BIOLOGY AND MANAGEMENT OF SHOOT AND FRUIT BORER, *Diaphania caesalis* (WALKER) (PYRALIDAE: LEPIDOPTERA) ON JACK AND SCREENING AVAILABLE GERMPLASMS FOR THEIR RESISTANCE.

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GKVK, BENGALURU - 560 065
2016

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Thesis Submitted to the

University of Agricultural Sciences, Bengaluru

in partial fulfillment of the requirements

for the award of Degree of

Master of Science (Agriculture)

in

Agricultural Entomology

BENGALURU **September, 2016**

Affectionately Dedicated to

My Beloved

Father M. Rudramuni

Mother Smt. H.D. Jyothi

Sister Jeevitha. S. R.

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU - 560 065

CERTIFICATE

This is to certify that the thesis entitled, **"Biology and management of shoot and fruit borer, *Diaphania caesalis* (Walker) (Pyralidae: Lepidoptera) on Jack and screening available germplasms for their resistance"** submitted by **Mr. JEEVAN. S. R., ID No. PALB 4099** in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY** to the University of Agricultural Sciences, Bengaluru, is a record of bonafide research work done by him during the period of his study in this University under my guidance and supervision and that no part of the thesis has previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar titles.

Bengaluru
September, 2016

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(Major Advisor)

Approved by:

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(V.V. Belavadi)

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With great memories.....

The moment has come to look into the deeper layer of heart, which is filled with the feelings of togetherness, loveliness, consolation and satisfaction, a sign of relief and sense of fulfilment. Some are momentary and some are permanent, but both involve a number of near and dear persons to whom I acknowledge my warm regards and take this opportunity to express my feelings during the course of my research and it is putting down in black and white.

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Bengaluru

September, 2016 ***(Jeevan. S.R.)***

Biology and management of shoot and fruit borer, *Diaphania caesalis* (Walker) (Pyralidae: Lepidoptera) on Jack and screening available germplasms for their resistance.

Jeevan, S. R.

ABSTRACT

Biology of *Diaphania caesalis* (Walker) was studied during October 2015 – January 2016 in the laboratory at Department of Entomology, UAS, GKVK, Bengaluru. The eggs of *D. caesalis* were oval-shaped, translucent and soft appearance with mean incubation period of 4.0, 4.8 and 5.05 days, the larval mean duration of first instar was 2.65, 2.85 and 3.01 days, second instar was 1.57, 1.71 and 2.17 days, third instar was 2.66, 3.00 and 3.55 days, fourth instar was 3.03, 3.41 and 3.51 days and fifth instar was 2.88, 3.65 and 3.15 days. The mean total life cycle occupied 29.2, 33.02 and 35.09 days during October – November, November – December 2015 and December – January 2016, respectively. Adults were medium sized and wings were greyish to whitish brown coloured with elliptical markings on the fore wings. The pre-mating and mating period was 23.6 and 3.3 hours, respectively. Pre-oviposition and oviposition period occupied 21.1 hours and 8.33 days, respectively. The mean fecundity was 110.9 eggs per female. The male and female adult moths lived for 8.05 and 9.65 days, respectively.

Field screening of 24 germplasms revealed that NSP 1, NSP 7 and NSP 8 offered highly resistance. Gumless, mottamarika, tubugere, janagere, NSP 2, NSP 14, NSP 5, NSP 6 and NSP 9 germplasms were recorded as highly susceptible to *D. caesalis.* Evaluation of seven insecticide molecules revealed that, all insecticides were found to be effective. Among the insecticides, lamdacyhalotrin 5 % EC is found to be low cost of spray per acre of jackfruit garden.

September, 2016

Department of Agricultural Entomology
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(**M. Thippaiah**)
Major Advisor

ಹಲಸಿನ ಮರದ ಕಾಯಿ ಮತ್ತು ಹಣ್ಣಿನ ಕೊರಕ, *ಡೈಪೆನಿಯ ಸೆಸಾಲಿಸ್‌ನ* (ವಾಕರ್) (ಪೈರಾಲಿಡೆ: ಲೆಪಿಡೊಪ್ಟೆರ) ಹುಳುವಿನ ಜೀವನ ಚಕ್ರ ಮತ್ತು ನಿರ್ವಹಣೆ ಹಾಗೂ ಹಲಸಿನ ತಳಿಗಳ ಕೀಟ ನಿರೋಧಕತೆಯ ಅಧ್ಯಯನ

ಜೀವನ್, ಎಸ್. ಆರ್.

ಸಾರಾಂಶ

ಡೈಪೆನಿಯ ಸೆಸಾಲಿಸ್‌ನ ಜೀವನ ಚಕ್ರವನ್ನು ಕೀಟಶಾಸ್ತ್ರ ವಿಭಾಗದ, ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ, ಬೆಂಗಳೂರು, ಪ್ರಯೋಗಾಲಯದಲ್ಲಿ ಅಧ್ಯಯನ ಮಾಡಲಾಯಿತು. *ಡೈ. ಸೆಸಾಲಿಸ್‌ನ* ಮೊಟ್ಟೆಗಳು ಅಂಡಾಕಾರದಲ್ಲಿದ್ದು, ಮೃದುವಾಗಿದ್ದು, ಪಾರದರ್ಶಕವಾಗಿರುತ್ತವೆ. ಮೊಟ್ಟೆಯ ಅವಧಿ ೪.೦, ೪.೮ ಮತ್ತು ೫.೦೫ ದಿನಗಳನ್ನು ತೆಗೆದುಕೊಂಡಿತ್ತು. ಮೊದಲನೆಯ ಹಂತದ ಮರಿಹುಳುಗಳ ಕಾಲಾವಧಿ ಸರಾಸರಿ ೨.೬೫, ೨.೮೫ ಮತ್ತು ೩.೦೧ ದಿನಗಳು, ಎರಡನೇ ಹಂತದ ಮರಿಹುಳುಗಳು ೧.೫೭, ೧.೭೧ ಮತ್ತು ೨.೧೭ ದಿನಗಳು, ಮೂರನೇ ಹಂತದ ಮರಿಹುಳುಗಳು ೨.೬೬, ೩.೦೦ ಮತ್ತು ೩.೫೫ ದಿನಗಳು, ನಾಲ್ಕನೇ ಹಂತದ ಹುಳುಗಳು ೩.೦೩, ೩.೪೧ ಮತ್ತು ೩.೫೧ ದಿನಗಳು ಮತ್ತು ಐದನೇ ಹಂತದ ಹುಳುಗಳು ೨.೮೮, ೩.೬೫ ಮತ್ತು ೩.೧೫ ದಿನಗಳು ತೆಗೆದುಕೊಂಡವು. ಒಟ್ಟು ಜೀವನ ಚಕ್ರವು ೨೯.೨೦, ೩೩.೦೨ ಮತ್ತು ೩೫.೦೯ ದಿನಗಳು ಕ್ರಮವಾಗಿ ಆಕ್ಟೋಬರ್ – ನವೆಂಬರ್ ೨೦೧೫, ನವೆಂಬರ್ – ಡಿಸೆಂಬರ್ ೨೦೧೫ ಮತ್ತು ಡಿಸೆಂಬರ್ ೨೦೧೫ – ಜನೇವರಿ ೨೦೧೬ ಕಾಲದಲ್ಲಿ ದಾಖಲಿಸಲಾಯಿತು. ವಯಸ್ಕ ಕೀಟಗಳು ಸಾಧಾರಣ ಗಾತ್ರದ್ದಾಗಿದ್ದು, ರೆಕ್ಕೆಯ ಮೇಲ್ಭಾಗದಲ್ಲಿ ಬಿಳಿ ಮತ್ತು ಬೂದು ಮಿಶ್ರಿತ ಗೆರೆಗಳಿರುತ್ತದೆ. ಪೂರ್ವಮಿಲನದ ಮತ್ತು ಮಿಲನದ ಅವಧಿಗಳು ಕ್ರಮವಾಗಿ ಸರಾಸರಿ ೨೩.೬೦ ಮತ್ತು ೩.೩೦ ಗಂಟೆಗಳು ದಾಖಲಾದವು. ಪೂರ್ವಮೊಟ್ಟೆಯಿಡುವ ಮತ್ತು ಮೊಟ್ಟೆಯಿಡುವ ಅವಧಿಗಳು ಕ್ರಮವಾಗಿ ೨೧.೧೦ ಘಂಟೆಗಳು ಮತ್ತು ೮.೩೩ ದಿನಗಳು ದಾಖಲಾದವು. ಪ್ರತಿ ಹೆಣ್ಣಿನ ಸಂತಾನ ಸರಾಸರಿ ೧೧೦.೯೦ ಮೊಟ್ಟೆಗಳು ದಾಖಲಾದವು. ಗಂಡು ಮತ್ತು ಹೆಣ್ಣು ಪ್ರೌಢ ಹುಳುಗಳು ಸರಾಸರಿ ೮.೦೫ ಮತ್ತು ೯.೬೫ ದಿನಗಳಕಾಲ ಬದುಕಿದವು.

ವಿಶ್ವವಿದ್ಯಾನಿಲಯದಲ್ಲಿ, ೨೪ ಹಲಸಿನಮರದ ತಳಿಗಳಲ್ಲಿ ಭಾದೆಯನ್ನು ಕಂಡು ಹಿಡಿಯಲು ಪರೀಕ್ಷೆಗೊಳಪಡಿಸಿತ್ತು. ಇದರಲ್ಲಿ ಎನ್.ಎಸ್.ಪಿ. ೧, ಎನ್.ಎಸ್.ಪಿ. ೭, ಎನ್.ಎಸ್.ಪಿ. ೮ ತಳಿಗಳಲ್ಲಿ ಕೀಟ ಬಾದೆ ಇಲ್ಲವೆಂದು ಕಂಡುಬಂದಿದೆ. ಗಮ್‌ಲೆಸ್, ಮೊಟ್ಟೆ ಮರಿಕ, ತೂಬುಗೆರೆ, ಜಾನಗೆರೆ, ಎನ್.ಎಸ್.ಪಿ. ೨, ಎನ್.ಎಸ್.ಪಿ. ೧೪, ಎನ್.ಎಸ್.ಪಿ. ೫, ಎನ್.ಎಸ್.ಪಿ. ೬ ಮತ್ತು ಎನ್.ಎಸ್.ಪಿ. ೯ ತಳಿಗಳಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು *ಡೈ. ಸೆಸಾಲಿಸ್‌ನ* ಭಾದೆ ಕಂಡುಬಂದಿದೆ. ಸುಮಾರು ಏಳು ಕೀಟನಾಶಕಗಳ ತುಲನಾತ್ಮಕ ಅಧ್ಯಯನ ಮಾಡಿದಾಗ, ಎಲ್ಲಾ ಕೀಟನಾಶಕಗಳು ಪರಿಣಾಮಕಾರಿಯೆಂದು ಕಂಡು ಬಂದಿದೆ. ಇತರೆ ಎಲ್ಲಾ ಕೀಟನಾಶಕಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಲ್ಯಾಮ್ಡಸೈಹ್ಯಾಲೋತ್ರಿನ್ ೬ೇ. ೫ ಅತ್ಯಂತ ಕಡಿಮೆ ಹಣದಲ್ಲಿ ಒಂದು ಎಕರೆ ಹಲಸಿನ ಮರಗಳಿಗೆ ಸಿಂಪಡಿಸ ಬಹುದಾಗಿ ಮತ್ತು ಪರಿಣಾಮ ಕಾರಿಯಾಗಿ ಕೀಟ ಭಾದೆಯನ್ನು ತಡೆಯ ಬಹುದಾಗಿ ಕಂಡು ಬಂದಿದೆ.

ಸಪ್ಟೆಂಬರ್ –೨೦೧೬
ಕೃ.ವಿ.ವಿ., ಗಾ.ಕೃ.ವಿ.ಕೇ.,
ಬೆಂಗಳೂರು–೬೫

ಎಂ. ತಿಪ್ಪಯ್ಯ
(ಪ್ರಧಾನ ಸಲಹೆಗಾರರು)

Studies on biology of shoot and fruit borer, *Diaphania caesalis* (Walker) (Pyralidae : Lepidoptera) on Jack.

Jeevan. S. R., Thippaiah. M. and Thirumalaraju. G.T.

Department of Agricultural Entomology, UAS, GKVK, Bengaluru-65

INTRODUCTION

- ✓ Jackfruit, (*Artocarpus heterophyllus* Lamk) belongs to family Moraceae, is native to Western Ghats of India.
- ✓ Thirtyfive species of insect pests have been recorded on jackfruit from India, among them shoot and fruit borer (*Diaphania caesalis*) is the major insect pest cause severe damage.
- ✓ Realizing the severity of pest, immediate need of understanding the life cycle of *D. caesalis,* present study was carried out .

OBJECTIVE:

❖To study the biology of jack shoot and fruit borer , *Diaphania caesalis* (Walker)

Materials and method

The biology of *D. caesalis* was studied on tender shoots and fruits of Jack , during September 2015 to January 2016 in College of Agriculture, G.K.V.K. Bengaluru.

↓

Infested shoots and fruits were collected from field. The stock culture was maintained in laboratory, rearing cages (35cm×30 cm×25 cm) used for adult emergence.

↓

20 pairs of male and females were allowed in a different cage for copulation.

↓

Tender shoots and fruits were kept for egg laying.

↓

The eggs were collected and kept for incubation and observations were recorded as given below:

↓

Site of oviposition, fecundity, its colour and shape, Incubation period, hatching per cent were worked out.

↓

Number of instars and larval duration (Larval measurement by using ocular micrometry, Dyer's law was used for estimate the no. of instars). Head capsule measurement were taken

↓

Duration of pre pupal and pupal period and adult longevity were recorded.

RESULTS

✓ The biology of *D. caesalis* revealed that oviposition by female moth on tender shoots, fruit, and on black cloth also, (Plate.1), the eggs were light pinkish to creamy colored and oval in shape.

✓ The mean incubation period of eggs was 4.5 days .

✓ The mean fecundity of female during first, second and third generation was 141.8, 128.75 and 62.15 eggs, respectively.(Graph 1)

✓ The observations revealed that *D. caesalis* larvae have five distinct instars, duration of each instar and respective head capsules length was measured, (Plates. 3 & 4) .The larval period ranged as 14.77 days, prepupal period 3.52 days and the average Pupal period is 9.33 days (Table.1).

✓ Adult longevity of first, second and third generation of Male fed with 10 % honey solution lived for about 13,11,9.5days and without food survied for about 8,6,5 days respectively. And female with 10% honey solution lived for 15,14,9 days and without honey solution 12, 10, 7 days respectively.

Table 1: Different Developmental stages of *Diaphania caesalis* on jack

Stage of insect	Duration (days)	Body length (mm)	Body width (mm)	Head capsule width (mm)
Eggs	4.5 (3.5-5)	0.72 (0.6-0.84)	0.60 (0.58-0.63)	-
1st instar	2.85 (2.6-2.9)	2.53 (2.4-2.7)	0.4 (0.3-0.6)	0.29 (0.25-3.7)
2nd instar	1.42 (1.121- 1.7)	4.2 (3.9-4.4)	0.91 (0.9-1.3)	0.51 (0.54-0.60)
3rd instar	3.2 (2.88-3.4)	6.4 (6.2-6.57)	1.87 (1.85-1.9)	0.94 (0.7-1.2)
4th instar	3.9 (2.5.5-3.4)	11.3 (11.1-11.5)	2.4 (2.1-2.8)	1.50 (1.4-1.7)
5th instar	3.4 (2.78-3.6)	22.34 (22.1-22.7)	3.7 (3.4-4.1)	2.13 (1.9-2.4)
Pre-pupa	3.52 (3.45-3.8)	12.5 (12.2-12.8)	2.2 (1.9-2.4)	-
Male pupa	8.1 (7.8-8.4)	11.73 (11.5-12)	2.8 (2.7-2.9)	-
Female Pupa	9.33 (8.5-10)	12.36 (12.10-12.61)	2.1 (1.7-2.4)	-

DISCUSSION

- ✓ The life cycle of *D. caesalis* on jack completed 28- 33 days, which is comparable to the study made by Manjunatha (2002) he recorded 26-30 days life span.
- ✓ The present study showed that female fecundity is 110.9 which is much lesser than the research done by Manjunatha who recorded average fecundity of 205 eggs per female moth.
- ✓ The Adult longevity is agreement with earlier study. where as minor differences were observed in present study due to the climatic variation.

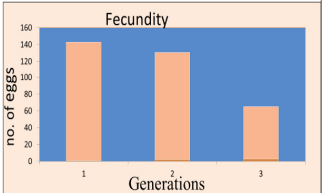

Fig. 1: Fecundity of subsequent generations

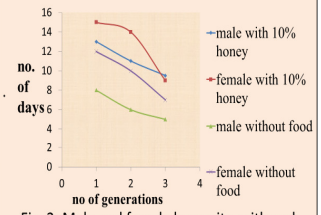

Fig. 2: Male and female longevity with and without food

Plate .4. Head capsules of molted larvae

Plate. 1 Eggs

plate.3. Different Developmental instars of *D.caesalis*

pupa **Adult**

SUMMARY

- ✓ Studies made on the biology of *D. caesalis* on jack from September 2015 to January 2016 under laboratory conditions. The adults readily oviposited on tender shoots, fruits and also on black cloth given under laboratory condition.
- ✓The observation on average incubation period was 4.5, larval period 14.77, pre pupal period 3.52 ,pupal period is 9.33 days respectively.
- ✓This study helps in understanding the life cycle, behavior of *D. caesalis*, it helps in the development of suitable management practices.

ADVISORY COMMITTEE

Chairperson: Dr. M. Thippaiah

Members : Dr. H. Khader khan, Dr. G.T. Thirumala raju, Dr. M . Chandre gowda

REFERENCE

MANJUNATHA, R., 2002, Insect pests of jackfruit (*Artocarpus heterophyllus* Lamk.) with special reference to the biology and management of jack shoot and fruit borer, *Diaphania caesalis* (Walker) (Lepidoptera: Pyralidae) , *M.Sc. Thesis,* University of Agricultural Sciences, Bengaluru, pp 68

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

I INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lamk.) belongs to the family Moraecae (mulberry family). It is native to the western ghats of India (Decondolle, 1886). It is indigenous to India and bears the biggest fruit and is a high yielder. The fruit is known as poor man's food in the eastern and southern parts of India. Immature fruit is generally used as a vegetable. Jackfruit is spread from India to other tropical countries also grown in Bangladesh, Burma, Malaysia, Indonesia, Philippines, and Brazil etc. Despite being a heavy producer with versatile uses, jackfruit is still considered as a minor crop in most of the countries.

India stands second in fruit production in the world and is considered as the motherland of jackfruit, but commercial cultivation is still at a primitive stage (Anon, 2002). In India during 2014-15 the estimated area under jackfruit is 118000 hectares with an annual production of 2088000 mts. (http: //agricoop.nic.in) of which one third area is occupied by Assam alone, followed by Tripura, Bihar, Kerala and Uttar Pradesh. Jackfruit is considered as national fruit of Bangladesh and they stand first in cultivation and production of jackfruit in the world.

Jackfruit is a nutritious fruit and is a rich source of vitamin A and C. The edible pulp is a rich source of Carbohydrates (23.4 %) and also contains protein (9.6 %), fat (0.6 %), minerals (0.9 %), fibre (1.8 %) and ash (0.5 %) (Purseglove, 1968). The seeds are rich source of starch (38.4 %) as well as proteins (11.05 %) (Shivananda, 1983).

The jackfruit is a multi-purpose species providing food, timber, fuel, fodder, and medicinal and industrial products. The primary economic product of jackfruit is the fruit, which is used both when mature and immature. When unripe (green), it is remarkably similar in texture to chicken, making jackfruit an excellent vegetarian substitute for meat. In fact, canned jackfruit is sometimes referred to as "vegetable meat". Jackfruit seeds (nuts) can be roasted like chestnuts, or boiled. Jackfruit value added products include chips, papads, pickles, ice cream, jelly, sweets, beverages like squash, nectar, wine and preserved flakes, etc. Additionally, jackfruit leaves, bark, inflorescence, seeds and latex are used in traditional medicines. The wood of tree is also used for various purposes (Anon., 2012).

The jackfruit is adapted only too humid tropical and near-tropical climates. The jackfruit tree flourishes in rich, deep soil of medium or open texture. It cannot tolerate water lodging; it is a medium-sized evergreen tree that is easily recognized by its fruit, largest tree-borne fruits in the world. Flowers are monoecious, having male and female inflorescences or spikes on the same tree. Pollination is by insects and wind, with a high percentage of cross-pollination. It bears a compound or multiple fruit with a green to yellow-brown exterior rind that is composed of hexagonal, bluntly conical carpel apices that cover a thick, rubbery and whitish to yellowish wall. (Haripriya *et al.,* 2006).

As an underutilized crop, jackfruit has escaped attention for intensive selection and cultivation. However, a wide range of genetic and morphological variation has been reported in jackfruit (Reddy *et al.,* 2004; Shyamalamma *et al*., 2008; Ullah and Haque, 2008).

Like any other crop jackfruit trees are also vulnerable to the attack of insect pests and mites. In India, as many as 35 different insect species have been recorded. (Ayyar, 1938; Nair, 1975; Nayar *et al.,* 1976). More than 250 species of insects, eight species of mites and seven species of nematodes have been reported to be infesting jackfruit trees all over the world.

Butani (1979) gave a list of 39 different insect pests in India belongs to six orders *viz.,* Hemiptera (Aleyrobidae, Aphididae, Cercopidae, Margarodidae, Pseudococcidae, Diaspididae, Cocccidae, Tingidae and Membracidae), Thysanoptera (Thripidae), Lepidoptera (Metarbelidae, Pyralidae and Lymantriidae), Diptera (Cecidomyiidae and Tephritidae), Hymenoptera (Formicidae), Coleoptera (Cerambycidae, Curculionidae and Scolytidae). Among these shoot and fruit borer, *Diaphania caesalis* (Walker.) is a major pest (Karim, 1995).

Jackfruit borer attacks the tender shoots and fruits of all developmental stages. The jackfruit borer attacks the jackfruit at different stages of fruit development. Early infestation results in deformation of fruits and sometimes dropping of the immature fruits. Later infested fruits frequently rotten due to entrance of rainwater in to the fruits. In nursery, larvae damage the tip of jackfruit sapling causing retardation of growth of the saplings and initiation of lateral branches. The average fruit infestation was 27.44 per cent (Khan and Islam, 2004).

The epidemiology of jack shoot and fruit boring caterpillar is a complex problem. Not much research work has been done on this crop in India. Only general information on its cultural requirements has been given in literature. So realising the immediate need of understanding insect pests of jackfruit and to generate more precise information, the present study was undertaken during 2015 to 2016 with following objectives:

1. To study the Biology of Jack shoot and fruit borer, *D. caesalis* under laboratory conditions.

2. To screen available germplasm lines for their resistance against *D. caesalis.*

3. To study the relative efficacy of insecticide molecules against *D. caesalis*

II REVIEW OF LITERATURE

The Literature pertaining to shoot and fruit borer, *Diaphania caesalis* on jackfruit is limited. Hence, literature related to *D. caesalis* on other crops has been reviewed and presented in this chapter.

2.1. Biology of shoot and fruit borer *D. caesalis* on jack

Fletcher (1914), Chowdhury and Majid (1954), Alam *et al.* (1964), Nair (1975) and Butani (1979) have studied the biology of *D. caesalis* (Walker), Manjunatha *et al*. (2014) and Mridha (2006) studied the biology of jack shoot and fruit borer.

The information regarding jack shoot and fruit borer, *D. caesalis* is inadequate. Hence, the reviews pertaining to mulberry defoliator, *Margaronia pulvulentalis* (Walker) was considered. Since, mulberry and jackfruit belongs to same family (Moraecae). Jack fruit and shoot borer and mulberry defoliator belongs to same family Pyralidae, so the studies on mulberry defoliator are being considered.

2.1.1. Egg

Female moth lays eggs singly on the surface of both male and female spikes or on the surface of the spathe and on the tip of the tender shoots and flower buds of jackfruit (Khan *et al*. 2003). Mridha (2006) also reported that the adult *D. caesalis* laid eggs singly on the surface of the spikes or on the surfaces of the spathe and on the tip of the tender shoots of Jackfruits. (Manjunatha *et al.,* 2014) reported that the eggs are laid on tender fruits, tender shoots and flower buds and morphologically oval in shape.

Freshly laid eggs are greenish yellow with gel like appearance, later the eggs turn pinkish red on second day and light pink on the third day of oviposition (Manjunatha *et al.,* 2014). Eggs were spindle shaped with smooth and shiny surface, and turn pale brown to brown in colour and average fecundity 31.29 eggs per female (Mridha, 2006). The eggs of jack shoot and fruit borer were measured 0.74 mm in length and 0.32 mm width. The incubation period occupied 3.5 to 4.0 days under laboratory condition. A day before hatching, under the microscope the larva could be seen curled inside the chorion. There was synchronized hatching in batch and per cent egg hatch was on an average 88.89 (Manjunatha *et al*., 2014).

Eggs of mulberry leaf roller

The female moth of *Glyphodes Pyloalis* laid eggs singly along the vein of mulberry leaf; the eggs are semitransparent and measure 0.7 mm width. The fecundity is 100 to 400 (Govindan *et al.,* 1995 and Aruga, 1994.) The eggs of *Diaphania sp*. are flat and pink in colour and hatch in between 5-7 days (Siddegowda *et al.,* 1995.)

2.1.2. Larvae:

The larval characteristics include yellowish head and prothorax and reddish brown body with numerous black flattened horny warts each bearing one short bristle. The larva undergoes four moults before entering into pupal stage. The total larval duration varies from 14 to 16 days with five instars (Fletcher, 1914; Nair, 1975; Butani, 1979; Tandon, 1993 and Martinez, 1999).

Mridha (2006) reported that newly hatched larvae were very minute, whitish brown body covered with sparsely distributed hairs and dark head, the matured larval body was pinkish with black spot on both the dorsal and lateral side of the body.

The first instars larva is light yellow coloured transparent body with minute black spots on lateral, upper lateral, lower lateral, ventral and dorsal region of each segment with a single seta on each spot (Manjunatha *et al*., 2014).

The body of larvae was soft and 11 segmented with abdominal prolegs and mature larvae bears a long head of orange colour (Mridha, 2006). The total duration of larval period was 12.01 days. The duration of first, scond, third, fourh and fifth instar larva is 2.8, 1.2, 2.5, 2.7 and 2.4 days, respectively (Manjunatha *et al*., 2014).

Larva of mulberry leaf roller

Rangaswami *et al.* (1976) observed that the larva of mulberry pyralid, *G. pyloali* is green in colour; it undergoes 4 to 5 moults and the mature larvae measures 18mm in length. In September, the larvae crawl down to the surface and make irregular shaped cocoons, where they hibernate in larval stage. The hibernation varies with warm and cold zones of Japan.

Inoue (1981) and Inoue *et al.* (1982) observed that initially the larvae were green in colour, after moulting, they turned pinkish brown. The fully grown caterpillar of *G. pyloalis* is bluish green, cylindrical with small dark black spots on either side of each segment (Shama and Tara, 1985). The larvae of mulberry pyralid, *G. pyloalis* were pale green with dark green dorsal median line and each segment had a pair of minute black spots with fine bristles (Minamizawia, 1986).

Aruga (1994) reported that the larvae of mulberry pyralid, *G. pyloalis* are usulally pale green in colour, undergo four moults in a period of two weeks and the mature larvae measures about 1 cm in length. The larvae of mulberry pyralid, *G. pyloalis* are green in colour, moults 4-5 times, and the mature larvae measures about 18 mm in body length (Govindan *et al*., 1995).

2.1.3. Pupa

The pupa is reddish brown in colour and the pupation takes place inside the tunnel. The pupal duration varies from 6 to 8 days in September and 8 to 10 days during May (Beeson, 1941; Nair, 1975 and Butani, 1979).

The larva spins the pupal case underside of jackfruit leaf or twisted dried leaf or on the surface of nearest two or more fruits or top of the made hole of fruits. Pupation occurred inside the pupal case. The pupa was chocolate in colour and obtect type with the length, breadth and weight were 13.23 mm, 2.92 mm and 0.11 gm, respectively. The average duration of the pupa was 6.83 days (Mridha, 2006). Pupal period lasts for 8.2 days during May to June and 8.5 days during September to October, under laboratory condition (Manjunatha *et al*., 2014).

Pupa of mulberry leaf roller

The pupa of *M. pyloalis* occurs in a cocoon between the leaves and lasts for 4 to 8 days in September and 6 to 11 days in October. The pupal hibernation occurs during the cold weather from mid-December to February (Beeson, 1941). The pupal period of leaf roller, *Diphania sp*. lasts for 10-12 days (Siddegowda *et al.,* 1995). The pupa of leaf roller, *M. pulverulentalis* is deep brown and measures about 1-1.5 cm in length, the pupal period lasts for 9 to 10 days (Anonymous, 1996a and Geethabai *et al.,* 1997). Rajadurai *et al.* (1999) reported that the pupa of mulberry leaf roller, *M. pulverulentalis* occurs in fallen dry leaves and debris or on the loose soil.

2.1.4. Adult

The moths were medium sized, whitish brown in colour with grayish elliptical patterns on the fore wings. The female and male moths measured 20.39 mm and 199.87 mm across the wings, respectively. (Ayyar, 1938; Beeson, 1941; Alam *et al*., 1964 and Butani, 1979).

The newly emerged moths were pale brown in colour and after a few hours changed to cream colour. The female was slightly larger than male. The body was covered with cream coloured scales, compound eyes are present and Antennae were segmented and covered with scales. The wings colour was combination of cream and brown. Semi-circular brown spots were present on the surface of the wings. Both the front and hind pairs of wings were covered with scales and fringed with hairs at the edge. The legs were walking type and more or less equal in size and shape. The average length, breadth and wings spread of the adult were 14.34 mm, 3.33 mm and 26.08 mm, respectively. Average longevity of the adult was 4.67 days (Mridha, 2006).

Adults of mulberry leaf roller

Sengupta *et al.* (1990) observed that the adults of mulberry leaf roller, *M. pulverulentalis* are greyish white in colour with black brown stripes in the fore wings and measures about 10 mm in body length. The moths are greyish white in body colour and measures about 1.0 cm in length and possess markings of the same colour on wings and live for 4 to 6 days (Anonymous., 1996a and Geethabai *et al.,* 1997).

The pest completed its life cycle in about 28-31days with 4 generations in a year (Anonymous., 1996b). The longevity of mulberry leaf roller, *D. pulverulentalis* female and male moths is 9-14 and 7-12 days, respectively (Rajadurai *et al.,* 1999).

2.1.5. Total life cycle of jackfruit shoot and fruit borer.

Martinez (1999) reported that the borers are capable of producing several generations in a year and the life cycle completes in 33.8 days. Manjunatha (2002) observed that the *D. caesalis* completes 12 generations in a year under laboratory condition. The life cycle varies from 25- 35 days. The duration of life cycle was maximum during December – January and minimum during June – July.

Total life cycle of mulberry leaf roller.

Siddegowda *et al.* (1995) observed that the life cycle of mulberry roller was ranging from 31-35 days, with 10 generations per year.

2.2. Nature of damage

On hatching the reddish brown caterpillar bores into shoots, flower buds and fruits of all developing stages (Soepadmo, 1991).

Khan and Islam (2004) reported that, the average percentage of fruit infestation caused by *D. caesalis* on jackfruit was 27.44 per cent. The borer attac1ks the tender shoots male and female spikes and fruits of all development stages.

At flowering stage, the larva bores into spike and feeds on internal tissues. At initial infestation, anthesis of the male spikes does not occur and later on the affected spikes are rotten and shaded off from the plant. Severely infested female spikes drop off before fruit setting. Early infestation results in deformation of fruits and sometimes dropping off the immature fruits. The larvae bore into the mature fruit and cause damage to the edible part. Later infested fruits frequently get rotten due to entrance of rainwater in to the fruits. In nursery, caterpillars damage the tip of jackfruit sapling causing retardation of growth of the saplings and initiation of lateral branches. The average percentage of fruit infestation was 27.44 (%). The average number of bored holes and amount of damage per infested fruit was 1.47 and 525.37 g, respectively.

Nature of damage of mulberry leaf roller

The early instar larvae inhabit terminal buds of mulberry plants and produce white silky filament, which bind the leaf blades together. They feed on the tissues found on the surface of leaves. Sometimes, the single leaf is rolled up and the caterpillar is found between the folded leaves (Anonymous., 1996a and Geethabai *et al.* 1997).

The major target area of the leaf roller larvae, *D. pulverulentalis* is the apical portion of mulberry shoot. They bind the leaflets together by silky secretion facilitating the larvae to settle inside comfortably and devour the leaf content (Rajadurai *et al.*1999).

2.3. Seasonal incidence

The pest incidence was severe in January to March in British India (Kalshoven, 1922). Whereas, Tandon (1993) reported that severe infestation was noticed during May to October. Manjunatha (2002) reported that the incidence of *D. caesalis* is more severe during February, September, October and January.

Seasonal incidence of mulberry leaf roller

The leaf roller, *D. pulverulentalis* activity starts from February and ends up at September in Malaysia (Sengupta *et al.,* 1990). Aruga (1994) reported that the activity would drastically increase in July- September months in Japan.

In Karnataka, Siddegowda *et al.* (1995) reported that the incidence of *Diaphonia* sp. on mulberry was ranging from 0 to 100 per cent; they also observed that the incidence was severe during winter months (October-February) at Koppal, Mandya and Mysore districts. Further, they found that the incidence was 0 to 30 per cent during summer months (March-June) in the above places.

2.4. Natural enemies of jack shoot and fruit borer.

Martinez (1999) reported that the *Apanteles* spp. a hymenopteran parasitoid is an important parasitoid of *D. caesalis.* Manjunatha (2002) recorded that *Apanteles* sp. is emerged from field collected larvae. Parasitisation found more sever during September and January with 53.50 and 14.20 per cent parasitisation.

Natural enemies of mulberry leaf roller

Geethabai *et al*. (1997*)* observed that the two braconids parasitoids *viz., Apanteles bisulcata and A. agilis* were abundant during December and January months, the per cent parasitization of the above parasitoids on *D. pulverulentalis* was 11.1 and 10.50 per cent, respectively. The per cent parasitization of *A. bisulcatus* was

9.4, 67.8, 33 and 10 per cent during July, August, September and February, respectively.

2.5. Alternate hosts

The larva bores the young shoots of *Artocarpous chaplasha, A. elastic* and *A. rigida* (Beeson, 1941) The Jack soot and fruit borer, *D. caesalis* were found on shoots of young plants of *A. chaplasha* Roxb (Anonymous., 1954). Martinez (1999) reported the larvae were feeding on Bread fruit (*A. communis* L.), Camansi (*A. altilis* L.), Maranga (*A. odoratissima* Blanco) and monkey jack (*A. rigidus* Lam.)

2.2. To screen available germplasm lines for resistance against *D. caesalis.*

Since the literature available for screening of jack fruit accessions for Shoot and fruit borer is limited, information related to screening on other horticultural crops has been considered to support present study.

Sixty-five germplasm collections of jackfruit were screened for relative resistance to shoot and fruit borer, *D. caesalis* under field conditions at Indian Institute of Horticultural Research, Bengaluru during 2013 - 2015. A significant variation in infestation of *D. caesalis* was observed among jack germplasm. The results showed that, out of 65 accessions, 4 accessions were found resistant, 26 were least susceptible, 22 were moderately susceptible and 13 were highly susceptible (Soumya *et al.,* 2015).

Field and laboratory experiments were conducted to investigate the reaction of sapota varieties to fruit fly, *Bactrocera dorsalis* (Hendel). The genotypes *viz.,* PKM-1, PKM-2, DHS-1, DHS-2, Bhuripatti, Pilipatti and Singapore were categorised as least susceptible to *B. dorsalis*. However, Zumakhiya, CO-2 and Kirthibarthi were found to be moderately susceptible. Kalipatti, Cricket Ball, Paria Collection, Murabba and Mohangoote were recorded as highly susceptible to *B. dorsalis*. Studies on effect of chemical constituents of all 15 sapota germplasm collections against fruit fly infestation revealed that the fruit fly infestation had significant positive correlation with total soluble solids (TSS) and total sugars whereas, it had negative correlation with acidity (Nandre and Shukla, 2013).

One hundred germplasms / varieties were taken to know their response against okra shoot and fruit borer, *Earis vittella* Sherborn, on the basis of shoot damage scale. Only two germplasm showed resistance, fifteen moderately resistances, 66 moderately susceptible and 17 susceptible in 2007, while during 2008 only single germplasm found resistance, 16 moderately resistance and rest follow same pattern. The minimum shoot damage observed in germplasm 315 whereas maximum shoot damage observed in Thin No. 3 (Gautam *et al*., 2014).

Five wild species of *Psidium viz., Psidium cattleianum* lucidum, *P. chinensis*, *P. friedrichsthalianum*, *P. molle* and *P. quadrangularis* were evaluated for resistance to fruit fly, *Bactrocera dorsalis* and tea mosquito bug, *Helopeltis antonii* Signoret, during 2002-04. Significant variations were recorded among species in their reaction to pests. Two species viz., *P. chinensis* and *P. quadrangularis* were resistant to fruit fly (Reddy *et al*., 2008)

Khan *et al.* (2010) conducted an experiment The aim of this experiment was to carry out a village-based survey and make morphological measurements to document and assess jackfruit diversity across trees associated with a gradient of three locations/habitats (homesteads, public lands, and forest or fallow lands). This was accomplished using 28 standardized morphological descriptors and represents the first large-scale assessment of jackfruit diversity in multiple locations (nine villages). 18.7 % and 23.7 % of the fruits found on public lands and forest/fallow lands, respectively, were still considered to be of excellent fruit quality and tree vigour was significantly higher in jackfruit in forest/fallow lands compared to the other location categories.

The genetic diversity and genetic relatedness of 50 jackfruit accessions studied using amplified fragment length polymorphism markers. Total 16 primer pairs evaluated, eight were selected for screening of genotypes based on the number and quality of polymorphic fragments were produced. These primer combinations produced 5976 bands, 1267 (22 %) of which were polymorphic. Among the jackfruit accessions, the similarity coefficient ranged from 0.137 to 0.978; the accessions also shared a large number of monomorphic fragments (78 %). Cluster analysis and principal component analysis grouped all jackfruit genotypes into three major clusters. Cluster I included the genotypes grown in a jackfruit region of Karnataka, called Tamaka, with very dry conditions; cluster II contained the genotypes collected from locations having medium to heavy rainfall in Karnataka; cluster III grouped the genotypes in distant locations with different environmental conditions. This information should be useful for tree breeding programs, as part of our effort to popularize jackfruit as a commercial crop. (Shyamalamma *et al*., 2008).

Thirteen solanum *sp*. genotypes and 30 F_1 crosses of *Solanum Melongena* were evaluated for resistance to *Leucinodes orbanalis* Guenee during February-october 2000 under field conditions in palampur, Himachal Pradesh, India. Arka Keshva was found resistant was found resistant to this pest. Four genotypes and 11 F_1 crosses were also found resistant to fruit infestation, recording 2.75-10.00% fruit damage. Six lines, Pusa Anupam, Punjab Barsati, SM 6-7, SM-141, CHES-243 and DBL V-4, with 17 F_1 crosses were identified as fairly resistant. It was observed that attack of *L. orbonalis* was comparatively less in the genotype having less fruits with tightly arranged seeds in the mesocarp (Sharma and choudhary, 2001).

Field screening of 52 brinjal (*Solanum melongena* L.) genotypes, collected from different regions of India, to evaluate their reaction to the shoot and fruit borer, *L. orbonalis* Guenee. Among the genotypes screened, four accessions *viz.,* IC136347,

IC127021, IC111077 and IC013332 were identified as resistant by recording a lower (<10 %) fruit damage, while seven genotypes as fairly resistant; 11 as tolerant; 20 as susceptible and 13 as highly susceptible to *L. orbonalis* (Ramesh *et al*., 2015).

A field experiment was conducted to study the response of cultivars/ hybrids/ germplasm of brinjal to major insect pests and their natural enemies. The study revealed that the hybrid, Sweta was the best in reducing the shoot and fruit damage by *Leucinodes orbonalis* Guen. recording the mean shoot and fruit damage of 8.0 and 8.7 per cent (number basis) and population of spotted leaf beetle, *Henosepilachna vigintioctopunctata* Fab., ash weevil, *Myllocerus* spp. Guerin, mealybug, *Coccidohystrix insolitus* Green, aphid, *Aphis gossypii* Glover, leafhopper, *Amrasca devastans* Ishida and whitefly, *Bemisia tabaci* (Gennadius) recording 8.0, 0.0, 6.5, 6.3, 0.0 and 0.0 nos./ three leaves, respectively. The biochemical characters such as total sugars, total chlorophyll and moisture content were positively correlated with shoot damage while total phenols and ash content have negative correlation (Elanchezhyan *et al*., 2008).

2.3. To study the relative efficacy of insecticide molecules against shoot and fruit borer, *D. caesalis*

Alam (1962) recommended spraying with 0.03 per cent phosphomidon or 0.2 % HCH or DDT for effective management of jackfruit shoot and fruit borer.

For the control of shoot and fruit borer, the affected shoots, flower buds and fruits should be removed and destroyed in the initial stage of attack. To protect from oviposition, fruits should be covered with alkathene bags and suggested spraying with 0.03 per cent endosulfan or 0.1 per cent carbaryl for the control of *D. caesalis* (Madhava Rao, 1965). Govindan *et al.* (1995) reported that the spraying of one per cent HCH resulted in effective management of mulberry pyralid, *M. Pyloalis.*

Foliar application of 0.072 per cent monocrotophos 36 EC @ 2 ml/l, given as 10 days after pruning, followed by a spray of 0.076 per cent DDVP (76 % TC) at 15 days after Monocrotophos application is found to be effective. Further, it was observed that recommended the spraying of botanicals like neem seed kernel extract, Rakshak (0.15% Azadiractin) and neem oil @ 2.5, 0.015 and 5 per cent, respectively against *D. pulverulentalis* given satisfactory control (Rajadurai *et al*., 1999).

Manjunatha (2002) suggested that spraying of endosulfon 0.07%, neem seed kernel extract 4% and fenvalrate 0.02 per cent are found to be effective chemicals in controlling the *D. caesalis.*

Mridha (2006) revealed that the bagging treatment and neem oil treated plants shows the more effective in controlling the *D. caesalis.*

III MATERIAL AND METHODS

The materials used and methods followed for the study of biology, screening available germplasm lines and relative efficacy of insecticides against jackfruit borer, *Diaphania caesalis* (walker) at the Department of Entomology, Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural sciences, Bengaluru, located at 12°58[1] N, 77°35[1] E at an altitude of 630 meters MSL during 2015-16 are described under the following heads.

3.1. Biology of jack shoot and fruit borer, *D. caesalis*

3.1.1. Development and maintenance of stock culture.

The pure culture of the jack shoot and fruit borer was maintained by collecting the large number of larvae from jack plantations at GKVK campus and was maintained in rearing cages (35 cm × 30 cm × 25 cm) in the laboratory (Plate 1); After pupation, pupae were sexed out based on the presence of slit on 8th or 9th sternite and transferred to the petri plates.

Adult soon after emergence given honey solution as adult feed, twenty pairs of male and females were subjected for mating in separate boxes (Plate 2). A cotton swab dipped in 10 per cent honey solution served as food and tender fruits, shoots and black cloth were provided for oviposition.

The tender shoots, fruits and black cloth containing eggs laid on the same day were transferred to petri dishes (20 cm × 5 cm), which were sterilized with 4 per cent Formalin solution. On hatching the individual larvae were transferred with the help of fine moist camel hair brush to tender shoots and fruits. The food was changed on two to three days.

3.1.2. Life history

Detailed biology of *D. caesalis* were carried out under laboratory conditions on tender shoots and fruits as well as on tender succulent leaves.

3.1.2.1 Incubation period

The eggs laid on tender shoots and fruits as well as on black cloth were placed in petri dish (20 cm × 5 cm) by enclosing equal sized petri dishs, which were sterilized with 4 per cent formalin and kept in a dark enclosed condition. Duration from the day of egg laying to the day of hatching formed the incubation period. Leica software based computer system was used to record the measurements of eggs.

$$\text{Hatching percentage} = \frac{\text{Total no. of eggs hatched}}{\text{Total no. of eggs laid}} \times 100$$

3.1.2.2 Larva

After hatching the larvae were picked up with the help of soft camel hair brush and transferred to tender shoots and fruits kept on filter paper in clean petri dishes (20 cm ×5 cm). Food used for rearing was changed as and when required. The ocular micrometry was used to measure the larval length, width and head capsule measurements. The observations were made daily for moulting which was indicated by the presence of head capsule. The Dyar's law was used to find out the instars. From this manner the number of instars passes through by the larva in the course of development was determined. Larval measurements were taken daily, then general morphological features associated with different stadia of larva, which were deemed helpful in the recognition of pest were recorded. Observations on the prepupal stages were also made in the same Petri dish.

Dyar's law was used to differentiate instars of immature insects to predict size of instars. Head capsule width of larvae follow a geometric progression.

Geometric progression: $\mathbf{y = ab^x}$

Where, y= measure of size

x= instar number

a and b= constants

3.1.2.3 Pupa.

The pupation can be seen in webbed leaves, then pupae were carefully separated from the leaf, sexed based on the presence of slit on 8^{th} or 9^{th} abdominal genital segment, then placed in a Petri dishes. Male and female pupal measurements were taken with the help of ocular micrometry; sex ratio is estimated.

3.1.2.4 Activity and habits of moth.

Twenty pairs of moths that emerged on the same day were enclosed, a pair of adults were introduced to each rearing cages with ten per cent honey solution as adult food and for egg laying tender shoots, fruits and as well as black cloth were given in laboratory condition as described earlier. The mating behaviour, oviposition, fecundity, and adult longevity, pre-mating, mating, pre-oviposition and post-

Plate 1. Rearing cage of *D. caesalis* under laboratory condition.

Plate 2. Mating boxes of *D. caesalis*

oviposition periods were recorded. Fresh tender shoots, fruits and black cloth were provided daily. The eggs laid on tender shoots, fruits and black cloth were collected daily until both the individuals died. Adult longevity is recorded when adult fed with and without food. The adult measurements were also recorded.

The fecundity is calculated as $= \frac{\text{Total no. of egg laid by all females}}{\text{Toal no. of replication}}$

3.1.2.5. Natural enemies on *D. caesalis* in field condition

D. caesalis larva were collected randomly from different trees at GKVK campus, which were used to maintained in laboratory to record the emergence of parasitoids and per cent parasitisation during different months were recorded.

$$\text{Per cent parasitisation} = \frac{\text{Total number of parasitized larva}}{\text{Total number of larva collected}} \times 100$$

3.2. Screening the available germplasm lines against jack shoot and fruit borer.

Field screening of jackfruit germplasm/accessions against shoot and fruit borer was conducted during 2015-2016 at University of Agricultural Sciences, GKVK, Bengaluru, Karnataka, India. The germplasms/accessions were selected at two different locations inside the GKVK campus, the locations are as fallows.

1. Horticultural garden
2. National seed project (NSP)

The some of the known germplasms/accessions are motta marika, janagere, tubugere, swarna halasu, malleshwaram, chadra halasu, NSP 1, NSP 2, NSP 3, NSP 4, NSP 5, NSP 6, NSP 7, NSP 8, NSP 9, NSP 10, NSP 11, NSP 12, NSP 13, NSP 14, NSP 15, NSP 16 and NSP 17, B7, gumless etc.

Table 1. Number of germplasms/accessions selected at two locations for screening

Location in GKVK	No. of trees selected
Horticulture garden	7
National seed project (NSP)	17

For better understanding the locations are named as Block 1 and Block 2, it is represented in following Table 2.

Sl. No	Name of the Block	Location
1	Block -1	Inside Horticulture garden
2	Block- 2	Inside NSP

These are all the trees selected for our studies. No insecticidal sprays were applied during the study period. All the trees were inside the GKVK campus only so that no differential environmental factors affected them.

Twenty-four germplasms/accessions were assessed for the attack of *D. caesalis*. From each tree twenty buds/shoots/tender fruits were randomly selected. The response of germplasm to *D. caesalis* was recorded (No. of damaged buds/20 buds/tree) during the period of study.

Observations were recorded at 5 metres above ground level for every tree at ten days' interval during September 2015 to April 2016. Based on the percent infestation recorded during survey the standard scoring was given and germplasms/accessions were categorized as highly resistant, least resistant, moderately susceptible and highly susceptible.

Methodology for screening of jackfruit trees to *D. caesalis* based on per cent shoot and fruit damage were categorised as fallows.

Table 3: Categorisation of jack germplasms based on resistance to *D. caesalis*

Per cent damage	Category
0	Highly resistant
< 10	Least susceptible
10 – 20	Moderately susceptible
>20	Highly susceptible

In this study the standard scoring procedure was followed with the reference of Soumya. *et. al.,* 2015.

$$\text{Per cent damage} = \frac{\text{Number of damaged fruits}}{\text{Total no.of fruits observed}} \times 100$$

Plate 3. Infested jack shoots were marked with tags.

3.3. To study the relative efficacy of insecticides against shoot and fruit borer, *D. caesalis*

A field experiment was conducted in jackfruit gardens in GKVK, Bengaluru, to evaluate the efficacy of insecticide molecules. The experiment was conducted with randomized complete block design with 7 treatments and three replications. The severely infested trees were selected randomly and before spraying, 2 × 2 m canopies were marked with the help of tread. The pre-treatment larval counts were taken and tagged for those infected shoots (Plate 3). Treatments were randomly assigning to individual plants; the insecticides were applied to severe infested plants. In the economical point of view, the cost of chemical required for one acre (69 trees, in 25×25 feet spacing) of jackfruit garden were calculated and represented (rupees) in Table 4**.**

Observations

Observations on the number of larvae on each marked canopy were recorded. Pre-treatment counts were being taken one day before imposition of treatments and post-treatment counts were taken on three, seven and ten days after imposition of treatment.

The collected data was being analysed by using analysis of variance for different dates of observation before and after the insecticide application.

Table 4: Details of insecticides used for evaluating their field efficacy against jack shoot and fruit borer, *D. caesalis*

Treatments	insecticides name	Trade name	Dosage ml/l of water	Dosage ml/10 l/tree	Dosage ml/69 trees/ acre	Cost of chemical (Rs) /acre
T1	Azadirachtin 10,000 ppm	Neemark	2.00	20.00	1380.00	1104.00
T2	Dichlorvos 76 % EC	Nuvan	1.00	10.00	690.00	228.00
T3	Imidacloprid 17.80 % SL	Confidor	0.40	4.00	276.00	233.00
T4	Lambdacyhalothrin 5% EC	Karate	0.75	7.50	517.50	207.00
T5	Fipronil 5% SC	Regent	1.50	15.00	1035.00	673.00
T6	Quinalphos 25 % EC	Ekalux	2.00	20.00	1380.00	662.00
T7	Spinosad 45 % SC	Tracer	0.30	3.00	207.00	828.00
T8	Control (untreated check)	-	-	-	-	-

IV EXPERIMENTAL RESULTS

The results pertaining to biology of *D. caesalis* on jackfruit, screening the germplasms and suitable management practices with effective insecticide molecules against, *D. caesalis* carried out during 2015 to 2016 at University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru are presented here under.

4.1. Biology of *D. caesalis* on jackfruit

Detailed investigation on biology of jack shoot and fruit borer, *D. caesalis* was carried out under laboratory condition at Department of Agricultural Entomology, UAS, GKVK, Bengaluru during October 2015 to January 2016 on tender shoots, fruits and also on tender leaves. The mean temperature and per cent relative humidity that prevailed during the period of this study are given in appendix- I. The results pertaining to the studies are presented here under.

4.1.1. Eggs

The eggs are oval shaped, soft and translucent, laid singly on tender shoots, fruits, flower buds and also on black cloth (Plate 4 & 5). The freshly laid eggs are greenish yellow in colour with gel like appearance, on second day turn to light pinkish to white colour, on third day the eggs were turn to pale brown colour. The microscopic observation on third day showed a brown head with light brownish slender body, the larvae feeding on a little part of the egg shall can be observe through the chorion. On prior to hatching, the eggs were turn to dull whitish to brown colour**.** The average length and breadth of the eggs were 0.72± 0.09 (0.6-0.84) mm and 0.60± 0.01 (0.58-0.63) mm (Table 5).

The incubation period under laboratory condition varied from 4 to 4.5 days with an average of 4 ± 0.21 days during October to November 2015 (Table 7), 4 to 5 days with an average of 4.8 ± 0.34 days during November to December 2015 (Table 8) and 4.5 to 5.5 days with an average of 5.05 ± 0.43 days during December to January 2016 (Table 9). The hatching took place in early morning hours and late evening hours. There was synchronization in hatching of eggs and the mean hatching percentage of eggs was ranges between 89.06-76.42 per cent with an average of 84.11(S.D. ± 6.75) per cent (Table 11) in the laboratory condition.

4.1.2. Larva

The larvae eventually come out by biting through the chorion during morning and evening hours at 6 to 8 AM and 6:30 to 7:30 PM respectively.

In About 2 to 4 minutes, the head came out through the cut end of chorion and larvae started feeding on chorion along the cut ends. The larva after hatching will moves all over the rearing box in search of food.

During its larval period, the larva moulted four times and thus has five larval instars. (Plate 6) and the different larval instars measurements can be observed (Table 5). The moulting took place on the surface of tender shoots and fruits. The moulted head capsule can be observed with the help of microscope, sometimes inside the shoots and fruits. At the time of moulting, larvae stopped feeding, lost colour and cast the exuvium and head capsule and rest of the body separately. By measuring the larval head capsule with the help of ocular micrometry and Leica software based microscope we can find out the number of larval instars are gone through (Plate 7).

4.1.2.1. First instar larva

Upon hatching, larvae were active and wander in search of food and begin to move all around the rearing boxes and they were gregarious in nature. Initially they also found to feed on tender leaves in a gregarious manner. Without food larva can live only for about 8 to 10 hours only. So during this stage each individual larva were transferred to the rearing boxes (Plate 8) having fresh tender shoots and fruits (Plate 9). The freshly hatched larva is having dark brown coloured head along with light brown coloured shield like prothoracic segment. The body is transparent with light yellowish in colour and having minute black spots on lateral, upper lateral, lower lateral, ventral and dorsal regions at each segment with a single seta on each spot.

The premoulting symptoms show yellow coloured transparent body, narrow head and caudal region, the larva rest flatly on the fruit and shoot surface. The first instar larval duration ranged from 2.5 to 3.0 days with an average of 2.65 (S.D. ± 0.24) days (Table 7), 2-3 days with an average of 2.85 (S.D. ± 0.33) days (Table 8) and 2.5 to 3.5 days with an average of 3.01 (S.D. ± 0.35) days (Table 9) during October to November, November to December, 2015 and December to January 2016, respectively. The first instars larval length ranged from 1.05 to 3.30 mm with an average of 2.54 (S.D. ± 0.76) mm and width ranged from 0.25 to 0.56 mm with an average of 0.45 (S.D. ± 0.11) mm and the larval head width ranged from 0.25 to 0.37 mm with an average of 0.29 (S.D. ± 0.05) mm (Table 6). The newly hatched larvae show the webbing behaviour, it constructs the silken barrier and feeds inside the shoots.

4.1.2.2. Second instar larva

The second instar larvae closely resembled the first instar larvae but the size of the body varies. The later part of second instar larvae had light greenish in colour body with thin white mid dorsal line further showed increased black spots with slender setae laterally. The feeding behaviour and webbing nature is similar to that of first instars larvae.

The larval head width ranged from 0.5 to 0.6 mm with an average of 0.51 (S.D. ± 0.03) mm. The larval length ranged from 4.1 to 4.9 mm with an average of 4.57 (S.D. ± 0.15) mm and width ranged from 0.6 to 0.9 mm with an average of 0.67

Plate 4. Eggs laid on tender leaves by *D. caesalis*

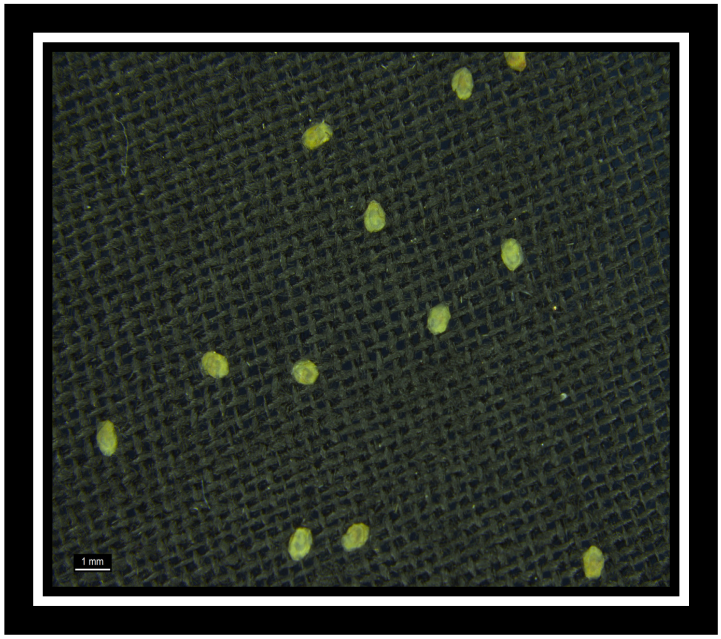

Plate 5. Eggs of *D. caesalis* on black cloth

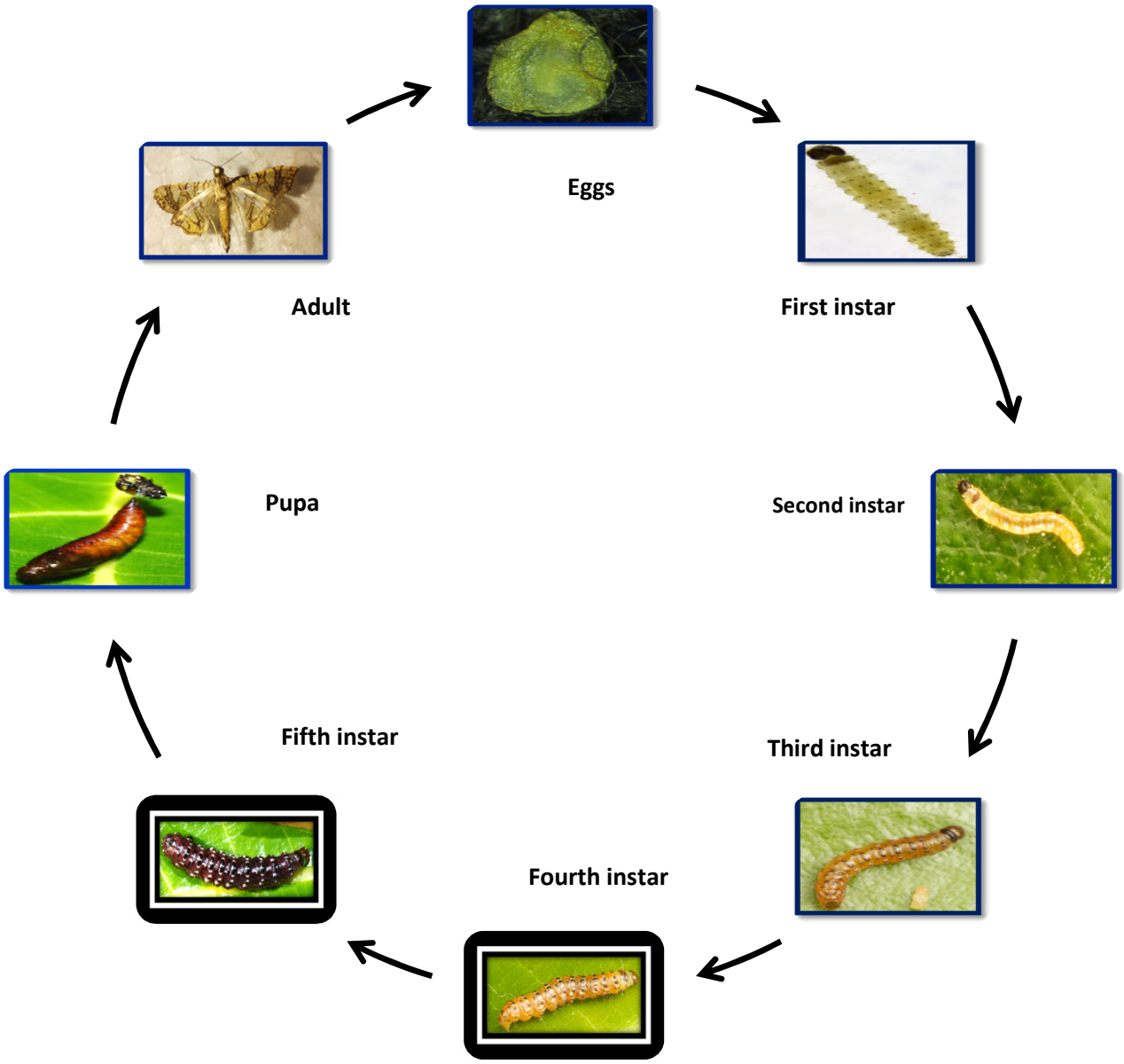

Plate 6: Total developmental stages of *D. caesalis*.

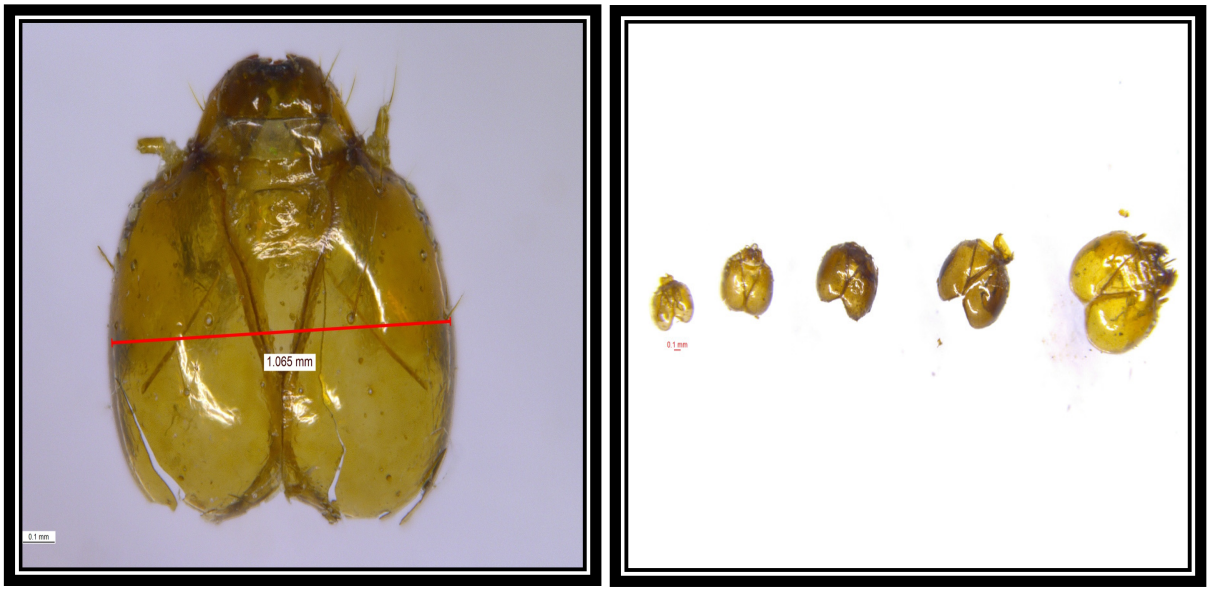

Plate 7. Larval head capsule of *D. caesalis* after moulting

Plate 8. Rearing boxes of *D. caesalis* under laboratory condition.

(S.D. ± 0.10) mm (Table 5 and 6). The second instar larval duration ranged from 1 to 2 days with an average of 1.57 (S.D. ± 0.24) days (Table 7), 1 to 2 days with an average of 1.71 (S.D. ± 0.32) days (Table 8) and 2 to 2.5 days with an average of 2.17 (S.D. ± 0.22) days (Table 9) during October to November, November to December, 2015 and December to January 2016, respectively.

4.1.2.3. Third instar larva

The third instar larva is bigger than the second instar larva. The larva is pale brownish in colour with prominent black spots on the body with a brown coloured setae on each spots towards lateral and sub lateral region. The prothorasic segment was fully covered with brown band. During third instar the mandibles are well developed and the larva starts feeding inside the tender fruits, shoots.

The third instar larval duration ranged from 2.5 to 3.0 days with an average of 2.66 (S.D. ± 0.23) days (Table 7), 2.5 to 3.5 days with an average of 03 (S.D. ± 0.33) days (Table 8) and 3 to 4 days with an average of 3.55 (S.D. ± 0.28) days (Table 9) during October to November, November to December, 2015 and December to January 2016, respectively. The third instar larval length ranged from 6.8 to 7.4 mm with an average of 7.02 (S.D. ± 0.16) mm and width ranged from 1.50 to 1.90 mm with an average of 1.61 (S.D. ± 0.15) mm and the larval head width ranged from 0.7 to 1.2 mm with an average of 0.94 (S.D. ± 0.12) mm (Table 6).

4.1.2.4. Fourth instar larva

The fully grown fourth instar larva was light brownish in colour and black spots are present on each body segments with discontinuous white mid dorsal line. The microscopic view shows that presence of brown coloured claspers at the tip of true legs, with fine, minute, setae around the caudal legs and prolegs were dark in colour. The larval feeding behaviour is similar to that of third instar larva.

The larval head width of fourth instar larva ranged from 1.0 to 1.7 mm with an average of 1.50 (S.D. ± 0.13) mm and larval length ranged from 17 to 21 mm with an average of 18.24 (S.D. ± 0.80) mm and width ranged from 2.4 to 2.8 mm with an average of 2.53 (S.D. ± 0.12) mm (Table 6). The larval duration ranged from 2.8 to 3.2 days with an average of 3.03 (S.D. ± 0.11) days (Table 7), 3 to 4 days with an average of 3.41 (S.D. ± 0.45) days and 3 to 4 days with an average of 3.51 (S.D. ± 0.56) days (Table 8 and 9) during October to November, November to December, 2015 and April to May 2016, respectively.

4.1.2.5. Fifth instar larva

The fifth instar larva shows dark reddish brown in colour. A discontinuous white mid dorsal line was clearly seen, the black spots present on the body became prominent and the size of the black spot is increased. These characters can be seen

from second thoracic segment to last abdominal segment. The larvae when touches they exhibits the jumping behaviour or some kind of defensive behaviour.

The fifth instar larval period varies from 2.5 to 3.5 days, on an average of 2.88 (S.D. ± 0.32) days, 3 to 4 days with average of 3.65 (S.D. ± 0.33) days and 3 to 4 days, on an average of 3.15 (S.D. ± 0.33) days (Table 7, 8 & 9) during October to November, November to December, 2015 and December to January 2016, respectively.

The larval head width of fifth instar larva ranged from 1.9 to 2.4 mm with an average of 2.13 (S.D. ± 0.14) mm and larval length ranged from 23 to 28 mm with an average of 25.8 (S.D. ± 1.32) mm and width ranged from 3.4 to 4.2 mm with an average of 3.65 (S.D. ± 0.20) mm (Table 5 and 6)

4.1.2.6. Total larval period

The total larval period ranged between 11.3 to 14.7 days with an average of 12 (S.D. ± 1.14) days, 11.5 to 16.5 with an average of 14.62 (S.D ± 1.76) days and 13.5-18.0 days with an average of 15.39(S.D. ± 1.74) day during October to November, November to December, 2015 and December to January 2016, respectively under laboratory conditions.

4.1.2.7. Pre- pupa

During the prepupal period the larvae stops feeding, shrinking of body can be seen and the body turn to light greenish in colour (Plate 10). The hairs present on each spots were shedds, the larvae start spun the silken cocoon between the two leaves or at the corner of the rearing box (Plate 11). This stage occupied a period of 3 to 4 days with an average of 3.51 (S.D. ± 0.31) days, 3.5 to 4.5 days with an average of 4.1 (S.D. ± 0.31) days and 4 to 5 days with an average of 4.55 (S.D. ± 0.43) (Table 9) days during October to –November, November-December, 2015 and December-January 2016, respectively. The prepupal length varies from 12.2 to 12.8 mm with an average of 12.5 (S.D. ± 0.27) mm and the prepupal width ranged from 1.9-2.4 mm with an average of 2.2 (S.D. ± 0.08) mm (Table 5).

4.1.3. Pupa

Pupal stage is a non-feeding stage. When larva attainted maturity, it stoped feeding and spins the pupal case around it. Pupation occurred inside the pupal case, the site of pupation can be seen between the webbed leaves (Plate 12) or inside the fruit (Plate 13) or between two or three shoots at the top of the rearing boxes under laboratory condition. The pupa was chocolate in colour and obtect type. Usually the female pupa was bigger and longer than the male pupa (Plate 14).

Plate 9 . Tender shoots and fruits used as larval feed

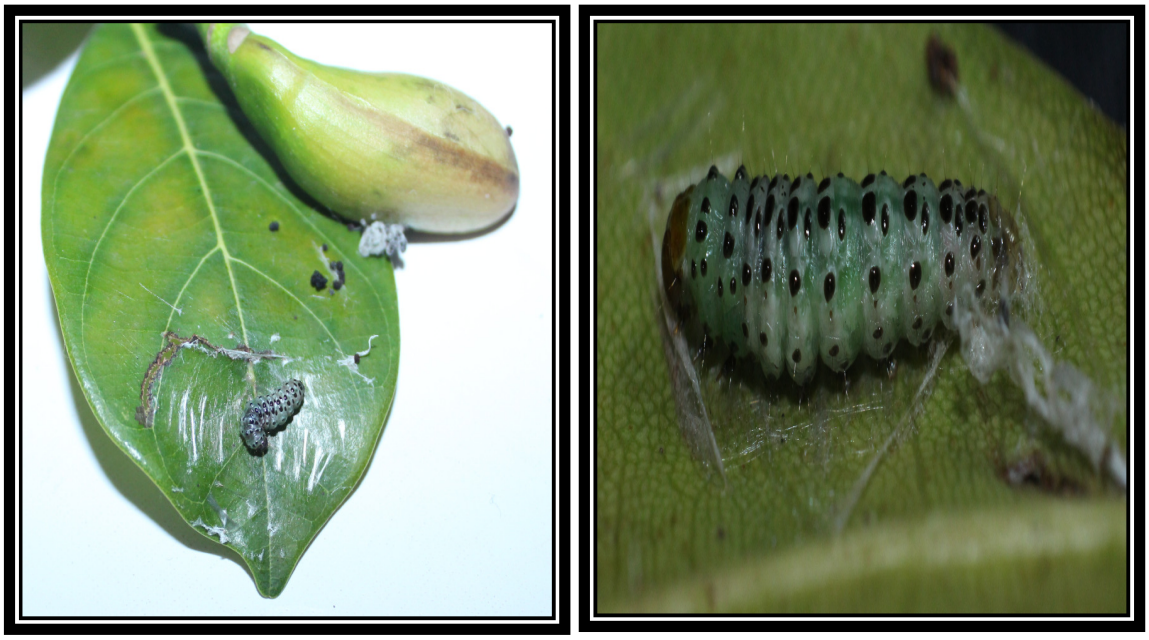

Plate 10. Larvae turn to greenish colour during pre-pupal period

Plate 11. *D. caesalis* larvae undergoes pre-pupal stage at the corner of rearing box

Plate 12. Pupation of *D. caesalis* on leaves

Plate 13. Pupation of *D. caesalis* inside fruit

The pupal development period lasted for 8.0-9.5 days with an average of 8.9 (S.D. ± 0.39) days, 9-10 days with an average of 9.5 (S.D. ± 0.52) days and 10-11 days with an average of 10.1 (S.D. ± 0.73) days (Table 7, 8 and 9) during October to - November, November-December, 2015 and December- January 2016, respectively. The length of male pupa was 9.8-12.6 mm with an average of 11.58 (S.D. ± 0.20) mm and width was 2.1-2.9 mm with an average of 2.73 (S.D. ± 0.09) mm. And female pupal length varies from 11.2-13.2 mm with an average of 12.04 (S.D. ± 0.08) mm and pupal width varies from 2.4-3.7 mm with an average of 2.84 (S.D. ± 0.11) mm respectively.

Table 5: Measurements of different developmental stages of *D. caesalis* during October to January under laboratory condition during 2015 to 16

Stages of insect	Length (mm)		Width (mm)	
	Range	**Mean ± S.D.**	**Range**	**Mean ± S.D.**
Egg	0.6 - 0.84	0.72 ± 0.09	0.58 - 0.62	0.60 ± 0.01
Larva				
I instar	1.05 - 3.30	2.54 ± 0.76	0.25 - 0.56	0.45 ± 0.11
II instar	4.10 - 4.90	4.57 ± 0.15	0.6 - 0.9	0.67 ± 0.10
III instar	6.8 - 7.4	7.02 ± 0.16	1.5 - 9.0	1.61 ± 0.15
IV instar	17 – 21	18.24 ± 0.80	2.4 - 2.8	2.53 ± 0.12
V instar	23 – 28	25.8 ± 1.32	3.4 - 4.2	3.65 ± 0.20
Pre- pupa	12.2 - 12.8	12.5 ± 0.27	1.9 - 2.4	2.2 ± 0.08
Pupa				
Male pupa	9.8 - 12.6	11.58 ± 0.20	2.1 - 2.9	2.73 ± 0.09
Female pupa	11.2 - 13.2	12.04 ± 0.08	2.4 - 3.7	2.84 ± 0.11

S.D. = standard deviation. n = 25

Table 6: Head capsule width of larval stages of *D. caesalis*

Instars	larval head width (mm)	
	Range	**Mean ± S.D.**
I instar	0.25 - 0.37	0.29 ± 0.05
II instar	0.5 - 0.6	0.51 ± 0.03
III instar	0.7 - 1.2	0.94 ± 0.12
IV instar	1.0 – 1.7	1.50 ± 0.13
V instar	1.9 - 2.4	2.13 ± 0.14

n = 25 larval observations in each instar; S.D. = Standard deviation

Table 7: Developmental period (days) of different stages of *D. caesalis* during October to November - 2015

Stages	**Range (days)**	**Mean ± SD (days) (n = 25)**
Egg	4.0 - 4.5	4.0 ± 0.21
Larval instars		
I	2.5 - 3.0	2.65 ± 0.24
II	1 – 2	1.57 ± 0.24
III	2.5 - 3.0	2.66 ± 0.23
IV	2.8 - 3.2	3.03 ± 0.11
V	2.5 - 3.5	2.88 ± 0.32
Total larval period	11.3 - 14.7	12 ± 1.14
Pre pupa	03 - 0 4	3.51 ± 0.31
Pupal period	8.0 - 9.5	8.9 ± 0.39
Total life cycle	**26.3 - 32.7**	**29.20 ± 2.05**

S.D. = Standard deviation, n = Sample size

Table 8: Developmental period (days) of different stages of *D. caesalis* during November to December - 2015

Stages	Range (days)	Mean ± SD (days) (n = 25)
Egg	04 - 05	4.8 ± 0.34
Larval instars		
I	02 - 03	2.85 ± 0.33
II	01 - 02	1.71 ± 0.32
III	2.5 - 3.5	3.00 ± 0.33
IV	03 - 04	3.41 ± 0.45
V	03 - 04	3.65 ± 0.33
Total larval period	11.5 - 16.5	14.62 ± 1.76
Pre pupa	3.5 - 4.5	4.10 ± 0.31
Pupal period	09 - 10	9.5 ± 0.52
Total life cycle	**28 - 36**	**33.02 ± 2.93**

S.D. =Standard deviation; n=Sample size

Table 9: Developmental period (days) of different stages of *D. caesalis* during December to January - 2016

Stages	Range (days)	Mean ± SD (days) (n = 25)
Egg	4.5 - 5.5	5.05 ± 0.43
Larval instars		
I	2.5 - 3.5	3.01 ± 0.35
II	02 - 2.5	2.17 ± 0.22
III	03 – 04	3.55 ± 0.28
IV	03 – 04	3.51 ± 0.56
V	03 - 04	3.15 ± 0.33
Total larval period	13.5 - 18.0	15.39 ± 1.74
Pre pupa	04 – 05	4.55 ± 0.43
Pupal period	10 – 11	10.1 ± 0.73
Total life cycle	**32.0 - 39.50**	**35.09 ± 3.33**

S.D. =Standard deviation; n=Sample size

4.1.4. Total life cycle

The shortest developmental period was 26.3 to 32.7 days with an average of 29.2 (S.D. ± 2.05) days, 28 to 36 days with an average of 33.02 (S.D. ± 2.93) days and the longest period was 32.0 to 39.5 days with an average of 35.09 (S.D. ± 3.33) days (Table 7, 8 & 9), during October to November, November to December, 2015 and December to January 2016, respectively.

The observations recorded on adult longevity and fecundity was depicted in Table 10 and details are presented here under.

Table 10: Adult activity, Oviposition, longevity and fecundity of *D. caesalis* on jackfruit

Insect stage	Range	Mean ± S.D.
Pre-mating period (hr)	18 - 25	23.60 ± 2.67
Mating period (hr)	2 - 4	3.30 ± 0.94
Pre-oviposition period (hr)	17 - 25	21.10 ± 3.38
Oviposition period (d)	8 - 9	8.33 ± 0.57
Fecundity (no.)	62.15 - 141.8	110.90 ± 42.71
Male adult longevity (d)	5 - 9	8.05 ± 1.23
Female adult longevity (d)	8 - 12	9.65 ± 1.17
Hatching percentage	89.06 - 76.42	84.11 ± 6.75

S.D = Standard deviation

4.1.5. Adult

The adults are medium sized moths which usually emerge from pupal case during the early morning or evening hours and some times during afternoon hours also. The adult after emergence remains inactive for a few minutes till the wings are fully stretch or till the wing expansion and later it starts to fly. The both male and female moths are inactive during day time and settle at the corner or side or at the bottom or at the top of the rearing boxes under laboratory condition. They were active during evening hours. The moths having medium sized body, with elliptical marking on the fore wings which were greyish, whitish brown in colour. The body was covered with cream coloured scales. Both the front and hind pairs of wings were covered with scales and fringed with hairs at the edge. The legs were walking type

and more or less equal in size and shape. The females are slightly larger than the males in case of wing expansion and abdominal length and width (Plate 15)

4.1.5.1. Premating period

The adult male and female moths were observed to mate in about 18 to 25 hours with a mean of 23.6 (S.D. ± 23.6) hours after the emergence from the pupa.

4.1.5.2. Mating period

The males were more active compared to female. The male chased the female and made a number of attempts to mate, after several attempts the male and females involved in the copulation (Plate 16). The mating lasted for a period of 2-4 hours with a mean of 3.3 (S.D. ± 0.94) hours (Table 11). The mating occurs during evening hours, the single mating is observed in both male and female but sometimes dual mating can also be observed in case of males.

4.1.5.3. Pre-oviposition period

The female starts laying the eggs 17 to 25 hours after mating. The average time period is 21.1 (S.D. ± 3.38) hours after the mating (Table 11).

4.1.5.4. Oviposition period

After copulation, the female moth lays the eggs singly on the tender leaves, shoots, fruits and laid in a group on black cloth given in the laboratory condition. The oviposition period ranges between 8 to 9 days with a mean of 8.33 (S.D. ± 0.57) days (Table 11).

4.1.5.5. Fecundity

During the oviposition period the maximum egg laying was observed on fourth, fifth followed by the sixth day after adult emergence with average of 25.42, 24.30 and 20.40 eggs by female and egg laying was gradually decreased after sixth day of adult emergence. The minimum egg laying was observed on twelfth day after adult emerge 0.07 eggs followed by eleventh day after adult emergence 0.68 eggs (Table 11).

The fecundity of female in three generations ranges between 62.15 to 141.8 eggs with a mean of 110.9 (S.D. ± 42.71) eggs per female.

Table 11: The mean number of eggs laid by *D. caesalis* on each day and three days after adult emergence

Average eggs laid by female on each day.				
Days after adult emergence	**First generation**	**Second generation**	**Third generation**	**Mean**
3	8.35	12.75	13.05	11.38
4	13.70	45.85	16.70	25.42
5	19.95	38.00	14.95	24.30
6	28.90	24.75	7.55	20.40
7	20.80	12.80	2.75	12.12
8	18.05	5.15	4.45	9.22
9	10.65	2.05	1.00	4.57
10	6.60	0.45	1.00	2.68
11	1.55	0	0.50	0.68
12	0	0	0.20	0.07

4.1.5.6. Adult longevity

The longevity of female fed with 10 per cent honey solution was survived for about 8-12 days with a mean of 9.65 (S.D. ± 1.17) days and male moth fed with 10 per cent honey solution survived for about 5 to 9 days with an average of 8.05 (S.D. ± 1.23) days.

4.1.6. Sex ratio

The present study revealed a sex ratio of Male: female is 1:1.78, 1:0.85 and 1:0.85 during October to November - 2015, November to December - 2015 and December to January-2016, respectively (Table 12).

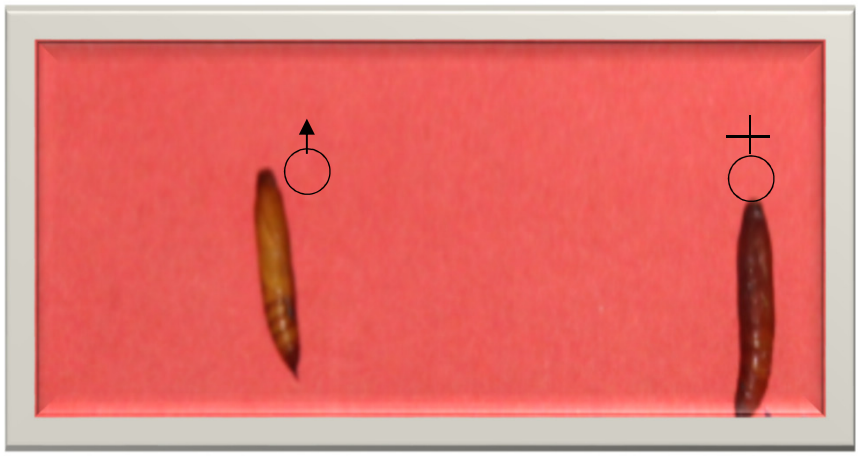

Plate 14. Male and female pupa of *D. caesalis*

Plate 15. Adult female and male moth of *D. caesalis*

Plate 16. Copulation of *D. caesalis* under laboratory condition.

Table 12: Sex ratio of *D. caesalis* during different months of 2015 to 2016

Month	Total number of pupa observed	Adult emergence		Per cent emergence		Sex ratio male to female
		Male	Female	Male	Female	
October-November	50.00	18	32	36	64	1:1.78
November-December	50.00	27	23	54	50	1:0.85
December-January	50.00	24	26	52	48	1.08:1

4.1.7. Nature of damage of *D. caesalis*

The larvae on hatching they were moving all over the rearing box in search of food. The first instars larva is gregarious in nature and feeds by scraping the tender leaves (Plate 17), shoots, fruits and leaf buds given in the laboratory (Plate 11). The second instar larva gradually disperses from each other and stars boring into the tender shoots and fruits (Plate 18.) as well as feeds on tender leaves, as a result of it the skeletisation of leaves can be seen (Plate 19). The late instar larva effectively feeds on the medium sized fruit. In the ripened fruits, the late instar larva also feeds on the seeds (Plate 20) as a result of it the germination of seed is affected. The damaged shoots and fruits were plugged with excreta and damaged bored holes can be seen (Plate 21), as a result of it drying of developing shoots takes place in case of tender shoots. In most of the cases the damaged fruits and shoots which were prone to attack by microorganisms as a secondary infection as a result of it the rotting of shoots and fruits takes place and fall down.

4.1.8. Natural enemies on *D. caesalis.*

As a potential pest on jackfruit, this is vulnerable to attack by one specific group of insect parasitoids. This parasitoid was identified as *Dolichogenidea* (=*Apanteles*) sp. belongs to family Braconidae and order Hymenoptera (Plate 22). The *Dolicogenidea* (= *Apanteles*) sp. found to be promising larval parasitoid, the maggots were present inside the *D. caesalis* larvae and found to feed internally (Plate 23). From single larvae on an average of ten to twenty parasitoids were found to emerge some times more than twenty parasitoid also were emerged from a single larva (Plate 24). After the completion of maggot stage the parasitoid goes for pupation on the body of the larvae of *D. caesalis* only (Plate 25).

This parasitoid is most effective in field condition and the field infestation of monthly survey of parasitoid is estimated (Table 13) from June-2015 to December-2016. It was maximum parasitisation in the month of October to -2016 (53.12 %) and minimum during April -2015 (6.66) and no parasitisation in the month of May-2015.

Table 13: Per cent parasitisation of jack shoot and fruit borer, *D. caesalis* in field condition during 2015 to 16 at UAS, GKVK, Bengaluru

Sl. no.	Months	No. of Larva collected from field	No. of larvae parasitised	Per cent parasitisation
1	January	30	9	30.00
2	February	25	13	52.00
3	March	20	3	15.00
4	April	15	1	6.66
5	May	15	0	0.00
6	June	10	2	20.00
7	July	10	2	30.00
8	August	15	5	33.33
9	September	30	12	40.00
10	October	32	17	53.12
11	November	36	11	30.50
12	December	30	7	23.33

4.2. To screen available germplasm lines for resistance against *D. caesalis.*

This study provides an actual picture of diversity and genetic relatedness among jackfruit germplasms. The data on per cent infestation showed a variation among the genotypes in the GKVK campus. The pooled mean observations from September 2015 to April 2016 data were presented here under. In this study germplasms were selected from two locations in UAS, GKVK, Bengaluru, such as from Horticultural garden and National seed project (NSP) and they were named as block 1 and block 2 for better understand. The obtained results during the study were categorised and presented here under.

Plate 17. *D. caesalis* larva scraping on tender leaves

Plate 18. Nature of damage by *D. caesalis* on jack shoots and fruits

Plate 19. Skeletonization of jack leaves due to feeding by *D. caesalis*

Plate 20. Seed damage by *D. caesalis*

Plate 21. Fruit plugged with excreta

Plate 22. Adult *Dolicogenidia* = (*Apenteles)* sp.

Plate 23. Larva of *Dolicogenidia* feeding on *D. caesalis*

Plate 24. Adult *Dolicogenidia* sp. emerged from single *D. caesalis* larvae

Plate 25. Pupation of *Dolicogenidia* sp. on dead *D. caesalis* larvae

4.2.1 Infestation of jack shoot and fruit borer, *D. caesalis* in Block-1 trees.

In block-1 seven germplasms were screened for the resistance of shoot and fruit borer, *D. caesalis,* they were named as B7, chandra halasu, swarna halasu, gumless, mottamarika, tubugere, janagere. These germplasms were introduced to GKVK, Horticultural garden from different locations of Karnataka. Among them three germplasms were observed and recorded as least susceptible. In the category of least susceptible B7, Chandra halasu, swarna halasu germplasms were recorded with 1.14, 4.43 and 6.93 per cent of shoot and fruit infestation respectively. During the course of study and these trees were found to be best over other germplasms/accessions in block-1.

In the block-1, four germplasms were grouped as highly susceptible with a record of 31.82, 34.72, 35.08 and 37.84 per cent of shoot and fruit infestation was found in gumless, mottamarika, tubugere and janagere. (Table 14.)

Table 14: Categorisation of jack trees germplasms based on *D. caesalis* infestation in Block 1

Category of infestation	Tree number	Percent infestation
Resistant (0% infestation)		
Least susceptible (<10% infestation)	B 7	1.14
	Chandra halasu	4.43
	Swarna halasu	6.93
Moderately susceptible (10 - 20% infestation)		
Highly susceptible (>20% infestation)	Gumless	31.82
	Mottamarika	34.72
	Tubugere	35.08
	Janagere	37.84

4.2.2 Infestation of jack shoot and fruit borer, *D. caesalis* in Block-2 trees.

In the block- 2, seventeen trees/accessions were screened for the resistance of shoot and fruit borer, *D. caesalis,* among them three trees were found to be resistant/no infestation with 0.00 per cent infestation and they were named as NSP 1, NSP 7, and NSP 8.

Five trees/accessions were found to be least susceptible, in which NSP 15, NSP 11, NSP 4, NSP 13 and NSP 12 trees/accessions were recorded with a mean of 0.45, 0.90, 3.18, 6.59 and 6.81 per cent shoot and fruit infestation. Four trees were grouped under moderately susceptible, of which NSP 16, NSP 17, NSP 3 and NSP 10 trees/accessions were recorded of 10.68, 12.04, 14.31 and 19.09 per cent of shoots and fruits infestation.

In the same block five trees were found to be highly susceptible with a record of 34.09, 20, 22.04, 23.40 and 26.13 per cent shoot and fruit infestation, they were named as NSP 9, NSP 2, NSP 14, NSP 5 and NSP 6 trees/accessions. Among all these trees/accessions NSP 9 found to be highly susceptible followed by NSP 6 tees/accessions with 34.09 and 26.13 per cent shoot and fruit infestation (Table 15).

Table 15: Categorisation of jack trees germplasms based on *D. caesalis* infestation in Block 2

Categories of Infestation	Tree number	Percent infestation
Resistant (0% infestation)	NSP 1	0.00
	NSP 7	0.00
	NSP 8	0.00
Least susceptible (<10% infestation)	NSP 15	0.45
	NSP 11	0.90
	NSP 4	3.18
	NSP 13	6.59
	NSP 12	6.81
Moderatively susceptible (10 - 20% infestation)	NSP 16	10.68
	NSP 17	10.68
	NSP 3	14.31
	NSP 10	19.09
Highly susceptible (>20% infestation)	NSP 2	20.90
	NSP 14	22.04
	NSP 5	23.40
	NSP 6	26.13
	NSP 9	34.09

4.3. To study the relative efficacy of insecticide molecules against mortality of *D. caesalis*

The field experiment was carried out in a randomized complete block design with 8 treatments (one control) and 3 replications during December 2015 at Horticulture garden UAS, GKVK Bengaluru to evaluate the effectiveness of insecticide molecules against mortality of Jack shoot and fruit borer, *D. caesalis*. One day before imposition of treatments the larval counts were taken for each treatment on jack trees. The mean larval count ranged from 10.66 to 14.33 larvae in a selected area (2 × 2 m plant canopy/tree). So there were no much significant differences among them with respect to mean number of larvae for each treatment. The obtained results after imposition of treatment on the mortality of *D. caesalis* (Plate 26) are presented here under (Table 16).

Table 16: Relative field efficacy of insecticide molecules against mortality of *D. caesalis*.

Sl. No	Treatments	Dosage ml/l of water	Pre-treatment count	Larval mortality (no.)				Per cent larval mortality
				3 DAT	5 DAT	7DAT	10 DAT	
1	Azadirachtin 10,000 ppm	2.00	14.33 (3.76)^{a}	0.00 (0.70)^{f}	1.67 (1.38)^{g}	5.33 (2.40)^{a}	5.00 (2.33)^{a}	83.74
2	Dichlorvos 76 EC	1.00	13.66 (3.76)^{ab}	10.66 (3.33)^{a}	3.00 (1.85)^{f}	0.00 (0.70)^{e}	0.00 (0.70)^{b}	100.00
3	Imidacloprid 17.80 % SL	0.40	13.66 (3.76)^{abc}	3.66 (2.03)^{d}	7.67 (2.84)^{a}	1.00 (1.09)^{bcd}	0.00 (0.70)^{b}	90.26
4	Lambdacyhalothrin 5% EC	0.75	11.66 (3.48)^{e}	6.00 (2.54)^{c}	5.67 (2.46)^{abcd}	0.00 (0.70)^{e}	0.00 (0.70)^{b}	100.00
5	Fipronil 5% SC	1.50	10.33 (3.29)^{h}	3.66 (2.03)^{d}	6.33 (2.61)^{abc}	0.00 (0.70)^{e}	0.00 (0.70)^{b}	96.70
6	Quinalphos 25 EC	2.00	11.66 (3.48)^{ef}	3.00 (1.85)^{e}	6.67 (2.66)^{ab}	2.00 (1.55)^{e}	0.00 (0.70)^{b}	100.00
7	Spinosad 45 SC	0.30	10.66 (3.33)^{efg}	6.66 (2.67)^{b}	4.00 (2.11)^{e}	0.00 (0.70)^{e}	0.00 (0.70)^{b}	100.00
8	Control (untreated check)	-	13.66 (3.76)^{abcd}	0.00 (0.70)^{f}	0.33 (0.87)^{f}	1.00 (1.17)^{bc}	0.00 (0.70)^{b}	9.33
S.EM			0.09	0.07	0.20	0.18	0.87	
CD (5%)			0.29	0.08	0.61	0.56	0.07	

Note: DAT – Days after treatment

Figures in the parenthesis were square root transformed value

3.1 Three days after spray

The highest mortality (10.66) of larvae was recorded in trees treated with dichlorvos 76 EC and it found significantly differs with other treatments which was followed by spinosad 45 SC (6.66) and lamdacyhalotrin 5 % EC (6.00). The lowest mortality was recorded in untreated control (0.00) and azardirachtin 10000 ppm (0.00) which was significantly inferior to all other treatments. However, dichlorvos 76 EC, spinosad 45 EC and lamdacyhalotrin 5 % EC were statistically superior to rest of the treatments (Figure 1).

3.2 Fifth days after spray

On fifth day after spraying the highest mortality was observed in imidacloprid 17.80 % SL (7.67) and which was on par with quinalphos 25 EC (6.67) followed by fipronil 5 % SC (6.33) which were found significantly differ with other treatments. The lowest mortality of larvae was recorded in untreated control (0.33), followed by azadirachtin 10000 ppm (1.67), dichlorvos 76 EC (3.00) and spinosad 45 EC (4.00). The azadiractin found to be slow effective when compare with other treatments (Figure 2).

3.3 Seventh day after spray

On seventh day after spraying the activity of azadirachtin 10000 ppm (5.33) effectiveness was increased and found significantly differ with other treatments which was followed by quinalphos 25 EC (2.00), untreated control (1.00) and imidacloprid 17.80% SL (1.00). The effective mortality can be seen in all the treatments and the lowest mortality was observed in untreated control (Figure 3).

3.4 Tenth day after spray

On tenth day after spraying the highest mortality seen in azadirachtin 10000 ppm (5.00) which was significantly differ with other treatments.

Trees treated with dichlorvos 76 EC, lamdacyhalotrin 5 EC, quinalphos 25 EC and spinosad 45 EC were found superior in controlling the *D. caesalis* with 100.00 percent mortality, fipronil 5 % SC with 96.70 per cent, imidacloprid 17.80 % SL with 90.26 per cent, azadiractin 10000 ppm with 83.74 percent mortality and 9.33 per cent mortality observed in untreated control were recorded (Figure 4).

In present study it revealed that the cost of spray per acre (for 69 trees with 25×25 ft) is estimated that highest cost is observed by spraying with azadirachtin 10000 ppm was 1,104 rupees followed by spinosad 45 EC with 828 rupees per acre, fipronil 5 % with 673 ruppes and quinalphos 25 EC with 662 rupees per acre of spray. The lowest cost of spray was recorded in spraying with lamdacyhalotrin 5 EC with

Plate 26. Mortality of *D. caesalis* larva after imposition of chemical spray

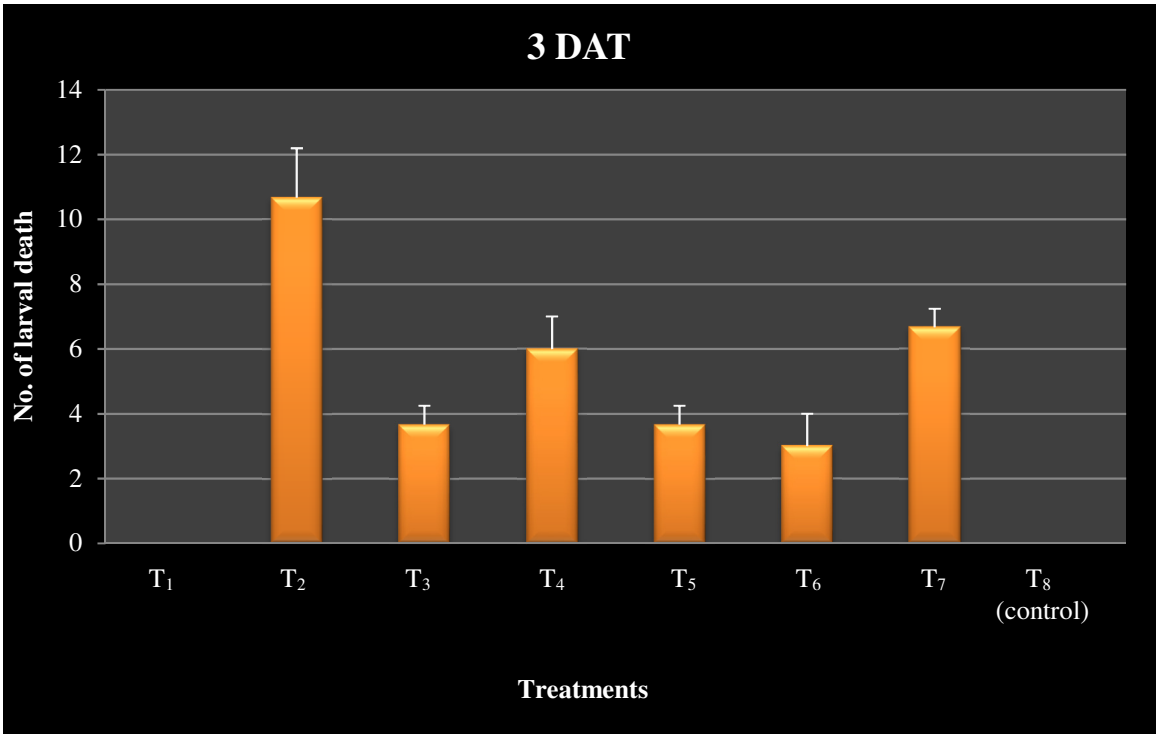

Fig. 1. Mortality of *D. caesalis* on three days after insecticidal spray.

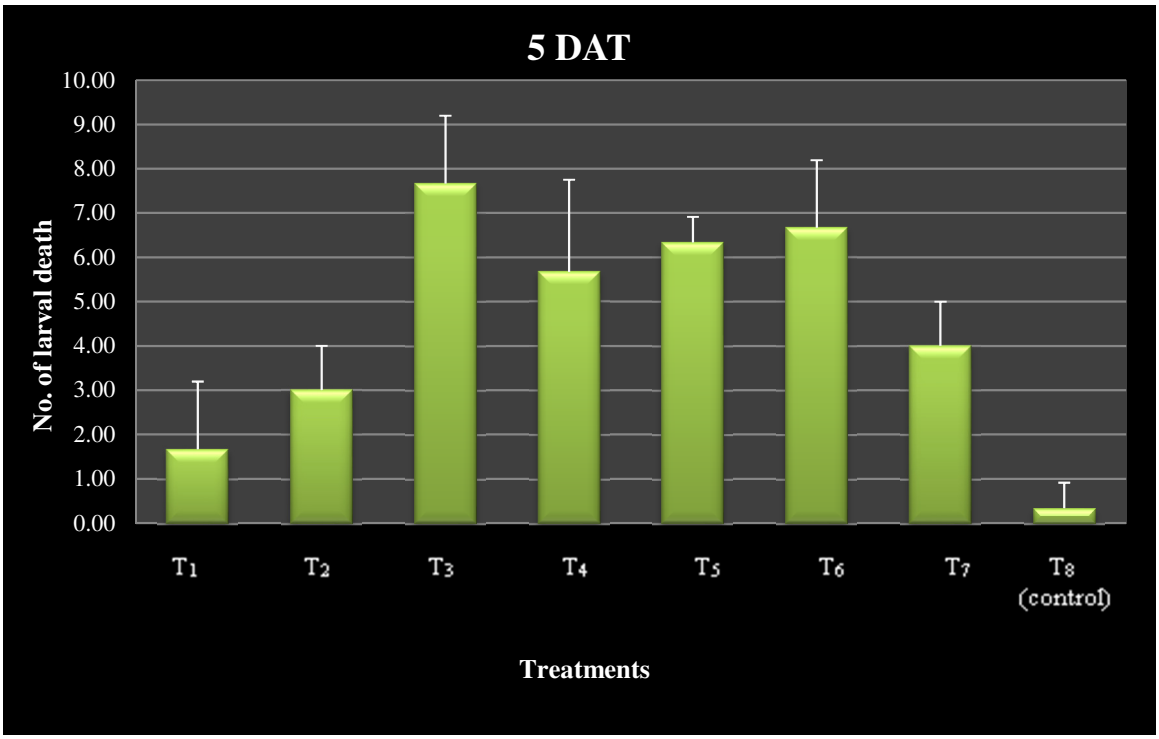

Fig. 2. Mortality of *D. caesalis* on five days after insecticidal spray.

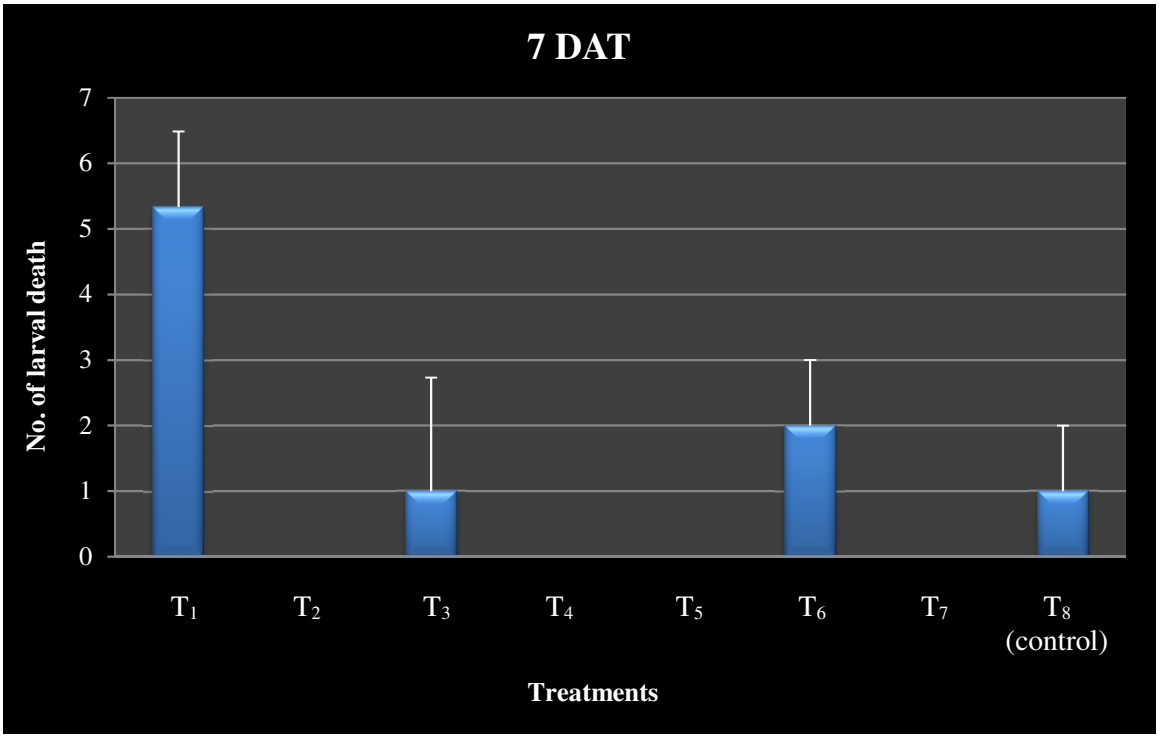

Fig. 3. Mortality of *D. caesalis* on seven days after insecticidal spray.

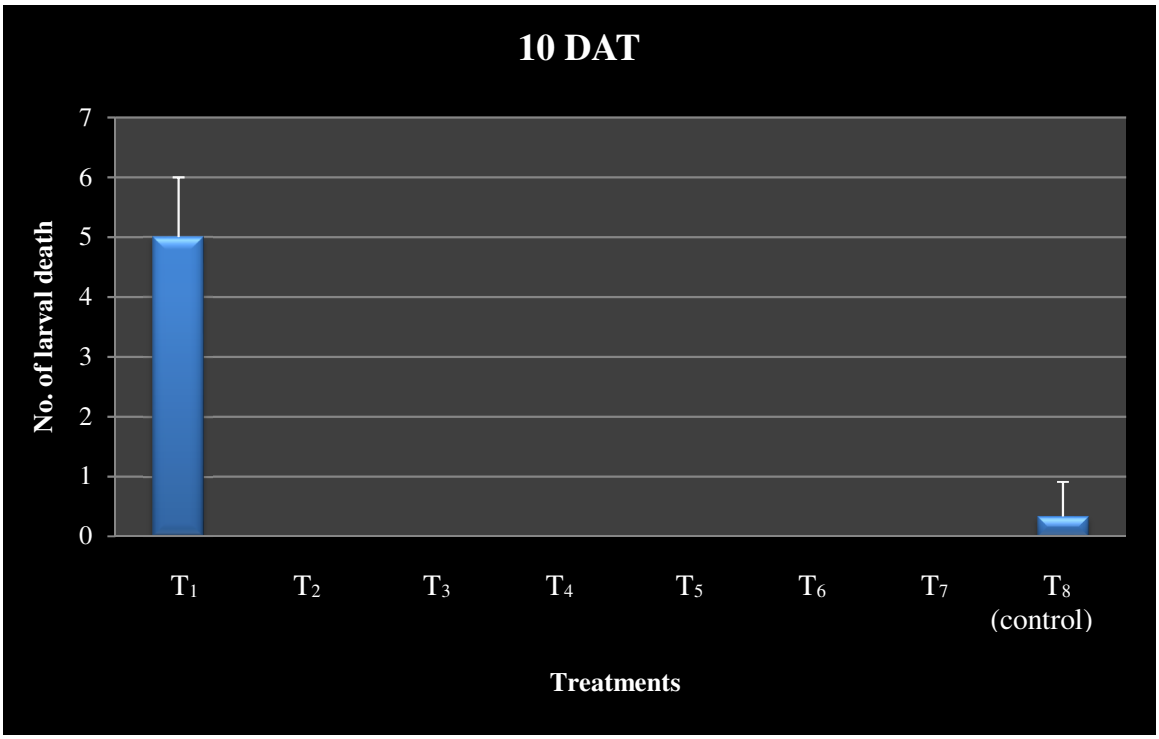

Fig. 4. Mortality of *D. caesalis* on ten days after insecticidal spray.

207 rupees per acre. Imidacloprid 17.80 % SL and dichlorvos 76 EC are more or less on par with each other with a cost (rupees) of 233 and 228 rupees per acre of spray respectively.

V DISCUSSION

Jackfruit is indigenous to India and bears the biggest fruit and is a high yielder. Jackfruit is known as poor man's food in the eastern and southern parts of India. Jackfruit is a multi-purpose tree provides food, nutrients, timber, fuel, fodder, and medicinal and industrial products.

As an underutilized crop, jackfruit has escaped attention for intensive selection and cultivation. However, a wide range of genetic and morphological variation has been reported in jackfruit. Jack fruit is attack by as many as 39 species of insect pests. Among them shoot and fruit borer, *D. caesalis* is a major pest and cause severe damage. So realising the importance of this pest the present work has been carried out during 2015-2016 in UAS, GKVK, Bengaluru both in laboratory and in field condition on biology, screening of available germplasms for the resistance and management of *D. caesalis* with suitable insecticide molecules. The obtained results during the course of study were discussed in this chapter.

5.1. Biology of *D. caesalis* on jackfruit

The results of the investigations on the biology of *D. caesalis* were studied on jack under laboratory condition in UAS, GKVK Bengaluru and the results were discussed here under.

5.1.1. Egg

The freshly laid eggs were oval shaped, soft, translucent and greenish yellow in colour with gel like appearance. The eggs were laid singly on tender shoots, fruits, flower buds and also on black cloth under laboratory condition. The length and breadth of the eggs were ranged from 0.6-0.84 mm and 0.58-0.62 mm with an average of 0.72 (S.D. ± 0.09) mm and 0.60 (S.D. ± 0.01) mm. This study was in agreement with Manjunatha (2002) who observed the average egg length of 0.74 mm (0.67-0.78 mm) and 0.32 mm (0.29-0.36 mm) in width. The study is also in line with the work done by Mridha (2006) who also observed the average length and breadth of the eggs were 0.76 mm and 0.57 mm.

5.1.2. Larva

5.1.2.1. First instar larva

Under laboratory condition the freshly hatched larva is having dark brown coloured head along with light brown coloured shield like prothoracic segment. The body is transparent with light yellowish in colour and have minute black spots on lateral, upper lateral, lower lateral, ventral and dorsal regions at each segment with a single seta on each spot. The first instar larval duration ranged from 2.5 to 3.0 days with an average of 2.65 (S.D. ± 0.24) days, 2-3 days with an average of 2.85 (S.D. ±

0.33) days and 2.5 to 3.5 days with an average of 3.01 (S.D. ± 0.35) days during October to November, November to December, 2015 and December to January 2016, respectively. The first instar larval length ranged from 1.05 to 3.3 mm with an average of 2.54 (S.D. ± 0.76) mm and width ranged from 0.25 to 0.56 mm with an average of 0.45 (S.D. ± 0.11) mm and the larval head width ranged from 0.25 to 0.37 with an average of 0.29(S.D. ± 0.05) mm. The present findings are in agreement with the findings of Manjunatha (2002) on *D. caesalis* who recorded first instar larval length was 2.65 (2.55-2.75) mm and width was 0.66 (0.6-0.7) mm with first instar larval duration was 2.8 (2.75-2.81) days.

5.1.2.2. Second instar larva

The second instar larval head width ranged from 0.5 to 0.6 mm with an average of 0.51 (S.D. ± 0.03) mm. The larval length ranged from 4.1 to 4.9 mm with an average of 4.57 (S.D. ± 0.15) mm and width ranged from 0.6 to 0.9 mm with an average of 0.67 (S.D. ± 0.10) mm. The second instar larval duration ranged from 1 to 2 days with an average of 1.57 (S.D. ± 0.24) days, 1 to 2 days with an average of 1.71 (S.D. ± 0.32) days and 2 to 2.5 days with an average of 2.17 (S.D. ± 0.22) days during October to November, November to December, 2015 and December–January 2016, respectively under laboratory condition. The second instar larva had light greenish coloured body with thin white mid dorsal line further showed increased black spots with slender setae laterally. These findings are similar with findings of Manjunatha (2002) who recorded of 4.4 (4.39-4.42) mm in length and 0.95 (0.8-1.2) mm in width. The second instar larval period varies from 1.11-1.21 days with an average of 1.2 days. There was slight variation in the second instar larval period, the difference occurred is due to the climatic variations.

5.1.2.3. Third instar larva

Under laboratory condition the third instar larvae were pale brownish in colour with prominent black spots on the body with a brown coloured seta on each spots towards lateral and sub lateral region. The prothoracic segment was fully covered with brown band. The third instar larval duration ranged from 2.5 to 3 days with an average of 2.66 (S.D. ± 0.23) days, 2.5 to 3.5 days with an average of 03 (S.D. ± 0.33) days and 3 to 4 days with an average of 3.55 (S.D. ± 0.28) during October to November, November to December, 2015 and December–January 2016, respectively. The third instar larval length ranged from 6.8 to 7.4 mm with an average of 7.02 (S.D. ± 0.16) mm and width ranged from 1.5-1.9 mm with an average of 1.61 (S.D. ± 0.15) mm and the larval head width ranged from 0.7 to 1.2 mm with an average of 0.94 (S.D. ± 0.12) mm. The length and width of third instar was almost similar to that reported by Manjunatha (2002) who recorded the length ranged from 6.62-6.67 mm with a mean of 6.65 mm and width ranged from 1.93-1.95 mm with a mean of 1.94 mm. The slight variation may be due to differences in the temperature and relative humidity during the course of study.

5.1.2.4. Fourth instar larva

The fully grown fourth instar larvae were more prominent and able feed on the bigger shoots and fruits. They were found to cause more severe damage during this stage and they are light brownish in colour and black spots are present on each body segments having discontinuous white mid dorsal line. The microscopic view shows that presence of brown coloured claspers at the tip of true legs, with fine, minute, setae around the caudal legs and prolegs were dark in colour.

Larval length ranged from 17 to 21 mm with an average of 18.24 (S.D. ± 0.80) mm and width ranged from 2.4 to 2.8 mm with an average of 2.53 (S.D. ± 0.12) mm. The larval duration ranged from 2.8 to 3.2 days with an average of 3.03 (S.D. ± 0.23) days, 3 to 4 days with an average of 3.65 (S.D. ± 0.33) days and 3 to 4 days with an average of 3.51 (S.D. ± 0.56) days (Table 3 and 5) during October to November, November to December, 2015 and April-May 2016, respectively. These results are contradicting with the results of Manjunatha (2002). He recorded the larval length of 11.20 (11.12-11.22) mm and width is 2.6 (2.48-2.61) mm. The variation in the duration and the size of fourth instar larva may be due to the nutrient factors, the kind of feed it consumed. It also influences in the change in duration and morphology of larvae in laboratory condition.

5.1.2.5. Fifth instar larva

The fifth instar larval colour was differing from the rest of the instars. The fifth instar larvae show dark reddish brown colour with discontinuous white mid dorsal line was clearly seen, the black spots present on the body became prominent and the size of the black spot is increased. The fifth instar larval period varies from 2.5 to 3.5 days on an average of 2.88 (S.D. ± 0.32) days, 3 to 4 days with average of 3.65 (S.D. ± 0.33) days and 3 to 4 days on an average of 3.15 (S.D. ± 0.33) (Table 3, 4 & 5) days during October to –November, November to December, 2015 and December – January 2016, respectively.

The larval head width of fifth instar larvae ranged from 1.9 to 2.4 with an average of 2.13 (S.D. ± 0.14) mm and larval length ranged from 23 to 28 mm with an average of 25.8 (S.D. ± 1.32) mm and width ranged from 3.4 to 4.2 mm with an average of 3.65 (S.D. ± 0.20) mm. This study is more or less agreement with findings of Manjunatha *et al* (2014) who reported that the fifth instars larva was reddish brown in colour and the black spot present on the body became prominent and increase in their area. He found the duration of fifth instar larva was 2.4 days. The difference in the larval period may be dependent on sources of food with the variability of different environment factors.

5.1.2.6. Pre-pupa

The pre pupal period is inactive period in which the larvae stop feeding and spun the silken cocoons around the body and undergoes pupation, the average pre pupal period is 3.51 (S.D. ± 0.31) days, 4.1 (S.D. ± 0.31) days and 4.55 (S.D. ± 0.43)

days during October to –November, November to December, 2015 and December to January 2016, respectively. This study is more or less agreement with records of Manjunatha (2002), who recorded 3.5 days and 3.9 days during May-June and September-October under laboratory condition.

5.1.3. Pupa

The pupae were object type and brownish in colour. Usually the female pupa was bigger and longer than the male pupa. Pupation occurred inside the pupal case, the site of pupation can be seen between the webbed leaves or inside the fruit or between two or three shoots or at the top of the rearing boxes under laboratory condition. The female pupa is bigger than the male pupa. The average pupal development period lasted for 9.0 (S.D. ± 0.39) days, 9.5 (S.D. ± 0.52) days and 10.1 (S.D. ± 0.73) days during October to November, November to December, 2015 and December to January 2016, respectively. This study is agreement with the earlier study done by Mridha (2006), who conducted a research in Bangladesh who reported that the pupation can be seen in underside of jackfruit leaf or twisted dried leaf or on the surface of nearest two or more fruits. The length and breadth of pupae were 13.23 mm and 2.92 mm. The average duration of the pupa was 6.83 days. Variation in the pupal period can be observed, it may be due to variation in the climatic condition between the countries.

The present study is more or less agreement with the earlier work done by Manjunatha (2002), who reported the pupal period of 8.2 days during May-June and 8.5 days during September-October, under laboratory condition and the average male pupal length and breadth was 11.12 mm and 1.74 mm. The female pupal length and breadth was 12.31 mm and 1.76 mm respectively. Variation in the pupal morphology and pupal period may be due to the food and climatic variations during the course of study.

5.1.4. Total life cycle

Under laboratory condition the average total developmental period was 29.2 (S.D. ± 2.05), 33.02 (S.D. ± 2.93) and 35.09 (S.D. ± 3.33) days during October to November, November to December, 2015 and December to January 2016, respectively. The obtained results were contrary with the results of Manjunatha (2002) who recorded that 27.3 days and 29 days on jack May-June and September-October respectively and Mridha (2006) who recorded total life cycle of *D. caesalis* was 23.34 days on jack. The variations among the studies on the life cycle of *D. caesalis* were may be due to source of food with the variability of different environmental factors and difference in the location of research conducted.

5.1.5. Adult

The adult moths are medium sized which usually emerges from pupal case during the early morning or evening hours and some times during afternoon hours.

The moths are active during dark or night time and shows inactive behaviour during day time.

5.1.5.1. Pre-mating and mating period

The study on pre mating period revealed to range of 18 to 25 hours with a mean of 23.6 (S.D. ± 23.6) hours after the emergence from the pupa. The present study is agreement with the observation of Manjunatha (2002) according to him the adults were involved in mating after 24 hours.

The present study reveals that the both male and female moths were involved in mating for about 2-4 hours with a mean of 3.3 (S.D. ± 0.94) hours. The mating occurs during evening hours, the single mating is observed in both male and female but occasionally dual mating can be observed in males.

These findings are similar with the findings of Manjunatha (2002) who observed that the male and female involve in copulation during evening hours and mating period varies from 90-130 minutes and dual mating can be observed in males they can capable of fertilizing 1-2 virgin females.

5.1.5.2. Pre-oviposition period

In laboratory condition the female moth starts laying the eggs 17 to 25 hours with a mean of 21.1 (S.D. ± 3.38) hours after copulation. The present observations are not confirming with the findings of Manjunatha (2002) who observed that female moths were started laying eggs 2-3 days after copulation. The difference in the pre oviposition period is may be due to manipulation of adult feed or it may be due to uncomfortable site for egg laying.

5.1.5.3. Oviposition period

The female moth lays the eggs singly on the tender leaves, shoots, fruits and laid in a group on black cloth given in the laboratory condition. The oviposition period varies from 8 to 9 days with a mean of 8.33 (S.D. ± 0.57) days. These findings are similar with the earlier study done by Manjunatha (2002) who observed that the eggs were laid singly as well as in small groups on surface of tender fruits and shoots of jack and recorded oviposition period was 9 days.

5.1.5.4. Adult longevity

Under laboratory condition the longevity of female moth fed with 10 per cent honey solution was survived for about 8-12 days with a mean of 9.65 (S.D. ± 1.17) days and male moth fed with 10 per cent honey solution survived for about 5-9 days with an average of 8.05 (S.D. ± 1.23) days. These findings are not agreement with the findings of Manjunatha (2002) according to him the female and male fed with 10 per

cent honey solution survived for about 16.5 days and 12 days, respectively. This study is against the findings of Mridha (2006) who recorded average longevity of the adult was 4.67 days. Difference in the adult longevity was depends on the nutritional factors, locality and also depends on the variation in the temperature and relative humidity during the course of investigation.

5.1.6. Nature of damage of *D. caesalis*

The larval stage was the most destructive stage which leads to considerable economic loss. During the larval period the larva effectively feed on tender leaves, leaf buds, shoots and fruits. The first instar larva was gregarious in nature and feed gregariously by scraping the tender leaves, shoots, tender fruits, leaf buds given in the laboratory. Second instar onwards the larvae start dispersing from each other and move to neighbouring places and feed on the individual shoots and fruits. The damaged shoots and fruits were plugged with excreta and damaged bored holes can be seen, as a result of it, the damaged shoots and fruits were easily attacked by microorganism as a secondary infection. The late instar larvae effectively feed on the medium sized fruit and also ripened fruit. In the ripened fruits, the late instar larvae found to feed on the seeds. As a result of it the seed quality is affected.

The similar observations were also recorded by Khan *et al*., 2004 and Manjunatha (2002) who reported that jackfruit borer attacks the tender shoots, male and female spikes and fruits of all developmental stages. At the flowering stage, the larva bores into spike and feeds on internal tissues. At initial infestation, anthesis of the male spikes does not occur and the affected spikes later become rotten and shaded off from the plant. Later stage the larvae bore into the mature fruit and cause damage to the edible part. Later infested fruits frequently get rotten due to entrance of rainwater in to the fruits. Who recorded the average percentage of fruit infestation was 27.4 per cent.

5.1.7. Natural enemies on *D. caesalis*

The present study revealed that *D. caesalis* was susceptible for the attack of larval parasitoid that is identified as *Dolichogenidea* (=*Apanteles*) sp. belongs to the family Braconidae and order Hymenoptera. The present observation is confirmed with the findings of Manjunatha (2002) who also recorded *Apanteles* spp. of parasitoid on *D. caesalis.*

In the present study the monthly records of *Dolichogenidea* on *D. caesalis* revealed that the maximum parasitisation can be observed during the month of October followed by February with per cent, parasitisation of 53.12 and 52 per cent respectively. No parasitisation can be observed during May month with zero per cent infestation under field condition (Figure 5). These findings are agreement with the findings of Manjunatha (2002) who recorded more parasitization during October with

53.50 per cent parasitization and minimum during January with a record of 14.20 per cent parasitization.

5.2. To screen the available germplasm lines for resistance against *D. caesalis.*

The available germplasm lines were screened for the resistance of *D. caesalis.* This study was conducted in UAS. GKVK, Bengaluru. In the present study twenty four germplasms were screened in two locations (Block-1 = Horticulture garden, Block-2 = National seed project) for the resistance of *D. caesalis,* among the germplasms a wide range of genetic variation has been reported in terms of per cent infestation. The obtained results during the course of study were discussed with available reviews in this chapter.

5.2.1 Infestation of jack shoot and fruit borer, *D. caesalis* in Block-1 trees.

In this location there are seven germplasms were screened for the resistance of *D. caesalis* among them three germplasms were recorded as least susceptible they are named as B7, Chandra halasu, swarna halasu with a record of 1.14, 4.43, and 6.93 per cent of shoot and fruit infestation respectively. During the course of study these trees were found to be best over other germplasms/accessions in block-1. In the same block four germplasms were observed as a highly susceptible, they are gumless, mottamarika, tubugere and janagere with a record of 31.82, 34.72, 35.08 and 37.84 per cent of shoot and fruit infestation respectively (Figure 6).

5.2.2 Infestation of jack shoot and fruit borer, *D. caesalis* in Block-2 trees.

In the block- 2, seventeen germplasms/accessions were screened for the resistance of shoot and fruit borer, *D. caesalis,* the present study revealed that among seven germplasms/accessions, three germplasms/accessions were found to be resistant/no infestation, five trees/accessions were found to be least susceptible and four trees were moderately susceptible.

The results revealed that NSP 1, NSP 7, and NSP 8 were recorded as resistant/no infestation with 0.00 per cent infestation. NSP 15, NSP 11, NSP 4, NSP 13 and NSP 12 germplasms/accessions were recorded as least susceptible with 0.45, 0.90, 3.18, 6.59, and 6.81 per cent shoot and fruit infestation respectively and NSP 16, NSP 17, NSP 3 and NSP 10 germplasms/accessions were recorded as moderately susceptible with 10.68 12.04, 14.31 and 19.09 per cent of shoots and fruits infestation respectively (Figure 7)

The present study is in agreement with the earlier studies done by Soumya *et al.,* 2015, who worked on the evaluation of jackfruit germplasms/accessions against *D. caesalis*. Who screened sixty-five accessions for evaluation, the results revealed that accession numbers G-61, G-72, G-73, and G-74, showed no infestation/ resistant to *D. caesalis* throughout the year. The accession numbers G-70, G-60, G-9, G-71, G-

80, G-65, G-57, G-46, G-77, G-49, G-42, G-34, G-50, G-43, G-51, G-54, G 38, G-78, G-24, G-58, G-10, G-76, G-59, G-44, G-52 and G-47 were found to be least susceptible. Whereas accession numbers G-48, G-55, G-75, G-18, G-41, G-45, G-37, G-79, G-36, G-39, G-26, G-53, G-20, G-21, G-25, G-27, G-23, G-22, G-19, G-28, G-56, and G-29, were found to be moderately susceptible. Accession numbers, G-35, G-3, G-4, G-32, G-6, G-2, G-1, G-8, G-5, G-11, G-7, G-31, and G-12 were recorded as highly susceptible.

According to present study there is a genetic diversity in the selected jackfruit accessions/ germplasms in terms of per cent infestation. The variation among the accessions against the *D. caesalis* it may be due to mechanisms of host-plant resistance, the particular accession may exhibit the mechanism of antibiosis, antixenosis or nonpreference and tolerance for the attack of *D. caesalis*. In jackfruit there is no much work has been conducted on the screening of germplasms for the resistant to *D. caesalis* in India and in other countries. Unlike other recognised crops there is no specific released variety in the jackfruit for the resistant to *D. caesalis*. So in present study the germplasms which are recognised as resistance to *D. caesalis* may help in future studies in developing the resistant germplasms through breeding programmes. By which in terms helps in reducing in usage of costly chemical pesticides for the management of *D. caesalis*.

5.3 To study the relative efficacy of insecticide molecules against shoot and fruit borer, *D. caesalis*

The jack shoot and fruit borer *D. caesalis* is a major insect pest and cause economical damage to jackfruit, according to the previous and present study. So keeping these in view eight treatments were imposed in the present study on the mortality of *D. caesalis.* The obtained results were discussed with available literature here under

The present study revealed that trees treated with dichlorvos 76 EC, lamdacyhalotrin 5 % EC, quinalphos 25 EC and spinosad 45 EC were found superior in controlling the *D. caesalis* with 100.00 percent mortality followed by fipronil 5 % SC with 96.70 per cent and imidacloprid 17.80% SL with 90.26 per cent mortality. The azadiractin 10000 ppm recorded 83.74 percent mortality and 9.73 per cent mortality was observed in untreated control. Initially activity of azadiractin 10000 ppm was slow because it acts as antifeedent, repellent and growth regulator. Later, 7 days of treatment the activity of azadiractin increased in controlling the *D. caesalis.* The similar observations were recorded by the Mridha (2002) who observed 78.98 % reduction of *D. caesalis* by Spraying of neem oil (@ 10 ml/L of water + soap solution 5 g/L) on jack.

The present study is more or less similar with the study done by Manjunatha (2002) who recorded spraying NSKE (4 %) and nimbicidin (0.03 %) were found effective in controlling *D. caesalis* followed by neem oil (1 %). Who also reported that NSKE (4 %) was initially slow action in controlling pest later after 10 days of

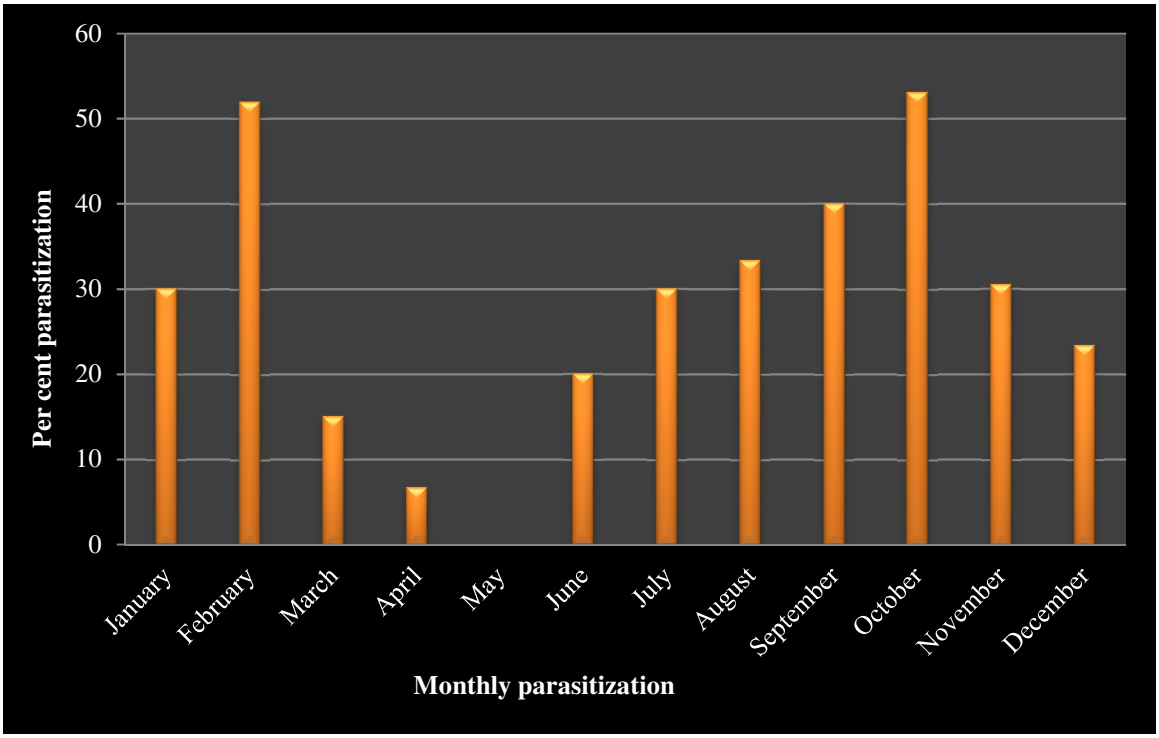

Fig. 5. Per cent parasitisation of *D. caesalis* at UAS, GKVK, Bengaluru in field condition during 2015-16.

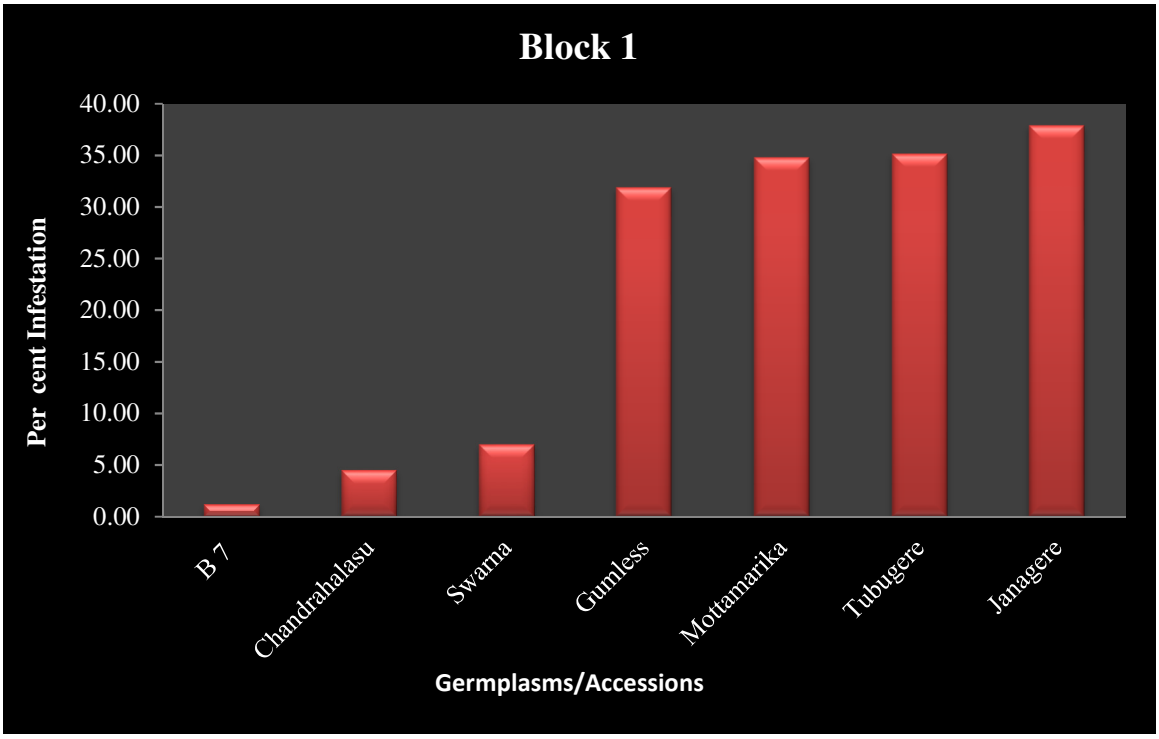

Fig. 6. Per cent infestation of *D. caesalis* in block 1 jackfruit germplasms/accessions.

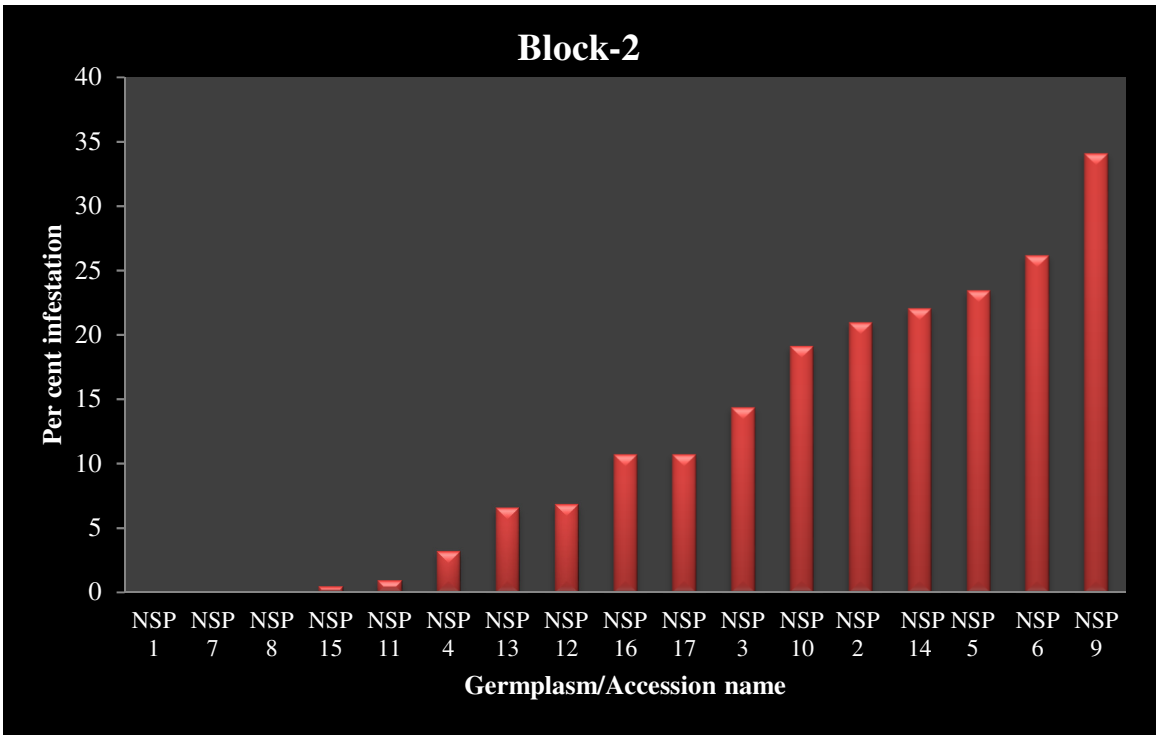

Fig. 7. Per cent infestation of *D. caesalis* in block 2 jackfruit germplasms/accessions.

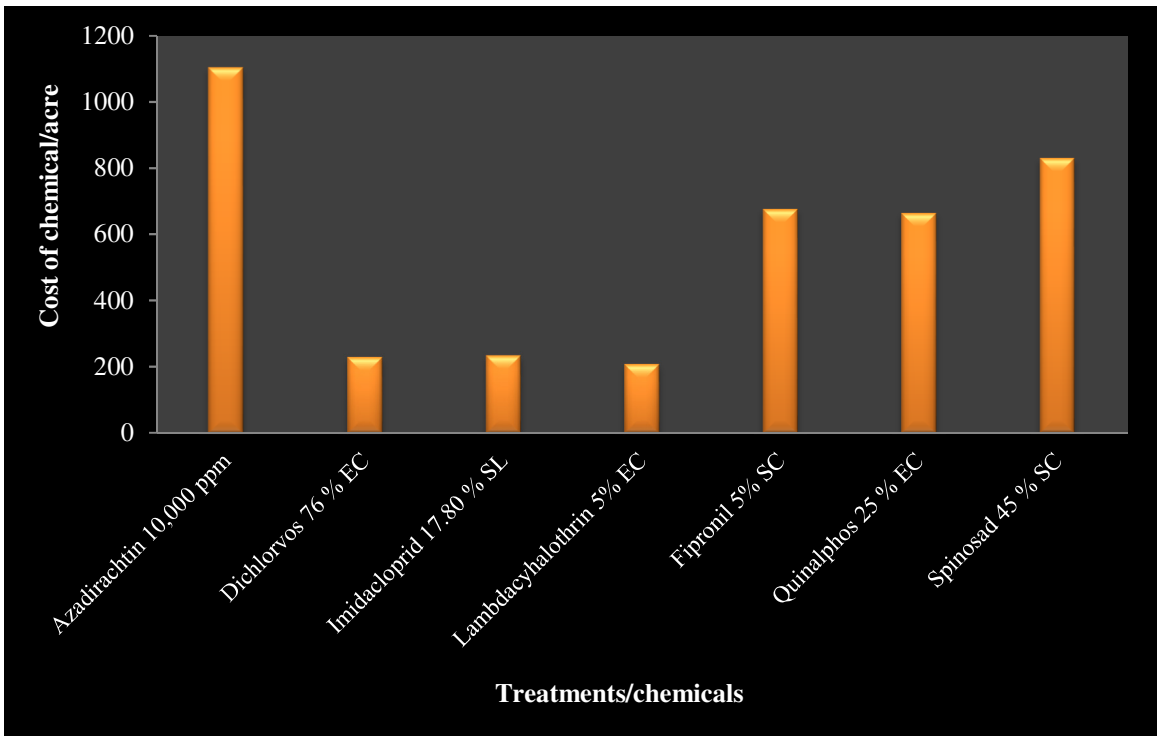

Fig. 8. Estimated cost of chemicals for spraying for one acre.

treatment the activity of NSKE (4 %) has been increased and they were found significantly on par with synthetic insecticides (endosulfan 0.07 % and fenvalurate 0.02 %).

The results obtained in the present study revealed that 100.00 per cent mortality were observed after imposition of few treatments, it may be due to selection of very young shoots or young flower buds or leaf buds for studies which were infested by *D. caesalis.* Because of young shoots or young flower buds or leaf buds selected for spraying there may be chance of direct contact of larvae to the chemical imposed or may be very fast movement of chemicals into the insect body when spayed to bigger fruits or shoots. So that the mortality may be increased, it revealed that as the size of the shoots or fruits increase the activity of chemicals on *D. caesalis* decreases so it indicates that control measures should be taken care at the young stage of shoots, fruits and at initial stage of infestation so that it reduces the further spreading of infestation.

In the present study estimated the cost of chemical for spraying the one acre (for 69 trees in 25×25 ft spacing) of jackfruit garden (Figure 8). The estimated cost of chemical for spray reveals that highest cost taken for azadirachtin 10,000 ppm was 1,104 rupees followed by spinosad 45 SC with 828 rupees, fipronil 5 % SC with 673 rupees and quinalphos 25 EC with 662 rupees per acre of spray.

Imidacloprid 17.80 % SL with 233 rupees and dichlorvos 76 EC with 228 rupees these two chemical cost were more or less on par with each other. Among the all treatments the lowest cost of chemical is recorded in lambdacyhalothrin 5 % EC with 207 rupees per acre.

Present study reveals that among all the chemicals lambdacyhalothrin 5 % EC found to be lowest price for cost of spray for one acre with 100.00 per cent mortality against *D. caesalis* followed by dichlorvos 76 EC and Imidacloprid 17.80 % SL in terms of cost per acre. In the farmer's point of view these three chemicals found to be most economical when compare to other chemicals and every farmer also easily can take up the chemical spray with lowest cost.

There were no much supporting studies were available on efficacy of insecticide molecules against the mortality of *D. caesalis*. So the present study provides preliminary basic information and further studies on the management of *D. caesalis* with different chemicals have to be taken care in future studies.

VI SUMMARY

The present investigation conducted on the biology and management of shoot and fruit borer, *D. caesalis* on jack and screening available germplasms for their resistance, during 2015 to 16 in UAS, GKVK, Bengaluru, are summarized below.

Biology of *D. caesalis* was studied during October to November, November to December 2015 and December to January 2016 under Laboratory condition with temperature range of 21 °C to 26 °C and 80 per cent relative humidity.

The eggs were oval shaped, soft and translucent, laid singly on tender shoots, fruits, flower buds and on black cloth under laboratory condition. The average incubation period of 4 ± 0.21 days during October to November 2015, 4.8 ± 0.34 days during November to December 2015 and 5.05 ± 0.43 days during December to January 2016. The first instar larvae with dark brown coloured head, body was transparent with light yellowish in colour and having minute black spots with single setae on each spot. First instar occupied average of 2.65 ± 0.24 days, 2.85 ± 0.33 days and 3.01 ± 0.35 days during study period respectively.

The second instar larva was light greenish in coloured body with thin white line on dorsal surface along with black spots and setae. The second instar larvae occupied the average duration of 1.57 ± 0.24 days, 1.71 ± 0.32 days and 2.17 ± 0.22 day during October to November, November to December, 2015 and December to January 2016, respectively. Third instar larva is bigger than the second instar larva it occupied an average duration of 2.66 ± 0.23 days, 03 ± 0.33 days and 3.55 ± 0.28 days during respective study period.

Fourth instar larva was light brownish in colour and the brown coloured claspers present at the tip of true legs, it lasted with an average of 3.03 ± 0.11 days, 3.41 ± 0.45 days and 3.51 ± 0.56 days during October to November, November to December, 2015 and December to January 2016, respectively.

Fifth instar larva was dark reddish brown in colour with discontinuous white dorsal line and prominent black spots on the body. The fifth instar larval duration lasts with an average of 2.88 ± 0.32 days, 3.65 ± 0.33 days and 3.15 ± 0.33 days during October to November, November to December, 2015 and December to January 2016, respectively.

Pre-pupa occupied with an average period of 3.51 ± 0.31 days, 4.1 ± 0.31 days and 4.55 ± 0.43 days during October to November, November to December, 2015 and December to January 2016, respectively. The pupal period occupied with an average of 8.9 ± 0.39 days, 9.5 ± 0.52 days and 10.1 ± 0.73 days during October to November, November to December, 2015 and December to January 2016, respectively.

The adult moths are of medium sized, with greyish to whitish brown coloured wings and having elliptical markings on the fore wings with fringed hairs at the edge of both wings. The female moths are slight bigger than the males. The pre-mating period is observed with a mean of 23.6 ± 23.6 hours after the emergence from the pupa and mating period is lasted with an average period of 3.3 ± 0.94 hours.

Pre-oviposition period is recorded with a mean of 21.1 ± 3.38 hours and the oviposition period with a mean of 8.33 ± 0.57 days. The fecundity of female with a mean of 110.90 ± 42.71 eggs. The adult longevity of female fed with 10 per cent honey solution lived with a mean of 9.65 ± 1.17 days and male moth fed with 10 per cent honey solution lived with an average of 8.05 ± 1.23 days. The average total life cycle was 29.2 ± 2.05, 33.02 ± 2.93 and 35.09 ± 3.33 days during October to November, November to December, 2015 and December to January 2016, respectively.

The potential larval parasitoid was recorded on *D. caesalis* under field condition that is identified as *Dolichogenidea* (= *Apanteles*) sp. (Hymenoptera: Braconidae). The maximum per cent parasitisation was recorded in the month of October-2016 and minimum during April -2015.

Twenty-four germplasms/accessions were screened in two locations of GKVK campus, against the *D. caesalis,* the germplasm NSP 1, NSP 7, and NSP 8 offered resistance to pest infestation. NSP 15, NSP 11, NSP 4, NSP 13, NSP 12, B7, Chandra halasu and swarna halasu germplasms/accessions were categorised as least susceptible. NSP 16, NSP 17, NSP 3 and NSP 10 germplasms/accessions were grouped as moderately susceptible. Gumless, mottamarika, tubugere, janagere, NSP 2, NSP 14, NSP 5, NSP 6 and NSP 9 germplasms/accessions were found to be highly susceptible.

In the management of *D. caesalis,* the seven different insecticides were evaluated for their effectiveness, among them all treatment was found to be effective in reducing *D. caesalis* and all the insecticides were found to be superior over untreated control.

Trees treated with dichlorvos 76 EC, lamdacyhalotrin 5 % EC, quinalphos 25 EC and spinosad 45 EC were found superior in controlling the *D. caesalis* with 100.00 percent mortality, fipronil 5 % SC with 96.70 per cent, imidacloprid 17.80 % SL with 90.26 per cent, azadiractin 10000 ppm with 83.74 percent mortality and 9.73 per cent mortality observed in untreated control were recorded. Among the all chemicals, the cost of chemical for spraying one acre reveals that the lowest cost recorded with spray of lamdacyhalotrin 5 % EC with 207 rupees per acre and highest cost with1,104 rupees per acre with azadirachtin 10,000 ppm. So the lamdacyhalotrin 5 % EC is found to be more effective and economical among all the chemicals. Further studies have to be taken care on the screening and management aspects of the *D. caesalis.*

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APPENDIX

Laboratory weather parameters of Entomology department UAS, GKVK, Bengaluru during the respective study period 2015-16

Months	Minimum temperature (°C)	Maximum temperature (°C)	Relative humidity (%)
October-2015	24	27	88.8
November-2015	23	26	88.46
December-2015	22	25	88
January-2016	23	25	92

Note: Values are the mean of 30 observations/ 1month observations