SEASONAL INFESTATIONS AND LIFE HISTORY TRAITS OF LITCHI FRUIT BORER *CONOPOMORPHA SINENSIS* BRADLEY (LEPIDOPTERA: GRACILLARIIDAE)

A THESIS

BY

MD. SELIM REZA
Student No. 1405020
Session: 2014-2015
Thesis Semester: January-June, 2015

MASTER OF SCIENCE (M.S.)

IN

ENTOMOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

JUNE, 2015

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Submitted to the

DEPARTMENT OF ENTOMOLOGY

In partial fulfillment of the requirements for the degree of

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DEPARTMENT OF ENTOMOLOGY
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ACKNOWLEDGEMENTS

I acknowledge and express my all praises due to the "Almighty Allah" who has created us to explore the hidden fact of the nature for the benefit of mankind and enabling me to complete this research work successfully in time.

It is my pleasure to express my sincere appreciation, heartfelt respect and indebtedness to my respectable teacher and supervisor, Dr. Hasan Fuad El Taj, Professor, Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his kind help, constant guidance, valuable advice, affectionate feelings, constructive criticism and encouragement throughout the tenure of this research work and completion of thesis.

Heartiest gratitude and deep sense of admiration to my respected co-supervisor, Dr. Mohammad Mosharof Hossain Bhuyain, Associate Professor, Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his supports and day to day cooperation in successful completion of this work

I express my gratefulness to all the teachers of the Department of Entomology, HSTU, Dinajpur, for their inspiration encouragement, deep feelings and for improving academic skills in Entomology during the course of M.S. studies and they were very kind to me. I also express my gratefulness to my roommates and my friends for their loved and helped. I would like to thank all the staffs of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University for their help and assistance during the period of the research.

I express a deep appreciation to my parents, elder and younger brother for their endless love, support, encouragement and prayer. They have always encouraged me in all of my pursuits and without them none of this would have been possible. I would like to give my thanks whole heartedly to all of my relatives, friends and well wishers for their co-operations, inspirations and affectionate feelings towards the successful completion of my study.

I would like to give my special highly gratitude to Professor Dr. Hasan Fuad El Taj for his continuous inspiration, encouragement, help and excellent composing of this thesis.

Finally, I acknowledge Almighty Allah for bestowing blessing on me in partial fulfillment of the requirements for the M.S. degree.

The Author

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ABSTRACT

The litchi fruit borer, *Conopomorpha sinensis* Bradley (Lepidoptera:Gracillariidae) is one of the most destructive cosmopolitan pests of litchi fruit. This experiment investigated the seasonal infestation and performance of litchi varieties on the life history parameters of *C. sinensis*. The fruit infestation was first detected on 18 April and 30% fruit infestation was recorded on April 25 while the fruits were (3.12 ± 0.04) cm in length, (1.33 ± 0.01) cm in diameter and (2.87 ± 0.12) g in weight and finally infestation increased up to 80% on May 30. Highest infestation was found in Bombai (44.29%) variety and lowest in China-3 (17.14%). Life history traits of *C. sinensis* was detected on two varieties of litchi viz. Madraji and Bombai. Female developmental times were shorter on Madraji (23.01 ± 0.42) than on Bombai (24.71 ± 0.52). The adult longevity periods were 11.75 and 11.83 days for female and male, when *C. sinensis* fed on Madraji and Bombai varieties respectively. On the contrary, it was shorter 11.57 and 10.60 days for both the sexes while reared on the two hosts. Lifetime fecundity was also the higher (31.28 ± 0.10) on Bombai and the lower (29.50 ± 0.53) on Madraji. The sex ratio (proportion of male) was the maximum (0.54) on Madraji variety and the minimum (0.47) on Bombai. Life table parameters were analyzed and found the lower generation time (T = 30.41) when *C. sinensis* fed on Madraji, but R_o (21.27) was the higher on Bombai. However, r_m (0.10) and λ (1.10) were also the higher when fed Madraji and Bombai, respectively. Daily fecundity found higher (7.31 ± 0.45) in the variety of Madraji. Therefore both the variety had little effect on the biological performance of the litchi fruit borer.

Key words: *Conopomorpha sinensis*, development, reproduction, life table, litchi varieties.

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CHAPTER I

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is one of the most important subtropical fruits originated in Southern China and possibly Northern Viet Nam belongs to *Sapindaceae* family. The fruit is famous for its unique taste, flavour, delicious fragrant, juicy, attractive colour and quality which are commercially important to the litchi growers of Bangladesh. Litchi is nutritionally very rich fruit because hundred grams of fresh edible portion contain 63-64 calories, 81.9-84.83% water, 0.68-1.00 g protein, 0.30-0.58 g fat, 13.31-16.4 g carbohydrates, 0.23-0.40 g fiber, 0.37-0.50 g ash, 8.00-10.00 mg calcium, 30-42 mg phosphorus, 0.40 mg iron, 3.00 mg sodium, 170.00 mg potassium, 28.00 mg thiamine, 0.40 mg nicotine acid, 0.05 mg riboflavin and 24-60 mg ascorbic acid (Mondal and Amin, 1990; Bose and Mitra, 1990; Scanlan,1995).

Litchi is grown almost all over the country but its production is mostly concentrated in the northern and eastern region of Bangladesh (Anonymous, 2006).The leading litchi producing districts are Dinajpur, Rajshahi, Pabna, Jessore, Mymensingh, and Chittagong. At present, the area of this fruit under cultivation is about 4602 hectares and production is 66466 metric tons (BBS, 2011). But the area has been increasing day by day due to its growing demand. As a result farmers are modifying their rice and other crop fields in to litchi orchard especially in Dinajpur and neighbor districts. In Dinajpur litchi is cultivated in 1420 hectare land and the production is 12367m.ton (BBS, 2012).

The litchi of Dinajpur is very attractive to people of Bangladesh and litchi cultivation is a promising industry. However, a considerable amount of litchi yield losses occurred every year due to insects, mites, bats, and diseases. About forty insects are identified which attack the litchi (Wadhi and Barta, 1964; Vevai, 1971) throughout the world.

Litchi cultivation is affected by the insect pests, which makes loss of not only the production but also of the quality of the litchi. For example due to infestation of fruit borer, the fruits emit foul smell and reduce market price very greatly (Jha and Sen-Sarma, 2003). Litchi fruit borer, Litchi mite, litchi bugs, Litchi fruit piercing moth, Litchi leaf feeding caterpillar etc are the important key pests of litchi. Among the insects, the litchi fruit borer, *Conopomorpha sinensis* Bradley (Lepidoptera: Gracillariidae), is a destructive pest of litchi causing significant economic losses (Zhang *et al*., 2011; Butani, 1979). The fruit borer is one of the key pests of litchi in Bangladesh (Waite & Hwang, 2002). The larva bores into a developing fruit and feeds inside the seed. As a result saw dust like substances are found near the stalk of the fruits which is unpleasant to the consumers. Additionally, a portion of the fruit pulp at the stem end is also spoiled. Major economical losses are caused due to poor fruit quality and fruit drop after infestation (Huang *et al*., 1994). Only one larva of the fruit borer bores into a developing fruit from the stem end and feeds on the seed. A portion of the fruit pulp at the stem end is also spoiled due to larval feeding on the seed. The larvae also develop in newly produced leaves or shoots of litchi during off season (Waite, 2005). Severe damage and yield reduction occurs due to the attack of fruits by the larvae. Due to the cryptic feeding behavior of the larvae in the plant tissues, spray application of chemical insecticides rarely results in sufficient control (Huang *et al*., 1994).

Management of litchi fruit borer is very difficult because the damaging stage, larvae feed inside the fruit seed and remain there. That's why litchi growers are tremendously applying synthetic pesticides to control the pest which cause health hazard and 8 children died in Dinajpur district in 2015 (June 24, 2015, www.bdnews24.com). So, for successful and safe management practices of the litchi fruit borer are essential to study

the life history traits of *C. sinensis*. This study may help to find out the effective management strategy of the borer without causing any harm for the human.

The present research was carried out to fulfill the following objectives-

1. To detect the fruit infestations in different fruiting stages of four litchi varieties, and
2. To study the developmental biology of the litchi fruit borer on litchi varieties for its effective management.

CHAPTER II

REVIEW OF THE LITERATURE

Litchi (*Litchi chinensis* Sonn.) is one of the most common, popular and important table fruit crop grown in Bangladesh. Various factors are responsible for low yield of litchi in Bangladesh and out of which attack of different pests is one of the most important one. Amongst them Litchi fruit borer (*Conopomorpha sinensis)* is the important insect pests occurring every year throughout litchi growing areas of Bangladesh. Study on different aspects of the above mentioned pest has been done elsewhere but few of them are related to the present study. Literatures related to litchi, biology of litchi fruit borer, varietal screening or finding of resistant or tolerant variety are presented under the following sub-headings:

2.1 Origin of litchi

The main centre of origin of litchi is believed to be between latitudes 23˚ and 27˚ north in the subtropical parts of southern China, northern Viet Nam and Malaysia. It seems to have been in cultivation since about 1500 BC by people of Malayan descent and has since been subjected to intense selection. China has a long history of litchi cultivation for more than 2000 years and from China it reached Burma (Myanmar) by the end or 17th century and was introduced in India and Thailand about 100 years later (Bose and Mitra,1990). Litchi reached Madagascar and Mauritius around 1870 and was introduced in Hawaii in 1873 by Chinese trader (Ghosh, 2001). It arrived in Florida from India, between 1870 and 1880 and was introduced in California in 1897(Ghosh, 2001). Litchi was probably brought to Australia by Chinese migrants in 1954 and arrived in Israel sometimes between 1930 and 1940 (Ghosh, 2001). China, Taiwan, Thailand, India,

South Africa, Madagascar, Mauritius and Australia are now major litchi producing countries in the world (Ghosh, 2001).

2.2 Utilities of litchi

The litchi is said to relieve coughing and to have a beneficial effect on gastralgia, tumors and enlargements of the glands .One stomach ulcer patient in Florida has reported that after eating several fresh litchis he was able to enjoy a large meal that, ordinarily, would have caused great discomfort. Chinese people believe that excessive consumption of raw litchi causes fever and nosebleed (Lim, 2013).

2.3 Drawbacks faced during litchi cultivation

A considerable amount of litchi fruits losses every year during harvesting, sorting, storing, transportation, selling and consumption due to its perishability. The perishability of this fruit is attributed to immense physiological changes after harvest (Momen *et al.*, 1993). Amiruzzaman (1990) reported that the magnitude of postharvest losses in fresh fruits including litchi in Bangladesh is 25-50%, while it is only 5-25% in developed countries (Khader, 1992).

For developing an effective post harvest handling and packaging technique to minimize the postharvest losses, it is necessary to know the actual causes of postharvest losses at poverty- stricken farmers, whole sellers, and retailers level. Postharvest handling, packaging and storage of fruits are important because they affect the postharvest quality and quantity of produce. However, very little information on the post harvest practices and losses of litchi at growers, arathdars, pikars, beparies, retailers, and consumers level. With this view in mind, the present study was conducted to know the

existing postharvest practices and losses of litchi fruits at different levels, which will help for developing appropriate postharvest practices to reduce its losses.

2.4 Brief history and alternate host of litchi fruit borer

Conopomorpha sinensis Bradley, known as also the litchi stem-end borer in China and the litchi fruit borer in Thailand, is the major pest in most seasons. This pest was previously recorded as *Acrocercops cramerella*. *C. sinensis* and the related *C. litchiella* Bradley both attack litchi, the latter preferring leaves and shoots, while *C. cramerella* is restricted to rambutan and cocoa.

Conopomorpha sinensis lays yellow, scale-like eggs 0.4 x 0.2 mm long on the fruit any time after flowering, as well as on new leaves and shoots. Both litchi and longan are affected. The eggs hatch in three to five days, with the larva immediately penetrating the fruit, leaf or shoot. They tunnel through the flesh of the fruit that often fall from the tree.

In Thailand, fruit are inspected weekly from fruit set to detect eggs of *C. sinensis*, which are very small and almost invisible to the naked eye. Infested fruit should be picked and destroyed, at infestation levels of 1 to 2 percent.

a) **Systematic position of litchi, *Litchi chinensis*** Sonn.

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: Sapindales

Family: Sapindaceae

Genus: *Litchi*

Species**:** *L. chinensis* Sonn. (eFloras: Flora of China,2011)

b) Varieties of litchi

Bombai is the oldest high yielding variety in the country, although there are a number of cultivars growing in different areas of Bangladesh. These are Rajshahi, Madraji, Mongalbari, Kadmi, and Kalipuri. Muzaffarpuri, Bedana and China-3. Bedana and China-3, introduced in the 1950s, are now cultivated successfully in different parts of Bangladesh. Also there are many unnamed land races, most of which are sour in taste with low pulp:stone ratio. The fruits of cultivars like Bedana, China-3, and Rajshahi local contain more edible portion, with high quality pulp. The fruit size in these varieties is bigger with attractive skin colour. Bedana is considered the best variety but gives the poorest yield. Average yield per plant is about 3,000 fruits. The variety is confined to the Dinajpur district, northwest Bangladesh, which is under in agro-ecological zone-1. Recently three varieties, namely: BARI Lichu-1, BARI Lichu-2 and BARI lichu-3 were released by the Bangladesh Agricultural Research Institute (BARI) for farmers adoption. Among the released varieties BARI Lichu-3 is considered the best in respect of fruit size, pulp, colour and yield. The variety closely resembles China-3 variety (Anonymous, 1992).

c) Description of litchi varieties

There are four major varieties of litchi in Bangladesh especially in Dinajpur are Madraji, Bombai, Bedana, and China-3.

i) Madraji

This is the most popular cultivar grown in Bangladesh. Besides having high quality fruit it has a distinct rose aroma. It is known as Madraji. The vegetative flush of this cultivar is light, and fruit weight ranges from 20-25 g. Flowering of this litchi comes in the end of

the march. This cultivar is earliest in maturity, and ripens during the second week of May to the first week of June at various locations. It matures on12-15 May in Bangladesh. Trees of this cultivar are very vigorous and produce fruits ranging from 100-150 kg per plant. Mature fruits are prone to cracking in zones with low humidity and poor moisture content in the soil. Fruits are globous heart or obtuse in shape having rose madder and purple background with red tubercles at ripening. Pulp is greyish-white, soft, moderately juicy and sweet, and TSS ranges from 19.0 to 22.0 brix. Seed size varies. It looks more or less round shape, seed is elongate, aril is fresh and tasty on the same plant larger fruits have big seeds while seeds in small fruits are shrunken. The fruits are known for excellent aroma and quality. This cultivar occupies a major area under litchi in Bangladesh.

ii) Bombai

Comes after the Madraji variety. Infestation is much than other variety. Fruiting season is longer than other varieties. Bombai is most widely cultivated and good yielding variety of Bangladesh. The trees attain an average height of 6 m and bear fruits regularly. It is an early variety, fruits generally mature in the 2nd week of May. Fruits are mostly heart shaped, carmine red in colour and each fruit has another tiny underdeveloped fruit attached to the fruit stalk. Average weight of the fruit is 18-20 g. Pulp is soft, juicy and sweet. TSS 17-18 percent, seed big, pulp : seed ratio 5:1 (www.fao.org).

iii) Bedana

Bedana litchi is much sweet to eat than other varieties. Seed is smaller than other varieties. This variety is considered the best variety in Bangladesh. The trees of this variety are medium in height (about 5 m) and spread of 6 m and regular bearer. The fruits are mostly globose in shape, bright red in colour and the surface of the fruit skin is

smooth. The fruit of this variety generally matures in the 2nd week of June. Average weight of the fruit is 25-28 g, pulp is creamy white and soft, juicy, TSS 18-19 percent, seed shrunken and pulp: seed ratio 28:1(www.fao.org).

iv) China-3

Fruit size is larger than other varieties. Aril is more than other varieties and infestation is less and one of the best varieties grown in Bangladesh. The trees attain an average height of 5 to 6 m with relatively smaller leaves. Bearing is regular if proper management and care is taken, otherwise they show an irregular bearing habit. This is a late variety and fruits ripen in the last week of June. Fruits are globose, with a mixture of red, orange and patches of green colour. Average weight of fruit is 25.0 g. Pulp is creamy white, soft and juicy. TSS 18 percent, seed small, pulp: seed ratio 15:1 (www.fao.org).

2.5 Pests of litchi

Litchi does not suffer from any serious pests or diseases in Bangladesh, but bats and birds cause serious damage at the ripening stage of fruit. Litchi mite and fruit borer are the two major pests of litchi.

A) Litchi fruit borer

The litchi fruit borer, *Conopomorpha sinensis* is a common pest of litchi in Bangladesh (Alam1974). Sharma (1985) reported that litchi fruit borer is one of the major pests of litchi in Bangladesh. Up to the previous century litchi fruit borer was considered as a minor pest. But now-a-days it is regarded as a major pest of litchi, especially in Indian sub-continent (Amin *et al.* 1990). However, four major and one minor insect pests of litchi are identified in Bangladesh (Alam, 1965).

i) Taxonomy of litchi fruit borer *Conopomorpha sinensis* Bradley

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Gracillariidae

Genus: *Conopomorpha*

Species*: C. sinensis* (Bradley, 1986)

ii) Varietal susceptibility of litchi to *C. sinensis*

Sharma (1985) reported that fruit borer thrives during April-May on inflorescence, after fruit setting, the moths lay eggs near the pedicel and on hatching the larvae enter into the fruit and bore through it.

Newton and Crause (1990) conducted an experiment on litchi fruit borer in South Africa in 1986 and reported low rate of oviposition by the moth early in the season at 0.02 eggs/fruit, but increased rapidly to 0.21 eggs/fruit after ripening began.

Singh and Kumar (1995) conducted an experiment with seven cultivars of litchi tested for suitability for the larval development of the litchi fruit borer (*Conopomorpha sinensis*) and Calcutta variety was the most suitable and Rose scented variety was least suitable with regard to larval length and weight and other varieties are intermediate.

iii) Host ranges of *C. sinensis*

There are some alternate host of *Conopomorpha sinensis* i.e. bael, ber, citrus and tamarind damaged fruits this insect was found only in damaged tamarind which might be utilized by this insect during off season as alternate host. Hill (1983) showed the same species of litchi fruit borer, *Conopomorpha sinensis* as a pest of tamarind fruit borer.

iv) Distribution of *Conopomorpha sinensis*

Bangladesh, India, Thailand, China, Japan, Taiwan, Province of China and Australia etc. (Mitra *et al*., 2000).

v) Nature and extent of damage by *Conopomorpha sinensis*

Only one larva of the fruit borer moth bores into a developing fruit from the stem end and feeds inside the seed. A portion of the fruit pulp at the stem end is also spoiled due to the larva feeding on the seed. Huang *et al.* (1994) investigated the damage and population of litchi fruit borer during fruiting period of litchi in Taiwan and reported damage rates 96.1 to 100% in dropped fruits and 41.5 to 96.7% in normal fruits on the trees in a orchard. In an experiment on the occurrence of litchi fruit borer, *Conopomorpha sinensis* Snell in 8 different block of the Kangra district, Himachal Pradesh, India, Ranjeet *et al.* (2000) observed that pest attack varied between 13.6 and 64.09 percent. Incidence of the borer on 9 cultivars indicated maximum attack on "Mclean (85.7%) while "Seedless Early" had minimum incidence of the pest. Varietal resistance to the insect pest may be helpful for its management. Varietal resistance to the insect pest may be helpful for its control.

vi) Biology of *C. sinensis*

From eggs laid onto the fruits or fruit stems, the larvae hatch after 3-5 days and immediately bore into the fruit, where they develop by feeding on the seed neck. During other periods than the fruiting season, the larvae develop in newly produced leaves or shoots of litchi (Waite, 2005).

a) Egg and Oviposition site

The creamy white eggs of these species are oval and flat with a reticulate surface and are about 1.0×0.8 mm. Both litchi and longan are affected (Plate 10). The eggs hatch in 3 to

5 days, with the larva immediately penetrating the fruit, leaf or shoot. They tunnel through the flesh of the fruit that often fall from the tree. Litchi fruit borer laid eggs singly or in groups of up to 35 on the fruit surface or leaf surface. *C. sinensis* lays yellow, scale-like eggs 0.4 x 0.2 mm long on the fruit any time after flowering, as well as on new leaves and shoots.

b) Larva

The larvae are yellow scale like and often have a pink tinge (Plate 10). Larval periods last for 16-18 days. First instar larvae are translucent white in colour and 1 mm long. Late instar larvae are 10 mm long and creamy coloured while still inside the fruit, but greenish after they emerge to pupate.

c) Pupa

When the pupa is formed it is light brown, then gradually becomes darker, and when time for adult emergence it is almost black (Plate 10). Pupal periods last for 8-12 days. Pupae lie beneath a light-brown waterproof silken membrane tightly drawn over a depression on a pod surface or leaf.

d) Adult

The wingspan is 12-15mm.It is an extremely variable species (Plate 10). The longevity of the adult varies from 11-14 day. The adult is a small brown moth, 7 mm in length. It has a wingspan of about 12 mm characterized by bright yellow patches at the tips of the forewings. The moths have very long antennae which are swept backwards in their natural resting position. Moths in flight have an appearance similar to that of large, slow flying mosquitoes.

e) Insecticides used against *C. sinensis*

Insecticides can also be used for the control of this insect pest. Cypermethrin (Ripcord/Cymbush/Basathrin/Arrivo/other) 10 EC @ 1.0 ml/litre of water can be sprayed on fruits 15-20 days before ripening of the fruits for the control of the litchi fruit borer. (www.fao.org).

B) Litchi mite

In Bangladesh eriophid (*Aceria litchi*, Acari: Eriophyidae) is the most destructive pest of the litchi tree. Both adults and nymphs infest the leaves. New leaves of the litchi trees are infested by the litchi mite and such infested leaves, at later stages of their growth, show leaf galls (known as erinose), which are thickened and wrinkled with abnormal hairs that are velvety brown in appearance. Infested leaves later dry up and fall from the trees. Inflorescences, flower buds and young fruits are also infested by the litchi mite. Twigs with severe infestation of leaves bear few inflorescences and fruits. The loss of large number of leaves due to severe mite infestations may affect yield in the following year because of the reduction in photosynthetic activities, though general loss of green leaves due to the mite infestation is mostly compensated by frequent flushes of new leaves in the affected twigs. All varieties of litchi are susceptible to infestation by the litchi mite and trees having dense foliage show more severe infestations.

There may be 10 to 12 overlapping generations of the litchi mite in a year. Litchi mites are found in both the adult and nymphal stages in the infested leaves at varying ratios throughout the year. Their populations remain very low from November to the middle of February. The population reaches its peak in April - May. Adults are mostly seen in infested leaves during February-March and June to August. The litchi mites

spread from one tree to another by movement through the soil and touching leaves of adjacent trees. The infestation starts in February, becomes maximum in May-June and continues up to October.

Controls are:

- Pruning and burning of affected twigs in June and August each year in severely infested trees and pruning and burning of affected twigs in August in less infested trees repeatedly for 2 to 3 years was found to be very effective in controlling the litchi mite.
- Spraying of litchi leaves during April and May with Kelthane 40 MF or Neoron 500 EC or Torque 50 EC or wettable sulphur @ 2.0 ml/litre of water will be helpful for the control of the litchi mite.
- Three species of predaceous spider mites (*Tetranychus* spp.) have been reported to predate on different stages of the litchi mite in Bangladesh, but their role as effective natural enemies in the control of the litchi mite has not been established (www.fao.org).

C) Caterpillar

The next important insect pest of litchi is the bark eating caterpillar (*Indarbela tetraonis*). The adult moth of this pest lays eggs during May and June in groups of 15-25, which hatch after 8-11 days. The larvae feed on the surface of the bark until September. Afterwards they bore into bark and underlying tissues in the branches. These become fully grown in December and pupate in April. Plugging the holes with fumigants such as carbon bisulphide, petroleum or formalin and then plastering with mud checks the caterpillars effectively (www.fao.org).

CHAPTER III

MATERIALS AND METHODS

The study was conducted in both the field and laboratory conditions under the department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur during March to June, 2015.

3.1 Estimation of natural fruit infestation by *C. sinensis*

In the orchard, untreated single fruit and tree of four litchi varieties viz. Bombai, Madraji, Bedana and China-3 were surveyed for the study (Plate 4, 5, 6, 7 and 8). From each tree of four varieties 10 fruits were collected weekly from April 18 to May 30 (7 weeks) in order to determine the fruit infestation rates by *C. sinensis* over the fruiting season. Each treatment was replicated in thrice. The infestation time, and length, diameter and weight of fruits were also measured during the fruiting stage. The fruits were instigated to measure just after the flowering stage (Plate 1). A fruit was assigned to be infested if a larva was present inside the fruit, or if any evidence was found that a larva had developed earlier (presence of entrance holes or insect excreta). The presence of larva was also verified by dissecting the fruits with observing under the microscope. In addition, length and diameter of the fruits were measured at the sampling dates, using a standard slide calipers (Plate 2) and the fruit weight was measured by digital electronic balance (Plate 3).

3.1.1 Percent fruit infestation by number

At each time of data collection, the healthy fruits (HF) and the infested fruits (IF) were separated and counted. The percent fruit infestation was calculated by using the following formula:

$$\% \text{ Fruit infestation by number} = \frac{\text{Number (No.) of IF}}{\text{No. of HF} + \text{No. of IF}} \times 100$$ (kulsum, 2014)

3.1.2 Percent fruit infestation by weight

After screening the healthy fruits from the infested fruits (IF), the weight was taken separately. The percent infested fruit as weight for each treatment was calculated by using the following formula:

$$\% \text{ Fruit infestation by weight} = \frac{\text{Weight (Wt.) of IF}}{\text{Wt. of HF} + \text{Wt. of IF}} \times 100$$ (kulsum, 2014)

3.1.3 Percent weight reduction per fruit

The percent weight reduction for each treatment was calculated by using the formula:

$$\% \text{ Weight reduction per fruit} = \frac{\text{Weight (Wt.) of single HF} - \text{Weight (Wt.) of single IF}}{\text{Wt. of single HF}} \times 100$$

(Kulsum, 2014)


Plate 1. Fruits measurement just after the flowering stage

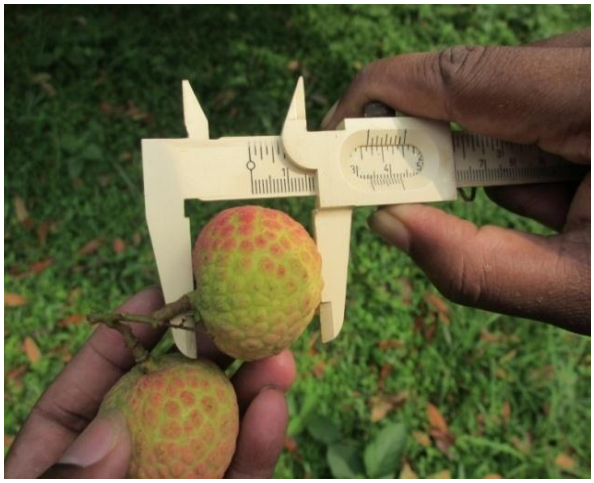

Plate 2. Measurement of fruit size (length and diameter) by slide calipers

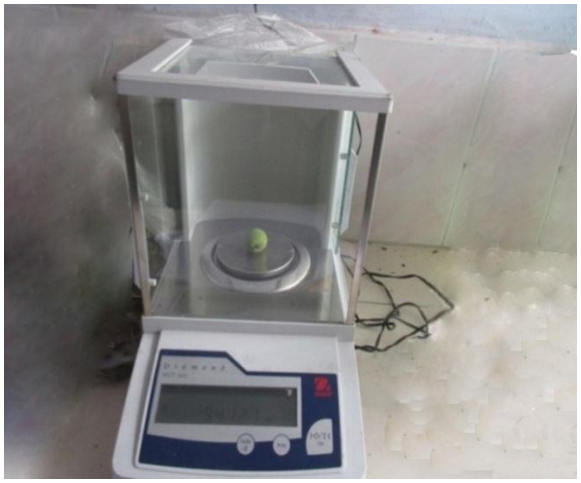

Plate 3. Measurement of fruit weight by electrical digital balance

3.2 *Conopomorpha sinensis* rearing

To initiate the stock culture, infested litchi fruits with larvae of *Conopomorpha sinensis* were collected from the litchi orchard. The larvae were reared inside the glass jar in the laboratory [(Temp. 20-30°C, RH. 85-90% and photoperiod 13-14:11-10 (L: D)].After emergence of adults sugar solution was provided for the survival of moths and encouraged the egg laying. The stock culture was then maintained supplied with fresh fruits. Proper hygienity was maintained during the mass rearing period.

3.3 Immature development and adult performance

Development and adult performance of the litchi fruit borer were examined on two varieties of litchi. To determine the developmental times of the immature stages and reproductive phases of adults, 15 gravid females per litchi varieties were randomly taken from the stock culture. Each female were allowed to lay eggs on fresh fruit for 12 hours. Twenty five individual eggs were maintained for each treatment (variety). Developing immature fruit borer from egg to adult were observed every 12 hour and the development stage were recorded. These observations were used to calculate the stage specific developmental times and the mortality rates at each variety. Newly emerged female adults were allowed to mate individually with an active male obtained from the same treatment conditions or from mass rearing within 12 hour of their emergence. The pre-oviposition, oviposition, post-oviposition periods and fecundity of these females were recorded at 12 hours intervals until each female died. After being counted newly laid eggs from each replication were collected and transferred to each fresh fruit where they were reared to adulthood and their sex ratio was determined.

3.4 Life table analysis

Observations on survival and development times of immature *C. sinensis* together with information on adult fecundity and longevity were used to construct a time-specific life table for *C. sinensis* under the laboratory rearing conditions. Deaths occurring in the egg or other immature stages were taken into account when the female survival rate at each variety was determined. Life table parameters for females at two varieties of litchi were estimated using Birch's (1948) equation:

$$\sum e^{-r_m x} l_x m_x = 1$$

Where, x = age in days, l_x = the age-specific survival rate, m_x = the age-specific fecundity, the intrinsic rate of natural increase (r_m = ln ($\sum l_x m_x$)/T), the finite rate of increase ($\lambda = e^r$), the net reproductive rate ($R_0 = \sum l_x m_x$), the mean generation time ($T = \sum X l_x m_x / R_0$), and the gross reproductive rate is the mean total number of eggs produced by a female over its lifetime, ($GRR = \sum m_x$) measured in female eggs/ female/generation. Doubling time is the time required for a given population to double its number, [DT = (ln 2)/r] measured in days were calculated as described by Mackauer (1983).

3.5 Statistical analysis

Data were analyzed using one way analysis of variance (ANOVA) using the software IBM SPSS Statistics version 20 (2011). For determination of correlation between the size of litchi fruits and natural fruit infestation rates by *C. sinensis* over time, the means were separated by Tukey's honest significant difference test (Tukey's HSD test). The biological parameters of *C. sinensis* between litchi varieties were compared using the independent sample *t*-test ($P < 0.05$).

Plate 4. A tested plant of litchi (Madraji)

Plate 5. A tested plant of litchi (Bombai)

Plate 6. A tested plant of litchi (Bedana)

Plate 7. A tested plant of litchi (China-3)

a) Madraji **b**) Bombai **c**) Bedana **d**) China-3

Plate 8. Morphological view of litchi fruits of four cultivars

a) Early stage of fruits

b) Mid stage of fruits

c) Late or matured stage of fruits

Plate 9. Observation of fruit infestation by *C. sinensis* in different growth stages of litchi fruits.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Estimation of fruit infestation by *C. sinensis*

The fruit infestation rate was observed in different growth periods is presented in Figure 1. The first fruit infestation was detected on 18, 25 April and 9 May in the variety of Madraji, Bombai, Bedana and China-3, respectively. After that it was increased exponentially in the following weeks. The infestation was the highest (80%) in the Bombai variety while it was the lowest (30%) in China-3. Peak infestation was observed on 30 May in all the varieties under study.

The observed fruit infestations by *C. sinensis* in different sizes (length and diameter) of litchi fruits are presented in Figure 2 and 3. As the increases of length and diameter of litchi fruits the rate of infestation was increased. The fruit infestation was first detected in the variety of China-3 when the fruit sizes were ranges from 1.11 to 1.50 cm in length. On the other hand, the fruit infestation by *C. sinensis* were delayed in Bombai while the length ranges from 2.51 to 3.00 cm. Similar trends of infestations were observed when with increasing measured the diameter of the fruits. Additionally, the infestation was estimated based on the fruits weight is presented in Figure 4. Fruit borer infestation was observed in all litchi varieties. On the basis of weight, the Bombai was the first variety attacked by *C. sinensis* during weight ranges from 1.00 to 2.00 g. Highest infestation was also estimated in Bombai while the fruit weight ranges from 10.00 to 11.00 g.

Initially the fruit infestation rate was 30% on April 25 while the fruits were 3.12 cm in length, 1.33 cm in diameter and 2.87g in weight. Highest infestation was found in Bombai (44.29%) variety and lowest in China-3 (17.14%) ($F=2.772$,df = 3, $P = 0.01$, Appendix table 2).

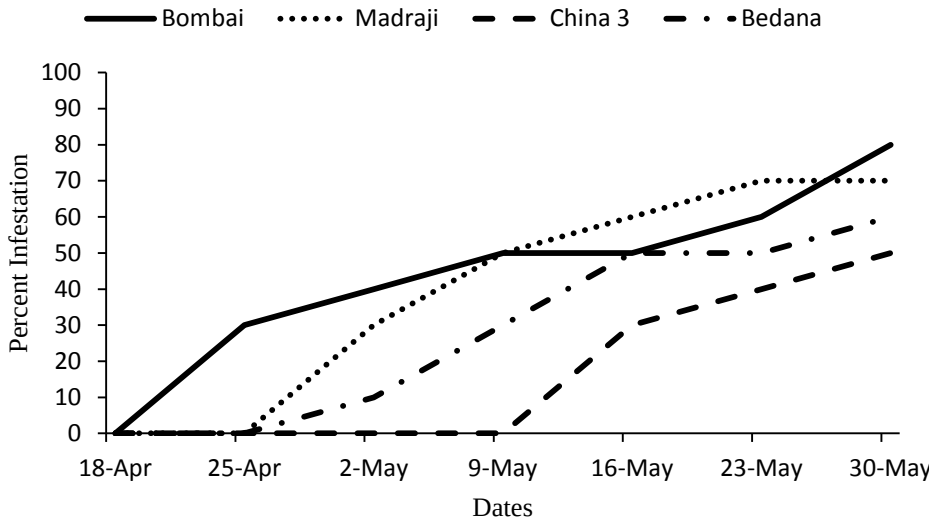

Figure 1. Percent fruit infestation by C. sinensis observed during the growth period of litchi varieties.

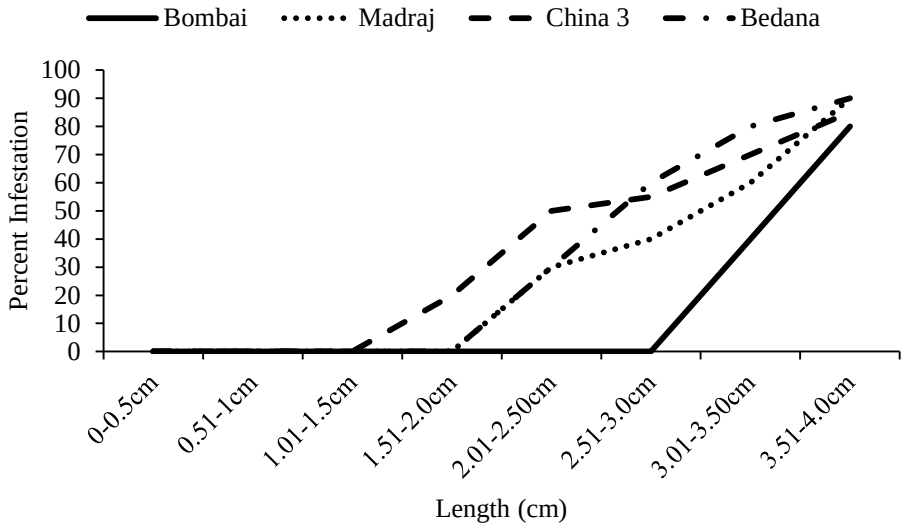

Figure 2. Percent fruit infestation by *C. sinensis* observed in different length (cm) of fruits in four litchi varieties.

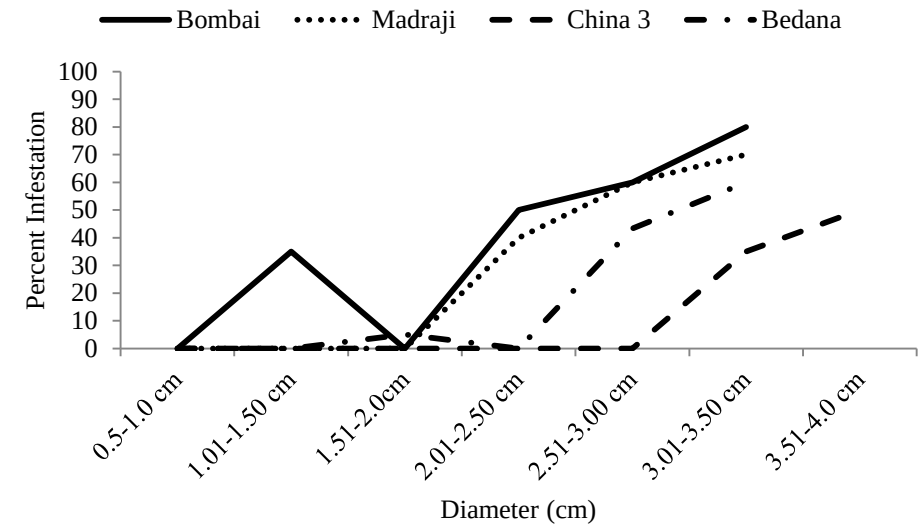

Figure 3. Percent fruit infestation by *Conopomorpha sinensis* observed in different diameters (cm) of fruits in four litchi varieties.

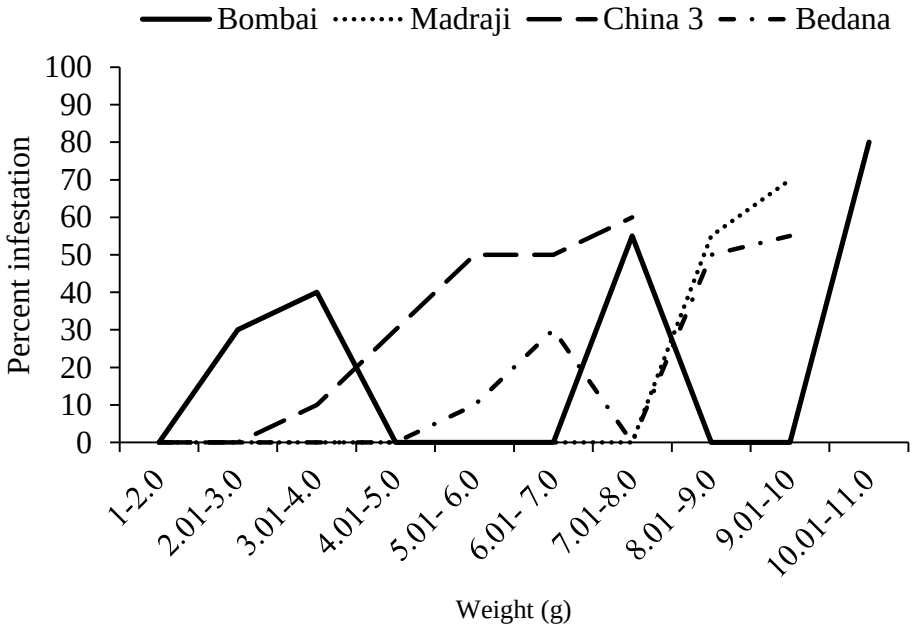

Figure 4. Percent fruit infestation by *Conopomorpha sinensis* observed in different weight (g) of fruits in four litchi varieties.

The relationship of infestation rate of the fruits by *C. sinensis* with the growth period and size of litchi fruits (length and diameter) are presented in Figure 5.

A highly significant ($P \leq 0.01$) positive correlation between the fruit size and infestation rate of *C. sinensis* was found in all the tested varieties (Madraji: y = 1.9388x - 81646; R^2 = 0.92; Bombai: y = 1.5816x - 66595; R^2 = 0.91; Bedana: y = 1.6327x - 68760; R^2 = 0.94; China-3: y = 1.3265x - 55874; R^2 = 0.82).

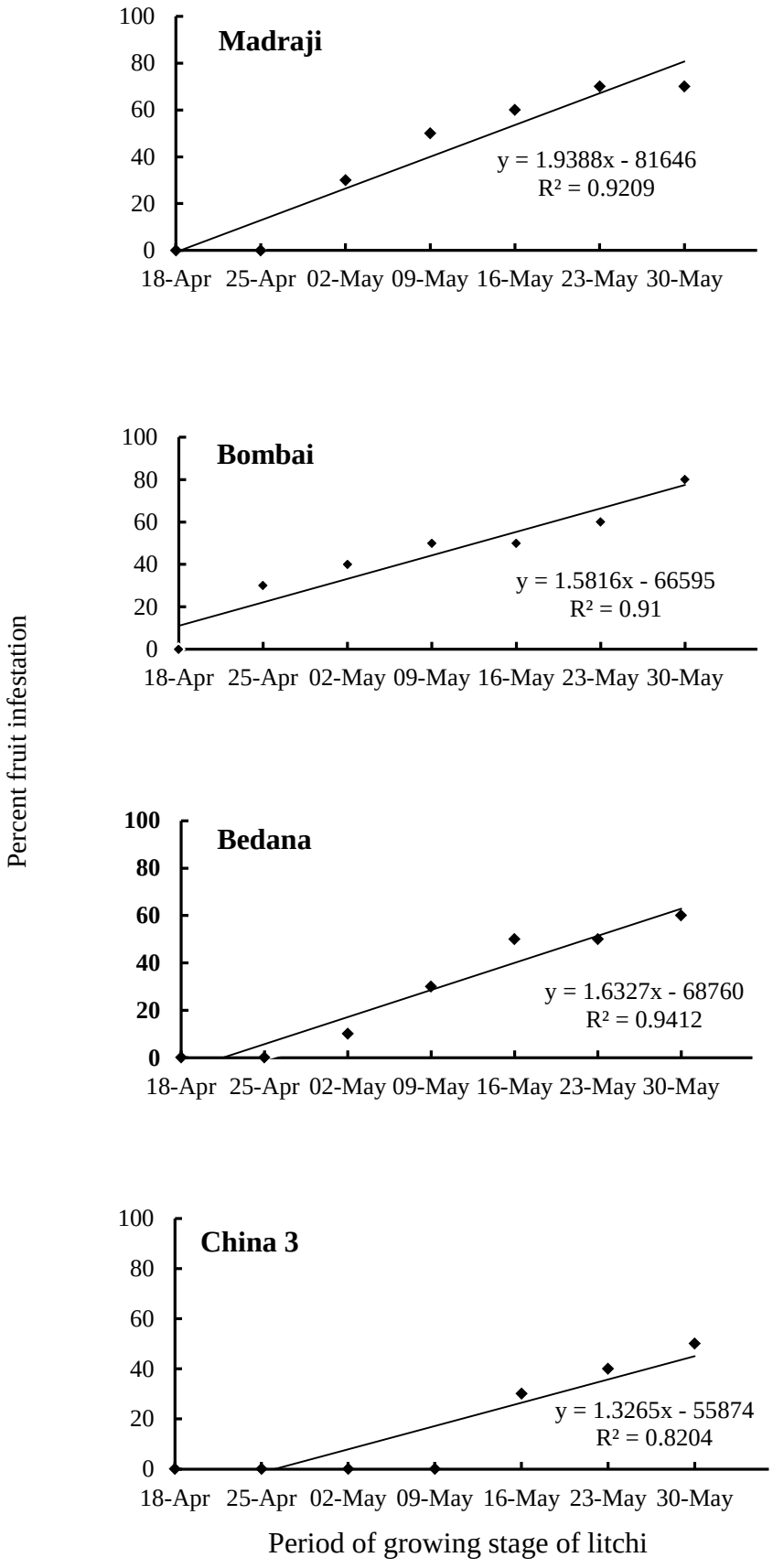

Figure 5. Relationship between infestation and growth period of fruit in four varieties of litchi

4.2 Life history traits of *C. sinensis*

4.2.1 Immature development

Developmental time of litchi fruit borer (*Conopomorpha sinensis*) in two litchi varieties is presented in Table 1. Between the tested litchi varieties, the developmental time was found higher in Bombai while lower in Madraji. Fluctuation was observed in the line of egg to adult developmental times in the litchi varieties.

The female and male immature developmental time (egg to adult emergence) and adult longevity are shown in Table 1. Significant variation was observed in eggs, larvae, pupae and overall developmental period (female: $t = 2.58$, df = 13, $P = 0.023$ and male: $t = 0.31$, df = 9, $P = 0.761$, Appendix table 5 & 6) in term of female progeny while litchi fruit borer fed the litchi varieties. But there was no significant difference found in case of adult longevity. Female *C. sinensis* developed faster on Bombai variety than Madraji (Table 1).

The duration of the egg stage ranged from 3.88 to 4.57 days in females and 3.17 to 3.60 days in males. The egg development time of female was 4.57 days in Bombai variety which is longer than Madraji variety where eggs developed within 3.88 days. Significant difference was observed in egg period between the tested litchi varieties (Female: $t = 3.02$, df = 13, $P = 0.010$ and Male: $t = 4.98$, df = 9, $P = 0.001$, Appendix table 5 and 6).

Newly hatched larvae of *C. sinensis* were white in color. The litchi varieties showed the variations in larval periods which presented in Table 1. The female and male larval development periods were 11.13, 13.57 days and 10.80, 13.33 days in Madraji and Bombai variety, respectively. The larval developmental times of the female showed

significant differences but not in male. (Female: t = 4.18, df = 13, P = 0.001 and male: t = 0.66, df = 9, P = 0.527, Appendix table 5 and 6).

It is reported the longer duration of female and male larvae were 13.52 and 13.29 days at 25^{o}C while the shorter durations were 11.16 and 12.11 days at 25^{o}C (Abd El-Wahed and El-Halawany, 2012).

Development times from the egg stage to adulthood of *C. sinensis* occurred in the litchi varieties are shown in Table 1. Different litchi varieties were not influenced the immature development of *C. sinensis*. The time ranges elapsed from egg stage to adult emergence was 23.01 to 24.71 days for female and 22.20 to 22.83 days for male. The longer female development time (24.71 days) occurred in Bombai but the shorter (23.01 days) in Madraji. It is also reported the duration of total immature stages was significantly longer for females than males (Kasap, 2004). Helle and Sabelis (1985a) also observed the development from egg to adult within 23.00 - 25.20 days at 25.0 – 30.0ºC and all the life stages present throughout the year, depending on the environmental conditions.

4.2.2 Adult performance

4.2.2.1 Adult longevity

The adult longevity, the length of time from adult emergence to natural death in both the sexes was not differed significantly between the tested litchi varieties. The adult females were lived longer than male. The female moth of litchi fruit borer survived (11.75 days) on the Madraji which is longer than Bombai variety where it lived (11.57 days) (Table 1). On the other hand, the adult longevity (11.83 days) of male litchi fruit borer was higher on Bombai than on Madraji litchi variety (10.60 days). Analysis of variance showed that mean adult longevity, the length of time from adult emergence to natural death, was not significantly different between the varieties in both the sexes.

Eggs

Larva

Pupa

Adult (male)

Adult (female)

Plate 10. Different life stages of *C. sinensis.*

Table 1. Developmental time and adult longevity of *Conopomorpha sinensis* reared on two litchi varieties under the laboratory conditions [Temp. 20-30°C, RH 80-90% and Photoperiod 13-14:11-10 (L:D)]

Variety	Sex[a]	N[b]	Egg	Larvae	Pupae	Egg-Adult	Adult longevity
Madraji	F	10	3.88 ± 0.13a	11.13 ± 0.30a	8.0 ± 0.27a	23.01 ± 0.42a	11.75 ± 0.37a
	M	10	3.60 ± 0.24a	10.80 ± 0.45a	7.80 ± 0.37a	22.20 ± 0.97a	10.60 ± 0.60a
Bombai	F	10	4.57 ± 0.20b	13.57 ± 0.53b	6.57 ± 0.20b	24.71 ± 0.52b	11.57 ± 0.20a
	M	10	3.17 ± 0.17b	13.33 ± 0.61a	6.33 ± 0.21a	22.83 ± 0.70a	11.83 ± 0.40a

[a]'F' means females and 'M' means males.

[b] Number of individuals tested.

All values are means ± SE. Means in the same column followed by different letters for each stage of the same sex between two varieties are significantly different at $P<0.05$ (*t*- test).

4.2.2.2 Reproduction

Reproductive phases and fecundity of *C. sinensis* are presented in Table 2. Upon adult emergence, the females were arranged to get mated with released males. Litchi varieties did not show significant effect on the duration of the pre-oviposition, but show significant differences on the duration of oviposition and post-oviposition period. The longer pre-oviposition and oviposition period were 3.75 and 5.28 days observed on Madraji and Bombai varieties, respectively. Whereas both the periods were 3.43 and 4.13 days which were shorter on the Bombai and Madraji varieties, respectively. The duration of the post-oviposition period was the longer (3.88) days on Madraji but shorter (2.86) days on Bombai. The age-specific fecundity rate (m_x) peaked on Bombai and the fecundity period was the narrower on Madraji.

Litchi varieties significantly affected the per capita total egg production of *C. sinensis* (Table 2). The maximum number (31.28 ± 0.99 eggs) was laid on Bombai, while minimum number (29.50 ± 0.53 eggs) oviposited on Madraji (df=13, t = 1.64 P = 0.125, Appendix table 5). The daily egg production, estimated by dividing the total egg production by oviposition period, was also influenced significantly by these litchi cultivars. Daily oviposition was the higher (7.31 ± 0.45 eggs) on Madraji and the lower (5.97 ± 0.30) eggs on Bombai variety (t =14.67, df =13, P<0.001). (Appendix table 5).

Table 2. Reproductive phases (days) and fecundity (number of eggs) of *C. sinensis* on two litchi varieties under laboratory conditions [(Temp. 20-30°C, RH. 85-90% and Photoperiod 13-14:11-10 (L: D)]

Variety	Pre-oviposition	Oviposition	Post-oviposition	Daily fecundity/♀	Lifetime fecundity/♀
Madraji	3.75 ± 0.25a	4.13 ± 0.23a	3.88 ± 0.30a	7.31 ± 0.45a	29.50 ± 0.53a
Bombai	3.43 ± 0.20a	5.28 ± 0.18b	2.86 ± 0.14b	5.97 ± 0.30b	31.28 ± 0.99a

Means in the same column followed by the different letters are significantly different and same letters are non- significantly different at $P<0.05$ (*t*- test).

4.2.2.3 Sex ratio

The proportion of males ranged from 0.47 to 0.54 across the two different litchi varieties (Figure 6). The sex ratio of the litchi fruit borer was female biased and it was unaffected by the variations of hosts. Kasap (2004) reported that the sex ratio (proportion of males) of C. sinensis ranged from 0.45 to 0.53 percent on different host plants at 25 ± 1ºC, 60 ± 10% RH.

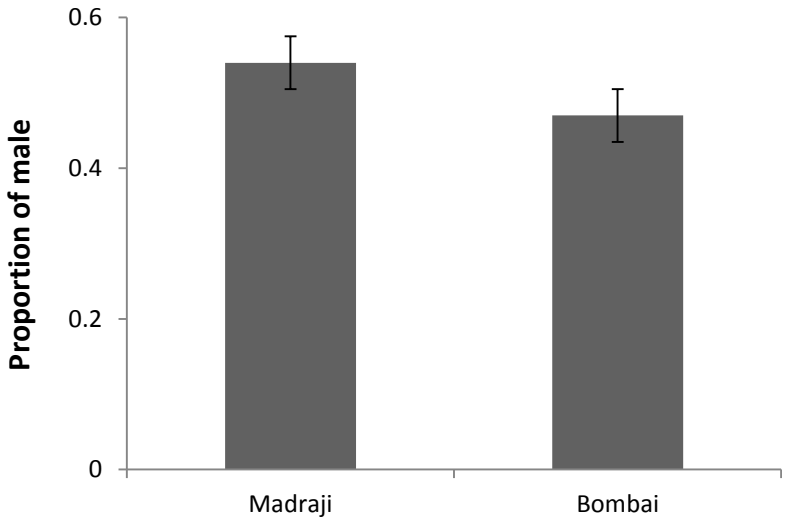

Figure 6. Sex ratio of *Conopomorpha sinensis* on two litchi varieties

4.3 Life table parameters

Variations of life table parameters were estimated on two different litchi varieties (Table 3). The net reproductive rate (R_0) was higher (21.27) while fed on Bombai and lower (19.26) on Madraji variety. Intrinsic rate of natural increase (r_m) was maximum (0.10) on Madraji and the minimum on (0.09) on Bombai variety. The intrinsic rate of natural increase (r_m) was higher (0.10) on Madraji variety. Normally, higher r_m is related to shorter developmental and generation time.

The intrinsic rate of natural increase is an important parameter, describing the growth potential of a population under climatic and food conditions, because it reflects the overall effects of temperature and food on development, reproduction and survival characteristics of the population (Southwood, 1978). Preceding studies of the litchi fruit borer also demonstrated that the r_m values varied significantly within host plants.

Mean generation time, *T* was the longer (32.34) days while fed Bombai variety but shorter (30.41) days on Madraji. Finite rate of increase (λ) was the higher (1.10) while fed on Bombai and the lower (1.099) on Madraji variety. Population doubling times, *DT* was the longer (7.33) on Bombai Variety and shorter (7.13) while fed Madraji. The gross reproductive rate (*GRR*) was higher (21.27) on the host Bombai variety and lower (19.26) on the host Madraji at 25°C and 85% RH.

Table 3. Life table parameters of *C .sinensis* while fed on two litchi varieties

Host(s)	R_0	r_m	T	λ	DT	GRR
Madraji	19.26	0.10	30.41	1.10	7.13	19.26
Bombai	21.27	0.09	32.34	1.10	7.33	21.27

Where,

R_0 = The net reproductive rate,

r_m = The intrinsic rate of natural increase,

T = The mean generation time

λ= The finite rate of increase

DT = The population Doubling time and

GRR =The gross reproductive rate.

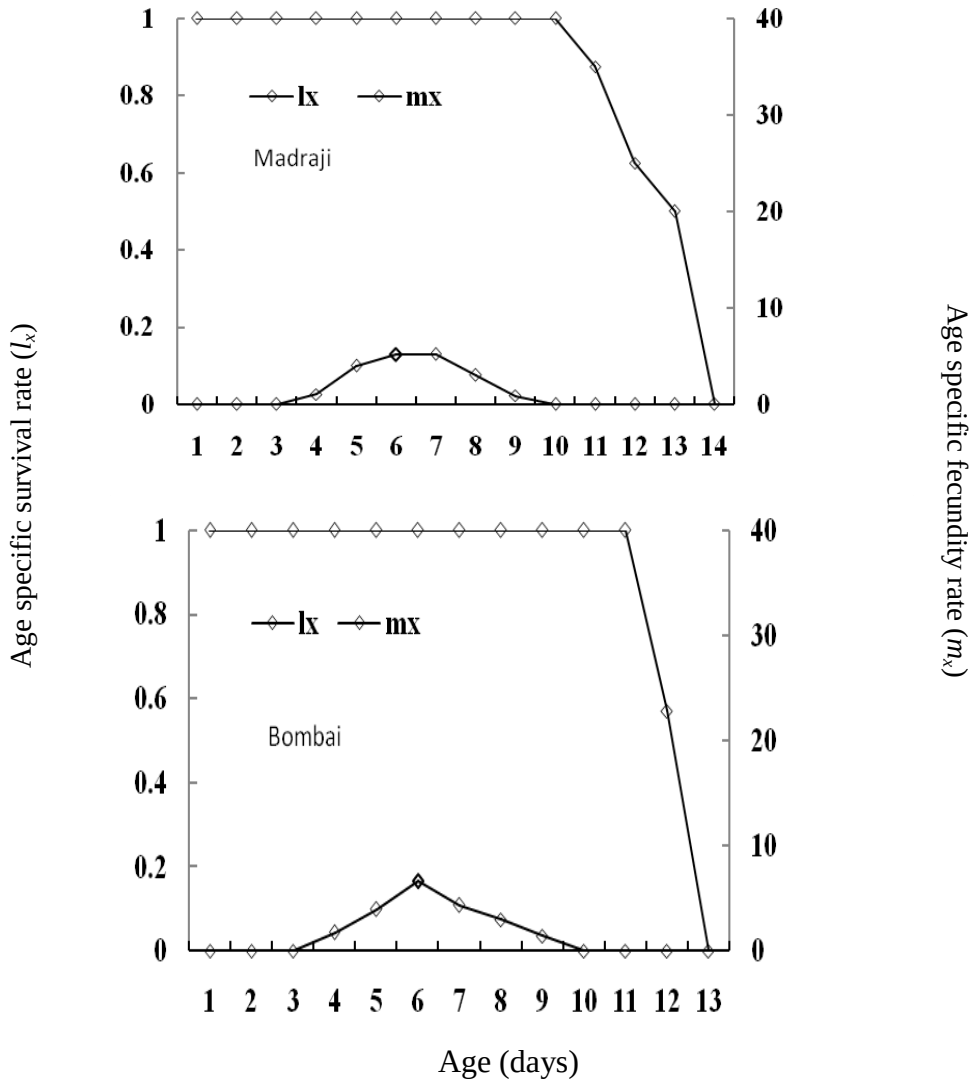

Figure 7 Age-specific survivorship (l_x) and age specific fecundity (m_x) of female *C. sinensis* on two litchi varieties. l_x = proportion of females alive at age x. m_x = (proportion of females) x (age specific oviposition).

a

b

c

Plate 11. Damaged fruits of litchi by litchi fruit borer i.e. a) Larva boring the fruit b) Larva inside the seed c) Entry of larva into the fruit

CHAPTER V

SUMMARY AND CONCLUSION

The litchi fruit borer, *Conopomorpha sinensis* is the most damaging insect pest of litchi. To know the biology of litchi fruit borer on different varieties litchi, nature and extent of damage and relationship of infestation with different fruit characters are essential.

The female and male immature developmental time (egg to adult emergence) and adult longevity are shown in Table 1. Female *C. sinensis* developed faster on Bombai varieties than Madraji because they fed on more and leads early to mature.

The duration of the egg stage ranged from 3.88 to 4.57 days in females and 3.17 to 3.60 days in males when fed the two litchi varieties. Female egg development time was the longer (4.57 days) in Bombai variety where (3.88 days) were taken in Madraji variety.

The female and male larval development periods were 11.13, 13.57 days and 10.80, 13.33 days while fed on Madraji and Bombai variety respectively.

The longer duration of female and male larvae were 13.57 and 13.33 days at 25^{o}C while the shorter durations were 11.13 and 10.80 days at 25^{o}C.

The time ranges elapsed from egg stage to adult emergence was 23.01 to 24.71 days for female and 22.20 to 22.83 days for male. The longer female development time occurred in Bombai but the shorter in Madraji.

The female litchi fruit borer survived markedly longer (11.75 days) on the Madraji variety but observed shorter (11.57 days) on Bombai (Table 1). On the other hand, the adult longevity of male litchi fruit borer found higher (11.83 days) on Bombai while shorter (10.60 days) on Madraji litchi variety.

Litchi varieties did not show significant effect on the duration of the pre-oviposition, but show significant difference on the duration of oviposition and post-oviposition period. The longer pre-oviposition and oviposition period 3.75 and 5.28 days were observed on Madraji and Bombai variety, respectively. Whereas, both the periods were shorter 3.43 and 4.13 days on the Bombai and Madraji variety respectively. The duration of the post oviposition period was the longer (3.88 days) on Madraji but shorter (2.86 days) on Bombai.

The maximum number (31.28 ± 0.99 eggs) was laid on Bombai, while minimum number (29.50 ± 0.53 eggs) oviposited on Madraji. The mean daily egg production, estimated by dividing the total egg production by oviposition period, was also influenced significantly by these litchi cultivars. Daily oviposition was higher (7.31 ± 0.45 eggs) on Madraji and lower (5.97 ± 0.30 eggs) on Bombai variety between all hosts.

The net reproductive rate (R_0) was higher (21.27) while fed on Bombai and lower (19.26) on Madraji variety. Intrinsic rate of natural increase (r_m) was maximum (0.10) on Madraji and the minimum on (0.09) on Bombai variety. The intrinsic rate of natural increase (r_m) was higher (0.10) on Madraji variety. Normally, higher r_m is related to shorter developmental and generation time.

Mean generation time, *T* was the longer (32.34) days while fed Bombai variety but shorter on (30.41) days on Madraji.

Finite rate of increase (λ) was the higher (1.10) while fed on Bombai and the lower (1.099) on Madraji variety. Population doubling times, *DT* was the longer (7.33) on Bombai Variety and shorter (7.13) while fed Madraji.

The gross reproductive rate (*GRR*) was higher (21.27) for the host Bombai variety and lower (19.26) for the host Madraji variety at 25°C and 85% RH.

All the studied varieties were susceptible to fruit borer infestation. The highest fruit borer infestation was found in Bombai and lowest in china-3. Based on the fruit borer infestation level Bombai and Madraji were most susceptible variety to litchi fruit borer and Bedana, China-3 were moderately resistant.

Litchi fruit borer infestation had significant correlation with fruit length, diameter, and weight.

From the above study it was observed that Bombai variety is highly susceptible to litchi fruit borer.

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APPENDICES

Appendix table 1. Daily minimum and maximum Temperature (ºC) relative humidity (RH) and rainfall (mm) from April, 1 to April 30, 2015 (source: Weather Station, HSTU, Dinajpur)

Date	Temperature (^{0}C)		Relative Humidity (%)	Rainfall (mm)
	Minimum	Maximum		
1-Apr	20.0	31.5	83	0
2-Apr	19.5	28.3	88	0
3-Apr	19.6	27.4	87	0
4-Apr	19.9	32.7	82	0
5-Apr	19.0	29.3	84	1
6-Apr	20.0	31.2	78	0
7-Apr	20.5	32.2	81	0
8-Apr	19.5	32.5	80	0
9-Apr	20.0	34.0	71	0
10-Apr	17.5	34.9	64	0
11-Apr	20.0	33.8	75	0
12-Apr	20.0	32.5	75	1
13-Apr	20.9	31.4	77	0
14-Apr	20.5	33.0	74	0
15-Apr	20.7	33.8	77	0
16-Apr	21.4	35.9	75	0
17-Apr	23.0	33.5	83	16
18-Apr	19.3	27.6	85	19
19-Apr	17.8	26.0	86	0
20-Apr	19.0	29.0	84	14
21-Apr	23.2	29.7	85	29
22-Apr	18.7	28.4	87	0
23-Apr	21.5	30.2	86	0
24-Apr	20.6	29.7	83	0
25-Apr	19.6	28.2	88	0
26-Apr	19.5	29.0	86	0
27-Apr	19.8	32.0	86	0
28-Apr	20.3	32.0	87	0
29-Apr	20.0	29.4	86	0
30-Apr	20.8	31.6	87	0

Appendix table 1. Daily minimum and maximum Temperature (ºC) relative humidity (RH) and rainfall (mm) from May, 1 to May 31, 2015

Date	Temperature (^{0}C)		Relative Humidity (%)	Rainfall (mm)
	Minimum	Maximum		
1-May	20.7	32.5	88	0
2-May	22.7	32.2	84	7
3-May	21.0	33.0	87	0
4-May	21.4	34.9	85	0
5-May	22.5	34.9	86	0
6-May	22.7	34.0	88	0
7-May	24.5	32.0	87	0.5
8-May	21.7	32.0	87	0
9-May	22.7	33.4	85	1
10-May	24.1	32.1	88	0
11-May	24.4	31.4	86	13
12-May	23.9	33.6	87	14
13-May	19.7	33.2	85	0
14-May	23.2	35.5	84	0
15-May	24.8	36.9	83	0
16-May	24.5	32.5	87	0
17-May	24.5	33.5	88	0
18-May	22.5	33.7	89	2
19-May	22.5	32.2	85	63
20-May	23.5	31.0	87	0
21-May	24.0	33.5	88	38
22-May	21.5	34.2	88	0
23-May	25.0	34.1	86	20
24-May	19.8	29.3	89	1
25-May	22.0	29.5	90	4
26-May	19.9	32.7	87	14
27-May	21.8	32.1	90	0
28-May	22.5	32.4	89	126
29-May	21.3	30.5	87	28
30-May	22.5	29.0	88	0
31-May	23.8	32.3	89	0

Appendix table 2. ANOVA table of length of different varieties of litchi

Dates	Treatments	Sum of Squares	df	Mean Square	F	Prob.
18.4.15	Between Groups	0.177	3	0.059	1.780	0.05
	Within Groups	1.192	36	0.033		
	Total	1.369	39			
25.4.15	Between Groups	2.717	3	0.906	21.688	0.05
	Within Groups	1.503	36	0.042		
	Total	4.221	39			
2.5.15	Between Groups	1.858	3	0.619	10.847	0.05
	Within Groups	2.056	36	0.057		
	Total	3.914	39			
9.5.15	Between Groups	5.246	3	1.749	55.155	0.05
	Within Groups	1.141	36	0.032		
	Total	6.387	39			
16.5.15	Between Groups	0.542	3	0.181	6.011	0.05
	Within Groups	1.082	36	0.030		
	Total	1.624	39			
23.5.15	Between Groups	0.729	3	0.243	7.351	0.05
	Within Groups	1.190	36	0.033		
	Total	1.919	39			
30.5.15	Between Groups	2.137	3	0.712	2.772	0.05
	Within Groups	9.248	36	0.257		
	Total	11.385	39			

Appendix table 3. ANOVA table of diameter of different varieties of litchi

Dates	Treatments	Sum of Squares	df	Mean Square	F	Prob.
18.4.15	Between Groups	0.851	3	0.284	14.946	0.05
	Within Groups	0.684	36	0.019		
	Total	1.535	39			
25.4.15	Between Groups	0.804	3	0.268	12.076	0.05
	Within Groups	0.799	36	0.022		
	Total	1.603	39			
2.5.15	Between Groups	1.687	3	0.562	14.569	0.05
	Within Groups	1.389	36	0.039		
	Total	3.076	39			
9.5.15	Between Groups	1.093	3	0.364	7.208	0.05
	Within Groups	1.820	36	0.051		
	Total	2.913	39			
16.5.15	Between Groups	2.749	3	0.916	9.901	0.05
	Within Groups	3.332	36	0.093		
	Total	6.081	39			
23.5.15	Between Groups	2.002	3	0.667	9.194	0.05
	Within Groups	2.613	36	0.073		
	Total	4.616	39			
30.5.15	Between Groups	4.003	3	1.334	20.918	0.05
	Within Groups	2.296	36	0.064		
	Total	6.299	39			

Appendix table 4. ANOVA table of weight of different varieties of litchi

Dates	Treatments	Sum of Squares	df	Mean Square	F	Prob.
18.4.15	Between Groups	1.975	3	0.658	2.989	0.05
	Within Groups	7.928	36	0.220		
	Total	9.903	39			
25.4.15	Between Groups	3.929	3	1.310	4.308	0.05
	Within Groups	10.946	36	0.304		
	Total	14.875	39			
2.5.15	Between Groups	78.453	3	26.151	20.626	0.05
	Within Groups	45.642	36	1.268		
	Total	124.095	39			
9.5.15	Between Groups	18.094	3	6.031	1.471	0.05
	Within Groups	147.649	36	4.101		
	Total	165.743	39			
16.5.15	Between Groups	54.139	3	18.046	12.724	0.05
	Within Groups	51.057	36	1.418		
	Total	105.196	39			
23.5.15	Between Groups	274.703	3	91.568	68.577	0.05
	Within Groups	48.069	36	1.335		
	Total	322.771	39			
30.5.15	Between Groups	229.045	3	76.348	159.957	0.000
	Within Groups	17.183	36	0.477		
	Total	246.228	39			

Appendix table 5. *t*-test of immature development of *Conopomorpha sinensis* (Female*)*

Parameters	df	*t*	*P*
Egg period	13	3.02	0.010
Larval period	13	4.18	0.001
Pupal period	13	4.16	0.001
Egg-adult period	13	2.58	0.023
Pre-oviposition period	13	0.98	0.345
Oviposition period	13	3.90	0.002
Post-oviposition period	13	2.96	0.011
Adult longevity	13	0.41	0.689
Total period	13	0.92	0.377
Total number of eggs	13	1.64	0.125
Eggs /day	13	14.67	0E+00
Fecundity (Eggs/day/female)	13	1.78	0.098

Appendix table 6. *t*-test of immature development of *Conopomorpha sinensis* (Male*)*

Parameters	df	*t*	*P*
Egg period	9	4.98	0.001
Larval period	9	0.66	0.527
Pupal period	9	1.30	0.226
Egg-adult period	9	0.31	0.761
Adult longevity	9	0.33	0.747
Total period	9	0.09	0.933