

**“Studies on Insect Pest Complex of  
Brinjal, *Solanum melongena* (Linn.) and  
their Management with microbials”**

**THESIS**

*Submitted to the*

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

**MASTER OF SCIENCE**

*In*

**AGRICULTURE  
(ENTOMOLOGY)**

*By*

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## CERTIFICATE – I

This is to certify that the thesis entitled "**Studies on insect pest complex of brinjal, *Solanum melongena* (Linn.) and their management with microbials** " submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (Entomology)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) is a record of the bonafide research work carried out by **Mr. Gaikwad Vaibhav Ramrao** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction, JNKVV, Jabalpur.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been acknowledged by him.

**( O.P.Veda )**

Chairman of the Advisory Committee

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## CERTIFICATE –II

This is to certify that the thesis entitle "**Studies on insect pest complex of brinjal, *Solanum melongena*(Linn.) and their management with microbials** " submitted by **Mr. Gaikwad Vaibhav Ramrao** to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, in partial fulfilment of the requirements for the degree of **Master of Science in Agriculture in the Department of Entomology** has been after evaluation approved by the External Examiner and by the Student's Advisory Committee after an oral examination of the same.

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## LIST OF ABBREVIATIONS

Symbol	Abbreviation	Stand for
@		At the rate of
±		Plus or minus
%		Percentage
°C		Degree centigrade
	CD	Critical difference
	cm	Centimeter
	ha	Hectare
	hr	Hour
	Kg	Kilogram
	l	Litre
	m	Meter
	mg	Milligram
	Max	Maximum
	Min	Minimum
	NS	Non significant
	RH	Relative humidity
	SEm ±	Standard error of mean
	SW	Standard weeks
	Temp	Temperature
	q	Quintle
	t	Tonnes

## CHAPTER – I

### INTRODUCTION

India is an agriculture based country having 2.4 per cent of the world's arable land with which to feed 15 per cent of world population. So, one of the main challenges is to provide food for one billion people (Biswas *et al.*, 2009). Enhancing production and productivity of vegetables can play a major role in this regard. India is the second largest producer of vegetables after China (75 million tonnes) constituting 9.4 per cent of the total production (Hegde *et al.*, 2009). Majority of the Indians are vegetarian. So lot of emphasis has been given to increase the production and productivity of vegetables in India.

Among the vegetables, brinjal (aubergine, egg plant), *Solanum melongena* Linnaeus, a native of India is highly cosmopolitan and popular vegetable grown as poor man's crop in the country. It is the most consumed and most sprayed (plant protection measures) vegetable in India, making it one of the main sources of cash for many farmers (Daniel , 2007).

In India brinjal occupies 29.41 per cent( 0.6 million ha) of the world's area of 2.04 million ha and produce 30.08 per cent (10.37 million tonnes) of the world's production of 34.48 tonnes. In Madhya Pradesh, brinjal occupies 0.226 million ha with a production 3.39 million tonnes. The productivity of brinjal in Madhya Pradesh is just 0.07 t/ha against that of the country 0.06 t/ha, and world's 16.90t/ha (Varmudy, 2011)

Brinjal fruit contains moisture 91.5 per cent, protein 1.3per cent, minerals 6.5 per cent, carbohydrates 6.4 per cent, calcium 0.02 per cent, phosphorus 0.06 per cent and iron 1.3 per cent respectively. It also contains vitamin A 5 mg /100 g, vitamin B 45 mg / 100 g, nicotinic acid 0.08 mg / 100 g, riboflavin 90 mg / 100 g, vitamin C 23 mg / 100 g (Wankhede, 2009).

Among the various causes of low productivity of the brinjal one of the most important factors acting against increasing the yield is the damage inflicted by the insect pests. Among them whitefly, leaf hopper and

lepidopteran insect pests especially shoot and fruit borer infestation have a major role.

The whitefly and leaf hopper are major sucking insect pests of brinjal and its incidence not only results in the loss of plant vigour, but also spreads mosaic virus disease affecting the fruit yield perceptibly.

The shoot and fruit borer (*Leucinodes orbonalis*) has a specific nature of feeding. After hatching, the tiny larva bore in the growing tips of young shoots during their early growth stage. Yellowing and wilting of the affected shoots is the common symptom of attack (Hegde *et al.*, 2009). During flowering and fruiting stage, the larvae prefers flower buds and young fruits and bores into the young fruits on initiation of fruiting by making a very small hole around the calyx. Thereafter, it completes its larval stage within the growing fruits and the mature larvae come out from fruit for pupation. The apparent loss of fruits has been reported to be varying from 20-90 per cent in various parts of the country (Raju *et al.*, 2007).

Chemical control is widely used means of managing insect pests in brinjal. Repeated use of broad spectrum synthetic chemicals also result in environmental contamination, bioaccumulation and biomagnification of toxic residues and disturbance in ecological balance (Dadmal *et al.*, 2004). Further it has been reported that due to indiscriminate use of insecticides, shoot and fruit borer has developed resistance to the conventional toxic insecticides (Raju *et al.*, 2007 and Hegde *et al.*, 2009). In addition, the residues of chemical pesticides on the economic parts are more than tolerable level (Jha *et al.*, 2006). Hence, there is an urgent need to look for alternate and safer method.

In order to evolve and design pest management practices based on sound ecological footing and economically feasible, information on the pest complex is a pre requisite. Similarly, influence of weather factors on pest population differs in different region; hence sufficient knowledge about the seasonal activity of the pest is necessary for adopting suitable control measures in a particular region.

Keeping in mind the above facts, research work were conducted with the following objectives:

1. To study the succession of insect pest complex and their natural enemies on brinjal.
2. To study the population dynamics of major insect pests of brinjal.
3. Management of insect pest complex of brinjal with reference to Shoot and fruit borer with microbials.

## CHAPTER – II

### REVIEW OF LITERATURE

The available literature relevant to the present studies had been reviewed are mentioned below:

#### **2.1 Study the succession of insect pest complex and their natural enemies on brinjal.**

Dhamdhare and Bhonsle, (1995) monitored major insect pests of brinjal, during summer and *kharif* 1993 at Gwalior (Madhya Pradesh) and recorded 6 hemipterous, 3 lepidopterous, 2 coleopterous and 1 acarina respectively. Insect pests recorded were jassids, *Amrasca biguttula biguttula*; aphid, *Aphis gossypii* (Glover); shoot and fruit borer, *Leucinodes orbonalis* (Guen.); stem borer, *Euzophora particella* (Rag.); leaf folder, *Antoba olivacea* (Wlk.); Epilachna beetle, *Epilachna vigintioctopunctata*; lace wing, *Urentius echinus*; cow bug, *Tricentrus bicolor*; mealy bug, *Centroccocus insolitus*; flower beetle, *Mylabris pustulata* (Thunb.) and leaf defoliator, *Selepta docillis*, respectively. Besides these, they also recorded mite, *Tetranychus telarius* (Linn.).

Bhadoria *et al.*, (1999) recorded thirteen species of insect pests on brinjal during summer and *kharif* season of 1995–96 however *Euzophora particella*, *Leucinodes orbonalis*, *Eublemma olivacea*, *Amrasca biguttula biguttula* and *Aphis gossypii* were found to be the most common pests.

Singh and Singh, (2002) studied the brinjal pest complex and their succession during 1994-95 at Barapani, Meghalaya. The study revealed that twenty seven pests and non insect pests were recorded to infest the brinjal crop.

Ghosh *et al.*,(2006) reported that predatory mites were found active throughout the year on brinjal crop in the tarai region of west Bengal, India

Kadam *et al.*, (2006) studied the insects associated with aubergine cv. Ajay at Rahuri, Maharashtra. The insects recorded were *Leucinodes orbonalis*, *Amrasca biguttula biguttula*, *Bemisia tabaci*, *Aphis gossypii* and coccinellid predators (*Chelomenes sexmaculatus*, *Coccinella septempunctata* and *Brumoids suturalis*).

Elanchezhyan *et al.*, (2008a) recorded spotted leaf beetle, *Henosepilachna vigintioctopunctata*.; ash weevil, *Myloccerus sp.*; mealy bug, *Coccidohystrix insolita*.; aphid, *Aphis gossypii*.; leafhopper, *Amrasca devastans* and whitefly, *Bemisia tabaci* on brinjal.

Naik *et al.*, (2008a) reported that *Epilachna vigintioctopunctata* and coccinellid predatory beetles as well as spiders were observed on brinjal crop.

Patial and Mehta, (2008) conducted studies on brinjal insect-pest complex and their succession in Palampur, Himachal Pradesh. The studies revealed that 27 insect pest species were associated with brinjal crop during different stages of crop growth in an overlapping manner. Jassid (*Amrasca biguttula biguttula*) appeared first, compared with the shoot and fruit borer, *Leucinodes orbonalis*, which appeared during the end of June and was found to be the major pest, while jassid, (*Amrasca biguttula biguttula*); aphid (*Aphis gossypii*) and whitefly (*Trialeurodes vaporariorum*) were moderate pests.

Latif *et al.*, (2009) conducted studies on arthropod biodiversity in brinjal field. They reported twenty species of harmful arthropods which were grouped under 17 families, belonging to 6 different orders. The brinjal shoot and fruit borer, (*Leucinodes orbonalis*), jassid (*Amrasca biguttula biguttula*), epilachna beetle (*Epilachna sp.*), whitefly (*Bemisia tabaci*) and aphid (*Aphis gossypii*) were found as the most common and major insect pests of brinjal. Further, predaceous arthropods were found which belonged to three families under order Coleoptera, followed by spider, under lycosidae family. Surface dwelling arthropods recorded were grouped into 17 families, among them 7 families were identified as predators.

Naik *et al.*, (2009) reported *Bemisia tabaci* and *Amrasca biguttula biguttula* on brinjal.

## 2.2. Study the population dynamics of major insect pests of brinjal:

Shah *et al.*, (1995) studied the population dynamics of larval population of *Leucinodes orbonalis* (Guen.) on brinjal and found that incidence was positively correlated with maximum and minimum temperature, respectively.

Tripathi *et al.*, (1996) reported that the peak infestation due to shoot and fruit borer were recorded between November 15<sup>th</sup> to 21<sup>st</sup> and December 13<sup>th</sup> to 19<sup>th</sup>, respectively and attained 5 distinct peak periods.

Prasad and Logiswaran, (1997a) reported that on brinjal, peak population of *Aphis gossypii* occurred during September-October and March-April in summer while, peak incidence of *Amrasca biguttula biguttula* was recorded during September–October and from April onwards in summer.

Prasad and Logiswaran, (1997b) studied the influence of weather factors on the insect infestation on brinjal. The study revealed that the incidence of shoot damage by *Leucinodes orbonalis* exhibited a significant positive correlation with maximum temperature, relative humidity and negative correlation with minimum temperature, respectively. The *Amrasca biguttula biguttula* population showed a significant positive correlation with rainfall, whereas *Bemisia tabaci* showed a significant positive correlation with maximum temperature, relative humidity and wind velocity, respectively.

Saeed and Khan, (1997) reported that *Leucinodes orbonalis* infestation began soon after brinjal fruits were formed, attaining peak during last week of August, then declining, but remaining fairly constant (50 -70 per cent) during September-November, finally disappearing in the first week of December.

Reddy *et al.*, (1998) reported rapid multiplication of cotton whitefly on brinjal at a temperature ranging from 29°C to 33°C, while high rainfall suppressed the pest activity, respectively.

Singh *et al.*, (2003) found that *Leucinodes orbonalis* was the most serious pest on shoots of brinjal and remained active during September–October, and attained peak during the third week of September. Upon initiation of flowering, borer infestation on shoots declined and reached zero by the end of October. At this stage, borer infestation shifted to the flowers and fruits, respectively. Fruit infestation decreased, attaining a small peak in the third week of November, and no infestation was recorded during December. Temperature was positively, while relative humidity was negatively correlated with pest multiplication, respectively.

Lodhi, (2005) reported that the brinjal fruit borer activity was maximum during the last week of March, when the average temperature and relative humidity were 26.5 °C and 35 per cent, respectively.

Ishar *et al.*, (2007) and Raju *et al.*, (2007) studied the seasonal incidence of shoot and fruit borer on brinjal and reported that shoot infestation was recorded during 3<sup>rd</sup> week of August and reached at its peak at the end of September.

Mahesh and Men (2007a) studied the seasonal incidence of shoot and fruit borer on brinjal. They reported that the shoot and fruit borer commenced from August and reached its first peak during middle of October with temperature ranging between 21.4 °C to 31.8 °C; relative humidity between 49per cent to 86per cent; rainfall and sunshine about 41.0 mm and 8 hrs, respectively. There was a positive significant association of *L. orbonalis* infestation with maximum temperature and sunshine, respectively.

Acharya *et al.*, (2008) revealed that the mean temperature and relative humidity had significant positive influence on the incidence of the brinjal shoot and fruit borer.

Naik *et al.*, (2008b) studied the seasonal incidence of *Leucinodes orbonalis* on aubergine grown in Andhra Pradesh. The results showed that the incidence of the shoot and fruit borer, in terms of shoot infestation, was observed during the third week of February and the incidence had no

significant relationship with temperature, relative humidity and rainfall but had a significant relationship with coccinellids and spiders.

Patil and Mehta, (2008) studied the population dynamics of *A. biguttula biguttula* on brinjal and they reported that the pest attained peak during mid August to September.

Sahu, (2008) studied the incidence of insect pests on brinjal crop and reported that the whitefly appeared in the last week of December and continued upto third week of May, when the maximum and minimum temperature were 34.2 and 16.9°C, respectively with 65 and 21 per cent morning and evening relative humidity, respectively. Evening relative humidity was found to be negatively correlated with whitefly population.

Ghosh and Senapati, (2009) reported *Leucinodes orbonalis* as a key pest of eggplant, and was found to be most active during May-August, and caused ( 49.5-81.0 ) per cent damage to the fruits. Peak infestation was noticed in the first week of June (22<sup>nd</sup> standard week), when the mean temperature, mean relative humidity and weekly rainfall were 27.8°C, 79.2 per cent and 81.2 mm, respectively. The pest became less active during winter months, particularly in December-January. Borer infestation showed a significant positive correlation with maximum and mean temperature, minimum and mean relative humidity and rainfall.

Naik *et al.*, (2009) studied the population dynamics of *B. tabaci* and *A. biguttula biguttula* on brinjal and reported that they attained peak during the 3<sup>rd</sup> week of February.

Singh *et al.*, (2009) studied the population dynamics of *L. orbonalis* on brinjal cv. Pusa purple round. The borer infested the crop from the early vegetative stage and continued upto crop maturity. Its infestation commenced first on shoots from the second week of April and attained peak during the third week of May to second week of June. The infestation of the borer on brinjal fruit was noticed from the third week of April. Correlation studies revealed that the mean temperature and relative humidity had positive, while sunshine and wind speed showed negative influence on the pest incidence,

whereas rainfall did not exhibit any influence on the borer incidence, respectively.

### **2.3 Management of insect pest complex of brinjal with reference to shoot and fruit borer with microbials :**

Patnaik and Singh, (1997) studied the efficacy of *Bacillus thuringiensis* subsp. *kurstaki* at a concentration of 0.05per cent against *L. orbonalis* on brinjal. It provided sufficient control of the pest but was not found to be cost effective.

Qureshi *et al.*, (1998) reported that *Bacillus thuringiensis* subsp. *kurstaki* @ 2 ml/L significantly reduced fruit damage caused by *L. orbonalis* and produced higher fruit yield than control.

Puranik *et al.*, (2002) evaluated different *B. thuringiensis* formulations against aubergine shoot and fruit borer, *L. orbonalis*. They reported that five sprays of (*B. thuringiensis* subsp. *kurstaki*) @ 0.2per cent at 10 days interval resulted in minimum shoot and fruit infestation and maximum yield of marketable fruits and proved to be the most effective treatment. This was followed by chemical insecticides and neem, which were found to be least effective treatments.

Mandal *et al.*, (2003) reported that *Bacillus thuringiensis* subsp. *kurstaki* @ 2 ml / L significantly reduced fruit damage caused by *L. orbonalis* and produced higher fruit yield than control.

Loureiro, Elisângela de S.; Moino Jr., Alcides; (2004) The aphids *Aphis gossypii* and *Myzus persicae* are cosmopolitan, poliphagous and damage cultivated plants. The effects of the entomopathogenic fungi *Beauveria bassiana* (isolate IBCB 66), *metarhizium anisopliae* (isolate IBCB 121), *Paecilomyces fumosoroseus* (isolate IBCB 141) and *Lecanicillium* (= *Verticillium*) *lecanii* (isolate JAB 02) on third instar nymphs of *A. gossypii* and *M. persicae* were evaluated in the laboratory at 25°C, 70 ± 10% RH and 12h photophase. The aphids were transferred to petri dishes with a foliar disk (cotton or pepper) with a layer of 1 cm thick of agar-water. The fungi were applied in a

suspension containing  $1.0 \times 10^6$  to  $1.0 \times 10^8$  conidia/ml. In the control treatment 1 ml of sterilized water was added to the foliar disks. The mortality of aphids was evaluated daily. *B. bassiana* and *M. anisopliae* caused 100% mortality at the seventh day after inoculation, for both species. *L. lecanii* was the fungus that provided mortality later in the aphids and *M. persicae* was more susceptible to both fungi than *A. gossypii*.

Yadav and Sharma, (2005) conducted field studies to assess the efficacy of bioagents and neem products in relation to Malathion against shoot and fruit borer, *Leucinodes orbonalis* on aubergine. The bioagents and neem products were not superior to Malathion 50 EC (0.05per cent), however, *Bacillus thuringiensis* subsp. *kurstaki* @ 2.5 ml / L water) provided sufficient control of the pest.

Singh, (2006) evaluated the comparative performance of microbial (*Bacillus thuringiensis*) and chemical insecticides. Bioagent, *B. thuringiensis* was found equally effective as that of the chemical insecticides.

Anonymous, (2007) reported Spinosad 45per cent SC @ 0.015per cent to be most effective against *L. orbonalis* reducing shoot and fruit infestation and recorded higher fruit yield.

Mahesh and Men (2007b) evaluated different commercial formulations of *Bacillus thuringiensis* subsp. *kurstaki* (*viz.* Delfin, Dipel and Bt PDKV) against brinjal shoot and fruit borer, *L. orbonalis*. They reported that Dipel 8L @ 1000 ml / ha was found to be most effective, recorded least damage of 14.4per cent and proved to be the best. It was however, at par with other treatments. However, all the treatments were significantly superior over control.

Singh and Yadav, (2007) evaluated chemical insecticides, microbials and neem products against brinjal shoot and fruit borer, *L. orbonalis*. They reported that chemicals were superior over microbials and neem products with respect to efficacy and yield.

Gautam *et al.*, (2008) evaluated chemical insecticides (*viz.* Malathion 50 EC @ 0.05per cent, Endosulfan 35 EC @ 0.07per cent and Quinalphos 25

EC @ 0.025per cent), microbials (*viz. B. thuringiensis* (Bt) Dipel 8L @ 0.07per cent and Biolep @ 0.07per cent) and neem products (*viz. Achook, Neemarin and Bioneem* all at 0.03 EC @ 0.03per cent) against aubergine shoot and fruit borer, *Leucinodes orbonalis*. They reported that chemical insecticides proved their superiority over neem and Bt products.

Adiroubane and Raghuraman, (2008) studied the efficacy of *Pongamia pinnata* oil (2per cent) (PPO), *Madhuca indica* [*M. longifolia*] oil (2per cent) (MIO), PPO + MIO at 1:1 (2per cent), oxymatrine 1.2 EC (0.2per cent), Spinosad 45 SC (225 g / ha), Acephate 75 SP (750 g / ha), Carbaryl 50 WP + Wettable Sulfur 50 WP (1:1), neem [*Azadirachta indica*] seed kernel extract (5per cent), and an untreated control against brinjal shoot and fruit borer. Oxymatrine and Spinosad were found to be most effective against brinjal shoot and fruit borer. The highest percentage reduction of shoot damage was observed in Oxymatrine and it was at par with Spinosad. Spinosad was effective at fruiting stage. The maximum percentage reduction of fruit damage was recorded in Spinosad and it was at par with Oxymatrine.

Ghosh and Senapati, (2009) evaluated insecticides and microbials against *L. orbonalis* and reported Avermectin @ 0.5 ml / l to be most effective in suppressing the dead heart caused by the pest followed by *Beauveria bassiana* @  $10^7$  conidia / ml and *Bacillus thuringiensis* @  $5 \times 10^7$  spores / ml.

Gopal *et al.*, (2009) evaluated chemical insecticides, microbials and neem products against aubergine shoot and fruit borer, *L. orbonalis*. They reported that chemicals were highly effective in reducing the infestation and increasing the fruit yields than the microbials and neem products. They further reported that *Bacillus thuringiensis* (Bt) based WDP formulation PUSA Bt was significantly effective in reducing the *L. orbonalis* infestation than the commercial Biolep.

Pareet and Basavanagoud, (2009) evaluated the efficacy of bio-pesticides *viz.* Spinosad @ 0.1 ml / l; Emamectin benzoate @ 0.2 ml / l; Avermectin @ 0.5 ml / l; *Bacillus thuringiensis* var. *kurstaki* (Btk) @ 2 ml / l; Difenthiuron @ 1 g / l and an untreated control against shoot and fruit borer (*Leucinodes orbonalis*) on aubergine cv. Mahyco-11. The lowest shoot

infestation and highest marketable fruit yield was recorded with Emamectin benzoate, which was at par with Spinosad. However, *Bacillus thuringiensis* was found to be the least effective treatment.

Naik And Shekharappa.(2009) A field experiment was carried out to study the bioefficacy of different entomopathogenic fungal formulations viz., crude, wettable powder and oil based formulation of *Beauveria bassiana*, *Metarhizium anisopliae* and *Verticillium lecanii* against sucking pests of okra during kharif 2007-08 Oil based formulation of *M. anisopliae* recorded minimum of 5.25 leafhopper/3 leaves followed by *B. bassiana* oil based (6.88) and *V. lecanii* oil based (7.75/e leaves)

Birla. M. ( 2011 ) insect pest complex of brinjal, *Solanum melongena* (Linn.) and their management and reported that On the basis of the effectiveness of different insecticides and microbials treatment against pest complex of brinjal. treatment, Endosulfan 35 EC @700 g.a./ha was found to be most effective as it recorded lowest infestation, this was followed by *Metarhizium anisopliae* @ 3.5 kg/ha and Highest fruit yield was registered by Endosulfan 35 EC @700 g.a./ha (152.50 q / ha), followed by *Beauveria bassiana* @ 1.5 kg / ha (147.44 q / ha) and *Metarhizium anisopliae* @ 3.5 kg/ha. (141.74 q / ha) as compared to control (77.43 q / ha).

## CHAPTER – III

### MATERIAL AND METHODS

The present investigation entitled, “Studies on insect pest complex of brinjal, *Solanum melongena* (Linn.) and management of shoot and fruit borer, *Leucinodes orbonalis* (Guen.) with microbials” was carried out in the experimental field of Department Of Entomology, Live Stock Farm, Adhartal, JNKVV, Jabalpur (M.P.) during *rabi* season 2011-2012

#### **3.1 Geographical location and climate:**

Jabalpur is situated between 22<sup>0</sup> 49" and 24<sup>0</sup> 8" North latitude and 78<sup>0</sup> 21" and 80<sup>0</sup> 58" East longitude and at an altitude of 411.78 m above the mean sea level.

The climate of the region is typically semi-humid and sub-tropical. Jabalpur comes under the agro-climatic region of Kymore Plateau and Satpura Hills and lies in the rice-wheat crop zone of the state. The mean annual rainfall is nearly 1423 mm, which is received mostly between mid - June to mid-September. The mean maximum temperature during the hottest months of May and June varies from 45.5 to 46.4<sup>0</sup>C. January is the coldest month with mean maximum and minimum temperature of 24.4<sup>0</sup>C and 7.3<sup>0</sup>C, respectively.

#### **3.2 Weather condition during the crop season:**

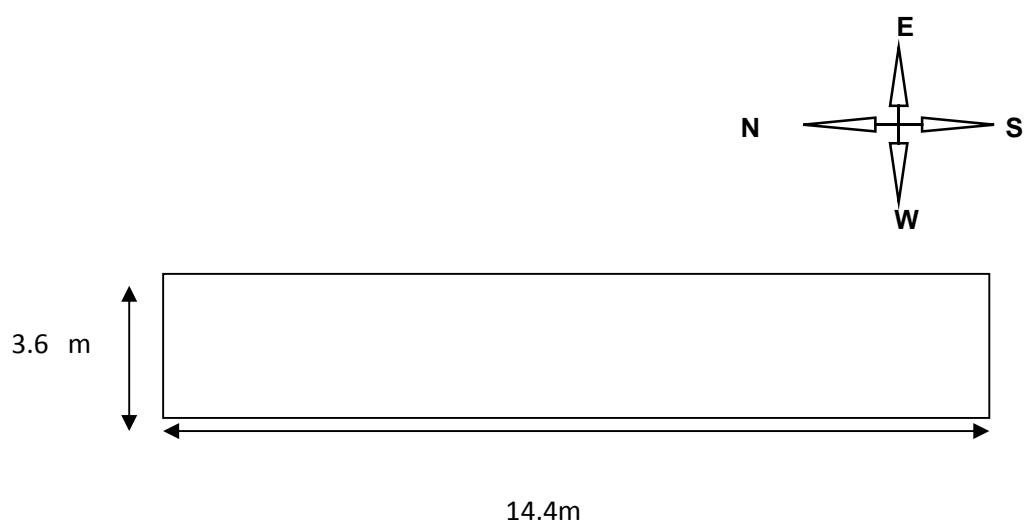
The weather conditions during the course of studies *i.e.* from November 2011 to May 2012. are presented in Appendix I

#### **3.3.1 To study the succession of insect pest complex and their natural enemies on brinjal:**

For conducting studies on insect pest succession and their natural enemies, the experimental details were as follows:

### Experimental details:

•Crop	:	Brinjal
•Variety	:	A.K.123
•Plot size	:	3.6 x14.4m
•No. of rows	:	23
•Row length	:	3.6 m
•Spacing : Row to row	:	0.60 m
•Spacing : Plant to plant	:	0.60 m
•Fertilizer (N : P : K kg / ha)	:	120 : 80 : 80
• Date of transplanting	:	25/11/2011



**Fig. 1: Layout plan of experimental trial – I**

### Method of observation:

Regular observations starting immediately after transplantation was carried out once in a standard week to record different insects of brinjal. The insects appearing on the crop right from transplantation upto harvest were recorded. The crop was kept unprotected for this purpose. The sequence in which the insects appeared was also noted. The status of different insect pests recorded was determined on the basis of the damage caused by them.

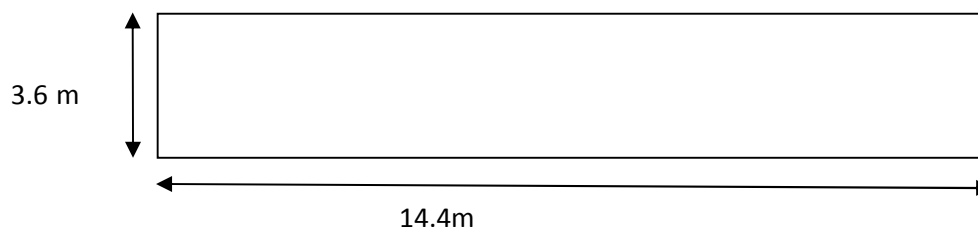
For observations 25 plants were randomly selected and population of different insect pests and natural enemies thereon was assessed.

### 3.3.2 To study the population dynamics of major insect pests of brinjal:

For conducting studies on population dynamics of major insect pests the experimental details were as follows:

#### Experimental details:

- Crop : Brinjal
- Variety : A.K.123
- Plot size : 3.6 X 14.4 m
- No. of rows : 23
- Row length : 3.6 m
- Spacing : Row to row : 0.60 m
- Spacing : Plant to plant : 0.60 m
- Fertilizer (N : P : K kg / ha) : 120 : 80 : 80
- Date of transplanting : 25/11/2011



**Fig. 2: Layout plan of experimental trial - II**

#### Method of observation:

Observations were recorded on 25 tagged plants (for sucking pest complex) once in a standard week, which started from the first appearance of the pest and were continued till their availability or maturity of the crop, whichever was earlier. At the same time a corresponding weekly record of meteorological data viz. minimum and maximum temperature, morning and evening percent relative humidity, total rainfall per week, number of rainy days per week, wind speed, sunshine morning and evening vapour pressure and

evaporation were maintained. The influence of different meteorological parameters on major insect pest population were studied by graphical super imposition technique.

Observations on different insect pests were recorded as detailed below:

**Jassid:**

The number of nymphs and adults of leafhopper, *Amrasca devastans* were counted on six leaves (each from 2 upper, middle and lower leaves per plant). by examining each leaf carefully during early morning hours, when the pest was less active. To begin with, leafhoppers on upper surface of the leaves were counted and then the leaf was tilted carefully to count population on the lower surface.

**Aphid and Whitefly:**

Six leaves (each from 2 upper, middle and lower per plant) were carefully examined for the presence of nymph and adults of aphids, *Aphis gossypii* and whitefly, *Bemisia tabaci*.

**Natural enemies:**

Similarly natural enemies viz. coccinellid, syrphid and spider population were also recorded. The population was expressed a numbers per plant.

**Shoot and fruit borer:**

Observation on intensity of infestation of borer were recorded as follows:

**Shoot infestation:**

Soon after noticing the *L. orbonalis* infestation, the shoot infestation was judged by counting healthy plants and plants having shoots infected by shoot and fruit borer of 25 randomly selected plants at five different locations. After each observation, damage shoots were removed.

### **Fruit infestation:**

Similarly, fruit infestation by *L. orbonalis* was judged by counting the number of total healthy fruits and fruits damaged by shoot and fruit borer at each picking per plot. After each observation damage fruits were recorded and percent shoot and fruit infestation were calculated.

$$\% \text{ shoot or fruit infestation} = \frac{\text{Number of shoots or fruits damaged}}{\text{Total number of shoots or fruits observed}} \times 100$$

### **3.3.3 Management of insect pest complex with reference to Shoot and fruit borer with microbials :**

For conducting studies on management of shoot and fruit borer with microbials the experimental details were as follows:

#### **Experimental details:**

- Design : RBD
- Replication : 3
- No. of treatments : 9
- Plot size : 3.6 x 4.8 m
- No. of rows/plot : 7
- Row length : 3.6 m
- Spacing: Row to row : 0.60 m
- Spacing: Plant to plant : 0.60 m
- Fertilizer (N : P : K kg / ha) : 120 : 80 : 80
- Date of transplanting : 25/11/2011
- Sprayer used : Knapsack sprayer
- Water required for spraying : 300 l / ha
- Spraying No. : 5

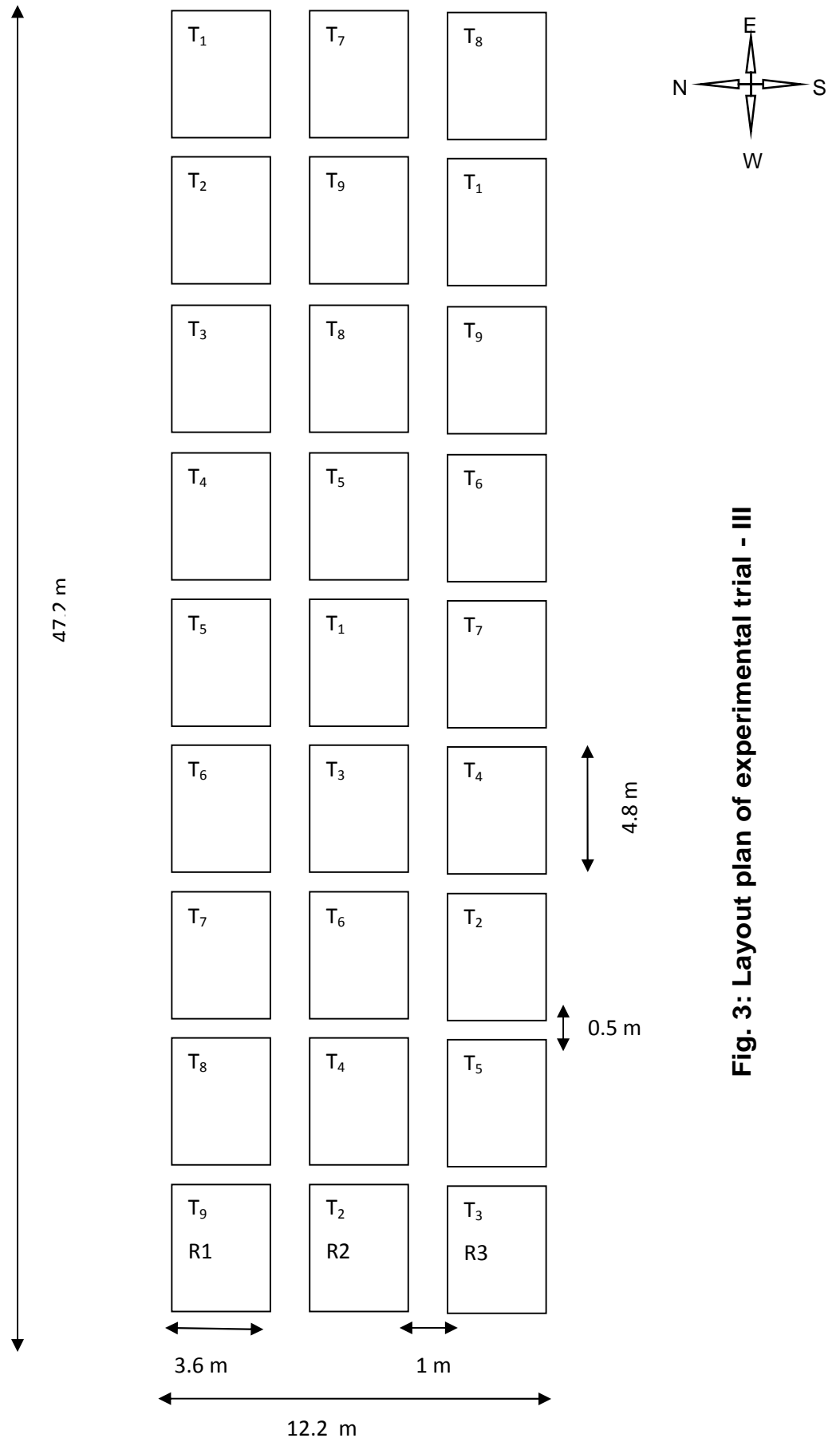
Dates : 24/02/2012  
05/03/2012  
15/03/2012  
25/03/2012

- 05/04/2012
- Irrigation No. : 9
  - Dates : 01/12/2011,19/12/2011,  
02/01/2012,22/01/2012,  
08/02/2012,25/02/2012,  
10/03/2012,28/03/2012,  
20/04/2012
  - Weeding No. : 5
  - Dates : 15/12/2011 .31/12/2012  
19/01/2012, 06/02/2012  
15/03/2012

**Table 1: Treatment details :**

<b>Treatment code</b>	<b>Treatment</b>	<b>Dose/ha</b>
T1	<i>Metarrhizium anisopliae</i>	2.5 kg
T2	<i>Metarrhizium anisopliae</i>	3.5 kg
T3	<i>Beauveria bassiana</i> 1.15 WP	1 kg
T4	<i>Beauveria bassiana</i> 1.15 WP	1.5 kg
T5	<i>Verticillium lecanii</i>	3.25 kg
T6	<i>Verticillium lecanii</i>	3.75 kg
T7 *	<i>Bacillus thuringiensis</i>	1 l
T8 *	<i>Bacillus thuringiensis</i>	1.5 l
T9	Control	-

\* Bioefficacy studies will not be conducted on sucking insect pest complex



**Fig. 3: Layout plan of experimental trial - III**

**Method of observation:**

Observations on shoot and fruit borer, *L. orbonalis* were recorded on 5 randomly selected tagged plants/plot, leaving the border rows.

Pre-treatment observations on shoot and fruit borer infestation were recorded 24 hours before spraying, while post-treatment observations were taken 3, 7 and 10 days after application of the treatments.

Fruit infestation by shoot and fruit borer was assessed by counting the number of total damage and healthy fruits at each picking per plot and percentage fruit infestation was calculated. Percent shoot and fruit infestation and fruit yield reduction over untreated control due to *L. orbonalis* was assessed by counting / weighing a known number of healthy and damaged fruits and computed as mentioned below :

$$\text{Percent loss in fruit weight} = \frac{\text{Wt. of } x \text{ number of fruits of treated plot} - \text{Wt. of } x \text{ number of fruits of untreated plot}}{\text{Wt. of } x \text{ number of fruits of treated plot}} \times 100$$

The percentage data on damaged fruits and fruit yield loss data were transformed to arcsin transformation values and statistically analyzed as per the method given by Snedecor and Cochran (1967). Similarly, data on healthy marketable fruit yield were also subjected to statistically analysis.

**Analysis of data:****Correlation and regression studies:**

Correlation and regression of the abiotic factors on major insect pests were worked out by using the formula as suggested by Snedecor and Cochran (1967).

$$\text{Correlation 'r'} = \frac{xy - \frac{x \cdot y}{n}}{\sqrt{\left\{ x^2 - \frac{(x)^2}{n} \right\} \left\{ y^2 - \frac{(y)^2}{n} \right\}}}$$

Regression  $Y = a + bx (r^2)$

a = Intercept.

b = Régression coefficient.

$r^2$  = Coefficient of multiple détermination

Following analysis of variance was used-

**Table 2: The skeleton of “Analysis of Variance” is given below:**

Sources of variance	D.F.	S.S.	M.S.S.	F.Cal	F.Table
Replications	(r-1)	SSR	VR	-	
Treatments	(t-1)	SST	VT	VT / VE	F at 5% (t-1), (r-1) (t-1)
Errors	(r-1) (t-1)	SSE	VE		
Total	(r.t-1)				

Where

r = number of replications

t = number of treatments

VR = replication mean sum of square

VT = treatment mean sum of square

VE = error mean sum of square

The significance among different treatment means was judged by critical difference (C.D) at 5% level of significance for comparison among the treatments, the marginal means of each treatment was considered. The following formula was used for various estimations:

(1) Standard error of mean =  $S. Em \pm = \sqrt{\frac{E ms}{r}}$

(2) Critical difference (C.D at 5%.) =  $SEm \times 2 \times t 0.05$

Where,

Ems = error mean sum of square

t = 't' value at 5 % level at error d.f.

r = number of replications

SEm± = standard error of any treatment mean

CD = Critical Difference

## CHAPTER – IV

### RESULTS

The results on insect pest succession, population dynamics of major insect pests and management of pest complex infesting brinjal (*Solanum melongena*) with microbials are presented in this chapter.

#### **4.1 To study the succession of insect pest complex and their natural enemies:**

Studies on succession of insects and field incidence revealed that about 4 species of insect pests and one species of natural enemy were observed to be associated with various stages of the brinjal crop (after transplanting) at Jabalpur, Madhya Pradesh in Central India during *rabi* 2011-2012 growing season (Table 3).

The first major group of insect pest to attack in the vegetative stage were jassid, aphid and whitefly and were available till maturity of the crop. From fruiting to maturity stage, shoot and fruit borer was the dominant pest.

Only one natural enemy Lady bird beetle was observed from vegetative stage to reproductive stage of the crop.

##### **4.1.1 Jassid, *Amrasca biguttula biguttula* (Ishida) (Hemiptera : Cicadellidae):**

In the present study jassid (Plate 1) was first observed when the crop age was about 7 days old (after transplantation) (Table 3) (Figure 4) (Plate1). From the figure it is evident that the pest was present on the crop during the entire cropping season and remained available upto the crop maturity stage *i.e.* first week of May.

##### **4.1.2 Aphid, *Aphis gossypii* (Glover) (Hemiptera : Aphididae):**

In the present study aphid (Plate-2) was first recorded when the crop age was about 11 days old (after transplantation) (Table 3) (Figure 4) From the figure it is evident that the pest was present on the crop almost during the

entire cropping season and remained available upto the crop maturity stage *i.e.* First week of May

#### **4.1.3 Whitefly, *Bemisia tabaci* (Genn.) (Hemiptera : Aleyrodidae):**

In the present study incidence of whitefly (Plate-3) was first observed when the crop age was about 18 days (after transplantation) (Table 3) (Figure 4) (Plate 3). From the figure it is evident that the pest was present on the crop during the entire cropping season and remained available upto the crop maturity stage *i.e.* first week of May.

#### **4.1.4 Shoot and fruit borer, *Leucinodes orbonalis* (Guen.) (Lepidoptera : Pyraustidae) :**

First incidence of the shoot and fruit borer infestation (Plate-4) was observed during the reproductive stage of the crop *i.e.* about 82 days old crop (after transplantation) (Table 3 and Figure 4) From the figure it is evident that the pest was present on the crop during the fruiting stage and remained available upto the crop maturity stage *i.e.* first week of May.

#### **4.1.5 Natural enemies :**

##### **1) Lady bird beetle, *Cheilomenes sexmaculatus* Fab (Coleoptera : Coccinellidae)**

First incidence of Lady bird beetle was observed when the crop age was about 39 days (Table 3 and Figure 4). From the figure it is evident that the predator was present on the crop during the vegetative stage and remained available upto the first week of March *i.e.* maturity stage of the crop.

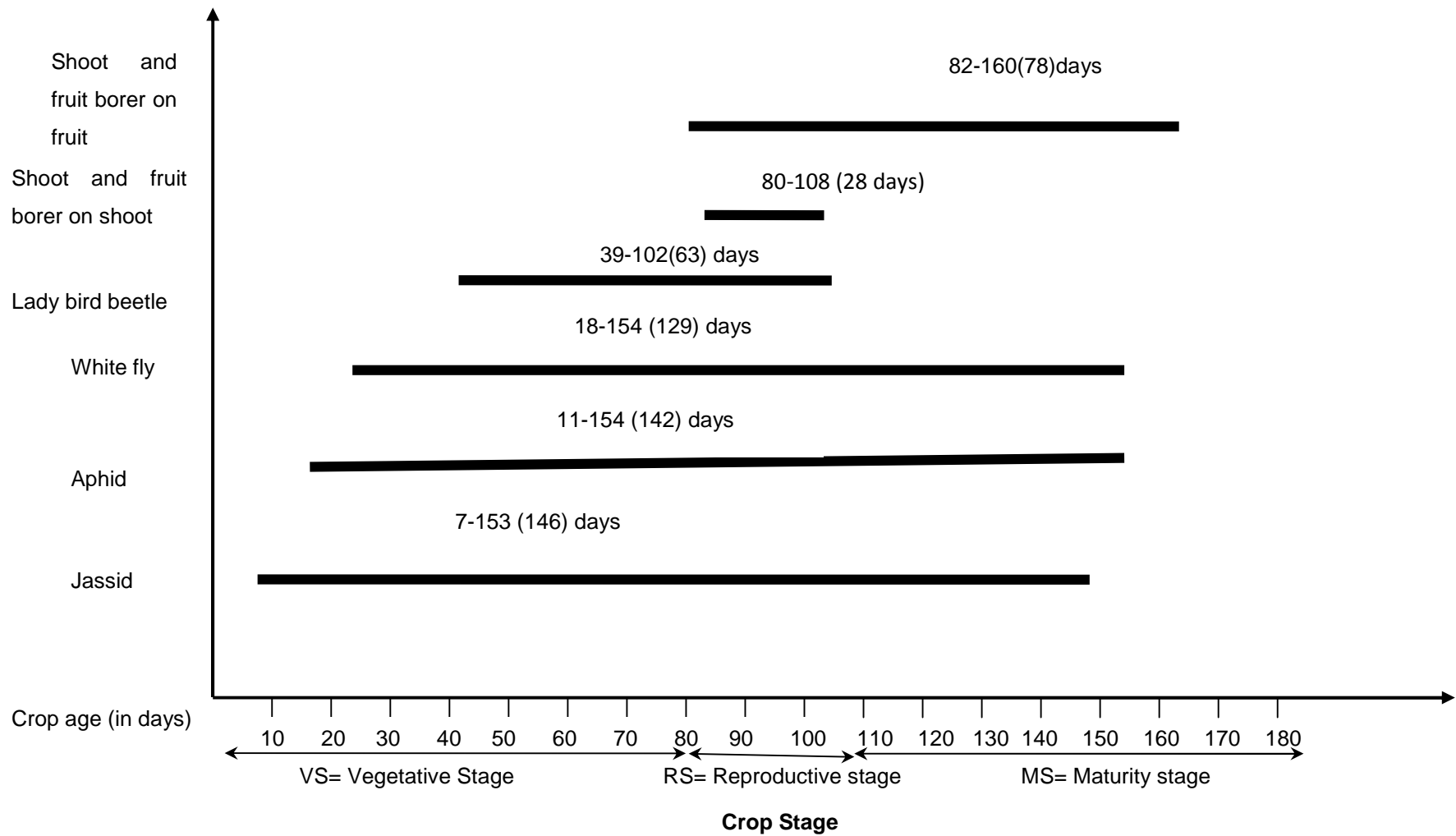
**Table 3: Succession of insect Complex on brinjal (after transplantation) at**

Date of observation	Insects				Crop age(day) (DAT)	Crop stage
	Name		Order	Family		
	Common	Scientific				
2 <sup>nd</sup> Dec.2011	Jassid	<i>Amrasca biguttula biguttula</i> (Ishida)	Hemiptera	Cicadellidae	7	Vegetative

**Jabalpur during *rabi* 2011–2012**

6 <sup>th</sup> Dec.2011	Jassid	<i>Amrasca biguttula biguttula</i> (Ishida)	Hemiptera	Cicadellidae	11	Vegetative
	Aphid	<i>Aphis gossypii</i> (Glover)	Hemiptera	Aphididae		
13 <sup>th</sup> Dec.2011 20 <sup>th</sup> Dec.2011, 27 <sup>th</sup> Dec.2011 and 3 <sup>rd</sup> Jan.2012	Jassid	<i>Amrasca biguttula biguttula</i> (Ishida)	Hemiptera	Cicadellidae	18- 39	Vegetative
	Aphid	<i>Aphis gossypii</i> (Glover)	Hemiptera	Aphididae		
	Whitefly	<i>Bemisia tabaci</i> (Genn.)	Hemiptera	Aleyrodidae		
	Lady bird beetle	<i>Cheilomenes sexmaculatus</i>	Coleoptera	Coccinellidae		
10 Jan.2012, 17 <sup>th</sup> Jan.2012 24 <sup>th</sup> Jan.2012, 31 <sup>st</sup> Jan.2012, 7 <sup>th</sup> Feb.2012, 14 <sup>th</sup> Feb.2012, 21 <sup>st</sup> Feb.2012, 28 <sup>th</sup> Febr.2012 and 6 <sup>th</sup> Mar.2012	Jassid	<i>Amrasca biguttula biguttula</i> (Ishida)	Hemiptera	Cicadellidae	46-100	Reproductive And 25% maturity
	Aphid	<i>Aphis gossypii</i> (Glover)	Hemiptera	Aphididae		
	Whitefly	<i>Bemisia tabaci</i> (Genn.)	Hemiptera	Aleyrodidae		
	Shoot and fruit borer	<i>Leucinodes orbonalis</i> (Guen.)	Lepidoptera	Pyraustidae		
	Lady bird beetle	<i>Cheilomenes sexmaculatus</i>	Coleoptera	Coccinellidae		
	Lady bird beetle	<i>Cheilomenes sexmaculatus</i>	Coleoptera	Coccinellidae		
13 <sup>th</sup> Mar.2012, 20 <sup>th</sup> Mar.2012, 27 <sup>th</sup> Mar.2012, 3 <sup>rd</sup> Apr.2012, 10 <sup>th</sup> Apr.2012 and 17 <sup>nd</sup> Apr.2012	Jassid	<i>Amrasca biguttula biguttula</i> (Ishida)	Hemiptera	Cicadellidae	107-140	50 % maturity
	Aphid	<i>Aphis gossypii</i> (Glover)	Hemiptera	Aphididae		
	Whitefly	<i>Bemisia tabaci</i> (Genn.)	Hemiptera	Aleyrodidae		
	Shoot and fruit borer	<i>Leucinodes orbonalis</i> (Guen.)	Lepidoptera	Pyraustidae		
24 <sup>th</sup> Apr.2012 and 1 <sup>st</sup> May 2012 and 7 <sup>th</sup> may 2012	Aphid	<i>Aphis gossypii</i> (Glover)	Hemiptera	Aphididae	147-160	Maturity
	Jassid	<i>Amrasca biguttula biguttula</i> (Ishida)	Hemiptera	Cicadellidae		
	Whitefly	<i>Bemisia tabaci</i> (Genn.)	Hemiptera	Aleyrodidae		
	Shoot and fruit borer	<i>Leucinodes orbonalis</i> (Guen.)	Lepidoptera	Pyraustidae		

DAT- Days After Transplantation



**Fig. 4: Succession of insect complex on brinjal (after transplantation) at Jabalpur during *rabi* 2011-2012**

Compilation of the information on insect succession on brinjal revealed that species of insects appeared at different stages of crop growth which constituted 3 species of order Hemiptera and 1 each of Lepidoptera and Coleoptera respectively (Table 4).

**Table 4: List of insects on brinjal (after transplantation) at Jabalpur during *rabi* 2011 – 2012**

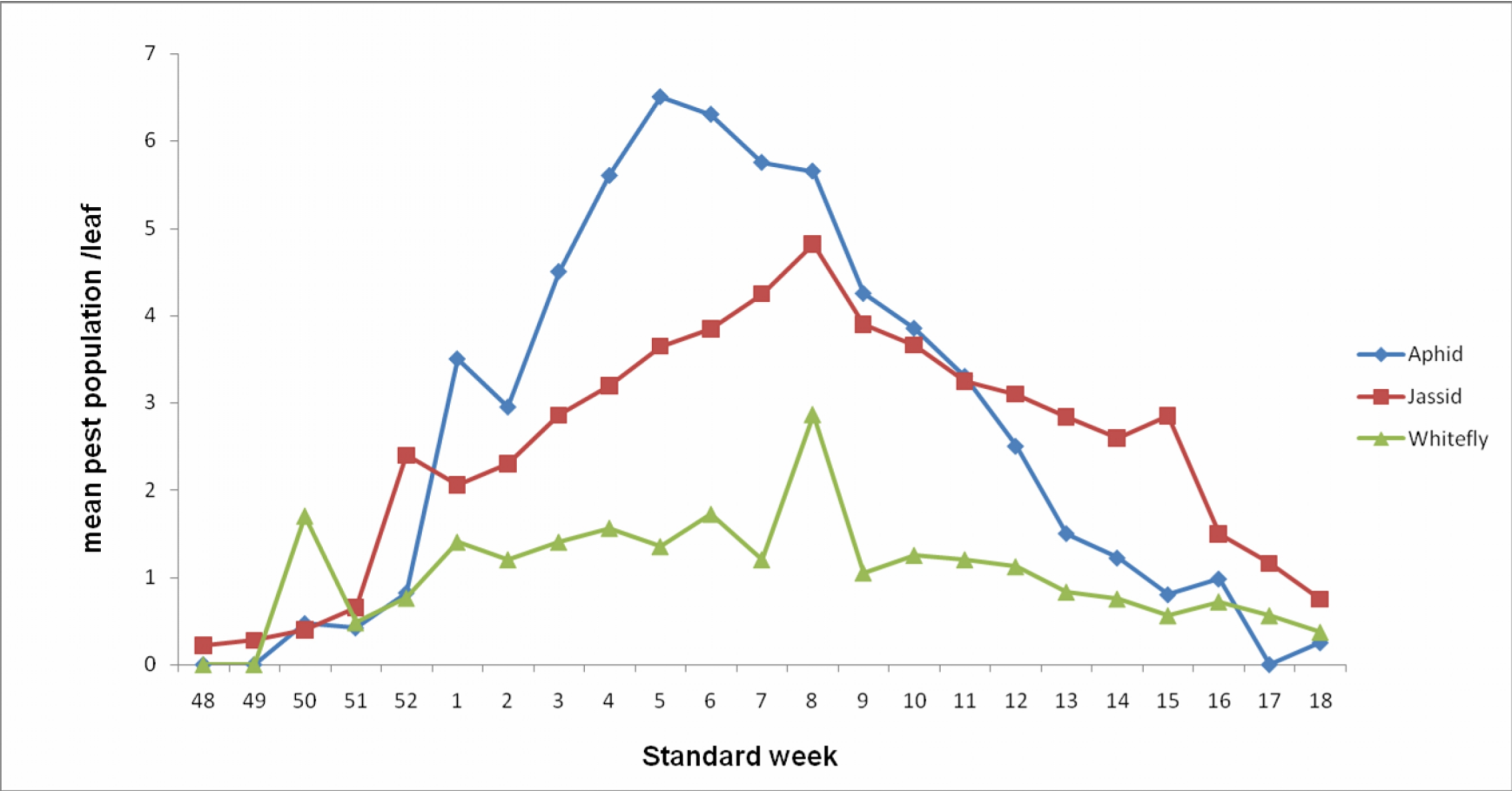
Common name	Scientific name	Order	Family	Status
Jassid	<i>Amrasca biguttula biguttula</i> (Ishida)	Hemiptera	Cicadellidae	Pest
Aphid	<i>Aphis gossypii</i> (Glover)		Aphididae	Pest
Whitefly	<i>Bemisia tabaci</i> (Genn.)		Aleyrodidae	Pest
Shoot and fruit borer	<i>Leucinodes orbonalis</i> (Guen.)	Lepidoptera	Pyraustidae	Pest
Lady bird beetle	<i>Cheilomenes sexmaculatus</i>	Coleoptera	Coccinellidae	Natural enemy

#### 4.2. To study the population dynamics of major insect pest of brinjal:

**Table 5: Incidence of insect complex on brinjal (after transplantation) at Jabalpur during *rabi* 2011-2012**

Month	Std week	Mean population (nymph+adult) /leaf			Shoot and fruit borer infestation (%)		Lady bird beetle/plant
		Jassid	Aphid	Whitefly	Shoot	Fruit	
November	48	0.22	0	0	0	0	0
December	49	0.28	0	0	0	0	0
	50	0.40	0.47	1.70	0	0	0
	51	0.66	0.42	0.48	0	0	0
	52	2.40	0.82	0.76	0	0	2
January	1	2.06	3.50	1.40	0	0	3
	2	2.30	2.95	1.20	0	0	2
	3	2.86	4.50	1.40	0	0	4
	4	3.20	5.60	1.56	0	0	7
February	5	3.65	6.50	1.35	0	0	4
	6	3.85	6.30	1.72	0	0	4
	7	4.25	5.75	1.20	1.85	10	3
	8	4.82	5.65	2.86	0	33.33	2
March	9	3.90	4.25	1.05	0	20.25	1
	10	3.66	3.85	1.25	0	25.50	0
	11	3.25	3.30	1.20	1.50	22.65	0
	12	3.10	2.50	1.12	0	33.35	0
April	13	2.84	1.50	0.83	0	30.01	3
	14	2.60	1.22	0.75	0	30.11	0
	15	2.85	0.80	0.56	0	25.25	0
	16	1.50	0.98	0.72	0	32.64	0
	17	1.16	0	0.56	0	33.60	0
May	18	0.75	0.25	0.37	0	38.55	0

Fig. 5: Incidence of major sucking pest complex on brinjal (after transplantaion) at Jabalpur during *rabi* 2011-2012



**Table 6: Correlation (r) and regression coefficient (byx) of abiotic factors on insect complex of brinjal crop (after transplantation) during *rabi* 2011-2012**

Weather factors	Jassid	Aphid		Whitefly		infestation by shoot and fruit borer				Lady bird beetle			
		Shoot		Fruit		r	byx	r	byx	r	byx		
	r	byx	r	byx	r							byx	r
<b>Max. temp. (°C)</b>	-0.19 NS	-	-0.47*	0.49	-0.20 NS	-	-0.01 NS	-	0.89**	0.17	-0.48 NS	-	
<b>Min. temp. (°C)</b>	-0.13 NS	-	-0.40 NS	-	-0.26 NS	-	-0.01 NS	-	0.80**	0.34	-0.42 NS	-	
<b>Morning RH (%)</b>	0.15 NS	-	0.47*	0.01*	0.20 NS	-	0.06 NS	-	-0.82**	0.97	0.50 NS	-	
<b>Evening RH (%)</b>	0.42 NS	-	0.45*	0.66	0.13 NS	-	0.08 NS	-	-	0.76**	0.41	0.45 NS	-
<b>Wind velocity (km/hr)</b>	0.20 NS	-	0.02 NS	-	-0.20 NS	-	0.14 NS	-	0.56**	0.39	-0.17 NS	-	
<b>Sunshine (hrs)</b>	0.16 NS	-	-0.06 NS	-	0.10 NS	-	0.08 NS	-	0.32 NS	-	-0.27 NS	-	
<b>Rainfall (mm)</b>	0.28 NS	-	0.28 NS	-	-0.28 NS	-	-0.10 NS	-	-0.32 NS	-	0.47 NS	-	
<b>No. of rainy days</b>	0.43 NS	-	0.43 NS	-	-0.27 NS	-	-0.11 NS	-	-0.35 NS	-	0.70 NS	-	
<b>Morning (mm )</b>	-0.14 NS	-	-0.29 NS	-	-0.30 NS	-	-0.06 NS	-	-0.58 NS	-	-0.24 NS	-	
<b>Evening vapour Pressure (mm)</b>	-0.16 NS	-	0.10 NS	-	-0.45 NS	-	0.21 NS	-	-0.13 NS	-	0.25 NS	-	
<b>Evapouration (mm)</b>	-0.12 NS	-	-0.45 NS	-	-0.34 NS	-	-0.11 NS	-	0.88	0.12	-0.12 NS	-	

\*Significant at 5% level,

\*\* Significant at 1% level ,

NS- Non Significant

#### 4.2.1 Jassid, *Amrasca biguttula biguttula* (Ishida) (Hemiptera : Cicadellidae):

In the present study, first appearance of the pest was observed on 2<sup>nd</sup> December *i.e.* 48<sup>th</sup> standard week (SW) (27-11-11 to 03-12-11) and regular observations were therefore started from 2<sup>nd</sup> December 2011. The number of jassids (nymph and adult) were worked out as weekly average per leaf and data are presented in (Table 5 and Fig.5)

From the figure 5 it is seen that jassid population started increasing from 48<sup>th</sup> SW and reached at its First peak (2.4) jassids / leaf) during 52<sup>th</sup> SW (25-12-2011 to 31-12-2011). During this period maximum and minimum temperature was 24.9 and 7.4<sup>o</sup>C, respectively, whereas morning and evening relative humidity were 89 and 32 percent, respectively. Further sunshine, wind velocity, morning and evening pressure vapour pressure and evaporation were 7.4 hrs, 2.6 km / hr, 7.7mm, 7.9mm, and 2.1mm respectively. After 52<sup>th</sup> SW there is decline in jassid population during 1<sup>st</sup> SW (1-1-2012 to 7-1-2012) and then after it gradually started increasing and attain its second peak (4.82) jassids / leaf) during 8<sup>th</sup> SW (19-2-2012 to 25-2-2012). During this period maximum and minimum temperature was 30.5 and 9.8<sup>o</sup>C, respectively, whereas morning and evening relative humidity were 86 and 28 percent, respectively. Further sunshine, wind velocity, morning and evening vapour pressure and evaporation were 9.6 hrs, 3.1 km / hr, 0 days, 0 mm, 9.3mm, 9mm, and 3.3 mm respectively.

After 9<sup>th</sup> SW there was a decline in the jassid population (3.9 jassids / leaf) and it reached 2.6 jassid/leaf in the 14<sup>th</sup> SW (1-04-2012 to 7-04-2012). After 14<sup>th</sup> SW there was a sudden increase in the population and it attained its third peak (2.85 jassids / leaf) in the 15<sup>th</sup> SW (8-4-2012 to 14-4-2012) During this period, maximum and minimum temperature was 39.4 and 18.4<sup>o</sup>C, respectively, whereas morning and evening relative humidity was 45 and 14%, respectively. Further sunshine, wind velocity, morning and evening vapour pressure and evaporation were 8.2 hrs, 5.6 km / hr, 10.5 mm, 6.9 mm and 7.3 mm, respectively. There was no rainfall during this week.

After 15<sup>th</sup> SW there was a gradual decline in the jassid population and was available upto in the 18<sup>h</sup> SW (29-04-2012 to 05-05-2012).

#### **Correlation studies:**

Correlation studies revealed that morning and evening relative humidity, wind velocity, sunshine, rainfall, no of rainy days were positively correlated with jassid population ( $r=0.15, 0.62, 0.2, 0.16, 0.28, 0.43$  respectively) but were found to be non significant.

While, maximum and minimum temperature, vapour pressure and evaporation were found to be negatively correlated ( $r = -0.91, -0.13, -0.14, -0.16, \text{ and } -0.12$  respectively) with jassid population, but were found to be non-significant (Table 6).

#### **4.2.2 Aphid, *Aphis gossypii* (Glover) (Hemiptera : Aphididea ):**

In the present study, first appearance of the pest was recorded in. 50<sup>th</sup> SW (10-12-2011 to 17-12-2011 and regular observations were therefore started from December 2011. The number of aphids (nymph and adult) were worked out as weekly average per leaf and data are presented in Table 5 and illustrated in Figure 5.

From the figure it is evident that aphid population started increasing with light fluctuation and reached at its first peak (3.5 aphids / leaf) during 1<sup>st</sup> SW (01-01-2012 to 07-01-2012). During this period maximum and minimum temperature was 23 and 12 °C, respectively, whereas morning and evening relative humidity was 95 and 69 percent, respectively. Further sunshine, wind velocity, morning and evening vapour pressure, evaporation rainfall and rainy days was 5.8 hrs, 3.2 km / hr, 11.2 mm and 13.5 mm, 1.1 mm, 28.6 mm and 1 day respectively.

After 1<sup>st</sup> SW there was a gradual increase in the aphid population (4.5 aphids /leaf) in the 3<sup>rd</sup> SW. However after 3<sup>rd</sup> SW there was gradual increase in the aphid population and reached its second peak (6.5 aphid /leaf) in 5<sup>th</sup> SW (29-01-2012 to 04-01-2012) during this period maximum and minimum temperature was 20.8 and 8°C respectively where as the morning and evening relative humidity was 91 to 46 per cent respectively, Further sunshine, wind velocity, morning and evening vapour pressure, evaporation,

rainfall and rainy days was 4.5 hrs, 3.5 km / hr, 8.1 mm and 9.2 mm, 1.6 mm, 7.6 mm and 1 day respectively,

After 5<sup>th</sup> SW there is gradual decline in the aphid population and was available up to the 18<sup>th</sup> SW (28-4 2012 to 5-5-2012) with slight fluctuation in the 16<sup>th</sup> SW (15-04-2012 to 21-04-2012).

### **Correlation studies :**

Correlation studies revealed that morning and evening relative humidity, showed significant positive correlation ( $r=0.47$  and  $0.45$ ,) respectively with aphid population (Table 6).

The regression equations being:

$$= 1.16 + 0.01 x (R^2 = 0.22)$$

$$= 0.80 + 0.66 x (R^2 = 0.20)$$

From the above equation it may be expressed that with every unit increase in morning relative humidity and evening relative humidity there was an increase of 0.01 and 0.66 aphid population per leaf respectively (Fig. 6 and 7).

Correlation studies further revealed that maximum temperature, showed significant negative correlation ( $r = -0.47$ ) with aphid population (Table 6).

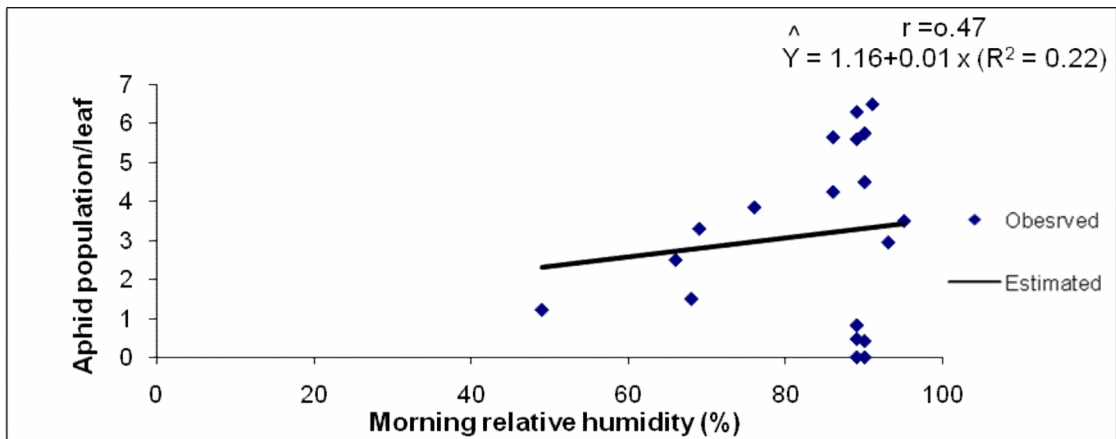
The regression equation computed was:

$$= 7.65 - 0.49 x (R^2 = 0.22)$$

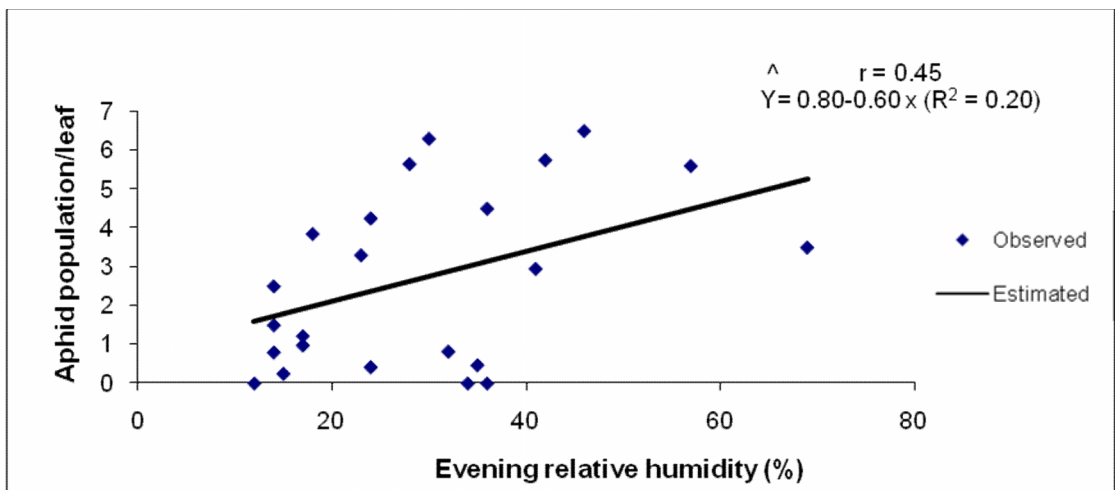
From the above equation it may be expressed that with every unit increase in maximum temperature, there was a decrease of 0.49 aphid population per leaf, respectively (Fig. 8).

Further, wind velocity, rainfall, number of rainy days, and evening vapour pressure exhibited positive correlation ( $r=0.02, 0.28, 0.43,$  and  $0.10$  respectively) with aphid population, but found to be statistically non-significant.

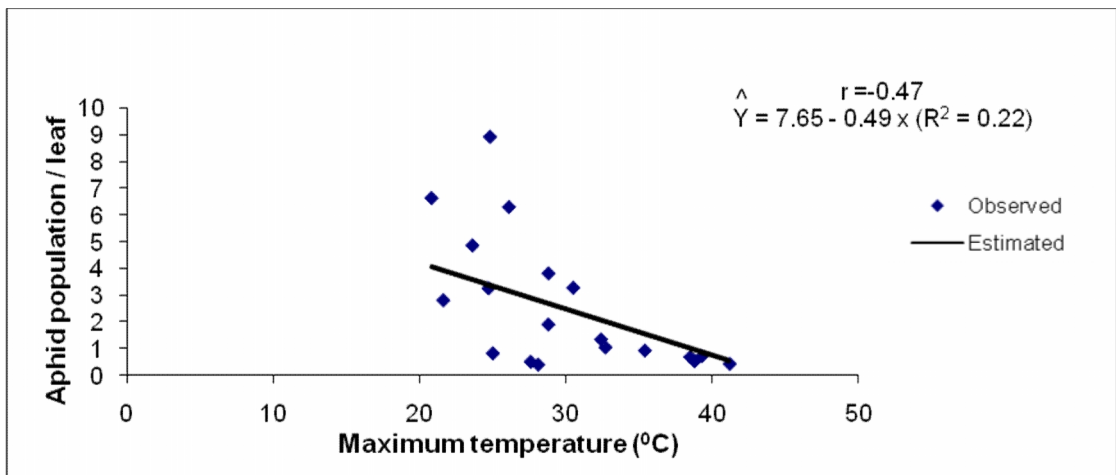
While minimum temperature, sunshine, morning vapour pressure and evaporation were found to be negatively correlated ( $r = -0.40, -0.06, -0.29$  and  $-0.45$ ) respectively with aphid population, but were found to be non-significant



**Fig.6: Regression of morning relative humidity on aphid infesting brinjal**



**Fig.7: Regression of evening relative humidity on aphid infesting brinjal**



**Fig.8: Regression of maximum temperature on aphid infesting brinjal**

### 4.2.3 Whitefly

In the present study, first appearance of the pest was observed on 50<sup>th</sup> SW.(10-12-2011 to 17-12-2011) regular observations were therefore started from 17<sup>th</sup> December 2011. The number of whitefly (nymph and adult) were worked out as weekly average per leaf and data are presented in Table 5 and illustrated in Figure 5.

From the figure it is seen that whitefly population attained its first peak on 50<sup>th</sup> SW, During this period maximum and minimum temperature was 25.3 and 7.2<sup>o</sup>C respectively where as the morning and evening relative humidity was 89 to 35 per cent respectively, Further sunshine, wind velocity, morning and evening vapour pressure, evaporation, were 8.2 hrs, 2.7 km / hr, 8 mm 8 mm and 2.3 mm respectively, there is no rainfall during this week.

After 50<sup>th</sup> SW there was sudden decline in whitefly population and was 0.48/leaf during 51<sup>th</sup> SW (18-12-2011 to 24-12-2011). After 51<sup>th</sup> SW there was gradual increase in the whitefly population with light fluctuation in 2<sup>nd</sup> SW it attains its second peak (1.56 whitefly /leaf ) during 4<sup>th</sup> SW (22-1-2012 to 28-1-2012) During this period maximum and minimum temperature was 21.5 and 9<sup>o</sup>C respectively whereas the morning and evening relative humidity was 89 to 57 per cent respectively, Further sunshine, wind velocity, morning and evening vapour pressure, evaporation, and rainfall were 6.8 hrs, 3.5 km / hr, 8.7 mm, 10.2 mm, 1.9 mm and 13.2 respectively, there is 2 rainy days during this week.

After 4<sup>th</sup> SW there was sudden decline in the 5<sup>th</sup> SW (1.35 whitefly/ leaf) and it attains its third peak during 6<sup>th</sup> SW (5-2-2012 to 11-2-2012) during this period maximum and minimum temperature was 26.4 and 8.8<sup>o</sup>C respectively whereas the morning and evening relative humidity was 89 to 30 per cent respectively, Further sunshine, wind velocity, morning and evening vapour pressure, and evaporation, were 8.6 hrs, 4k m / hr, 8.6 mm, 7.3 mm, and 2.7 mm respectively, There is no rainfall during this week.

After 6<sup>th</sup> SW there was sudden decline in whitefly population in the 7<sup>th</sup> SW (12-2-2012 to 18-2-2012) and it attain its fourth peak (2.86 whitefly/leaf) during 8<sup>th</sup> SW(19-2-2012 to 25-2-2012) During this period maximum and

minimum temperature was 30.5 and 9.8<sup>0</sup>C respectively whereas the morning and evening relative humidity was 86 to 24 per cent respectively, Further sunshine, wind velocity, morning and evening vapour pressure, and evaporation, were 9.6 hrs, 3.1 k m / hr, 9.3 mm, 9mm, and 3 mm respectively, There is no rainfall during this week.

After 8<sup>th</sup> SW there was gradual decline in the whitefly population with light fluctuation in 10<sup>th</sup> SW (4-3-2012 to 10-3-2012) and 16<sup>th</sup> SW (15-4-2012 to 21-4-2012) and was available up to the 18<sup>th</sup> SW (29-4-2012 to 5-5-2012)

#### **Correlation studies:**

Correlation studies revealed that morning, and evening relative humidity and sunshine showed positive correlation with whitefly population (0.20 ,0.13, 0.10,) respectively but found non significant (Table 6).

While maximum temperature, minimum temperature, wind velocity, rain fall , no of rainy days, morning vapour pressure ,evening vapour pressure and evaporation showed negative correlation(-0.20,-0.26,-0.20,-0.27,-0.30,-0.34,-0.45) respectively but found to be non significant (Table 6)

#### **4.2.4. a. Shoot damage:**

During the entire period of study the shoot damage due to shoot and fruit borer were only observed (13-2-2012 to 19-2-2012) 7<sup>th</sup>SW and 8<sup>th</sup>SW.

#### **4.2.4. b. Fruit damage:**

In the present study, fruit infestation due to shoot and fruit borer was first observed in 7<sup>th</sup> SW (12-02-2012 to 19-02-2012) and regular observations were therefore started from that week . The fruit infestation was worked out as weekly percent fruit damage and data are presented in Table 5 and illustrated in Figure 9.

From the figure it is seen that that there was sudden increase in the fruit infestation due to shoot and fruit borer after 7<sup>th</sup> SW. And it attaine its first peak during the 8<sup>th</sup> SW. during this period maximum and minimum temperature was 30.5 and 9.8<sup>0</sup>C, respectively, whereas morning and evening relative humidity was 86 and 28 percent, respectively. Further sunshine, wind velocity, morning and evening vapour pressure and evaporation were (9.6

hrs, 3.1 km / hr, 9.3 mm, 9 mm and 3.3 mm) respectively. There was no rainfall during this week

After 8<sup>th</sup> SW there was decline in the fruit infestation in 9<sup>th</sup> SW (28-2-2012 to 3-3-2012) (20.25 %) Immediately after 9<sup>th</sup> SW there was sudden increase in fruit infestation and reached its second peak in 10<sup>th</sup> SW. During this period maximum and minimum temperature was 30.8 and 11.6 °C respectively where as morning and evening relative humidity was 76 and 18 per cent. respectively. Further wind velocity, sunshine, morning and evening vapour pressure and evaporation was 4.9 km/hr, 8.3 hrs, 8.9 mm, 6 mm, 4.8 mm respectively.

After 10<sup>th</sup> SW there was sudden decline in the fruit infestation in the 11<sup>th</sup> SW however immediately after 11<sup>th</sup> SW there was sudden increase in fruit infestation and it attained its third peak (33.35%) during 12<sup>th</sup> SW. During this period maximum and minimum temperature was 35.1 and 13 °C, respectively, whereas morning and evening relative humidity was 66 and 14 percent, respectively. Further sunshine, wind velocity, morning and evening vapour pressure and evaporation were (8.7 hrs, 3.4 km / hr, 8.1 mm, 5.7 mm and 5.1 mm) respectively. There was no rainfall during this week.

After 12<sup>th</sup> SW there was a decline in the fruit infestation due to shoot and fruit borer up to 14<sup>th</sup> SW (1-4-2012 to 7-4-2012) and was (25.25%) After 14<sup>th</sup> SW there was gradual increase in the fruit infestation and attained its fourth peak (38.55%) during 18<sup>th</sup> SW (29-4-2012 to 5-5-2012). During this period maximum and minimum temperature was 38.9 and 20.7 °C, respectively, whereas morning and evening relative humidity were 45 and 15 percent, respectively. Further sunshine, wind velocity, morning and evening vapour pressure and evaporation were 7.4 hrs, 5.2 km / hr, 10.9 mm, 12 mm and 8.1 mm, respectively. There was no rainfall during this week.

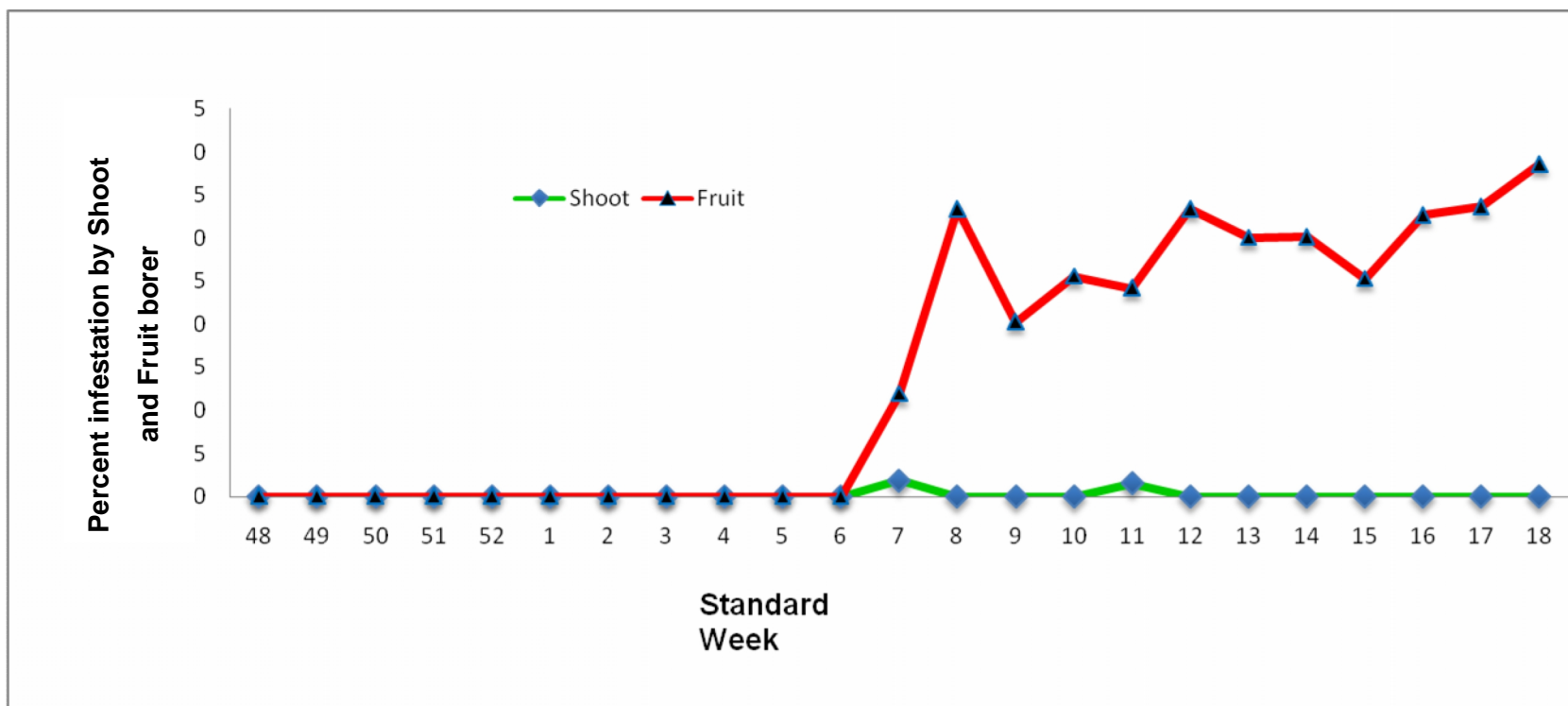


Fig. 9: Incidence of shoot and fruit borer infestation on brinjal (after transplantation) at Jabalpur during *rabi* 2011-2012

### Correlation studies :

Correlation studies revealed that maximum temperature, minimum temperature, wind velocity and evaporation showed significant positive correlation ( $r = 0.89, 0.80, 0.56, 0.88$ ) respectively with fruit infestation due to shoot and fruit borer (Table 6).

The regression equations computed were:

$$= -48.56 + 0.17 x (R^2 = 0.79)$$

$$= 15.81 + 0.34 x (R^2 = 0.64)$$

$$= 17.87 + 0.39 x (R^2 = 0.31)$$

$$= 1.31 + 0.12 x (R^2 = 0.77)$$

From the above equations it may be expressed that with every unit increase in maximum temperature, minimum temperature, wind velocity and evaporation there was an increase of (0.17, 0.34, 0.39 and 0.12) percent infestation due to shoot and fruit borer respectively respectively (Fig. 10, 11, 12, 13).

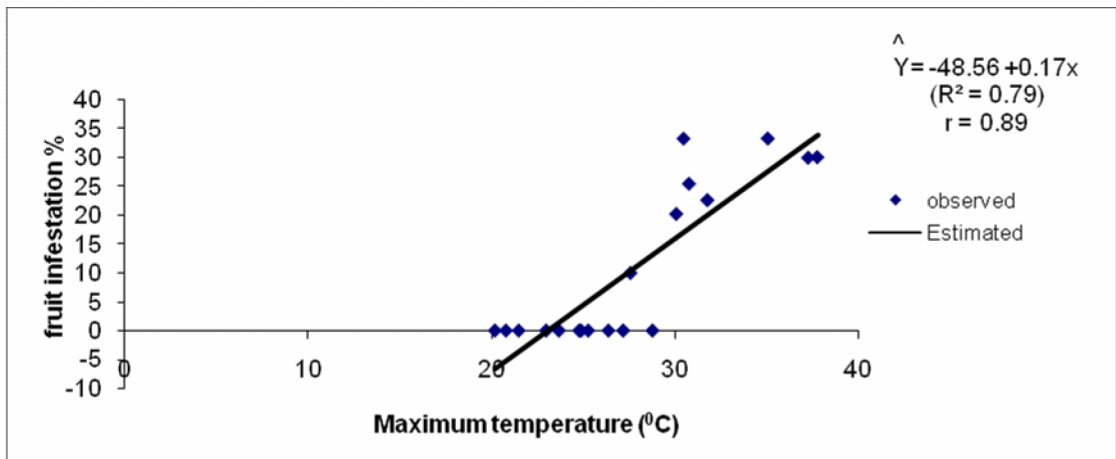
Correlation studies further revealed that morning and evening relative humidity showed significant negative correlation (-0.82 and -0.76) respectively, with fruit infestation by shoot and fruit borer.

The regression equation computed were

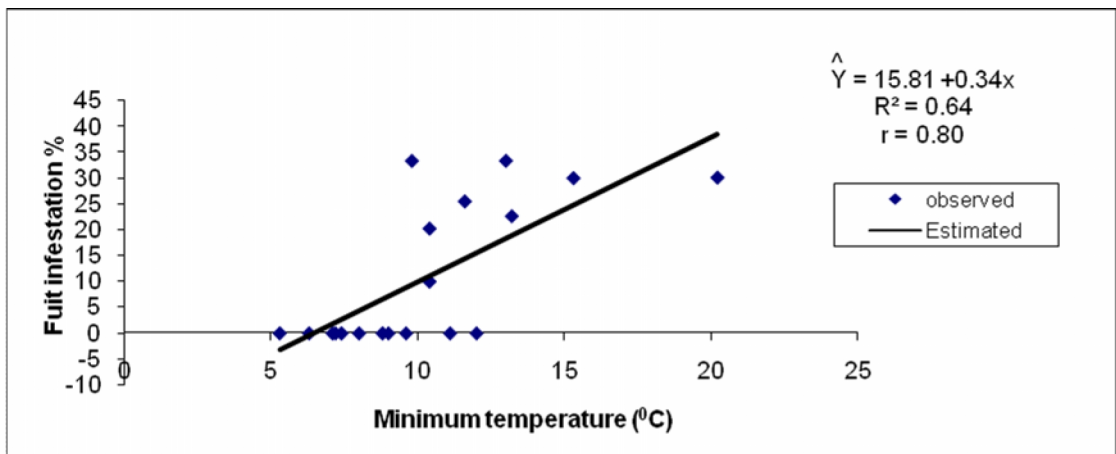
$$= 67.18 + 0.97 x (R^2 = 0.67)$$

$$= 37.72 + 0.41 x (R^2 = 0.57)$$

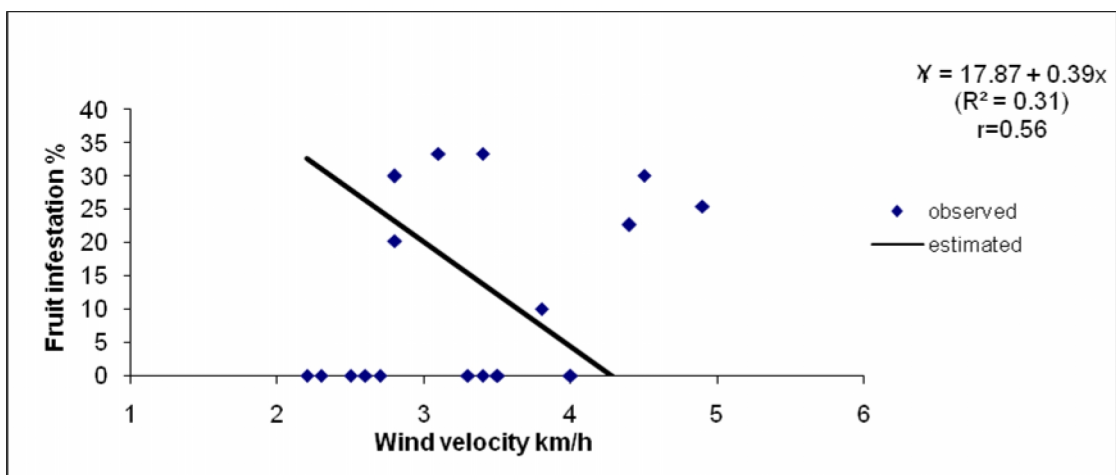
From the above equation it may be said that with every 1% increase in morning and evening relative humidity there was an increase of 0.17 and 0.34% fruit infestation respectively due to shoot and fruit borer (Fig 14 and 15). Correlation studies further revealed that sunshine exhibited positive correlation ( $r = 0.32$ ) with fruit infestation but found to be non significant while the rainfall, rainy days morning vapour pressure and evening vapour pressure showed negative correlation ( $r = -0.32, -0.35, -0.58$  and  $-0.13$  respectively) on fruit infestation due to shoot and fruit borer, but were found to be non-significant (Table 6).



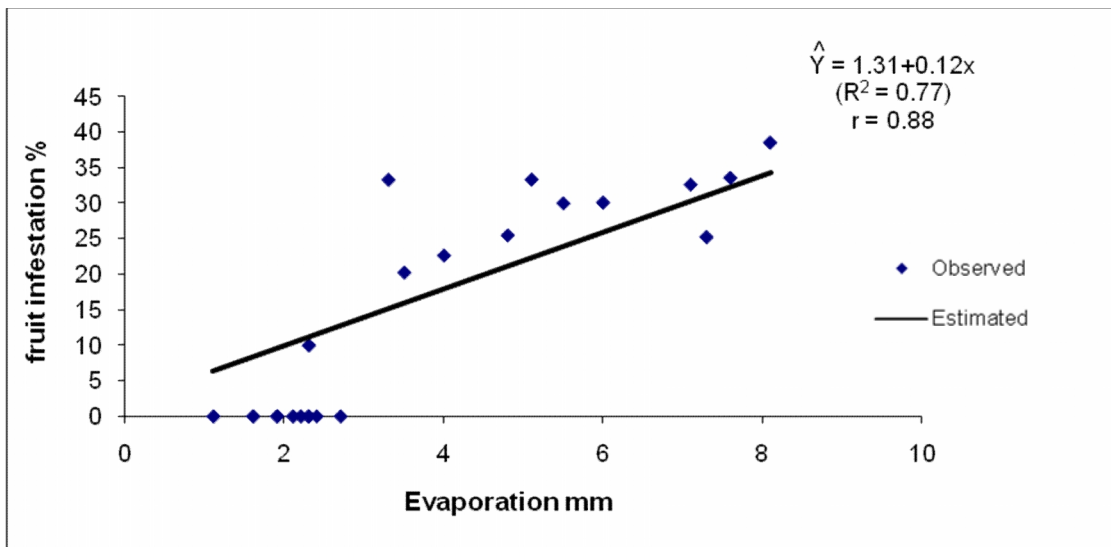
**Fig. 10: Regression of maximum temperature on brinjal shoot and fruit borer infestation**



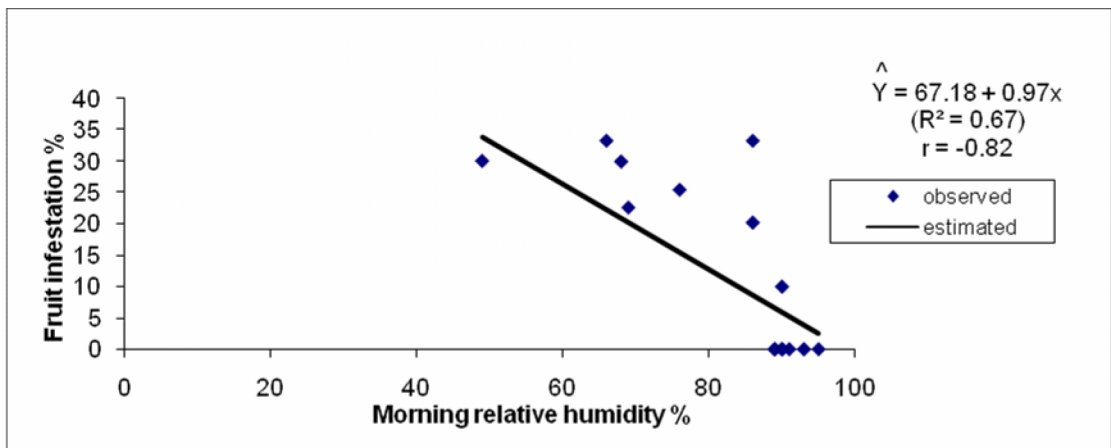
**Fig. 11: Regression of minimum temperature on brinjal shoot and fruit borer infestation.**



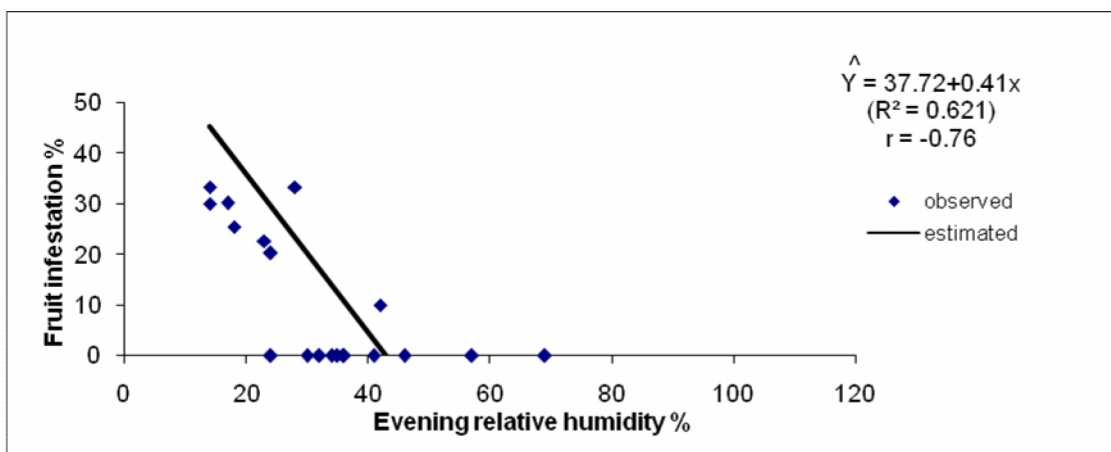
**Fig. 12: Regression of wind velocity on brinjal shoot and fruit borer infestation**



**Fig. 13: Regression of Evaporation on brinjal shoot and fruit borer infestation**



**Fig. 14: Regression of morning relative humidity on brinjal shoot and fruit borer infestation**



**Fig. 15: Regression of evening relative humidity on brinjal shoot and fruit borer infestation**

## 4.2.5: Natural enemy

### 1) Lady bird beetle

In the present study, first appearance of the predator was observed on 1<sup>st</sup> SW.(1-1- 2012 to 7- 1- 2012) regular observations were therefore started from 1<sup>st</sup> Sw January 2012. The number of adult beetle per plant were worked out as weekly average per plant and data are presented in Table 5 and illustrated in Figure16

From the figure it is seen that .there is sudden increase in population and it attain its first peak(3 beetle/plant ) during 2<sup>nd</sup> SW (07-01-2012 to 14-01-2012) During this period maximum and minimum temperature was 20.2 and 6.3 °C, respectively, whereas morning and evening relative humidity were 93 and 41 percent, respectively. Further sunshine, wind velocity, morning and evening vapour pressure and evapouration were 7.1 hrs, 4 km / hr, 8 mm,7 mm and 1.9 mm, respectively. There was no rainfall during this week.

After 2<sup>nd</sup> SW there is slight fluctuation in the beetle population up to the 4<sup>th</sup> SW but there is sudden increase in population after 4<sup>th</sup> SW and it attains its second peak( 7 beetle / plant ) during the 5<sup>th</sup> SW ( 29-01-2012 to 04-02-2012) During this period maximum and minimum temperature was 20.8 and 8 °C, respectively, whereas morning and evening relative humidity were 91 and 46 percent, respectively. Further sunshine, wind velocity, morning and evening vapour pressure and evapouration were 4.5 hrs, 3.5 km / hr,8.1 mm,9.2 mm and 1.6 mm, respectively. There was 7.6 mm rainfall and 1 rainy day during this week. during this week.

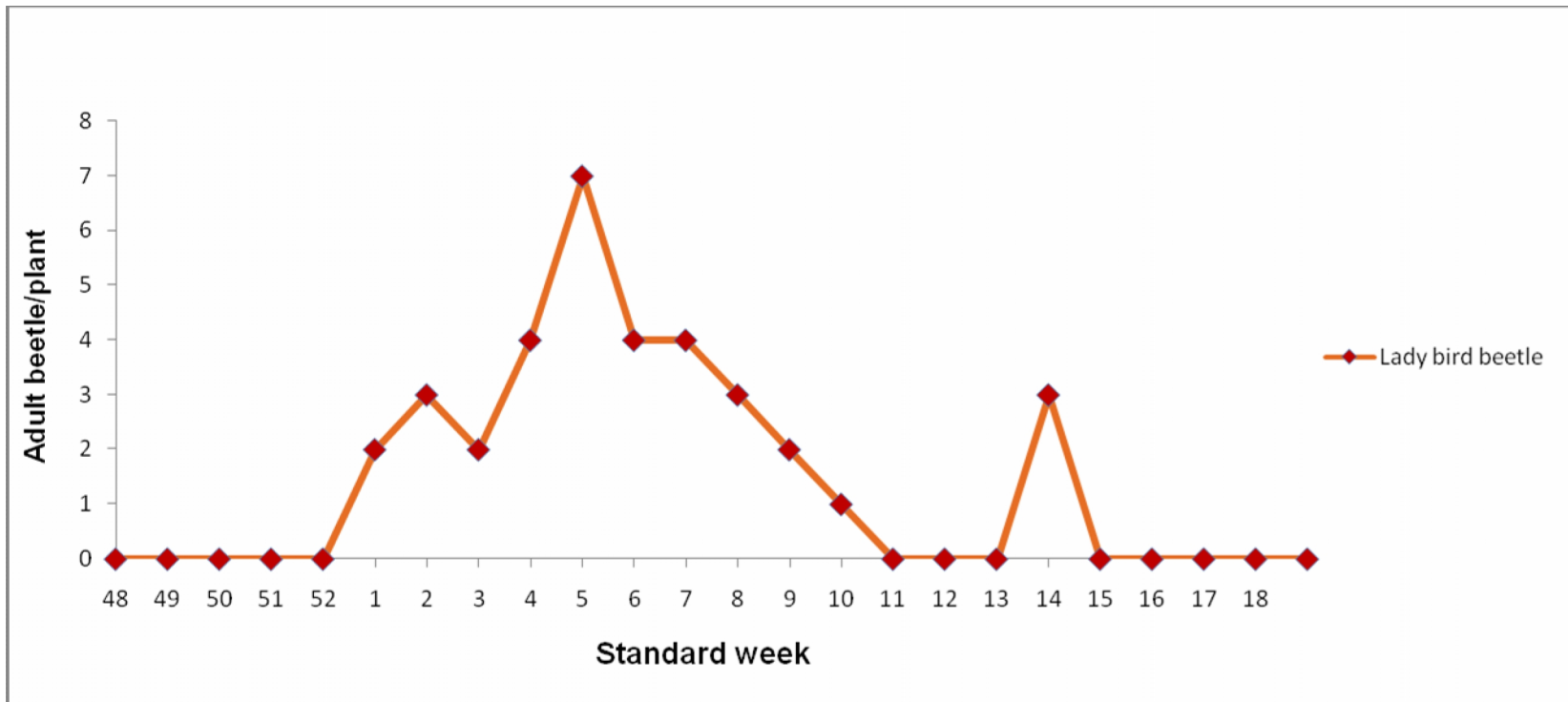
After 5<sup>th</sup> SW there is gradual decline in the beetle population up to the 13<sup>th</sup> SW (25 -03-2012 to 31-03-2012).After 13<sup>th</sup> SW there is sudden increase in beetle population in 14<sup>th</sup> SW (3 beetle /plant ) and it attains its third peak .During this period maximum and minimum temperature was 37.8 and 20.2 °C, respectively, whereas morning and evening relative humidity were 49 and 17 percent, respectively. Further sunshine, wind velocity, morning and evening vapour pressure and evapouration were 7.1 hrs, 4.5 km / hr, 11.1

mm,7.5 mm and 6 mm, respectively After 14<sup>th</sup> SW there is sudden decline in the beetle population.

#### **Correlation studies :**

Correlation studies revealed that morning, and evening relative humidity ,rainfall, rainy days and evening vapour pressure showed positive correlation with beetle population (0.50 ,0.65,0.47,0.70 and 0.25) respectively but found non significant (Table 6).

While maximum temperature, minimum temperature, wind velocity, sunshine, morning vapour pressure, and evaporation showed negative correlation(-0.58,-0.42,-0.17,-0.27,-0.24 and-0.12) respectively but found to be non significant (Table 6)



**Fig :16 Incidence of Lady bird beetle on the brinjal crop during *rabi* 2011-2011**

### **4.3 Management of insect pest complex of brinjal with reference to shoot and fruit borer with microbials**

#### **4.3.1 Jassid**

The effect of different microbial treatments against pest complex of brinjal presented in Table 7.

##### **Pre- treatment:**

The population of jassid before spraying of microbials was found to be non significantly which indicate that there was uniform distribution of the pest population in all the treatments.

##### **Three days after spray:**

Data presented in the table 7 showed that at three days after treatment, the differences in the mean jassid population among different treatments were significant. The minimum jassid population (49 /30 leaves) was observed in the tretment *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantaly superior to all the other treatments. The maximum population (71.47/30 leaves) was observed in control which was significantaly inferior to all the other tretments.

##### **Seven days after spray:**

Persual of the data after seven days spray of the microbials revealed that the minimum jassid population (27.93 jassid/30leaves) was observed in *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantly superior to all other microbial treatments but at par with *Verticillium lecanii* @ 3.75kg/ha (29.60 jassid/30 leaves) and *Beauveria bassiana* @1.0 kg/ha (30.27 jassid/30 leaves). The maximum population (69.93 jassid/30leaves) was observed in control which was significantly inferior to all the microbial treatments.

##### **Ten days after spray:**

Ten days after spray of microbial showed that the minimum jassid population (25.13 jassid/30leaves) was observed in with *Verticillium lecanii* @ 3.25 kg./ha (26.80 jassid/30 leaves), which was significantly superior to all the other microbial treatments but at par with *Verticillium lecanii* @ 3.75 kg/ha (26.93 jassids/30leaves). The maximum jassid population (64.67 jassid/30 leaves) was observed in control which was significantly inferior to all the microbial treatments.

**Overall mean:**

On the basis of overall mean the minimum jassid population (28.29 jassids/30leaves) was observed in *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantly superior to all other microbials but at par with *Verticillium lecanii* 3.75 kg/ha (30.62jassids/30leaves), *Verticillium lecanii* @ 3.25 kg/ha (31.75 jassids/30 leaves), and *Beauveria bassiana* @ 1.0 kg/ha (31.87jassid/30leaves). respectively The maximum jassid population (68.69 jassids /30leaes) was observed in control which was significantly inferior to all the microbial treatments.

**Table 7: Efficacy of different microbials against jassid infesting brinjal crop during *rabi* 2011-12**

Treatment Nos.	Treatment details	Dose /ha	Mean jassid population /30 leaves *				Over all mean
			Pre Treatment	Day after spraying			
				3	7	10	
T1	<i>Metarrhizium anisopliae</i>	2.5 Kg	58.00 (7.64)	27.47 L (5.29)	27.93 L (5.33)	29.47 (5.47)	28.29 L (5.36)
T2	<i>Metarrhizium anisopliae</i>	3.5 Kg	52.67 (7.29)	40.67 (6.41)	34.60 (5.92)	31.20 (5.63)	35.49 (5.99)
T3	<i>Beauveria bassiana</i>	1.0 Kg	51.33 (7.18)	36.87 (6.11)	30.27 (5.54)	28.47 (5.38)	31.87 (5.68)
T4	<i>Beauveria bassiana</i>	1.5 Kg	49.00 L (6.99)	38.33 (6.23)	31.93 (5.69)	29.60 (5.48)	33.29 (5.80)
T5	<i>Verticillium lecanii</i>	3.25 Kg	57.00 (7.58)	36.67 (6.10)	31.73 (5.68)	26.80 (5.21)	31.73 (5.67)
T6	<i>Verticillium lecanii</i>	3.75 Kg	52.00 (7.24)	35.33 (5.99)	29.60 (5.49)	26.93 (5.23)	30.62 (5.57)
T7	Control		58.67 (7.69)	71.47 H (8.48)	69.93 H (8.39)	64.67 H (8.07)	68.69 H (8.32)
<b>SEm±</b>			<b>0.24</b>	<b>0.09</b>	<b>0.11</b>	<b>0.16</b>	<b>0.11</b>
<b>CD at 5%</b>			<b>NS</b>	<b>0.28</b>	<b>0.34</b>	<b>0.51</b>	<b>0.35</b>

( ) figures in parenthesis are square root transformed value

L-Lowest, H-Highest, \*mean of 5 Spraying

### **4.3.2. Aphid**

The effect of different microbial treatments against aphid infesting brinjal are presented in Table 8.

#### **Pre- treatment:**

The population of aphid before spraying of microbials was found to be non significantly which indicate that there was uniform distribution of pest population in all the treatments.

#### **Three days after spray:**

After three days of spraying the minimum population (22.80aphid/30leaves) was observed in *Metarrhizium anisopliae* @2.5 kg/ha which was significantly superior to all other microbial. The maximum aphid population (62.87 aphid/30leaves) was observed in control which was significantly inferior to all the microbials.

#### **Seven days after spray:**

Several data after seven days spray of microbials revealed that the minimum aphid population (17.47 aphid/30leaves) was observed in *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantly superior to all other microbial. Whereas the maximum aphid population (58.40 aphid/30 leaves) was observed in control, which was significantly inferior to all the microbial treatments.

#### **Ten days after spray:**

Ten days after spray of microbials the minimum population (14.13 aphid/30leaves) was observed in *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantly superior to all other microbial. Whereas the maximum aphid population (53.87aphid/ha) was observed in control, which was significantly inferior to all the microbials treatments

#### **Overall mean:**

On the basis of overall mean microbial the minimum aphid population (18.87 aphid/30leaves) was observed in *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantly superior to all other microbial. The maximum Whitefly population (59.07 aphid/30leaves) was observed in control, which was significantly inferior to all the microbials.

**Table 8: Efficacy of different microbials against aphid infesting brinjal crop during *rabi* 2011-20**

Treatment Nos.	Treatment details	Dose /ha	Mean aphid population /30 leaves *				Over all mean
			Pre Treatment	Day after spraying			
				3	7	10	
<b>T1</b>	<i>Metarrhizium anisopliae</i>	2.5 kg	64.67 (8.03)	22.80 L (4.82)	17.47 L (4.24)	14.53 L (3.88)	27.72 (5.26)
<b>T2</b>	<i>Metarrhizium anisopliae</i>	3.5 kg	65.33 (8.09)	33.27 (5.81)	27.33 (5.27)	25.40 (5.09)	29.17 (5.39)
<b>T3</b>	<i>Beauveria bassiana</i>	1.0 kg	68.33 (8.28)	32.73 (5.76)	28.67 (5.40)	25.00 (5.05)	29.22 (5.41)
<b>T4</b>	<i>Beauveria bassiana</i>	1.5 kg	54.33 L (7.38)	32.00 (5.70)	26.33 (5.18)	23.93 (4.94)	27.88 (5.27)
<b>T5</b>	<i>Verticillium lecanii</i>	3.25 kg	57.33 (7.60)	33.73 (5.85)	28.47 (5.38)	25.47 (5.09)	29.77 (5.44)
<b>T6</b>	<i>Verticillium lecanii</i>	3.75 kg	59.33 (7.63)	33.07 (5.79)	28.80 (5.41)	26.67 (5.21)	29.77 (5.47)
<b>T7</b>	Control		77.33 H (8.77)	62.87 H (7.96)	58.40 H (7.67)	53.87 H (7.37)	59.07 H (7.67)
<b>SEm± CD at 5%</b>			<b>0.42</b>	<b>0.06</b>	<b>0.09</b>	<b>0.06</b>	<b>0.04</b>
			<b>NS</b>	<b>0.18</b>	<b>0.28</b>	<b>0.20</b>	<b>0.13</b>

( ) figures in parenthesis are square root transformed value

L-Lowest, H-Highest, \*mean of 5 Sprayings

### 4.3.3. Whitefly

The effect of different microbial treatments against brinjal Whitefly are presented in Table 9.

#### **Pre- treatment:**

The population of Whitefly before spraying of microbials was found to be non significantly which indicate that there was uniform distribution of the pest population in all the treatments.

#### **Three days after spray:**

Data presented in the table 8 showed that at three days after treatment the difference in the mean of whitefly population among different treatments were significant minimum population (22.13 whitefly/30leaves) was observed in *Metarrhizium anisopliae* @2.5 kg/ha which was significantly superior to all other microbial. where as the maximum Whitefly population (65.6 whitefly/30leaves) was observed in control which was significantly inferior to all the microbial treatments.

#### **Seven days after spray:**

Several data after seven days of spray of the minimum population (18.07 whitefly/30leaves) was observed in *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantly superior to all other microbial. Where as the maximum Whitefly population (65.63 whitefly/30 leaves) was observed in control, which was significantly inferior to all the microbials treatments.

#### **Ten days after spray:**

Ten days after spray of the microbials revealed that minimum population (17.20 whitefly/30leaves) was observed in *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantly superior to all other microbial. Where as the maximum Whitefly population (64.00 whitefly/30 leaves) was observed in control, which was significantly inferior to all the microbial treatments.

#### **Overall mean:**

On the basis of overall mean of microbial treatments the minimum whitefly population (19.13 whitefly/30leaves) was observed in *Metarrhizium anisopliae* @ 2.5 kg/ha which was significantly superior to all other microbial. The maximum Whitefly population (65.04 whitefly/30leaves) was observed in control, which was significantly inferior to all the microbials treatments.

**Table 9: Efficacy of different microbials against Whitefly infesting brinjal crop during *rabi* 2011-2012**

Treatment Nos.	Treatment details	Dose /ha	Mean Whitefly population /30 leaves *				Over all mean
			Pre Treatment	Day after spraying			
				3	7	10	
T1	<i>Metarrhizium anisopliae</i>	2.5 Kg	37.33 (6.14)	22.13 L (4.75)	18.07 (4.31) L	17.20 L (4.21)	19.13 L (4.42)
T2	<i>Metarrhizium anisopliae</i>	3.5 Kg	42.67 (6.53)	33.93 (5.87)	31.60 (5.67)	30.13 (5.53)	31.89 (5.69)
T3	<i>Beauveria bassiana</i>	1.0 Kg	41.00 (6.34)	32.53 (5.74)	28.60 (5.39)	27.47 (5.28)	29.53 (5.48)
T4	<i>Beauveria bassiana</i>	1.5 Kg	34.33 (5.90)	32.33 (5.73)	29.00 (5.43)	28.80 (5.41)	30.04 (5.52)
T5	<i>Verticillium lecanii</i>	3.25 Kg	44.33 (6.69)	32.33 (5.73)	29.87 (5.51)	27.67 (5.31)	29.96 (5.52)
T6	<i>Verticillium lecanii</i>	3.75 Kg	44.67 (6.68)	31.53 (5.66)	28.13 (5.35)	26.60 (5.21)	28.76 (5.41)
T7	Control		46.33 H (6.83)	65.6 H (8.13)	65.53 H (8.12)	64.00 H (8.03)	65.04 H (8.32)
<b>SEm± CD at 5%</b>			<b>0.47 NS</b>	<b>0.12 0.37</b>	<b>0.10 0.31</b>	<b>0.10 0.31</b>	<b>0.05 0.15</b>

( ) figures in parenthesis are square root transformed value

L-Lowest,H-Highest, \*mean of 5 Spraying

### 4.3.b 3. Shoot and fruit borer:

The data on efficacy of different microbial treatments against brinjal shoot and fruit borer infestation is depicted in Table 10.

#### Pre- treatment:

The percentage of shoot and fruit borer infestation in the fruit before spraying of microbials was found to be non significant which indicate that there was uniform distribution of the pest population in all the microbial treatments

**Table 10: Efficacy of different microbials against brinjal shoot and fruit borer infestation during *rabi* 2011-12.**

Treatment nos.	Treatment details	Dose /ha	Pretreatment	Fruit infestation by shoot and fruit borer (%)*
T1	<i>Metarrhizium anisopliae</i>	2.5 Kg	21 (27.27)	7.27 (15.57)
T2	<i>Metarrhizium anisopliae</i>	3.5 Kg	12.33 (20.26)	8.23 (16.47)
T3	<i>Beauveria bassiana</i>	1.0 Kg	15 L (22.78)	9.87 (18.28)
T4	<i>Beauveria bassiana</i>	1.5 Kg	31.66 (33.83)	8.93 (17.35)
T5	<i>Verticillium lecanii</i>	3.25 Kg	26 (38.65)	7.49 (15.76)
T6	<i>Verticillium lecanii</i>	3.75 Kg	22.66 (27.97)	7.2 (15.32)
T7	<i>Bacillus thuringiensis var. kurstaki</i>	1.0 l	17 (24.35)	5.91 (13.83)
T8	<i>Bacillus thuringiensis var. kurstaki</i>	1.5 l	20 (26.26)	4.97 L (12.86)
T9	Control	-	23.33 H (28.65)	17.07 H (24.35)
<b>SEm±</b>			<b>2.71</b>	<b>1.29</b>
<b>CD at 5%</b>			<b>NS</b>	<b>3.88</b>

\* mean of 7 pickings,

( ) Figures in parentheses are arcsin transformed value

L = Lowest, H = Highest.

### **Fruit infestation:**

The overall percent fruit damage by brinjal shoot and fruit borer was found to be minimum (4.97%) in plot treated with *Bacillus thuringiensis* var.*kurstaki*,1.5 l /ha in which was significantly superior than all the microbials but at par with the *Bacillus thuringiensis* var.*kurstaki*,1 l /ha(5.91%),*Verticillium lecanii* 3.75 kg/ha (7.2%), *Metarrhizium anisopliae*2.5 kg/ha (7.27%) *Verticillium lecanii* 3.25 kg/ha (7.49 %), *Metarrhizium anisopliae*(8.23%), respectively whereas the maximum damage (17.07%) was observed in control.which is significantly inferior to all microbial treatments .

### **4.3. 4: Fruit yield :**

On the basis of cumulative healthy marketable fruit yield, significant difference among different treatments were observed. All the microbial treatments significantly recorded higher fruit yields as compared to control (184.41 q / ha). Among the treatments *Bacillus thuringiensis* var.*kurstaki*@,1.5 l /ha recorded highest healthy fruit yield (255.01 q / ha), this was followed by *Verticillium lecanii* @ 3.25 kg/ha (222.99 q / ha),*Bacillus thuringiensis* var.*kurstaki*@, @ 1 l/ha(221.45 q / ha) and *Verticillium lecanii* @ 3.75 kg / ha (212.57 q / ha), but all were at par with each other. The next effective group of treatments were, *Beauveria bassiana* @ 1.0 kg/ha (207.17 q / ha) followed by *Metarrhizium anisopliae*@ 3.5 kg / ha (201.77 q / ha), *Beauveria bassiana* @ 1.5 kg/ha( 200.61q/ha) and *Metarrhizium anisopliae* @ 2.5 kg/ha (187.5 q/ha) but all the treatments were at par with control.

### **4.3.5: Economic of treatments:**

#### **Increase in yield over control:**

Among the different treatments, highest increase in fruit yield over control was registered in *Bacillus thuringiensis* var.*kurstaki*@,1.5 l /ha (59.02 q / ha), this was followed by *Verticillium lecanii* @ 3.25 kg / ha (38.58 q/ha), *Bacillus thuringiensis* var.*kurstaki*@,1 l /ha (37.02 q/ha), *Verticillium lecanii* @ 3.75 kg / ha (28.16 q/ha), *Beauveria bassiana* @ 1 kg/ha (22.76 q/ha) *Metarrhizium anisopliae* @ 3.5 kg/ha (17.36 q/ha),*Beauveria bassiana* @ 1.5 kg/ha (16.20 q/ha) and lowest in *Metarrhizium anisopliae* @ 2.5 kg/ha(3.08 q / ha), all the treatments respectively.

**Net profit :**

Among the different treatments, highest net profit was registered in *Bacillus thuringiensis* var.*kurstaki*@,1.5 l /ha (Rs 24185/ha), this was followed by *Verticilium lecanii* @ 3.25 kg / ha (Rs15390/ha), *Bacillus thuringiensis* var.*kurstaki*@,1 l /ha (Rs14465/ha), *Verticilium lecanii* @ 3.75 kg / ha (Rs 9168/ha), *Beauveria bassiana* @ 1 kg/ha (Rs 7880/ha), *Beauveria bassiana* @ 1.5 kg/ha (Rs 3600/ha) and lowest in *Metarhizium anisopliae* @ 3.5 kg/ha (Rs 2595/ha),.respectively.

**Cost benefit ratio :**

Among the different treatments, highest cost benefit ratio was registered in *Bacillus thuringiensis* var.*kurstaki*@,1.5 l /ha (1:4.55/ha), this was followed by *Verticilium lecanii* @ 3.25 kg / ha (1:3.94/ha), *Bacillus thuringiensis* var.*kurstaki*@,1 l /ha (1:3.57/ha), *Beauveria bassiana* @ 1 kg/ha (1:2.25/ha), *Verticilium lecanii* @ 3.75 kg / ha (1:1.86/ha) *Beauveria bassiana* @ 1.5 kg/ha (1:0,8/ha), *Metarhizium anisopliae* @ 3.5 kg/ha (1:0.42/ha) respectively .

**Table11:- Efficacy and economics of different microbials on brinjal fruit yield during *rabi* 2011-12.**

Tr. no s	Treatment details	Dose kg/ha	Fruit yield (q/ha)	Increase in yield over control (q/ha)	Percent avoidable losses	Cost of treatments*	Cost of increased yield over control @ 500 /- per quintal	Net profit (Rs/ha)	Cost benefit ratio
T1	<i>Metarrhizium anisopliae</i>	2.5 kg	187.5	3.08 L	1.64 L	4775	1540 L	-	-
T2	<i>Metarrhizium anisopliae</i>	3.5 kg	201.77	17.36	8.60	6085	8680	2595 L	1:0.42 L
T3	<i>Beauveria bassiana</i>	1.0 kg	207.17	22.76	10.98	3500 L	11380	7880	1:2.25
T4	<i>Beauveria bassiana</i>	1.5 kg	200.61	16.20	8.07	4500	8100	3600	1:0.80
T5	<i>Verticillium lecanii</i>	3.25kg g	222.99	38.58	17.30	3900	19290	15390	1:3.94
T6	<i>Verticillium lecanii</i>	3.75kg g	212.57	28.16	13.24	4912	14080	9168	1:1.86
T7	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1.0 l	221.45	37.03	16.72	4050	18515	14465	1:3.57
T8	<i>Bacillus thuringiensis</i> var. <i>kurstaki</i>	1.5 l	255.01 H	59.02 H	24.24 H	5325 H	29510 H	24185 H	1:4.55 H
T9	Control	-	184.41 L	-	-	-	-	-	-
<b>SEm<sub>±</sub></b>			0.11						
<b>CD at 5%</b>			0.33						

Labour rate per day = Rs 300 /- (Two labours required for spraying 1 ha brinjal crop in 1 day)  
*Beauveria bassiana* = Rs 400 /- per kg  
*Metarrhizium anisopliae* = Rs 262 /- per kg  
*Verticillium lecanii* = Rs 240 /- per kg  
*Bacillus thuringiensis* = Rs 510 /- per kg L=Lowest H=Highest

## CHAPTER - V

### DISCUSSION

The findings on insect pest succession, population dynamics and management of pest complex infesting brinjal with microbials have been discussed below:

#### **5.1. To study the succession of insect pest complex and their natural enemies on brinjal :**

Incidence of different insect pests on brinjal was recorded regularly at different stages of the crop *i.e.* vegetative stage, flowering stage, maturity stage and at harvest. In all four insect pests and natural enemies listed below were recorded on different stages of the crop.

1. Jassid, *Amrasca biguttula biguttula* (Ishida)
2. Aphid, *Aphis gossypii* (Glover)
3. Whitefly, *Bemisia tabaci* (Genn.)
4. Shoot and fruit borer, *Leucinodes orbonalis* (Guen.)
5. Lady bird beetle, *Cheilomenes sexmaculatus*.

Thus a total of five species of insects four pest and one natural enemies appeared as pests in different stages of crop growth belonging to two orders *viz.* Hemiptera, Lepidoptera and Coleoptera representing five families *viz.* Cicadellidae, Aphididae, Aleyrodidae Pyraustidae and coccinellidae, respectively

Dhamdhare and Bhonsle (1995); Bhadauria *et al.*, (1999); Singh and Singh (2002); Ghosh *et al.*, (2006); Kadam *et al.*, (2006); Naik *et al.*, (2008a); Patial and Mehta (2008); Latif *et al.*, (2009) and Naik *et al.*, (2009) also studied the succession of insects on brinjal from seedling to maturity stage and reported thirtyfive, twelve, five, twenty seven, three, six, two, twenty seven and three insects at various stages of brinjal crop growth, respectively. They further reported that jassid, *Amrasca biguttula biguttula* (Ishida); aphid, *Aphis gossypii* (Glover); whitefly, *Bemisia tabaci* (Genn.); and shoot and fruit

borer, *Leucinodes orbonalis* (Guen.) were identified as the major pests of brinjal. which are in the confirmity with the present findings.

**5.1.1 Jassid, *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae) :**

First incidence of jassid was observed when the crop age was about 7 days old (after transplantation). It is evident that the pest was present on the crop during the entire cropping season and remained available upto the crop maturity stage *i.e.* third week of April. Present studies collaborate with the finding of Birla.M. (2011)

**5.1.2. Aphid, *Aphis gossypii* (Glover) (Hemiptera : Aphididae):**

First incidence of aphid was recorded when the crop age was about 11 days old (after transplantation). It is evident that the pest was present on the crop during the entire cropping season and remained available upto crop maturity stage *i.e.* third week of March.the present study conformity with rhe finding of Birla .M. (2011)

**5.1.3. Whitefly, *Bemisia tabaci* Genn. (Hemiptera: Aleyrodidae):**

First appearance of Whitefly was observed when the crop age was about 18 days *i.e.* vegetative stage. It is evident that the pest was present on the crop during vegetative stage and remained available upto first week of May *i.e.* maturity stage of the crop.

**5.1.4. Shoot and fruit borer, *Leucinodes orbonalis* (Guen.) (Lepidoptera : Pyraustidae) :**

First incidence of the shoot and fruit borer infestation was observed during the fruiting stage of the crop *i.e.* about 82 days old crop (after transplantation). It is evident that the pest was present on the crop during the fruiting stage and remained available upto the crop maturity stage *i.e.* first week of May. Similarly Singh and Singh, (2009) reported that the borer infested the summer crop from early vegetative stage and continued upto maturity.

### **5.1.5. Natural enemies :**

First incidence of Lady bird beetle was observed during the vegetative stage of the crop *i.e* about 39 days old crop (after transplantation) It is evident that the the predatory beetle present on the crop during vegaetative stage and remain available up to maturity stage *i.e* 102 days old crop (after transplantation) the present finding collaborate with the finding of Kadam *et al.*, (2006), Naik *et al.*, (2008a) and Latif *et al.*, (2009) they also reported coccinellid predatory beetles on brinjal crop.

## **5.2. To study the population dynamics of major insect pests of brinjal:**

### **5.2.1. Jassid, *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae):**

Jassids were first recorded in the last week of November *i.e* 30<sup>th</sup> November (48<sup>th</sup> SW). In the present study the activity of the pest continued from first week of December to first week of May. The peak activity of the pest was observed during 52<sup>th</sup> to 15<sup>th</sup> SW (*i.e.* last week of December to second week April). During this period maximum and minimum temperature ranged from 20.2 to 39.4 °C and 6.3 to 20.2°C, respectively, whereas morning and evening relative humidity ranged from 45 to 95 and 14 to 69 %, respectively. Further sunshine, wind velocity, evapouration, rainfall, vapour pressure morning and evening, ranged from 4.5 to 9.6 hours, 2.6 to 5.6 km/hr, 1.1 to 7.3 mm, 0 to 28.6 mm, 7.7 to 11.2 mm, 6 to 11.2 respectively. The present finding confirms the finding of Prasad and Logiswaran, (1997a and 1997b) observed peak activity of the pest during April in summer brinjal crop.

Correlation studies between various abiotic factors and jassid population revealed that the weather factor included in the study did not inhibit any significant influence on the pest population. On the contrary, Prasad and Logiswaran, (1997b) reported that rainfall exhibited positive influence on jassid population.

### **5.2.2. Aphid, *Aphis gossypii* (Glover) (Hemiptera : Aphididae):**

Aphids were first recorded in the second week of December (50<sup>th</sup> SW). In the present study the activity of the pest continued from second week of December to first week of May. The peak activity of the pest was observed during 1<sup>st</sup> to 5<sup>th</sup> SW (*i.e.* first week of January to First week of February). During this period the maximum and minimum temperature ranged from 20.2 to 23.7 °C and 6.3 to 12 °C, respectively. Whereas morning and evening relative humidity ranged from 89 to 43 % and 36 to 69 %, respectively. Further, sunshine, wind velocity, evaporation, vapour pressure morning and evening and rainfall ranged from 4.5 to 8.6 hours, 3.3 to 4 km/hr, 1.1 to 2.3 mm, 7.8 to 11.2 mm, 7 to 13.5 and 0 to 28.6 mm, respectively. The present findings are in accordance with the findings of Prasad and Logiswaran, (1997a) they also reported that peak activity of the pest was observed during April in summer brinjal crop,

Correlation studies between various abiotic factors and aphid population revealed that maximum temperature, exhibited negative influence on the pest population. However, morning and evening relative humidity showed positive influence on the pest population.

### **5.2.3. Whitefly, *Bemisia tabaci* Genn. (Hemiptera: Aleyrodidae):**

Whitefly was first recorded in the third week of December (50<sup>th</sup> SW). In the present study the activity of the pest continued from second week of December to first week of May. The present findings are in conformity with the findings of Sahu (2008). He also reported that the activity of the pest was observed from last week of December but it extended up to third week of May. In the present findings, the peak activity of the pest was observed during 50<sup>th</sup> SW to 8<sup>th</sup> SW (*i.e.* third week of December to First week of March). The present findings are in accordance with the findings of Naik *et al.*, (2009). They also reported that the peak activity of the pest was recorded during third week of February. In the present study, during the peak activity period the maximum and minimum temperature ranged from 20.2 to 30.5 °C and 6.3 to 12 °C, respectively, whereas morning and evening relative humidity ranged from 89 to 95 % and 24 to 69 %, respectively. Further sunshine, wind velocity, evaporation and morning and evening vapour pressure ranged from ( 4.5 to 9.6 hours, 2.3 to 4 km/hr and 1.1 to 3 mm, 6.9 to 11.2 and, 5.6 to 13.5)

respectively. The present findings confirms the findings of Reddy *et al.*, they reported that mean temperature ranging from 29 to 33 °C will congenial for the maximum activity of the pest, However the present finding contradicts the finding of (Sahu 2008). for the pest in present finding range of humidity seem to be in conformity with the findings of (Sahu 2008), he reported morning and evening relative humidity of 65% and 21%, respectively have been found to be congenial for the multiplication and development of the pest. In the present study rainfall ranging from 0.8 to 2.8 mm have been found favourable for the pest. On the contrary, Sahu (2008) reported that rainfall did not have any impact on the insect, whereas Raddy *et al.*, (1998) observed that high rainfall had unfavourable effect on the pest population.

Correlation studies between various abiotic factors and Whitefly population revealed that none of the weather factor exhibited significant influence on the pest population. On the contrary, Prasad and Logiswaran, (1997b) reported that maximum temperature and wind velocity had positive impact on the pest population.

On the contrary Prasad and Logiswaran, (1997b). reported that relative humidity showed positive impact on pest population.

Further, in the present study, rainfall showed negative influence on the pest population but statistically found to be non-significant. However, similar findings have been reported by Sahu (2008), but statistically found to be significant.

#### **5.2.4. Shoot and fruit borer, *Leucinodes orbonalis* (Guen.) (Lepidoptera : Pyraustidae) :**

##### **5.2.4.a. Shoot damage:**

During the entire period of study the shoot damage due to shoot and fruit borer was observed on 7<sup>th</sup>, 11<sup>th</sup> SW. the present findings are in conformity with Naik *et al.*, (2008b) they also reported that pest was observed during third week of February. on the contrary the peak activity of the pest was recorded during September end while reported it during third week of November on *kharif* brinjal crop whereas (Singh and Singh, 2009) reported that it during third week of May on summer brinjal crop



#### **5.2.4.b. Fruit damage:**

Fruit infestation due to shoot and fruit borer was first recorded in the second week of February *i.e.* (7<sup>th</sup> SW). In the present study the activity of the pest continued from second week of February to first week of May *i.e.* from reproductive to maturity stage. The present findings are in conformity with the findings of Saeed and Khan, (1997). They also reported that the brinjal fruit borer activity started from fruit formation stage. In the present study, the fruit borer was less active prior to fruit formation stage *i.e.* February. These findings are in accordance with the findings of Ghosh and Senapati, (2009). They also observed that the pest was less active during December to January. On the contrary, Tripathi *et al.*, (1996) reported that maximum activity of the pest was observed between 13-19<sup>th</sup> December.

In the present study the peak activity of the pest was observed during 8<sup>th</sup> to 18<sup>th</sup> SW (*i.e.* third week of February to first week of May). The present findings confirm the findings of Lodhi, (2005). He also reported that the peak activity of the pest was recorded during last week of March. However, the peak activity of the pest on the *kharif* brinjal crop was recorded during 4<sup>th</sup> week of August (Saeed and Khan, 1997), mid August to September (Patil and Mehta, 2008), third week of September (Singh *et al.*, 2003) and middle of October (Mahesh and Men, 2007a) while on the summer crop, it was during first week of June (Ghosh and Senapati, 2009), respectively.

In the present study, during the peak activity period, maximum and minimum temperature ranged from 30.1 to 37.8 °C and 9.8 to 20.2 °C respectively, whereas morning and evening relative humidity ranged from 49 to 86 % and 14 to 28 % respectively. Further, sunshine, wind velocity, evaporation, morning vapour pressure and evening vapour pressure rainfall ranged from (7.1 to 9.6 hours, 2.8 to 4.9 km/hr, 3.3 to 6 mm, 8.1 to 11.1 mm, 5.7 to 8 mm, ) respectively. Similar findings have been reported by Lodhi, (2005); Mahesh and Men, (2007a) and Ghosh and Senapati, (2009). They also reported that the average temperature 21.4 to 31.8°C, average relative

humidity 35 to 86% have been found congenial for the multiplication and development the pest.

In the present study correlation studies between temperature *viz.* maximum and minimum with shoot and fruit borer infestation revealed that they exhibited significant positive influence on the pest infestation, The present findings corroborate the findings of Shah *et al.*, 1995 ; Singh *et al.*, 2003 ; Naik *et al.*, 2008 and Ghosh and Senapati, 2009. They also reported that temperature *viz.* maximum, minimum and average, showed a positive impact on the pest infestation.

In the present study correlation studies further revealed that relative humidity *viz.* morning and evening had a negative influence on the pest infestation, the present finding confirm the findings of Singh *et al.*, 2003 and Naik *et al.*, 2008b. They also reported that relative humidity had a negative impact on the pest infestation.

In the present study correlation between rainfall and number of rainy days with shoot and fruit borer infestation revealed that they exhibited negative influence but statistically found to be non significant on the pest infestation. Contrary Ghosh and Senapati (2009). reported that rainfall had positive impact on the pest infestation. On the contrary, Naik *et al.*, 2008b and Singh and Singh, 2009 reported that rainfall had no influence on the pest infestation.

Further, in the present study, wind velocity and sun shine were positively correlated with pest infestation, but statistically found to be non-significant. these finding is contradicts the finding of Singh and Singh, 2009 reported that sunshine and wind velocity were negatively correlated with pest infestation.

### **5.3 Management of insect pest complex with reference to shoot and fruit borer with microbials.**

The efficacy of four microbials at two doses at *Metarhizium anisopliae* @ 2.5 kg/ha and 3.5 kg/ha, *Beauveria bassiana* @ 1 kg / ha and 1.5 kg / ha, *Verticillium lecanii* @ 3.25 kg / ha and 3.75 kg / ha, *Bacillus thuringiensis*

var. *kurstaki* @ 1.0 l / ha and 1.5 l / ha, were tested against insect pest complex on brinjal.

### **5.3.1 Jassid**

Among microbials *Metarhizium anisopliae* @ 2.5 kg/ha, was found to be most effective against jassid In the present study among the microbials *Beauveria bassiana* @ 1.5 kg / ha was the least effective against brinjal jassid. The present studies collaborate with the finding of Birla. M. (2011)

### **5.3.2 Aphid**

In the present study, among the microbial *Metarhizium anisopliae* @ 2.5 kg/ha, was found to be most effective against Aphid infesting brinaj crop and *Verticilium lecanii* @ 3.25 kg / ha and 3.75 kg / ha was the least effective against brinjal aphid.

### **5.3.3 Whitefly**

In the present study, among the microbial *Metarhizium anisopliae* @ 2.5 kg/ha, was found to be most effective against Whitefly. Present finding is conformity with the finding of Birla.M.(2011)

### **5.3. 4 Shoot and fruit borer :**

#### **Percent fruit damage by *Leucinodes orbonalis* :**

On the basis of overall mean, the differences in the percent fruit damage among different treatments were significant. All the microbial treatments significantly reduced the fruit damage and registered higher fruit yields as compared to untreated control. Several workers have also reported similar findings, that application of microbials effectively reduced the fruit damage due to *L. orbonalis* with increased fruit yields than control (Patnaik and Singh, 1997 ; Qureshi *et al.*, 1998 ; Puranik *et al.*, 2002; Mandal *et al.*, 2003; Yadav and Sharma, 2005; Singh, 2006; Anonymous, 2007; Mahesh and Men, 2007b; Singh and Yadav, 2007; Gautam *et al.*, 2008; Adiroubane and Raguhuraman, 2008; Naik *et al.*, 2008c; Ghosh and Senapati, 2009; and Pareet and Basavanagoud, 2009 ).

Treatment, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha was found to be most effective as it recorded lowest fruit damage, this was followed by *Bacillus thuringiensis* var. *kurstaki* @ 1 l / ha, but were at par with each other. Similar findings have been reported by several workers viz. Patnaik and Singh, (1997); Qureshi *et al.*, (1998); Puranik *et al.*, (2002); Mandal *et al.*, (2003); and Mahesh and Men,(2007b).They also reported that *Bacillus thuringiensis* var. *kurstaki* @ 0.05% to 0.25 or 2.0 to 2.5 ml / L or 1 L / ha were found effective in reducing the fruit infestation due to *L. orbonalis*. In the present study, the next effective group of treatments were *Verticillium lecanii* @ 3.75 kg / ha, *Metarhizium anisopliae* @ 2.5 kg/ha, followed by *Verticillium lecanii* @ 3.25 kg / ha, but did not differ significantly from each other. The next but least effective treatment was, *Beauveria bassiana* @ 1 kg / ha, *Beauveria bassiana* @ 1.5 kg / ha, and was found to be significantly superior to control.

#### **5.3.5 Fruit yield :**

All the microbial treatments significantly recorded higher fruit yields as compared to control. Treatment *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l/ha(255.01q/ha) recorded highest healthy fruit yield, this was followed by *Verticillium lecanii* @ 3.25 kg / ha(222.99 q/ha), but were at par with each other. In the present study the next effective group of treatments were *Bacillus thuringiensis* var. *kurstaki* @ 1 l/ha(221.45q/ha) followed by *Verticillium lecanii* @ 3.75 kg / ha(212.57 q/ha) and but both the treatments were at par with control. On the contrary, several workers have reported that (Yadav and Sharma, 2005; Mahesh and Men, 2007b; Singh and Yadav, 2007; Moreover Singh, (2006) have compared the efficacy of chemicals and microbials against fruit infestation by *L. orbonalis* and reported that both of them were at par with each other.

#### **5.4 Economics of treatments :**

Maximum increase in fruit yield over control was registered in *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha (59.02 q / ha), followed by *Verticillium lecanii* @ 3.25 kg / ha,(38.58 q/ha) *Bacillus thuringiensis* var. *kurstaki* @ 1 l / ha(37.03 q/ha) *Verticillium lecanii* @ 3.75 kg / ha,(28.16 q/ha) *Beauveria bassiana* @ 1. kg / ha (22.76 q/ha), *Metarhizium anisopliae* @ 3.5

kg/ha(17.36 q/ha), *Beauveria bassiana* @ 1.5 kg / ha (16.20 q/ha), and, lowest in *Metarhizium anisopliae* @ 2.5 kg/ha (3.09 q/ha) respectively.

Maximum net profit was registered in *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha (24,185 /-), followed by *Verticillium lecanii* @ 3.25 kg / ha (15,390 /-) and *Bacillus thuringiensis* var. *kurstaki* @ 1 l / ha (14,465 /-), *Verticillium lecanii* @ 3.75 kg / ha (9,168 /-), *Beauveria bassiana* @ 1 kg / ha (7880/-), *Beauveria bassiana* @ 1.5 kg / ha,(3600 /-) and lowest in *Metarhizium anisopliae* @ 3.5 kg/ha(2595/-) respectively.

Maximum cost benefit ratio was obtained in case of, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha (1 :4.55), followed by *Verticillium lecanii* @ 3.25 kg / ha (1:3.94), *Bacillus thuringiensis* var. *kurstaki* @ 1 l / ha (1:3.57), *Beauveria bassiana* @ 1 kg / ha(1:2.55), *Verticillium lecanii* @ 3.75 kg / ha (1:1.86) respectively.

It showed that spraying of *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha, on brinjal crop gave maximum cost benefit ratio,however its price is high as compared to other treatments. This was followed by), *Verticillium lecanii* @ 3.25 kg / ha (1:1.86) and *Bacillus thuringiensis* var. *kurstaki* @ 1 l / ha, respectively.

**CHAPTER - VI**

**SUMMARY, CONCLUSION AND SUGGESTIONS FOR  
FURTHER WORK**

Present research work on “Studies on insect pest complex of brinjal, *Solanum melongena* (Linn.) and their management with microbials” was carried out in the experimental field of Department Of Entomology, Live Stock Farm, Adhartal during *rabi* season 2011-2012. The experiment was conducted with the following objectives

- 1) To study the succession of insect pest complex and their natural enemies.
- 2) To study the population dynamics of major insect pests of brinjal.
- 3) Management of insect pest complex with reference to shoot and fruit borer *Leucinodes orbonalis* (Guen.) with microbials .

**6.1. To study the succession of insect pest complex and their natural enemies.:**

Studies on insect pest complex and their natural enemies revealed that the following insects were the major pests which were observed infesting the brinjal crop. Jassid, *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae); aphid, *Aphis gossypii* (Glover) (Hemiptera: Aphididae); whitefly, *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae) and shoot and fruit borer, *Leucinodes orbonalis* (Guen.) (Lepidoptera : Pyraustidae). Among them, jassid appeared when the crop age was about 7 days old *i.e.* during vegetative stage and remained available upto maturity stage of the crop. Aphid and Whitefly were the next insect pests to appear on the crop, when the crop age was about 11 days and 18 days old, respectively *i.e.* during vegetative stage and remained available upto maturity stage of the crop.

Shoot and fruit borer appeared when the crop age was about 82 days old *i.e.* during reproductive stage of the crop and remained available upto maturity of the crop.

Only one natural enemy lady bird beetle *Chelonemus sexmaculata* (Fab.) (Coleoptera : Coccinelidae) was recorded, which appeared when the crop age was 39 days old during vegetative stage and remained available upto maturity stage of the crop.

## **6.2 To study the population dynamics of major insect pests of brinjal :Jassid:**

Jassid incidence was first recorded in the last week of November (48<sup>th</sup> SW). In the present study the activity of the pest continued from third week of November to first week of May. The peak activity of the pest was observed during 52<sup>nd</sup> to 15<sup>th</sup> SW (*i.e.* last week of December to second week of April) During this period maximum and minimum temperature ranged from 20.2 to 39.4 °C and 6.3 to 20.2°C, respectively, whereas morning and evening relative humidity ranged from 45 to 95 and 14 to 69 %, respectively. Further sunshine, wind velocity, evaporation, rainfall, vapour pressure morning and evening, ranged from 4.5 to 9.6 hours, 2.6 to 5.6 km/hr, 1.1 to 7.3 mm, 0 to 28.6 mm, 7.7 to 11.2 mm, 6 to 11.2 respectively.

Correlation studies between various abiotic factors and jassid population revealed the weather factors did not exhibit any influence on the pest population.

### **Aphid:**

Aphids were first recorded in the second week of December *i.e.* (50<sup>th</sup> SW). In the present study the activity of the pest continued from second week of December to First week of May ). The peak activity of the pest was observed durin 1<sup>st</sup> to 5<sup>th</sup> SW (*i.e.* first week of January to first week of February). During this period the maximum and minimum temperature ranged from 20.2 to 23.7 °C and 6.3 to 12 °C, respectively. Whereas morning and evening relative humidity ranged from 89 to 73 % and 36 to 69 %, respectively. Further, sunshine, wind velocity, evaporation, vapour pressure morning and evening and rainfall ranged from 4.5 to 8.6 hours, 3.3 to 4 km/hr, 1.1 to 2.3 mm, 7.8 to 11.2 mm, 7 to 13.5, and 0 to 28.6 mm, respectively,

Correlation studies between various abiotic factors and aphid population revealed that maximum temperature, and sunshine exhibited negative while morning and evening relative humidity exhibited positive influence on the pest population.

#### **Whitefly:**

Whitefly incidence was first recorded in the third week of December *i.e.* 16<sup>th</sup> December (50<sup>th</sup> SW). In the present study the activity of the pest continued from third week of December to first week of May. During the peak activity period the maximum and minimum temperature ranged from 20.2 to 30.5 °C and 6 to 12°C, respectively, whereas morning and evening relative humidity ranged from 89 to 95 % and 24 to 69 %, respectively. Further sunshine, wind velocity, evaporation and morning and evening vapour pressure ranged from 4.5 to 9.6 hours, 2.3 to 4 km/hr and 1.1 to 3 mm, 6.9 to 11.2 mm, 5.6 to 13.5 respectively.

Correlation studies between various abiotic factors and Whitefly population revealed that more of the weather factors exhibited significant influence on the pest population, respectively.

#### **Shoot and fruit borer, *Leucinodes orbonalis* (Guen.) (Lepidoptera : Pyraustidae) :**

##### **Shoot damage:**

During the entire period of study the shoot damage due to shoot and fruit borer was observed during 7<sup>th</sup> and 11<sup>th</sup> SW.

##### **Fruit damage:**

Fruit infestation due to shoot and fruit borer was first recorded in the third week of February *i.e.* (7<sup>th</sup> SW). In the present study the activity of the pest continued from third week of February to first week of May *i.e.* (10<sup>th</sup> SW to 18<sup>th</sup> SW) from reproductive to maturity stage. In the present study, during the peak activity period, maximum and minimum temperature ranged from 30 to 37.8 °C and 9.8 to 20.2 °C respectively, whereas morning and evening relative humidity ranged from 49 to 86 % and 14 to 28 % respectively. Further, sunshine, wind velocity, evaporation, morning vapour pressure and evening

vapour pressure ranged from 7.1 to 9.6 hours, 3.3 to 6 km/hr, 3.3 to 6 mm, 8.1 to 11.1 mm, 5.7 to 8 mm, respectively.

Correlation studies between various abiotic factors and shoot and fruit borer infestation revealed that maximum and minimum temperature, wind velocity exhibited positive whereas morning relative humidity, evening relative humidity, exhibited negative influence on the pest infestation, respectively.

### **6.3. Management of insect pest complex with reference to shoot and fruit borer with microbials.**

On the basis of the effectiveness of different microbial treatments against insect pest complex it can be said that *Metarhizium anisopliae* @ 2.5 kg/ha was found to be most effective against aphid jassid and Whitefly, while *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha, was found to be most effective against Shoot and fruit borer.

Highest fruit yield was registered by *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha (255.01 q / ha), this was followed by *Verticillium lecanii* @ 3.25 kg/ha (222.99 q / ha) and *Bacillus thuringiensis* var. *kurstaki* @ 1 l/ha (221.45 q / ha), @ 1. *Verticillium lecanii* @ 3.75 kg / ha (212.57 q / ha), but were at par with each other. The next effective group of treatments were, *Beauveria bassiana* @ 1.0 kg/ha (207.17 q / ha) followed by *Metarhizium anisopliae* @ 3.5 kg / ha (201.77 q / ha), *Beauveria bassiana* @ 1.5 kg/ha (200.61 q/ha) and *Metarhizium anisopliae* @ 2.5 kg/ha (187.5 q/ha), respectively.

Further, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha recorded highest healthy fruit yield (255.01 q / ha) The quantity and cost of increased fruit yield over control is 59.02 q / ha, worth Rs 29,510 /- per ha; giving 24.24 % increase in fruit yield. Taking into account the cost of the plant protection inputs, the cost benefit ratio comes to 1:4.55. It means that a farmer is likely to get a profit of Rs 4.55 after investing an amount of Rs 1 /- on plant protection measures.

### **Conclusion:**

Four different species of insect pests and one natural enemy were recorded on the brinjal crop at experimental field of Department Of

Entomology, Live Stock Farm, Adhartal, JNKVV, Jabalpur (M.P.) during *rabi* season 2011-2012 which represented 3 orders (Coleoptera, Hemiptera and Lepidoptera) and 5 families (Coccinelidae, Cicadellidae, Aphididae, Aleyrodidae and Pyraustidae), respectively.

The jassids appeared when the crop age was 7 days old *i.e.* from vegetative stage and remained available upto crop maturity stage. The next group of insects to appear on the crop were aphid and whitefly, at 11 days and 18 days old crop respectively *i.e.* from vegetative stage and remained available upto crop maturity stage. Shoot and fruit borer infestation was first observed when the crop age was 82 days old *i.e.* from reproductive stage and remained available upto crop maturity stage. Lady bird beetle appeared on the crop when the crop age was 39 days and remained available upto maturity stage of the crop.

The jassid, *Amrasca biguttula biguttula* (Ishida) was first observed during 48<sup>th</sup> SW (first week of December). Correlation between various abiotic factors and jassid and whitefly population showed that the weather factors had no impact on jassid and whitefly population. Aphid, *Aphis gossypii* (Glover) and Whitefly, *Bemisia tabaci* (Genn.) were first observed during 50<sup>th</sup> SW (third week of December). Maximum temperature had a negative influence and morning and evening relative humidity had positive influence on aphid and whitefly population, respectively. The incidence of shoot and fruit borer *Leucinodes orbonalis* (Guen.) on the fruit was first observed during 7<sup>th</sup> SW (2<sup>nd</sup> week of February). Morning and evening relative humidity exhibited a negative while maximum and minimum temperature and wind speed exhibited a positive impact on the fruit infestation, respectively.

Spray of microbial insecticide *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha on 99 days old crop (after transplanting) was found to be most effective against *L. orbonalis* fruit infestation, and also found effective against sucking pest complex aphid, jassid and Whitefly.

Treatment *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha was found to be most economic as it gave highest cost benefit ratio followed by (1:4.55),

*Verticillium lecanii* @ 3.25 kg / ha (1:3.94) and *Bacillus thuringiensis* var. *kurstaki* @, 1 l /ha (1:3.57), respectively

### **Suggestions for further work:**

In view of the changing climatic conditions, the studies on succession of insect pests and their natural enemies, population dynamics of major insect pests, and testing of microbials against the major pest brinjal shoot and fruit borer should be carried out consecutively for 3 years in order to arrive at any concrete conclusion.

Studies should be carried out as sequential approach of microbials for the management of insect pest complex of brinjal.

Further identification of natural enemies, extent of predation or parasitization, abiotic factors favourable for their abundance is very essential, and is also the need of the day.

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\* = Unpublished

## APPENDIX – I

**Weekly meteorological data during crop season 25 ovember 2011 To 07  
May 2012 of Entomology Experimental field,Adhartal, JNKVV, Jabalpur  
(M.P.)**

Std week	Dates		Temperature (°C)		Vapour Pressure(mm)		Relative Humidity (%)		Wind velocity (km/hr)	Suns hine (hrs)	Rainfall (mm)	No. of rainy days	Evapor ation mm
	From	To	Max	Min.	Morn	Even.	Morn	Even					
48	27-09-11	03-12-11	27.2	9.6	9.5	9.4	89	36	2.2	7.3	0	0	2.3
49	04-12-11	10-12-11	28.8	11.1	10.1	9.8	90	34	2.5	8.1	0	0	2.4
50	11-12-11	17-12-11	25.3	7.2	8	8	89	35	2.7	8.2	0	0	2.3
51	18-12-11	24-12-11	24.8	5.3	6.9	5.6	90	24	2.3	8.6	0	0	2.2
52	25-12-11	31-12-11	24.9	7.4	7.7	7.9	89	32	2.6	7.4	0	0	2.1
1	01-01-12	07-01-12	23	12	11.2	13.5	95	69	3.3	5.8	28.6	1	1.1
2	08-01-12	14-01-12	20.2	6.3	8	7	93	41	4	7.1	0	0	1.9
3	15-01-12	21-01-12	23.7	7.1	7.8	7.6	90	36	3.4	8.6	0	0	2.3
4	22-01-12	28-01-12	21.5	9	8.7	10.2	89	57	3.5	6.8	13.2	2	1.9
5	29-0-12	04-02-12	20.8	8	8.1	9.2	91	46	3.5	4.5	7.6	1	1.6
6	05-02-12	11-02-12	26.4	8.8	8.6	7.3	89	30	4	8.6	0	0	2.7
7	12-02-12	18-02-12	27.6	10.4	10	11.2	90	42	3.8	8.3	0	0	2.3
8	19-02-12	25-02-12	30.5	9.8	9.3	9	86	28	3.1	9.6	0	0	3.3
9	26-02-12	03-03-12	30.1	10.4	9.2	7.3	86	24	2.8	9.1	0	0	3.5
10	04-03-12	10-03-12	30.8	11.6	8.9	6	76	18	4.9	8.3	0	0	4.8
11	11-03-12	17-03-12	31.8	13.2	9.3	8	69	23	4.4	7.8	0	0	4
12	18-03-12	24-03-12	35.1	13	8.1	5.7	66	14	3.4	8.7	0	0	5.1
13	25-03-12	31-03-12	37.3	15.3	10.9	6.3	68	14	2.8	8.5	0	0	5.5
14	01-04-12	07-04-12	37.8	20.2	11.1	7.5	49	17	4.5	7.1	0	0	6
15	08-04-12	14-04-12	39.4	18.5	10.5	6.9	45	14	5.6	8.2	0	0	7.3
16	15-04-12	21-04-12	38.7	20.2	12.1	8.6	47	17	4.5	7.6	0	0	7.1
17	22-04-12	28-04-12	39.2	18.9	11.3	9.3	43	12	4.7	7.6	0	0	7.6
18	29-04-12	05-05-12	38.9	20.7	10.9	12	45	15	5.2	7.4	0	0	8.1

## APPENDIX - II

**Efficacy of different microbials against jassid infesting brinjal:**

### **ANOVA-1: Pre-treatment**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	1.23	0.61	3.52	2.18
Treatment	6	1.25	0.21	1.20	
Error	12	2.09	0.17		
Total	20	4.57			

SEm± 0.24

CD at 5% NS

### **ANOVA-2: 3 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.00	0.00	0.04	2.18
Treatment	6	17.84	2.97	118.03	
Error	12	0.30	0.03		
Total	20	18.14			

SEm± 0.09

CD at 5% 0.28

### **ANOVA-3: 7 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.02	0.01	0.32	2.18
Treatment	6	20.53	3.42	96.06	
Error	12	0.43	0.04		
Total	20	20.98			

SEm± 0.11

CD at 5% 0.34

**ANOVA 4-: 10 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.07	0.04	0.44	2.18
Treatment	6	18.70	3.12	38.40	
Error	12	0.97	0.08		
Total	20	19.75			

SEm± 0.16

CD at 5% 0.51

**ANOVA 5-: Overall mean**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	1.23	0.61	16.10	2.18
Treatment	6	18.55	3.09	80.96	
Error	12	0.46	0.04		
Total	20	20.23			

SEm± 0.11

CD at 5% 0.35

**Efficacy of different microbials on aphid infesting brinjal.**

**ANOVA 6-: Pretreatment**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	6.03	3.02	5.73	2.18
Treatment	6	4.07	0.68	1.29	
Error	12	6.32	0.53		
Total	20	16.41			

SEm± 0.42

Cd at 5% NS

**ANOVA-7: 3 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.12	0.06	5.77	2.18
Treatment	6	16.38	2.73	265.45	
Error	12	0.12	0.01		
Total	20	16.62			

SEm± 0.06

CD at 5% 0.18

**ANOVA-8: 7 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.04	0.02	0.70	2.18
Treatment	6	19.51	3.25	128.39	
Error	12	0.30	0.03		
Total	20	19.85			

SEm± 0.09

CD at 5% 0.28

**ANOVA-9: 10 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.04	0.02	1.48	2.18
Treatment	6	19.73	3.29	266.25	
Error	12	0.15	0.01		
Total	20	19.92			

SEm± 0.06

CD at 5% 0.20

**ANOVA-10: Overall mean**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	1.87	0.94	175.35	2.18
Treatment	6	18.47	3.08	577.25	
Error	12	0.06	0.01		
Total	20	20.40			

SEm± 0.04

CD at 5% 0.13

**Efficacy of different microbials on white fly infesting brinjal .****ANOVA-: 11 pretreatment**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.49	0.25	0.38	2.18
Treatment	6	2.02	0.34	0.52	
Error	12	7.81	0.65		
Total	20	10.31			

SEm± 0.47

CD at 5% NS

**ANOVA-12: 3 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.00	0.00	0.02	2.18
Treatment	6	19.23	3.21	73.35	
Error	12	0.52	0.04		
Total	20	19.76			

SEm± 0.12

CD at 5% 0.37

**ANOVA-13: 7 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.07	0.03	1.06	2.18
Treatment	6	24.42	4.07	131.59	
Error	12	0.37	0.03		
Total	20	24.85			

SEm± 0.10

CD at 5% 0.31

**ANOVA-14: 10 days after spraying**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.08	0.04	1.30	2.18
Treatment	6	24.65	4.11	136.15	
Error	12	0.36	0.03		
Total	20	25.10			

SEm± 0.10

CD at 5% 0.31

**ANOVA-15: Overall mean**

Source of variation	d.f	S.S	M.S.S	F Cal.	T.tab 5%
Replication	2	0.52	0.26	35.42	2.18
Treatment	6	22.68	3.78	513.42	
Error	12	0.09	0.01		
Total	20	23.29			

SEm± 0.05

CD at 5% 0.15

**Efficacy of different microbials on brinjal shoot and fruit borer infestation.**

**ANOVA-16: pretreatment**

<b>Source of variation</b>	<b>d.f</b>	<b>S.S</b>	<b>M.S.S</b>	<b>F Cal.</b>	<b>T.tab 5%</b>
Replication	2	247.22	123.6	5.63	2.59
Treatment	8	433.09	54.1	2.46	
Error	16	351.27	21.95		
Total	26	1031.58			

SEm $\pm$  = 2.71      CD at 5% =3.88

**ANOVA-17: Overall mean**

<b>Source of variation</b>	<b>d.f</b>	<b>S.S</b>	<b>M.S.S</b>	<b>F Cal.</b>	<b>T.tab 5%</b>
Replication	2	23.07	11.5	2.29	2.59
Treatment	8	265.48	33.2	6.60	
Error	16	80.44	5.02		
Total	26	369.00			

SEm $\pm$  1.29                      CD at 5% 3.88

**ANOVA-18: Yield of fruit**

<b>Source of variation</b>	<b>d.f</b>	<b>S.S</b>	<b>M.S.S</b>	<b>F Cal.</b>	<b>T.tab 5%</b>
Replication	2	0.16	0.1	2.16	2.59
Treatment	8	4.18	0.5	14.10	
Error	16	0.59	0.03		
Total	26	4.94			

SEm $\pm$  0.11                      CD at 5% 0.33

## ABSTRACT

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## ABSTRACT

Present research work on “Studies on insect pest complex of brinjal, *Solanum melongena* (Linn.) and their management with microbials” was carried out in the experimental fields of Department Of Entomology, Live Stock Farm, Adhartal JNKVV, Jabalpur (M.P.) during *rabi* season 2011-12. The experiment was conducted with the following objectives :

1. To study the succession of insect pest complex and their natural enemies on brinjal.
2. To study the population dynamics of major insect pests of brinjal.
3. Management of insect pest complex of brinjal with reference to Shoot and fruit borer with microbials.

Studies on insect pest complex and their natural enemies revealed that the following insects were the major pests which were observed infesting the brinjal crop. Jassid, *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae); aphid, *Aphis gossypii* (Glover) (Hemiptera: Aphididae); whitefly, *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae) and shoot and fruit borer, *Leucinodes orbonalis* (Guen.) (Lepidoptera : Pyraustidae). Among them, jassid appeared when the crop age was about 7 days old *i.e.* during vegetative stage and remained available upto maturity stage of the crop. Aphid and Whitefly were the next insect pests to appear on the crop, when the crop age was about 11 days and 18 days old, respectively *i.e.* during vegetative stage and remained available upto maturity stage of the crop. Shoot and fruit borer appeared when the crop age was about 82 days old *i.e.* during reproductive stage of the crop and remained available upto maturity of the crop.

Only one natural enemy lady bird beetle *Chelonemus sexmaculata* (Fab.) (Coleoptera : Coccinellidae) was recorded, which appeared when the crop age was 39 days old during vegetative stage and remained available upto maturity stage of the crop.

Jassid incidence was first recorded in the last week of November (48<sup>th</sup> SW). In the present study the activity of the pest continued from third week of November to first week of May. The peak activity of the pest was observed during 52<sup>nd</sup> to 15<sup>th</sup> SW (*i.e.* last week of December to second week of April) During this period maximum and minimum temperature ranged from 20.2 to 39.4 °C and 6.3 to 20.2°C, respectively, whereas morning and evening relative humidity ranged from 45 to 95 and 14 to 69 %, respectively. Further sunshine, wind velocity, evaporation, rainfall, vapour pressure

morning and evening, ranged from 4.5 to 9.6 hours, 2.6 to 5.6 km/hr, 1.1 to 7.3 mm, 0 to 28.6 mm, 7.7 to 11.2 mm, 6 to 11.2 respectively.

Correlation studies between various abiotic factors and jassid population revealed the weather factors did not exhibit any influence on the pest population.

Aphids were first recorded in the second week of December *i.e* (50<sup>th</sup> SW). In the present study the activity of the pest continued from second week of December to First week of May ). The peak activity of the pest was observed durin 1<sup>st</sup> to 5<sup>th</sup> SW (*i.e*. first week of January to first week of February). During this period the maximum and minimum temperature ranged from 20.2 to 23.7 °C and 6.3 to 12 °C, respectively. Whereas morning and evening relative humidity ranged from 89 to 73 % and 36 to 69 %, respectively. Further, sunshine, wind velocity, evapouration, vapour pressure morning and evening and rainfall ranged from 4.5 to 8.6 hours, 3.3 to 4 km/hr, 1.1 to 2.3 mm, 7.8 to 11.2 mm, 7 to 13.5, and 0 to 28.6 mm, respectively,

Correlation studies between various abiotic factors and aphid population revealed that maximum temperature, and sunshine exhibited negative while morning and evening relative humidity exhibited positive influence on the pest population.

Whitefly incidence was first recorded in the second week of December *i.e*. (50<sup>th</sup> SW). In the present study the activity of the pest continued from third week of December to first week of May. During the peak activity period the maximum and minimum temepature ranged from 20.2 to 30.5 °C and 6 to 12°C, respectively, whereas morning and evening relative humidity ranged from 89 to 95 % and 24 to 69 %, respectively. Further sunshine, wind velocity, evapouration and morning and evening vapour pressure ranged from 4.5 to 9.6 hours, 2.3 to 4 km/hr and 1.1 to 3 mm, 6.9 to 11.2 mm ,5.6 to 13.5 respectively.

Correlation studies between various abiotic factors and Whitefly population revealed that more of the weather factors exhibited significant influence on the pest population, respectively.

During the entire period of study the shoot damage due to shoot and fruit borer was observed during 7<sup>th</sup> and 11<sup>th</sup> SW.

Fruit infestation due to shoot and fruit borer was first recorded in the third week of February *i.e.* ( 7<sup>th</sup>SW). In the present study the activity of the pest continued from third week of February to first week of May *i.e.* (10<sup>th</sup> SW to 18<sup>th</sup> SW) from reproductive to maturity stage. In the present study, during the peak activity period, maximum and minimum temperature ranged from 30 to 37.8 °C and 9.8 to 20.2 °C respectively, whereas morning and evening relative humidity ranged from 49 to 86 % and 14 to 28 % respectively. Further, sunshine, wind velocity, evapouration, morning

vapour pressure and evening vapour pressure ranged from 7.1 to 9.6 hours, 3.3 to 6 km/hr, 3.3 to 6 mm, 8.1 to 11.1 mm, 5.7 to 8 mm, respectively.

Correlation studies between various abiotic factors and shoot and fruit borer infestation revealed that maximum and minimum temperature, wind velocity exhibited positive whereas morning relative humidity, evening relative humidity, exhibited negative influence on the pest infestation, respectively.

On the basis of the effectiveness of different microbial treatments against insect pest complex it can be said that *Metarhizium anisopliae* @ 2.5 kg/ha was found to be most effective against aphid jassid and Whitefly, while *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha, was found to be most effective against Shoot and fruit borer.

Further, *Bacillus thuringiensis* var. *kurstaki* @ 1.5 l / ha recorded highest healthy fruit yield (255.01 q / ha) The quantity and cost of increased fruit yield over control is 59.02 q / ha, worth Rs 29,510 /- per ha; giving 24.24 % increase in fruit yield. Taking into account the cost of the plant protection inputs, the cost benefit ratio comes to 1:4.55. It means that a farmer is likely to get a profit of Rs 4.55 after investing an amount of Rs 1 /- on plant protection measures.