibility aubergine cultivars of brinjal for resistance to *L. orbonalis* and observed the lowest infestation on shoots in Arka Kusumakar (3.28%) and on fruits in Arka Kusumakar (18.33%) and SM-10 (20.23%). Neelam Long (30.72%) and Pusa Purple Long (31.60%) were found moderately susceptible. Fruit infestation was highest in Pusa Purple Round (46.51%). Pant Ritruaj and Arka Kusumakar had the highest fruit yield (23.74 and 22.94 t ha^{-1}, respectively). Arka Kusumakar and SM-10 were resistant to shoot and fruit borer. Senapati (2003) observed the lowest percentage of shoot infestation in Pusa Purple Long (4.0%), while, the lowest percentage of fruit infestation by weight (16.24%) and number (27.4%) basis were recorded in Hissar shyamal and Milky White. The present results were also supported by Arvind *et al.* (2007) who found that Pusa Kranti, compostie-2, Pusa Purple Cluster, Pusa Purple Long, CH-249, GC-7, GC-2, SM-141, BB-60-C, Arka Nidhi, Arka Neelkanth, BR-116 and Arka Keshav had moderate infestation. Pusa Purple Round, CH-309, Nisha Improved, Safal, Kashmiri and Hissar Shyamal were categorized as susceptible. On the basis of per cent infestation of fruits, Pusa Purple Long, Pusa Purple Cluster, GC-7, GC-2, Arka Neel Kanth, Arka Nidhi, Composite-2 and Local were graded as moderately tolerant and cultivars, CH-309, Hissar Shyamal, Nisha Improved and Safal were categorized as highly susceptible. Whereas, the results found by Elanchezhyan *et al*. (2008) was aberrated from our findings. Besides, the number of shoots per plant was one of the factors on which the intensity of infestation was responsible, thus ultimately assigning a category to an entry. The present findings envisage the least shoot infestation (1.95) in Local brinjal cultivar which, therefore, corroborates the above results.

5.3.2 Red Spider Mites (RSM)

The screening of twenty five commonly grown brinjal varieties against Red Spider Mites showed two varieties (RCMBL-01 and Swarn Pratibha) were recorded moderately tolerant, three varieties (CHBR-1, Arka Sree and Ramnagar Giant) were found to be low in resistance, the six varieties (MDV-01, DBR-31, Arka Shree, PBL-24, JB-24 and BCB-464) were observed to be susceptible with score of 10.1-15.00 and fourteen varieties (JB-18, PLP-1, IBH-3, KS-331, HIC-13311, IBL-116, Brinjal Round Green, JBH-8, Rajindra brinjal, KS-356, DRNKU-03-26, IBH -02, JB-06, JB-64 and Kahmiri Brinjal) were found highly susceptible with score of 15.1 and above.

The results obtained during 2015 were more or less similar to that of previous year. Screening of brinjal varieties against red mite showed that the seven varieties *viz*., RCMBL-01, PLP-1, MDV-01, Rajindra brinjal, Ramnagar Giant, DBR-31and Swarn Pratibha were found to be moderately resistant, the seven varieties like CHBR-1, JB-18, KS-356, Arka Sree, BCB-464, JB-24 and JB-64 were found to be low in resistance, four varieties *i.e*., IBH-3, KS-331, Brinjal Round Green, and JBH-8 were found to be susceptible with score of 10.10-15.00 and seven varieties such as HIC-13311, IBL-116, PBL-24, DRNKU-03-26, IBH -02, JB-06, and Kahmiri Brinjal were observed to be highly susceptible.

Pooled data on screening of brinjal varieties against red mite revealed that the three varieties RCMBL-01, Ramnagar Giant, and Swarn Pratibha were recorded as moderately resistant, four varieties CHBR-1, MDV-01, Arka Sree and JB-24 were found as Low resistant, five varieties, IBH-3, JB-18, Rajindra brinjal, DBR-31and BCB-464 were found to be susceptible and thirteen varieties PLP-1, KS-331, HIC-13311, IBL-116, PBL-24, Brinjal Round Green, JBH-8 DRNKU-03-26, IBH -02, KS-356, JB-06, JB-64 and Kahmiri Brinjal were recorded as highly susceptible.

Our results on screening of 25 brinjal varieties against BSFB and Red Spider Mites coincide with the studies reported earlier by Parker et al., 1995 and Kumar *et al*., 2013. They also found that three varieties namely Pechiparai, Pusa - 5, Pusa Purple Cluster were categorized as low resistance. The other entries viz., Palur – 2, Arka Kusumakar, Elavambady, MBH-114, Round Beauty Black, Pusa –6, Pusa Kranti, Pusa Anmol these varieties fall under the category susceptible. Rest of the varieties was observed under the category highly susceptible. Hence, there was no variety found properly resistant.

5.4 Management of Brinjal Shoot and Fruit Borer

Three different Modules were formulated to evaluate the impact of eco-friendly Integrated Pest Management of BSFB larval population reduction on brinjal. For comparing the data sets, Post-hoc data analysis (Tukey-HSD test) was used. The performance of different IPM Modules in term of reduction of BSFB larval population are presented as follows-

Among the three Modules tested during 2014, Module-I was found to be superior in reducing the BSFB larval population (1.33 larvae/5plants) on shoots during the month of April 2014 and found at par with Module-III. During the May month, the Module-III and Module-I were found at par in reducing the BSFB pest population (2.58 and 3.83 larvae/5plants) than the Module-II (5.83). Similar trend was also noticed during June month 2014. Module-III was found to be superior in reducing the larval population on brinjal shoots during the months of July (6.41) and found significantly different from Module-I and Module-II. During August, Module-III (3.11) and Module-I (3.88) were found to be at par in reducing the BSFB larval population. Overall, the impact of Module-III (4.63) was found to be the best and superior treatment combination than Module-I (5.71) and Module-II (7.98) in suppressing the BSFB larval population. The descending order of performance of Modules follows as: Module-III >Module-I>Module-II. Similar trend was also noticed during 2015 wherein, overall impact of Module-III (5.60) was found to be the best and superior treatment combination, although Module-II was at par with Module-I (6.08) in suppressing the BSFB larval population on shoots. The descending order of performance of three different Modules during 2015 was as: Module-III >Module-I>Module-II.

For the two consecutive years of experimentation, Module-III was found to be superior in obtaining the healthy fruits (47.20 /5 plants) and reduction in infested fruits

(17.60 /5 plants) on the basis of number whereas, and on weight basis, 3.60 kg/5 plants healthy fruits and 1.07 kg/5 plants infested fruits were obtained, respectively. In Module-I, the total number of the healthy fruits obtained on number basis were 39.26 /5 plants and reduction in infested fruits were found to be 32.33/5 plants whereas, on weight basis, 2.28 kg/5 plants healthy fruits and 1.58 kg/5 plants infested fruits were obtained. Similarly, in Module-II, the healthy fruits on number basis was found to be 23.60/5 plants and on weight basis 1.66 kg/5 plants were recorded. Whereas, the total number of infested fruits 38.66 kg/5 plants and on weight basis 2.37 kg/5 plants were recorded.

Similar findings were also recorded during 2015 in Module-III which was found to be superior in obtaining the healthy fruits on number basis (46.46 /5 plants) and reducing the infested fruits (19.20 /5 plants) and on weight basis (3.22 kg/5 plants healthy fruits) and 0.94 kg/5 plants infested fruits. Module-III was found to be superior in suppressing the larval pest population and increase in healthy fruits on the fruit number (72.86 /5 plants) and on weight basis (4.12 kg/5 plants) followed by Module-I (67.00 infested fruits/5 plants and 3.42 kg healthy fruits/5 plants) and Module-II (55.53 infested fruits/5 plants and 2.79 healthy fruits/5 plants). Module-II was found to be less effective in reducing the BSFB larval population during the entire course of investigation. The descending order of performance of three Modules was as: Module-III >Module-I>Module-II.

The present findings are in conformity with the results obtained by Chatterjee (2009) who highlighted that the Module with three components i.e. pheromone trap, timely mechanical control and application of azadex (neem based insecticides) was most effective in reduction of shoot damage (76.59%) followed by the farmer's practice (i.e. twenty times application of insecticides) (76.36%). Whereas highest protection in fruit damage (48.26%) and yield increment (53.19%) were obtained from the practices of setting trap+timely mechanical control and trap+application of azadex, respectively. Samota et al. (2014) recorded the similar findings in which they demonstrated that the Module-3 comprising of neem cake+clipping of affected shoots+Btk was most effective against *L. orbonalis* in their efficacy. Similar findings were also reported by the Chiranjeevi et al. (2005) who found that cypermethrin and profenofos, applied at 5 sprays, and alternate spraying with NSKE, profenofos and cypermethrin along with IPM package resulted in the best control of the pest and the highest yield 213.87, 208.25 and 203.98 q/ha, respectively.

The present findings are differed with the results found by Nagesh *et al.* (2009) who found that the IPM Module with application of FYM, neem cake, seedling dip with imidacloprid before transplanting, maize as border crop, monitoring through pheromone traps, mechanical destruction of damaged shoots and fruits and need based application of insecticides proved to be the best Module in managing *L. orbonalis* and also resulted in low shoot and fruit damage, higher marketable fruits with high C:B ratio compared with BIPM and farmers' practice Modules.

Shanmugam et al. (2015) evaluated the biointensive pest management practices to manage Brinjal Shoot and Fruit Borer, *L. orbonalis* under precision farming system and revealed that the biointensive approaches recorded lowest shoot and fruit damage of 9.06 and 16.53% during *kharif* and 9.46 and 15.06% during *rabi* season respectively. The bio-rational approaches recorded 16.80 and 18.00 % shoot damage and 22.93 and 23.60% fruit damage during *kharif* and *rabi* season respectively. The mean shoot and fruit damage was 11.40 and 11.46% and 16.93 and 17.20% for farmers practice during *kharif* and *rabi* seasons, respectively.

5.5 Parasitization of larval parasitoid, *Trathala flavo-orbitalis*

The larval and pupal parasitoid of BSFB, *T. flavo-orbitalis* was found abundantly in the field condition and recovered from different types of Modules used during both years of experimentation. The mean population of *T. flavo-orbitalis* was found to be superior in IIIrd Module with the highest overall mean population of 4.60 adult/20 infested fruits. Again, the maximum parasitisation was recorded in Module-IIIrd with 22.99±7.60 per cent followed by Module Ist with mean population 3.99 adult/20 infested fruits and parasitization per cent was found to be 19.98±6.14%. While in case of IInd Module, 1.80 adult population/20 infested fruits was recovered with 8.98% parasitization during 2014. The larval parasitoid of BSFB, *T. flavo-orbitalis* was found to be superior in IIIrd Module with the overall mean population of 5.86 adult/20 infested fruits and percentage parasitization was recorded to be 29.33±6.62 during 2015 experimentation. Module IIIrd was followed by the Module Ist with the overall mean population 3.59 adult/20 infested fruits and parasitization per cent was 17.99±5.35. while in case of IInd Module, 1.66 adult population/20 infested fruits were recovered with 8.32±2.42 per cent parasitisation, respectively. Pooled data on occurrence of larval parasitoid, *T. flavo-orbitalis* and its parasitization in different Modules revealed that

Module III[rd] was found to be superior in overall mean population of 5.26 adult/20 infested fruits and overall parasitization which was recorded to be 26.31 per cent. Module I[st] was found to be intermediate in terms of overall population 3.79 adult/20 infested fruits and parasitization 18.82 per cent.

For the foreseeable future, insecticides will continue to remain a powerful and essential tool in BSFB management. However, it is necessary that their use be minimized so as to prevent the present trend from reaching a 'disaster phase' (Smith, 1969). A prime strategy is to formulate a broader ecological base that would make possible the integration of various pest management techniques. Largely because biological control is a natural ecological phenomenon and can potentially provide a relatively harmonious, economical and a near permanent solution, the consideration of BSFB and Red Spider Mites natural enemies has in recent years been given priority.

Thus, in the present studies the abundance of predators and parasitoids in the field as a potential biological agent of *L. orbonalis* and Red Spider Mites on brinjal crop was clearly established. Our results on the abundance of *T. flavor-orbitalis* as dominant larval parasitoid were in support with the studies conducted by Singh and Singh, 2002; Srinivasan, 2008; Yasodha and Natarajan, 2009 who highlighted about the different strategies like resistant cultivars, sex pheromone, cultural, mechanical and biological control methods in integrated pest management (IPM) programme in controlling the eggplant fruit and shoot borer (BFSB). They further revealed that the profit margins, and production area significantly increased whereas pesticide use and labour requirement decreased for those farmers who adopted this IPM technology by proliferation of *T. flavo-orbitalis*. The parasitization by *T. flavo-orbitails* to shoot and fruit borer ranged from 1.59 to 6.81 per cent (average 5.56%) with highest in September which was little bit aberrated from the present findings. The present results were in conformity with Hazarika *et al*. (2001) who reported that the Green lacewings (*Mallada basalis* Walker and *Chrysoperla carnea* Stephens) are effective generalist predators of spider mites who consumed 25–30 spider mite adults per day. To date, the natural enemy complex has yet to provide a full biological control of BSFB larvae locally. However, knowing the relative potential of the individual species and how they should be utilized is particularly important and could prove crucial in determining factor in integrated management of BSFB on brinjal and Red Spider Mites.

5.6 Economics of different IPM Modules for management of BSFB in brinjal

For each Module, increase in fruit yield over control plots was worked out and monetary value of additional quantity of brinjal for each Module was estimated at the prevailing market rate of Rs. 1500/q. The net benefit due to each Module was calculated after deducting the expenditure incurred on implementing various control methods under Modules and labour charges for treatments.

The perusal of the data during 2014 revealed that all Modules were found to be cost effective. The highest yield was found in case of Module-III (BIPM) 250 q/ha followed by Module-I (Recommended practices of SKUAST-J) 190 q/ha and Module-II (Farmer's practices) 110 q/ha. The Module-III was found in giving the highest benefit of Rs. 146850.00 than the Module-I which obtained the benefits of Rs. 75550.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III (1:2.33) than Module-I which showed (1:1.70) C: B ratio. While during 2015, all Modules were found to be cost effective. The highest yield was found in case of Module-III (BIPM) 230 q/ha followed by Module-I (Recommended practices of SKUAST- J) 175 q/ha and Module-II (Farmer practices) 105 q/ha. The Module-III was found to be best in giving the highest benefit of Rs. 124350.00 than Module-I which gave the benefit of Rs. 60500.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III (1:1.96) while (1:1.35) cost: benefit ratio was obtained in Module-I.

The perusal of pooled data on Cost benefit ratio for different IPM Modules during both the years showed that all Modules were found to be cost effective. The highest yield was obtained in case of Module-III (BIPM) 240 q/ha followed by Module-I (Recommended practices of SKUAST- J) 182.5 q/ha and Module-II (Farmer's practices) 107.5 q/ha. The Module-III gave the highest benefit of Rs. 199350.00 than Module-I which received the benefits of Rs. 68000.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III with 1:3.15 than Module-I which showed 1:1.52 cost:benefit ratio.

While judging the utility of any safer and eco-friendly insecticides in the pest management programme, the chemical is evaluated not only by its relative potency against the target pest and the period for which its application provides protection to the crop, but the economics of the treatment also remains a major consideration. As such in the present investigation the cost-benefit ratio of individual treatment in different Modules were also worked out.

The present findings are in conformity with Das (2015) who also highlighted that Integrated Pest Management Module consisting of soil application of neem cake @ 2.5 q/ha, removal and destruction of infected shoots and fruits and alternate spraying of triazophos 40 EC @ 1250 ml/ha and neem oil @ 2.5 lit/ha at 10 days interval as most effective and economical among three Modules assessed for management of shoot and fruit borer of brinjal. Further, he showed that the treatments resulted in 29.8% additional yield over the traditional practice of indiscriminate application of insecticides exhibiting a net profit of Rs 75,721/ha hectare with B:C ratio of 3.03:1.

The present findings are little bit aberrated from Shanmugam *et al.* (2015) who had recorded a little bit higher cost benefit ration. They showed that the biointensive, bio-rational and farmers practice recorded benefit cost ratio of 9.14, 5.68 and 7.05 during *kharif* and 9.10, 5.43 and 7.22 BCR during *rabi* season, respectively. Further they emphasized that more reliance on insecticides led to increased cost of cultivation and environmental pollution in the farmers practice which in turn reduces the export potential of the produce. But the present findings are in conformity with Shanmugam *et al.* (2015) who advocated that the farmers can effectively use the biointensive pest management strategies for the management of shoot and fruit borer in brinjal.

Chapter 6

Summary and Conclusion

Chapter-6

SUMMARY AND CONCLUSION

The thesis embodies the results of experimentation made on "Biointensive Integrated Pest Management of major insect pests of brinjal (*Solanum melongena* Guen.)" carried out during cropping season of 2014 and 2015. The broad objectives of present studies were as follows:

1. To monitor the occurrence of red mites, Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* and natural enemy fauna in brinjal ecosystem
2. Screening of twenty five (25) brinjal varieties against Red Mites and Brinjal Shoot and Fruit Borer
3. To develop an eco-friendly Integrated Pest management programme for *Leucinodes orbonalis*

A large magnitude of insect pest and natural enemy fauna (predators and parasitoids) were recorded in brinjal crop during two years of experimentation *i.e*., 2014 and 2015. The studies revealed that the more than 29 insect pests specie were associated with brinjal crops in the Jammu region. Out of fourteen (14) insect pests, five (5) insect pests were categorized as major insect pest on the basis of economic losses caused in brinjal ecosystem. Apart from insect pest, a large number of natural enemy fauna (12 species of predators and 3 species of parasitoids) such as lady bird beetles, ground beetles, rove beetles, reduviid bug, big eyed bug, pentatomid bug, earwigs, praying mantis, green lacewing, european wasp, and predatory mites along with the three parasitoid namely *Trathala flavo-orbitalis*, *Goryphus nursei* and *Campoletes chlorideae* were recorded during both the years of experimentation.

The monitoring of major insect pests observed at experimental sites indicated that Brinjal Shoot and Fruit Borer (BSFB) and Red Spider Mite (RSM) were found damaging and remain active throughout the cropping season at various growth stages. The observations on seasonal natural fluctuation of BSFB and RSM on brinjal were recorded at weekly intervals starting from 15th standard week i.e., soon after the appearance of larval population with twigs dropping symptoms, till 36th standard week during 2014 and 17th standard week to 37th standard weeks during 2015.

The seasonal incidence of BSFB infestation was first observed nearly 30 days after transplanting *i.e*., from 16th standard week with an initial population of 0.33 larvae per plant. The population was observed to be increasing gradually till 24th SW recording a maximum of 14.33 larvae per plant. The larval population of BSFB then decreased till 30th standard week on the same crop up to 6.00 larvae per plant. Again, the population was observed to increasing up to 32nd SW, recording a maximum density of 11.66 mean larval population per plant. Thus, there was two peak of BSFB larval population build-up observed during 24th and 32nd standard weeks on brinjal crop during 2014.

The seasonal incidence of BSFB larval population was recorded on 2nd year brinjal crop from the 17th SW up to 37th standard week, 2015. Incidence of this pest revealed that the mean BSFB larval population per plant in brinjal ranged from 1.0 to 14.00. The population was quite fluctuating and observed to low up to 22nd SW and then the population was observed to be increasing gradually till 30th standard week recording a peak larval number with maximum of 14.00 larvae per brinjal plant.

The data on trap catches of BFSB male adult population showed that the trap catches was recorded up to 20th standard week with peak catches of 5.33 moths per trap per week. The moth activity was observed in pheromone traps up to the harvest of crop i.e., 36th standard week. The adult population fluctuated and exhibiting one 'V' shaped oscillations between 22nd to 30th standard week. Thus, there were two peaks of adult trap catch population noticed during 20th standard week and in 30th standard week during 2014. The trap catches of BFSB (adult) population data during 2015 showed that the peak trap catches of 11.33 moths per trap per week in 30th standard week. The moth activity through trap catches continued to be noticed up to 37th standard week (0.6733 mean number of BSFB trap catches) at the time of harvesting.

Similarly, the initial population of BSFB adult moth catches (0.66) was recorded in Wota trap during 15th standard week. A gradual increase was recorded up to 22th standard week with the peak catches of 22.33 moths per trap. The adult trap population fluctuated between 22th to 30th standard week, exhibiting two 'V' shaped oscillations between 22th to

28th standard week and 28th to 30th standard week. Thus, the two peaks were noticed during the year *viz*., first one on 22nd standard week and second during 30th standard week during 2014 which constituted the two overlapping generations of BSFB pest in Jammu region. While, during 2015, the trap catches were noticed up to 31st standard week with the peak activity of 19.67 moths per trap per week in Wota trap.

The seasonal incidence of Red Spider Mite (RSM), *T. neocalidonicus* was found infesting the brinjal crop during the different stages of crop growth and recorded throughout the cropping season during 2014 whereas, *T. urticae* was confined only to seedlings grown in the nursery. The mean number of red spider mite population/ 4 cm^2 on brinjal ranged from 0.67 to 51.81. The maximum mite population 51.81 mean number of mites per 4 cm^2 on brinjal was observed in 25th standard week.

While during 2015, there were two peaks of adult mite populations *i.e*., in 26th SW with 36.02 red mite per 4cm^2 leaf area and in 35th SW with 24.37 mite per 4cm^2 leaf area, respectively.

The relationship between mean maximum and minimum temperature, mean morning and evening relative humidity, rainfall and incidence of BSFB larval population when worked out during 2014, it was observed that BSFB larval populations was found significantly correlated with temperature (minimum and maximum) and non significantly correlated with relative humidity (morning and evening) and rainfall. However, during 2015, a highly positive correlation between BSFB larval incidences with mean maximum temperature, mean relative humidity (morning and evening) and rainfall existed which was found to be statistically significant except minimum temperature which exhibited the highly negative correlation. The linear regression equations for BSFB larval population was calculated to be Y= –1.612– 0.310 X1 +1.097 X2 -0.038 X3 – 0.137 X4 +0.016 X5. The multiple determination (R^2) values indicated that the overall impact of weather factors on population build up of BSFB larval population was 57.3 per cent. While during 2015, the overall impact of weather factors on the Brinjal Shoot and Fruit Borer (BSFB) larval population was 83.8%.

The **Pooled data on** correlation studies showed that the BSFB (larvae) populations were found positively correlated with relative humidity (morning, evening) and rainfall and negatively correlated with maximum temperature. The linear regression equations for BSFB larval population was calculated to be Y= 7.478–0.600X1+1.210X2 -0.035X3 - 0.115X4 +0.018 and overall impact of weather on the BSFB larval population was found to be 83.8%.

The relationship between abiotic factors and trap catches of adult population of BSFB in pheromone trap showed that BSFB (adult) populations in pheromone trap catches was found significantly correlated with minimum temperature and non significantly correlated with relative humidity (morning and evening), maximum temperature and rainfall While it was found positively correlated with temperature (minimum), relative humidity (morning), negatively correlated with rainfall and maximum temperature during 2015.

The correlation study showed that BSFB (adult) populations in wota trap catches was found significantly positive correlated with temperature (minimum and maximum) and negative with morning relative humidity during 2014. While during 2015, wota trap catches of BSFB (adult) were found positively correlated with relative humidity (morning, evening), temperature (minimum) and negatively correlated with maximum temperature, and rainfall. The overall impact of weather factor was found to be 58.0 per cent in Wota trap catches during 2014. While during 2015, weather factors regulated the trap catches in Wota traps was found to be 64.3 %.

The perusal of pooled data on BSFB (adult) populations in pheromone trap catches were observed to be positively correlated with temperature (minimum), relative humidity (morning). The overall impact of weather for population build up was 27.5%. While, in case of wota trap catches, it was recorded to be positively correlated with temperature (minimum).

The population of Red Spider Mites populations was found significantly and positively correlated with temperature (minimum and maximum) during 2014 whereas, it was found negatively correlated with relative humidity (morning and evening), rainfall and positively correlated with temperature (maximum). The overall impact of weather factors on population build up was 44.1 per cent on Red Mites. The overall impact of weather factors on population build up of red mite was found to be 60.0 per cent during 2015. The pooled data on correlation studies showed that the adult population of the red mite was recorded to be negatively correlated with relative humidity (morning) and rainfall, and positively correlated with temperature (Maximum and Minimum). The overall impact of weather factors on population build up of red mite was 42.2 per cent.

The larval and pupal parasitoid of BSFB, *T. flavo-orbitalis* was found abundantly in the field condition and mean population of *T. flavo-orbitalis* was found to be superior in IIIrd module with the highest overall mean population of 4.60 adult/20 infested fruits. Again, the maximum parasitisation was recorded in module-IIIrd with 22.99±7.60 per cent followed by module Ist with mean population 3.99 adult/20 infested fruits and parasitization per cent was found to be 19.98±6.14% during 2014. While during 2015, similar trend was noticed in IIIrd module with the overall mean population of 5.86 adult/20 infested fruits and percentage parasitization to be 29.33±6.62. Pooled data on occurrence of larval parasitoid, *T. flavo-orbitalis* and its parasitization in different modules revealed that module IIIrd was found to be superior in overall mean population of 5.26 adult/20 infested fruits and overall parasitization which was recorded to be 26.31 per cent.

Screening of twenty five brinjal varieties against Brinjal Shoot and Fruit Borer for resistance response revealed that the ten varieties RCMBL- 01, PLP-1, IBH-3, IBL-116, JBH-8, Rajindra brinjal, KS-356, JB-24, IBH-02 and BCB-464 were found to be tolerant with score of 0.0-2.0 (larvae/5 plants), the four varieties CHBR-1, Arka Sree, DRNKU-03-26 and JB-64 were found to be moderately tolerant with score of 2.1-3.0, the nine varieties JB-18, KS-331, MDV-01, HIC-13311, PBL-24, Brinjal Round Green, Ramnagar Gaint, Swarn Pratibha and JB-6 were observed to be susceptible with score of 3.1-5.0 and the two varieties DBR-31 and Keshmiri Brinjal were recorded to be highly susceptible with score of 5.1- above 5.1 during 2014. Similarly observations on screening of twenty five brinjal varieties against Brinjal Shoot and Fruit Borer (BSFB) for resistance response were also recorded during 2015. **Pooled** data on Screening of 25 brinjal varieties for the resistance against BSFB revealed that the ten varieties RCMBL- 01, PLP-1, IBH-3, IBL-116, Rajindra brinjal, KS-356, JB-24, JBH-8, IBH-02 and CHBR-1were showed tolerant response, five varieties Arka Sree, DRNKU-03-26, JB-6, BCB-464 and JB-64 were found moderately tolerant, eight varieties JB-18, HIC-13311, Ramnagar Gaint, MDV-01, Swarn Pratibha, Brinjal Round Green, KS-331 and PBL-24 were susceptible and the two varieties DBR-31and Kashmiri brinjal were found to be highly susceptible.

The screening of twenty five commonly grown brinjal varieties against red spider mite showed that the two varieties RCMBL-01 and Swarn Pratibha were recorded moderately tolerant, three varieties CHBR-1, Arka Sree and Ramnagar Gaint were found to be low in resistance, the six varieties MDV-01, DBR-31, Arka Shree, PBL-24, JB-24 and BCB-464 were observed to be susceptible with score of 10.10-15.00 and fourteen varieties JB-18, PLP-1, IBH-3, KS-331, HIC-13311, IBL-116, Brinjal Round Green, JBH-8, Rajindra brinjal, KS-356, DRNKU-03-26, IBH -02, JB-06, JB-64 and Kahmiri Brinjal were found highly susceptible with score of 15.10 – above. The results obtained during 2015 experimental period were more or less similar to that of previous year.

Pooled data on screening of brinjal varieties against Red Mite revealed that the three varieties RCMBL-01, Ramnagar Gaint, and Swarn Pratibha were recorded as moderately tolerant, four varieties CHBR-1, MDV-01, Arka Sree and JB-24 were found as tolerant, five varieties, IBH-3, JB-18, Rajindra brinjal, DBR-31and BCB-464 were found to be susceptible and thirteen varieties PLP-1, KS-331, HIC-13311, IBL-116, PBL-24, Brinjal Round Green, JBH-8 DRNKU-03-26, IBH -02, KS-356, JB-06, JB-64 and Kahmiri Brinjal were recorded as highly susceptible.

Among the three modules tested, the overall impact of Module-III (5.60) was found to be the best and superior treatment combination than Module-I (6.08) and Module-II (7.65) in suppressing the BSFB larval population on the basis of shoot infestation during 2014. While, the overall impact of Module-III (5.60) was found to be the best and superior treatment combination than Module-I (6.08) and Module-II (7.65) for suppressing the BSFB larval population on shoots during 2015.

The descending order of performance of modules follows as: Module-III >Module-I>Module-II.

Among the entire period of investigation, on the basis of fruits infestation Module-III was found to be superior in obtaining the healthy fruits (47.20/5 plants) and reduction in infested fruits (17.60 /5 plants) on the basis of number whereas, and on weight basis, 3.60 kg/5 plants healthy fruits and 1.07 kg/5 plants infested fruits were obtained, respectively. Whereas, during 2015, Module-III was found to be superior in obtaining the healthy fruits on number basis (46.46 /5 plants) and reducing the infested fruits (19.20 /5 plants) and on weight basis (3.22 kg/5 plants healthy fruits) and 0.94 kg/5 plants infested fruits, respectively. The descending order of performance of three modules were found follows as: Module-III >Module-I>Module-II.

For each module, increase in fruit yield over control plots was worked out and monetary value of additional quantity of brinjal for each module was estimated at the prevailing market rate of Rs. 1500/q. The highest yield was found in case of module-III (BIPM) 250 q/ha giving the highest benefit of Rs. 146850.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III (1:2.33) than module-I which showed (1:1.70) C: B ratio. Similar result was also obtainbed during 2015. The highest yield was found in case of module-III (BIPM) 230 q/ha which was found to be best in giving the highest benefit of Rs. 124350.00 which gave the benefit of Rs. 60500.00.

The perusal of pooled data on cost benefit ratio for different IPM modules during both the years showed that all modules were found to be cost effective. The highest yield was obtained in case of module-III (BIPM) 240 q/ha which gave the highest benefit of Rs. 199350.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III with 1:3.15 than module-I which showed 1:1.52 cost:benefit ratio.

The conclusion drawn during present investigation is summarized below:

- Brinjal is an important vegetable crop grown commercially in and around Jammu region. The crop recorded a huge pressure of insect pests especially Brinjal Shoot and Fruit Borer and red spider mite as the major pest of economic significance which requires constant intervention for the successful cultivation of this crops.
- The seasonal incidence of Brinjal Shoot and Fruit Borer and Red Spider Mite during the two consecutive years provides a holistic information about the seasonal population fluctuation and impact of abiotic factors on the population build up of the above pest. On the basis of information generated, we are enable to forecast the timely intervention for the management of BSFB and RSM population on brinjal.
- Apart of insect pests, a large number of parasitoids and predatory fauna are also present in brinjal crop ecosystem which mitigates the population of BSFB larval population. The parasitization of larval parasitoids can be enhanced by the use of Bio-intensive integrated pest management methods which in turn can be helpful in reducing the pesticidal application.
- Screening of 25 varieties of brinjal showed that the varieties found resistant and moderately resistant can be promoted in Jammu region.
- Among the different modules evaluated, module III which comprises the use of net as mechanical barrier, pheromone and water traps @ 1 trap/100m^2, neem oil 5% (spray), clipping-off infested shoots, foliar spray of *Beauvaria bassiana*@750 ml/ha

(Biorin 1ml/l), foliar spray of *Pongamia pinnata* oil (2%) and spray of Bt @ 500g per hectare (Biolep 1g/l) was found to the best treatment in controlling the brinjal shoot and fruit borer larval population on shoots as well on fruits and also helpful in getting the healthy fruits.

- Cost benefit analysis revealed that the module-III recorded highest yield 240 q/ha which gave the highest benefit of Rs. 199350.00. The results showed that the highest cost benefit ratio was obtained in case of Module-III with 1:3.15.

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Certificate - IV

Certified that all the necessary corrections as suggested by the external examiner/ evaluator and the Advisory committee have been duly incorporated in the thesis entitled **"Bio-intensive Integrated Pest Management of Major Insect Pests of Brinjal, (*Solanum melongena* Guen.)"** submitted by **Mr. Amit Kumar** Registration No. **J-12-D-153-A.**

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