BIOLOGY AND MANAGEMENT OF RICE MOTH, *Corcyra cephalonica* Stainton (*Lepidoptera : Pyralidae*) INFESTING OAT (*Avena sativa* Linnaeus) UNDER STORAGE CONDITION

A

THESIS

SUBMITTED TO THE

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FOR THE AWARD OF THE DEGREE

OF

Master of Science

(AGRICULTURE)

IN

AGRICULTURAL ENTOMOLOGY

BY

PATEL SANDEEPKUMAR BHOLABHAI

B. Sc. (Agri.)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

B. A. COLLEGE OF AGRICULTURE

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ANAND – 388 110

GUJARAT (INDIA)

2010

Reg. No. : 04-0565-2007

PATEL SANDEEPKUMAR BHOLABHAI M.Sc. AGRICULTURAL ENTOMOLOGY 2010

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C E R T I F I C A T E

This is to certify that the thesis entitled **"Biology and management of rice moth, *Corcyra cephalonica* Stainton (Lepidoptera : Pyralidae) infesting Oat (*Avena sativa* Linnaeus) under storage condition"** submitted by **Mr. Patel Sandeepkumar Bholabhai** in partial fulfillment of the requirements for the degree of **M. Sc. (Agri.)** in **Agricultural Entomology** of the Anand Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision. The thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Anand
(C. C. Patel)
Date : / 07 /2010
Major Guide

DECLARATION

This is to declare that the whole of research work reported herein

the thesis for partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in the subject of **Agricultural Entomology** by the undersigned is a result of investigation done by me under direct guidance and supervision of **Dr. C. C. Patel**, Research Scientist (Ent.), Main Forage Research Station, Anand Agricultural University, Anand–388 110 and no part of work had been submitted for any other degree so far.

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This is to certify that I have no objection for supplying to any scientist or worker a copy of thesis or any part of it for rendering the reference service either in a library or documentation centre.

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This is to certify that **Patel Sandeepkumar Bholabhai**, **Reg. No.: 04-0565-2007** has successfully completed the comprehensive examination of major and supporting subjects on as required under the regulation for M. Sc. in Agriculture.

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CERTIFICATE - II

Date: 05/07/2010

This is to certify that the thesis entitled **"Biology and management of rice moth, *Corcyra cephalonica* Stainton (Lepidoptera : Pyralidae) infesting oat (*Avena sativa* Linnaeus) under storage condition"** submitted for the degree of **Master of Science** in the subject of **Agricultural Entomology** embodies bonafide research work carried out under my guidance and supervision and that no part of this thesis or research work has been submitted for any other degree. The assistance, guidance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by advisory committee on **30/06/2010**.

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Date: 05/07/2010

This is to certify that the thesis entitled **"Biology and management of rice moth, *Corcyra cephalonica* Stainton (Lepidoptera : Pyralidae) infesting oat (*Avena sativa* Linnaeus) under storage condition"** submitted by **Patel Sandeepkumar Bholabhai**, **Reg. No.: 04-0565-2007** to the Anand Agricultural University, Anand in the partial fulfillment of requirement for the degree of **Master of Science** in Agriculture in the subject of **Agricultural Entomology** after suggestion and recommendation by external examiner was discussed and defended by the candidate before the following members of the advisory committee. The performance of the candidate in the oral examination on this thesis has been found satisfactory; we therefore, recommended that the thesis may be approved.

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This is to certify that **Patel Sandeepkumar Bholabhai**, **Reg. No.: 04-0565-2007** Department of **Agricultural Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand** has made all corrections/ modifications in the thesis entitled **"Biology and management of rice moth, *Corcyra cephalonica* Stainton (Lepidoptera : Pyralidae) infesting oat (*Avena sativa* Linnaeus) under storage condition"** which were suggested by the External Examiner and the advisory committee in the oral examination held on **30/06/2010**. The final copies of the thesis duly bound and corrected were submitted on **05/07/2010** are enclosed here with for approval.

(C. C. Patel)
Major Advisor

Principal/Dean

Approved (Seal and date)

Director of Research and
Dean Faculty of P.G. Studies,
AAU, Anand.

DECLARATION

This is to certify that whole of the research work reported in the thesis in partial fulfillment of the requirement for the award of the degree of **Master of Science** in Agriculture in the subject of **Agricultural Entomology** is the result of investigation done by undersigned under the direct guidance and supervision of **Dr. C. C. Patel, Research Scientist (Ento.), Main Forage Research Station**, **Anand Agricultural University, Anand** and no part of the research work has been submitted for any other degree so far.

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BIOLOGY AND MANAGEMENT OF RICE MOTH, *Corcyra cephalonica* Stainton (Lepidoptera : Pyralidae) infesting Oat (*Avena sativa* Linnaeus) UNDER STORAGE CONDITION

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ABSTRACT

Present investigations on biology and management of rice moth, *Corcyra cephalonica* Stainton (Lepidoptera : **Pyralidae**) through plant products and insecticides as grain protectants infesting oat (*Avena sativa* Linnaeus) under storage condition were carried out at Main Forage Research Station, Anand Agricultural University, Anand during 2007-08 and 2008-09.

Studies on biology of this pest were carried out under the laboratory conditions at temperatures ranging from 27 to 30 ^{0}C and 69 to 87 per cent relative humidity.

The study revealed that the eggs of rice moth were pearly white, oval in shape with a rough surface and yellowish in colour and measured on an average 0.40 ± 0.02 mm in length and 0.34 ±

0.02 mm in breadth. The average incubation period was 4.10 ± 1.19 days with hatchability of 93.00 per cent on oat grains.

The larvae passed through seven distinct instars. The average duration of first to seventh instar larvae was recorded to be 4.54 ± 0.51, 5.10 ± 0.83, 5.88 ± 0.97, 6.03 ± 0.98, 6.28 ± 0.46, 6.75 ± 0.87 and 6.90 ± 0.87 days with total larval duration of 37.80 ± 0.95 days. Measurement of first to seventh instar larvae indicated that average body length was 0.74 ± 0.15, 1.24 ± 0.13, 2.80 ± 0.16, 4.45 ± 0.16, 5.66 ± 0.35, 7.83 ± 0.62 and 9.60 ± 0.61 mm with breadth of 0.20 ± 0.005, 0.23 ± 0.013, 0.30 ± 0.010, 0.41 ± 0.010, 0.55 ± 0.008, 0.64 ± 0.013 and 0.77 ± 0.022 mm, respectively. The average pre-pupal and pupal periods were 1.48 ± 0.50 and 8.43 ± 1.20 days, respectively. The average length of pre-pupa and pupa were 8.27 ± 0.79 and 8.12 ± 0.54 mm, respectively and breadth of 1.41 ± 0.32 1.47 ± 0.31mm, respectively.

The moths of both the sexes were pale greyish brown in colour with wings uniformly dark grey in colour, sometimes streaked with darker lines along the veins. Average longevity of male and female moths was 8.35 ± 1.11 and 7.09 ± 1.41 days, respectively. Thus, the male moth lived longer than female moth. Measurement of male and female adults indicated that females, (Av. 18.80 ± 1.70 mm) were larger than males (Av. 17.00 ± 2.30 mm). The average pre-oviposition, oviposition and post-oviposition period of female moth were 1.35 ± 0.49, 5.47 ± 0.72 and 1.18 ± 0.39 days,

respectively. Whereas, average fecundity was 122.22 ± 8.39 eggs per female. The average life span of male and female adults recorded 62.70 ± 7.80 and 71.50 ± 11.90 days, respectively. The sex ratio, survival percentage, mean developmental period and growth index of *C. cephalonica* were recorded to be 1 : 1.08, 80 per cent, 60.20 days and 1.33, respectively on oat seeds.

The results of laboratory trials on evaluation of various plant products against *C. cephalonica* in stored oat revealed that mixing of neem (*Azadirachta indica*), eucalyptus (*Eucalyptus globulus*) and custard apple (*Annona squamosa*) leaf powder @ 2.00 per cent with the oat grains were found the most effective in controlling *C. cephalonica*.

The grain protecting efficacy of nine insecticides against *C. cephalonica* were evaluated as seed treatment at 4 ppm and as spray/impregnation on/in two types (Hessian and B-twill) of jute bags all at 0.025 per cent up to 5 months of storage period. As seed treatment, the periodical larval mortality revealed that all the insecticides gave 99.90 % mortality up to 45 days of storage (DOS). After 45 DOS, the larval mortality decreased as storage period increased in case of all the insecticides, except deltamethrin and cypermethrin in which larval mortality was 99.90 % up to 75 DOS. As sprayed/impregnated on/in jute bags as prophylactic treatment, the periodical data on larval mortality revealed that all the insecticides could maintain larval mortality above 90 per cent up to

15 DOS. Deltamethrin found most effective and long lasting grain protectant of oat against *C. cephalonica*. Spinosad, cypermethrin and fipronil were next effective insecticides. Malathion was found less effective insecticide. Insecticide application as impregnation in jute bag was found more effective than spray on jute bag. B-twill jute bag was found more effective than hessian jute bag for insecticide spray or impregnation.

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Looking forward for bright future.....with greatest hope.....

Place: Anand ***(Patel Sandeepkumar B.)***
Date: / 07 / 2010

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LIST OF ABBREVIATIONS

Anon.	:	Anonymous
@	:	At the rate of
a. i.	:	Active ingredient
cm	:	Centimeter
C. D.	:	Critical difference
C. V.	:	Coefficient of variation
^{0} C	:	Degree Celsius
et al	:	et allii; and others
etc.	:	Etcetera
Fig.	:	Figure
g	:	Gram
>	:	Greater than
<	:	Less than
ha	:	Hectare
i. e.	:	That is
Kg	:	Kilogram
m^2	:	Meter square
mm	:	Millimeter
ml	:	Milliliter
l	:	Liter
NS	:	Not significant
S. Em. ±	:	Standard error of mean
viz.,	:	Namely
%	:	Per cent
DOS	:	Day of storage

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I. INTRODUCTION

Oat (*Avena sativa* Linnaeus) is an important cereal fodder crop having a wider adaptability in India. In our country, oat is cultivated in area of about 2 lakh ha. (Singh, 1999). In Gujarat, farmers grow oat as a quality fodder crop during the *rabi* season. It is a quick growing highly nutritious fodder crop having crude protein content of 12 to 14%. Kent, JHO- 851, JHO- 822 and UPO- 212 are popular varieties of oat among the farmers. Oat crop is a heavy yielder and the average yield varies from 45 to 55 tones of green fodder per hectare (Anon., 2008).

Due to unsurety of rains and fluctuating environmental factors in our country, food stuff and other commodities are required to be stored properly as long as possible. About 70 % of food grains produced is stored in traditional and primitive structures of storage (Lal, 1990). Therefore, stored materials are likely to be attacked by various insects, mites, moulds, rodents etc. Among these, insects are responsible for causing enormous losses in terms of quality and quantity in transport as well as storage.

At the time of harvest, the grains are dried until their moisture content is less than 9 per cent which is ideal for storage. Sometimes, uncertain weather would not allow the proper drying up of the grains. The warm season and the high moisture content of the grain are highly conducive to the proper development and rapid multiplication of insect pests of stored grains.

✍.....
.....*Introduction*

When the grains are harvested in the field, they are practically free from insect infestation. The insects reach the grains either through the infested gunny bags or receptacles or through the storage of fresh grains in godowns already having infested grains.

Stored grain pests are the main limiting factor in successful storage of seeds for longer periods. Almost all the insect pests of stored grains have a remarkably high rate of multiplication. During storage, the stored grain insect-pests destroy up to 40 % of the total stored cereals and pulses (Anon., 1999).

Nearly one thousand species of insects have been found damaging to stored grains and their products in the world (Girish, 1978). Among these, *Corcyra cephalonica*, Stainton (Lepidoptera: Pyralidae) is one of the most important pests. It is commonly known as “rice moth”. It is attacking on number of commodities like grains of rice, sorghum, bajra, wheat, sesamum etc. under storage condition. It is very serious pest of stored commodities in tropical and sub-tropical region of the world (Darling, 1952). It occurs in many parts of Europe, Asia, Africa, America and Nigeria (Chittenden, 1919). It causes not only sanitation problem in warehouses or godowns but also makes the seeds unviable for germination.

Corcyra create not only sanitation problem in warehouses but also hinders the commodities qualitatively and quantitatively. The damaged grains can be recognized by the presence of webbing.

The creamy white larvae start feeding on the grains immediately after hatching. The larvae damage the stored materials by moving, feeding and living silken threads, which are later form dense and tough webbing.

Rice moth has been used as a main laboratory host for mass multiplication of different parasitoids of phytophagous pests and acquires the predominant position in the bio-control programme.

In our country, most of the food grains produced is being stored at farmer’s level under the most primitive conditions of storage and are easily accessible to a variety of insect pests. The synthetic chemicals recommended for insect pest control in storage are least useful at farmers level due to either the problem of residues or development of insect resistance or non-suitability for specific conditions.

In Indian conditions, use of plant products have several advantages over recommended synthetic insecticides and considered as one of the important approaches of insect pest management programme. The degree of protection by phytoproducts to storage, operator and non target animals is much higher than with the synthetic insecticides. Plant products possess least or no mammalian toxicity and thus, constitute no health hazard; surface persistence lasts for long time with no adverse effect on seed germination. Plant products are indigenous resource

with insecticidal, anti-feedent and insect repellent properties (Prakash *et al*., 1981).

Though, *C. cephalonica* is one of the most destructive pests of stored grains, no systematic study has been made on biology and management of this pest infesting oat. Thus, there is a need to guide the farmers to protect the oat seeds for longer period by keeping the seeds free from the infestation of *C. cephalonica*. Therefore, sufficient information on its biology and effective control measures are required for the better management of this pest in storage condition. Hence, present investigations were carried out on the following aspects:

- Study on biology of *Corcyra cephalonica* Stainton on oat.
- Evaluation of bio-efficacy of different botanicals as grain protectant against *C. cephalonica* on oat.
- Evaluation of bio-efficacy of different synthetic insecticides as grain protectant against *C. cephalonica* on oat.

II. REVIEW OF LITERATURE

An attempt was made to review the available literature on the biology of *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae) as well as bio-efficacy of different botanicals and synthetic insecticides as grain protectant against *C. cephalonica* on oat. From literature, it revealed that none of the earlier workers have studied the biology and management of *C. cephalonica* on oat.

2.1 Biology of rice moth, *Corcyra cephalonica*

The information especially in relation to oat is not available. Therefore, some related references are reviewed.

2.1.1 Egg

2.1.1.1 Colour and shape

Srivastava *et al.* (1983) observed that the eggs were laid scattered and loose in the grain mass. The freshly laid eggs were pearly white ellipsoids with a rough, irregularly sculpted surface and small nipple at one end, which gradually turned yellowish as they developed (Subramaniyam and Hagstrum, 1996). Patel and Patel (2007) observed that the eggs of rice moth appeared pearly white, oval in shape with a rough, irregularly sculpted surface.

2.1.1.2 Incubation period

The incubation period of *C. cephalonica* was reported to be varied from 4 to 5 days on sorghum (Rao, 1954). Devraj and Mukharjee (1966) reported that the average egg period was 4.44 and 4.30 days on groundnut and till seeds, respectively. Cox *et al.*

(1981) reported the average duration of egg period varied from 4.00 to 16.70 days at various temperature and relative humidity levels, while Shazali and Smith (1986) reported it to be 4.0 to 6.4 days at 25 to 35 ^{0}C temperature and 40 to 80 per cent relative humidity.

Dhanani (1989) reported that the duration of egg stage ranged from 3 to 5 (Av. 4.10) and 4 to 6 (Av. 5.05) days on sorghum and rice, respectively. The average incubation period at 28 $\pm$ 1 ^{0} C temperature and 75 per cent relative humidity was 7 days each on sorghum (Ray *et al.,* 1990) and maize (Ray, 1994).

The incubation period of 4.3 days was reported by Kamel and Hassanein (1969) on maize and wheat; whereas, Mbata (1989) and Hill (1992) reported it to be 4 days on sorghum.

Kumar *et al*. (2002) found that the incubation periods of *C. cephalonica* were 3.64, 3.10, 3.15 and 3.89 days on rice, sorghum, maize and wheat, respectively, while it was 4.21, 5.32 and 7.41 days on pearlmillet, rice and sorghum, respectively (Prakash and Senthilkumar, 2005).

Patel and Patel (2007) revealed that the mean egg period ranged from 4.06 to 5.06 days on broken grains of sorghum, wheat, pearl millet and rice, at room temperature.

2.1.1.3 Hatchability

Dhanani (1989) reported that the egg hatchability on sorghum and rice was 96 and 95 per cent, respectively. The hatching per cent of eggs was from 93 to 95 per cent on different

varieties of sunflower (Tejani, 1989). Patel and Patel (2007) reported that the hatchability of eggs of rice moth was 97.5, 95.0, 95.0 and 92.5 per cent on sorghum, wheat, pearlmillet and rice, respectively.

2.1.2 Larva

2.1.2.1 Colour, shape and size

Rao (1954) reported that the length of first to eight instars larvae was 0.60 to 1.00, 0.95 to 1.20, 2.00 to 2.25, 3.33 to 4.50, 4.05 to 5.75, 4.56 to 7.00, 7.00 to 9.43 and 9.55 to 11.00 mm with an average of 0.75, 1.08, 2.12, 3.95, 4.89, 5.73, 8.11 and 10.23 mm, respectively. He also reported that an average width was 0.19, 0.23, 0.29, 0.40, 0.52, 0.63 and 0.76 mm for first to seven instars larvae, respectively.

According to Hill (1992), the larva was white with brown head and prothoracic shield; there were characteristic setae above each spiracle arising from a small clear patch of cuticle surrounded by a dark ring of cuticle. Subramaniyam and Hagstrum (1996) reported that *C. cephalonica* larva an external feeder was initially creamy white in colour and gradually darkens to a dirty white with a reddish brown head capsule.

2.1.2.2 Number of instars

As reported by Usman (1968), the male of *C. cephalonica* had 6 larval instars, while the females had 7, the first three being shortest and last one the longest. Russell *et al*., (1980) found that the females generally had one more instar than the males bred at

the same relative humidity. There were 7 instars in males and 6 instars in females at 30 per cent relative humidity.

The larvae of *C. cephalonica* passed through seven larval instars on sorghum and rice (Dhanani, 1989). Cheng and Hung (1990) reported that the larvae of *C. cephalonica* had six, seven or eight instars and majority of 7th and almost all 8th instars larvae were female.

According to Patel and Patel (2007), the larvae of *C. cephalonica* passed through 6 instars in case of male and 7 instars in case of female on broken grains of sorghum, wheat, pearlmillet and rice, respectively.

2.1.2.3 Larval period

Rao (1954) studied the biology of *C. cephalonica* on sorghum and found that the average duration of first to eight larval instars was 4.0, 4.7, 4.7, 4.7, 6.9, 4.9, 5.3 and 5.6 days, respectively. The average larval period of 46.36 and 58.93 days was recorded on groundnut and til seeds, respectively (Devaraj and Mookherjee, 1966). According to Jacob *et al.* (1966), the average larval period was 33.52 and 35.23 days with a mortality of 10 and 20 per cent on wheat and rice, respectively. Usman (1968) concluded that the highest larval mortality was recorded in second instars.

Kamel and Hassanein (1969) found that the average duration of larval stage of rice moth at 25.5 ^{0}C temperature and 75

per cent relative humidity was about 37.2, 49.5 and 37.2 days on maize flour, sifted wheat flour and powder field beans, respectively.

Rao *et al.* (1980) reported that the larval period of *C. cephalonica* was 33.0 and 37.1 days when it was reared on sorghum and rice, respectively. The larval period at various temperature and relative humidity, varied from 17.50 to 67.67 days (Hugar and Jairao, 1985) and 21.70 to 29.10 days (Shazali and Smith, 1986).

Dhanani (1989) reported that the average duration of first to seven instars was 4.15, 4.71, 5.53, 5.90, 6.92, 6.72 and 6.96 days, respectively on sorghum, while it was recorded as 7.00, 7.20, 7.41, 7.82, 7.34, 8.02 and 8.17 days, respectively on rice. He also recorded larval mortality of 4.5, 6.5 and 2.5 per cent on sorghum and 8.00, 14.25 and 5.25 per cent on rice for first, second and third instars, respectively.

The total larval period was recorded to be 40.90 days on sorghum and 52.96 days on rice (Dhanani, 1989); 44 days on crushed sorghum (Ray *et al*., 1990) and 41 days on maize (Ray, 1994).

Kumar *et al*. (2002) found that larval periods were 35.75, 26.72, 23.48 and 33.54 days on rice, sorghum, maize and wheat, respectively while 25.61, 27.21 and 28.32 days on bajra, rice and sorghum, respectively (Prakash and Senthilkumar, 2005). As reported by Patel and Patel (2007), the duration of 1st, 2nd, 3rd, 4th, 5th, 6th and 7th instars varied from 4.03 to 6.77, 4.10 to 7.20,

4.83 to 7.16, 5.85 to 7.41, 6.44 to 7.52, 5.75 to 7.81 and 5.76 to 8.09 days, respectively on different food grains.

2.1.3 Prepupa

The prepupal period of *C. cephalonica* was 1.39 to 1.59 days on different varieties of groundnut (Patel, 1985); 1.38 days on sorghum and 1.43 days on rice (Dhanani, 1989); 1 to 2 days on different sunflower varieties (Tejani, 1989) and 1.23 to 1.74 days on different food grains (Patel and Patel, 2007).

2.1.4 Pupa

After completing development, full fed larvae weaves a cocoon incorporating food grains, debris and other materials for pupation. Cocoons were often found in clusters and matted together in sheets. The cocoon was thinner but stronger and more closely woven (Srivastava *et al*., 1983; Subramaniyam and Hagstrum, 1996).

2.1.4.1 Colour and size

Subramaniyam and Hagstrum (1996) described that the pupae were leathery brown and 8 mm in length. Patel and Patel (2007) observed that the pupation took place in silken cocoon. The cocoon was thinner but stronger and more closely woven. The pupa was leathery brown coloured.

2.1.4.2 Pupal period

Rao (1954) reported that the pupal period of *C. cephalonica* varied from 6 to 11 (Av. 9.0) days on sorghum, while it was 10.63

and 13.66 days on groundnut and til seeds, respectively (Devraj and Mookherjee, 1966).

The pupal period was recorded as 7.8 days on sorghum, 10.2 days on rice (Rao *et al., 1980*); 11.0 to 12.19 days on different varieties of groundnut (Patel, 1985); 9.75 days on sorghum, 10.45 days on rice (Dhanani, 1989) and 6 to 12 days on different varieties of sunflower (Tejani, 1989).

Shazali and Smith (1986) reported that the pupal period varied from 7.9 to 14.4 days on sorghum at various levels of temperature and relative humidity. The pupal period of *C. cephalonica* at 28 $\pm$ 1 ^{0} C temperatures and 75 per cent relative humidity was 11 days on sorghum (Ray *et al.,* 1990) and 10 days on maize (Ray, 1994).

The pupal mortality of *C. cephalonica* was 35.20 and 39.58 per cent on wheat and rice, respectively (Jacob *et al.*, 1966) and 2.5 and 5.5 per cent on sorghum and rice, respectively (Dhanani, 1989). Kumar *et al*., (2002) found that pupal periods were 8.23, 7.78, 7.75 and 8.02 days on rice, sorghum, maize and wheat, respectively, while 10.11, 11.22 and 13.12 days on bajra, rice and sorghum, respectively (Prakash and Senthilkumar, 2005). Patel and Patel (2007) reported that the pupal period was 8.40 to 10.58 days on broken grains of sorghum, wheat, pearlmillet and rice.

2.1.5 Adult

2.1.5.1 Colour, appearance and size

Ayyar (1934) reported that the male was smaller than female. He further stated that the forewings were brown with distinct shoulders and were held on lightly addressed forwarded to body. The hind wings had fringes of short posterior directed hairs. The labial palps were pointed straight forward in female, whereas blunt and inconspicuous in male adult.

According to Rao (1954), the male moth of *C. cephalonica* had wing expansion of 13 to 18 mm and body length of 6.5 to 9.5 mm, whereas female had 15 to 21 mm wing expansion and 7.5 to 10.5 mm body length.

Hill (1992) reported that *C. cephalonica* was a brown moth with pale brown hind wings and wing span of 15 to 25 mm. He also observed that male had short, blunt labial palps but the female had long and pointed palps. According to Subramaniyam and Hagstrum (1996), *C. cephalonica* was more variable in size, but typically had a wing span of 17 mm in male and 19 mm in female. They also reported that the wings were uniformly dark grey, sometime streaked with darker lines along with veins. Patel and Patel (2007) observed that the moths were pale grayish brown in colour and the wings were uniformly dark grey in colour, sometimes streaked with darker lines along the veins.

2.1.5.2 Pre-oviposition, oviposition and post-oviposition period

According to Devraj and Mukharjee (1966), the average pre-oviposition and oviposition period were 0.3 and 4.5 days on groundnut and 0.5 and 5.0 days on til seeds, respectively.

The oviposition period of *C. cephalonica* at 25 ^{0} C was 2 to 6 days while at 30 ^{0} C it was 3 to 7 days (Kulkarni, 1968) while it was 1 to 7 days (Kamel and Hassanein, 1969) and 5 days on cereals (Pajni *et al*., 1979).

Kamel *et al*. (1981) reported that the diets *viz*., whole meal wheat flour, sifted flour and highly sifted flour had no effect on duration of the pre-oviposition, oviposition and post-oviposition periods. Chakravorty and Das (1983) observed that the pre-oviposition, oviposition and post-oviposition periods varied from 6 to 26, 24 to 120 and 12 to 192 hrs with an average of 14.47, 72.80 and 62.80 hrs, respectively.

Dhanani (1989) observed that the oviposition period of *C. cephalonica* was varied from 6 to 7 (Av. 6.4) and 5 to 7 (Av. 5.8) days on sorghum and rice, respectively. Tejani (1989) reported that the oviposition period of *C. cephalonica* was 4.8 to 6.0 days on different sunflower varieties. Patel and Patel (2007) reported that the preoviposition, oviposition and postoviposition period ranged from 1.18 to 1.45, 5.50 to 6.21 and 0.88 to 1.23 days, respectively on different host commodities.

2.1.5.3 Fecundity

The female of *C. cephalonica* laid 89 to 191 eggs (Av. 156 eggs) as reported by Ayyar (1934). Rao (1954) observed that the large moths emerged from the cereals had laid more number of eggs (139) as compared to pulses, whereas small moths emerged laid less number of eggs (93).

The average fecundity of female of *C. cephalonica* was recorded to be 255 eggs on groundnut and 159 eggs on til seeds (Devraj and Mookherjee, 1966); 347.60 eggs on wheat and 225 eggs on rice (Jacob *et al.*, 1966) and 84 to 416 eggs on sorghum (Kulkarni, 1968) and 110 eggs on pulses (Pajni *et al*., 1979).

Kamel and Hassanein (1969) recorded that egg laying capacity of female varied from 13 to 399 eggs during summer and 9 to 268 eggs during winter season. Rao *et al.* (1980) reported that the fecundity on sorghum flour and rice bran was 139 and 116 eggs, respectively. Russel *et al.* (1980) reported that the number of eggs laid per female of *C. cephalonica* ranged from 18 to 467 eggs and was positively correlated with body weight of female.

The fecundity of female of *C. cephalonica* was varied from 86 to 242 eggs (Av. 152.8 eggs) at 35 ^{0} C temperature and 70 per cent relative humidity (Shazali and Smith, 1986). According to Mbata (1989), the average fecundity of female was 148.9 $\pm$ 6.5 eggs at 70 per cent relative humidity and 131.8 $\pm$ 4.1 eggs at 50 per cent relative humidity.

Dhanani (1989) reported that the fecundity of female of *C. cephalonica* was 219.5 and 193.0 eggs on sorghum and rice, respectively while it was 136.4 to 189.6 eggs on different varieties of sunflower (Tejani, 1989).

Kumar and Krishna (1991) reported that the fecundity of *C. cephalonica* in presence of gram, sorghum, wheat, mustard, cotton, sesame and groundnuts averaged 364.4, 160.2, 111.2, 438.4, 348.4 and 329.6 eggs, respectively. According to Patel and Patel (2007), the average number of eggs laid by female was an average 159.00, 127.14, 125.86 and 112.93 eggs on various food grains.

2.1.5.4 Longevity

Ayyar (1934) reported that the longevity of male and female was recorded as 9.5 and 10.5.5 days, respectively. As reported by Kulkarni (1968), the average longevity of female was 5.7 and 6.4 days at 25 and 30 ^{0}C temperature, respectively when reared on sorghum. Shazali and Smith (1986) found that the longevity of male and female was 8.3 and 4.8 days. From the laboratory study, Etman *et al*. (1988) reported that the adult life span averaged 9.1 and 7.0 days for mated and unmated males, respectively and 8.3 and 8.0 days for mated and unmated females, respectively at 28 ^{0} C temperatures with

65 per cent relative humidity.

Dhanani (1989) reported that the longevity of male and female of *C.*

cephalonica was 9.9 and 7.8 days, respectively on sorghum, where as 9.2 and 7.0 days, respectively on rice. According to Chen and Peng (1998), the male moth emerged 2 to 3 hrs earlier than the female and average longevity of male and female was 12.9 and 8.1 days, respectively when it was reared on rice. Patel and Patel (2007) found that the longevity of female moths was 8.93, 7.43, 7.86 and 7.56 days whereas 9.00, 8.18, 8.72 and 9.53 days for male moths on various food grains.

2.1.5.5 Sex ratio

Kamel and Hassanaein (1969) reported that when the *C. cephalonica* reared on wheat, the sex ratio (Male: Female) was 1: 1.

Dhanani (1989) studied the sex ratio of *C. cephalonica* and revealed that the male constituted about 45.64 per cent and female about 54.36 per cent (Sex ratio 1: 1.191) when reared on sorghum, while in case of rice, the sex ratio was 1: 1.039. As reported by Tejani (1989), the sex ratio of *C. cephalonica* on different sunflower varieties was varied from 1: 0.733 to 1: 1.063. The sex ratio was 1: 1 in the population of *C. cephalonica* in rice (Chen and Peng, 1998). Patel and Patel (2007) observed that the sex ratio ranged from 1: 1.095 to 1: 1.222 among different commodities.

2.1.6 Survival percentage and growth index

Rao (1954) reported that the adult emergence was recorded as 68, 64 and 52 per cent on broken sorghum, wheat and coarse rice, respectively.

Dhanani (1989) observed that survival per cent of *C. cephalonica* on sorghum and rice was 80 and 62, respectively. He also revealed that the growth index was 1.442 and 0.886 on sorghum and rice, respectively. As reported by Patel and Patel (2007), the survival per cent of *C. cephalonica* was 82, 80, 76 and 70 per cent whereas growth index was 1.62, 1.43, 1.27 and 1.01 on sorghum, wheat, pearlmillet and rice, respectively.

2.2 Evaluation of plant products against *C. cephalonica*

In present era of pest management, the natural plant materials and their derivatives are considered as important component due to their eco-friendly nature.

Pruthi (1937) reported that neem leaves mixed with grain at 5 per cent kept in 5 to 7 cm layer on the stored grains protected the commodity from storage insect pests for the longer period. Pandey *et al.* (1985) observed that mixing of powder of neem leaves, kernel, cake and flowers @ 1.0, 1.0, 5.0 and 0.5 per cent (w/w), respectively in wheat seed found effective as ovipositional deterrent for the adults of *C. cephalonica.*

Agarwal *et al.* (1988) reported that the plant powders of neem, *Ipomea*, custard apple, *Ardusi* and turmeric leaves at 4 per cent were effective to protect food grains from insect infestation. Prusty *et al*. (1989) evaluated various plant products *viz.,* leaves of neem, pudina, bel, wild sag and begonia @ 2 per cent w/w against

rice moth in rice and found that leaves of neem and wild sag inhibited the larval and adult population.

Senguttuvan *et al*. (1995) tested nochi (*Vitex nigunto* L.) leaf powder,

neem (*Azadirachta indica* L.) leaf powder, neem kernel powder, neem cake powder (@ 10 and 25 g/kg of seeds) and oils (@ 10 and 25 ml of oil/kg of seeds) of neem, castor (*Ricinus communis* L.), sesame (*Sesamum indicum* L.) and groundnut for their efficacy in protecting stored groundnuts against rice moth, *C. cephalonica.* They found that the neem leaf powder, nochi leaf powder and neem oil were most effective followed by neem kernel powder.

Modgil and Samuels (1997) observed that mint leaves powder at 2 per cent was able to protect wheat stored in different storage structures for 6 months, whereas eucalyptus leaves powder at 2 per cent had their protective effects for 5 months.

Patel and Patel (2002) studied the efficacy of neem leaf powder, eucalyptus, custard apple, lantana, bael, ipomoea, Indian mustard oil, cotton, groundnut, sunflower and sesamum all at 2 % under laboratory conditions as grain protectants against the rice moth, *C. cephalonica*, infesting stored rice. They revealed that mixing of neem and eucalyptus leaf powders at 2 % was highly effective against rice moth, *C. cephalonica* in stored rice.

Veeranki and Reddy (2004) studied the effect of various plant products *viz*; neem leaf and seed kernel powder, custard apple

seed powder and inert dusts (attapulgite and dolomite) each at 2 per cent as grain protectants against rice moth in maize and reported that complete pupal mortality and no adult emergence (male and female) were found in maize grains treated with neem leaf and neem seed kernel powder and attapulgite dust.

Meena and Bhargava (2005) studied the effect of different plant powders i.e. dharak (*Melia azadirach*) kernel and leaf, neem (*Azadirachta indica*) kernel and leaf, Karanj (*Pongamia glabra*) kernel and leaf, oak (*Calotropis procera*) leaf, datura (*Datura alba*) leaf, citrus (*Citrus limon*) leaf, podina (*Mentha arvensis*) leaf and tulsi (*Ocimum sanctum*) leaf at 1.0, 2.5 and 5.0 parts/100 parts of grain (w/w), on fecundity, egg viability and longevity of adults of *C. cephalonica* were investigated. They found that the per cent reduction in fecundity of the test insect increased with the increase in the concentration of each treatment. The mean percentage reduction in egg viability varied from 17.46 to 29.41 % and 13.78 to 35.17 %. The longevity of male and female adults gradually decreased with the increase in the concentration of the treatments.

2.3 INSECTICIDES AS GRAIN PROTECTANTS

In light of present studies, the available literature on insecticides as grain protectant for control of stored grain pests, have been reviewed and presented hereunder.

II.3.1 Seed treatment

Laboratory experiments indicated that treatment of a small proportion of a wheat bulk with high concentration of malathion may prove effective method of application than attempting to treat all the grains uniformly with the same level of insecticide. One or two % of the grains treated with malathion at 10 ppm gave an effective control against *Sitophilus oryzae, Tribolium castaneum* and *Rhizopertha dominica* (Minett and Williams, 1971).

Malathion at 10, 20 and 30 ppm as a protectant for the prevention of damage by *Callosobruchus maculatus* and *C. chinensis* to stored gram was evaluated by Srivastava and Dadhich (1973) in the laboratory condition. The periodical data on adult mortality indicated that malathion treatment at 10, 20 and 30 ppm provided absolute protection for 6, 7 and 8 months, respectively as all the introduced beetles died in 48 hours exposure period.

Weaving (1975) carried out studies on comparative toxicities of some insecticides [fenitrothion (0.5, 2 & 8 ppm), pirimiphos-methyl (5 & 10 ppm), fenthion, malathion & isofenphos (8 ppm), diazinon & phenthoate (4 ppm), tetrachlorvinphos (8 & 20 ppm) and pyrithrin (2.5 ppm): piperonyl butoxide (1:5)] for their use as grain protectants in maize and sorghum under tribal storage condition. At 8 ppm of malathion, the per cent mortality of *S. oryzae* after 6 days exposure was 100 and 90 % up to 2 months of storage which reduced to 12.0 and 5 % after 12 months of storage of maize and sorghum, respectively. Thus, malathion at 8 ppm was found

effective grain protectant for 2 months against *S. oryzae* infesting maize and sorghum.

The relative efficacy of some organophosphates (fenitrothion, malathion, gordona and isofenphos) as grain protectants against *S. oryzae* in wheat was evaluated by Krishnaiah *et al*. (1976). Malathion was evaluated at 0.5, 1, 2, 5, 10, 20 and 30 ppm which were exposed to the adults of *S. oryzae* for 14 days. A cent per cent mortality of adults was obtained after 10 days of exposure to wheat grains treated with 1 and 2 ppm malathion, after 3 days of exposure to wheat grains treated with 5 ppm malathion and after 1 day of exposure to wheat grains treated with 10, 20 and 30 ppm malathion.

Govindrajan *et al.* (1978) evaluated fenvalerate at 0.2 and 0.1 % (w/w) mixed with seeds of green gram. They found that fenvalerate afforded good
protection of green gram against infestation of *C. chinensis* for 12 months.

According to Bengston *et al*. (1979), chlorpyriphos at 10 ppm was effective grain protectant against malathion resistant strains of insect pests of stored grains. Fenvalerate at 2 ppm in combination with piperonyl butoxide at 10 ppm was also effective against stored grain insect pests.

The treatment of cypermethrin (10 and 25 EC), deltamethrin (2.8 EC) and fenvalerate (20 EC) each at 2, 4 and 8 ppm were

proved to be highly effective, whereas malathion was found to be the least effective against stored grain pests infesting wheat (Chahal and Ramzan, 1982).

Salunkhe (1982) tested the effectiveness of seed treatment with 6 insecticides including malathion at 25, 50 and 100 ppm for the control of *T. castaneum* infesting stored sorghum grains. Malathion was found very effective with 100 % mortality from commencement of the experiment till six months of storage even at the lowest level of 25 ppm.

Yadav and Jha (1985) tested the effectiveness of deltamethrin, cypermethrin and permethrin all at 1, 2 and 3 ppm for their persistence on various storage surfaces. Nine test insects including *C. cephalonica* were used to evaluate persistence on storage surfaces as well as on wheat seeds. They reported that deltamethrin at 3 ppm on wheat was found to be the most effective followed by cypermethrin at 3 ppm.

Hamel *et al.* (1986) studied the effectiveness of organophosphorus insecticides including chlorpyriphos and malathion against stored grain insect pests in wheat. Wheat was sprayed with 5 ppm of chlorpyriphos and 10 ppm of malathion. Both the insecticides showed good initial and residual action against the insect pests. Malathion was more effective than chlorpyriphos during 7 months of storage of wheat.

According to Yadav (1986), the treatment of wheat seed with 3 ppm of deltamethrin dust gave effective control of insect pests of stored grains for up to 6 months under rural storage system.

Ramzan and Chahal (1987) evaluated synthetic pyrethroids including cypermethrin, deltamethrin and fenvalerate all at 2, 4 and 8 ppm against *R. dominica* by mixing them with wheat grains. Treated wheat grains were filled in jute bags and placed in a heavily infested room where various storage pests were maintained. At 4 ppm level, cent per cent mortality of *R. dominica* was obtained in all the pyrethroids immediately after treatments but it was maintained at same level one month after treatment only in case of cypermethrin. As the storage period increased, there was a corresponding decreased in mortality in case of all the three pyrethroids. The per cent mortality recorded at one month after treatment was 100, 93 and 81, which reduced to 75, 66 and 63 % at 6 months after treatment at 4 ppm of cypermethrin, fenvalerate and deltamethrin, respectively.

According to Bareth and Gupta (1989), out of 6 insecticides tested in the laboratory against *R. dominica* infesting stored wheat seeds, deltamethrin at 2 ppm was the best followed by 2 ppm fenvalerate, cypermethrin, fenitrothion and chlorpyriphos, as compared to malathion as standard.

Singh and Rai (1991) reported that malathion (50 EC) applied at 10

ppm was effective in controlling *S. oryzae* and *R. dominica* in stored wheat. There was no significant reduction in germination of wheat in all the treatments except control after 2, 4 and 6 months of treatment.

Sattigi *et al.* (1993) evaluated the efficacy of 4 insecticides (malathion and carbaryl at 5, 6 & 16 ppm, fenitrothion and etrimfos at 5 & 8 ppm) against *R. dominica* infesting stored sorghum grains. They found that malathion was most effective against *R. dominica* up to 45 days after treatment followed by fenitrothion at 5 & 8 ppm.

Arthur (1994) studied the bio-efficacy of deltamethrin at 0.5, 0.75 and 1 ppm as grain protectant against *R. dominica* and *S. oryzae* in stored wheat. The results of bioassays conducted at every 2 months interval during storage period of 10 months revealed that deltamethrin residues from applications of 0.5, 0.75 or 1.0 ppm on wheat controlled *R. dominica* for at least 10 months, but an application rate of at least 1.0 ppm was necessary to give equivalent control of *S. oryzae.*

Ghanekar *et al.*, (1996) tested various insecticides (chlorpyrifos, fenvalerate and carbaryl) for their effectiveness against *C. cephalonica*. Fenvalerate at 4 g/kg seed showed quick action and killed all the *Corcyra* eggs within 48 hrs. Fenvalerate and carbaryl were significantly superior to a range of rates of chlorpyrifos up to 180 days after treatment.

Rani (1997) carried out the laboratory tests using populations of rice moth, *Corcyra cephalonica* to measure the effectiveness and stability of deltamethrin in protecting cereals and pulses. Rice bran and rice husk treated with various toxicants were mixed with the food grains and exposed to the rice moth resulting in 100 % mortality. A single application of deltamethrin prevented insect infestation for a period of up to 20 months.

According to Yao and Lo (2000), deltamethrin at 0.75 ppm against *R. dominica* and 1.1 ppm against *S. cerealella* was found effective in rough rice up to 5 months of storage period.

Malathion at 10, 20 & 30 ppm and cypermethrin & fenvalerate both at 5, 10 and 15 ppm were evaluated for their grain protecting efficiency against *C. maculatus* on moth bean by Singh and Yadava (2001). A cent per cent adult mortality was obtained up to 150 days at 10 ppm and up to 180 days at 20 and 30 ppm of malathion. In case of cypermethrin, cent per cent adult mortality was obtained up to 90, 120 and 180 days, respectively at 10, 20 and 30 ppm. While in case of fenvalerate cent per cent adult mortality was obtained up to 60 days at 10 ppm and up to 90 days, both at 20 and 30 ppm.

Huang and Subramanyam (2004) carried out the laboratory bioassay and found that the *C. cephalonica* was highly susceptible to spinosad at 0.5 and 1 mg/kg of corn and sunflower seeds. At both rates of spinosad, reduction in larval survival and egg to adult

emergence relative to the control treatment was ≥ 93% on both corn and sunflower seeds.

Flinn *et al.* (2004) evaluated the effects of a commercial biological insecticide, spinosad at 1 mg a.i. /kg seeds, in suppressing insect populations in stored wheat. They found that no live *T. castaneum* or *C. ferrugineus* and very low densities of *R. dominica* (< 0.008 adult/kg) were found in wheat treated with spinosad during 6 month period. Population of *C. ferrugineus* and *T. castaneum* in aerated bins did not exceed two adults per kilogram, whereas *R. dominica* subsequently decreased to three adults per kilogram in storage condition.

Sharma and Michaelraj (2006) revealed that maize seeds treated with spinosad (@ 0.5, 1.0 or 2.0 mg a.i. /ka) gave complete mortality of 0 to 24 hrs old eggs of *C. cephalonica* for 20 days. Seed damage and progeny production were not evident in treated seeds for 4 months and also protect the seeds from attack of other stored grain pests for longer time.

Kher (2006) evaluated various insecticides (*viz*., deltamethrin, cypermethrin, fipronil, fenvalerate and fenpropathrin) @ 4 ppm and malathion @ 10 ppm as seed treatment for their efficacy as grain protectants against *R. dominica* in wheat. He found that cypermethrin at 4 ppm was more effective and long lasting effect as grain protectant of wheat against *R. dominica*.

Deltamethrin, fipronil and fenvalerate at 4 ppm were next to cypermethrin.

2.3.2 Application on jute bag

Girish *et al.* (1973) studied the efficacy of residual toxicity of malathion on jute bags as grain protectant against *R. dominica*. Malathion (50 % EC) was sprayed on jute bag @ 0.538, 1.076, 1.614 and 2.152 g / m^2 and adult mortality of *R. dominica* was determined after 1 hour, 3, 7, 15 and 30 days of treatment application. The adult mortalities were 38.5, 61.2, 77.5 and 92.8 at 1 hours after treatment, which after 30 days of treatment reduced with per cent loss given in bracket to 1.0 (97.4), 3.0 (95.0), 5.1 (93.4) and 9.2 (90.00), at dosages of 0.538, 1.076, 1.614 and 2.152 g /m^2 respectively. The per cent adult mortality increased as dosage of malathion increased, while the per cent mortality decreased as the interval after spray application increased.

Malathion 50 % EC applied at 0.15 g/m^2 on gunny bags containing wheat grains resulted into 100 % mortality of *R. dominica* adults on surface of bags up to 30 days after treatment application. The average per cent adult mortality of *R. dominica* in grain bags ranged between 30 to 45 % after 15 and 30 days of treatment application at both the godowns (Doharey *et al*., 1981).

Sarkar *et al.* (1984) conducted an experiment to evaluate the efficacy of fenvalerate 20 EC on jute bags for the control of *T. castaneum.* Fenvalerate was applied on jute bags at two dosages,

1.00 and 1.5 g a.i. /m^2 with the help of sprayer. The data on mortality of the test insect on exposure to jute bag surface revealed that both the concentrations of fenvalerate gave 100 % mortality of the test insect up to one month of spraying. After 3 months of storage period, the mortality of test insect decreased to 11.77 % in lower concentration and 18.68 % in higher concentration.

Yadav and Jha (1985) studied the persistence of deltamethrin and cypermethrin applied at 20 mg/m^2 on jute surface. Both the insecticides persisted to produce complete kill of *C. maculatus* after 1/2 month and of *C. chinensis* after 1 month on jute bags. After 10 months, persistence against *S. oryzae* was retained at very high level from deltamethrin. Cypermethrin was found less stable than deltamethrin.

According to Yadav (1986), deltamethrin (K-Othrine) wettable powder at 20 mg/m^2 on jute bags and cement surface persisted up to 120-170 days and gave total kill of eight species of stored product insects including *C. cephalonica.*

Mishra *et al.* (1988) evaluated the toxicity of fenvalerate (at 0.02 and 0.03%) and deltamethrin (at 0.002 and 0.003 %) against larvae of *C. cephalonica*, using malathion at 0.08 and 0.1% for comparison. Mortality was determined at 24, 48, 72 and 96 hour after treatment. Total mortality was recorded for fenvalerate and deltamethrin at the higher rates after 96 hour, as compared with

66.7 % for malathion at the higher rate. Between 48 and 72 hours, deltamethrin was the most effective compound.

Lal *et al*. (1988) carried out experiment with deltamethrin 2.5 % WP (30 mg a.i./m^2) and malathion 50 % EC (0.15 g a.i./m^2) to evaluate their efficacy as surface treatment on jute bags against *R. dominica*. Deltamethrin caused 100 % mortality up to 15 days after treatment which reduced to 80 % after 30 days of treatment. While malathion caused only 70 % mortality after 15 days of treatment which reduced to 50 % after 30 days of treatment. The per cent adult mortalities of *R. dominica* in bags after 30 days of treatment were 50 and 40 %, respectively in deltamethrin and malathion. Thus, deltamethrin was found more effective than malathion as surface treatment on jute bags.

According to Pandey *et al.* (1988), malathion sprayed on jute bags of wheat (0.15 g a.i./m^2) gave cent per cent mortality in *S. oryzae* and *R. dominica* after 15 days of the treatment; while the low mortality was observed in *T. castaneum* and *C. cautella* after 24 hours of treatment at both the depots.

Deltamethrin sprayed @ 20 and 10 mg/m^2 bags of rice and wheat gave protection up to 6 months of storage periods against *T. granarium, S. oryzae* and *R. dominica*. There was total kill of *R. dominica* in 20 mg/m^2 deposit of malathion after 25 and 75 days on bags of rice and 50 days on bags of wheat. At 10 mg/m^2 deposit of

malathion, 90 to 100, 100 and 95 to 100 per cent kill of *R. dominica* were recorded on rice and wheat bags (Yadav, 1988).

Efficacy of deltamethrin at 30 mg a.i./m^2 in comparison with malathion 50 % EC at 150 mg a.i./m^2 was evaluated against the stored grain insect-pests by Lal *et al*. (1989). Both the insecticides were applied on bags of grain and surrounding areas at respective dose. Deltamethrin at 30 mg a.i./m^2 gave cent per cent kill of *R. dominica* up to 135 days after treatment, while malathion 50 EC at 150 mg a.i./m^2 gave cent per cent mortality of *R. dominica* up to 15 days after treatment. In the bags treated with deltamethrin, no alive insect was observed up to 105 days, while it was for 7 days only in case of malathion treated bags. The results clearly indicated that deltamethrin was more effective and had longer residual effect as surface treatment on jute bags against *R. dominica* as compared to malathion.

Yadav and Singh (1994) studied on persistence toxicity and efficacy of four insecticides *viz.,* malathion (25 % WP), deltamethrin (2.5 % WP), chlorpyriphos-methyl (50 % EC) and fluvalinate (20 % EC) as jute bag treatment to protect cereals (wheat, maize and sorghum) against stored grain insect pests. Based on value of gross persistency, malathion retained its full toxicity up to 7, 30 and 60 days at dosage 50, 100 and 150 mg/m^2, respectively. Deltamethrin at 20 mg/m^2 could retain its full toxicity up to 180 days. Deltamethrin 20 mg/m^2, malathion 150 mg/m^2 and chlorpyriphos-

methyl 50 mg/m^2 showed higher protection against the test insects. Malathion at 150 mg/m^2 was persistent on jute bags for sufficient period, but protected the seed up to 1 month. Deltamethrin 20 mg/m^2 was found most effective to protect seeds of wheat and maize up to 6-9 months beside sorghum and chickpea up to 3 months.

According to Yadav (1997), deltamethrin when applied to jute bags prior to the storage of wheat gave excellent protection against *C. cephalonica.* Dwivedi and Kumar (1999) tested synthetic insecticides (fenvalerate, tafethion, monocrotophos and cypermethrin each at 0.10 & 0.25 %) for their ovicidal action against *C. cephalonica*. Fenvalerate at 0.10 % and cypermethrin at 0.25 % led to total failure of hatching. The effects of lower concentrations of these insecticides were not significant as compared to the control.

Shipra and Chatterjee (2001) evaluated the toxicity of spinosad and carbosulfan to fourth instar larvae of *C. cephalonica* through different bioassay methods. Based on LC_{50} values obtained for spinosad, spraying on larvae was a more efficient bioassay technique and could be categorized as highly effective.

Pathak *et al.* (2002) conducted a study to determine the efficacy of storing maize and rice seeds in jute bags and polypropylene bags treated with deltamethrin 20 mg/m^2, chlorpyriphos-methyl 100 mg/m^2 and malathion 150 mg/m^2. Deltamethrin was found most effective in controlling the pests of

stored maize and rice seeds followed by chlorpyriphos-methyl and malathion.

Kher (2006) evaluated deltamethrin, cypermethrin, fipronil, fenvalerate, fenpropathrin and chlorpyriphos, endosulfan, malathion, Nurelle-D 505 EC and Spark 36 EC all at 0.025 % as surface application on/in two types (Hessian and B-twill) of jute bags for their efficacy as grain protectants against *R. dominica* in wheat. He found that deltamethrin at 0.025 % was more effective and long lasting effect as grain protectant of wheat against *R. dominica* when sprayed on/in jute bags as prophylactic treatment. Cypermethrin, fipronil and fenvalerate were next to deltamethrin. B-twill jute bag was found more effective than hessian jute bag for insecticide spray.

2.3.3 Impregnate in jute bag

According to Pali (1960), malathion at 1.0 % concentration gave good protection when impregnated in jute bags for the period of 2 months of storage against *S. oryzae* and *T. castaneum.*

Kuppuswamy and Subramanium (1976) carried out studies on the impregnation of gunny bags with dichlorvos (100 EC), fenitrothion (50 EC), malathion (50 EC) and phoxim (50 EC) by spraying at the rate of 50 and 100 mg a.i./sq. ft. They found that malathion at higher dose was significantly more effective than at lower dose in reducing the percentage of adults penetrating in the bag, oviposition and infestation of *C. chinensis* in red gram.

Chahal and Ramzan (1982) reported that deltamethrin, cypermethrin and fenvalerate each at 0.005 % were most effective as jute bag impregnation against infestation of *R. dominica* during 8 months of storage. They further reported that pyrethroids were significantly better than organophosphate insecticides and deltamethrin was significantly better than all the treatment in giving protection to wheat stored in impregnated bags.

Field trials on the impregnation of gunny bags with synthetic pyrethroids were conducted by Ramzan *et al*. (1987). Based on per cent kernel damage after 6 months of wheat storage, cypermethrin and deltamethrin (at 0.0125 %) were found equally effective but significantly more effective than fenvalerate at 0.0125 % which was more effective than malathion 0.1 %. Deltamethrin at lower dose (0.005 %) was found significantly more effective than higher dose (0.025 %) of cypermethrin and fenpropathrin 0.025 % but was at par with higher dose (0.025 %) of fenvalerate. Malathion 0.1 % was significantly less effective than all the pyrethroids.

Impregnation of gunny bags with malathion at 0.1 per cent failed to give satisfactory protection of stored wheat, whereas all the synthetic pyrethroids (cypermethrin, deltamethrin, fenpropathrin and fenvalerate) at 0.0125 per cent concentration proved significantly better than malathion in stored wheat as reported by Ramzan and Chahal (1987).

Mahla (2001) studied the role of gunny bags dipped in different insecticides including 0.1 % chlorpyriphos and malathion; 0.01 and 0.025 % cypermethrin and fenvalerate; and 0.002 and 0.005 % deltamethrin, for checking insect-pest infestation to the stored wheat grains under natural conditions for 2 years. Based on infested grains on number basis, chlorpyriphos, both doses of fenvalerate and cypermethrin, and higher dose of deltamethrin were found better in comparison to malathion for 9 months.

Patil *et al*. (2004) studied the efficacy of the gunny bag treatment in controlling *R. dominica* infestation on wheat seed during storage. Wheat seeds were stored in gunny bags either surface treated or pre-soaked in deltamethrin (0.0125 %) and malathion (0.5 %). During 9 months of storage, the minimum damage was recorded in the wheat grains stored in gunny bags socked in deltamethrin 0.0125 % solution, while maximum was observed in untreated gunny bags.

Kher (2006) evaluated deltamethrin, cypermethrin, fipronil, fenvalerate, fenpropathrin and chlorpyriphos, endosulfan, malathion, Nurelle-D 505 EC and Spark 36 EC at 0.025 % as impregnation on/in two types (Hessian and B-twill) of jute bags for their efficacy as grain protectants against *R. dominica* in wheat. He found that deltamethrin at 0.025 % was more effective and long lasting effect as grain protectant of wheat against *R. dominica* when impregnated on/in jute bags as prophylactic treatment.

Cypermethrin, fipronil and fenvalerate were next to deltamethrin. B-twill was found more effective than hessian jute bag for insecticide impregnation.

III. MATERIALS AND METHODS

The materials used and methods followed for present investigations on various aspects of *C. cephalonica* are presented here. The study on various aspects of *C. cephalonica* was carried out in the laboratory of Main Forage Research Station, A.A.U., Anand at temperatures ranging from 27 to 30 ^{0}C and 69 to 87 per cent relative humidityduring the year 2008-09.

3.1 Maintenance of culture

Adults collected from the stock culture maintained at Bio-control Research Laboratory, Anand Agricultural University, Anand were used for mass culturing of *C. cephalonica*.

The broken grains of oat were used for mass rearing of the pest. The grains were sterilized by heating at 55º C temperature for four hours in an oven and the moisture content of the grains was adjusted between 14 to 16 per cent by putting the grains in dessicator at high humidity level. The grains of oat were taken separately in wide mouth plastic jars (diameter 15 cm, height 20 cm) upto three fourth level. A few pairs of male and female moths were released in each jar for oviposition. The top of the jars were covered with two fold muslin cloth tied with the help of rubber band. The jars were then kept in an incubator at 32º C, the optimum temperature for the development of pest. The sufficient number of larvae and adults, thus obtained were used to study various aspects on *C. cephalonica.*

For egg collection, moths confined in glass jars were provided folded black paper strips for egg laying. Next day, the strips with eggs were taken out and the eggs were collected with the help of fine camel hair brush.

3.2 Biology of rice moth, *C. cephalonica*

The biology of *C. cephalonica* on oat grains was studied at 27 to 30 ^{0}C temperature and 69 to 87 per cent RH in the laboratory. The detail methodology of various parameters of biology is described here under;

3.2.1 Egg

The freshly laid eggs were examined under microscope for studying their colour, shape and size. The length and breadth of eggs were measured with microscope using stage and ocular micrometer.

For the study of incubation period and hatchability of the eggs, counted numbers of freshly laid eggs were observed daily till hatching. Average incubation period was calculated. The eggs were considered as hatched when larva emerged out from it. Hatching percentage was calculated from the number of eggs hatched out of total number of eggs kept under observation.

3.2.2 Larva

With a view to determine the number and duration of different larval instars and total larval period, newly hatched larvae

were placed individually in specimen tubes (diameter 3.5 cm; length 6.0 cm) containing broken grains with the help of camel hair brush.

In order to determine the number of larval instars, the larvae were observed daily for moulting. The moulting was determined under microscope by the presence of head capsule casted off as well as change in size and colour of larva. The body measurements of different instars were recorded under microscope with the help of stage and ocular micrometers. The total larval period was calculated from the date of hatching of eggs to the date of formation of prepupa.

3.2.3 Prepupa

The prepupal stage was considered when fully-grown larvae stopped feeding and become wrinkled and sluggish. The prepupae were observed critically under microscope for their shape, size and colour. The length and breadth of prepupae were measured using ocular and stage micrometers. The period between formation of prepupa and pupa was considered as prepupal period.

3.2.4 Pupa

Observations on pupae were taken for their colour, size and pupal period. The length and breadth were also measured using ocular and stage micrometer. The pupal period was considered from the date of formation of pupa to the date of adult emergence.

3.2.5 Adult

The newly emerged male and female adults were killed by using insect killing jar. They were pinned, dried and preserved with wing expanded. Such preserved adults were observed under the microscope to study the difference between male and female by observing colour and appearance of adult moth. The size of the adults with wings expanded was measured using millimeter scale.

3.2.5.1 Pre-oviposition, oviposition, post-oviposition and fecundity

The freshly emerged male and female adults were collected from each host commodity and released in plastic jars (diameter 6 cm; height 12 cm) containing respective host commodity. The jars were covered with muslin cloth tied with rubber band. Five per cent honey solution was provided as food every day. The eggs laid by each female on grain and jar surface as well as on muslin cloth were removed and counted daily with the help of moist camel hair brush and total number of eggs laid by each female were recorded. The period between the time of emergence of female and commencing egg laying was considered as pre-oviposition period. Period between starting and ceasing of egg laying was noted as oviposition period. While, period between ceasing of egg laying to the death of female was considered as post-oviposition period.

3.2.5.2 Longevity

Longevity of female and male was observed separately from the date of emergence to the date of adult death.

3.2.5.3 Sex ratio

To study the sex ratio, laboratory reared adults were examined critically to determine male or female and the ratio was calculated by separating male and female on the basis of their morphological characters.

3.2.6 Growth index

The growth index of *C. cephalonica* was calculated for different host commodities using following formula;

$$\text{Growth index} = \frac{\text{Percentage of adult emergence}}{\text{Average developmental period (days)}}$$

The percentage of adult emergence was worked out on the basis of total number of adults emerged out of total number of eggs taken. The period from eggs to adult emergence was considered as developmental period.

3.3 Evaluation of plant products against *C. cephalonica*

In order to evaluate the effectiveness of different plant products against *C. cephalonica* in stored oat, a laboratory experiment was conducted at Main Forage Research Station, A.A.U., Anand following Completely Randomized Design with 10 treatments (Table 3.1) including control and three repetitions. The details of treatments are given as under,

3.3.1 Details of experiment

The leaves/chhal (outer skin) of Neem, Guava, Custard apple, Eucalyptus, Mint, Santra chhal, Lantana, Tamarind and Tulsi

were collected from adjoining areas of Anand. The leaves/chhal dried under shade and thereafter, the dried leaves/chhal were powdered through an electric grinder. The oat grains were sterilized properly in hot air oven at 55º C for a period of four hours and grain moisture of 14 to 16 per cent was restored by water wetting the grains after sterilization. The powder thus obtained was sieved through 100 mesh sieve. Two per cent leaf powders were mixed in oat grains. These treated grains were stored in plastic jars @ 150 gram grains/jar. The opening of jars was covered with fine muslin cloth tied with rubber bands. There were three replications of each treatment including control (without treatment) which was conditioned for 48 hours before release of eggs. Freshly laid fifty eggs of rice moth were kept in each jar. All the jars were kept in the laboratory at room temperature for the development and emergence of adults.

Table 3.1: Details of plant product treatments as oat protectants against *C. cephalonica.*

3.3.2 Method of recording observations

The effectiveness of different treatments were evaluated on the basis of total number of adults emerged, developmental period, growth index and weight loss of grains.

3.3.2.1 A

Sr. No.	Common name	Scientific name	Dose (%) (W/W)
1	Neem leaf powder	*Azardirachta indica A.* Juss	2
2	Guava leaf powder	*Psidium guajava* Linn.	2
3	Custard apple leaf powder	*Annona squamosa* Linn.	2
4	Eucalyptus leaf powder	*Eucalyptus globules* Labill	2
5	Mint leaf powder	*Mentha spicata* Labiatae	2
6	Santra chhal powder	*Citrus sinensis (L.)* Osbeck	2
7	Lantana leaf powder	*Lantana camera* Linn.	2
8	Tamarind leaf powder	*Tamarindus indica*	2
9	Tulsi leaf powder	*Ocimum sanctum* Linn.	2
10	Control	-	-

dult emergence

The number of adults emerged in each jar were recorded daily until ceasing of emergence. The newly emerged adults were removed daily from the jars to avoid further oviposition.

3.3.2.2 Developmental period

The average developmental period of *C. cephalonica* in different

treatments was calculated by multiplying the days (from eggs to adult emergence) with the number of adults emerged on the

respective day and dividing it with the total number of adults emerged in each treatment.

3.3.2.3 Growth index

The per cent adult emergence and mean developmental period was recorded to work out the growth index.

3.3.2.4 Weight loss of grains

The weight loss of grains was worked out as apparent and real weight loss using the following formulae;

a) Apparent weight loss (%) = $\frac{Wa - Wb}{Wa} \times 100$

b) Real weight loss (%) = $\frac{Wa - Wc}{Wa} \times 100$

Where,

Wa = Weight of oat grains before infestation.

Wb = Weight of oat grains after infestation.

Wc = Weight of infested grains after removal of frasses, excreta etc.

3.4 Evaluation of insecticides as grain protectants against *C. cephalonica* infesting oat

Nine different insecticides (Table 3.2) were evaluated for their grain protectant efficacy based on periodical larval mortality of *C. cephalonica* during storage period of 5 months. These insecticides were evaluated as seed treatment and as spray/impregnate on/in jute bags made from Hessian and B-twill cloth. The experiment was conducted in laboratory of Main Forage Research Station, A.A.U., Anand.

3.4.1 Seed treatment

To evaluate the efficacy of different insecticides against *C. cephalonica* in stored oat, the experiment was carried out in the laboratory condition following Completely Randomized Design with 10 treatments including control and three repetitions.

Each insecticide was applied at respective dose to previously sterilized (in oven at 55º C for 4 hours) bulk of 2.5 kg oat grains. Water was used as a carrier for uniform smearing of insecticide on oat grains.

The quantity of water required for uniform smearing of insecticides on all seeds was standardized as it was 12.5 ml per 2.5 kg of seeds. For seed treatment, oat grains (2.5 kg) were spread on plastic sheet. The uniform smearing of insecticidal solution on seeds was established by turning over them repeatedly on plastic sheet. The seeds were dried under fan in well aerated room for 24 hours. The bulk of oat grains (2.5 kg) under each treatment were stored in an airtight plastic jars (Diameter: 8.0 cm and Height: 22.00 cm) at room temperature and utilized for further experimentation.

3.4.1.1 Evaluation based on larval mortality

Experiment was carried out at 15 days interval and three samples of treated oat, each of 50 g (one sample for one repetition) were drawn from each bulk of treatment. The samples were filled in plastic jar (Diameter: 6.0 cm and Height: 10.00 cm) individually. Twenty larvae (two days old) of *C. cephalonica* obtained from

laboratory culture were released in each of the plastic tubes and covered them with a piece of two fold muslin cloth, which was held in position with a rubber band. The observations on number of dead larvae out of 20 larvae were made at 7 and 15 days after release of larvae and per cent larval mortality was work out. The data on per cent mortality were corrected using Abbott's formula (Abbott, 1925).

3.4.2 Application on/in jute bag

The comparative efficacy of various insecticides (Table 3.2) in the form of prophylactic spray application on jute bag and impregnation of jute bag was evaluated against *C. cephalonica* infesting oat grains in storage condition. Simultaneously, two types of jute cloths *viz*; Hessian cloth (11 × 10 mesh) and B-twill cloth (6 × 7 mesh) used in making bags was also evaluated for their grain protecting effectiveness after insecticidal spray/impregnation. For the purpose, an experiment was carried out in laboratory condition following Factorial Completely Randomized Design with 10 treatments including control and three repetitions.

For each treatment, 12 bags (6 of Hessian cloth and 6 of B-twill cloth) each of 15 x 20 cm size were prepared. Out of 12 bags under each insecticidal treatment, 6 bags (3 Hessian cloth bags and 3 B- twill cloth bags) were filled up with previously sterilized 200 gram of oat grains and mouth of each bag was closed properly using jute fibre thread. All the 6 bags were sprayed with respective insecticide using hand sprayer. For each bag about 8-10 ml spray

fluid of insecticide was required for uniform spray application. Under control treatment the bags were sprayed with water without insecticides. The sprayed bags were dried under fan in well aerated room for 24 hours.

Out of 12 bags under each insecticidal treatment, 6 bags (3 Hessian cloth bags and 3 B-twill cloth bags) were impregnated with respective insecticide. For impregnation of insecticides in jute bags, all the 6 empty bags were soaked in 1 liter solution of respective insecticides in water for about 10 minutes and then dried under fan in well aerated room for 24 hours. Under control treatment, the bags were soaked in water only. After impregnation, each bag was filled up with previously sterilized 200 gram oat grains and mouth was closed properly using jute fibre thread.

3.4.2.1 Evaluation based on larval mortality

The jute bags filled up with oat grains and sprayed/impregnated with insecticides as described above were placed individually in plastic bowl (diameter 16 cm, height 7.0 cm) with netted lid. Twenty larvae (two days old) of *C. cephalonica* obtained from laboratory culture were released on bags placed inside the bowl and the bowl was closed with lid. The observations on number of dead larvae (inside or outside of bags) out of total larvae were made at 7 and 15 days after release of larvae. The experiment was repeated at 15 days interval using same bags refilled with fresh and previously sterilized 200 gram oat grain. The

data on per cent larval mortality were computed, corrected using Abbott's formula (Abbott, 1925).

3.5 Method of analysis

Statistical analysis was carried as per standard procedure of ANOVA technique as suggested by Steel and Torrie (1960).

IV. RESULTS AND DISCUSSION

The results of the studies carried out on biology and management through plant products and insecticides as grain protectants against rice moth, *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae) infesting oat (*Avena sativa* Linnaeus) under storage condition are presented herein this chapter. The present results are also discussed in relation to the results of the research done elsewhere and have a direct and indirect relation with the present investigations.

4.1 BIOLOGY OF RICE MOTH, *C. cephalonica* ON OAT

The biology of rice moth was carried out on oat grains under the laboratory conditions at temperatures ranging from 27 to 30 ^{0}C and 69 to 87 per cent relative humidity. Results obtained are presented in the following sub headings.

4.1.1 Egg

4.1.1.1 Colour, shape and size

It was found that the females of rice moth laid their eggs singly on walls, flour, bags as well as on grains in storage. In laboratory condition, they were observed to lay their eggs on the walls of rearing jar, outer surface of muslin cloth and on the grains kept in the rearing jar. The freshly laid eggs when observed under microscope, appeared pearly white, oval in shape with a rough surface. At the time of hatching, the eggs turned yellowish in colour. After hatching, the egg shell appeared transparent. Similar

observations were also reported by Srivastava *et al.* (1983), Subramanyam and Hagstrum (1996) and Patel and Patel (2007).

The eggs laid by the females emerged from the oat grains were measured under microscope and the data are presented in table 4.2. The length of freshly laid eggs ranged from 0.38 to 0.43 mm with an average of 0.40 ± 0.02 mm and the breadth ranged from 0.29 to 0.37 mm with an average of 0.34 ± 0.02 mm.

4.1.1.2 Incubation period

The incubation period (Table 4.1) of the eggs of *C. cephalonica* was ranged from 3 to 6 days with an average of 4.10 ± 1.19 days. The results obtained are in close agreement with earlier reports of Cox *et al*. (1981); Dhanani (1989); Prakash and Senthilkumar (2005) and Patel and Patel (2007).

4.1.1.3 Hatchability

The hatching percentage (Table 4.1) recorded was about 93.00 %. More or less similar results were also reported by Tejani (1989) on sunflower and Patel and Patel (2007) on wheat.

4.1.2 Larva

With a view to study the larval instars and duration of *C. cephalonica*, newly hatched larvae were reared individually up to pupation on separate tube containing oat grains.

During the study, it was observed that the larvae of *C. cephalonica* passed through seven distinct instars reared on the oat grains (Table 4.1). Similarly, Dhanani (1989) also reported seven

distinct instars on sorghum and rice. While, Usman (1968) and Patel and Patel (2007) reported six larval instars for male and seven instars for female on different host commodities. The data on measurements of body length and breadth of each larval instar are presented in table 4.2 as well as durations of various larval instars are summarized in table 4.1.

4.1.2.1 Colour, shape, size and duration

First instar: On hatching, the young larva was creamy white in colour with reddish brown head. The larva had three pairs of true legs on thoracic segments, while each of the third to seventh abdominal segments carried a pair of prolegs. There was characteristic seta above each spiracle arising from a small clear patch of cuticle surrounded by a dark ring of cuticle. The newly hatched larva moved on the grains for about few minutes and start feeding the grains. Hill (1992) and Subramanyam and Hagstrum (1996) were also made similar observations.

The length and breadth of body ranged from 0.61 to 1.03 and 0.19 to 0.20 mm with an average of 0.74 ± 0.15 and 0.20 ± 0.005 mm, respectively (Table 4.2). More or less similar observations were also reported by Rao (1954) and Patel and Patel (2007).

Duration of the first instar was recorded and data are presented in table 4.1. The duration of first instar was 4 to 5 days with an average of 4.54 $\pm$ 0.51 days. Almost similar observations on larval duration were also reported by Patel and Patel (2007).

Table 4.1: Duration (in days) of different stages of *C. cephalonica* in stored oat

Stages	Particulars	Min	Max	Mean ± SD
Egg	Egg	3	6	4.10 ± 1.19
	Hatching %			93.00 %
Larva	1st instar	4	5	4.54 ± 0.51
	2nd instar	4	6	5.10 ± 0.83
	3rd instar	5	7	5.88 ± 0.97
	4th instar	5	7	6.03 ± 0.98
	5th instar	6	7	6.28 ± 0.46
	6th instar	5	8	6.75 ± 0.87
	7th instar	6	8	6.90 ± 0.87
Total		35	48	37.80 ± 0.95
Pupa	Prepupa	1	2	1.48 ± 0.50
	Pupa	7	11	8.43 ± 1.20
Adult				
	Pre oviposition	1	2	1.35 ± 0.49
	Oviposition	4	6	5.47 ± 0.72
	Post oviposition	1	2	1.18 ± 0.39
	Longevity (M)	7	11	8.35 ± 1.11
	Longevity (F)	6	10	7.09 ± 1.41
	Fecundity	109	135	122.22 ± 8.39
Total life span	Male	53	78	62.70 ± 7.80
	Female	58	87	71.50 ± 11.90

Second instar: In general, second instar larvae resembled the first instar larvae except in size. The body colour changed to creamy white with reddish brown head. The data on measurement (Table 4.2) revealed that the body length and breadth ranged from 0.92 to 1.34 and 0.21 to 0.24 mm with an average of 1.24 ± 0.13 and 0.23 ± 0.013 mm, respectively. The present finding also falls in same line with Patel and Patel (2007).

Duration of the second instar larva ranged from 4 to 6 days with an average of 5.10 ± 0.83 days (Table 4.1). The present finding on duration of second instar larvae are in close agreement with the finding of Rao (1954), Dhanani (1989) and Patel and Patel (2007).

Third instar: Third instar larva was the same as the second instar larva in morphology but it was bigger in size. The colour of the body was darken white with reddish brown head.

The average measurement (Table 4.2) of body length and breadth ranged from 2.48 to 2.93 and 0.29 to 0.32 mm with an average of 2.80 ± 0.16 and 0.30 ± 0.010 mm, respectively. Present data on measurement are in close conformity with the observations of Rao (1954) and Patel and Patel (2007).

Duration of the third instar larva (Table 4.1) ranged from 5 to 7 days with an average of 5.88 ± 0.97 days. Almost similar observation on instar duration was reported by Rao (1954) on sorghum and Patel and Patel (2007) on various food grains.

F**ourth instar:** Morphology of fourth instar larva closely resembled to that of third instar but slightly bigger in size. The body of larva was darken white in colour with reddish brown head. Similar observations have been reported by Patel and Patel (2007).

The average measurement (Table 4.2) of body length and breadth of fourth instar ranged from 3.91 to 4.51 and 0.39 to 0.42 mm with an average of 4.45 ± 0.16 and 0.41 ± 0.01 mm, respectively. Present observations are more or less in accordance with the observations of Patel and Patel (2007).

The average duration (Table 4.1) of fourth instar ranged from 5 to 7 days with an average of 6.03 $\pm$ 0.98 days. The observation of instar duration during present study is more or less tally with the observations of Patel and Patel (2007).

Fifth instar: The full-grown fifth instar larva was slightly longer than the fourth instar larvae. The colour of this instar was dirty white with reddish brown head. The five pairs of prolegs were present on 3rd, 4th, 5th, 6th and 10th abdominal segments.

The length of full-grown fifth instar larva ranged from 4.94 to 5.87 mm with an average of 5.66 $\pm$ 0.35 mm, while the breadth ranged from 0.54 to 0.56 mm with an average of 0.55 $\pm$ 0.008 mm (Table 4.1). Rao (1954) reported that the average length of fifth instar larva was 5.05 mm on sorghum while 5.75 $\pm$ 0.27, 5.12 $\pm$ 0.53, 5.66 $\pm$ 0.33 and 5.69 $\pm$ 0.32 mm on sorghum, rice, pearlmillet and wheat, respectively (Patel and Patel, 2007). The duration of fifth

instar larvae varied from 6 to 7 days with an average of 6.28 ± 0.46 days (Table 4.2). Patel and Patel (2007) also reported more or less similar results.

Table 4.2: Measurement of different stages of rice moth, *C. cephalonica* in stored oat

Stages	**Particulars**		Measurements (mm)		
			Min	**Max**	**Mean ± SD**
Egg	Length		0.38	0.43	0.40 ± 0.02
	Breadth		0.29	0.37	0.34 ± 0.02
Larva					
	1st Instar	Length	0.61	1.03	0.74 ± 0.15
		Breadth	0.19	0.20	0.20 ± 0.005
	2nd Instar	Length	0.92	1.34	1.24 ± 0.13
		Breadth	0.21	0.24	0.23 ± 0.013
	3rd Instar	Length	2.48	2.93	2.80 ± 0.16
		Breadth	0.29	0.32	0.30 ± 0.010
	4th Instar	Length	3.91	4.51	4.45 ± 0.16
		Breadth	0.39	0.42	0.41 ± 0.010
	5th Instar	Length	4.94	5.87	5.66 ± 0.35
		Breadth	0.54	0.56	0.55 ± 0.008
	6th Instar	Length	5.57	8.15	7.83 ± 0.62
		Breadth	0.62	0.65	0.64 ± 0.013
	7th Instar	Length	8.51	10.63	9.60 ± 0.61
		Breadth	0.75	0.81	0.77 ± 0.022
Pupa	Pre-pupa	Length	7.48	9.59	8.27 ± 0.79
		Breadth	1.07	1.87	1.41 ± 0.32
	Pupa	Length	7.45	9.30	8.12 ± 0.54
		Breadth	1.19	1.97	1.47 ± 0.31
Adult (Male)	Length		6.30	9.30	7.90 ± 1.10
	Breadth (wing expanded)		13.30	19.40	17.00 ± 2.30
Adult (Female)	Length		7.20	10.20	8.70 ± 1.10
	Breadth (wing expanded)		16.90	21.30	18.80 ± 1.70

Sixth instar: The sixth instar larvae were longer than the fifth instar and dirty white in colour with reddish brown head. The larva had three pairs of thoracic legs and five pairs of abdominal prolegs.

The length and breadth of sixth instar larva ranged from 5.57 to 8.15 and 0.62 to 0.65 mm with an average of 7.83 ± 0.62 and 0.64 ± 0.013 mm, respectively (Table 4.1). Rao (1954) and Patel and Patel (2007) reported that average length of sixth instar larva was 7.91 ± 0.63, 7.40 ± 0.72, 7.80 ± 0.62 and 7.85 ± 0.63 mm on various food grains which is more or less similar to the present investigations. The duration of sixth instar larvae varied from 5 to 8 days with an average of 6.75 ± 0.87 days (Table 4.2). Rao (1954) reported that it was 4.9 days on sorghum, 6.72 and 8.02 days on sorghum and rice, respectively (Dhanani, 1989). Whereas, Patel and Patel (2007) reported that it was 5.75, 7.81, 7.33 and 6.78 days on various food grains. These reports fall in the same line with present findings.

Seventh instar: The seventh instar larva was full grown and it was uniform in shape. The larva was dirty white in colour with reddish brown head and bigger in size than the sixth instar larva. The seventh instar larva had also three pairs of thoracic legs and five pairs of abdominal prolegs.

The length of seventh instar larva ranged from 8.51 to 10.63 mm with an average of 9.60 ± 0.61, while the breadth ranged from

0.75 to 0.81 mm with an average of 0.77 ± 0.022 mm. Rao (1954) reported that the seventh instar larva was 8.11 mm long on sorghum while it was 9.88 ± 0.48, 8.75 ± 0.59, 9.08 ± 0.63 and 9.24 ± 0.77 mm on various food grains (Patel and Patel, 2007).

The duration of seventh instar larvae varied from 6 to 8 days with an average of 6.90 ± 0.87 days (Table 4.2). More or less similar duration of seventh instar larva was reported by Rao (1954) on sorghum (5.30 days), by Dhanani (1989) on sorghum and rice (6.72 and 8.17 days, respectively) and Patel and Patel (2007) on rice (8.09 days), pearlmillet (7.61 days) and wheat (6.93 days).

4.1.2.2 Total larval period:

The total larval duration (Table 4.1) ranged from 35 to 48 days with an average of 37.80 ± 0.95 days. More or less similar total larval period was also reported by Rao *et al*. (1980) on sorghum; Dhanani (1989) on rice and Patel and Patel (2007) on various food grains.

4.1.3 Prepupa

When the larva became full grown, it reached to prepupal stage. Prepupa was formed in a white delicate silken cocoon inside the webbing. The colour of prepupa was dirty white.

The prerpupa measured from 7.48 to 9.59 mm with an average of 8.27 ± 0.79 mm in length and 1.07 to 1.87 mm with an average of 1.41 ± 0.32 mm in breadth. The duration (Table 4.1) of pre pupal period ranged from 1 to 2 days with an average of 1.48 ±

0.50 days. Earlier, Dhanani (1989) reported prepupal period of 1 to 2 days with an average of 1.38 and 1.43 days on sorghum and rice, respectively, while it was 1.23, 1.74, 1.61 and 1.49 days on various food grains (Patel and Patel, 2007).

4.1.4 Pupa

4.1.4.1 Colour, shape, size and duration

The pupation took place in silken cocoon near the wall or side of the plastic jars/tubes under laboratory conditions. The cocoon was thinner but stronger and more closely woven. The pupa was leathery brown coloured. Similar description of pupa was also reported by Subramanyam and Hagstrum (1996) and Patel and Patel (2007).

The average length (Table 4.2) of pupae ranged from 7.45 to 9.30 mm with an average of 8.12 ± 0.54 mm, while breadth of pupa ranged from 1.19 to 1.97 mm with an average of 1.47 ± 0.31 mm. Subramanyam and Hagstrum (1996) also reported that the average length of pupa was 8.00 mm, while it was 8.44 ± 0.84, 7.42 ± 0.61, 7.97 ± 0.81 and 8.14 ± 0.65 mm on sorghum, rice, pearlmillet and wheat, respectively (Patel and Patel, 2007), which are more or less similar to the present findings.

The duration (Table 4.1) of pupal period ranged from 7 to 11 days with an average of 8.43 ± 1.20 days. The average pupal period reported by Rao *et al.* (1980) was 7.8 days on sorghum and 10.2

days on rice and 7.9 to 14.4 days on sorghum (Shazli and Smith, 1986). As reported by Dhanani (1989), the pupal period was 9.75 days on sorghum and 10.45 days on rice, whereas it was 8.40, 10.58, 9.08 and 8.43 days on sorghum, rice, pearlmillet and wheat, respectively (Patel and Patel, 2007). Thus, the results obtained through present investigations are more or less tally with the results of earlier workers. The average pupal mortality was 3.09 per cent, which was more or less similar to the report of Dhanani (1989) on sorghum and rice and Patel and Patel (2007) on sorghum, wheat, pearlmillet and rice.

4.1.5 Adult

4.1.5.1 Colour and appearance

The moths of both the sexes were pale grayish brown in colour. At emergence, the wings were found folded or unexpanded, which did not cover the entire abdomen. The newly emerged adults moved for sometimes and then gradually expanded the wings to its normal size. The wings were uniformly dark grey in colour, sometimes streaked with darker lines along the veins. Morphologically, both male and female moths were closely resembled to each other except the labial palp which was blunt and inconspicuous in male, while long, pointed and straight forward in female. Similar characters of adult moth were also described by Ayyar (1934), Subramanyam and Hagstrum (1996) and Patel and Patel (2007).

4.1.5.2 Measurements

The length of male moth ranged from 6.30 to 9.30 mm with an average of 7.90 ± 1.10 mm and breadth across the expanded wings of male moth ranged from 13.30 to 19.40 mm with an average of 17.00 ± 2.30 mm. In case of female, body length ranged from 7.20 to 10.20 mm with an average of 8.70 ± 1.10 mm, whereas, the body breadth across the expanded wings ranged from 16.90 to 21.30 mm with an average of 18.80 ± 1.70 mm (Table 4.2). Thus, the data clearly indicated that the female moth was bigger than male. Rao (1954) reported that male moth of *C. cephalonica* had wing expansion of 13 to 18 mm and body length of 6.5 to 9.5 mm, whereas the female had 15 to 21 mm wing expansion and 7.5 to 10.5 mm body length. According to Subramanyam and Hagstrum (1996), *C. cephalonica* had a wing span of 17 mm in male and 18 mm in female. Patel and Patel (2007) observed that the male moth of *C. cephalonica* had an average wing span of 17.9 $\pm$ 1.7, 17.2 $\pm$ 2.1, 16.7 $\pm$ 2.3 and 15.6 $\pm$ 2.5 mm and an average body length of 8.4 $\pm$ 1.1, 8.2 $\pm$ 1.4, 7.8 $\pm$ 1.2 and 7.6 $\pm$ 1.3 mm, whereas the female had an average 19.5 $\pm$ 1.6, 19.0 $\pm$ 1.7, 18.9 $\pm$ 1.6 and 18.7 $\pm$ 1.8 mm wing span and 9.1 $\pm$ 0.9, 8.8 $\pm$ 1.0, 8.6 $\pm$ 1.0 and 8.6 $\pm$ 1.1 mm body length on sorghum, wheat, pearmillet and rice, respectively.

4.1.5.3 Pre-oviposition, oviposition and post-oviposition period

The pre-oviposition, oviposition and post-oviposition periods (Table 4.1) varied from 1 to 2, 4 to 6 and 1 to 2 days with an average of 1.35 ± 0.49, 5.47 ± 0.72 and 1.18 ± 0.39 days, respectively. More or less similar observations were also reported by Pajni *et al*. (1979) on cereals, Chakraborty and Das (1983) on sorghum, Dhanani (1989) on sorghum and rice, and Patel and Patel (2007) on sorghum, wheat, pearmillet and rice.

4.1.5.4 Longevity

The longevity of male and female moths (Table 4.1) ranged from 7 to 11 and 6 to 10 days with an average of 8.35 ± 1.11 and 7.09 ± 1.41 days, respectively. The longevity of adults was recorded as 8.3 days for male on sorghum (Shazli and Smith, 1986); 9.1 days for male and 8.3 days for female on wheat (Etman *et al*., 1988); 9.9 days for male and 7.8 days for female on sorghum and 9.2 days for male and 7.0 days for female on rice (Dhanani, 1989); 12.9 days for male and 8.1 days for female on rice (Chen and Peng, 1998); 8.18 and 8.72 days for male and 7.43 and 7.86 days for female on wheat and pearlmillet, respectively (Patel and Patel, 2007). Thus, the observations made in the present study also fall in the same line with the findings of earlier workers.

4.1.5.5 Fecundity

The female moth laid 109 to 135 (Av. 122.22 ± 8.39) eggs in its entire life span (Table 4.1). The fecundity of rice moth was recorded as 111.2 eggs on wheat (Kumar and Krishna, 1991);

127.14, 125.86 and 112.93 eggs on sorghum, wheat and pearlmillet, respectively (Patel and Patel, 2007).

4.1.5.6 Sex ratio

The adults emerged from oat seeds were identified as male and female on the basis of morphological characters and sex ratio was worked out. The data revealed that the sex ratio was recorded as 1 : 1.08. The sex ratio of *C. cephalonica* recorded was 1 : 1, on wheat by Kamel and Hassanein (1969); 1 : 1.19 on sorghum and 1 : 1.04 on rice (Dhanani, 1989); 1 : 1 on rice by Chen and Peng (1998) and from 1 : 1.10 to 1 : 1.22 on different commodities by Patel and Patel (2007). Thus, the results are in close agreement with previous workers.

4.1.6 Survival percentage and growth index (Table 4.3)

The survival percentage of *C. cephalonica* was 80 when reared on oat seeds. The mean developmental period of the moth was 60.20 days and growth index was 1.33 on host seeds. The survival percentage of *C. cephalonica* recorded was 80 and growth index was 1.44 on sorghum by Dhanani (1989)

Table 4.3: Survival per cent, developmental period and growth index of rice moth, *C. cephalonica* on oat grains.

No. of individuals observed	No. of adults survived	Survival % (S)	Mean Developmental period (D) days	Growth Index (S/D)
50	40	80	60.20	1.33

and 82 to 70 survival percentage and 1.01 to 1.62 growth index on different host commodities as reported by Patel and Patel (2007). Thus, the present findings are in closer with the results of previous workers.

4.1.7 Entire life span

The results on entire life span from eggs to death of adults were recorded and summarized in table 4.1. The data clearly indicated that the entire life span of the male varied from 53 to 78 days with an average of 62.70 ± 7.80 days while that of the female varied from 58 to 87 days with an average of 71.50 ± 11.90 days. The total life span observed during present study is more or less tally with that reported by Dhanani (1989) on rice and Patel and Patel (2007) on sorghum, wheat, rice and pearlmillet.

4.2 EVALUATION OF DIFFERENT PLANT PRODUCTS AS GRAIN PROTECTANTS

Powders of various plant products *viz*., leaves of neem, guava, custard apple, eucalyptus, mint, lantana, tamarind and pongamia and chhal of santra at 2.00 % were tested for their grain protecting efficacy against *C. cephalonica* in laboratory conditions on oat grains. The grain protecting value of various plant products was evaluated based on their effect on adult mortality, half-life and gross persistency and population growth.

4.2.1 Adult emergence

The data on total number of adults emerged in different treatments are presented in table 4.4 and graphically illustrated in Fig. 1

The results indicated that among various treatments, minimum numbers of adults were emerged in the treatment of neem leaf powder (18.95) which was at par with eucalyptus leaf powder (20.94). The treatment of custard apple leaf powder was at par on one side with eucalyptus leaf powder and on other side with mint leaf powder. Similarly, tulsi leaf powder was at par on one side with santra chhal powder and on other side with lantana and guava leaf powders. Maximum adults were emerged out from control. The order of effectiveness of treatments on the basis of adult emergence was powders of neem leaf (18.95) > eucalyptus leaf (20.94) > custard apple leaf (23.31) > mint leaf (25.31) > santra chhal (29.97) > tulsi leaf (33.02) > lantana leaf (36.71) > guava leaf (36.95) > tamarind leaf (39.32) > control (40.59).

4.2.2 Developmental period

From table 4.4 and Fig. 1, it can be seen that mean developmental period of *C. cephalonica* varied from 52.33 to 65.00 days in various treatments. The longest developmental period was found in the neem leaf powder (65.00 days) and it was at par with eucalyptus (63.33 days), custard apple (59.32 days) and mint (58.67 days) leaf powders. The leaf powders of tamarind, guava, lantana,

tulsi and santra chhal powder were recorded shorter developmental period ranging from 53.31 to 57.31 days than rest of the

Table 4.4: Effect of various plant products on emergence of adults, mean developmental period and growth index of *C. cephalonica* in stored oat

Sr. No.	Treatments	Dose (%)	No. of eggs released	Average No. of adults emerged	Mean develop-mental period (Days)	Average growth index
1.	Neem leaf powder	2	50	4.41 (18.95)	65.00	0.51
2.	Guava leaf powder	2	50	6.12 (36.95)	54.34	1.30
3.	Custard apple leaf powder	2	50	4.88 (23.31)	59.32	0.90
4.	Eucalyptus leaf powder	2	50	4.63 (20.94)	63.33	0.59
5.	Mint leaf powder	2	50	5.08 (25.31)	58.67	0.97
6.	Santra chhal powder	2	50	5.52 (29.97)	57.31	1.03
7.	Lantana leaf powder	2	50	6.10 (36.71)	54.67	1.24
8.	Tamarind leaf powder	2	50	6.31 (39.32)	53.31	1.43
9.	Tulsi leaf powder	2	50	5.79 (33.02)	56.00	1.13
10.	Control	-	50	6.41 (40.59)	52.33	1.70
	S. Em. ±			0.12	1.34	0.04
	C.D. at 5 %			0.35	3.94	0.17
	C.V. %			3.71	4.03	6.30

Note: Means in parentheses are retransformed values, those outside are transformed values.

treatments and proved less effective in increasing the developmental period of the pest. Thus, on the basis of developmental period, the leaf powders of neem, eucalyptus and custard apple proved most effective than the other plant products.

4.2.3 Growth index

Statistical analysis of the data on growth index (table 4.4) indicated that all the treatments were significantly superior to control in reducing the growth of the pest. Among the various treatments, neem leaf powder recorded the lowest growth index (0.51) which was at par with eucalyptus leaf powder (0.59). Mint leaf (0.97) and santra chhal (1.03) powders were at par with each other as well as on one side with custard apple leaf powder (0.90) and on other side with tulsi leaf powders (1.13). However, tulsi leaf powder was at par with lantana (1.24) and guava (1.30) leaf powders. The order of effectiveness on the basis of growth index was powders of neem leaf (0.51) > eucalyptus leaf (0.59) > custard apple leaf (0.90) > mint leaf (0.97) > santra chhal (1.03) > tulsi leaf (1.13) > lantana leaf (1.24) > guava leaf (1.30) > tamarind leaf (1.43) > control (1.70).

4.2.4 Weight loss of grains

The weight loss of grains was calculated as apparent and real weight loss. The data are presented in Table 4.5 and graphically depicted in Fig. 2.

The data on apparent weight loss (Table 4.5 and Fig. 2) indicated that all the treatments were significantly superior to control in preventing weight loss of grains. Among the various treatments, minimum per cent of apparent weight loss was observed in neem leaf powder (4.41) and it was statistically at par with eucalyptus leaf powder (4.84). Next effective treatment was custard apple leaf powder (6.08). Santra chhal powder (7.21) and tulsi leaf powder (7.43) were at par with each other as well as on one side with mint leaf powder (6.82) and with lantana leaf powder (7.92) on other side. However, lantana leaf powder was also at par with guava leaf powder (8.25). Tamarind leaf powder (9.13) was found least effective against rice moth.

Statistical analysis of the data on per cent real weight loss of grain (Table 4.5 and Fig. 2) indicated that all the treatments were significantly superior to control. The lowest real weight loss of grain (7.65) was recorded in neem leaf powder treatment which was significantly superior to rest of the treatments. The leaf powders of eucalyptus (9.60) and custard apple (12.60) were next to neem leaf powder in effectiveness. Santra chhal powder was at par on one side with mint leaf powder and on other side with tulsi leaf powder. The leaf powders of lantana, guava and tamarind were at par with each other. The order of effectiveness was powders of neem leaf > eucalyptus leaf > custard apple leaf > mint leaf > santra chhal > tulsi leaf > lantana leaf > guava leaf > tamarind leaf > control.

Thus, it can be concluded from the present laboratory study that the leaf powders of neem (*Azadirachta indica*), eucalyptus (*Eucalyptus globulus*) and custard apple (*Annona squamosa*) @ 2.00 per cent mixed with the oat grains were the most effective in controlling *C. cephalonica* infestation and reducing the weight losses in stored oat. The treatments of mint (*Mentha spicata*) leaf

Table 4.5: Effect of various plant products on weight loss of oat grains due to *C. cephalonica*

Sr. No.	Treatments	Dose (%)	Average weight loss (%)	
			Apparent	Real
1.	Neem leaf powder	2	12.62 (4.41)	16.56 (7.65)
2.	Guava leaf powder	2	17.19 (8.25)	25.92 (18.43)
3.	Custard apple leaf powder	2	14.78 (6.08)	21.29 (12.60)
4.	Eucalyptus leaf powder	2	13.21 (4.84)	18.55 (9.60)
5.	Mint leaf powder	2	15.64 (6.82)	22.50 (14.03)
6.	Santra chhal powder	2	16.08 (7.21)	22.94 (14.57)
7.	Lantana leaf powder	2	16.85 (7.92)	25.13 (17.37)
8.	Tamarind leaf powder	2	18.09 (9.13)	25.95 (18.47)
9.	Tulsi leaf powder	2	16.32 (7.43)	23.95 (15.84)
10.	Control	-	19.76 (10.88)	29.01

				(22.78)
	S. Em. ±		0.29	0.35
	C.D. at 5 %		0.84	1.04
	C.V. %		3.08	2.62

Note: Means in parentheses are retransformed values, those outside are arc sin transformed values

powder, santra (*Citrus sinensis*) chhal powder and tulsi (*Ocimum sanctum*) leaf powder were moderately effective, while those leaf powders of lantana (*Lantana camara*), guava (*Psidium guajava*) and tamarind (*Tamarindus indica*) were found less effective.

In past, neem products were tested by Pandey *et al.* (1985) against *C. cephalonica* and reported it to be effective in preventing the infestation of the pest. Mixing of neem leaf powder @ 2.00 per cent was found to reduce the larval and adult population and proved effective (Prusty *et al*., 1989). Sengutuvan *et al*. (1995) reported that neem leaf powder @ 2.00 per cent was most effective against *C. cephalonica* in stored groundnut. Modgil and Samuels (1997) observed that eucalyptus and mint leaves powder @ 2 per cent were able to protect stored wheat against *C. cephalonica* in different storage structures for 6 months. Patel and Patel (2002) reported that mixing of neem and eucalyptus leaf powders at 2 % was highly effective against *C. cephalonica* in stored rice. Meena and Bhargava (2005) found that the leaf powders of neem, mint and

tulsi @ 1.0, 2.5 and 5.0 per cent adversely affect on the fecundity, egg viability and longevity of adults of *C. cephalonica*. Thus, present findings fall in the same line with the findings of the above cited workers.

4.3 EVALUATION OF INSECTICIDES AS GRAIN PROTECTANTS

Nine different insecticides were evaluated as seed treatment as well as surface application and impregnation on/in two types of jute bags (Hessian and B-twill cloth bags) for their grain protectant efficacy against *C. cephalonica*.

4.3.1 Seed treatment

The insecticides have been evaluated based on periodical larval mortality of *C. cephalonica* up to five months of storage periods. The data on periodical per cent larval mortality are presented in Table 4.6, depicted graphically in Figure 3 and discussed hereunder.

All the insecticides recorded 99.90 % mortality after 7, 15, 30 and 45 days of storage (DOS) and as such there was no significant difference among them indicating that they were equally effective as seed grain protectant against *C. cephalonica* up to 45 DOS.

After 60 DOS, deltamethrin, cypermethrin and chlorpyriphos recorded maximum (99.90 per cent) larval mortality and were at par with each other as well as with endosulfan, spinosad, fipronil and fenpropathrin. However, fenpropathrin was at par with fenvalerate.

Malathion was found less effective. The chronological order of effectiveness of insecticides based on per cent larval mortality was deltamethrin (99.90 %) = cypermethrin (99.90 %) = chlorpyriphos (99.90 %) > endosulfan (99.01 %) = spinosad (99.01 %) > fipronil (98.93 %) > fenvalerate (98.20 %) > fenpropathrin (92.84 %) > malathion (90.70 %).

After 75 DOS, deltamethrin and cypermethrin recorded higher larval mortality and were at par with chlorpyriphos, fipronil, fenvalerate, spinosad and endosulfan. However, fenpropathrin was at par with fipronil, fenvalerate, spinosad and endosulfan. The order of effectiveness of various insecticides was deltamethrin (99.90 %) = cypermethrin (99.90 %) > chlorpyriphos (98.36 %) > fenvalerate (97.25 %) = spinosad (97.25 %) > fipronil (97.20 %) > endosulfan (96.10 %) > fenpropathrin (89.54 %) > malathion (84.75 %).

The analysis of the data on per cent larval mortality after 90 DOS showed that deltamethrin recorded maximum larval mortality (99.24 %) and it was at par with cypermethrin (98.30 %). However, spinosad was at par on one side cypermethrin and on another side with fenvalerate and fipronil. Similarly, fenvalerate and fipronil were at par with chlorpyriphos and fenpropathrin. Fenpropathrin and endosulfan were at par with each other as well as on one side with fipronil and chlorpyriphos and with malathion on other side. The order of efficacy of various insecticides was deltamethrin (99.24 %) > cypermethrin (98.30 %) > spinosad (93.99 %) > fenvalerate

(90.20 %) > fipronil (88.50 %) > chlorpyriphos (86.09 %) > fenpropathrin (82.45%) > endosulfan (80.55 %) > malathion (74.56 %).

After 105 DOS of oat, maximum larval mortality was found in deltamethrin and it was at par with cypermethrin and both were significantly superior to rest of the treatments. Spinosad, fipronil, fenvalerate, fenpropathrin, chlorpyriphos and malathion were at par with each other. However, fenvalerate, fenpropathrin, chlorpyriphos and malathion were at par with endosulfan. The chronological order of insecticides based on larval mortality was deltamethrin (98.12 %) > cypermethrin (96.86 %) > spinosad (83.82 %) > fipronil (82.33 %) > fenvalerate (80.99 %) > fenpropathrin (76.33 %) > chlorpyriphos (75.62 %) > malathion (70.89 %) > endosulfan (63.85 %).

After 120 DOS, deltamethrin exhibited maximum larval mortality and it was statistically at par with cypermethrin and found superior to rest of the treatments. Fenvalerate, spinosad, fipronil and fenpropathrin were at par with each other. However, fipronil and fenpropathrin were also at par with malathion and chlorpyriphos. Fenpropathrin, malathion and chlorpyriphos were again at par with endosulfan. The order of efficacy of various insecticides was deltamethrin (96.27 %) > cypermethrin (95.17 %) > fenvalerate (79.05 %) > spinosad (77.32 %) > fipronil (72.42 %) > fenpropathrin (70.38 %) > malathion (60.45 %) > chlorpyriphos (60.36 %) > endosulfan (56.34 %).

After 135 DOS of oat, cypermethrin exhibited maximum larval mortality and it was statistically at par with deltamethrin and found superior to rest of the treatments. Spinosad, fenvalerate, fipronil and fenpropathrin were again at par with each other. However, malathion and chlorpyriphos were at par with each other as well as on one side with fenvalerate, fipronil and fenpropathrin and on another side with endosulfan. The order for the grain protecting efficacy with per cent larval mortality obtained was cypermethrin (93.30 %) > deltamethrin (92.08 %) > spinosad (74.64 %) > fenvalerate (61.06 %) > fipronil (60.98 %) > fenpropathrin (60.77 %) > malathion (48.26 %) > chlorpyriphos (47.82 %) > endosulfan (37.57 %).

The analysis of data on larval mortality after 150 days of treatment showed that cypermethrin and deltamethrin were at par with each other and found significantly superior to rest of the treatments. Spinosad was found next effective insecticide. Fenvalerate was at par on one side with fipronil and fenpropathrin and on other side with malathion and chlorpyriphos. However, endosulfan was also at par with malathion and chlorpyriphos. The order of efficacy of various insecticides was cypermethrin (88.69 %) > deltamethrin (87.46 %) > spinosad (66.38 %) > fipronil (53.12 %) > fenpropathrin (52.97 %) > fenvalerate (44.34 %) > malathion (36.18 %) > chlorpyriphos (35.46 %) > endosulfan (28.55 %).

✍.....*Results & Discussion*

The analysis of data on larval mortality pooled over period revealed that maximum larval mortality was found in the treatment of deltamethrin and it was at par with cypermethrin and spinosad. However, spinosad was at par with fipronil, fenvalerate, chlorpyriphos and fenpropathrin. Malathion recorded minimum larval mortality. The source 'period' was also significant indicating that there was significant difference among mean mortalities obtained at different period which was because of decrease in efficacy of all insecticides as period of storage increased. The interaction (treatment x period) was also significant indicating inconsistence performance of insecticides at different period of storage of oat. The order of efficacy of various insecticides based on pooled data on larval mortality was deltamethrin (98.70 %) > cypermethrin (98.56 %) > spinosad (94.11 %) > fipronil (91.98 %) > fenvalerate (91.83 %) > chlorpyriphos (89.63 %) > fenpropathrin (89.25 %) > endosulfan (86.20 %) > malathion (85.19 %).

Various scientists have evaluated different insecticides at different doses for their grain protecting efficiency against different store grain insect-

TABLE 4.6

pests during storage period. At 8 ppm of malathion, the per cent mortality of *S. oryzae* was 100 % up to 2 months of storage, which reduced to 12 % after 12 months of storage of maize. At same dose of malathion, the per cent mortality was 90 % up to 2 months of storage which reduced to 5 % after 12 months of storage of sorghum (Weaving, 1975). A cent per cent mortality of *S. oryzae* adults was obtained after 10 days of exposure to wheat grain treated with 1-2 ppm malathion; after 3 days with 5 ppm malathion and after one day with 10-30 ppm malathion (Krishnaiah *et al*., 1976). Malathion at 25 ppm resulted into 100 % mortality of *T. castaneum* till 6 months in stored sorghum grains (Salunkhe, 1982). Deltamethrin and cypermethrin mixed at 1, 2 and 3 ppm with wheat seeds resulted into 100 % kill of adults of *R. dominica* after one month of storage period (Yadav and Jha, 1985). The per cent mortality of 100, 93 and 81 was recorded one month after storage of wheat grains treated with cypermethrin, fenvalerate and deltamethrin (all at 4 ppm), which reduced to 75, 66 and 63 % after 6 months of treatment, respectively during storage period. Cypermethrin was found more effective followed by fenvalerate and deltamethrin as grain protectant of wheat grain against *R. dominica* (Ramzan and Chahal, 1987). A cent per cent adult mortality of *C. chinensis* up to 150 days was obtained on moth bean treated with malathion at 10 ppm, while cypermethrin and fenvalerate at 10 ppm resulted into cent per cent mortality up to 90 and 60 days,

respectively (Singh and Yadava, 2001). Spinosad at 0.5 and 1 mg/kg of corn and sunflower seeds against *C. cephalonica*, reduced the larval survival, egg to adult emergence and seed damage relative to the control treatment was ≥ 93 % (Huang and Subramanyam, 2004). No live *T. castaneum* and *C. ferrugineus* and very low densities of *R. dominica* (< 0.008 adults per kg) were found in wheat treated with spinosad at 1 mg a.i. /kg seeds during the 6-month of period (Flinn *et al*., 2004). The maize seeds treated with spinosad (@ 0.5, 1.0 or 2.0 mg a.i. /kg) gave complete mortality of 0 to 24 hrs old eggs of *C. cephalonica* for 20 days (Sharma and Michaelraj, 2006). Cypermethrin at 4 ppm was more effective and had long lasting effect as grain protectant of wheat against *R. dominica*. Deltamethrin, fipronil and fenvalerate at 4 ppm were next to cypermethrin (Kher, 2006).

4.3.2 **Application on/in jute bags sprayed/impregnated with insecticides**

The insecticides evaluated as seed treatment were further evaluated for their efficacy as prophylactic spray and impregnation on/in two types of jute bag (Hessian and B-twill). The efficacy of insecticides, method of application and types of jute bag were evaluated based on periodical larval mortality of *C. cephalonica* up to five months of storage periods.

The analysis of data on per cent larval mortality of *C. cephalonica* after 7 DOS (Table 4.7) revealed that deltamethrin

and spinosad both recorded highest larval mortality and were at par with cypermethrin and fipronil. However, fenvalerate was at par on one side with cypermethrin and fipronil and on other side with fenpropathrin, chlorpyriphos, endosulfan and malathion. There was a significant difference between two types of bags. B-twill jute bag (86.01 %) recorded higher mean mortality and was more effective than Hessian jute bag (84.42 %). Method of insecticidal application

Table 4.7: Bio efficacy of various insecticides against *C. cephalonica* after 7 days of stored oat grains

Insecticides (all at 0.025 %)	**Corrected per cent larval mortality**						
	Methods of insecticide application and type of jute bags						**Mean**
	Spray			**Impregnation**			
	Hessian cloth	**B-twill cloth**	**Mean**	**Hessian cloth**	**B-twill cloth**	**Mean**	
Deltamethrin	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)
Cypermethrin	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	85.64 (99.28)	87.16 (99.66)	87.92 (99.80)
Fenvalerate	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	84.57 (98.93)	76.61 (94.24)	80.59 (97.04)	84.64 (98.96)
Malathion	72.96 (90.92)	84.69 (98.98)	78.83 (95.91)	79.35 (96.26)	88.68 (99.90)	84.02 (98.73)	81.42 (97.51)
Chlorpyriphos	84.69 (98.98)	80.68 (97.09)	82.69 (98.15)	78.78 (95.87)	84.69 (98.98)	81.74 (97.68)	82.21 (97.92)
Endosulfan	74.44 (92.35)	79.34 (96.25)	76.89 (94.464)	84.69 (98.98)	88.68 (99.90)	86.69 (99.56)	81.79 (97.71)
Fipronil	84.86 (99.03)	88.68 (99.90)	86.77 (99.58)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	87.73 (99.77)
Fenpropathrin	88.68 (99.90)	84.80 (99.01)	86.74 (99.57)	77.02 (94..57)	84.80 (99.01)	80.91 (97.22)	83.82 (98.65)
Spinosad	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)
Two way table	Type of bags		Methods of application				Mean
			Spray		Impregnation		
	Hessian cloth		84.48 (98.90)		84.35 (98.85)		84.42 (98.88)
	B-twill cloth		85.88 (99.35)		86.13 (99.42)		86.01 (99.39)
	Mean		85.18 (99.14)		85.24 (99.16)		85.22 (99.15)
	Source		S. Em ±		CD at 5 %		

ANOVA	Treatment (T)	1.20 0.54	3.38 NS
	Method (M)	0.54	1.47
	Bag (B)	1.70	NS
	T x M	0.76	NS
	M x B	1.70	NS
	T x B	2.40	NS
	T x M x B		
	CV %	5.41	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values

2. Means with letter(s) in common do not differ significantly in respective column.

3. NS: Not significant

did not differ significantly from each other. Performance of method did not vary with the type of bags and vice versa as interaction (method x bag) was not significant. Performance of insecticides did not vary in two types of methods as well as two types of bags. The chronological order of effectiveness of insecticides based on per cent larval mortality was deltamethrin (99.90 %) = spinosad (99.90 %) > cypermethrin (99.80 %) > fipronil (99.77 %) > fenvalerate (98.96 %) > fenpropathrin (98.65 %) > chlorpyriphos (97.92 %) > endosulfan (97.71 %) > malathion (97.51 %).

There was significant difference among various treatments after 15 DOS (Table 4.8). Deltamethrin, spinosad and cypermethrin were at par with each other and found significantly superior to rest of the insecticides. Fipronil and fenvalerate were next effective insecticides. Fenpropathrin, chlorpyriphos and endosulfan were at par with each other. Malathion was found significantly least effective treatment. There was no significant difference between two types of methods and bags. Treatment performance was inconsistent with type of bags as well with type of methods. Performance of methods did not vary with type of bags and vice versa. The order of effectiveness of various insecticides was deltamethrin (97.50 %) > cypermethrin (97.18 %) > spinosad (97.16 %) > fipronil (95.85 %) > fenvalerate (93.50 %) > fenpropathrin (91.37 %) > chlorpyriphos (91.08 %) > endosulfan (91.03 %) > malathion (88.79 %).

Table 4.8: Bio efficacy of various insecticides against *C. cephalonica* after 15 days of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	71.90 (89.83)	88.68 (99.90)	80.29 (96.86)	88.68 (99.90)	76.37 (94.04)	82.53 (98.08)	81.41 (97.50)
Cypermethrin	71.82 (89.74)	74.17 (92.09)	73.00 (90.96)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	80.84 (97.18)
Fenvalerate	69.33 (86.96)	72.36 (90.31)	70.85 (88.69)	72.55 (90.50)	88.68 (99.90)	80.62 (97.06)	75.73 (93.50)
Malathion	71.82 (89.74)	72.04 (89.97)	71.93 (89.86)	68.48 (85.94)	71.43 (89.33)	69.95 (87.68)	70.94 (88.79)
Chlorpyriphos	74.09 (92.02)	74.17 (92.09)	74.13 (92.06)	74.04 (91.97)	70.17 (87.93)	72.10 (90.04)	73.12 (91.08)
Endosulfan	74.48 (92.38)	72.58 (90.53)	73.53 (91.48)	72.58 (90.53)	72.67 (90.62)	72.62 (90.57)	73.07 (91.03)
Fipronil	88.68 (99.90)	76.70 (94.31)	82.69 (98.15)	74.76 (92.64)	74.83 (92.70)	74.80 (92.68)	78.74 (95.85)
Fenpropathrin	74.92 (92.79)	71.03 (88.89)	72.98 (90.94)	73.11 (91.07)	74.61 (92.50)	73.86 (91.80)	73.42 (91.37)
Spinosad	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	73.96 (91.90)	71.89 (89.82)	72.93 (90.89)	80.80 (97.16)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	76.19 (93.89)	76.32 (94.00)	76.25 (93.94)
	B-twill cloth	76.71 (94.32)	76.59 (94.22)	76.65 (94.27)
	Mean	76.45 (94.11)	76.45 (94.11)	76.45 (94.11)

ANOVA	Source	S. Em ±	CD at 5 %
	Treatment (T)	0.46	1.29
	Method (M)	0.21	NS
	Bag (B)	0.21	NS
	T x M	0.65	NS
	M x B	0.29	NS
	T x B	0.65	NS
	T x M x B	0.92	NS
	CV %	2.30	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values
2. Means with letter(s) in common do not differ significantly in respective column.
3. NS: Not significant

✍.....*Results & Discussion*

After 30 DOS (Table 4.9), maximum larval mortality was observed in deltamethrin and it was not differed significantly from spinosad and cypermethrin. However, cypermethrin was at par with fipronil and fenvalerate. Chlorpyriphos and endosulfan were at par with each other as well as on one side with fenpropathrin and on other side with malathion. There was no significant difference between two types of methods and bags. Treatment performance was not consistent with type of bags as well with type of methods. Performance of methods did not vary with type of bags and vice versa. The order of effectiveness of various insecticides was deltamethrin (94.85 %) > spinosad (94.60 %) > cypermethrin (92.88 %) > fipronil (90.53 %) > fenvalerate (90.52 %) > fenpropathrin (87.06 %) > chlorpyriphos (84.77 %) > endosulfan (83.26 %) > malathion (82.09 %).

After 45 DOS of oat (Table 4.10), deltamethrin recorded the highest larval mortality and it was at par with spinosad, cypermethrin, fipronil and fenvalerate. However, fipronil and fenvalerate were at par with fenpropathrin. Chlorpyriphos was at par on one side with fenpropathrin and with endosulfan and malathion on another side. Methods of insecticide application and type of bags did not differ significantly from each other. Performance of insecticides was consistent with type of bags and methods of insecticide application. Performance of methods did not vary with the type of bags and vice versa. The order for the grain protecting

efficacy of insecticides was deltamethrin (89.59 %) > spinosad (88.81 %) > cypermethrin (88.25 %) > fipronil (87.36 %) > fenvalerate (86.20 %) > fenpropathrin (8.79 %) >

Table 4.9: Bio efficacy of various insecticides against *C. cephalonica* after 30 days of stored oat grains

Insecticides (all at 0.025%)	**Corrected per cent larval mortality**						
	Methods of insecticide application and type of jute bags						**Mean**
	Spray			**Impregnation**			
	Hessian cloth	**B-twill cloth**	**Mean**	**Hessian cloth**	**B-twill cloth**	**Mean**	
Deltamethrin	84.56 (98.93)	68.24 (85.65)	76.40 (94.07)	72.14 (90.08)	84.56 (98.93)	78.35 (95.57)	77.38 (94.85)
Cypermethrin	82.52 (98.07)	84.56 (98.93)	83.54 (98.53)	65.04 (81.52)	67.95 (85.29)	66.49 (83.44)	75.02 (92.88)
Fenvalerate	72.65 (90.60)	83.34 (98.45)	78.00 (95.32)	65.08 (81.57)	69.21 (86.82)	67.14 (84.28)	72.57 (90.52)
Malathion	63.93 (79.99)	63.66 (79.61)	63.80 (79.81)	67.78 (85.08)	66.45 (83.39)	67.11 (84.24)	65.46 (82.09)
Chlorpyriphos	66.18 (83.04)	70.05 (87.79)	68.11 (83.04)	69.13 (86.72)	64.77 (81.15)	66.95 (84.04)	67.53 (84.77)
Endosulfan	64.33 (80.55)	67.09 (84.21)	65.71 (82.42)	65.47 (82.10)	68.49 (85.95)	66.99 (84.09)	66.35 (83.26)
Fipronil	69.19 (86.79)	68.60 (86.09)	68.89 (86.44)	83.34 (98.45)	69.17 (86.77)	76.26 (93.95)	72.58 (90.53)
Fenpropathrin	67.80 (85.11)	69.12 (86.71)	68.46 (85.92)	70.94 (88.79)	69.81 (87.52)	70.38 (88.79)	69.42 (87.06)
Spinosad	70.44 (88.23)	68.53 (86.00)	69.49 (87.15)	84.56 (98.93)	84.69 (98.98)	84.63 (98.95)	77.06 (94.60)
Two way table	Type of bags		Methods of application				Mean
			Spray		Impregnation		
	Hessian cloth		71.29 (89.17)		71.50 (89.40)		71.39 (89.28)
	B-twill cloth		71.47 (89.37)		71.68 (89.59)		71.57 (89.48)
	Mean		71.38 (89.27)		71.59 (89.50)		71.49 (89.39)
	Source		S. Em ±		CD at 5 %		

ANOVA	Treatment (T)	1.11	3.13
	Method (M)	0.50	NS
	Bag (B)	0.50	NS
	T x M	1.57	NS
	M x B	0.70	NS
	T x B	1.57	NS
	T x M x B	2.22	NS
	CV %	5.95	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values
2. Means with letter(s) in common do not differ significantly in respective column.
3. NS: Not significant

Table 4.10: Bio efficacy of various insecticides against *C. cephalonica* after 45 days of stored oat grains

Insecticides (all at 0.025 %)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	63.92 (79.98)	61.94 (77.14)	62.93 (78.58)	80.44 (96.95)	80.44 (96.95)	80.44 (96.95)	71.68 (89.59)
Cypermethrin	65.88 (82.64)	66.88 (83.95)	66.38 (83.30)	64.48 (80.76)	84.56 (98.93)	74.52 (92.42)	70.45 (88.25)
Fenvalerate	61.81 (76.95)	75.80 (93.56)	68.81 (86.34)	73.84 (91.78)	63.32 (79.13)	68.58 (86.06)	68.69 (86.20)
Malathion	60.48 (74.97)	60.65 (75.23)	60.57 (75.51)	63.28 (79.08)	62.95 (78.61)	63.11 (78.84)	61.84 (77.00)
Chlorpyriphos	67.41 (84.62)	64.48 (80.76)	65.95 (82.74)	63.14 (78.88)	63.14 (78.88)	63.14 (78.88)	64.55 (80.85)
Endosulfan	64.94 (81.38)	63.01 (78.69)	63.98 (80.06)	61.94 (77.14)	63.32 (79.13)	62.63 (78.15)	63.30 (79.11)
Fipronil	75.74 (93.51)	75.31 (93.13)	75.53 (93.33)	64.51 (80.80)	63.10 (78.82)	63.80 (79.81)	69.67 (87.36)
Fenpropathrin	67.33 (84.52)	65.87 (82.63)	66.60 (83.59)	67.95 (85.29)	65.88 (82.64)	66.91 (83.98)	66.76 (83.79)
Spinosad	78.50 (95.68)	72.43 (90.38)	75.46 (93.27)	67.83 (85.14)	65.07 (81.56)	66.45 (83.39)	70.96 (88.81)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	67.33 (84.52)	67.49 (84.72)	67.41 (84.62)
	B-twill cloth	67.37 (84.57)	67.98 (85.33)	67.68 (84.96)
	Mean	67.35 (84.54)	67.73 (85.02)	67.54 (84.78)
	Source	S. Em ±	CD at 5 %	

ANOVA	Treatment	1.15	3.24
	(T)	0.52	NS
	Method (M)	0.52	NS
	Bag (B)	1.63	4.59
	T x M	0.73	NS
	M x B	1.63	NS
	T x B	2.31	NS
	T x M x B		
	CV %	6.54	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values

2. Means with letter(s) in common do not differ significantly in respective column.

3. NS: Not significant

chlorpyriphos (80.85 %) > endosulfan (79.11 %) > malathion (77.00 %).

After 60 DOS (Table 4.11), maximum larval mortality was observed in deltamethrin and it was not differed significantly from spinosad, cypermethrin, fipronil and fenvalerate. However, fenvalerate and fenpropathrin were at par with each other as well as with chlorpyriphos. Endosulfan and malathion were at par with each other and found significantly inferior to rest of the insecticides. Impregnation method recorded higher mean larval mortality than spray method. Hessian and B-twill bags did not differ significantly from each other. Performance of insecticides varied with the type of method of their application. Performance of methods did not vary with the type of bags and vice versa. The order of efficacy of various insecticides was deltamethrin (84.24 %) > spinosad (82.05 %) > cypermethrin (82.01 %) > fipronil (81.75 %) > fenvalerate (80.62 %) > fenpropathrin (78.00 %) > chlorpyriphos (76.73 %) > endosulfan (69.99 %) > malathion (69.62 %).

After 75 DOS, deltamethrin recorded the highest larval mortality and it was at par with spinosad, cypermethrin, fipronil and fenvalerate. However, fenpropathrin and chlorpyriphos were at par with each other as well as with cypermethrin, fipronil and fenvalerate. Malathion and endosulfan were at par with each other and found less effective. The data on larval mortality (Table 4.12) on/in jute bags sprayed/impregnated with different insecticides and

filled with oat indicated that impregnation method was more effective than spray method. Hessian and B-twill bags did not differ significantly from each other. Performance of insecticides varied with the type of method but not

Table 4.11: Bio efficacy of various insecticides against *C. cephalonica* after 60 days of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	58.62 (72.11)	61.48 (76.47)	60.05 (74.32)	72.14 (90.08)	76.19 (93.89)	74.17 (92.09)	67.11 (84.24)
Cypermethrin	63.14 (78.88)	60.36 (74.79)	61.75 (76.86)	76.19 (93.89)	61.90 (77.09)	69.04 (86.62)	65.40 (82.01)
Fenvalerate	70.54 (88.35)	71.19 (89.07)	70.86 (88.70)	56.51 (68.75)	59.28 (73.13)	57.90 (70.97)	64.38 (80.62)
Malathion	56.16 (68.18)	57.21 (69.87)	56.69 (69.04)	54.59 (65.60)	60.24 (74.61)	57.42 (70.21)	57.05 (69.62)
Chlorpyriphos	60.39 (74.83)	62.92 (78.56)	61.65 (76.72)	61.71 (76.81)	61.62 (76.67)	61.66 (76.73)	61.66 (76.73)
Endosulfan	57.00 (69.54)	56.77 (69.17)	56.89 (69.36)	58.57 (72.03)	56.78 (69.18)	57.67 (70.61)	57.28 (69.99)
Fipronil	64.79 (81.18)	74.18 (92.10)	69.48 (87.13)	60.61 (75.17)	61.47 (76.45)	60.94 (75.66)	65.21 (81.75)
Fenpropathrin	61.40 (76.35)	61.33 (76.24)	61.37 (76.30)	62.86 (78.48)	64.52 (80.81)	63.69 (79.66)	62.53 (78.00)
Spinosad	71.24 (89.12)	58.02 (71.16)	64.63 (80.96)	61.22 (76.08)	71.24 (89.12)	66.23 (83.10)	65.43 (82.05)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	62.59 (78.09)	62.71 (78.26)	62.65 (78.18)
	B-twill cloth	62.61 (78.12)	63.69 (79.66)	63.15 (78.89)
	Mean	62.60 (78.10)	63.19 (78.95)	62.89 (78.52)

ANOVA	Source	S. Em ±	CD at 5 %
	Treatment	1.23	3.45
	(T)	0.55	1.43
	Method (M)	0.55	NS
	Bag (B)	1.73	4.88
	T x M	0.78	NS
	M x B	1.73	NS
	T x B	2.45	NS
	T x M x B		
	CV %	7.47	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values

2. Means with letter(s) in common do not differ significantly in respective column.

3. NS: Not significant

Table 4.12: Bio efficacy of various insecticides against *C. cephalonica* after 75 days of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	53.86 (64.38)	57.48 (70.30)	55.67 (67.38)	56.12 (68.11)	74.05 (91.98)	65.09 81.59)	60.38 (74.82)
Cypermethrin	51.82 (60.94)	48.26 (54.81)	50.04 (57.89)	74.11 (92.04)	63.89 (79.94)	69.00 (86.57)	59.52 (73.50)
Fenvalerate	65.66 (82.35)	60.87 (75.56)	63.27 (79.06)	56.27 (68.36)	51.28 (60.02)	53.78 (64.25)	58.52 (71.95)
Malathion	51.04 (59.61)	51.54 (60.46)	51.29 (60.04)	48.84 (55.82.)	49.89 (57.63)	49.36 (56.72)	50.33 (58.39)
Chlorpyriphos	58.80 (72.39)	55.55 (67.18)	57.17 (69.81)	55.10 (66.44)	57.50 (70.34)	56.30 (68.41)	56.74 (69.12)
Endosulfan	50.74 (59.09)	50.79 (59.18)	50.76 (59.13)	52.03 (61.30)	50.57 (58.80)	51.30 (60.05)	51.03 (59.59)
Fipronil	48.50 (55.23)	67.17 (84.32)	57.83 (70.86)	62.79 (78.38)	56.46 (68.67)	59.63 (73.67)	58.73 (72.28)
Fenpropathrin	56.51 (68.75)	57.41 (70.19)	56.96 (69.47)	58.45 (71.84)	56.25 (68.33)	57.35 (70.10)	57.15 (69.78)
Spinosad	67.37 (84.57)	59.95 (74.16)	63.66 (79.61)	56.29 (68.39)	57.33 (70.07)	56.81 (69.23)	60.24 (74.61)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	56.03 (67.97)	57.78 (70.78)	56.91 (69.39)
	B-twill cloth	56.56 (68.83)	57.47 (70.29)	57.02 (69.57)
	Mean	56.29 (68.39)	57.62 (70.53)	56.96 (69.47)

ANOVA	Source	S. Em ±	CD at 5 %
	Treatment (T)	1.06	2.98
	Method (M)	0.47	1.19
	Bag (B)	0.47	NS
	T x M	1.50	4.22
	M x B	0.67	NS
	T x B	1.50	NS
	T x M x B	2.12	NS
	CV %	7.12	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values

2. Means with letter(s) in common do not differ significantly in respective column.
3. NS: Not significant

with type of bags. Performance of methods did not vary with the type of bags and vice versa. The chronological order of the efficacy of insecticides based on per cent larval mortality was deltamethrin (74.82 %) > spinosad (74.61 %) > cypermethrin (73.50 %) > fipronil (72.28 %) > fenvalerate (71.95 %) > fenpropathrin (69.78 %) > chlorpyriphos (69.12 %) > endosulfan (59.59 %) > malathion (58.39 %).

After 90 DOS (Table 4.13), maximum larval mortality was observed in deltamethrin and it was not differed significantly from spinosad, cypermethrin and fipronil. However, fenvalerate was at par on one side with cypermethrin and fipronil and on other side with fenpropathrin and chlorpyriphos. Malathion recorded minimum larval mortality. Further, impregnation was significantly more effective than spray application. Hessian and B-twill bags did not differ significantly from each other. Performance of insecticides varied with the type of method. Performance of method of insecticide application did not vary with type of bags and vice versa. The chronological order of insecticides was deltamethrin (69.33 %) > spinosad (69.01 %) > cypermethrin (67.05 %) > fipronil (65.90 %) > fenvalerate (61.88 %) > fenpropathrin (58.72 %) > chlorpyriphos (57.56 %) > endosulfan (54.65 %) > malathion (51.01 %).

After 105 DOS of insecticides on/in jute bags filled with oat grains (Table 4.14), deltamethrin recorded the highest larval mortality and it was at par with spinosad, cypermethrin and fipronil.

However, cypermethrin and fipronil were at par with fenvalerate. Similarly, fenvalerate and fenpropathrin

Table 4.13: Bio efficacy of various insecticides against *C. cephalonica* after 90 days of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	49.30 (56.61)	54.05 (64.70)	51.68 (60.70)	53.85 (64.37)	70.26 (88.03)	62.06 (77.32)	56.87 (69.33)
Cypermethrin	46.14 (51.12)	44.87 (48.90)	45.50 (50.00)	68.45 (85.91)	62.45 (70.89)	65.45 (82.07)	55.47 (67.05)
Fenvalerate	55.04 (66.34)	45.82 (50.56)	50.43 (58.56)	52.69 (62.42)	55.92 (67.79)	54.31 (65.14)	52.37 (61.88)
Malathion	47.39 (53.30)	47.39 (53.30)	47.39 (53.30)	44.90 (48.95)	44.66 (48.53)	44.78 (48.74)	46.08 (51.01)
Chlorpyriphos	53.88 (64.42)	51.29 (60.04)	52.58 (62.23)	47.90 (54.18)	47.15 (52.88)	47.12 (52.83)	49.85 (57.56)
Endosulfan	48.43 (55.10)	49.77 (57.42)	49.10 (56.27)	49.60 (57.13)	44.87 (48.90)	47.23 (53.02)	48.17 (54.65)
Fipronil	54.86 (66.05)	53.54 (63.85)	54.20 (64.95)	55.98 (67.89)	54.71 (65.80)	55.35 (66.85)	54.77 (65.90)
Fenpropathrin	43.77 (46.98)	55.87 (67.71)	49.82 (57.51)	52.44 (61.99)	49.99 (57.80)	51.21 (59.90)	50.52 (58.72)
Spinosad	63.73 (79.71)	58.41 (71.78)	61.07 (75.86)	51.02 (59.57)	53.53 (63.83)	52.28 (61.72)	56.67 (69.01)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	51.39 (60.21)	52.98 (62.91)	52.19 (61.57)
	B-twill cloth	51.22 (59.92)	53.73 (64.17)	52.48 (62.06)
	Mean	51.31 (60.07)	53.31 (63.46)	52.31 (61.77)

ANOVA	Source	S. Em ±	CD at 5 %
	Treatment (T)	1.17	3.28
	Method (M)	0.52	1.47
	Bag (B)	0.52	NS
	T x M	1.65	4.64
	M x B	0.74	1.98
	T x B	1.65	NS
	T x M x B	2.33	NS
	CV %	8.53	

✍……*Results & Discussion*

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values

2. Means with letter(s) in common do not differ significantly in respective column.

3. NS: Not significant

were at par with chlorpyriphos. Minimum larval mortality was found in malathion. Again, impregnation was significantly more effective than spray application of insecticides. Hessian and B-twill bags did not differ significantly from each other. Performance of insecticides varied with the type of method. Performance of method of insecticide application was consistent with type of bags and vice versa. The order of efficacy of various insecticides based on larval mortality was deltamethrin (64.25 %) > spinosad (62.55 %) > cypermethrin (60.70 %) > fipronil (58.44 %) > fenvalerate (55.21 %) > fenpropathrin (53.37 %) > chlorpyriphos (51.40 %) > endosulfan (48.59 %) > malathion (45.29 %).

After 120 DOS (Table 4.15), maximum larval mortality was observed in deltamethrin and it was at par with spinosad and cypermethrin. However, cypermethrin and fipronil were at par with each other as well as on one side with spinosad and on another side with fenvalerate. Chlorpyriphos and endosulfan were at par with each other as well as on one side with fenpropathrin and on other side with malathion. Further, impregnation method was significantly more effective than spray application. There was no significant difference between two type of bags. The performance of method of insecticide application was consistent with type of bags and vice versa. The chronological order of efficacy of various insecticides based on larval mortality was deltamethrin (58.72 %) > spinosad (56.51 %) > cypermethrin (54.34 %) > fipronil (51.06 %) >

fenvalerate (50.21 %) > fenpropathrin (43.61 %) > chlorpyriphos (40.24 %) > endosulfan (38.51 %) > malathion (36.37 %).

Table 4.14: Bio efficacy of various insecticides against *C. cephalonica* after 105 days of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	61.98 (77.20)	53.59 (63.93)	57.79 (70.80)	48.97 (56.04)	50.57 (58.80)	49.77 (57.42)	53.78 (64.25)
Cypermethrin	43.59 (46.67)	39.21 (39.11)	41.40 (42.87)	63.97 (80.05)	59.95 (74.16)	61.96 (77.17)	51.68 (60.70)
Fenvalerate	50.50 (58.68)	45.98 (50.84)	48.24 (54.77)	48.23 (54.76)	49.25 (56.53)	48.74 (55.64)	48.49 (55.21)
Malathion	44.01 (47.40)	43.29 (46.15)	43.65 (46.77)	41.27 (42.64)	42.64 (45.02)	41.96 (43.84)	42.80 (45.29)
Chlorpyriphos	48.28 (54.84)	47.38 (53.28)	47.83 (54.06)	45.78 (50.49)	43.77 (46.98)	44.78 (48.74)	46.30 (51.40)
Endosulfan	45.02 (49.16)	45.00 (49.13)	45.01 (49.14)	45.02 (49.16)	43.74 (46.93)	44.38 (48.05)	44.69 (48.59)
Fipronil	50.06 (57.93)	47.79 (53.99)	48.93 (55.97)	53.53 (63.83)	50.06 (57.93)	51.79 (60.89)	50.36 (58.44)
Fenpropathrin	41.25 (42.61)	50.91 (59.39)	46.08 (51.01)	48.85 (55.83)	48.70 (55.57)	48.77 (55.69)	47.43 (53.37)
Spinosad	45.98 (50.84)	50.38 (58.48)	48.18 (54.67)	48.16 (54.64)	66.55 (83.52)	57.36 (70.11)	52.77 (62.55)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	47.85 (54.10)	49.31 (56.63)	48.58 (55.37)
	B-twill cloth	47.06 (52.72)	50.58 (58.82)	48.82 (55.78)
	Mean	47.46 (53.42)	49.95 (57.74)	48.70 (55.57)

ANOVA	Source	S. Em ±	CD at 5 %
	Treatment (T)	1.26	3.54
	Method (M)	0.56	1.59
	Bag (B)	0.56	NS
	T x M	1.78	5.01
	M x B	0.80	2.19
	T x B	1.78	NS
	T x M x B	2.52	NS
	CV %		

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values

2. Means with letter(s) in common do not differ significantly in respective column.

3. NS: Not significant

Table 4.15: Bio efficacy of various insecticides against *C. cephalonica* after 120 days of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	44.41 (48.10)	48.94 (55.99)	46.68 (52.06)	46.67 (52.04)	62.07 (77.33)	54.37 (65.23)	50.52 (58.72)
Cypermethrin	37.38 (36.02)	37.57 (36.34)	37.47 (36.17)	60.96 (75.69)	56.04 (67.98)	58.50 (71.92)	47.99 (54.34)
Fenvalerate	43.84 (47.10)	41.53 (43.09)	42.68 (45.09)	50.80 (59.20)	46.32 (51.43)	48.56 (55.33)	45.62 (50.21)
Malathion	36.66 (34.81)	37.82 (36.76)	37.24 (35.78)	35.75 (33.31)	40.13 (40.68)	37.94 (36.96)	37.59 (36.37)
Chlorpyriphos	43.77 (46.98)	41.52 (43.08)	42.64 (45.02)	37.80 (36.72)	36.41 (34.40)	37.10 (35.55)	39.87 (40.24)
Endosulfan	37.17 (35.67)	39.85 (40.20)	38.51 (37.92)	40.99 (42.16)	37.45 (36.13)	39.22 (39.13)	38.86 (38.51)
Fipronil	47.80 (54.01)	42.15 (44.17)	44.98 (49.09)	46.67 (52.04)	47.83 (54.06)	47.25 (53.05)	46.11 (51.06)
Fenpropathrin	40.35 (41.06)	44.74 (48.67)	42.54 (44.84)	43.40 (46.34)	38.85 (38.50)	41.12 (42.39)	41.83 (43.61)
Spinosad	58.63 (72.12)	50.99 (59.52)	54.81 (65.96)	42.50 (44.77)	44.83 (48.83)	43.67 (46.81)	49.24 (56.51)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	43.33 (46.22)	45.06 (49.23)	44.20 (47.73)
	B-twill cloth	42.79 (45.28)	45.55 (50.09)	44.17 (47.68)
	Mean	43.06 (45.75)	45.30 (49.65)	44.18 (47.70)

ANOVA	Source	S. Em ±	CD at 5 %
	Treatment (T)	1.28	3.61
	Method (M)	0.57	1.62
	Bag (B)	0.57	NS
	T x M	1.82	5.11
	M x B	0.81	2.21
	T x B	1.82	NS
	T x M x B	2.57	NS
	CV %	11.12	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values

2. Means with letter(s) in common do not differ significantly in respective column.

3. NS: Not significant

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After 135 DOS (Table 4.16), deltamethrin recorded the highest larval mortality and it was at par with spinosad and cypermethrin. However, fipronil was at par on one side with spinosad and cypermethrin, while with fenvalerate on other side. Similarly, fenpropathrin was at par on one side with fenvalerate and on other side with chlorpyriphos. Endosulfan and malathion were at par with each other and less effective. Further, impregnation recorded significantly higher mean larval mortality than spray application of insecticides. B-twill recorded higher mean larval mortality than Hessian bag. The performance of method of application of bags did not vary with types of bag and vice versa. Performance of insecticides varied with the type of method. The chronological order of insecticides was deltamethrin (44.18 %) > spinosad (41.25 %) > cypermethrin (41.13 %) > fipronil (37.67 %) > fenvalerate (34.78 %) > fenpropathrin (30.56 %) > chlorpyriphos (28.08 %) > endosulfan (23.22 %) > malathion (21.71 %).

The analysis of data on per cent larval mortality of *C. cephalonica* after 150 DOS (Table 4.17) revealed that deltamethrin gave higher mean larval mortality and found significantly superior to rest of the treatments. Cypermethrin was at par with spinosad on one side and with fipronil on another side. Similarly, fenvalerate was at par with fipronil on one side and with fenpropathrin on another side. Endosulfan and malathion were at par with each other and found significantly least effective

insecticide. Impregnation of insecticide on jute bags was more effective method than spray application. B-twill was found more effective jute bag than Hessian.

Table 4.16: Bio efficacy of various insecticides against *C. cephalonica* after 135 days of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	51.43 (60.28)	42.37 (44.55)	46.90 (52.44)	37.37 (36.00)	37.49 (36.20)	37.43 (36.10)	42.16 (44.18)
Cypermethrin	25.57 (17.95)	32.57 (28.19)	29.07 (22.87)	53.97 (64.57)	49.46 (56.89)	51.72 (60.77)	40.39 (41.13)
Fenvalerate	39.99 (40.44)	35.39 (32.72)	37.69 (36.54)	36.82 (35.08)	34.34 (31.01)	35.58 (33.03)	36.64 (34.78)
Malathion	29.66 (23.44)	29.58 (23.62)	29.62 (23.68)	24.01 (15.91)	29.84 (24.01)	26.93 (19.81)	28.27 (21.71)
Chlorpyriphos	36.66 (34.81)	34.41 (31.12)	35.54 (32.96)	30.79 (25.44)	28.13 (21.51)	29.46 (23.44)	32.50 (28.08)
Endosulfan	30.84 (25.52)	32.49 (28.07)	31.67 (26.79)	29.71 (23.82)	24.19 (16.14)	26.95 (19.84)	29.31 (23.22)
Fipronil	37.16 (35.65)	38.61 (38.39)	37.88 (36.86)	38.88 (38.55)	38.82 (38.45)	38.85 (38.50)	38.36 (37.67)
Fenpropathrin	27.03 (19.95)	38.77 (38.36)	32.90 (28.71)	36.61 (34.73)	33.84 (30.21)	35.22 (32.44)	34.06 (30.56)
Spinosad	35.54 (32.96)	35.52 (32.93)	35.53 (32.95)	36.72 (34.91)	54.05 (64.70)	45.39 (49.81)	40.46 (41.25)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	34.88 (31.89)	36.10 (33.89)	35.49 (32.88)
	B-twill cloth	35.52 (32.93)	36.68 (34.85)	36.10 (33.89)
	Mean	35.20 (32.41)	36.39 (34.37)	35.80 (33.39)

ANOVA	Source	S. Em ±	CD at 5 %
	Treatment (T)	1.03	2.90
	Method (M)	0.46	1.17
	Bag (B)	0.46	1.17
	T x M	1.46	NS
	M x B	0.65	NS
	T x B	1.46	NS
	T x M x B	2.06	NS
	CV %	11.01	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values

2. Means with letter(s) in common do not differ significantly in respective column.

3. NS: Not significant

Table 4.17: Bio efficacy of various insecticides against *C. cephalonica* after 150 days of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	35.01 (32.10)	45.68 (50.31)	40.34 (41.04)	29.58 (23.62)	32.51 (28.10)	31.04 (25.82)	35.69 (33.21)
Cypermethrin	27.81 (21.05)	24.90 (17.07)	26.36 (19.02)	27.81 (21.05)	49.29 (56.60)	38.55 (37.99)	32.46 (28.02)
Fenvalerate	27.05 (19.98)	30.93 (25.65)	28.99 (22.75)	28.47 (22.00)	28.40 (21.90)	28.44 (21.95)	28.71 (22.34)
Malathion	20.63 (11.84)	20.63 (11.84)	20.63 (11.84)	18.75 (9.81)	22.23 (13.71)	20.49 (11.69)	20.56 (11.77)
Chlorpyriphos	27.09 (20.03)	29.58 (23.62)	28.34 (21.81)	23.88 (15.75)	22.33 (13.83)	23.11 (14.78)	25.72 (18.16)
Endosulfan	22.32 (13.82)	23.96 (15.85)	23.14 (14.82)	22.63 (14.19)	20.72 (11.95)	21.67 (13.04)	22.40 (13.91)
Fipronil	27.73 (20.94)	32.91 (28.73)	30.32 (24.73)	30.34 (24.76)	31.85 (27.07)	31.10 (25.91)	30.71 (25.32)
Fenpropathrin	31.31 (26.23)	22.57 (14.12)	26.94 (19.83)	28.65 (22.26)	23.88 (15.75)	26.26 (18.89)	26.60 (19.35)
Spinosad	20.34 (11.52)	18.74 (9.80)	19.54 (10.64)	48.19 (54.69)	44.84 (48.85)	46.51 (51.76)	33.03 (28.92)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	26.59 (19.34)	28.70 (22.33)	27.64 (20.81)
	B-twill cloth	27.77 (20.99)	30.67 (25.26)	29.22 (23.09)
	Mean	27.18 (20.16)	29.69 (23.79)	28.43 (21.94)

ANOVA	Source	S. Em ±	CD at 5 %
	Treatment (T)	0.79	2.21
	Method (M)	0.35	0.99
	Bag (B)	0.35	0.99
	T x M	1.11	3.13
	M x B	0.50	1.41
	T x B	1.11	NS
	T x M x B	1.57	NS
	CV %	10.54	

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values
2. Means with letter(s) in common do not differ significantly in respective column.
3. NS: Not significant

Performance of method of insecticide application did not vary with type of bags and vice versa. The performance of insecticides varied with type of methods of insecticide application. However, performance of insecticides was inconsistent on two types of bags. The chronological order of efficacy of various insecticides was deltamethrin (33.21 %) > spinosad (28.92 %) > cypermethrin (28.02 %) > fipronil (25.32 %) > fenvalerate (22.34 %) > fenpropathrin (19.35 %) > chlorpyriphos (18.16 %) > endosulfan (13.91 %) > malathion (11.77 %).

The analysis of data on larval mortality of *C. cephalonica* pooled over period (Table 4.18) revealed that maximum larval mortality was observed in deltamethrin and it was not differed significantly from spinosad, cypermethrin, fipronil and fenvalerate. However, fipronil and fenvalerate were at par with fenpropathrin and chlorpyriphos. Malathion recorded minimum larval mortality. Among two types of method of insecticide application, impregnation recorded higher means larval mortality and was more effective than spray application. However, the performance of methods was not consistent at different time interval. There was no significant difference between two types of bags. The performance of insecticides varied with type of methods but not with type of bags. Performance of methods of insecticides application varied with type of bags and vice versa. The performance of insecticides with respect to type of bags was consistent over periods, while with respect to

type of methods, it was inconsistent over periods. The source 'period' of ANOVA was also significant indicated that

Table 4.18: Bio efficacy of various insecticides against *C. cephalonica* at pooled over periods of stored oat grains

Insecticides (all at 0.025%)	Corrected per cent larval mortality						
	Methods of insecticide application and type of jute bags						Mean
	Spray			Impregnation			
	Hessian cloth	B-twill cloth	Mean	Hessian cloth	B-twill cloth	Mean	
Deltamethrin	60.33 (74.75)	61.01 (75.77)	60.67 (75.26)	61.33 (76.25)	66.65 (83.66)	63.99 (80.08)	62.33 (77.72)
Cypermethrin	54.94 (66.18)	54.73 (65.83)	54.84 (66.01)	66.30 (83.20)	66.62 (83.62)	66.46 (83.41)	60.65 (75.23)
Fenvalerate	58.64 (72.15)	59.26 (73.11)	58.95 (72.63)	56.17 (68.20)	57.32 (70.06)	56.75 (69.13)	57.85 (70.89)
Malathion	51.50 (60.39)	50.62 (58.88)	51.06 (59.64)	50.58 (58.81)	51.80 (60.91)	51.19 (59.86)	51.12 (59.75)
Chlorpyriphos	56.11 (68.10)	56.00 (67.92)	56.06 (68.01)	54.00 (64.61)	52.16 (61.52)	53.04 (63.01)	54.55 (65.53)
Endosulfan	52.24 (61.65)	52.34 (61.83)	52.29 (61.74)	53.38 (63.59)	51.59 (60.55)	52.49 (62.07)	52.39 (61.90)
Fipronil	59.38 (73.29)	60.17 (74.49)	59.77 (73.89)	60.01 (74.25)	57.91 (70.98)	58.95 (72.62)	59.36 (73.26)
Fenpropathrin	54.22 (64.99)	56.94 (69.43)	55.58 (67.23)	57.10 (69.69)	54.85 (66.03)	55.97 (67.87)	55.78 (67.55)
Spinosad	62.65 (78.17)	59.12 (72.89)	60.88 (75.58)	59.92 (74.12)	63.88 (79.93)	61.90 (77.09)	61.39 (76.34)

Two way table	Type of bags	Methods of application		Mean
		Spray	Impregnation	
	Hessian cloth	56.67 (69.01)	57.64 (70.56)	57.16 (69.79)
	B-twill cloth	56.69 (69.04)	58.09 (71.27)	57.39 (70.16)
	Mean	56.68 (69.02)	57.86 (70.91)	57.27 (69.97)

ANOVA	Source	S. Em ±	CD at 5 %
	Method (M)	0.20	0.62
	Bag (B)	0.14	NS
	Treatment (T)	1.77	4.94
	M x B	0.20	0.49
	M x T	0.65	1.82
	B x T	0.45	NS
	M x B x T	0.64	NS
	Period (P)	0.34	0.93
	M x P	0.48	1.32
	B x P	0.48	NS
	T x P	1.06	2.95
	M x B x P	0.67	NS
	M x T x P	1.50	4.17
	B x T x P	1.50	NS
	M x B x T x P	2.13	NS
	CV %	7.11	

✍……*Results & Discussion*

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values 2. Means with letter(s) in common do not differ significantly in respective column.

3. NS: Not significant

there was significant difference among mean mortalities obtained at different periods which was because of decrease in efficacy of all insecticides as period of storage increased (Figure 5). Similarly, there was an inconsistency in performance of various insecticides at different periods of storage. The order of efficacy of various insecticides based on pooled data on larval mortality was deltamethrin (62.33 %) > spinosad (61.39 %) > cypermethrin (60.65 %) > fipronil (59.36 %) > fenvalerate (57.85 %) > fenpropathrin (55.78 %) > chlorpyriphos (54.55 %) > endosulfan (52.39 %) > malathion (51.12 %).

Based on larval mortality of stored grain pests, numbers of workers have evaluated the insecticides either as surface treatment or impregnation on/in jute bags. The per cent adult mortality of *R. dominica* on wheat jute bags sprayed with malathion (0.538 to 2.152 g/m^2) ranged between 38 to 93 % at 1 hour after treatment and decreased to 1 to 9 % after 30 days of treatment (Girish *et al*., 1973). Malathion applied at 0.15 g/m^2 on stack of gunny bags of wheat grains resulted into 100 % mortality of *R. dominica* adults up to 30 days after treatment (Doharey *et al.,* 1981). At 0.15 g/m^2, it also gave cent per cent mortality of *R. dominica* after 15 days of treatment on stacks of wheat (Pandey *et al*., 1988). Spraying of deltamethrin at 20 mg/m^2 on stacks of wheat, it resulted into total kill of *R. dominica* after 50 days of application (Yadav, 1988). Spraying of malathion at 150 mg/m^2 on grain bags, it also gave cent

per cent kill of *R. dominica* up to 15 days after treatment (Lal *et al*., 1989). Fenvalerate sprayed at 1 and 1.5 g a.i./m^2 on jute bag gave 100 and 12-18 % mortality of *T. castaneum* up to 30 and 90 days, respectively during storage period (Sarkar *et al*., 1984). Spraying of deltamethrin and cypermethrin at 20 mg/m^2 on jute bag gave complete kill of *C. maculatus* after 15 days and of *C. chinensis* after 1 month (Yadav and Jha, 1985). Spraying of deltamethrin and malathion at 30 mg a.i./m^2 on jute bag caused 100 and 70 % adult mortality of *R. dominica* up to 15 day of treatment which reduced to 70 and 50 % after 30 days of treatment, respectively (Lal *et al*., 1988). Spraying of deltamethrin at 30 mg/ m^2 on stack of grain bag of wheat, resulted into cent per cent kill of *R. dominica* up to 135 days after treatment (Lal *et al.*, 1989). During present investigation, spray application of deltamethrin and spinosad at 0.025 % as on jute bag are found effective insecticides and remained the adult mortality more than 90 % up to 30 days.

Impregnation of jute bags with cypermethrin and deltamethrin at 0.0125 % were equally effective, but significantly more effective than fenvalerate (0.0125 %) which was in turn more effective than malathion (0.1 %) in preventing the damage of insect pests of stored wheat (Ramzan *et al*., 1987). Impregnation of jute bags with cypermethrin, deltamethrin, fenpropathrin and fenvalerate at 0.0125 % proved significantly better than malathion (0.1 %) in giving protection against insect pests in stored wheat (Ramzan and

Chahal, 1987). Spraying of cypermethrin at 0.25 % and fenvalerate at 0.10 % led to total failure of hatching of eggs of *C. cephalonica* (Dwivedi and Kumar, 1999). Spraying of spinosad on the larvae of *C. cephalonica* was more efficient than carbosulfan (Shipra and Chatterjee, 2001). Chlorpyriphos (0.1%) fenvalerate and cypermethrin (0.01 and 0.025 %) and deltamethrin (0.005 %) as impregnation in gunny bags provided effective control of *R. dominica* up to 6 months in stored wheat grains, than malathion at 0.1% (Mahla, 2001). Spraying of deltamethrin at 20 mg/m^2 was found most effective in controlling the pests of stored maize and rice in jute bags followed by malathion at 150 mg/m^2 (Pathak *et al*., 2002). As impregnation in gunny bag, deltamethrin (0.0125 %) was found more effective than malathion (0.5 %) in controlling *R. dominica* infestation on wheat seeds during 8 months of storage. Impregnation of insecticide was found better method than spray application of insecticide on jute bags for the control of *R. dominica* (Patil *et al*., 2004). Deltamethrin at 0.025 % was more effective and had long lasting effect as grain protectant of wheat against *R. dominica* when sprayed on/in jute bags as prophylactic treatment followed by cypermethrin, fipronil and fenvalerate (Kher 2006). The above reports about more effectiveness of synthetic pyrethroids and chlorpyriphos than malathion corroborates the present results.

V. SUMMARY AND CONCLUSION

Rice moth, *Corcyra cephalonica* Stainton is one of the major pests of stored grains. The present investigations on biology and management through plant products and insecticides as grain protectants against rice moth were carried out at Main Forage Research Station, Anand Agricultural University, Anand. The main findings on various aspects are summarized hereunder.

5.1 BIOLOGY OF RICE MOTH, *C. cephalonica* ON OAT

The study on biology of rice moth was carried out on oat grains under laboratory conditions at temperatures ranging from 27 to 30 ^{0}C and 69 to 87 per cent relative humidity.

The freshly laid eggs were pearly white, oval in shape with a rough surface and turned yellowish in colour at hatching. The dimensions of freshly laid eggs on oat were measured from 0.38 to 0.43 mm (Av. 0.40 ± 0.02 mm) in length and from 0.29 to 0.37 mm (Av. 0.34 ± 0.02 mm) in breadth. The incubation period was 3 to 6 (Av. 4.10 ± 1.19) days with hatchability of 93.00 per cent.

It was observed that the larvae of *C. cephalonica* passed through seven distinct instars reared on the oat grains. The newly hatched larva was creamy white in colour with reddish brown head. The body length and breadth of first instar larva on oat grains were 0.61 to 1.03 (Av. 0.74 ± 0.15) and 0.19 to 0.20 (Av. 0.20 ± 0.005) mm, respectively with duration was 4 to 5 (4.54 $\pm$ 0.51) days.

The body colour of second instar larvae changed to creamy white with reddish brown head. The body length and breadth of second instar larva on oat grains were 0.92 to 1.34 (Av. 1.24 ± 0.13) and 0.21 to 0.24 (Av. 0.23 ± 0.013) mm, respectively with duration was 4 to 6 (5.10 ± 0.83) days.

The third instar larvae were gradually turned darken white with reddish brown head. The body length and breadth of third instar larva were 2.48 to 2.93 (Av. 2.80 ± 0.16) and 0.29 to 0.32 (Av. 0.30 ± 0.010) mm, respectively with duration was 5 to 7 (5.88 ± 0.97) days.

The fourth instar larvae were slightly bigger in size than the third instar. The measurement on body length and breadth of fourth instar ranged from 3.91 to 4.51 (Av. 4.45 ± 0.16) and 0.39 to 0.42 (Av. 0.41 ± 0.010) mm, respectively with duration was 5 to 7 (6.03 ± 0.98) days.

The fifth instar larvae were dirty white in colour with reddish brown head. The body length and breadth of fifth instar larva were 4.94 to 5.87 (Av. 5.66 ± 0.35) and 0.54 to 0.56 (Av. 0.55 ± 0.008) mm, respectively with duration was 6 to 7 (6.28 ± 0.46) days.

The length and breadth of sixth instar larva ranged from 5.57 to 8.15 and 0.62 to 0.65 mm with an average of 7.83 ± 0.62 and 0.64 ± 0.013 mm, respectively while duration of larva was 5 to 8 (Av. 6.75 ± 0.87) days.

The seventh instar was full grown larva which had body length about 8.51 to 10.63 (Av. 9.60 ± 0.61) and breadth of 0.75 to 0.81 (Av. 0.77 ± 0.022) mm, respectively with duration of larva was 6 to 8 (6.90 ± 0.87) days.

The mean larval period of *C. cephalonica* was 35 to 48 (Av. 37.80 ± 0.95) days on oat grains. The maximum larval mortality was found in second instar larva, while none of the larva was died after third instar.

The prepupa formed in a white delicate silken cocoon inside the webbing. The measurement of prepupa was from 7.48 to 9.59 mm with an average of 8.27 ± 0.79 mm in length and 1.07 to 1.87 mm with an average of 1.41 ± 0.32 mm in breadth. The duration of prepupal period ranged from 1 to 2 days with an average of 1.48 ± 0.50 days.

The pupation of *C. cephalonica* took place in thin silken cocoon. The pupa was leathery brown in colour. The length and breadth of pupa ranged from 7.45 to 9.30 (Av. 8.12 ± 0.54) mm and 1.19 to 1.97 (Av. 1.47 ± 0.31) mm, respectively while duration of larva was 7 to 11 (Av. 8.43 ± 1.20) days. The average pupal mortality was 3.09 per cent on oat grains.

The moths of both the sexes were pale grayish brown in colour. The wings were uniformly dark grey in colour, sometimes streaked with darker lines along the veins. The length and breadth with wingspan of male moths were observed as 6.30 to 9.30 (Av.

7.90 ± 1.10) and 13.30 to 19.40 (Av. 17.00 ± 2.30) mm, respectively. Whereas, the body length and breadth with wingspan of female moths were 7.20 to 10.20 (Av. 8.70 ± 1.10) and 16.90 to 21.30 (Av. 18.80 ± 1.70) mm, respectively.

The pre-oviposition, oviposition and post-oviposition periods varied from 1 to 2, 4 to 6 and 1 to 2 days with an average of 1.35 ± 0.49, 5.47 ± 0.72 and 1.18 ± 0.39 days, respectively.

The longevity of male and female moths ranged from 7 to 11 and 6 to 10 days with an average of 8.35 ± 1.11 and 7.09 ± 1.41 days respectively. The female moth laid 109 to 135 (Av. 122.22 ± 8.39) eggs in its entire life span.

The sex ratio (male: female) of *C. cephalonica* was recorded as 1: 1.08. The survival percentage of *C. cephalonica* was found to be 80 whereas, the mean developmental period was 60.20 days and growth index was 1.33.

The entire life span of the male moth varied from 53 to 78 days with an average of 62.70 ± 7.80 days while that of the female was varied from 58 to 87 days with an average of 71.50 ± 11.90 days.

5.2 EVALUATION OF DIFFERENT PLANT PRODUCTS AS GRAIN PROTECTANTS

Powders of various plants products were tested for their grain protecting efficacy against *C. cephalonica* on oat grains in the laboratory. The results showed that all the plant products were

significantly superior in preventing adult emergence, increasing developmental period, decreasing the growth of the pest and reducing the weight loss of grains. Among the various treatments neem, eucalyptus and custard apple leaf powders each at @ 2 per cent were proved most effective against *C. cephalonica*. The treatments *viz.,* mint, santra chhal and tulsi leaf powders @ 2 per cent were moderately effective. The lantana, guava and tamarind leaf powders each @ 2 per cent were less effective against *C. cephalonica.*

5.3 EVALUATION OF INSECTICIDES AS GRAIN PROTECTANTS

The grain protecting efficacy of ten different insecticides (deltamethrin, cypermethrin, fenvalerate, malathion, chlorpyriphos, endosulfan, fipronil, fenpropathrin and spinosad) against *C. cephalonica* were evaluated as seed treatment (Malathion at 10 ppm and all others at 4 ppm) as well as spray/impregnation (all at 0.025 %) on/in two types of jute bags (Hessian and B-twill).

Seed treatment

Experimental results on larval mortality revealed that all the tested insecticides gave 99.90 % mortality up to 45 DOS. After 45 DOS, the larval mortality decreased as storage period increased in case of all the insecticides except deltamethrin and cypermethrin in which larval mortality was 99.90 % up to 75 DOS. It was only after 75 DOS that larval mortality decreased as storage period increased in case of deltamethrin and cypermethrin. Larval mortality pooled

over period revealed that maximum larval mortality was found in deltamethrin and it was at par with cypermethrin and spinosad. However, spinosad was at par with fipronil, fenvalerate, chlorpyriphos and fenpropathrin and found moderately effective. Malathion recorded minimum larval mortality. The order of efficacy of insecticides was deltamethrin (98.70 %) > cypermethrin (98.56 %) > spinosad (94.11 %) > fipronil (91.98 %) > fenvalerate (91.83 %) > chlorpyriphos (89.63 %) > fenpropathrin (89.25 %) > endosulfan (86.20 %) > malathion (85.19 %).

Application on/in jute bags sprayed/impregnated with insecticides

The insecticides evaluated as seed treatment were also evaluated at 0.025 per cent concentration for their efficacy as spray and impregnation on/in two types of jute bags (Hessian and B-twill). The efficacy of insecticides, method of application and types of jute bag were evaluated based on periodical larval mortality. The data on larval mortality revealed that up to 15 days, all the insecticides could maintain the larval mortality above 90 per cent. Deltamethrin, cypermethrin, fenvalerate, fipronil and spinosad could maintain the larval mortality above 90 % up to 30 days. Above 50 % larval mortality was maintained up to 135 days in case of deltamethrin, cypermethrin, fenvalerate, fipronil and spinosad, while it was only up to 90 days in case of malathion and endosulfan. Among two types of method of insecticide application on/in jute bag,

impregnation remained significantly more effective than spray application. Further, B-twill recorded higher mean larval mortality than Hessian bag. The analysis of data on larval mortality of *C. cephalonica* pooled over period revealed that maximum larval mortality was observed in deltamethrin and it was not differing significantly from spinosad, cypermethrin, fipronil and fenvalerate. However, fipronil and fenvalerate were at par with fenpropathrin and chlorpyriphos. Malathion recorded minimum larval mortality. Among two methods of insecticide application, impregnation recorded higher mean larval mortality and it was more effective than spray application. There was no significant difference between two types of bags. Performance of methods of insecticide application varied with type of bags and vice versa. The performance of insecticides with respect to type of bags and methods of application was inconsistent over periods. There was significant difference among mean mortalities obtained at different period which is because of decrease in efficacy of all insecticides as period of storage increased. The order of efficacy of various insecticides based on pooled data on larval mortality was deltamethrin (62.33 %) > spinosad (61.39 %) > cypermethrin (60.65 %) > fipronil (59.36 %) > fenvalerate (57.85 %) > fenpropathrin (55.78 %) > chlorpyriphos (54.55 %) > endosulfan (52.39 %) > malathion (51.12 %).

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Table 3.2: Details of various insecticides tested for their grain protectant efficacy against *C. cephalonica* during storage of oat

Sr. No.	Technical Name	Trade Name	Source	Dose used	
				As seed treatment (w/w)	As spray / impregnate on/ in jute bags
1.	Deltamethrin	Decis 2.8 EC	AgrEvo India Ltd., Hoechst Centre, 54-1 M. V. Road, Chakala Andheri (E), Mumbai-400 093	4 ppm	0.025 % (8.92 ml formul./l water)
2.	Cypermethrin	Ankush 10 EC	BASF India Ltd., S. K. Ahire Marg, Mumbai-400025	4 ppm	0.025 % (2.5 ml formul./l water)
3.	Fenvalerate	Tatafen 20 EC	Rallis India Ltd. 21 D Sukhadvala Marg, Mumbai-400 018	4 ppm	0.025 % (1.25 ml formul./l water)
4.	Malathion	Cythion 50 EC	BASF India Ltd. S. K. Ahire Marg, Mumbai-400025	10 ppm	0.025 % (0.5 ml formul./l water)
5.	Chlorpyriphos	Durmet 20 EC	BASF India Ltd. S. K. Ahire Marg, Mumbai-400025	4 ppm	0.025 % (1.25 ml formul./l water)
6.	Endosulfan	Thiodan 35 EC	Bayer Crop Science Ltd., Bayer House, Central Avenue, Hiranandani, Powai, Mumbai-400076	4 ppm	0.025 % (0.71 ml formul./l water)
7.	Fipronil	Regent 5 SC	Aventis Crop Science, Aventis House, M. V. Road, Andheri(E), Mumbai-400 093	4 ppm	0.025 % (5.0 ml formul./l water)
8.	Fenpropathrin	Meothrin 30 EC	Sumitomo Chemical India Ltd., Jeedimetis Hyderabad-500055	4 ppm	0.025 % (0.83 ml formul./l water)

9.	Spinosad	Spintor 45 SC	Bayer Crop Science Ltd., Bayer House, Central Avenue, Hiranandani, Powai, Mumbai-400076	4 ppm	0.025 % (0.56 ml formul./l water)

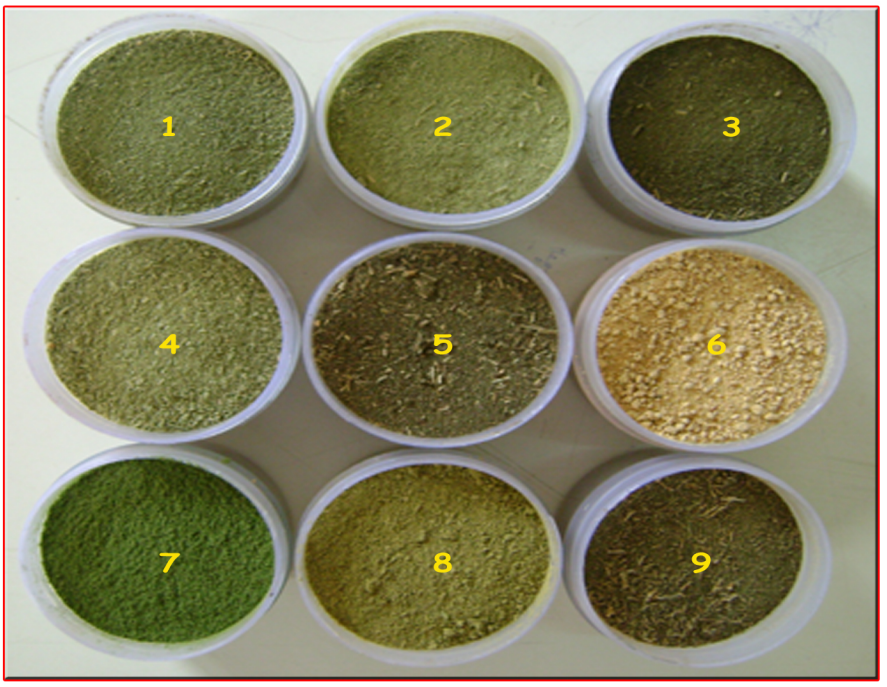
Table 4.6: Effectiveness of various insecticides as seed treatment against *C. cephalonica* in stored oat

Treatments	Corrected per cent larval mortality after indicated days of storage											
	7	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**	**135**	**150**	**Pooled**
Deltamethrin @ 4 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68a (99.90)	88.68a (99.90)	85.49a (99.24)	82.61a (98.12)	79.37a (96.27)	74.16a (92.08)	69.76a (87.46)	83.95a (98.70)
Cypermethrin @ 4 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68a (99.90)	88.68a (99.90)	83.00ab (98.30)	80.30a (96.86)	77.81a (95.17)	75.50a (93.30)	70.85a (88.69)	83.60a (98.56)
Fenvalerate @ 4 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	82.79ab (98.20)	80.95ab (97.25)	72.26cd (90.20)	64.65bc (80.99)	63.26b (79.05)	51.89bc (61.06)	42.25cd (44.34)	73.89bc (91.83)
Malathion @ 10 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	72.74c (90.70)	67.51c (84.75)	60.21f (74.56)	57.85bc (70.89)	51.53cd (60.45)	44.50cd (48.26)	37.48de (36.18)	67.87c (85.19)
Chlorpyriphos @ 4 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68a (99.90)	83.14a (98.36)	68.60de (86.09)	60.91bc (75.62)	51.48cd (60.36)	44.25cd (47.82)	37.05de (35.46)	71.71bc (89.63)
Endosulfan @ 4 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	84.79a (99.01)	79.11ab (96.10)	64.33ef (80.55)	53.54c (63.85)	47.99d (56.34)	38.30d (37.57)	32.80e (28.55)	68.69c (86.20)
Fipronil @ 4 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	84.56a (98.93)	80.97ab (97.20)	70.68cde (88.50)	65.64b (82.33)	58.82bc (72.42)	51.84bc (60.98)	47.29c (53.12)	74.05bc (91.98)
Fenpropathrin @ 4 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	74.98bc (92.84)	71.63bc (89.54)	65.73def (82.45)	61.39bc (76.33)	57.53bcd (70.38)	51.72bc (60.77)	47.20c (52.97)	71.36bc (89.25)
Spinosad @ 4 ppm	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	84.78a (99.01)	80.95ab (97.25)	76.31bc (93.99)	66.78b (83.82)	62.06b (77.32)	60.26b (74.64)	55.06b (66.38)	76.45ab (94.11)
Mean	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	88.68 (99.90)	83.41 (98.48)	80.18 (96.79)	71.85 (89.77)	65.96 (82.75)	61.09 (75.89)	54.71 (65.80)	48.86 (55.85)	74.62 (92.51)
S. Em. ± Treatment (T)	0.45	0.45	0.45	0.45	3.01	3.74	2.43	4.05	3.30	2.99	2.01	2.54
Period (P)	-	-	-	-	-	-	-	-	-	-	-	0.80
TxP	NS	NS	NS	NS	8.89	11.04	7.16	11.95	9.76	8.80	5.94	2.46
CD at 5 %	-	-	-	-	-	-	-	-	-	-	-	7.53
T												2.27
P												7.32
TxP												
C V %	0.98	0.98	0.98	0.98	6.90	8.95	6.47	11.74	10.37	10.44	7.88	6.48

✍.....Results & Discussion

Notes: 1. Means in parentheses are retransformed values, those outside are arc sin transformed values
2. Means with letter(s) in common do not differ significantly in respective column.
3. NS: Not significance

Plate I: Culture of *C. cephalonica* maintained on oat in laboratory condition



1. Neem leaf powder
2. Guava leaf powder
3. Custard apple leaf powder
4. Eucalyptus leaf powder
5. Mint leaf powder
6. Santra Chhal powder
7. Lantana leaf powder
8. Tamarind leaf powder
9. Tulsi leaf powder

Plate 2: Plant powders evaluated as grain protectant against *C. cephalonica*

Plate 3: Plastic jars each with bulk (2.5 kg) of oat grains treated with different insecticides and stored in laboratory

Plate 4: Jute bags used for spraying /impregnation of insecticide evaluated against *C. cephalonica*

Plate 5: Method of insecticide spray application on jute bags

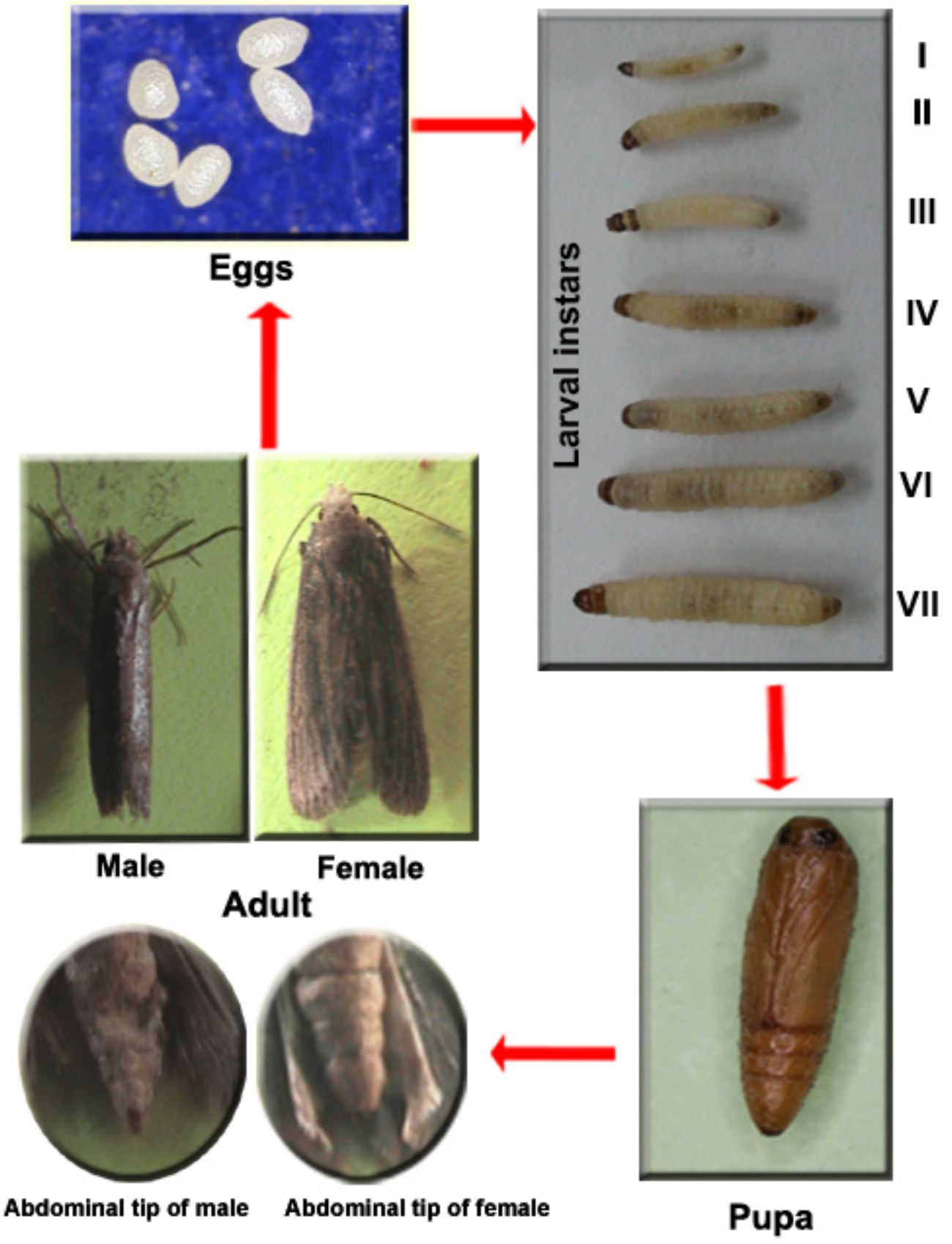


Plate 6 : Different life stages of C. cephalonica on oat