Mass Rearing of Bamboo Borer; *Omphisa fuscidentalis* (Lepidoptera; Pyralidae) for Eggs and Larvae Production for Sustainable Management and Utilization of the Species

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PREFACE

Bamboo borer, one of the most delicious edible insect, is a main source of protein for deprived communities. The population of bamboo borer is gradually declining from their natural habitat due to frequently application of pesticides, forest fire, and unscientifically harvesting of the young bamboo shoots. Bamboo worms are highly demanded in local and international markets. The local markets demand 2,000-3,000 kg of bamboo worms per month which will cost around 400,000-600,000 bahts per month. This demand cannot fulfill by searching bamboo worms from the bamboo forests of Doi Tung in traditional ways. Therefore, to fulfill the demand of local markets, this species has to be commercialized. In order to commercialization of this species, I have developed a mass rearing technique of adult moths in the laboratory, and release them in the field. I hope, the out puts of this research will help in poverty alleviation in Thailand.

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Ratna Thapa

EXECUTIVE SUMMARY

Bamboo borer, *Omphisa fuscidentalis* Hampson (Lepidoptera; Pyralidae), commonly known as a bamboo borer, is a tropical moth found in South, and Southeast Asia. Bamboo borer, one of the most delicious edible insect, is a main source of protein for deprived communities. Beside this, it is an additional source of income of deprived communities. The main was to egg production in the laboratory.

The collected pupae from Ban Samakkee, Amphur Mae Fah Luang, were detached from the culms, washed with distilled water and then put on filter paper to drain excess water for 5 minutes. The pupae were weight individually in order to differentiate male and female sex ratio. Eggs laid on young bamboo shoots were collected and put on a petri dish. The petri discs were lined with moist filter paper. Larvae hatched from eggs were reared on fresh young bamboo shoot. The larvae were reared in at 24°C, and RH 86%. Four different types of ovipositor substrates; waxy brown paper, plastic paper, paper and bamboo shoot leaf were used as an artificial egg laying substrates.

The results showed that each culm had slightly high number of males than females. The larvae were pupating at the rate of 80% in the laboratory. The age of pupal stage was 32-35 days at 24.6-26.5°C, and RH 83-84%. Adult's emergence rate was 87.5% in the laboratory. The females were survived for 4 days and males were 3 days at 24.6-26.5°C, and RH 83-84%. The mortality of larvae in laboratory was 26%. Female laid eggs on brown waxy paper, and young bamboo shoot leaf. The high percentages of egg (90%) laid on young bamboo shoot leaf. The other ovipositor substrates did prefer by females.

In conclusion, the males were higher than females in each culm. The larvae pupating rate was higher in the laboratory. Adult's emergence rate was higher in the laboratory. The females were survived for 4 days and males were 3 days. The larval mortality was not high in the laboratory. Bamboo sheet was found a suitable artificial ovipositor substrate.

ABSTRACT

Bamboo borer, *Omphisa fuscidentalis*, one of the most delicious edible insect, is a main source of protein for deprived communities. The objective of this research was to eggs and larval production in the laboratory and establishment of a bamboo borer rearing center at Mae Fah Luang University. Pupae were detached from the culms, washed, weight individually to differentiate male and female sex ratio. After sexing the pupae, males and females were separated as different recipients. Eggs were put on a Petri dish lined with moist filter paper, and incubated at 28°C, and RH 80-90%. Young larvae were fed with young bamboo shoots for a month, and then transferred to fresh culms. The upper side of the culm was filled with water, and the lower side was used to rear larvae. The larvae were reared in at 24°C, and RH 86%. The larvae after pupating were kept in the Petri dish lined with moist filter paper at 25-26°C, and RH 68-75%. Four different types of ovipositor substrates; (a) waxy brown paper, (b) plastic paper, (c) paper (color), and (d) bamboo shoot leaf (size $2cm^2$) were used. The egg laying substrates were daily check for eggs. The results showed that each culm had slightly high number of males (64.13%) than females (57.13%). Maximum adult emergence (87.5%) was observed in the laboratory. The females were survived longer (4 days) than male moths (3 days) at 24.6-26.5°C, and RH 83-84%. The maximum percentage of larva mortality was 26% in the laboratory. The variation in larvae mortality was due to larval injury during the transfer of larvae from the old culm to new culm. The high number of egg laying substrate was bamboo shoot leaf. It is recommended for further research on study of termination of diapause stages of larvae and pupae.

Keywords: Bamboo borer / sexes / eggs/ larvae / pupae / egg laying substrates

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CHAPTER -1

INTRODUCTION

1.1 Statement and significance of this research

Bamboo borer, *Omphisa fuscidentalis* Hampson (Lepidoptera; Pyralidae), commonly known as a bamboo borer, is a tropical moth found in South, and Southeast Asia. The bamboos borers are caterpillars (larvae), which live in internodes of some selective bamboo species. Adult females lay around 200 on an average (personal observation) on young bamboo shoots in the raining season. Larvae are hatched within 5-7 days, and make a hole at the basal stem, and migrate inside the young bamboo shoot. Then, they start to feed inner pulp of the internodes till the pupal stage. Bamboo borers usually make a characteristic noise, which helps the bamboo borer hunters to locate their position (Yhoungaree and Puwastien, 1997). The mature larvae enter the diapause in September and pupae in June (Singtripop *et al.*, 1999). The diapause is a strategy for survival of larvae in a harsh environment condition (Denlinger, 1985). The larval stage lasts for 280-300 days. The pupal stage lasts for 30-40 days (Leela, 2541). The adult moths can live 8-13 days.

Bamboo borer, one of the most delicious edible insect, is a main source of protein for deprived communities (Jordon, 1993; Chen *et al.*, 1998). Beside this, it is an additional source of income of deprived communities. The population of bamboo borer is gradually declining from their natural habitat due to frequently application of pesticides, forest fire, and unscientifically harvesting of the young bamboo shoots. In previous research, I have developed a mass rearing technique of adult moths in the laboratory, and release them in the field. This study however has some drawback such as the adult moths can not transfer a long distance. It is real difficult to maintain the moth population during transportation from the laboratory to field. So, it is necessary to develop a technique for mass production of eggs in the laboratory, and then transfer directly to the young bamboo shoots. Harvesting method of bamboo borers also need to discover a scientific harvesting method for 7-8 months for sustainable income generation. Until now, the biology of this species has been poorly studied, so it extremely necessary to study biology of this species in order to understand the life

cycle for sustainable management, and utilization of this species for poverty alleviation.

1.2 Objectives

The following objectives of this research are to:-

- egg production in the laboratory,
- distribute of eggs for larva production, and
- establishment of a bamboo borer rearing center at MFLU

1.3 Scope of this research

Bamboo worms are dependable source of income generation and food supply to ethnic groups in Doi Tung. The bamboo worms, one of the most delicious edible insect, are a main source of protein for many poor communities (Jordon, 1993; Chen *et al.,* 1998). However, the population of bamboo worms is gradually declining from their natural habitat due to frequently application of pesticides, frequent forest fire, and unscientifically harvesting method of the young bamboo shoots. On the other hands, bamboo worms are highly demanded in local and international markets. The local markets demand 2,000-3,000 kg of bamboo worms per month which will cost around 400,000-600,000 bahts per month. This demand cannot fulfill by searching bamboo worms from the bamboo forests of Doi Tung in traditional ways. Therefore, to fulfill the demand of local markets, this species has to be commercialized. In order to commercialization of this species, it is urgently needed to transfer artificial rearing technology of bamboo worms at grass root level to enhance their income generation by harvesting forest byproducts, and sustainable conservation of bamboo forests in the northern parts of Thailand. In previous research, I developed the mass rearing techniques of adult moths in the laboratory and release them in the bamboo forests. This study focuses on food crises, conservation of bamboo forests and poverty allocation of hill tribe people in Doi Tung, the northern parts of Thailand. The local hill tribe people is Doi Tung do have their own lands for cultivation of crops. Therefore, they have to depend on the forest products like honey, edible insects and or wild life.

1.4 Benefits of this research

1. Bamboo worms are the main sources of protein to hill tribe people. The villagers will not have malnutrition problems in their family.
2. Bamboo worms are highly demanded in local markets as well as in international markets. Therefore, the villagers will have income source which will help to alleviate poverty, and
3. Bamboo worms are main source of bamboo forests conservation. Because, the bamboo worms are lived inside the bamboo culm without damaging the bamboo. Therefore, if the villagers want to make extra income by selling b bamboo worms, they have rear in the bamboo which is a natural habitat of bamboo borers. Another reason is that the villagers have to protect the young bamboo shoots, which are heavily harvested from Doi Tung and sell to the can food factories.

CHAPTER 2
LITERATURE REVIEW

2.1 Edible worms

Human consumption of insects is a common throughout the world. It is estimated 2,000 insect species are consumed around the world. Insects often contain more protein, fat, and carbohydrates than equal amounts of beef or fish, and a higher energy value than soybeans, maize, beef, fish, lentils, or other beans. Food and Agriculture Organization (2004) reported that the caterpillars of many species are rich in potassium, calcium, magnesium, zinc, and iron, as well as B-vitamins. In some African regions, children fight malnutrition by eating flour made out of dried caterpillars. Pregnant and nursing women as well as anemic people also eat caterpillar species high in protein, calcium, and iron. Chinese consumers spend about $100 million per year on edible ants alone. FAO stated that "edible insects from forests are an important source of protein, and unlike those from agricultural land, they are free of pesticides". Edible insects will be an alternative income source for poverty alleviation.

Eating insects in the ethnic groups a Thai society is a traditional culture, which has been practiced since a long time ago in the northern and northeastern of Thailand. Insects are the common source of protein for the rural farmers in Thailand (Sungpuang and Puwastien, 1983; Somnasang, *et al.,* 1984). In Thailand, 308 types of edible insects belong to 5 orders, 9 families and 16 species eat (Chansang *et al.* 2542). The bamboo worm (Figure 1.1), one of the most delicious edible insect, is a main source of protein for many deprives communities, but a delicious for socioeconomic group (Jordon, 1993; Chen *et al.,* 1998). Indigenous Thai people harvest bamboo worms and sell to generate additional income sources. The bamboo worms are very difficult to harvest all round the year. The population of bamboo worm moths is gradually declining from their natural habitat due to unscientific harvesting of young bamboo worms and young bamboo shoots. The most important factor is that bamboo forests in dramatically replacing by other cash crops.

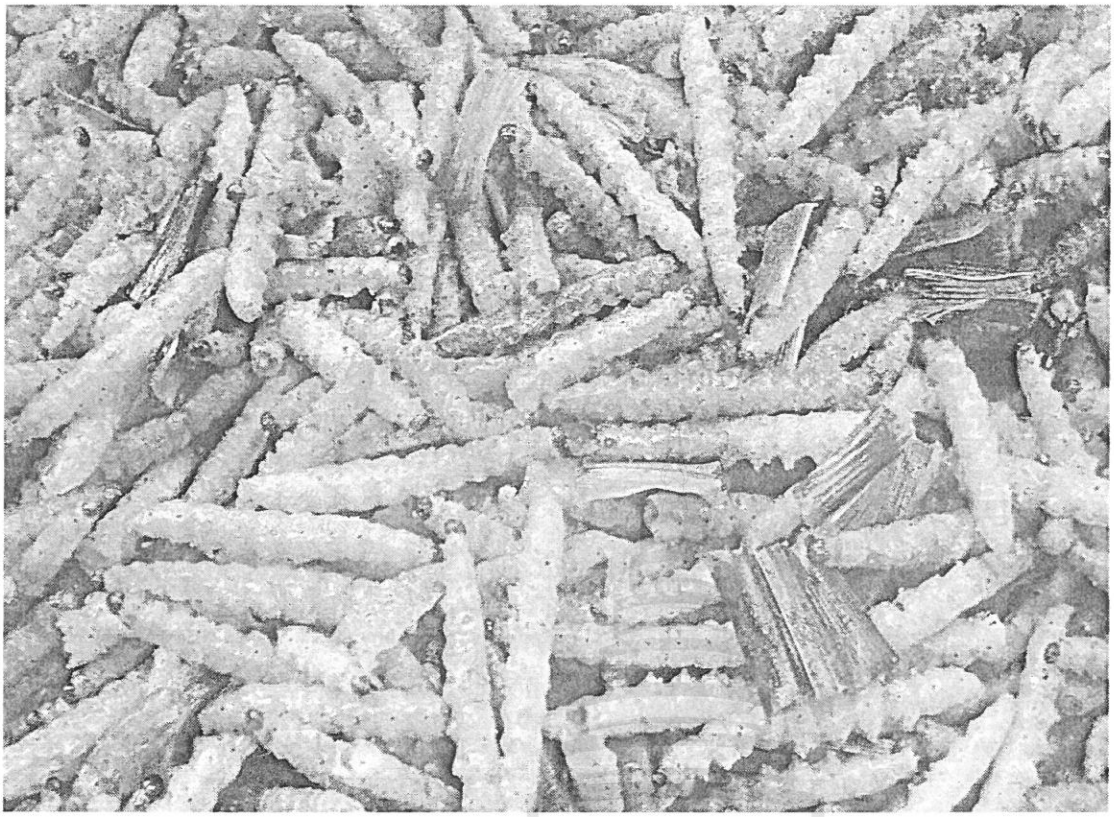

Figure 1. Deep fried bamboo borers

Every 100 grams of dried larvae contains about 53 grams of protein, about 15 percent of fat and 17 percent of carbohydrates. Their energy value is about 430 kilocalories per 100 grams. The insects are also believed to have a higher proportion of protein and fat than beef and fish with a high energy value (Table 1).

Depending on the species, larvae are rich in minerals such as potassium, calcium, magnesium, zinc, phosphorus and iron, as well as various vitamins. Previous results show that 100 grams of insects provide more than 100 percent of the daily requirements of the respective minerals and vitamins.

"Due to their high nutritional value, in some regions, flour made from caterpillars is mixed to prepare pulp given to children to counter malnutrition (FAO, 2004).

Table 1 Comparison of nutritional values of edible insects with meat.

	Bamboo worms	Honey Bee larvae	Cavorting emperor Moths	African palm weevils	Pork	Chicken	Shrimp
Energy (kcal)		-	370.50	561.00	318.85	138.46	92.38
Protein (g)	25.5	15.21	28.23	6.69	12.09	15.24	7.99
Lipid (g)	55.3	19.80	-	-	21.84	4.14	0.62
Calcium (mg)	41.1	0.50	0.35	0.19	7.02	8.88	39.56
Sodium (mg)	609.2	4.40	-	-	45.24	61.05	62.78
Potassium (mg)	674.4	83.10	-	-	202.80	265.66	114.38
Phosphorus(mg)	356	-	0.70	0.31	137.28	148.00	96.32
Magnesium (mg)	-	26.80	54.00	30.00	-	27.38	28.81
Iron (mg)	2.7	1.89	35.50	13.10	1.79	1.33	0.76
Copper (mg)	-	0.04	2.40	1.40	-	0.22	0.10
Zinc(mg)	-	1.05	22.99	23.70	-	0.63	0.99
Thiamine (mg)	-	0.02	3.67	3.02	0.51	0.06	0.02
Riboflavin (mg)	-	0.20	1.91	2.24	0.62	0.37	0.36
Niacin (mg)	-	-	5.20	7.78	2.89	5.03	1.04

(Source: Pingping, *et al.*, 1998)

Edible insects and animals are sold in local markets have potential income generation for in Thailand (Table 2 and 3). Out of 308 species of edible insects, bamboo worm is one of the most highly nutritional organic insect food sell in the local and international markets. The cost of bamboo worms in the local markets is around 200-450 baht per kilograms. The cost of bamboo worms is depended on the season of the year.

Table 2 Edible insects cost in local markets of Thailand (Questionnaire survey n=110)

Edible insects	Price (per kg)	
	Fresh	Fried
Bamboo worms	200 - 450	12,00 - 1,800
Grasshoppers	70	450
Crickets	150	240
Silk moths	100	270

Table 3 Edible animals cost in local markets of Thailand (Questionnaire survey n=110)

Edible animals	Price (per kg)	
	Fresh	Fried
Frogs	70	220
Lizards	40	75

2.2 Distribution of moth

Bamboo borer, *Omphisa fuscidentalis*, belongs to Pyralidae, also commonly known snout moth, is a tropical moth found in bamboo forests of Bangladesh, Bhutan, Cambodia, China, India, Laos, Myanmar, Nepal, Thailand, Vietnam (Figure 2).

Figure 2 Distribution of bamboo borer in Asia

2.3 Morphology of moth

The bamboo borer belongs to class *insecta*. Adult moth diagnosis: ♀♂ Dried bamboo sheet straw yellow color. ♂ *upperside*: light straw yellow with blackish patches and dark zigzag lines with two black spots. *Underside*: light yellow color. ♀ *upperside*: straw pale yellow-brown with blackish patches and zigzag lines on forewings. *Underside*: Pale yellow (Figure 3). Body length (BL) ♂: 19.2±0.3 mm long and ♀: 22.5±0.3 mm. The male moths were significantly different from female moths (t= -7.489, df=50, p<0.000, CI=-4.151-2.395). Fore wingspan ♂: 37.7±0.4 mm long and ♀: 41.4.0±1.0 mm. There was a significant difference in the fore wingspan of males and females moths (t=3.741, df=19, p<0.001). Female moths survived 3.7±0.2 days and male 3.8±0.2 days at 24.7±0.2°C with 83.3±1.2% of RH in the laboratory.

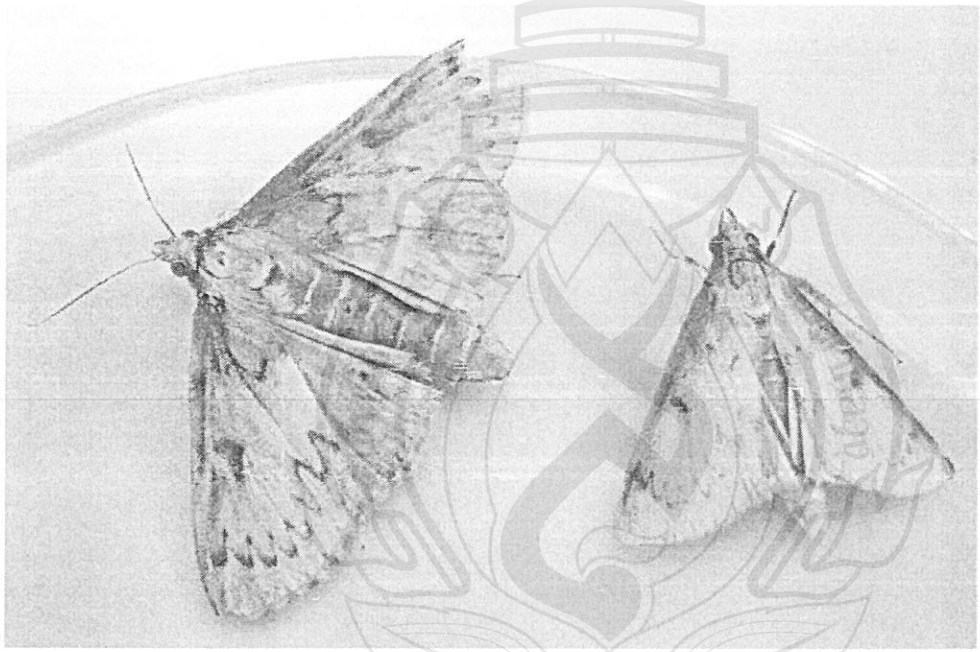

Figure 3 Adult female and male moths

2.4 Different stages of moth

Females lay eggs in clusters at the base of young bamboo shoots (Figure 4). The eggs are flat and overlap like fish scales. The length of eggs was 8.8±0.2 μm and 6.9±0.1 μm wide.

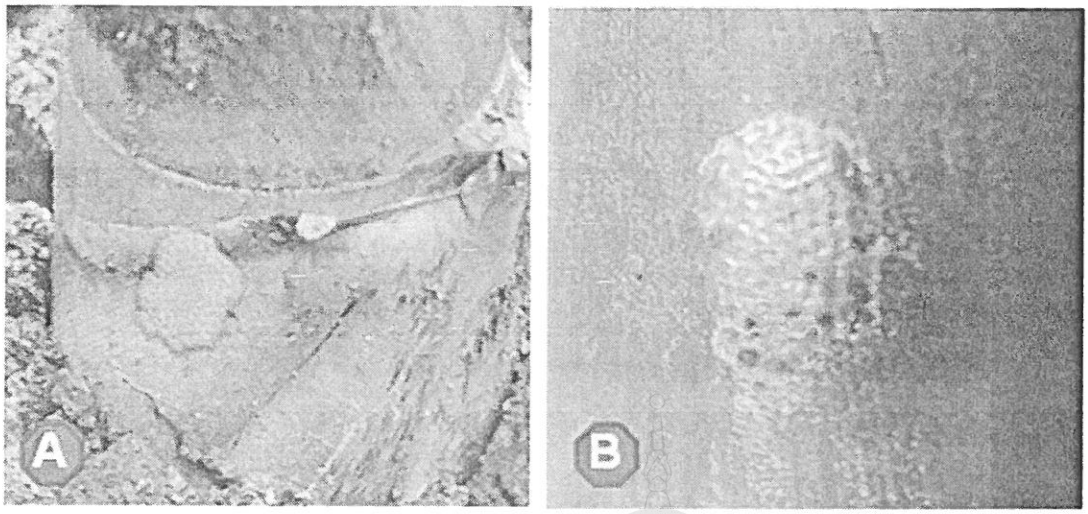

Figure 4 Eggs (A) Freshly laid eggs, (B) Eggs started to hatch

The mature larva is 31.82±2.30mm long. Larvae are hatched within 5-6 days after laying the eggs on the young bamboo shoot. After hatching from eggs, the larvae bore and enter into the young bamboo shoot. The newly born larvae (caterpillar) have distinct orange brown head with well developed mandible. Head has short antennae. There are 3 pairs of articulated legs on the thorax and 5 pairs of fleshy prolegs on the abdomen. Each leg bears a single claw. So, the larvae can freely move up and down inside the culms of bamboo. The larvae are seldom hairy, milky white in color, and gregarious (Figure 5). They mold four to six times before entering the pupal stage. The newly hatched larvae feed on inner pulp of young bamboo shoot that sprouts in the rainy seasons. The matured larvae enter diapause in September and pupae in June in the same internode. The diapause is a strategy to survive in harse environment in the bamboo. The larval stage is last from 280-300 days (10 months).

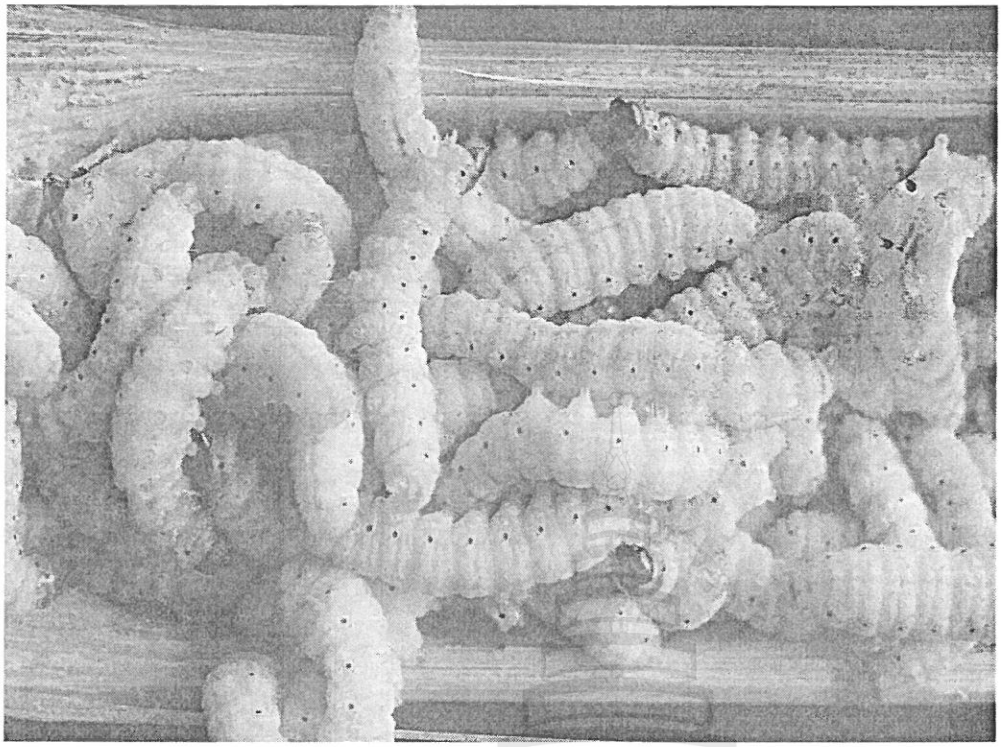

Figure 5 5th instar larvae

Male pupae were 22.6±0.1 mm long and 5.2±0.0 mm in diameter and female pupae 24.4±0.1 mm long and 5.5±0.0 mm in diameter. There is a significant difference in the lengths of male and female pupae. The average weight of male pupae was 0.3±0.0 g and females 0.4±0.0 g. The male pupae were lighter than female pupae. The pupae were light yellowish-brown in the first three weeks, and turned dark black before emerging. The pupal abdomen consists of 10 segments and the 10th segment is equipped with cremaster (eight clusters of small hooks). The pupae hung head down in clusters of 90-214 individuals from the participating node of bamboo culm during May-August (Figure 6). The pupal stage lasted for 35 days at 24.7±0.2°C with 83.3±1.2% of RH in the laboratory.

Figure 6 Pupae of bamboo borers

2.5 Life cycle of moth

Female deposits eggs from 30 to 195 on a young bamboo shoot at the night. Bamboo borers produce one generation in a year. The bamboo worm has four stages; egg → larvae → pupa → adult stages to complete the lifecycle (Figure 7). The life cycle complete within 10 months.

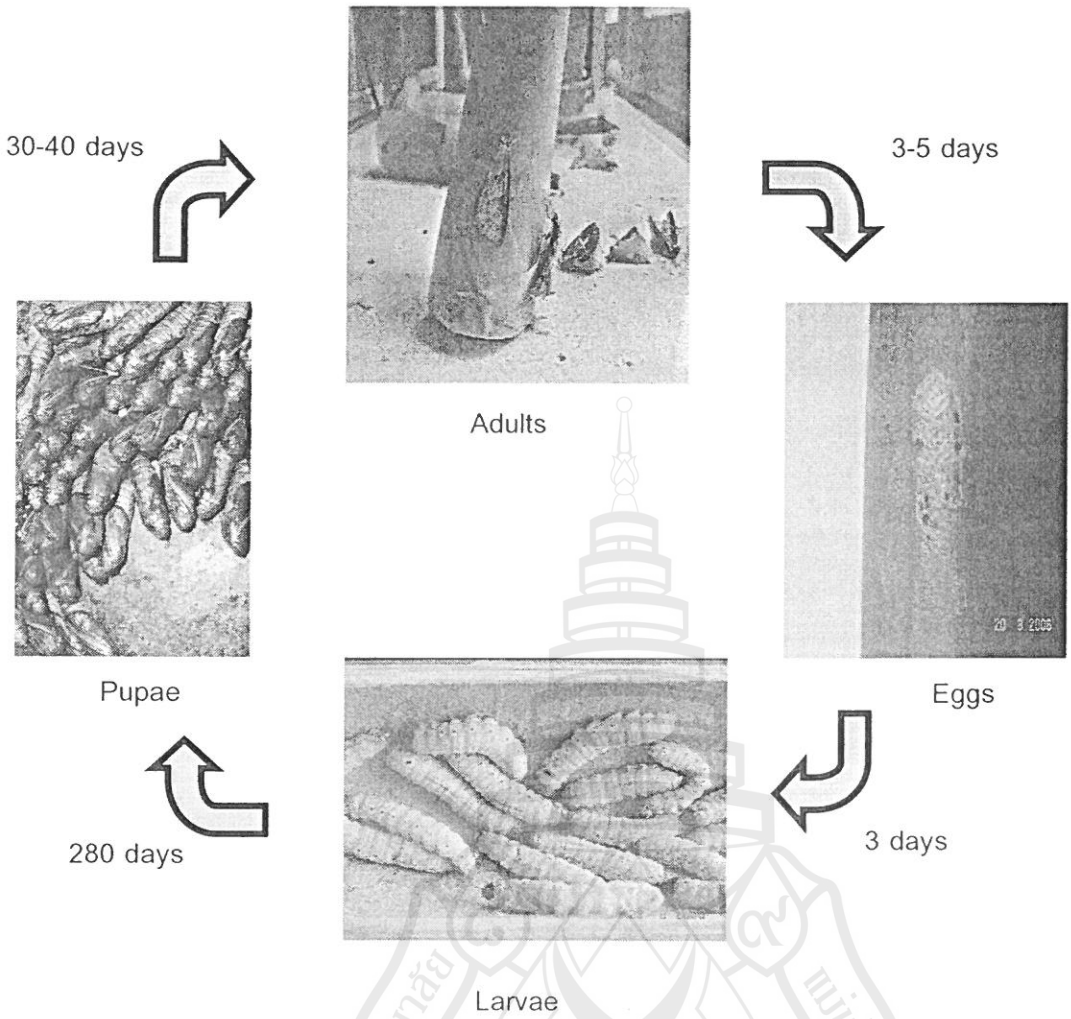

Figure 7 Life cycle of bamboo borers

Fifteen genera and 82 species of bamboos are found in Thailand (Subansenee, 1995). The bamboo worms are very specific species in food preferences. That means they eat only certain type of bamboo species. Out of 82 species of bamboo, 3 bamboo species; *Dendrocalamus hamiltonii* (pai huk), *D. strictus* (pai sang), and *Thysastachys siamensis* Gamble (pai ruak) are the main food sources of bamboo worms. These bamboo species are called bamboo hosts. *D. hamiltonii* is look like light golden color, which has short stems. *D. strictus* is commonly known as dark green bamboo, because it has green stems. *T. siamensis* is the smallest bamboo; the internal part of the stem is very small. *T. siamensis* species of bamboo is usually grown in garden or along the road side for shading. Out of these 3 bamboo species, *D. hamiltonii* and *D. strictus* are the best bamboo species for rearing of bamboo worms. The bamboo worms are lived in internodes of bamboo and feed on inner pulp of the culms, which contains higher

fibre (40-60%), highest quantity of sucrose and 20 per cent of starch (lignin). Lignin is water resistant and keeps the fibers from separating freely during the beating cycle till the pupal stage.

CHAPTER -3

MATERIALS AND METHODOLOGY

3.1 Collection of pupae and sex determination

Pupae were collected from Ban Samakkee, Amphur Mae Fah Luang, 47 km northwest from Mae Fah Luang district between May and Augusts. The collected pupae were detached from the culms, washed with distilled water till they look clean, and then put on filter paper to drain excess water for 5 minutes. The pupae were weight individually in order to differentiate male and female sex ratio. The heavier weigh means female, and *vice versa*. After weighing, the tip of pupa was checked under the stereomicroscope to differentiate the sexes (n=3760). After sexing the pupae, males and females were separated as different recipients. In this ways, it was avoided the need to separate sexes after the emergence. A batch of 100 pupae were pasted on a chopstick individually and kept in tray (size 9 ×1.5 cm depth) (Figure 8). The trays were lined with moist tissue. The trays were kept at 28°C, and RH 80-90% in the insectaria room.

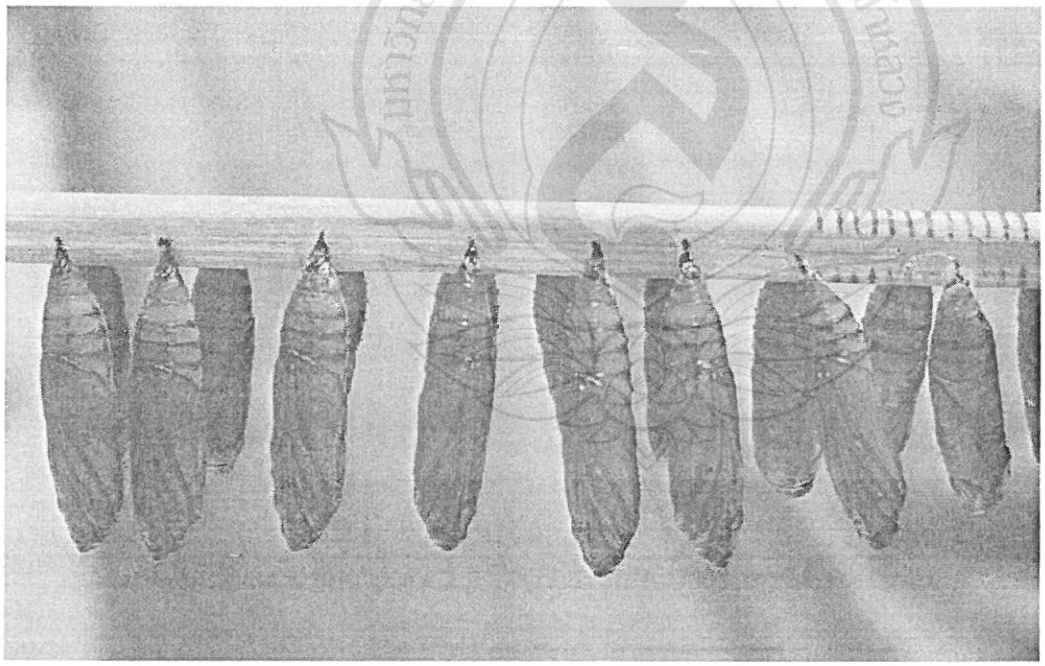

Figure 8. Sexing female pupae pasted on a chopstick

3.2 Egg rearing in the laboratory

Eggs laid on young bamboo shoots were collected and put on a petri dish. The petri discs were lined with moist filter paper (Figure 9). The eggs were incubated in a sterilized plastic petri dish at 28°C, and RH 80-90%.

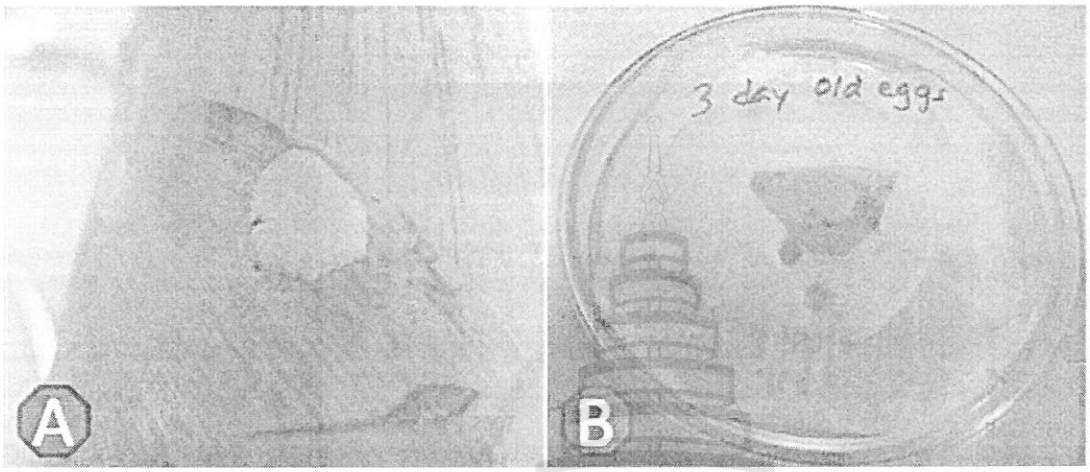

Figure 9. Eggs on petri dish (A) Fresh eggs, (B) 3 hours old eggs

3.3 Larvae rearing in the laboratory

Larvae hatched from eggs were reared on fresh young bamboo shoot. The young bamboo shoots were cut in 1.5 cm thickness (Figure 10). The young shoots were daily changed. After one month of feeding the young bamboo shoot, the larvae were transferred to culms. The mouth of culm was covered with nylon net.

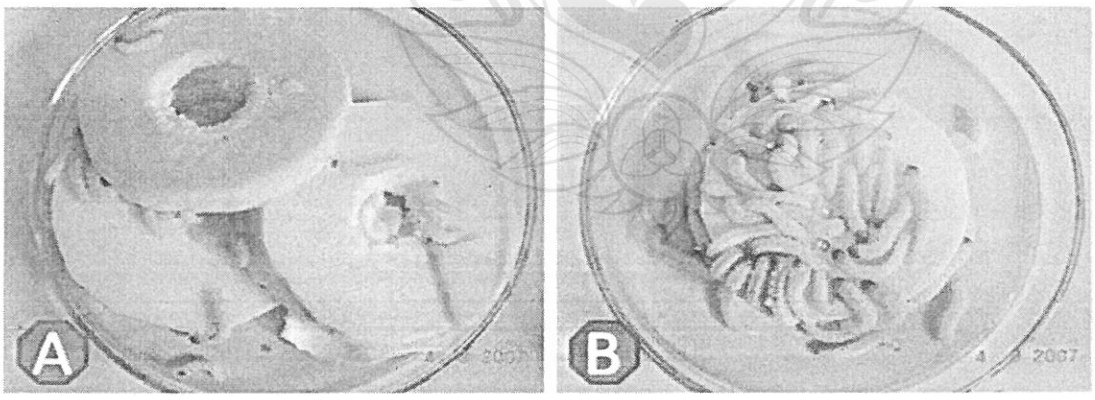

Figure 10. Rearing of bamboo borer larvae on young bamboo shoot (A) 3rd instar, (B) 4th instar

3.4 Single culm rearing techniques

The larvae were reared in at 24°C, and RH 86% to determine the mortality of larva under the controlled environmental conditions (Figure 11).

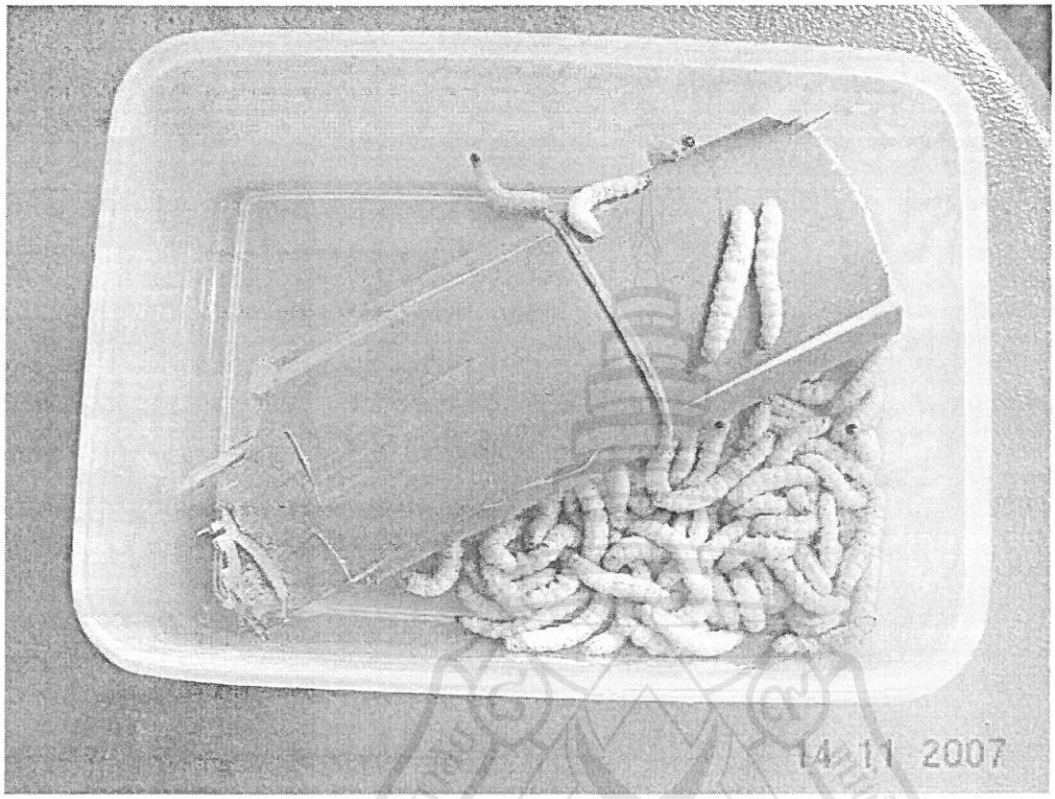

Figure 11. Single culm techniques

3.5 Modification of rearing techniques

The culms were opened on both sides. The upper side of the culm was filled with water, and the lower culm was used to rear larvae. In this way, larvae get moisture all the time. The larvae were reared in at 24°C, and RH 86% to determine the mortality of larva under the controlled environmental conditions.

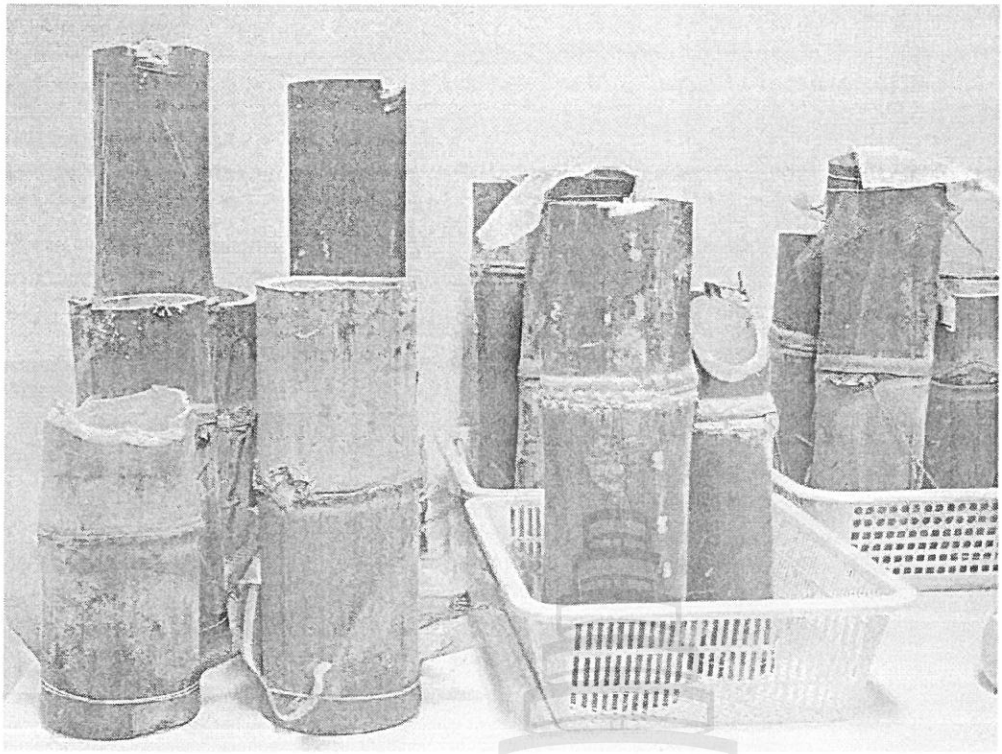

Figure 12. Modified larvae rearing techniques

3.6 Age of pupae

The larvae after pupating were kept in the petri dish lined with the filter paper moist with distilled water at 25-26°C, and relative humidity 68-75%.

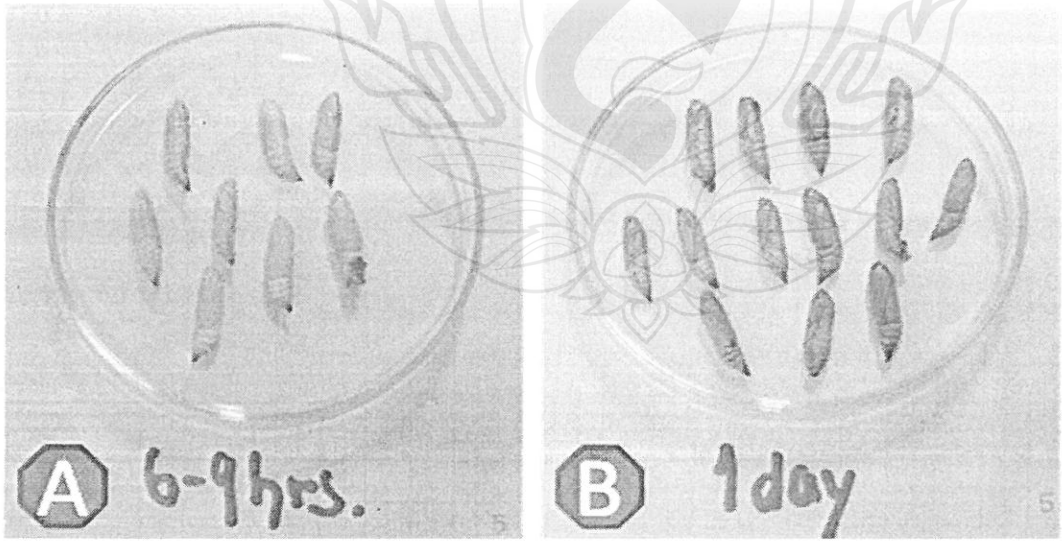

Figure 13. Pupating larvae (A) 6 hours, (B) 1 day old

3.7 Artificial ovipositor substrates

Four different types of ovipositor substrates; (a) waxy brown paper, (b) plastic paper, (c) paper (color) and (d) bamboo shoot leaf were used. All these ovipositor substrates were cut into $2cm^2$. One day old one female and male were put in each plastic cup. Each cage had an ovipositor substrate dipped in fresh bamboo shoot. Experiments were replicated three times. The egg laying substrate was daily check for eggs.

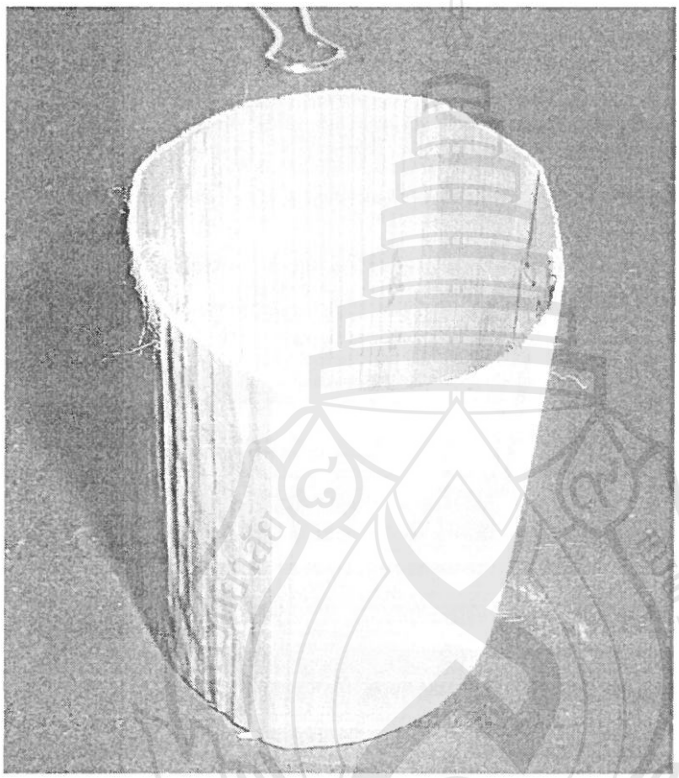

Figure 14. Artificial bamboo shoot leaf egg laying substrate

CHAPTER -4

RESULTS & DISCUSSION

4.1 Sex determination of pupae

Each culm had slightly high number of males (54.13%) than females (46.12%) (Figure 15). The ratio of male was slightly higher than female.

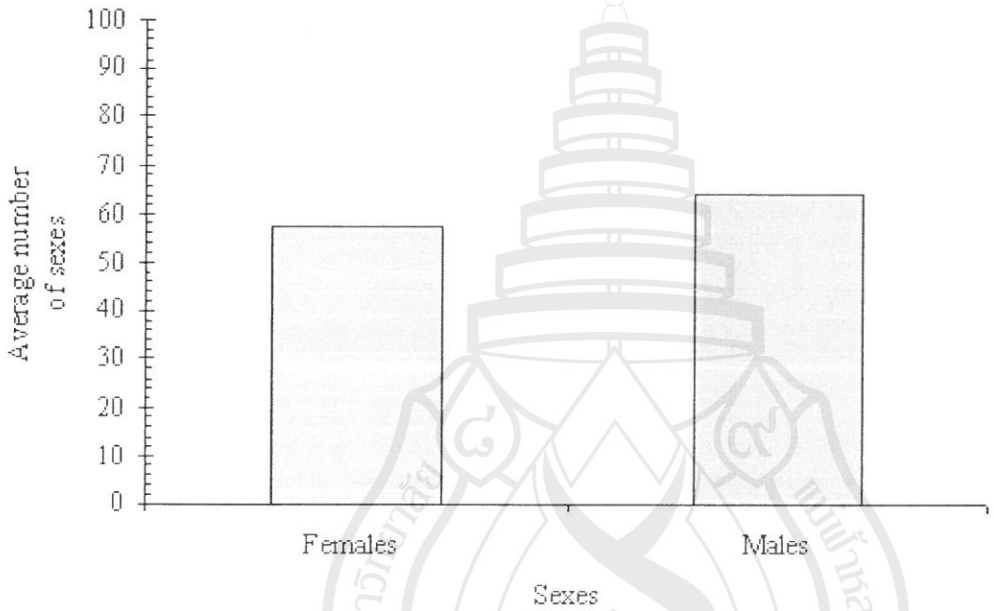

Figure 15. Average number of sexes of bamboo borer per culm

4.2 Age of pupae

The larvae were pupating at the rate of 80% in the laboratory. The age of pupal stage was 32-35 days at 24.6-26.5°C, and RH 83-84%. The pupal stage in the laboratory was shorter than the previous report (40-45 days).

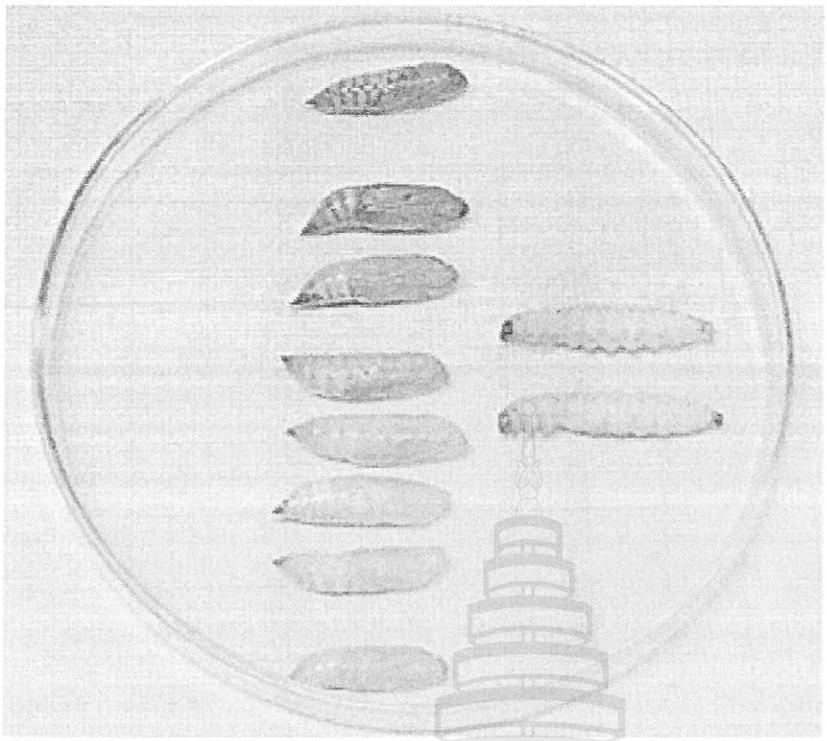

Figure 16. Different ages of pupae

4.3 Emerging rate of adult moths

Adult's emergence rate was 87.5% in the laboratory. The females were survived for 4 days and males were 3 days at 24.6-26.5°C, and RH 83-84% (Figure 17). The females were survived 1 day more than male.

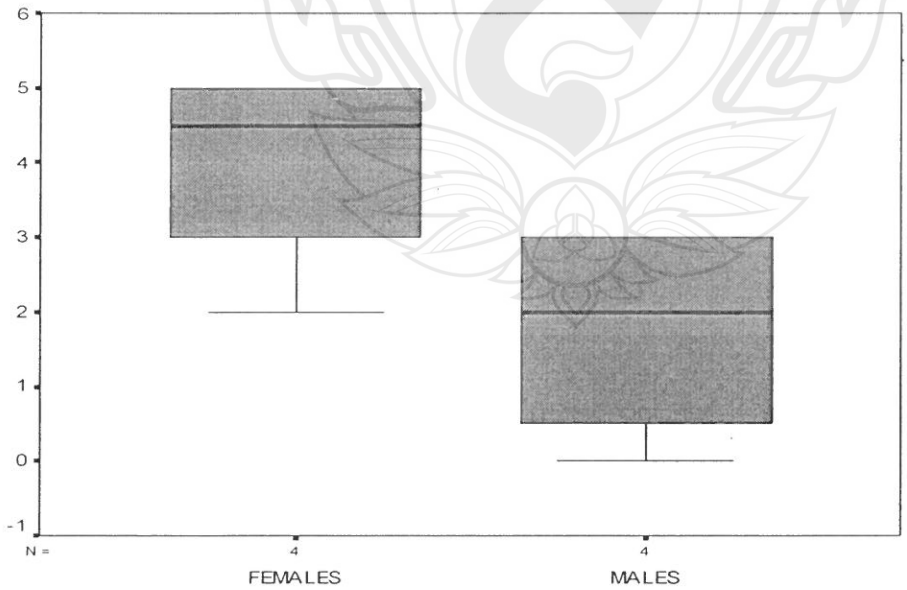

Figure 17. Age of adult moth

4.5 Rearing of larvae in the laboratory

The table 4 showed that maximum percentage of larva mortality (26%) was found in the culm number 13. However, the larva mortality seems to have no relation with culm.

Table 4. Survival rate of larvae in the laboratory.

Number of culm	Total larvae reared /culm	Larval mortality (%)	Temp (°C)	RH (%)
1	67	5.9	23.5	83
2	102	5.8	23.8	74
3	71	0.0	24.8	82
4	91	1.2	23.8	74
5	52	11.5	24.8	82
6	93	3.2	24.6	86
7	41	9.7	24.8	82
8	108	2.8	24.6	86
9	39	0.0	23.8	74
10	49	0.0	24.8	82
11	47	0.0	24.6	86
12	40	12.5	23.8	74
13	46	26.0	24.8	82
14	86	4.6	24.6	86
15	55	5.4	23.8	74
16	57	0.0	24.8	82
17	61	1.6	23.8	74
18	52	11.5	24.8	82
19	49	0.0	24.6	86
20	50	6.0	23.8	74
21	56	3.5	24.8	82
22	60	1.7	24.6	86
23	41	2.4	23.8	74
24	51	0.0	24.8	82
25	48	0.0	23.8	74
26	40	0.0	24.8	82
27	49	0.0	24.6	86

4.6 Artificial ovipositor substrates

Female laid eggs on brown waxy paper, and young bamboo shoot leaf. The high percentages of egg (90%) laid on young bamboo shoot leaf (Table 5). The other ovipositor substrates did prefer by females.

Table 5. Percentages of egg laid on different substrates.

Substrates	Egg laying (%)
Brown waxy paper	10
Plastic paper	0
Paper (color)	0
Bamboo shoot leaf	90

CHAPTER -5

CONCLUSION

The males were higher than females in each culm. The eggs did not hatch in the laboratory. The larvae pupating rate was higher in the laboratory. Maximum adult's emergence was observed in the laboratory. The females were survived for 4 days and males were 3 days. The larval mortality was not high in the laboratory. Bamboo sheet was found a suitable artificial ovipositor substrate.

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