

**BIOLOGY AND MANAGEMENT OF BRINJAL SHOOT AND
FRUIT BORER (*Leucinodes orbonalis* G.) IN LOW HILLS OF
HIMACHAL PRADESH**

Thesis

by

**GOKUL KUMAR
(NH-2019-07-M)**

Submitted to



**Dr. YASHWANT SINGH PARMAR UNIVERSITY
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Dr. V K Rana
Professor and Head

Department of Entomology
College of Horticulture and Forestry
Dr. Y. S. Parmar University of
Horticulture & Forestry
(Nauni) Solan (HP) – 173230 (India)

CERTIFICATE - I

This is to certify that the thesis entitled, “**Biology and management of brinjal shoot and fruit borer (*Leucinodes orbonalis* G.) in low hills of Himachal Pradesh**” submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE) ENTOMOLOGY** of Dr. Yashwant Singh Parmar University of Horticulture & Forestry, Nauni Solan (H.P.) is a record of bonafide research work carried out by **Mr. Gokul Kumar** son/daughter of Sh. Rakesh Kumar under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation has been fully acknowledged.

Place: Neri, Hamirpur

Date:

Dr. V K Rana
Chairman
Advisory committee

CERTIFICATE-II

This is to certify that the thesis entitled “**Biology and management of brinjal shoot and fruit borer (*Leucinodes orbonalis* G.) in low hills of Himachal Pradesh**” submitted by **Mr. Gokul Kumar (NH-2019-07-M)** son of Sh. Rakesh Kumar to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP), in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE) ENTOMOLOGY** has been approved by the Student’s Advisory Committee after an oral examination of the student in collaboration with the external examiner.



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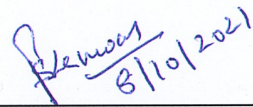


Dr. K C Sharma
External Examiner

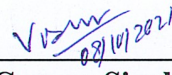


(Dean's Nominee)

Members of Advisory Committee



Dr. Shiv Pratap Singh
Associate Professor
Department of Vegetable Science



Dr Vishav Gaurav Singh Chandel
Scientist (Entomology)
RHR&TS, Jachh (Co-opted member)

Professor and Head
Department of Entomology

Dean
College of Horticulture and Forestry
Neri, Hamirpur

CERTIFICATE - III

This is to certify that all the mistakes and error pointed out by external examiner have been incorporated in the thesis entitled “**Biology and management of brinjal shoot and fruit borer (*Leucinodes orbonalis* G.) in low hills of Himachal Pradesh**” submitted by **Mr. Gokul Kumar (NH-2019-07-M)** son of Sh. Rakesh Kumar to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni), Solan (H.P.) - 173320 India in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in the discipline of **ENTOMOLOGY**.

Dr. V K Rana

Chairman

Advisory committee

Professor and Head

Department of Entomology

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Place: Neri, Hamirpur

(Gokul Kumar)

Dated:

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ABBREVIATIONS

%	:	Per cent
<i>et. al</i>	:	Co-workers
amsl	:	Above mean sea level
° C	:	Degree Celsius
etc.	:	Etcetera
Kg	:	Kilogram
Ha	:	Hectare
Cm	:	Centimeter
ml	:	Millileter
@	:	At the rate of
i.e.	:	That is
MT	:	Metric ton
G	:	Gram
mm	:	Millimeter
<i>viz.</i>	:	Namely
CD	:	Critical difference
DF	:	Degree of freedom
ANOVA	:	Analysis of variance
sp.	:	Species
EC	:	Emulsifiable Concentrate
WG	:	Water dispersible Granules
SL	:	Soluble concentrate
WSC	:	Water Soluble Concentrate
G	:	Granules
WP	:	Wettable Powder
OD	:	Oil Dispersion
SC	:	Suspension Concentrate
Lit	:	Litre
N	:	North
E	:	East

PM	:	Post Meridien
RBD	:	Randomized Block Design
M	:	Metre
w.e.f.	:	With effect from
N/A	:	Not available
B : C ratio	:	Benefit : Cost ratio
Rs.	:	Rupees
/	:	Or
°	:	Degree
'	:	Minutes
"	:	Seconds
FAO	:	Food and Agriculture Organization
Anon	:	Anonymous
Cal	:	Calorie
B	:	Beta
H	:	Hour
RH	:	Relative Humidity
CRD	:	Completely Randomized Design
LSD	:	Least Significant Difference
BSFB	:	Brinjal Shoot and Fruit Borer
<i>Bt</i>	:	<i>Bacillus thuringiensis</i>
a.i.	:	Active Ingredients
Q	:	Quintal
FYM	:	Farm yard Manure
<i>Bb</i>	:	<i>Beauveria bassiana</i>
SP	:	Soluble Powder

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Chapter – 1

INTRODUCTION

Vegetables are rapidly becoming an important source of income for the rural population. Brinjal, *Solanum melongena* L. is one such vegetable and its commercial cultivation not only helps to improve human nutrition, but also increases income generation for the grower. This crop is considered cosmopolitan in nature. In the hot wet monsoon season when other vegetables are in short supply. Brinjal is practically the only vegetable that is available at an affordable price for rural and urban poor (Panda *et al.*, 2015). India and Indo-China are considered the centres of origin for brinjal (Vavilov, 1951).

India is the second largest producer of brinjal after China. Indonesia, Egypt, Turkey, Iraq and the Philippines are also the other major eggplant producing countries. It is being cultivated in an area of about 7,30,400 ha in India with a production of 12,80,800 MT. In Himachal Pradesh, it is being cultivated in an area of about 1,110 ha with the production of 25,700 MT (Anonymous, 2018).

Brinjal is an important vegetable crop of subtropics and tropic with fuel, nutritional and ayurvedic medicinal value. Eggplant is composed of moisture 92.7 g/100g, carbohydrates 4.0 g/100g, protein 1.4 g/100g, fat 0.3 g/100g, minerals 0.3 g/100g, crude fibre 1.3 g/100g, energy 24 Kcal./100g, calcium 18mg/100g, phosphorus 47 mg/100g and iron 0.38 mg/100g of edible part (Gopalan *et al.*, 1989).

The brinjal crop is attacked by about 140 species of insect pests. (Dwivedi *et al.*, 2014). The major arthropod pests of brinjal include fruit and shoot borer, *Leucinodes orbonalis* G. (Lepidoptera: Pyralidae), Jassids, *Amrasca biguttula biguttula* Ishida. (Homoptera: Cicadellidae), Epilachna (Hadda) beetle, *Epilachna vigintioctopunctata* Fab. (Coleoptera: Coccinellidae), Whitefly, *Bemisia tabaci* Genn. (Hemiptera: Aleyrodidae), Aphids, *Myzus persicae* Sulz. (Hemiptera: Aphididae), Spider mites, *Tetranychus* spp. etc. Some pests of regional significance are Bud worm, *Scrobipalpa blapsigona* Meyr. (Lepidoptera: Gelechiidae), Mealybug,

Phenacoccus solenopsis Tinsley. (Hemiptera: Pseudococcidae), Leaf roller, *Eublemma olivacea* Walker (Lepidoptera: Noctuidae), Leaf webber, *Psara bipunctalis* Fabricius (Lepidoptera: Pyralidae) and Termite, *Microtermes obesi* (Termitidae: Isoptera) throughout India (Srinivasan, 2009).

The brinjal shoot and fruit borer (Lepidoptera: Pyralidae) is the most obnoxious detrimental and ubiquitous insect pest. It also damages potato and other solanaceous crops. This pest is active throughout the year at places having moderate climate but it is adversely affected by severe cold. It is known to damage the shoot and fruit of brinjal in all stages of its growth. The caterpillar bores into young growing shoots, petioles, midrib of leaves and fruits leaving no sign of entry. It riddles the plants parts, feeds on internal tissue causing the plants to fade and wither resulting into drying and drooping of growing shoot which is the typical symptom produced. Once the fruit setting begins, caterpillar bores into fruits by entering under calyx and feed inside. One larva damages four to six fruits during its complete larval development. Larval stage of this pest causes the damage varies from 1 to 90 per cent in India. (Kalloo, 1988). A full grown larva before going for pupation comes out of the fruit by making exist hole. Pupation take place in boat shaped silken cocoon in the fallen leaves or soil.

For the management of any pest, a single management strategy is hardly employed, and ultimately the use of insecticides is the only choice. However chemical control measures are not fully effective against brinjal shoot and fruit borer. It is therefore imperative to think of the most economical, eco-friendly, and sustainable method of pest control which reduce the cost of production. Repeated use of broad spectrum synthetic chemicals also results 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 to manage this pest.

Keeping in view the economic importance of the crop, the present study entitled “Biology and Management of brinjal shoot and fruit borer in low hills of Himachal Pradesh” have been contemplated with the following objectives:

- A) To study the biology of brinjal shoot and fruit borer.
- B) To study the management of brinjal shoot and fruit borer.

Chapter – 2

REVIEW OF LITERATURE

The relevant research information available in the literature on the study entitled ‘Biology and management of brinjal shoot and fruit borer (*Leucinodes orbonalis* G.) in low hills of Himachal Pradesh’ is presented below:

2.1 Biology of brinjal shoot and fruit borer:

Hussain *et al.* (1937) revealed the appearance of *L. orbonalis* in Punjab and the examined biology under Punjab conditions. They reported that the incubation period of this pest was 3 to 4 days, duration of larval stages lasted 8 to 26 days depending on the season and pupal period varied from 6 to 13 days. A single female of this moth could deposit up to 40 eggs, which were laid singly or in clusters on the underside of brinjal leaves.

Lall and Ahmad (1965) revealed that the life cycle of *L. orbonalis* G. ranged from 26-39 days with 10 generation per year. Average number of eggs laid by adult female ranged from 92.5 to 233. The grown-up is a little white moth with 40-sectioned radial veins (Sexena, 1965) and having spots on forewings of 20 to 22 mm spread.

Atwal and Verma (1972) studied the growth of *L. orbonalis* in relation to various temperatures and relative humidity levels, revealing that temperatures of 30°C and relative humidity levels of 70 to 90% were more conducive to the pest's survival, with no egg hatching at 40°C. They also studied the growth of the brinjal shoot and fruit borer on long and round fruited brinjal and tomato cultivars, finding that brinjal supplied better nutrition to the pest than tomato, with a lower survival rate on tomato. During the months of July to September, the pest caused the most damage, with a maximum of 9 larvae observed from a single fruit. Hatchlings go through at any rate five instars (Atwal, 1976).

The grown-up gained full development in 10 to 14 days. Life span of grown-ups keep going 1.5 to 2.4 days for males and 2.0 to 3.9 days for females. The pre-oviposition and oviposition periods ranged 1.2 to 2.1 and 1.4 to 2.9 days, individually (Mehto *et al.*, 1981).

Oviposition took place during the night and eggs are laid singly on the lower surface of the young leaves, green stems or flower buds of the fruits and number of eggs laid by a female varies from 80 to 253 (Taley *et al.*, 1984).

Baang and Corey (1991) studied the life history of *L. orbonalis* on eggplant under laboratory conditions and found that flat-oval eggs were laid most frequently at night hours. The average number of eggs laid per female was 121.5, with 79.24 percent of those eggs being viable. There were six larval instars in total. The duration of the egg, larval, and pupal stages was 6, 15.3, and 11.5 days, respectively. The average life spans of male and female varied 4 and 7.5 days, respectively.

The grown-up male passed on subsequent to mating and the female moth bites the dust in the wake of laying eggs (Kar *et al.*, 1995). The general life cycle completed in 22 to 55 days.

Kumar *et al.* (2000) studied the life cycle of brinjal shoot and fruit borer (*L. orbonalis*) and natural enemies of insect-pests of *Solanum melongena* and reported that rear during the early spring of 1996 on natural diet in laboratory and at the same time pesticide free crops were raised in the field and observed that adult were nocturnal, feeding, mating and egg laying activities occurred during night (2- 6 h) and lasted for about 16 minutes. The eggs were laid either singly or in group on the ventral surface of the leaves. The larvae penetrate to the fruits and shoot. They also recorded that as temperature increases, humidity decreased so duration of life cycle also decreases.

Singh and Singh (2001) studied the development of brinjal shoot and fruit borer at medium high altitude hills of Meghalaya. They revealed that the adults mated more than once for a female, and mating took either at night or early in the morning. The egg laying started on the same day of mating, but with each passing day, the

number of eggs reduced. A female laid an average of 174.95 eggs, mostly singly. The duration of incubation period was 5.65 days, and the viability was 83 per cent. The larval period was 18.66 days with 5 larval instars, while the pupal period was 10.43 days on average. Male and female moths lived for 3.53 and 5.80 days, respectively. The total life cycle was completed in 36.82 days. Females frequently mated during their life span.

Jat *et al.* (2003) studied that brinjal shoot and fruit borer laid eggs individually or in batches of 2-4 near the veins on the undersurface of leaves, with an average of 174 eggs per female. The pre-ovipositional, ovipositional, and post-ovipositional periods were 7.40 hours, 2.43 days, and 1.26 days, respectively. The egg, larval, and pupal periods were respectively 4.30, 12.83, and 9.42 days. The male moth lived for 1.82 days, whereas the female lived for 3.12 days. From egg to adult stage, the average period was 25.87 days.

Singh and Singh (2003) revealed the effect of climatic conditions on the development of brinjal shoot and fruit borer. When the average maximum and minimum temperatures and relative humidity were 27.45°C, 18.90°C, and 90%, respectively, the highest fecundity of 240.3 eggs was recorded, while the lowest fecundity (88 eggs per female) was recorded when the average maximum and minimum temperatures and relative humidity were 21.95°C, 11.90°C, and 86.75 per cent, respectively.

Youthful grown-ups are large and found on the lower leaf surfaces following development or covering up under the leaves inside the plant shelter (Alam *et al.*, 2003). During day, they like to cover up in close by obscure plots yet around evening time every significant movement, such as taking care of mating and discovering a spot for egg-laying happen (FAO, 2003).

The pupal period varied 6 to 17 days relying on temperature (Alam *et al.*, 2003). While it is 7 - 10 days during summer and 13 - 15 days during winter season (Rahman, 2006). The tone and surface of the casing matches the environmental factors making it hard to identify.

Ghosh *et al.* (2005) reported the egg period, larval period and pupal period of *L. orbonalis* was 5.08, 15.43 and 13.05 days, respectively. The duration of life cycle was 33.56 days. They further concluded that the temperature had a significant impact on the various biological stages of this pest.

Rahman (2006) reported that incubation period of eggs were 3-5 days and 7-8 days in summer and winter respectively. The larval period ranged 12-15 days during summer and 14-22 days during winter season (Rahman *et al.*, 2009).

Eggs are flattened, elliptical with a diameter of 0.5 mm, and creamy-white in colour, but turn red before hatching (Alam *et al.*, 2006). The eggs are placed singly or in bunch on the ventral surface of the leaves in the early morning hours (CABI, 2007).

Anjana *et al.* (2007) studied the biology of brinjal shoot and fruit borer in the mid-hill zone of Himachal Pradesh, and revealed that *L. orbonalis* completed 8-9 overlapping generations per year. The larval period was 12-18 days in most of the generations except the winter generation in which the fifth instar caterpillars overwintered for a period of about 134 days. The total life cycle was completed in 22-30 days between March and September but there was large variation between November and February.

Kavitha *et al.* (2008) reported that *L. orbonalis* completed its life cycle in 35.27 days, under laboratory conditions. Mating occurred the same day or the next day after emergence. Pre-oviposition, and oviposition periods varied from 1.35 and 2.01 days, respectively and incubation, larval, and pupal durations were found to be 2.98, 16.32, and 8.01 days. A single female laid 170 eggs during its life span of 5.70 days. Male live for 3.50 days.

According to Varma and Anandhi (2009) the incubation period of borer was four days. The duration of first, second, third, fourth, fifth, and sixth larval instars was 1.40, 2, 1.90, 1.90, 2.20 and 1.70 days, respectively. The total larval and pupal period was 11.10 days and 5.70 days, respectively. The longevity of male was 4.28 days and that of female was 5.71 days and the pre-oviposition, oviposition and post-

oviposition periods were 0.28, 3 and 2.43 days, respectively. The average fecundity was 149.42 eggs per female.

Wankhede *et al.* (2009) reported that the duration of egg, larva and pupa was 3.80, 13.80 and 10.20 days, respectively. The longevity of male and female moth was 1.70 days and 3.30 days, respectively. The mean time taken from egg to adult stage was 27.80 days. The number of eggs laid by a female was 120.30 eggs.

Radhakrishore *et al.* (2010) studied on the biology of brinjal shoot and fruit borer and reported that wing expanse of the male and female moth measured 18.69 ± 1.45 mm and 19.37 ± 1.45 mm respectively. The average number of eggs laid by single female varied from 15 to 137 eggs in 2 to 5 days. The larvae passed through six instars. The incubation, larval and pupal periods were 5.22 ± 0.07 , 16.86 ± 0.02 , 9.09 ± 0.3 days respectively. The adult longevity was 5.38 ± 0.2 days. The total duration from egg to adult stage was 41.88 ± 6.03 days.

Kumar *et al.* (2011) conducted a laboratory experiment during the year 2009-10 to study the biology of brinjal shoot and fruit borer. The studies revealed that the pest complete its life cycle in 36.27 days. Mating occurred on the following day after rise. The pre-oviposition, oviposition, incubation, larval and pupal periods were found to be 1.20, 1.90, 3.66, 15.72 and 9.66 days, separately. Female laid 160 eggs. The life span of male and female was 3.0 and 5.20 days.

Pramanik *et al.* (2012) studied the biology of brinjal shoot and fruit borer and found that larval period, pupal period and adult longevity was 16.2, 7.6 and 3.8 days respectively. The mean length of generation was 26.9 days. The fecundity was 35.40 eggs per female. The above biological parameters indicated that the insect could complete a generation within a month.

Prithwiraj *et al.* (2012) studied the biology of the brinjal shoot and fruit borer under laboratory conditions at $27 \pm 1^\circ\text{C}$ and 80 ± 5 per cent relative humidity. The larval duration, pupal period, adult longevity and mean length of generation were 16.20, 7.60, 3.80 and 26.90 days respectively.

Maravi *et al.* (2013) studied the biology of brinjal shoot and fruit borer. The result revealed that the eggs, larval and pupal period of shoot and fruit borer were 3.49, 11.50 and 8 days respectively and the life span of adult was 4.60 days. Absolute life cycle finished in 27.59 days and male to female proportion was 1:1.53.

Onekutu *et al.* (2013) studied the biology of this pest on a sensitive variety (Lv Makurdi at $27\pm 3^{\circ}\text{C}$ and at 85 ± 4 per cent RH). The average duration of incubation period was 5.93 days. The duration of first, second, third, fourth and fifth larval instar was 1.00, 1.16, 1.48, 2.63, and 4.46 days, respectively. The pupal stage lasted for 11.2 days. Females lived for 4.14 days, and males lived for 4.31 days. The pest completed its life cycle in 28.17 days.

Mainali (2014) studied that female of *L. orbonalis* laid 80-253 eggs of around 0.5 mm large. Incubation period was of 3 to 5 days in summer and 7 to 8 days in winter. The larval period lasted for 12-15 days in summer and 14-22 days in winter season. There were five instars, the first instar larvae were less than 1 mm in size whereas the last instar was of 15-18 mm in size. The pupal period varied from 6-17 days and these pupated in soil at depth of 1-3 cm, the adult longevity of male insect varied 1.5-2.4 days and that of female it varied from 2.0-3.9 days. Pre-ovipositional period varied 1.2 to 2.1 days and the ovipositional period was of 1.4-2.9 days. The total life cycle of the pest was completed in 22-55 days.

Bindu *et al.* (2015) studied on biology of brinjal shoot and fruit borer and found that the incubation period was 3.80 days. The overall larval period was 16.20 days long. The pupal period was 8.60 days on average. Pre-oviposition lasted 1.81 days, while oviposition lasted 2.55 days. The average longevity of a female moth was 5.80 days, with a total life cycle of 35.20 days.

Yadav *et al.* (2015) studied the biology of brinjal shoot and fruit borer, during the years 2009 and 2010 under laboratory condition. Mating was seen around the same time or a day after development. Female begins egg laying around the same time or a day in the wake of mating. During both the years the normal pre-oviposition time frame was recorded as 1.293 ± 0.071 and 1.334 ± 0.060 days, oviposition period

2.223 ± 0.103 and 2.192 ± 0.099, fruitfulness 170.13 ± 0.945 and 170.90 ± 1.823 eggs/female, brooding period 4.867 ± 0.231 and 5.33 ± 0.750 days, larval period 13.27 ± 0.416 and 13.27 ± 0.416 days, pre-pupal period 1.60 ± 0.200 and 1.40 ± 0.200 days respectively. The pupal period was recorded as 6.73 ± 0.305 and 6.40 ± 0.400 days during both the years respectively. During 2009 and 2010, the male normal development period was 25.20 ± 0.916 and 24.70 ± 0.500 days, individually with 3.20 ± 0.200 and 3.33 ± 0.230 long periods of male life span respectively.

Ambhure *et al.* (2016) revealed that the brooding, larval and pupal periods were 3.72, 11.29 and 7.35 days, individually. The life span of grown-up was 4.03 days. All out life cycle finished in 26.40 days and male to female proportion was 1:1.95.

Sharma *et al.* (2017) studied the biology of the brinjal shoot and fruit borer and found that the incubation period was 3.51 to 3.72 days whereas the larval period was 13.52 to 14.39 days. The total developmental period was 24.52 to 26.41 days. The fecundity of the pest was 193.40 to 210.2 eggs per female.

Singla *et al.* (2018) considered the biology of brinjal shoot and fruit borer on brinjal assortment Punjab Sada bahar. The outcomes revealed that least length of hatching period (3.19 days), larval period (11.31 days), pupal period (7.11 days) was seen during August when mean temperature and relative moistness was 29.5°C and 79.25 per cent individually.

Hung *et al.* (2020) found that *L. orbonalis* adult had white insect into dark brown colour. Incubation period, larval period and pupal period was around 5-6 days, 10-12 days and 8-9 days respectively. The life cycle of *L. orbonalis* lasted 25.30 days. The density of this pest was highest on the young shoot and fruit of egg plant at the stage after planting 95 -150 days.

Iesa (2021) found that the number of eggs laid, egg length, breadth and fecundity were 195, 0.78mm, 0.50mm and 217 respectively. The pre- oviposition, oviposition, incubation, larval and pupal periods were 1.15, 4.5, 3.95, 9.75 and 6.71 days, respectively.

2.2 Management of brinjal shoot and fruit borer:

Faqir and Muhammad (1998) tested the efficacy of insecticides insegar (fenoxycarb), bactospine (*Bacillus thuringiensis*), dimethoate, and dichlorvos against *L. orbonalis* infesting aubergine cultivars such as Nirala, Faisalabad, Swat Local, Swat Selection, and Mirpurkhas and reported that all of the insecticides significantly reduced the infestation of shoot and fruit. Furthermore, they discovered considerable differences in cultivar susceptibility, with Nirala being the most susceptible and Swat Selection being the least susceptible.

Sasikala *et al.* (1999) found that multiple methods, either in single or in combination, were effective in controlling *L. orbonalis*. In comparison to control plots, neem oil (0.2 %), neem oil (0.1 %) + lufenuron (0.01%), neem oil (0.1 %) + *Bt* (0.075 %), and neem oil (0.1 %) + carbaryl (0.075 %) all produced larger fruit yields.

Jat and Pareek (2001) evaluated the insecticides against *L. orbonalis* and found that cypermethrin was the most effective followed by carbaryl and endosulfan with high yield potentials. Neem based insecticides were found least effective against this pest.

Babu *et al.* (2002) evaluated the efficacy of mixture of deltamethrin and triazophos with *Bacillus thuringiensis* and azadiractin for the management of brinjal insect pests including *L. orbonalis* in field conditions. Early spray of either *Bt* or the mixture of insecticides was effective in controlling fruit borer. However, deltamethrin + triazophos followed by *Bt* and azadiractin were the most effective sequence of pest management in brinjal.

Puranik *et al.* (2002) studied the various formulations of *Bacillus thuringiensis* with neem and chemical insecticides against the brinjal shoot and fruit borer. They reported that five dipel 8L @0.2 per cent at 10 days interval with resulted in minimum shoot (9.56%) as well as fruit (11.78%) infestation and maximum yield of marketable fruits (196.96 q/ha) and proved to be the most effective treatment. It was however, at par with Delfin WG, Halt WP and Biolep WP all at 0.2 per cent concentrations. This was followed by Biobit HPWP, Spicturin and chemical

insecticides *viz.*, cypermethrin and endosulfan, while neem was found to be least effective treatment.

Singh (2003) assessed insecticides and plant extracts, *viz.*, neem cake (20 q ha⁻¹), karanj cake (20 Kg ha⁻¹), neem oil (3%) and karanj oil (3%) against brinjal shoot and fruit borer. The foliar use of quinalphos 20 EC with basal utilization of neem cake diminished the occurrence of borer and increased the yield of brinjal. The occurrence and yield recorded in basal utilization of neem cake with foliar splash of neem oil was at standard with blend of customary insecticides. From ecological contamination perspective, neem items alone or in blend with customary bug sprays were suggested.

Kaur *et al.* (2004) revealed that insecticides along with mechanical clipping of infested shoots and incorporation of neem as soil and foliar application for the management of brinjal shoot and fruit borer. In comparison to open field conditions, enclosed sowing or sowing under net conditions produced superior brinjal fruits with reduced borer infestation.

Yadav and Sharma (2005) conducted a field experiment to evaluate the efficacy of bioagents and neem products in comparison to malathion against *L. orbonalis* which showed that malathion is better than bioagents and neem products while *B. thuringiensis* sufficiently controlled this pest.

Mathur and Jain (2006) conducted a field experiment to assess cypermethrin (0.007%), carbaryl (0.02%), endosulfan (0.07%), malathion (0.05%), and triazophos (0.10%), as well as *B. thuringiensis* (0.012%) for the management of *L. orbonalis*. In comparison to all other treatments, cypermethrin (0.007 %) and carbaryl (0.02 %) was found superior.

Misra (2008) assessed two new insecticides, *viz.*, rynaxypyr 20 % SC @ 40 and 50g a.i./ha and flubendiamide 480 SC in the field against brinjal shoot and fruit borer during winter, 2007 and summer, 2008 with brinjal cultivar "Utkal Anushree". Four foliar spray applications of the chemicals were given at 11 days intervals starting from fruit initiation. The results revealed that rynaxypyr 20 % SC @ 40 and

50g a.i./ha gave 95–97 per cent decrease in the shoot damage and 87–90 per cent decrease fruit damage on number basis and 88–90 per cent on weight basis at ten days after fourth spray, compared with untreated control. Both the new compounds were safe to natural enemies at 0, 3, 7 and 10 days after spraying. The healthy fruit yield recorded was significantly highest in plots treated with rynaxypyr 20 % SC @ 40 and 50g a.i./ha during both the seasons of field testing.

Suradkar *et al.* (2008) evaluated different IPM modules against the brinjal shoot and fruit borer with one insecticidal schedule. The result revealed that spinosad + Metazhizium anisoplae + chelating agent + cartap hydrochloride module was found to be the most effective in reducing shoot infestation (7.47%), number of fruit damage (25.59%), damage to fruits on a weight basis (25.83%), and giving higher yield (81.82 q/ha) with the added advantage of monitoring.

Ghatak *et al.* (2009) treated the new substance emamectin benzoate against brinjal shoot and fruit borer and revealed that when applied @ 0.28 g/l of water it reduced the saturation up to a degree of 73.04 per cent.

Rahman *et al.* (2009) studied the several treatment strategies on brinjal shoot and fruit borer infestation at Gazipur and Jessore districts of Uttar Pradesh. The findings revealed that among insecticides, marshal® 20 EC @1.5 ml L⁻¹ of water (carbosulfan) and suntap® 50 SP @ 5 mg L⁻¹ were the most effective, followed by sex pheromone and other alternatives.

Singh *et al.* (2009) reported that profenofos 15 EC @ 0.1% and spinosad 45 SC @ 0.01% were best to reduce shoot and fruit infestation of *L. orbonalis*.

Wankhede *et al.* (2010) stated that emamectin benzoate treatment was substantially superior to diflubenzuron and *BtK* (5.0 and 4.8 per cent shoot damage in kharif, 2007 and 2008 trials, respectively). It was followed by novaluron, which exhibited 5.7 and 5.2 (59.6 and 51.2 per cent reduction) per cent shoot damage in

kharif 2007 and 2008, respectively. The percentage mortality of larvae from the treatment was maximum in emamectin benzoate, with a mean of 11.5; 11.4 and 12.3; 12.4% fruit damage on a number and weight basis, during kharif, 2007 and 2008, respectively. Novaluron significantly reduced fruit damage (53 & 54% reduction on number and weight basis, respectively). Maximum coccinellides population recorded in untreated control and *BtK* was 4.16, 3.22, and 3.74, 3.49 during two years, respectively, followed by emamectin benzoate and novaluron which recorded 2.24, 1.80, and 2.66, 2.58 during two years, respectively. The yield of healthy fruits in emamectin benzoate and novaluron treated plots were recorded 24.06, 23.14 and 20.46, 19.71 t ha⁻¹ during two seasons, respectively.

Misra (2011) tested chlorantraniliprole 20 SC during the winter of 2007 and the summer of 2008, in the field against the brinjal shoot and fruit borer. Starting from fruit initiation, four foliar sprays of the chemical were applied at varying doses at 11 days intervals, along with a regular check carbosulfan 25 EC @ 500 g a.i./ha and an untreated control. After the 10 days of fourth spray the results showed that treatments chlorantraniliprole @ 40 and 50 g a.i./ha were significantly superior and statistically on par with each other in terms of efficacy, with 95-97 per cent reduction in per cent shoot harm; 87-90 per cent reduction in fruit damage on a number basis; and 88-90 per cent reduction in fruit damage on a weight basis. Natural enemies were unaffected by chlorantraniliprole at doses ranging from 20 to 50g a.i./ha.

Field explore were led during Kharif 2009 and 2010 to assess the adequacy of chlorantraniliprole 18.5 SC (coragen), flubendiamide 39.3 SC (fame), indoxacarb 14.5 SC (avaunt), chlorfenapyr 10 SC (intrepid) and spinosad 45 SC (spintor) against brinjal shoot and natural product drill. Chlorantraniliprole 18.5 SC and flubendiamide 39.3 SC demonstrated their predominance over the insect sprays in decreasing invasion of *L. orbonalis* G. also, brought about more significant returns, (Shirale *et al.*, 2012).

The bioefficacy of spinosad (56.25, 72 and 90g a.i./ha) and emamectin benzoate (5, 6.25 and 12.5g a.i./ha) was found best to control brinjal shoot and fruit borer, (Kalawate *et al.*, 2012).

Abdullah *et al.* (2014) tested the bioefficacy of spinosad, imidacloprid and carbosulfan against the infestation of *L. orbonalis*. All the tested insecticides were found to be effective in reducing shoot and fruit borer damage although spinosad 45 SC @ 1ml/l was the most effective that recorded 78.90 per cent protection over control.

Ashadul *et al.* (2014) reported that the use of neem leaf extract at 50g/l of water was found to be more efficient than other plant extract treatments in reducing shoot and fruit infestation thus gave higher fruit yield.

Dwivedi *et al.* (2014) evaluated the six insecticides against *L. orbonalis* in the field. Imidacloprid 17.8 SL @ 250 g a.i./ha was most effective followed by indoxacarb 14.5 SC @ 50 g a.i./ha and dimethoate 30 EC @ 1 lit/ha. Imidacloprid treatment produced the highest fruit yield (220.61 q/ha), followed by indoxacarb (217.88 q/ha) and dimethoate (216.22 q/ha).

Spraying of spinosad (libsen 45 SC) along with pheromone trap was found to be the best treatment to diminish shoot (1.16%) and fruit infestation (5.95%) in correlation with that in the water-treated control shoot infestation 26.37 per cent while fruit infestation as (46.35%), (Mamun *et al.*, 2014).

Singh *et al.* (2015) conducted a field experiment during Kharif 2014, at the Crop Research Center, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.), India to determine the comparative efficacy of *Bacillus thuringiensis*, *Beauveria bassiana*, neemarin (neem oil), neemarin- *Bt-Bb*, *Bt-Bb-Bt*, spinosad 45 SC, and in contrast to the control. The treatments were found to be effective in reducing the infestation of shoot and fruit borer. At all observational intervals, application of spinosad 45 SC @ 200 ml/ha was the most effective treatment in reducing shoot and fruit damage, followed by chlorpyrifos 20 EC @ 1 lit/ha and neemarin @ 3 lit/ha.

Yousafi *et al.* (2015) in a field study in Sahiwal, Pakistan, different insecticides were tested for brinjal shoot and fruit borer control during the spring and fall sowing seasons. The Nirala variety of brinjal was used in the research. Spinosad

(tracer 45 SC), flubendiamide (belt 48 SC), emamectin benzoate (timer 1.9 EC), bifenthrin (talstar 10 EC), spinetoram (delegate 25 WG), and chlorantraniliprole (coragen 20 SC) were used as insecticides. Insecticides were sprayed on the spring sown crop on April 2, 17 and May 2, and on the fall sown crop on September 3, 18 and October 4. One day before insecticide application, all infested fruits were removed from plots. One day before spraying, infected shoots were identified by tying a ribbon to all drooping shoots. Plants in the middle two rows of each plot had fruit and shoot infestations seven and fourteen days after insecticide application. When compared to the control, both treatments significantly reduced shoot and fruit infestation. However, flubendiamide (belt 48 SC) and emamectin benzoate (timer 1.9 EC) treated plots had the least shoot infestation. For control of the borer in fruits, spinosad (tracer 45 SC) proved to be the most effective insecticide.

Awal *et al.* (2017) reported that spinosad (Tracer 45 SC) @ 0.4ml/l could be the best bug spray for getting best return of eggplant and furthermore in controlling the brinjal shoot and fruit borer. It was revealed that, spinosad (Tracer 45 SC) was successful in decreasing 88.22 per cent shoot invasion over control during summer and 84.41 per cent shoot pervasion over control during winter season.

Niranjana *et al.* (2017) conducted a field trial to evaluate the efficacy of 10 insecticides *viz.*, imidacloprid 17.8% SL, thiacloprid 21.7% SC, thiodicarb 75% WP, chlorantraniliprole 18.5% SC, flubendiamide 20Wg, emamectin benzoate 5 SG, diafenthuron 50 WP, spinosad 2.5% SC, chlorpyrifos 20% EC, and dimethoate 30% EC along with untreated control against *L. orbonalis* on brinjal. The findings revealed that the insecticide chlorantraniliprole 18.5% SC was effective and significantly superior over other treatments in reducing the shoot and fruit infestation of *L. orbonalis* with least effect on natural enemies existed in brinjal fields.

Tripura *et al.* (2017) studied the efficacy of some insecticides *viz.* chlorantraniliprole 18.5 SC (0.4ml/l), spinosad 45 SC (0.5ml/l), chlorfenapyr 10 SC (2ml/l), indoxacarb 14.5 SC (1ml/l), *Bacillus thuringiensis* (*Bt*) (2g/l), azadirachtin 0.03 EC (5ml/l), *Metarhizium anisoplae* (2.5g/l), *Beauveria bassiana* (2.5g/l) and chlorpyrifos 20 EC (2.5 ml/l) against the brinjal shoot and fruit borer and revealed

that shoot infestation was minimum in chlorantraniliprole plots (6.32%) followed by spinosad, chlorfenapyr, indoxacarb. Among bio-pesticides, *Beauveria* and *Bt* were found effective treatments in reducing shoot infestation. Chlorantraniliprole recorded the lowest fruit infestation (8.25%).

Karmakar *et al.* (2018) conducted the field investigation to assess the effectiveness of certain biopesticides against the brinjal shoot and fruit borer during the rabi season in 2015-2016. With 10.92 per cent mean shoot infestation and 10.04 per cent mean fruit infestation, azadirachtin 1 per cent EC @ 2ml/L was found to be superior to other treatments, followed by karanjin 2 per cent EC @ 2ml/L. (13.42 % shoot and 12.83 % fruit infestation).

Jacob and Revathi (2019) conducted farm trials in ten locations in Andhra Pradesh and reported that by adoption of eco-friendly IPM practices in all the four years, the shoot damage was reduced on an average by 4.02 per cent compared to 9.19 per cent in farmers practice. The fruit damage on an average was also reduced by 16.42 per cent compared to 31.55 per cent in farmers practices. The total moth trap catches per trap per season on an average was 86.64 helping in reducing the pest load, damage and enabled in correct decision making in application of insecticides.

Chapter – 3

MATERIALS AND METHODS

Experiments were laid out to the current research entitled “**Biology and management of brinjal shoot and fruit borer, (*Leucinodes orbonalis* G.) in low hills of Himachal Pradesh (Lepidoptera:Pyralidae)**” were carried out in the experimental farm, Department of Entomology, College of Horticulture and Forestry, Neri (Hamirpur), Himachal Pradesh (31°41' N and 76° 28' E; 650 m amsl. This chapter contains information about the materials used and the methods used during the research.

3.1 Sowing of crop

The seeds of Pusa Purple Long variety of brinjal were sown in the experimental farm of the Department of Entomology on March, 2020. Proper irrigation was provided to the nursery. After 2 months, brinjal seedlings were transplanted in the field on May, 2020 at recommended spacing of 60×45 cm. The experiments were laid out in the Randomized Block Design (RBD) with three replications. Only FYM was added as nutrient source for brinjal plants whereas, under field condition all the agronomical practices recommended for the crop were followed except insecticidal applications.

3.2 Biology of brinjal shoot and fruit borer

To study the biology, the observations were taken with the onset of infestation in an experimental farm, Department of Entomology, COHF, Neri, Hamirpur. The initial culture of shoot and fruit borer was kept in the laboratory, Department of Entomology. Infested brinjal fruits were harvested from experimental farm and held in rearing cage for further studies.

3.2.1 Maintenance of laboratory culture

Infested fruits were collected from the experimental farm after daily visits to farm and kept in the rearing cages (30×30×30 cm) for further studies. Fruits of Pusa Purple Long variety of brinjal were provided to *Leucinodes orbonalis* larvae as food. The food was replaced by fresh ones as per the requirements and proper hygienic conditions were maintained. A layer of sand was provided at the base of rearing cage for pupation. After pupation, pupae were collected and placed in separate cages for mating purpose. Tender terminal shoots of brinjal with fresh fruits were kept in glass flask having water in it to keep leaves and fruits fresh for a longer time also providing natural conditions for egg laying. Adult feeding was accomplished by dipping cotton swabs in a 10 per cent honey solution and placing it in the rearing cage. Adults laid eggs in the brinjal fruits inside the rearing cage after mating. The fruits with newly laid eggs were utilized for the study of biology.

3.2.2 Eggs

Eggs were examined under a binocular microscope for shape, size, and colour. The length and breadth of eggs were measured with a digital vernier caliper and expressed in mm. To determine the average incubation period, ten freshly laid eggs were observed daily during the morning hours before hatching. When a tiny larva emerges from an egg, it was referred to as a hatched egg.

3.2.3 Larvae

The observations were recorded on larvae soon after their hatching. On the basis of their morphometrics, different larval instars were differentiated. There were total five larval instar. Larvae of first instar were held in one petri dish, along with soft leaves and tender brinjal buds. From the second instar, larvae of *L. orbonalis* soft slices of brinjal fruits were given, which were changed daily. The larval period defined as the time from hatching to initiation of pupation.

3.2.4 Pupa

At the point when the larvae pupated inside the petri-dish, it was held undisturbed to complete its cycle. The colour and size of each pupa was examined. The length and width of the ten pupae were determined by using vernier caliper. The pupal period was counted as the time needed from pupal formation to the eclosion of the adult stage.

3.2.5 Pre-oviposition, oviposition and post-oviposition periods

A newly emerged male and female adult pair was placed in a wooden cage for mating and to study the pre-oviposition, oviposition, and post-oviposition periods as well as the survival of individual male and female moth. The rearing cage (30×30×30 cm) was provided with ten per cent honey solution soaked cotton, some fresh brinjal slices and a glass flask filled with water and was examined for eggs laid by a female on a regular basis till the death of female. Pre-oviposition means the period taken by female before egg laying was calculated from the date of emergence of female and till the date of egg laying. The oviposition period was the time taken by adult females to lay eggs and it was recorded from the start to end of egg laying by females. The post-oviposition period was the time spent by female adults after egg laying stopped till death, and it was recorded from the end of egg laying to the death of the female.

3.2.6 Adult Longevity

For the study of adult longevity the newly emerging adults were kept alike by providing 10% honey solution in cotton swabs as food. Adult lifespan was recorded from the time of eclosion upto death.

3.3 Management of brinjal shoot and fruit borer

3.3.1 Efficacy of different insecticides /biopesticides /non chemical method

The studies on the management of brinjal shoot and fruit borer were completed in the experimental farm of Department of Entomology at College of Horticulture and Forestry, Neri, Hamirpur. The experiment was set up in a

Randomized Block Design with three replications. Regular visit to experimental farm was done for recording observations like initiation of flowering and infestation by brinjal shoot and fruit borer.

3.3.2 Insecticides and Biopesticides

Chlorantraniliprole, cyantraniliprole, spinosad, fenvalerate and agni astra were tested against the brinjal shoot and fruit borer.

Table 1: Details of insecticides/biopesticides used against brinjal shoot and fruit borer

Sr. No.	Insecticide/Biopesticide	Formulation	Trade Name	Manufacturer
1	Chlorantraniliprole	18.5 SC	Coragen	DuPont India Pvt. Ltd.
2	Cyantraniliprole	10.26% w/w OD	Benevia	FMC India Pvt. Ltd.
3	Spinosad	45 SC	Tracer	Dow Agro Science India Pvt. Ltd.
4	Fenvalerate	20 EC	Sumicidin	Insecticides (India) Limited
5	Agni Astra		Agni Astra	Prepared in Laboratory

In control, only foliar application of water was given. In the experimental farm, three sprays of these insecticides/ biopesticides were scheduled. The schedule for various sprays is described below:

First spray : At initiation of infestation

Second spray : 15 days after first spray.

Third spray : 15 days after second spray.

3.3.3 Preparation of Agni Astra

The following ingredients were used to make Agniastra, as shown in Table 2.

Table 2: Agni Astra Ingredients

Sr. No.	Ingredients	Quantity
1	Cow urine	20 L
2	Garlic	½ kg
3	Green chillies	½ kg
4	Neem leaves	5 kg

In an utensil, all of these ingredients were boiled for about 30 minutes, or 3 to 4 boils. This mixture was kept for 48 hours until the liquid was extracted and the solid waste decomposed. Agni Astra is now ready to use (Devvrat, 2017).

3.4 Observations recorded

3.4.1 Shoot infestation

In order to determine the effect of different treatments on shoot infestation initially a pre count of infested shoots was taken before first spray application. Thereafter the observations on the per cent shoot infestation were recorded after 7 and 14 days of the first, second and third spray. To find the infestation rate, the infestation in different treatments were compared between all the treatments, as well as the control, after statistical analysis.

3.4.2 Fruit infestation

In order to determine the effect of different treatments on fruit infestation similar methodology as use in shoot infestation was followed. Initially a pre count of infested fruits was taken before first spray application. Thereafter the observations on the per cent fruit infestation were recorded after 7 and 14 days of the first, second and third spray. To find the infestation rate, the infestation in different treatments were compared between all the treatments, as well as the control, after statistical analysis.

Table 3: Details of different insecticides and biopesticides for the management of brinjal shoot and fruit borer

Treatments	Insecticide/Biopesticide	Concentration (%)	Dose (ml/l)
T₁	Chlorantraniliprole	0.005	0.27
T₂	Chlorantraniliprole	0.01	0.54
T₃	Cyantraniliprole	0.01	0.97
T₄	Cyantraniliprole	0.02	1.94
T₅	Spinosad	0.002	0.17
T₆	Spinosad	0.004	0.34
T₇	Agni Astra	5.0	50
T₈	Fenvalerate	0.01	50g/l
T₉	Control	Water	-

3.5 Statistical analysis

The observations recorded in the laboratory experiments pertaining to shoot and fruit infestation were analyzed using one factor analysis (ANOVA) in a Completely Randomized Design (CRD). The per cent data obtained from field experiment were firstly subjected to the suitable transformations and then the one factor analysis was performed (ANOVA) in a Randomized Block Design (RBD) using OPSTAT computer program and critical difference (CD) thus obtained was used to perform the Fisher's least significant difference (LSD) post hoc test in order to compare the treatments as suggested by Gomez and Gomez (1986).

Chapter – 4

RESULTS AND DISCUSSION

This chapter presents the findings of the current study on the “**Biology and management of the brinjal shoot and fruit borer (*Leucinodes orbonalis* G.) in low hills of Himachal**”. The current findings are also examined and compared to the findings of other studies that have a direct or indirect relationship with the current investigations.

4.1 Biology

4.1.1 Egg

4.1.1.1 Colour, shape and size

Before hatching, newly laid eggs were oval in shape and creamy white in colour. These became deep orange colour with a prominent black mark at the egg's tip (Plate 1). The length and breadth of eggs ranged from 0.70 to 0.90 mm with an average of 0.82 ± 0.02 mm and 0.40 to 0.60 mm with an average of 0.50 ± 0.02 mm, respectively (Table 4).

Our results are in accordance with Bindu *et al.* (2015), Singh and Singh (2001) and Onekutu *et al.* (2013) who reported that the egg measured 0.80 mm in length and 0.52 mm in width and 0.75 mm in length and 0.53 mm in breadth, 0.94 mm in length and 0.5 mm in width, respectively.

4.1.1.2 Incubation Period

The incubation period ranged from 3-5 days with a mean duration of 3.90 ± 0.23 days (Table 6). These findings are in accordance with the observations of Kumar *et al.* (2011) who reported the mean incubation period of 3.66 days on brinjal. The present findings are also in accordance with the findings of Mehto *et al.* (1983), Jat *et*

al. (2002) and Singh and Singh (2003) who reported the incubation periods of 5.4, 4.30 and 5.65 days, respectively.

4.1.2 Larva

4.1.2.1 Nature of damage

The pest confined its feeding activity mostly to the shoot and also on petiole of the compound leaves. The newly hatched larva bored into the tender shoots, feeding on the pith, making the shoot hollow and plugging the entrance hole with excreta. This resulted in wilting, drooping and drying of the shoot. The larva tense its whole development inside the shoots. The blackish brown coloured excreta was ejected from the entry hole. The larva emerged from the shoot through the exit hole after completing its larval stage.

4.1.2.2 Number of instars

The larvae were found to pass through five instars on brinjal fruits in the laboratory. Singh and Singh (2001), Harit and Shukla (2005) and Patial *et al.* (2007) support the current finding that this pest has five instars.

4.1.2.3 First instar

Newly hatched larva was dirty white in coloration with conspicuous dark head (Plate 2). The length and breadth of first instar larva varied from 1.60 to 2.55 mm with an average of 2.14 ± 0.11 mm and 0.20 to 0.35 mm with an average of 0.30 ± 0.02 mm, respectively (Table 4). The head capsule width varied from 0.35 to 0.60 mm with an average 0.48 ± 0.03 mm (Table 5). The first instar larvae's lifespan ranged from 2 to 3 days, with an average of 2.5 ± 0.17 days (Table 6).

The present investigations results are in conformity with these reports. Bindu *et al.* (2015) reported that first instar larva to be 1.60 to 2.45 mm with an average of 2.03 ± 0.36 mm in length, 0.2 to 0.32 mm with an average of 0.26 ± 0.05 mm in width and duration varied from 2 to 3 days, with an average of 2.6 ± 0.55 days. However the findings are in contrast to the findings of Varma and Anandhi (2009) who reported that the duration of first larval instar was 1.40 days with mean length of



Plate 1. Eggs of Brinjal shoot and fruit borer



1st instar



2nd instar



3rd instar



4th instar



5th instar

Plate 2. Different larval instars of Brinjal shoot and fruit borer

1.21 mm and mean width of 0.27 mm. Onekutu *et al.* (2013) reported that newly hatched larva was cream to brownish pink, and cylindrical with a mean head capsule measurement of 0.45 mm with an average body length and breadth of 4.19 mm and 0.47 mm, respectively.

Table 4: - Morphological parameters of brinjal shoot and fruit borer

Sr. No.	Parameter (Insect stage)	Range	Measurement in (mm)
			(Mean \pm SE)
1.	Egg		
	Length	0.70-0.90	0.82 \pm 0.02
	Width	0.40-0.60	0.50 \pm 0.02
2	First instar larvae		
	Length	1.60-2.55	2.14 \pm 0.11
	Width	0.20-0.35	0.30 \pm 0.02
3.	2nd instar larvae		
	Length	3.5-4.8	4.11 \pm 0.13
	Width	0.50-0.90	0.71 \pm 0.05
4.	3rd instar larvae		
	Length	6.5-9.5	7.92 \pm 0.37
	Width	1.2-1.8	1.53 \pm 0.07
5.	4th instar larvae		
	Length	10-14	11.99 \pm 0.47
	Width	1.7-2.0	1.85 \pm 0.04
6.	5th instar larvae		
	Length	15.5-20.0	17.57 \pm 0.57
	Width	3.5-4.5	4.10 \pm 0.11
7.	Pupa		
	Length	10.5-14.5	11.81 \pm 0.36
	Width	4.0-5.2	4.73 \pm 0.11
8.	Adult Moth (Male)		
	Length	10.5-15.5	12.5 \pm 0.58
	Width	2.3-3.5	2.97 \pm 0.14
	Wing span	18-23	20.69 \pm 0.60
9.	Adult Moth (Female)		
	Length	12-16	13.8 \pm 0.40
	Width	2.6-3.6	3.10 \pm 0.13
	Wing span	21-25	22.90 \pm 0.42

SE- Standard Error

Number of observations : 10

4.1.2.4 Second instar

The second instar larva increased in size and slight change in colour. Colour of the second instar larva was whitish brown mixed with pink colour (Plate 2). Length of the second instar larva ranged from 3.50 to 4.80 mm with an average of 4.11 ± 0.13 mm, while the breadth ranged from 0.50 to 0.90 mm with an average of 0.71 ± 0.05 mm (Table 4). The width of head capsule varied from 0.65 to 0.85 mm with an average width of 0.74 ± 0.03 mm (Table 5). The duration of second instar larvae varied from 1 to 4 days with an average of 2.6 ± 0.31 days (Table 6).

Bindu *et al.* (2015) reported that the second instar larva was whitish brown mixed with pink color, 4.00 mm in length with 0.70 mm in breadth and range varied from 1 to 4 days with mean duration of 2.8 ± 0.71 days. Onekutu *et al.* (2013) reported that width of the head capsule of second instar larva varied from 0.60 to 0.85 mm with an average of 0.74 ± 0.06 mm. The average of developmental period, body length and body width varied from 1.16 ± 0.40 days, 6.98 ± 2.16 mm and 0.90 ± 0.16 mm, respectively. Singla *et al.* (2018) reported that the mean length, mean width and head capsule width of second instar larva varied from 4.55 mm, 0.80 mm and 0.43 mm, respectively. Varma and Anandhi (2009) reported that duration of second instar was 2 days.

4.1.2.5 Third instar

Third instar larva was similar to second instar in shape but the third instar varied in size and colour. Third larval instar was pink in colour (Plate 2). Length and breadth of third instar larva ranged from 6.50 to 9.50 mm with an average of 7.92 ± 0.37 mm and 1.20 to 1.80 mm with an average of 1.53 ± 0.07 mm respectively (Table 4) and head capsule width ranged from 0.95 to 1.20 mm with an average of 1.09 ± 0.03 mm, respectively (Table 5). The duration of third instar larvae varied from 2 to 4 days with an average of 3.1 ± 0.18 days (Table 6).

Table 5:- Head capsule width in different larval instars of brinjal shoot and fruit borer

Larval Instar	Range(mm)	Head capsule Measurement in (mm) (Mean \pm SE)
1 st	0.35 - 0.60	0.48 \pm 0.03
2 nd	0.65 - 0.85	0.74 \pm 0.03
3 rd	0.95 - 1.20	1.09 \pm 0.03
4 th	1.30 - 1.60	1.45 \pm 0.03
5 th	1.65 - 2.20	1.98 \pm 0.06

*Values are averages of 10 observations, SE- Standard Error.

Bindu *et al.* (2015) reported that the length and breadth of third instar larva was 6.55 to 9.25 mm with an average of 8.03 ± 0.64 mm and 1.20 to 1.70 mm with an average of 1.48 ± 0.20 mm, respectively. The duration of third instar larva was 2-4 days with a mean of 3.2 ± 0.84 days. Onekutu *et al.* (2013) reported that the head capsule width of third instar larva varied from 0.90 to 1.20 mm with an average of 1.06 ± 0.11 mm. The developmental period, body length and body width varied from 1.48 ± 0.41 days, 11.10 ± 2.32 mm and 1.38 ± 0.16 mm, respectively. Singla *et al.* (2018) reported that the mean length, mean width and head capsule width of third instar varied from 8.48 mm, 1.69 mm and 0.77 mm, respectively. The mean duration of third instar larvae was 3.11 to 5.83 days.

4.1.2.6 Fourth instar

The colour of fourth instars larva was pinkish brown, somewhat more broad in the middle (Plate 2).The length and breadth of fourth instar larva ranged from 10 to 14 mm with an average of 11.99 ± 0.47 mm and 1.70 to 2.0 mm with an average of 1.85 ± 0.04 mm respectively (Table 4).The width of head capsule of fourth instar larva varied from 1.30 to 1.60 mm with an average of 1.45 ± 0.03 mm (Table 5). The

duration of fourth instar larvae varied from 3 to 4 days with an average of 3.4 ± 0.16 days (Table 6).

Bindu *et al.* (2015) mentioned that the length and breadth of fourth instar larva was 10.55 to 13.25 mm with an average of 11.74 ± 0.46 mm and 1.76 to 1.95 mm with an average of 2.13 ± 0.39 mm, respectively and the duration of fourth instar larva was 3-4 days ranged with a mean of 3.4 ± 0.89 days. Onekutu *et al.* (2013) reported that the head capsule width of fourth instar larva varied from 1.25 to 1.55 mm with an average of 1.44 ± 0.08 mm. The developmental period, body length and body width varied from 2.63 ± 0.45 days, 16.58 ± 1.75 mm and 1.71 ± 0.15 mm, respectively. Singla *et al.* (2018) reported that the mean length, mean width and head capsule width of fourth instar varied from 10.05 mm, 2.10 mm and 1.34 mm, respectively. The mean duration of fourth instar larvae was 2.00 to 3.69 days. Saxena (1965) mentioned that the mean larval length and width of fourth instar varied from 9.30 mm and 1.80 mm, respectively.

4.1.2.7 Fifth instar

The full grown larva was pinkish in colour (Plate 2). The length and breadth of fifth instar larva varied from 15.5 to 20.0 mm with an average of 17.57 ± 0.57 mm and 3.5 to 4.5 mm with an average of 4.10 ± 0.11 mm, respectively (Table 4). Width of head capsules ranged from 1.65 to 2.20 mm with an average of 1.98 ± 0.06 mm (Table 5). The duration of fifth instar larvae varied from 2 to 3 days with an average of 2.4 ± 0.84 days (Table 6).

Bindu *et al.* (2015) mentioned that the length and breadth of fifth instar larva was 15.25 to 19.55 mm with an average of 17.30 ± 1.15 mm and 3.3 to 4.25 mm with an average of 3.92 ± 0.35 mm, respectively and the duration of fifth instar larva was 2-3 days ranged with a mean of 2.8 ± 0.55 days. Onekutu *et al.* (2013) reported that the head capsule width of fifth instar larva varied from 1.60 to 2.20 mm with an average of 1.73 ± 0.15 mm. The developmental period, body length and body width varied from 4.46 ± 0.71 days, 18.44 ± 0.28 mm and 2.15 ± 0.29 mm, respectively. Singla *et al.* (2018) reported that duration of fifth instar larvae varied from 1.56 to

3.80 days. The mean length, mean width and head capsule width of fifth instar was 13.08 mm, 2.28 mm and 1.36 mm, respectively.

4.1.2.8 Total larval period

The total larval period ranged from 15 to 18 days with an average 16.6 ± 0.37 days (Table 6).

This is in agreement with the findings of Bindu *et al.* (2015) who observed that the larval period was 14 to 18 days with an average 16.2 ± 1.48 days. Kumar *et al.* (2011) mentioned that the total larval period was 15.72 days. Singh and Singh (2001) observed the total larval period was 18.16 days. Baang and Corey (1991) and Singh and Singh (2003) mentioned that the larval period was 15.0 and 18.6 days, respectively.

4.1.3 Pupa

The pupa had a soft body with light brown in colour (Plate 3). The length of pupa varied from 10.5 to 14.5 mm with an average of 11.81 ± 0.36 mm, while breadth ranged from 4.0 to 5.2 mm with an average 4.73 ± 0.11 mm (Table 4). The duration of pupal stage varied from 8 to 10 days with an average of 9.1 ± 0.28 days (Table 6).

This is in agreement with the findings of Bindu *et al.* (2015) who mentioned that the length of pupa varied from 10.45-14.65 with an average of 12.34 ± 1.67 mm, while breadth ranged from 3.9 to 5.1 mm with an average 4.40 ± 0.47 mm. The duration of pupal stage varied from 8 to 10 days with an average of 8.6 ± 0.89 days. Kumar *et al.* (2011) mentioned the duration of pupal period as 9.66 days. Butani and Verma (1976) observed the pupal period was 7-10 days. Whereas Saxena (1965) found it to vary from 8 to 9 days.

4.1.4 Adult

The adult moth was white, with greyish and brown scales covering its head and thorax. On the fore wings, the colour was creamish white with large bands of light brown colour. A small black wavy line was seen towards the apical border of the hind wing. The edges of the wings were somewhat fringed. The adult male moth

length and width varied from 10.5 to 15.5 mm with an average of 12.5 ± 0.58 and 2.3 to 3.5 mm with a mean of 2.97 ± 0.14 , respectively. The adult female moth length and width varied from 12 to 16 mm with an average of 13.8 ± 0.40 and 2.6 to 3.6 mm with a mean of 3.10 ± 0.13 , respectively (Plate 4). The wing expansion of adult male and female moth varied from 18 to 23 mm with an average of 20.69 ± 0.60 and 21 to 25 mm with an average of 22.90 ± 0.60 , respectively (Table 4). The adult male moth longevity ranged from 1 to 3 days with mean longevity of adult male moth ranged from 2.2 ± 0.25 days whereas the adult female moth longevity ranged from 3 to 5 days and mean of adult female moth ranged from 4.1 ± 0.23 days (Table 6).

Bindu *et al.* (2015) mentioned the adult male moth longevity was ranged from 3 to 5 days and mean of adult male moth was 4.2 ± 0.84 days. The mean longevity of female moth was observed 5.8 ± 0.71 with the range from 4-7 days. The length of adult male was found to be 13.54 mm whereas the breadth was 2.98 mm with wing span of 20.55 mm. The length of adult female was observed as 14.53 mm whereas the breadth was 4.41 mm with wing span of 23.41 mm. Onekutu *et al.* (2013) reported the adult measures 20-22 cm when its wings are widely spread. The wingspan of male adult moth was found 21.59 mm. The mean body length was 13.26 mm, while the mean body breadth was 4.20 mm. On the other hand, wingspan of adult female moth was measured as 24.33 mm, mean body length of 14.17 mm, while the mean body breadth was 4.59 mm. Kumar *et al.* (2011) reported that longevity of male and female adult moths was 3.00 and 5.20 days, respectively. Singh and Singh (2001) observed the longevity of male as 3.53 days.

4.1.4.1 Pre-oviposition Period

The pre-oviposition period of female moth varied from 1 to 2 days with an average of 1.50 ± 0.17 days (Table 6).

Bindu *et al.* (2015) observed the pre-oviposition period of female moth was around 1 to 2 days with an average 1.81 ± 0.21 days. Kumar *et al.* (2011), Onekutu *et al.* (2013) and Kavitha *et al.* (2008) reported the pre-oviposition period of female moth as 1.20 days, 1.19 days and 1.35 days, respectively.



Plate 3. Pupa of Brinjal shoot and fruit borer

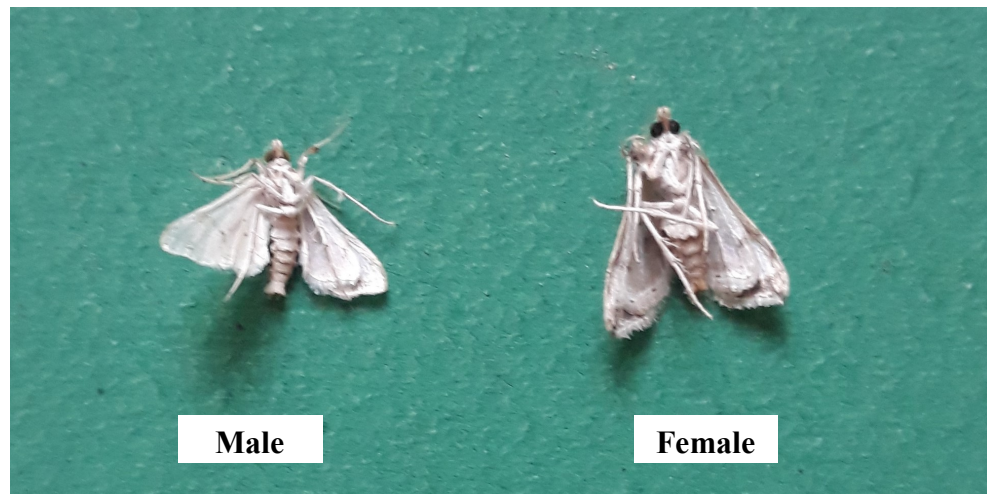


Plate 4. Adults of Brinjal shoot and fruit borer

Table 6:- Duration of different stages of brinjal shoot and fruit borer

Sr. No.	Parameters (insect stages)	Mean duration (days)	
		Range	Mean \pm SE
1.	Incubation period	3-5	3.9 \pm 0.23
2.	Total larval period	15-18	16.6 \pm 0.37
3.	Pupal Period	8-10	9.1 \pm 0.28
4.	Total developmental period	32-39	35.3 \pm 0.76
5.	Pre-oviposition period	1-2	1.5 \pm 0.17
6.	Oviposition period	1-3	2.2 \pm 0.25
7.	Post-oviposition period	2-6	3.7 \pm 0.40
8.	Adult longevity		
	Male	1-3	2.2 \pm 0.25
	Female	3-5	4.1 \pm 0.23
9.	Fecundity (eggs/female)	160-240	202.6 \pm 8.31

SE- Standard Error

Number of observations : 10

4.1.4.2 Oviposition Period

The oviposition period of female moth varied from 1 to 3 days with an average of 2.20 ± 0.25 days (Table 6).

This is in agreement with the findings of Bindu *et al.* (2015) mentioned the oviposition period of female moth varied from 2 to 3 days with an average of 2.55 ± 0.43 days. Kumar *et al.* (2011), Onekutu *et al.* (2013), Kavitha *et al.* (2008) and Jat *et al.* (2003) reported the oviposition period as 1.90 days, 2.71 days, 2.01 days and 2.43 days, respectively.

4.1.4.3 Post-oviposition Period

The post-oviposition period of female moth varied from 2 to 6 days with an average of 3.70 ± 0.40 days (Table 6).

Onekutu *et al.* (2013), Varma and Anandhi (2009) and Jat *et al.* (2003) reported post-oviposition period of female moth was 3.75 days, 2.43 days and 1.26 days, respectively.

4.1.5 Total life cycle

Brinjal shoot and fruit borer takes 32 to 39 days with an average of 35.3 ± 0.76 days to complete its life cycle (Table 6).

The present results are in conformity with reports of Bindu *et al.* (2015) who reported that the duration of life cycle varied from 32 to 37 days with an average of 35.2 ± 1.72 days. Lall and Ahmad (1965), Singh and Singh (2001), Kavitha *et al.* (2008), Kumar *et al.* (2011) and Onekutu *et al.* (2013) reported that *L. orbonalis* complete its life cycle in 28.17 days, 35.27 days, 36.27 days, 30 days and 36.82 days, respectively.

4.2 Efficacy of different insecticides/natural products

The efficacy of some insecticides and biopesticides was studied against the brinjal shoot and fruit borer, infesting the brinjal crop. The data was recorded on the per cent shoot and fruit infestation. The study on the use of insecticides and

biopesticides in the management of the brinjal shoot and fruit borer, infesting the brinjal crop were carried out in three spray schedules. Non-chemical strategies were also examined independently for pest management in addition to chemical methods. The results obtained are given in the table 7 and 8 and discussed further in section 4.2.1 and 4.2.2.

4.2.1 Effect of different insecticides, biopesticides and biorationals on shoot infestation

It is cleared from the Table 7 that prior to treatment of insecticides and biopesticides, the number of infested shoots ranges from 63.03 to 67.55 per cent in different plots. After 7 and 14 days of first spray, a treatment consisting of chlorantraniliprole @ 0.01% was found to be the most effective against the shoot borer with only 30.90 and 25.65 per cent damaged shoots, respectively. This treatment was followed by cyantraniliprole @ 0.02% with 32.46 and 27.53 per cent damaged shoots, respectively. After the 14 days of first spray cyantraniliprole @ 0.02% (27.53% shoot damage) and the spinosad @ 0.004% (31.96% shoot damage) were statistically at par. After 7 days and 14 days of first spray, the agni astra @ 5% treatment showed the lowest reduction in per cent shoot infestation among the treatments and 48.43 and 40.69 per cent shoot infestation was observed in the respective treatment. However, in the control 63.09 and 63.84 per cent damage was recorded in 7th and 14th day after the spray.

After the 15 days of first spray, second spray was applied to crop. After 7 and 14 days of second spray again the treatment consisting of chlorantraniliprole @ 0.01% was found to be the most effective against the shoot and fruit borer, with 19.05 and 12.54 per cent infested shoots, respectively. This was followed by cyantraniliprole @ 0.02% with 20.76 and 14.37 per cent infested shoots, respectively at 7 and 14 days after spray. The agni astra @ 5% again had a lowest effect on the reduction of shoot infestation with 36.16 and 31.60 per cent infestation in the shoots, respectively after the 7 days and 14 days of second spray. After the 15 days of second spray the third spray was applied to crop. A treatment consisting of chlorantraniliprole @ 0.01% was determined to be the most effective against the

shoot borer with 10.02 and 7.33 per cent respectively followed by cyantraniliprole @ 0.02% with 11.40 and 10.06 per cent respectively after the 7 days and 14 days of third spray. After the 14 days of third spray cyantraniliprole @ 0.02% and spinosad @ 0.004% are statistically at par. The agni astra @ 5% treatment had the minimum reduction of shoot borer with 25.75 and 16.65 per cent reduction respectively after the 7 days and 14 days of third spray.

In chlorantraniliprole @ 0.01% the mean shoot borer infestation was 17.58 per cent and this treatment gave 70.56 per cent protection compared to the control. This treatment was followed by cyantraniliprole @ 0.02% chlorantraniliprole @ 0.005% and cyantraniliprole @ 0.01% with mean shoot borer infestation of 19.43, 19.84 and 20.83 per cent, respectively and per cent protection over the control by these treatment were 67.46, 66.77 and 65.11 per cent respectively. In spinosad @ 0.004% and spinosad @ 0.002% the mean shoot borer infestation was 21.98 and 22.43 per cent respectively, and per cent protection over the control by these treatment were 63.19 and 62.44 per cent respectively. In fenvalerate @ 0.01% and agni astra @ 5% the mean shoot borer infestation were 27.20 and 33.21 per cent respectively, whereas per cent protection over the control by these treatment were 54.45 and 44.38 per cent, respectively.

This is in agreement with the findings of Tripura *et al.* (2017) reported that mean shoot infestation was minimum in chlorantraniliprole treated plots (5.20 %) followed by spinosad, chlorfenapyr, indoxacarb. Among bio-pesticides, *Beauveria bassiana* and *Bt* were found effective treatments in reducing shoot borer infestation.

Present findings are in conformity with findings of Phule (2015) who found that the treatment with chlorantraniliprole @ 40 g a.i. ha⁻¹ resulted in the lowest percentage of shoot infestation, 4.85 per cent, with a reduction of 77.05 per cent compared to the control.

According to Shirale *et al.* (2012) chlorantraniliprole 18.5 per cent SC and flubendiamide 39.35 per cent SC were preferable pesticides for achieving higher

yields. The plots sprayed with chlorantraniliprole 18.50% SC recorded the lowest shoot damage of 8.20 per cent. While the lowest fruit damage of 8.84 per cent.

It is cleared from the Table 8 that prior to treatment of insecticides and natural products, the number of infested fruits ranged from 65.03 to 68.74 per cent in different plots. After 7 and 14 days of first spray, a treatment consisting of chlorantraniliprole @ 0.01% was found to be the most effective against the fruit borer with only 34.33 and 28.50 per cent damaged fruits, respectively. This treatment was followed by cyantraniliprole @ 0.02% with 36.07 and 30.59 per cent damaged fruits, respectively.

After the 7 days of first spray, chlorantraniliprole @ 0.005% and spinosad @ 0.004% were statistically at par. The agni astra @ 5% treatment had the lowest reduction of fruit borer with 51.13 and 42.83 per cent, respectively after 7 days and 14 days of first spray. After the 14 days of first spray chlorantraniliprole @ 0.005% and fenvalerate @ 0.01% were statistically at par with each other.

After the 15 days of first spray, second spray was applied to crop. After 7 days and 14 days of the second spray a treatment consisting of chlorantraniliprole @ 0.01% was found to be the most effective against fruit borer, with 21.17 and 13.93 per cent respectively followed by cyantraniliprole @ 0.02% with 23.07 and 15.97 per cent respectively.

After the 7 days of second spray chlorantraniliprole @ 0.005% and spinosad @ 0.004% were statistically at par. The agni astra @ 5% treatment had the lowest reduction of shoot borer with 38.07 and 33.27 per cent respectively after the 7 days and 14 days of second spray. After 14 days of second spray cyantraniliprole @ 0.02% and spinosad @ 0.004% were found to be statistically at par with each other.

Table 7: Effect of different insecticides, biopesticides and biorationals on shoot infestation:

Treatment	Conc. (%)	Pre-treatment	Per cent shoot infestation (days after each spray)						Mean shoot infestation (%)	% protection over untreated control
			Spray I		Spray II		Spray III			
			7DAS ₁	14DAS ₁	7DAS ₂	14DAS ₂	7DAS ₃	14DAS ₃		
Chlorantranilprole 18.5 SC	0.005	65.02±0.62 (53.74)*	34.56±0.68 (36.00) ^e	28.60±0.35 (32.33) ^{de}	21.11±0.17 (27.35) ^e	13.92±0.35 (21.91) ^g	12.29±0.48 (20.51) ^e	8.57±0.17 (17.02) ^{de}	19.84	66.77
Chlorantranilprole 18.5 SC	0.01	65.84±1.60 (54.24)	30.90±0.54 (33.77) ^f	25.65±1.45 (30.41) ^e	19.05±0.25 (25.88) ^f	12.54±0.06 (20.74) ^h	10.02±0.12 (18.45) ^f	7.33±0.50 (15.69) ^e	17.58	70.56
Cyantranilprole 10.26% OD	0.01	66.67±0.96 (54.74)	34.62±0.69 (36.04) ^e	29.31±0.52 (32.78) ^{de}	21.78±0.82 (27.81) ^{de}	16.92±0.55 (24.28) ^d	12.51±0.05 (20.71) ^e	9.85±0.77 (18.27) ^{cde}	20.83	65.11
Cyantranilprole 10.26% OD	0.02	63.81±0.34 (53.02)	32.46±0.78 (34.73) ^f	27.53±0.47 (31.64) ^{de}	20.76±0.24 (27.10) ^e	14.37±0.03 (22.28) ^{fg}	11.40±0.22 (19.73) ^e	10.06±0.88 (18.46) ^{cde}	19.43	67.46
Spinosad 45 SC	0.002	64.16±1.43 (53.23)	38.37±1.12 (38.27) ^d	32.87±0.50 (34.98) ^{cd}	22.85±1.01 (28.54) ^d	15.86±0.52 (23.46) ^{de}	14.10±0.59 (22.05) ^d	10.57±1.13 (18.92) ^{cde}	22.43	62.44
Spinosad 45 SC	0.004	63.03±0.42 (52.55)	37.09±0.56 (37.52) ^d	31.96±1.03 (34.42) ^{cd}	22.26±0.31 (28.15) ^{de}	15.43±0.23 (23.13) ^{ef}	14.16±0.49 (22.09) ^d	11.02±1.08 (19.34) ^{cd}	21.98	63.19
Fenvalerate 20 EC	0.01	65.95±0.70 (54.30)	44.02±0.69 (41.56) ^e	36.13±3.12 (36.91) ^{bc}	28.75±0.35 (32.43) ^e	23.05±1.13 (28.68) ^e	18.18±0.56 (25.23) ^c	13.07±2.10 (21.06) ^{bc}	27.20	54.45
Agni Astra	5	67.26±0.39 (55.10)	48.43±1.72 (44.10) ^b	40.69±5.39 (39.55) ^b	36.16±0.71 (36.97) ^b	31.60±0.35 (34.21) ^b	25.75±0.45 (30.49) ^b	16.65±3.91 (23.74) ^b	33.21	44.38
Control		67.55±1.40 (55.28)	63.09±1.86 (52.60) ^a	63.84±0.38 (53.04) ^a	60.48±1.14 (51.05) ^a	56.68±0.84 (48.84) ^a	55.99±0.06 (48.44) ^a	58.37±0.40 (49.82) ^a	59.71	
CV		NS	1.86	6.08	1.934	2	2.25	8.63		
CD		NS	1.27	3.82	1.061	1.10	0.99	3.36		

Mean ± SE followed by common letters are not significantly different at $\alpha=0.05$ ($p \leq 0.05$) according to Fisher's least significant difference post hoc test.

*The data in the paranthesis are the arc sine transformation

Table 8: Effect of different insecticides, biopesticides and biorationals on fruit infestation:

Treatment	Conc. (%)	Pre-treatment	Per cent fruit infestation (days after each spray)						Mean fruit infestation (%)	% protection over untreated control
			Spray I		Spray II		Spray III			
			7DAS ₁	14DAS ₁	7DAS ₂	14DAS ₂	7DAS ₃	14DAS ₃		
Chlorantraniliprole 18.5 SC	0.005	65.03±0.62 (53.75)	38.40±0.76 (38.29) ^e	31.78±0.39 (34.31) ^{cd}	23.45±0.19 (28.96) ^d	15.47±0.39 (23.16) ^f	13.65±0.53 (21.68) ^{ef}	9.52±0.19 (17.97) ^d	22.04	64.91
Chlorantraniliprole 18.5 SC	0.01	65.19±1.58 (53.85)	34.33±0.60 (35.87) ^f	28.50±1.61 (32.27) ^d	21.17±0.27 (27.39) ^e	13.93±0.07 (21.92) ^g	11.13±0.13 (19.49) ^g	8.15±0.56 (16.57) ^d	19.53	68.91
Cyantraniliprole 10.26% OD	0.01	66.24±0.95 (54.48)	38.47±0.77 (38.33) ^e	32.57±0.58 (34.80) ^{cd}	24.20±0.92 (29.47) ^d	18.80±0.61 (25.70) ^d	13.90±0.06 (21.89) ^e	10.95±0.86 (19.29) ^{cd}	23.14	63.16
Cyantraniliprole 10.26% OD	0.02	65.25±0.35 (53.88)	36.07±0.87 (36.91) ^f	30.59±0.52 (33.58) ^d	23.07±0.27 (28.70) ^d	15.97±0.03 (23.55) ^{ef}	12.67±0.24 (20.85) ^f	11.18±0.98 (19.50) ^{cd}	21.59	65.63
Spinosad 45 SC	0.002	67.70±2.06 (55.38)	42.63±1.24 (40.76) ^d	34.10±1.35 (35.73) ^{cd}	24.20±0.31 (29.47) ^d	17.20±0.70 (24.50) ^e	15.67±0.66 (23.31) ^d	11.75±1.25 (19.99) ^{cd}	24.25	61.39
Spinosad 45 SC	0.004	66.07±0.79 (54.38)	39.20±0.42 (38.76) ^e	33.83±1.17 (35.57) ^{cd}	23.77±0.61 (29.18) ^d	16.63±0.63 (24.07) ^{ef}	14.90±0.52 (22.70) ^{de}	11.48±1.12 (19.76) ^{cd}	23.30	62.90
Fenvalerate 20 EC	0.01	67.80±0.72 (55.43)	46.53±0.93 (43.01) ^c	38.03±3.28 (38.08) ^{bc}	30.27±0.37 (33.38) ^c	24.27±1.19 (29.51) ^c	19.13±0.59 (25.93) ^c	13.61±2.19 (21.51) ^{bc}	28.64	54.40
Agniastra	5	68.74±0.40 (56.00)	51.13±0.59 (45.65) ^b	42.83±5.67 (40.88) ^b	38.07±0.74 (38.10) ^b	33.27±0.37 (35.22) ^b	27.10±0.47 (31.37) ^b	17.35±4.07 (24.27) ^b	34.95	44.36
Control		69.36±1.44 (56.40)	66.63±0.41 (54.72) ^a	67.20±0.40 (55.06) ^a	63.67±1.20 (52.93) ^a	59.67±0.88 (50.57) ^a	58.93±0.07 (50.15) ^a	60.80±0.42 (51.24) ^a	62.81	0.00
CV		NS	1.77	5.93	1.932	2.41	2.27	8.53		
CD		NS	1.27	3.88	1.105	1.20	1.04	3.45		

Mean ± SE followed by common letters are not significantly different at $\alpha=0.05$ ($p \leq 0.05$) according to Fisher's least significant difference post hoc test.

*The data in the paranthesis are the arc sine transformations.

After the 15 days of second spray, the third spray was applied to crop. Chlorantraniliprole @ 0.01% was found to be the most effective against the fruit borer with 11.13 and 8.15 per cent respectively followed by cyantraniliprole @ 0.02% with 12.67 and 11.18 per cent respectively after the 7 days and 14 days of third spray. After 14 days of third spray cyantraniliprole @ 0.02% and fenvalerate @ 0.01% were statistically at par with each other. The agni astra @ 5% treatment had the minimum reduction of shoot borer with 27.10 and 17.35 per cent respectively after the 7 days and 14 days of third spray.

In the treatment chlorantraniliprole @ 0.01% the mean fruit borer infestation was 19.53 per cent and this treatment provided 68.91 per cent protection compared to the control. This treatment was followed by cyantraniliprole @ 0.02%, chlorantraniliprole @ 0.005% and cyantraniliprole @ 0.01% which had mean fruit borer infestation of 21.59, 22.04 and 23.14 per cent, respectively and per cent protection over the control by these treatment were 65.63, 64.91 and 63.16 per cent respectively .

In the treatment spinosad @ 0.004% and spinosad @ 0.002%, the mean fruit borer infestation were 23.30 and 24.25 per cent respectively, and per cent protection over the control by these treatment were 62.90 and 61.39 per cent respectively. In the treatment fenvalerate @ 0.01% and agni astra @ 5% the mean fruit borer infestation were 28.64 and 34.95 per cent respectively, whereas per cent protection over the control by these treatment were 54.40 and 44.36 per cent respectively.

This is in agreement with the findings of Tripura *et al.* (2017) who reported that mean fruit infestation was minimum in chlorantraniliprole (8.37%) followed by spinosad, chlorfenapyr, indoxacarb. Among bio-pesticides, *Beauveria bassiana* and *Bt* were found to be effective treatments in reducing fruit infestation.

Present findings are in conformity with findings of Phule (2015) who found that the treatment with chlorantraniliprole @ 40 g a.i. ha⁻¹ resulted in the lowest percentage of fruit infestation, 6.31 per cent followed by spinosad @ 50 g a.i. ha⁻¹, which had a 9.42 per cent infection rate and was at par with indoxacarb @ 72.5 g a.i. ha⁻¹, which had a 10.83 per cent infestation rate.

According to Shirale *et al.* (2012) chlorantraniliprole 18.5 per cent SC and flubendiamide 39.35 per cent SC are preferable pesticides for achieving higher yields. The plots sprayed with chlorantraniliprole 18.5 per cent SC recorded the lowest fruit damage of 8.84 per cent.

Chapter – 5

SUMMARY AND CONCLUSION

The present investigations entitled “**Biology and management of brinjal shoot and fruit borer (*Leucinodes orbonalis* G.) in low hills of Himachal Pradesh (Lepidoptera: Pyralidae)**” were carried out in the College of Horticulture and Forestry, Neri, Hamirpur, Himachal Pradesh. Various biological parameters of *L. orbonalis* were studied at room temperature under laboratory conditions. Observations were recorded daily for different parameters like oviposition period, incubation period, larval period, pupal period, adult longevity and fecundity. The findings of the studies are being summarized here in this chapter:

- The pre-oviposition period of female moth varied from 1 to 2 days with an average of 1.50 ± 0.17 days. The oviposition period of female moth varied from 1 to 3 days with an average of 2.20 ± 0.25 days. The post-oviposition period of female moth varied from 2 to 6 days with an average of 3.70 ± 0.40 days.
- The incubation period ranged from 3-5 days with a mean duration of 3.90 ± 0.23 days. The first instar larvae lifespan ranged from 2 to 3 days, with an average of 2.5 ± 0.17 days. The duration of second instar larvae varied from 1 to 4 days with an average 2.6 ± 0.31 days. The duration of third instar larvae varied from 2 to 4 days with an average of 3.1 ± 0.18 days. The duration of fourth instar larvae varied from 3 to 4 days with an average of 3.4 ± 0.16 days. The duration of fifth instar larvae varied from 2 to 3 days with an average of 2.4 ± 0.84 days. The total larval period ranges from 15 to 18 days with an average 16.6 ± 0.37 days.
- The duration of pupal stage varied from 8 to 10 days with an average of 9.1 ± 0.28 days. The adult male longevity varied from 1 to 3 days with an average of 2.2 ± 0.25 mm, while the longevity of adult female varied from 3 to 5 days

with an average of 4.1 ± 0.23 mm. Fecundity ranges from 160 to 240 eggs per female.

- The adult male moth longevity ranged from 1 to 3 days and mean of adult male moth ranged from 2.2 ± 0.25 days, whereas the adult female moth longevity ranged from 3 to 5 days and mean longevity of adult female moth ranged from 4.1 ± 0.23 days. Brinjal shoot and fruit borer takes about 32 to 39 days with an average of 35.3 ± 0.76 days to complete life cycle.
- The incidence of shoot and fruit borer was significantly reduced by all insecticidal/ biopesticidal treatments. Among different management practices chlorantraniliprole @ 0.01% was found most effective to control shoot and fruit infestation of brinjal shoot and fruit borer, followed by cyantraniliprole @ 0.02%.

From the study, it was concluded that incubation period of brinjal shoot and fruit borer ranged from 3 to 5 days. The pest passed through five instars ranging from 15 to 18 days, pupal duration of 8 to 10 days, adult longevity of male and female moth vary from 1 to 3 days and 3 to 5 days, respectively. However the fecundity of adult female ranges from 160 to 240 eggs. Adult male moth was found shorter than adult female moth in length and also in wing span. Among different insecticides/ biopesticides, the treatment chlorantraniliprole @ 0.01% was found most effective to control shoot and fruit infestation, followed by cyantraniliprole @ 0.02%.

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APPENDIX

**Analysis of Variance Table 7:
Pre-Count of shoot infestation**

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.462			
Treatment	8	63.253	7.907	1.843	0.14177
Error	16	68.635	4.290		
Total	26	132.350			

First Spray: Shoot infestation after 7 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.233			
Treatment	8	2,436.423	304.553	194.271	0.00000
Error	16	25.083	1.568		
Total	26	2,468.739			

First Spray: Shoot infestation after 14 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	70.969			
Treatment	8	3,363.781	420.473	29.667	0.00000
Error	16	226.770	14.173		
Total	26	3,661.521			

Second Spray: Shoot infestation after 7 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.278			
Treatment	8	4,420.031	552.504	537.479	0.00000
Error	16	16.447	1.028		
Total	26	4,441.756			

Second Spray: Shoot infestation after 14 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6.610			
Treatment	8	5,172.492	646.562	652.227	0.00000
Error	16	15.861	0.991		
Total	26	5,194.963			

Third Spray: Shoot infestation after 7 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.299			
Treatment	8	5,448.320	681.040	1,143.536	0.00000
Error	16	9.529	0.596		
Total	26	5,458.149			

Third Spray: Shoot infestation after 14 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	65.975			
Treatment	8	6,577.777	822.222	142.405	0.00000
Error	16	92.381	5.774		
Total	26	6,736.133			

**Analysis of Variance Table 8:
Pre-count of fruit infestation**

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.196			
Treatment	8	59.996	7.500	2.279	0.07658
Error	16	52.661	3.291		
Total	26	112.854			

First Spray: Fruit infestation after 7 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	36.923			
Treatment	8	2,485.705	310.713	198.106	0.00000
Error	16	25.095	1.568		
Total	26	2,547.723			

First Spray: Fruit infestation after 14 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	43.321			
Treatment	8	3,286.489	410.811	30.684	0.00000
Error	16	214.218	13.389		
Total	26	3,544.028			

Second Spray: Fruit infestation after 7 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	8.639			
Treatment	8	4,201.400	525.175	576.529	-0.00000
Error	16	14.575	0.911		
Total	26	4,224.614			

Second Spray: Fruit infestation after 14 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.639			
Treatment	8	4,845.753	605.719	720.472	-0.00000
Error	16	13.452	0.841		
Total	26	4,862.843			

Third Spray: Fruit infestation after 7 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.265			
Treatment	8	5,058.045	632.256	1,238.645	0.00000
Error	16	8.167	0.510		
Total	26	5,066.477			

Third Spray: Fruit infestation after 14 days

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	58.797			
Treatment	8	6,184.497	773.062	146.001	0.00000
Error	16	84.719	5.295		
Total	26	6,328.012			

**Department of Entomology
Dr. Yashwant Singh Parmar University of
Horticulture & Forestry
(Nauni) Solan (HP) – 173230 (India)**

Title of Thesis : “**Biology and management of brinjal shoot and fruit borer (*Leucinodes orbonalis* G.) in low hills of Himachal Pradesh**”
Name of the Student : Gokul Kumar
Admission Number : NH-2019-07-M
Major Advisor : Dr. VK Rana
Major Field : Entomology
Minor Field(s) : Vegetable Science
Degree Awarded : M. Sc. (Agriculture) Entomology
Year of Award of Degree : 2021
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Date of Thesis submission :

ABSTARCT

The present investigations entitled “**Biology and management of brinjal shoot and fruit borer (*Leucinodes orbonalis* G.) in low hills of Himachal Pradesh**” were carried out at College of Horticulture and Forestry, Neri, Hamirpur. The study was conducted to record data on biology and management of brinjal shoot and fruit borer. From the study, it was concluded that incubation period of brinjal shoot and fruit borer ranged from 3 to 5 days. The pest passed through five instars ranging from 15 to 18 days, pupal duration of 8 to 10 days, adult longevity of male and female moth varied from 1 to 3 days and 3 to 5 days, respectively. The fecundity of adult female ranged from 160 to 240 eggs. Adult male moth was shorter than adult female moth in length and also in wing span. During the pre-treatment, number of infested shoots ranged from 63.03 to 67.55 per cent and number of infested fruits ranged from 65.03 to 68.74 per cent in different plots. The incidence of shoot and fruit borer was significantly reduced by all insecticidal/ biopesticidal treatments. Among different management practices chlorantraniliprole @ 0.01% was found most effective to control shoot and fruit infestation of brinjal shoot and fruit borer, followed by cyantraniliprole @ 0.02%.

Signature of the Student
Name: Gokul Kumar
Date:

Signature of the Major Advisor
Name: Dr. VK Rana
Date:

**Professor and Head
Department of Entomology
College of Horticulture and Forestry
Neri, Hamirpur (HP) 177001**

BRIEF BIO-DATA

Name : **Gokul Kumar**
Father's Name : Sh. Rakesh Kumar
Mother's Name : Smt. BimlaDevi
Date of Birth : 28.01.1997
Sex : Male
Marital status : Unmarried
Nationality : Indian
Academic Qualification :

Examination Passed	Year of Passing	School	University/Board	Division	Marks (%)
Matriculation	2012	SVM High School Deol	HPBOSE	First	80.80 %
10+2	2014	GSSS Chauntra	HPBOSE	First	69.20 %
Graduation	2019	College of Agriculture, Palampur	CSK HPKV Palampur	First	66.70 %

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Gokul Kumar