BIOLOGY AND DAMAGE ASSESSMENT OF DIFFERENT STORED GRAINS INFESTED BY ANGOUMOIS GRAIN MOTH *SITOTROGA CEREALELLA* (OLIVIER) IN THE LABORATORY

MST. RUPALI KHATUN

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA 1207

JUNE, 2014

BIOLOGY AND DAMAGE ASSESSMENT OF DIFFERENT STORED GRAINS INFESTED BY ANGOUMOIS GRAIN MOTH *SITOTROGA CEREALELLA* (OLIVIER) IN THE LABORATORY

BY

MST. RUPALI KHATUN

REGISTRATION NUNBER: 13-05784

A thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2014

Approved by:

____
(Dr. Tahmina Akter)
Associate Professor
Supervisor
Department of Entomology
SAU, Dhaka

____
(Prof. Dr. Mohammed Ali)
Co-Supervisor
&
Department of Entomology
SAU, Dhaka

____
Chairman
Department of Entomology
&
Examination Committee

DEDICATED TO

MY

BELOVED PARENTS

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/Entomology/

CERTIFICATE

This is to certify that thesis entitled, **'Biology and Damage Assessment of Different Stored Grains Infested by Angoumois Grain Moth *Sitotroga cerealella* (Olivier) in the laboratory'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***Master of Science in Entomology*,** embodies the result of a piece of bona fide research work carried out by **Mst. Rupali Khatun**, **Registration No. 13-05784** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:
Place: Dhaka, Bangladesh

(Dr. Tahmina Akter)
Supervisor
&
Associate Professor
Department of Entomology
SAU, Dhaka

ACKNOWLEDGEMENT

The author first wants to articulate her enormous wisdom of kindness to the Almighty Allah for His never ending blessing, protection, regulation, perception and assent to successfully complete of research and prepare thesis.

The author likes to express her deepest sense of gratitude to her respected Supervisor Dr. Tahmina Akter, Associate Professor, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for her scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.

The author also expresses her gratefulness to her respected Co-Supervisor Dr. Mohammed Ali, Professor and Chairman, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.

The author also expresses heartfelt thanks to all the teachers of the Department of Entomology, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author expresses her sincere appreciation to her brother, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The Author

BIOLOGY AND DAMAGE ASSESSMENT OF DIFFERENT STORED GRAINS INFESTED BY ANGOUMOIS GRAIN MOTH *SITOTROGA CEREALELLA* (OLIVIER) IN THE LABORATORY

ABSTRACT

Consequently two experiment was conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from May to December, 2014 to study to study biology and damage assessment of different stored grains infested by Angoumois grain moth *Sitotroga cerealella* (Olivier) in the laboratory. Rice, wheat and maize seeds were used as experimental materials. The rice moth, *S. cerealella* (livier) adults started mating after 24 hrs of emergence. On rice grains the female moth lays 80-140 eggs with an average of 109 eggs, whereas on wheat grains the female moth lays 71-97 eggs with an average of 82.7 eggs and in maize the female moth lays 49-73 eggs with an average of 55 eggs throughout its life. Morphometric measurement revealed that in consideration of larva, length was 16.0 ± 0.19, 17.5 ± 0.18 and 18.2 ± 0.07 mm, respectively for rice, wheat and maize grains and width was 2.90 ± 0.04, 3.10 ± 0.09 and 3.27 ± 0.12 mm, respectively for rice, wheat and maize grains. At 1st generation in weight basis, the highest (14.29%) infestation was recorded in rice stored grains, whereas the lowest (8.70%) infestation was recorded in maize grains seeds. At 2nd generation in weight basis, the highest (21.79%) infestation was recorded in rice stored grains which was closely followed (17.07%) by wheat grains, whereas the lowest (13.64%) infestation was recorded in maize grains seeds. At 3rd generation in weight basis, the highest (22 g) weight of infested seeds was recorded in rice grains, while the lowest (16 g) was found in maize grains. Consideration of infestation, the highest (33.85%) infestation was recorded in rice stored grains, whereas the lowest (19.51%) infestation in maize grains seeds. At 1st generation in case of weight loss, the highest (16.50%) weight loss was observed in rice seeds, whereas the lowest (10.15%) weight loss was recorded in maize seeds as a grain store. At 2nd generation in case of weight loss, the highest (30.25%) weight loss was observed in rice seeds, whereas the lowest (21.63%) weight loss was recorded in maize seeds. At 3rd generation in case of weight loss, the highest (43.50%) weight loss was observed in rice seeds, whereas the lowest (15.20%) weight loss was recorded in maize seeds as stored grains.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Cereals are said to be the dominant source of nutrition for one-third of the world's population and among the cereals; rice (*Oryza sativa*), wheat (*Triticum aestivum* L.*)* and maize (*Zea mays* L.) constitute about 85% of total global production (Sofia *et al*., 2009). Rice, wheat and maize are an important cereal crop in Bangladesh serving as source of food, feed and industrial raw material. Among the cereals, wheat is the second most important staple food crop in Bangladesh after rice (BBS, 2008). On the other hand, after rice and wheat, maize (*Zea mays* L.) is an important cereal crop in Bangladesh serving as source of food, feed and industrial raw material.

Rice as a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. Rice are attacked by a wide range of insect pests both in the field and in the storage. The most economically important insect pests of stored rice are the maize weevils (*Sitophilus zeamais*), rice weevils (*Sitophilus oryzae*), lesser grain borer (*Rhyzopertha dominica*), larger grain borer (*Prostephanus truncatus*), Angoumois grain moth (*Sitotroga cerealella*), Indian meal moth (*Plodia interpunctella*), rice moth (*Corcyra cephalonica*) and red flour beetle (*Tribolium castaneum*). Among them *S. cerealella* has been known as a primary serious and injurious pest of rice.

Wheat is a cereal grain, originally from the Levant region of the Near East and Ethiopian Highlands, but now cultivated worldwide. This grain is grown on more land area than any other commercial food. It is attacked by various insect pests between harvest and storage. The most economically important insect pests of stored wheat are the granary weevils (*Sitophilus granarius*), maize weevils (*Sitophilus zeamais*), rice weevils (*Sitophilus oryzae*), lesser grain borer (*Rhyzopertha dominica*), larger grain borer (*Prostephanus truncatus*), Angoumois grain moth (*Sitotroga cerealella*), Indian meal moth (*Plodia interpunctella*), rice moth (*Corcyra cephalonica*) and red flour beetle (*Tribolium castaneum*). *S. cerealella* has been known as a primary serious and injurious pest of wheat in the Angoumois province of France since 1736 it is now cosmopolitan in distribution particularly in the tropics and the warm temperate regions.

Maize is a large grain plant domesticated by indigenous peoples in Mesoamerica in prehistoric times. Maize is an important cereal crop in Africa serving as source of food, feed and industrial raw material (Meseret, 2011). Based on consumption it is regarded as the second most important cereal crop and the major staple food of the hill people. Unfortunately, its productivity is low (1.7 t/ha) and a considerable quantity of the total maize production is lost after harvest. Nearly one thousand species of insects have been found associated with stored products in various parts of the world. Among many stored pests Angoumois grain moth (*Sitotroga cerealella*), maize rice weevil (*Sitophilus oryzae*), lesser grain borer *(Rhyzopertra dominica*), Khapra beetle (*Trogoderma granarium*), Rust-red flour beetle (*Tribolim castaneum*), legume weevil (*Callosobruchus sp.*) etc. are the most notorious.

Loss of rice, wheat and maize, due to the infestation by Angoumois grain moth have been increasing along with the higher production and amount of cereal grains being stored in farmer households. Angoumois grain moth shows its activity only in storage in Bangladesh. It is an extremely efficient seed penetrator (Cogburn, 1974). In Bangladesh, it is known as ‘surui’ and considered as one of the most serious pest of stored rice, wheat and maize at post harvest level. A substantial amount of rice, wheat and maize is stored at farmer level which is badly damaged by *Angoumois* grain moth. In addition the pest is found to infest other stored products, such as joar, bran, sudan grass, etc. Being small in size can keep itself concealed in the grains and are transported easily unnoticed throughout the world and thus has become cosmopolitan in distribution. The insect is more or less active throughout the year but less active during the period from mid December to first part of March.

The adult is a small, buff to yellowish brown or straw colored moth is about one-third of an inch long with a wing span measuring of one-half of an inch. Both wings end in a thumb like projection and have fringed margins. The eggs are white when first deposited, but soon turn red. Adults do not feed on commodity. Only larvae cause serious damage to grain. Larval feeding inside the grain caused an appreciable amount of damage which has been stated about 8.1% (Shahjahan, 1974). Angoumois grain moth larvae feed on a number of whole kernel grains.

Larval feeding produces large cavities within the infested grain and causes a reduction in grain weight and quality. Pupation takes place inside the seed coat. Heavily infested grain smells bad and is less attractive for consumption. Infestations produce abundant heat and moisture that may encourage mould growth and attract secondary pests (Cogburn, 1974). This insect alone can account for over 40% of the total losses in stored grain in some areas.

In Bangladesh, most of the farmers are poor and marginal. They store small quantities of rice, wheat and maize for consumption and cannot afford expensive control measures. Therefore, they essentially need some cheap, easy, readily available but effective methods for safe storing of rice. So it is necessary to know the biology of *S. cerealella* as the serious damaging pest of stored grains, and also to assess the extent of damasges caused by this pest in rice, wheat and maize grains. Considering the above perspective the present study was undertaken to fulfill the following objectives-

- To know the biology of Angoumois Grain moth, *Sitotroga cerealella* (Olivier) developed on stored rice, wheat and maize grains.

- To assess the extent of damages of different stored grains (Rice, Wheat and Maize) caused by Angoumois grain moth, *S. cerealella* (Olivier).

CHAPTER II

REVIEW OF LITERATURE

Rice (*Oryza sativa*), Wheat (*Triticum aestivum* L.) and Maize (*Zea mays*) are the first, second and third most important cereal crops in Bangladesh (BBS, 2013). Nutritional values as well as diversified uses of rice, wheat and maize prove its importance for cultivation and expansion. Insect pests cause heavy losses of these food grains in storage, particularly at the farm level in tropical countries. The efficient control and removal of stored grain pests from food commodities have long been the goals of entomologists throughout the world as it is a serious problem of stored grain and stored products. Losses due to insect infestation is the most serious problem of cereal grains, pulses, oil seeds in storage, particularly, in villages and towns of developing countries like Bangladesh. The insect, *Sitotroga cerealella* (Oliver) is the most destructive and most common pest of stored rice, wheat & maize. It is also the most common pest in godowns and stores crops. A search in the literature revealed that the biology of the pest developed on rice varied with environmental conditions, seasons and types of grains. Information about the biology of rice moth on rice, wheat and maize grains is not available in Bangladesh perspective. However, some literatures on such studies relevant to the present study available through literature and CD-ROM search have been reviewed here in brief under the following sub-headings-

2.1 Origin and distribution of Angoumois grain moth, *S. cerealella*

Sitotroga cerealella is worldwide in distribution but found in abundance in mountainous and coastal areas where the climate is rather humid. This pest derives its common name from the colossal depredations caused by it in the province of Angoumois, France in about 1736.

2.2 Host of Angoumois grain moth *S. cerealella* (Olivier)

Angoumois grain moth is a serious pest of rice and it attacks all cereals both in the field as well as in storage. It is a major pest of stored unhusked rice, though it commonly attacks wheat, maize, sorghum, barley and oat (Fletcher and Ghosh, 1919). Burkholder (1990) considered the attack of this moth as an index for judging the quality of rice grain.

2.3 Systematic Position

Phylum: Arthropoda

Class: Insecta

Sub-class: Pterygota

Division: Endopterygota

Order: Lepidoptera

Family: Gelechiidae

Genus: *Sitotroga*

Species: *Sitotroga cerealella* (Olivier)

2.4 Biology of Angoumois grain moth, *S. cerealella* (Olivier)

Mating: Adults mate 24 hrs after their emergence. Longevity of females is more than males.

Oviposition: On grains it lays 30-70 eggs with an average of 40 eggs throughout its life whereas it lays 120-350 eggs on paddy grains and other cereals and also on depressions, cracks, crevices and holes of storage structures and godowns (Fletcher and Ghosh, 1919). Dhotmal and Dumbre (1982) reported 40.88 to 57.88 eggs laid by a female on different rice varieties in a laboratory test and found that fine grain varieties were preferred for its egg laying. Fecundity was found to vary in the wild and domesticated strains of this moth. Oviposition period was reported as being from 3.3 to 5.0 days. Eggs are laid singly or in groups of 4-7 eggs depending upon the season and ovipositional site. Newly hatched or laid egg is white in color but gradually changes to redish brown. It measures about 0.5 mm in diameter. The egg is oval shaped and is hatched within a week. An average incubation period is 6 days. Hatching was reported to take 11 days at 17.3^0c temperature and 68.3% R.H. (Germanov, 1982). Unmated females have also been reported to lay eggs within a day of emergence (Ayertey, 1975). Prakash *et al*. (1981) reported that the female prefers a rough surface for egg lying than a smooth one in stored rice.

Larval period: Larva is yellowish white with a dark head and 6-10 mm in length depending upon the grain length. The tiny larva lives inside a grain. They crawl around for sometimes and soon find a comparatively weaker spot or a crack or split in the husk through which they enters the grains. Larval migration is reported as being up to 10 cm horizontally and 5 cm vertically (Germanvo, 1982). After entering the grain, the larva often closes the entry hole with a silken web. The larval life then begins in an environment of plenty of food and safety and continues in that state till it is fully grown to about 5 mm within two or three weeks. The larva then cuts out a circular exit hole leaving over it just a sort of cap (Anon., 1981). Germanov (1982) described 4 larval stages during his studies under conditions of mass rearing and reported that larval stages I, II, III and IV were observed on the 9^{th}, 12^{th}, 18^{th} and 20^{th} days after grain infestation, respectively, at 65.8% R.H. and 22.3^{0}C temperature. Duration of larva was found to be 13.66 to 19.33 days in different rice varieties and development was found faster in fine-grained varieties (Dhotmal and Dumber, 1982). Full-grown larvae spin silken cocoons around them in hollows in the grain and become inactive 2 days before pupation (Crombiwe, 1943).

Pupal period: Pupa is brown colored, develops inside silken cocoon and 4-5 mm in length. Pupal period is 4-7days (Crombiwe, 1943). The moth on emergence pushes off the cap of the circular exit hole. Germanov, (1982) reported pupation on the 15^{th} day after infestation at 22.3^{0}C temperature and 68.8% R.H.

Adult emergence: The adult is short-lived (5-7) days, gray or buff colored moth, usually nocturnal in habit. The wingspan is 10-15 mm, body length 5-10 mm with grayish/yellowish, darker spots on forewings. The apex of hind wings is fringed with hairs, which is sharply pointed towards the tips and widely separated so that abdomen is partially visible. Adults mate 24 hrs after emergence. Longevity of females is more than that of males. The shape of their abdomen can distinguish male and female. In male, the abdomen is thinner, pointed and blackish when viewed from the ventral side where as in females; abdomen is bulky and long without any blackish coloration.

2.5 Nature and extent of damage

Only larvae feed on grain kernels. Ramesh *et al.* (2000) studied storage losses in unhusked rice in farmer's stores of district Kangra, Himachal Pradesh, India, during August 1998. A total of 180 samples collected from six blocks of the district were found to be infested with six species of insects, viz., rice weevil, *Sitophilus oryzae*, lesser grain borer, *Rhizopertha dominica,* rust red flour beetle, *Tribolium castaneum*, saw-toothed grain beetle, *Oryzaephilus surinamensis*, Angoumois grain moth, *S. cerealella* and rice moth *C. cephalonica.* The maximum infestation was 66.14 percent by *S. oryzae* followed by 23.53 percent by *T. castaneum*, 4.59 percent by *O. surinamensis*, 3.80 percent by *C. cephalonica*, 1.14 percent by *S. cerealella* and 0.79 percent by *R. dominica*. On an average 18.09 percent grains were found to be damaged and there were 3.96 percent weight losses due to insect feeding in unhusked rice.

Aviles and Guibert (1986) reported that the pyralid*, Sitotroga cerealella* and the bostrichid *Rhizopertha dominica* were the most important pests of grain and seed rice, respectively and they were able to survive and reproduce under the adverse condition of storage.

Acevedo and Aviles (1985) studied the ability of *C. cephalonica* to infest different types of stored rice grains in Cuba. A pair of adults was caged for 6 days with Petri dishes containing the different types of grains and larvae were sieved from the grains after 10 days. Polished (de-husked) grain contained more larvae than unpolished ones.

Sardar (1976) observed the susceptibility of certain varieties of stored rice to rice moths. The observation indicated that IR 140 was more susceptible to rice moth attack as compared with Dacca-17, IR 5 and Dacca-25.

Shahjahan (1974) stated that an average damage of 8% unhusked rice seeds was observed due to the attack of only Angoumois grain moth.

Mookherjee *et al*. (1970) observed the extent of damage due to insect pests of stored seeds. They collected the seeds of rice, corn, wheat, barley, jowar and bajra and stored at different levels. These seeds were examined in the laboratory for insect infestation. The study revealed that the damage varied from 0 to 70%, 0 to 100%, 0 to 75%, 0 to 22.7%, 0 to 11% and 0.9% in the above mentioned 6 seeds, respectively.

Podoler and Applebaum (1968) stated that the thicker seed coat reduced the damage to various genotypes. Badhera (1944) carried out an experiment on susceptibility of 12 different varieties of stored rice seeds and he stated that the oviposition preference by the pyralid (as indicated by adult emergence and maximum food consumption) was the highest on BK-814-15 and lowest on Ratna.

Maize crops are attacked by a wide range of insect pests both in the field and in the storage. Several insect pests attack maize in storage, of which them Angoumois grain moth (*Sitotroga cerealella*) Olivire (Lepidoptera: Gelechiidae) is the most serious storage insect pest of maize.

2.6 Effect of Environment on Pest Survival

Marity *et al.* (1999) stated that storing grain at high temperature but low humidity curbed the infestation by the pest.

Chen *et al*. (1998) reared rice moth, larvae on crushed brown rice in a growth chamber at 30±1^{o}C, 70±5% R.H. with LD 12:12 (the light was turned on at 6.00 and turned off at 18.00 hr.) Adult emerged from 12.00 to 22.00hr each day. Male moth emerged 2-3 hrs earlier than the female. The peak emergence was observed at 17.00-19.00 and 18.00- 20.00 hr for males and females, respectively. Based on the $\chi 2$ test of goodness of fit, the ratio of females to male was 1:1 in the population of females 83.3% produced offspring whose ratio of females to males was equal to 1, the rest produced offspring with a ratio greater or less than 1. The mean longevity of mated females was 8.1 to 17.9 days of those unmated it was 10.2 to 16.4 days.

Hugar and Rao (1990) investigated the effect of temperature and relative humidity and their interaction on the incubation period and hatching of *C. cephalonica* eggs within a temperature range of 15-40^{0}C and 30-90% R.H. The pyralid was reared on broken grain of sorghum. The incubation period decreased with an increase in temperature and egg development took place at 35^{0}C with 90% R.H.

Warren (1956) reported that *Sitotroga cerealella* (Olivier) exhibited variable responses when reared on several strains of corn at two moisture levels.

2.7 Factors regulating loss of grain in storage

2.7.1 Biotic factors

Gentile and Trematerra (2004) recorded a total of twenty insect pests in stored grain and *Troqium pulsatorium, Ephestia elutella, Plodia interpunctella, Sitotroga cerealella, Cryptolestes ferrugineus, Oryzaephilus surinamensis, Rhyzopertha dominica, Sitophilus granaries, Sitophilus oryzae* and *Tribolium castaneum* being the most dominant pests. *Sititroga cerealella* occurred during pre harvest and post harvest storage.

Chudhary and Mahla (2001) reported that insect pests of stored cereal food grains varied depending upon the prevailing climatic conditions and reported that about 10 (ten) insect species were infested in stored grains.

Samuels and Modigli (1999) observed that wheat was infested by rice weevil, rust red flour beetle and Angoumois grain moth when was stored in jute bags, perus, metal bins and polyethylene bags for 6 (six) months.

Both biotic and abiotic factors are responsible for the loss of stored grain in storage. Baloch *et al.* (1994) revealed that the major biotic factors influencing grain loss during storage were insects, moulds, birds and rats.

2.7.2 Abiotic factors

Abiotic factors including temperature, humidity and storage condition, all affect environmental conditions in storage. High temperature causes deterioration, while low temperature is good for storage. High temperature accelerates the respiration of grain, which produces carbon dioxide, heat and water, conditions favourable for spoilage. Humidity equally impacts on storage of grains. Increasing humidity increases spoilage, while decreasing humidity is good for storage for any crop (Baloch *et al*., 1994).

The type of storage plays a fundamental role in storage efficiency. In case of concrete or mud storage structure can absorb water or allow the water vapors to pass through, in case of a jute bag, the bio-chemical changes and mould attack are minimal, but the risk of insect infestation increases. Sun drying or turning of food grain has many advantages as it provides an opportunity for inspection and precautionary measures to avoid spoilage. Aeration greatly minimizes mould growth, insect activity and respiration of the seed. Further aeration provides a cooling action and equalizes the temperature throughout the mass of the grain stored (Baloch *et al*., 1994).

Climate conditions, grain conditions at storage, grain and pest control practices all contribute to the rate of loss caused by insects and mould growth. As these factors interact, it is difficult to isolate them or identify one factor, which has a direct influence on loss. Average statistics for loss, whether for storage types, areas, or quantities of grain stored are inconclusive. An average figure for loss for a region or a country holds no significance unless a decision regarding a new system of storage, or new pest control technique is required. Nevertheless average loss figures are always sought (Baloch *et al*., 1994).

2.8 Storage structure for protection of stored grain

Singh (2001) made a survey on the storage structures used by the farming community in North Bihar, India. He reported that they owned at least 13 different types of storage structures for storing of their agricultural products. Among all gunny bags were maximum (25.78%), however, the farmers use different types of structures at a time.

Mandal *et al*. (1984) reported that average losses and deterioration of grains in silo/godown storage were estimated to be 1.5% and for warehouse storage to be 2.8%. Among the existing structures used by the private sector, bamboo made “dole” was suitable for short term storage.

Local storage structures which are commonly used in rural India and Bangladesh fail to provide complete grain protection from insects. In general, these structures are not moisture proof. The moisture content is high in stored grain which facilitates insect multiplication. The longer the storage period, higher is the insect infestation (Prakash, 1982).

Ramesh *et al*. (2000) studied storage losses in unhusked rice in farmers’ stores of district Kangra, Himachal Pradesh, India, during August 1998.A total of 180 samples collected from six blocks of the district were found to be infested with six species of insects, viz., rice weevil, *Sitophilus oryzae*, lesser grain borer, *Rhizopertha dominica*, rust red flour beetle, *Tribolium castaneum*, saw-toothed grain beetle, *Oryzaephilus surinamensis*, angoumois grain moth, *S. cerealella* and rice moth, *Corcyra cephalonica*.The maximum infestation was 66.14 percent by *S. Oryzae* followed by 23.53 percent by *T. castaneum*, 4.59 percent by *O. surinamensis*, 3.80 percent by *C. cephalonica*, !.14 percent by *S. cerealella* and 0.79 percent by *R. dominica*. On an average 18.09 percent weight losses was observeddue to insect feeding in unhusked rice.

2.9 Toxicity Test

Facknath and Sunita (2006) reported that neem (*Azadirachta indica A. juss*.) reduced insect population in stored products through its toxic, growth-disrupting and other effects on the pests. Grain movement and percussion also help to kill pests in grain. Effects of neem products and grain movement on population growth and development of four insect pests is reported in this study. Dried whole neem leaves, neem leaf powder and neem seed kernel oil were combined individually with dried beans and rice in separate experiments and subjected to varying degrees of gentle grain tumbling. The results showed that the combined treatments were more effective in reducing populations and disturbing growth and development of insect pests.

Sharma (1999) reported that neem seed (*A. indica*) kernel powder at 4% and neem leaf powder at 5% protected maize for 5 months against *Sitotroga cerealella, S. oryzae, R. domonica* and *T. granarium*. Neem oil (nimbicidine, 1%) was toxic to the adults of *S. cerealella, S. oryzae, R. dominica, T. granarium and T. castaneum.* Neem oil (nimbicidine, 2%) effectively reduced the emergence of F_1 and F_2 progeny of the pests and completely protected maize up to a month and suggested that neem products could be mixed with stored maize to protect the grains up to 9 months from the attack of these major pests.

David *et al*. (1998) showed that it had repellent, insecticidal and juvenile hormone activity against several species of insect pests including stored product pest larvae of Leepidoptera and *Culex quinquefasciatus*.

Padmanaban *et al.* (1997) evaluated fresh leaves, dried leaves, dried leaf powder of *N. negundo* against second instar larvae of *C. chinensis* and reported that Vitex dried leaf powder were comparatively more effective than the other plant products after 30 days of application.

Rouf *et al.* (1996) found that *C. chinensis* caused 100% damage to lentil seeds in untreated conditions but the seed weight loss was found significantly less when the seeds were treated with neem, nishinda or biskatali (*Polygenum hydropiper*) leaf powder up to 60 days of storage.

Senguttuvan *et al.* (1995) evaluated a range of plant products against *Corcyra cephalonica* on the basis of % dry matter loss % damaged kernels and pods. They observed that *V. negundo* leaf powder, neem leaf powder and neen oil were most effective than neem kernel powder against adult emergences.

Dayrit *et al.* (1995) tested volatile oils from the leaves of nishinda (*V. negundo*) using plutella xylostella and confirmed that *V. negundo* and neem seeds oils acted as a promising botanical insecticide showing lower egg hatching in ovicidal tests and in topical toxicity tests.

A paper presented by Prakash *et al*. (1993) at a national symposium held on January 1990 in India showed that only 7 products of 20 plants reduced adult populations of *S. cerealella* significantly. These were neem seed oil followed by *Piper nigrum* seed powder leaves of *V. negundo* leaves of *Andrographis paniculata*, dried mandarin fruit peel rhizome powder of turmeric and seed powder of *Cassia fistula* respectively.

Miah *et al.* (1993) showed that nishinda (*V. negundo*) leaf powder was most effective, in reducing egg number and adult emergence of *S. cerealella* among several local plant materials in Bangladesh.

Dakshinamurthy *et al*. (1992) reported on the effectiveness of pre- harvest insecticide treatments for the control of *S. cerealella* in stored rice. Fenvalerate 0. 002% was the most effective treatment followed by 0.04% Monocrotophos and 0.05% Malathion. There applications within 20-30 days or one after 50 per cent flowering were effective. Pre-harvest treatment resulted in increased grain hardness of 6.63-9.10 kg, improved head rice recovery of 65.28 – 68.74 per cent and increased seed germination of 70.54 – 79.54 percent.

Dakshinamurthy (1988) carried out an experiment to study the effectiveness of some plant products on the development and cross infestation by the stored rice pests. *Rhizopertha dominica* and *Sitotroga cerealella* in the laboratory. They found that eucalyptus powder mixed with rice at the rate of 1% by weight was effective in reducing the number of adults of *S. cerealella*.

Singh *et al.*, (1988) evaluated six plant extracts against *R. dominica* in the laboratory, extracts of neem, *Azadirachta indica*, *Bassia longifolia* and *Pongamia glabra* were highly toxic. The crude extract of water hyacinth (*Eichorrnia rassipes*) was evaluated for its biological activity against the *T. castanium, S. cerealella, S. oryzae, Callosobruchus maculatus* and *C. cephalonica*

Tiwari and Bhatt (1987) studied on the toxicity on two insecticides on the development stage of stored product pest *C. cephalonica*; toxicity was directly proportional to the concentration in the larval diet. Diets containing 0.012% BHC (HCH) and 0.3% Malathion caused 100 per cent larval mortality.

Jilani and Saxena (1987) reported that several indigenous plant materials have traditionally been used as stored grain protectant against insect pests in various parts of the world.

Muda (1985) reviewed the pest problems and pesticide usage in various types of grain storage in Malaysia. Paddy and milled rice account for most of the grain stored and both bag and bulk storage were practiced. The curculionid *Sitophilus spp*., the bostrichid *R. dominica* and the Gelechiid *S. cerealella* are the main pests of stored paddy. Malathion and Lindane are applied at 2-5 % a.i. as residual sprays and by thermal fogging at rates of 51/100 and 11/100m^2 respectively. Fumigation with Phosphine and Methyl Bromide is also carried out. It is suggested that more research on ways of improving the choice and application of insecticides in bulk rice is necessary in the context of an integrated pest management program.

CHAPTER III

MATERIALS AND METHODS

Experiment 1: Study of the bio-ecology of Angoumois grain moth, *Sitotroga cerealella* (Olivier) development on different stored grains in the laboratory

The study was conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from May to August, 2014. Rice, wheat and maize seeds were used as experimental materials which were collected from farm's store house of Sher-e-Bangla Agricultural University. The initial stock (Plate 1) culture of rice moth, *Sitotroga. cerealella* was taken from the Department of Entomology, Sher-e-Bangla Agricultural University. Male (Plate 1) and female (Plate 1) adult moths were sorted under a simple microscope on the basis of their abdominal characteristics (Setaceous abdominal tergites present on the 3-6 abdominal segments). The male abdomen is thinner, pointed and blackish when viewed from the ventral side where as in females; the abdomen is bulky, longer without any blackish coloration and larger in size. The biology of *S. cerealella* was studied on rice, wheat and maize grains under laboratory conditions by maintaining them at room temperature during 2014. The collected moths were enclosed in container (measuring 25 cm × 30 cm) for successful mating and oviposition.

3.1.1 Collection of eggs for the study of biology

For ensuring supply of fresh egg masses rearing of *S. cerealella* (Olivier) was carried out in a special mass rearing chamber using wheat grain as diet. The mass

Plate 1. Stock culture of *S. cerealella* (Olivier) with rice

Plate 4. Special mass rearing chamber for Angoumois grain moth, *S. cerealella* (Upper portion, A and Lower portion, B)

rearing chamber is a metallic square type chamber having two portions, the upper portion (Plate 4, A) and the lower portion (Plate 4, B). The upper portion is rearing case, where the moths emerge from the infested grains. The lower portion is a funnel shared structure having an exit whole at the end connecting a removal container. The newly emerged adults crawl through the exit whole and are collected in the storesaid detachable container. The process ensures a continuous supply of adults and which are kept in a glass cylinder measuring (18 × 10 cm in size) (Plate 5) having a 32 mesh lid cover on its top.

The adults were kept in the cylinder for one day for mating and subsequent egg laying (Plate 6). The eggs laid on the wall of the cylinder were brushed off and were collected avoiding body parts of moth and other debris (Plate 7). The collected eggs were kept in glass tubes (12 cm ht. × 3 cm dia.) labeled and stored in the refrigerator at 4^0C to ensure continuous supply for the studies.

3.1.2 Biology of *S. cerealella*

Eggs (Plate 8) were transferred on pieces of white paper in Petridish (2 cm ht. × 10 cm dia.) for hatching. After hatching (Plate 9) the newly hatched larvae of S. *cerealella* (Olivier) were transferred in Petri dishes containing paddy grains. The morphological characteristics of the larvae (Plate 10) and pupae (Plate 11) were studied and recorded during the period of larval and pupal development, respectively. Data pertinent to growth and developmental stages of *S. cerealella* (Olivier) such as incubation period, larval period, pupal period and adult longevity were recorded during the study. The incubation period was measured by the time interval between egg laying and larval hatching. Larval and pupal periods were recorded by dissecting infested grains with the help of a blade and observed under the microscope. The emerged adults of *S. cerealella* (Olivier) were kept in the glass tube till their death and the adult longevity was recorded.

adult *S.*

Plate 6. A glass cylinder used to facilitate egg laying by *S. cerealella*

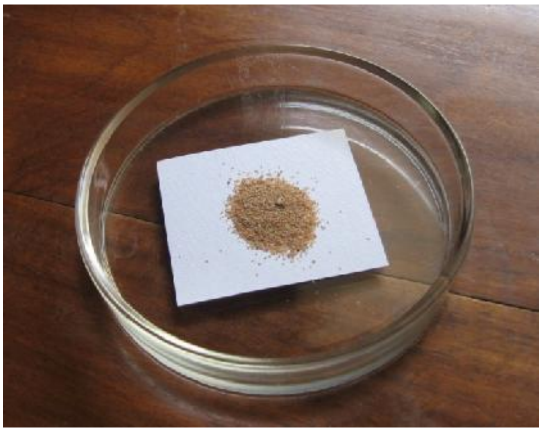

Plate 7. Fresh eggs of *S. cerealella* (Olivier)

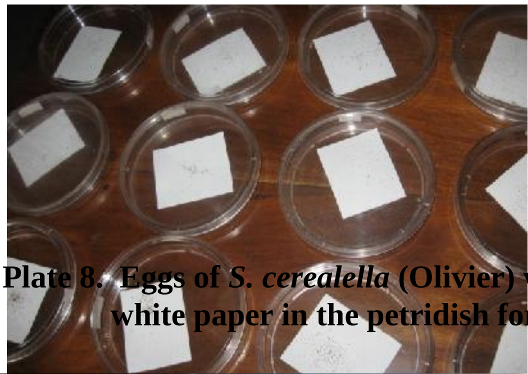

Plate 8. Eggs of *S. cerealella* (Olivier) were placed on white paper in the petridish for hatching

Plate 9. Egg exuviae of *S. cerealella* (Olivier)

Plate 10. Larva of *S. cerealella* (Olivier) **Plate 11. Pupa of *S. cerealella* (Olivier)**

3.1.3 Length and width of different stages of the insect

The length and width of different larval instars of the insect were measured under sterio- microscope and longer parts were measured with the help of slide calipers.

3.1.4 Design of the experiment

The experiment was laid out in CRD (Completely randomized design) with 5 replications.

3.1.5 Data recorded

- No. of egg deposition per selected sample
- Incubation period
- Larval period
- Pre-pupal period
- Pupal period
- Adult longevity
- Abundance of different growth and developmental stages

Experiment 2: Damage assessment of different stored grains caused by angoumois grain moth

The experiment was conducted to study the extent of damages of different stored grains infested by angoumois grain moth during the period from July to December 2014. A brief description of the experimental site, experimental design, treatments, data collection and analysis of different parameters under the following headings are presented below:

3.2.1 Experimental material

Stored rice, wheat and maize were collected from the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka. Collected stored grains were kept in 20 plastic pots each having one kg per pot and were placed in the room under ambient temperature of the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University.

3.2.2 De-infestation of rice, wheat and maize grains

Before artificial infestation of rice, wheat and maize grains with angoumois grain moth, the parboiled rice and the other test grains were dried in the sun for few days. Nawab Ali *et al*. (1980) reported that solar heat treatment of grains destroys the initial insect infestation in the grains before storage.

3.2.3 Collection and rearing of angoumois grain moth

The process of collection of eggs of angoumois grain moth, *S. cerealella* (Olivier) has been described in 3.1.1 of the experiment 01.

3.2.4 Experimental design and layout

The experiment was laid out in Completely Randomized Design (CRD)ambient temperature condition of the laboratory. There were four replications for each of the treatments.

3.2.5 Estimation of different status of damage of Angoumois grain moth

Efficacy of different grain protectants against *S. oryzae* were evaluated considering adult emergence, adult life span, number of damaged seeds and grain weight loss from treated and untreated grains of rice, wheat and maize. Data were collected on different parameters stated below-

3.2.5.1 Observation on adult emergence

50 gm of insect free rice, wheat and maize grains were taken into Petridishes.

Five pairs of newly emerged adult angoumois grain moth were released carefully in each of the Petridishes. Insect mortality was recorded at 24 hours intervals up to 3 days. New adults started emerge from the grains after 24-28 days of infestation. The number of emerged angoumois grain moth at different days from each of the treated Petridishes including control, was recorded. The emerged adult moths were counted by opening the lid. A few angoumois grain moth became visible on the surface of grains at first but a gentle shake of the petridishes allowed the other adults to come out.

Regular observation (daily) taken on the five pairs of moths, initially released in each of the petridishes, provided the data for calculation of adulu life span and mortality.

Plate **mine**

A

Plate 13. Healthy rice grain (A) and infested rice grain by Angoumois grain moth (B)

3.2.5.2 Extent of damage and weight loss

When the emergence of the angoumois grain moth was completed the seeds were cleaned and the numbers of damaged and normal seeds were counted for rice, wheat and maize grains. Grains with hole were considered as damaged or infested seeds. To determine the percentage of damaged seeds, number of seeds having hole and normal seeds were counted per Petri dish or replicate and percentage of damaged seeds were calculated by using the following formula-

$$\% \text{ of damaged seeds in No.} = \frac{\text{Total no. of seeds} - \text{no .of damaged seeds}}{\text{Total number of seeds}} \times 100$$

$$\% \text{ Infestation (by Number)} = \frac{\text{Number of infested seeds}}{\text{Total number of seeds}} \times 100$$

The final weight of seeds was taken to obtain the weight loss. Sieving and winnowing was done to clean the rice, wheat and maize seeds. The clean seeds except those having holes in each Petri dish were weighed separately. The weight losses of grains were found out by subtracting the final weight from the initial weight (50 gm). The weight losses were converted into percentage of weight loss of rice, wheat and maize seeds. From the above mentioned data, percentage of weight loss, percentage (%) of infested seeds (by weight), percentage reduction in infestation and percent protection of weight loss over control were calculated as follows:

$$\% \text{ Weight loss} = \frac{\text{Initial weight of seeds} - \text{Final weight of seeds}}{\text{Initial weight of seeds}} \times 100$$

Plate 14. Infested wheat grain by Angoumois grain moth, *S. cerealella*

Plate 15. Infested maize grain by Angoumois grain moth, *S. cerealella*

$$\% \text{ Infestation (by weight)} = \frac{\text{Weight of infested seeds}}{\text{Total weight of seeds}} \times 100$$

$$\% \text{ Infestation reduction} = \frac{(\% \text{ Infestation in control} - \% \text{ Infestation in the concerned treatment})}{\% \text{ Infestation in control}} \times 100$$

3.2.6 Statistical analysis

The data obtained from the experiments were statistically analyzed on one factor CRD with the help of computer based programme MSTAT-C software. The means were separated following Duncan’s Multiple Range Test (DMRT) and Least Significance Difference (LSD) wherever necessary at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the biology and assess the damages of different stored grains caused by Angoumois grain moth *Sitotroga cerealella* (Olivier) in the laboratory. The results have been presented using different Table & Graphs and discussed with possible interpretations under the following headings and sub headings:

4.1 Biology of Angoumois grain moth, *Sitotroga cerealella* (Olivier) developed on different stored grains

4.1.1 Mating and Oviposition

The rice moth, *S. cerealella* (livier) adults started mating after 24 hrs of emergence. On rice grains the female moth laid 80-140 eggs with an average of 109 eggs, whereas on wheat grains the female laid 71-97 eggs with an average of 82.7 eggs and in maize the female moth lays 49-73 eggs with an average of 55 eggs throughout its life (Table 4.1.1). *S. cerealella* laid eggs singly or in groups of 4-7 eggs. Fletcher and Ghosh (1919) observed that it laid 120-350 eggs on paddy grains and other cereals and also in cracks, crevices and holes of storage structures and godowns. Dhotmal and Dumbre (1982) reported that 40.88 to 57.88 eggs were laid by a female on different rice varieties in a laboratory test and found that fine grain varieties were preferred for egg laying. Newly hatched eggs were white but turned gradually to redish brown with time. The oval shaped eggs, measuring about 0.5 mm in diameter, hatched within a week. The average incubation periods of the eggs laid on rice, wheat and maize grains were 5.5 ± 0.03 days, 6.00 ± 0.03 and 6.67 ± 0.03, respectively (Table 4.1.2). Germanov (1982) reported that egg hatching required 11 days at 17.3^{0}C with 68.3% R.H.. Unmated females have also been reported to lay eggs within a day of emergence (Ayertey, 1975). Prakash *et al*. (1981) reported that female prefered a rough grain surface for egg lying than on a smooth one in stored rice.

4.1.2 Developmental period of different life stages

The newly hatched larvae were yellowish white in color with light brown heads. Larval period were 35.6 ± 0.17, 37.3 ± 0.03 and 39.9 ± 0.09 days, respectively were reared on in rice, wheat and maize grains respectively (Table 4.1.2). The adult longevity were found 8.2 ± 0.13, 9.1 ± 0.08 and 9.6 ± 0.03 in rice, wheat and maize and 10.1 ± 0.32, 9.8 ± 0.07 and 9.9 ± 0.04 days for females when developed on rice, wheat and maize, respectively (4.1.2).

Table 4.1.1. Age specific fecundity of Angoumois grain moth, *Sitotroga cerealella* on rice, wheat and maize grain in the laboratory condition

Insect	Number of laid eggs												Total number of eggs		
	1st day			2nd day			3rd day			4th day					
	Rice	Wheat	Maize	Rice	Wheat	Maize	Rice	Wheat	Maize	Rice	Wheat	Maize	Rice	Wheat	Maize
1st pair	83	52	32	45	29	22	11	12	8	1	0	0	140	93	62
2nd pair	54	47	18	48	33	19	22	15	7	7	2	0	131	97	44
3rd pair	64	36	29	25	31	24	7	6	2	0	1	2	96	74	57
4th pair	38	53	22	31	27	21	22	11	5	2	2	4	93	93	52
5th pair	42	45	36	48	31	28	16	7	8	10	1	1	116	84	73
6th pair	56	41	24	29	19	23	15	3	4	6	4	2	106	67	53
7th pair	60	48	28	18	24	16	12	5	3	0	2	2	90	79	49
8th pair	49	57	22	23	26	25	8	8	6	0	4	4	80	95	57
9th pair	45	39	28	32	22	14	17	11	5	11	2	3	105	74	50
10th pair	69	42	31	51	18	18	10	9	2	3	2	2	133	71	53
Average	56	46	27	35	26	21	14	8.7	5	4	2	2	109	82.7	55

4.1.3 Morphometric measurement of different life stages

Morphometric measurement revealed that in consideration of larva, length was 16.0 ± 0.19, 17.5 ± 0.18 and 18.2 ± 0.07 mm, respectively for rice, wheat and maize grains and width was 2.90 ± 0.04, 3.10 ± 0.09 and 3.27 ± 0.12 mm, respectively for rice, wheat and maize grains. For pre-pupal condition, length was 4.0 ± 0.07, 4.1 ± 0.02 and 4.2 ± 0.02 mm, respectively for rice, wheat and maize grains and width was 1.20 ± 0.05, 1.25 ± 0.01 and 1.28 ± 0.05 mm, respectively for rice, wheat and maize grains. In pupal condition, length was 3.5 ± 0.03, 3.5 ± 0.05 and 3.8 ± 0.03 mm, respectively for rice, wheat and maize grains and width was 1.50 ± 0.05, 1.60 ± 0.01 and 1.65 ± 0.05 mm, respectively for rice, wheat and maize grains. In case of male adult wing span, length was 11.2 ± 0.06, 11.8 ± 0.09 and 11.9 ± 0.03 mm, respectively for rice, wheat and maize grains and width was 11.9 ± 0.03, 12.4 ± 0.01 and 12.8 ± 0.01 mm, respectively for rice, wheat and maize grains. In consideration of female adult wing span, length was 12.7 ± 0.04, 12.9 ± 0.06 and 13.01 ± 0.04 mm, respectively for rice, wheat and maize grains, whereas the width was 13.1 ± 0.04, 14.1 ± 0.01 and 14.4 ± 0.06 mm, respectively for rice, wheat and maize grains (Table 4.1.3).

Table 4.1.2. Developmental period of different life stages of the Angoumois grain moth, *Sitotroga cerealella* feeding on rice, wheat and maize grain in the laboratory

Development stage	Rice		Wheat		Maize	
	Duration (days)	Statistics	Duration (days)	Statistics	Duration (days)	Statistics
Incubation period	5.50 ± 0.03	P<0.005	6.00 ± 0.03	P<0.002	6.67 ± 0.03	P<0.001
Larval period	35.6 ± 0.17	P<0.000	37.3 ± 0.03	P<0.21	39.9 ± 0.09	P<0.34
Adult Longevity						
Male	8.2 ± 0.13	P<0.001	9.1 ± 0.08	P<0.005	9.6 ± 0.03	P<0.001
Female	10.1 ± 0.32	P<0.004	9.8 ± 0.07	P<0.002	9.9 ± 0.04	P<0.004

Table 4.1.3. Morphometric measurement of different life stages of the Angoumois grain moth, *Sitotroga cerealella* feeding on rice, wheat and maize grain in the laboratory

Life Stage	Size (mm)					
	Length (mm)			Width (mm in diameter)		
	Rice	Wheat	Maize	Rice	Wheat	Maize
Larva	16.0 ± 0.19	17.5 ± 0.18	18.2 ± 0.07	2.90 ± 0.04	3.10 ± 0.09	3.27 ± 0.12
Pre-pupa	4.0 ± 0.07	4.1 ± 0.02	4.2 ± 0.02	1.20 ± 0.05	1.25 ± 0.01	1.28 ± 0.05
Pupa	3.5 ± 0.03	3.5 ± 0.05	3.8 ± 0.01	1.50 ± 0.03	1.60 ± 0.06	1.65 ± 0.02
Adult wing span						
Male	11.2 ± 0.06	11.8 ± 0.09	11.9 ± 0.03	11.9 ± 0.03	12.4 ± 0.04	12.8 ± 0.01
Female	12.7 ± 0.04	12.9 ± 0.06	13.1 ± 0.04	13.1 ± 0.04	14.1 ± 0.01	14.4 ± 0.06

4.2 Damage assessment of Angoumois grain moth in different stored grains

4.2.1 Number of dead insects

Number of cumulative dead insects showed statistically significant variation for different stored grains after 24, 48 and 72 hours of observation (Table 4.2.1).

After 24 hours of observations, the highest number of dead insects (1.00) was recorded in rice grain whereas all the insects were found alive on wheat and maize stored grains. After 48 hours of observations, the highest number of dead insects (2.00) was recorded in rice grain followed (1.00) by wheat grain but no dead insect was observed for maize stored grains. After 72 hours of observations, the highest number of dead insects (4.00) were recorded in rice grain which was followed (2.00) by wheat grain but the lowest (1.00) dead insect was observed for maize stored grains (Table 4.2.1). Data revealed that the survival rate of Angoumois grain moth was the highest on maize stored grains.

Table 4.2.1. Number of dead insects of Angoumois grain moth after different times in stored grains of rice, wheat and maize

Stored grain	No. of dead insects after		
	24 hours	48 Hours	72 Hours
Rice	1.00 a	2.00 a	4.00 a
Wheat	0.00 b	1.00 b	2.00 b
Maize	0.00 b	0.00 c	1.00 c
$LSD_{(0.05)}$	0.254	0.845	0.682
Level of Significance	0.01	0.05	0.05
CV(%)	5.22	3.55	4.22

In a column means having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at the indicated percent level of probability and numeric data represents the mean value of 4 replications.

4.2.2 Adult emergence

Adult emergence of Angoumois grain moth for 1st, 2nd and 3rd generations varied significantly for different stored grains (Table 4.2.2).

At 1st generation, the highest (81.75) number of adults emerged on rice grains which was followed (43.75) by the number that emergence on wheat grains, while the lowest (9.50) number of adults was recorded for rice stored grains. In the 2nd generation, the highest (122.00) number of adults emerged on wheat grains which was followed (89.25) by the number that developed on maize, while the lowest (14.00) was recorded for rice stored grains. At 3rd generation, the highest (406.75) number of adults emerged in rice grains which was followed (133.00) by wheat grains, while the lowest (48.50) number of adults were recorded in maize stored grains.

Table 4.2.2. Adult emerged of Angoumois grain moth at 1st, 2nd, 3rd generations & total adult emerged and insect mortality in stored grains of rice, wheat and maize grains

Stored grain	Adult emerged at			
	1st generation	2nd generation	3rd generation	Total
Rice	81.75 a	122.00 a	203.00 a	406.75 a
Wheat	43.75 b	89.25 b	91.25 b	133.00 b
Maize	9.50 c	14.00 c	23.00 c	46.50 c
$LSD_{(0.05)}$	4.581	11.251	18.56	22.15
Level of Significance	0.01	0.05	0.01	0.05
CV(%)	5.22	4.84	6.19	8.25

In a column means having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at the indicated percent level of probability and numeric data represents the mean value of 4 replications.

4.2.3 Status of seeds in 1st, 2nd and 3rd generation by weight

Significant variation (Table 4.2.3, 4.2.4 and 4.2.5) in grains status, in ter4ms of healthy and infested grains and consequently the percent infestation, was observed in the trials conducted to assess the damages caused by Angoumois grain moth in different generations on different stored grains.

4.2.3.1 Percent of infestation of different grain moth at 1st generation of *S. cerealella*

The highest weight of healthy seeds was recorded for rice grain (92.00g) which was closely followed by that of maize grain (86.00 g) whereas lowest was observed in case of wheat grain (84.00 g) by weight bais at the time of development of 1st generation. Consequently, the highest weight of infested seed was recorded for wheat grain (12.00g) which was significantly different from those of the others. In case of % infestation, the highest infestation was recorded for wheat grains (14.29%) which was statistically different from those of all other test grains (Table 4.2.3).

Table 4.2.3. Infestation of angoumois grain moth in stored grains of rice, wheat and maize at 1st generation by weight basis

Treatment	Total weight of seeds		
	Healthy (g)	Infested (g)	Infestation (%)
Rice	92 a	8 c	8.70 c
Wheat	84 c	12 a	14.29 a
Maize	86 b	11 b	12.79 b
$LSD_{(0.01)}$	3.452	0.512	0.879
Significance level	0.05	0.01	0.05
CV (%)	3.88	6.31	4.28

In a column means having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at the indicated percent level of probability and numeric data represents the mean value of 4 replications.

4.2.3.2 Percent of infestation of different grain seeds at 2nd generation of *S. cerealella*

The same trend of infestation levels, like 1st generation was observed for 2nd generation als0. The highest weight of healthy seeds was recorded incase of rice grain (88.00 g) which was closely followed by maize grain (82.00 g) and the lowest was observed in case of wheat grain (78.00 g). The reverse scenario was found in case of the weight of infested grains and consequently, the highest infestation was recorded for wheat grain (21.79%) which was statistically different from those of all other grains (Table 4.2.4).

Table 4.2.4. Infestation of angoumois grain moth in stored grains of rice, wheat and maize at 2nd generation by weight basis

Treatment	Total weight of seeds		
	Healthy (g)	Infested (g)	Infestation (%)
Rice	88 a	12 c	13.64 c
Wheat	78 c	17 a	21.79 a
Maize	82 b	14 b	17.07 b
$LSD_{(0.01)}$	3.561	1.015	2.158
Significance level	0.01	0.05	0.01
CV (%)	5.66	6.51	3.55

In a column means having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at the indicated percent level of probability and numeric data represents the mean value of 4 replications.

4.2.3.3 Percent of infestation of different grain seeds at 3rd generation of *S. cerealella*

The highest weight of healthy seeds was observed for rice grain (82.00 g) which was closely followed by that of maize grain (78.00 g). Wheat had the lowest weight for healthy grain (65.00 g). Wheat showed the highest (22.00 g) weight for the infested seeds which was statistically different from those found for the grains. The highest infestation was recorded from wheat grain (33.85%) which was statistically different from those other grains (Table 4.2.5).

Table 4.2.5 Infestation of angoumois grain moth in stored grains of rice, wheat and maize at 3rd generation by weight basis

Treatment	Total weight of seeds		
	Healthy (g)	Infested (g)	Infestation (%)
Rice	82 a	16 c	19.51 c
Wheat	65 c	22 a	33.85 a
Maize	78 b	18 b	23.08 b
$LSD_{(0.01)}$	3.161	1.568	2.584
Significance level	0.01	0.01	0.01
CV(%)	4.05	3.22	4.89

In a column means having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at the indicated percent level of probability and numeric data represents the mean value of 4 replications.

4.2.4 Weight loss of different stored grains

At 1st generation in case of weight loss, the highest weight loss was recorded in wheat grain (16.50%) which was statistically different from all other grains and the lowest weight loss was recorded in rice grain (10.15%). At 2nd generation in case of weight loss, the highest (30.25%) weight loss was observed in wheat seeds followed (25.85%) by maize seeds, whereas the lowest (21.63%) weight loss was recorded in rice seeds. At 3rd generation in case of weight loss, the highest (43.50%) weight loss was observed in wheat seeds followed (35.25%) by maize seeds, whereas the lowest (15.20%) weight loss was recorded in rice seeds as stored grains (Table 4.2.6).

Table 4.2.6. Weight loss due to angoumois grain moth infestation of stored grains of rice, wheat and maize at different generation

Treatment	Weight loss (%)		
	1st generation	2nd generation	3rd generation
Rice	10.15 c	21.63 c	15.20 c
Wheat	16.50 a	30.25 a	43.50 a
Maize	13.51 b	25.85 b	35.25 b
$LSD_{(0.05)}$	2.156	2.561	3.561
Level of Significance	0.05	0.01	0.05
CV(%)	3.66	5.22	6.33

In a column means having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at the indicated percent level of probability and numeric data represents the mean value of 4 replications.

4.2.5 Correlation between percent of infestation and weight loss of rice grain by *S. cerealella*

Correlation study was done to establish the relationship between percent of infestation and weight loss of rice grain. From the Figure 01, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 0.418x + 9.820 gave a good fit to the data and the co-efficient of determination (R^2 = 0.155) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that percent of infestation was strongly as well as positively correlated with weight loss of rice grain. Weight loss of rice grain was increased due to increase of percent of infestation.

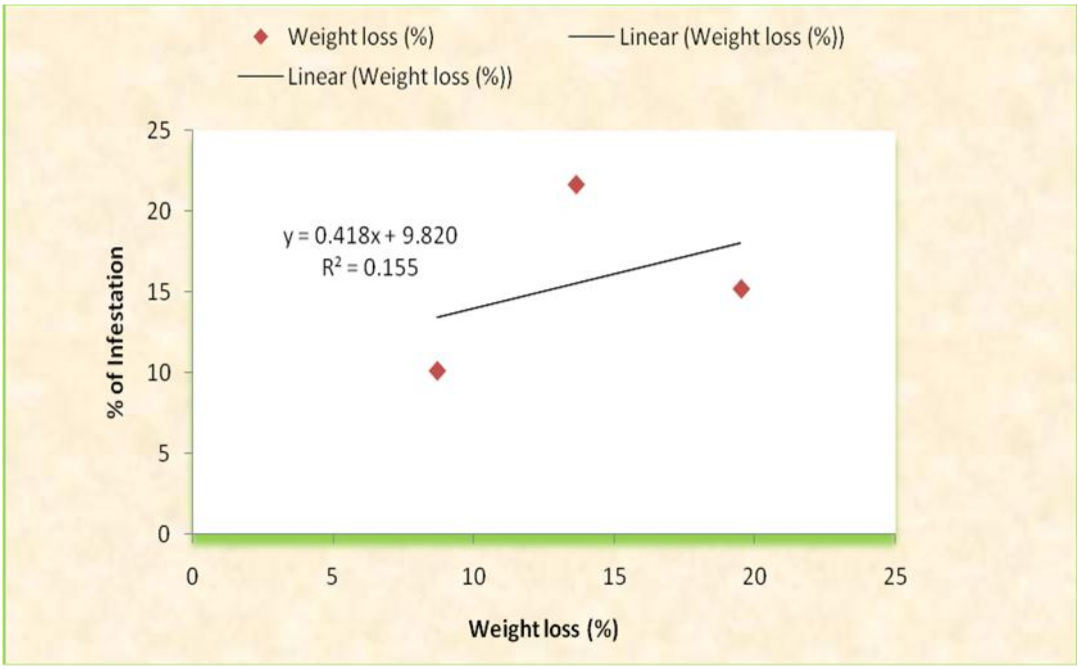

Figure 1. Relationship between percent of infestation and weight loss of rice grain at the 1st, 2nd and 3rd generations by *S. cerealella* (Olivier)

4.2.6 Correlation between percent of infestation and weight loss of wheat grain by *S. cerealella*

Correlation study was done to establish the relationship between percent of infestation and weight loss of wheat grain. From the Figure 02, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y =1.353 x- 1.475 gave a good fit to the data and the co-efficient of determination (R^2 = 0.979) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that percent of infestation was strongly as well as positively correlated with weight loss of wheat grain. Weight loss of wheat grain was increased due to increase of percent of infestation wheat grains.

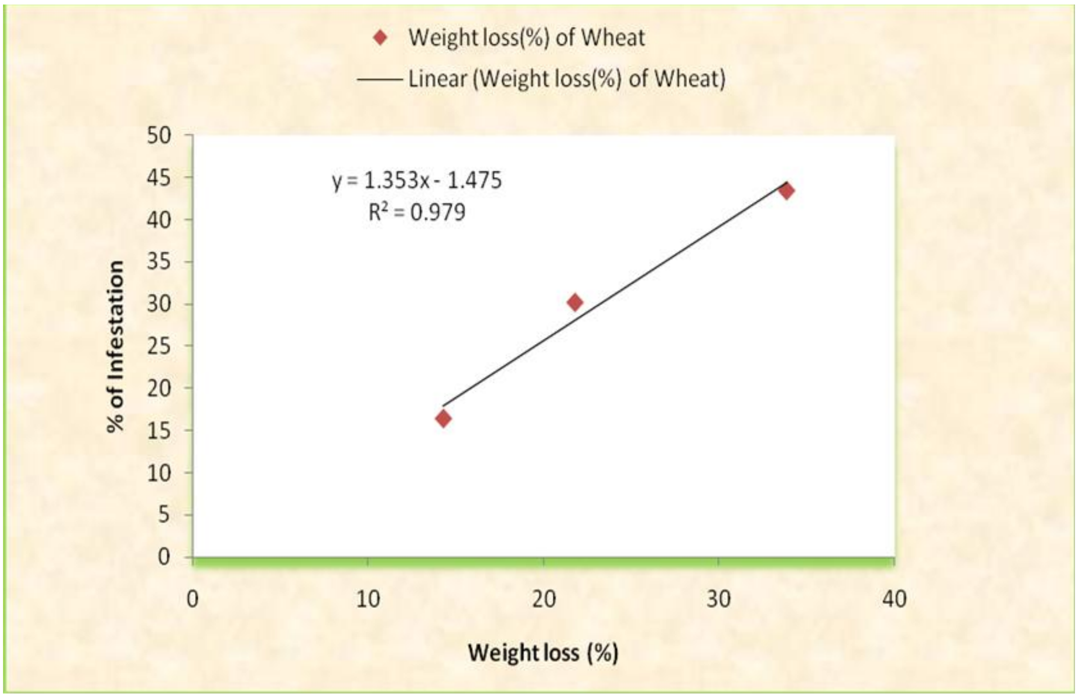

Figure 2. **Relationship between percent of infestation and weight loss of Wheat grain at the 1st, 2nd and 3rd generations by *S. cerealella* (Olivier)**

4.2.7. Correlation between percent of infestation and weight loss of maize grain by *S. cerealella*

Correlation study was done to establish the relationship between percent of infestation and weight loss of maize grain. From the Figure 03, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 0.692x + 8.111 gave a good fit to the data and the co-efficient of determination (R^2 = 0.325) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that percent of infestation was strongly as well as positively correlated with weight loss of maize grain. Weight loss of maize grain was increased due to increase of percent of infestation maize grains.

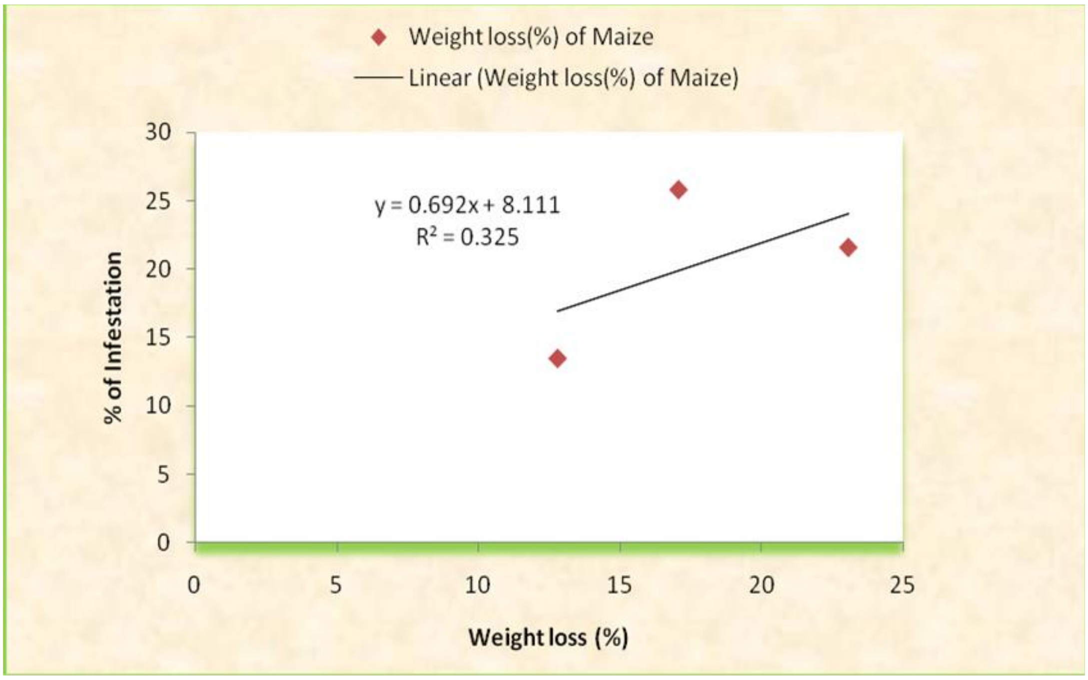

Figure 3. Relationship between percent of infestation and weight loss of maize grain at the 1st, 2nd and 3rd generations by *S. cerealella* (Olivier)

CHAPTER V

SUMMARY AND CONCLUSION

Two experiments was conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from May to December, 2014 to study to study biology and damage extent of different stored grains caused by Angoumois grain moth *Sitotroga cerealella* (Olivier) in the laboratory. Rice, wheat and maize seeds were used as experimental materials.

Experiment-1: Study of the bio-ecology of Angoumois grain moth, *Sitotroga cerealella* (Olivier) development on different stored grains in the laboratory

The rice moth, *S. cerealella* (livier) adults started mating after 24 hrs of emergence. The female moth laid eggs on all the test grains (rice, wheat and maize) but the total number of eggs varied for different grains. The highest number of eggs were found to be laid on rice and that varied from 80-140 with an average of 109 egg per female. The average number of eggs laid per female on wheat and maize were 82.7 and 55, respectively. The larval periods were 35.6 ± 0.009 days when they developed on rice, wheat and maize, respectively. Male adult longevity was 8.2 ± 0.13, 9.1 ± 0.08 and 9.6 ± 0.03, respectively in rice, wheat and maize, whereas 10.1 ± 0.32, 9.8 ± 0.07 and 9.9 ± 0.04, respectively for female adult longevity. The larvae developed on different grains varied in sdize. The observed larval lengths were found 16.0 ± 0.19, 17.5 ± 0.18 and 18.2 ± 0.07 mm and the 2.90 ± 0.04, 3.10 ± 0.09 and 3.27 ± 0.12 mm, respectively, for rice, wheat and maize grains. For pre-pupal condition, length was 4.0 ± 0.07, 4.1 ± 0.02 and 4.2 ± 0.02 mm, respectively for rice, wheat and maize grains and width was 1.20 ± 0.05, 1.25 ± 0.01 and 1.28 ± 0.05 mm, respectively for rice, wheat and maize grains. In pupal condition, length was 3.5 ± 0.03, 3.5 ± 0.05 and 3.8 ± 0.03 mm, respectively for rice, wheat and maize grains and width was 1.50 ± 0.05, 1.60 ± 0.01 and 1.65 ± 0.05 mm, respectively for rice, wheat and maize grains. In case of male adult wing span, length was 11.2 ± 0.06, 11.8 ± 0.09 and 11.9 ± 0.03 mm, respectively for rice, wheat and maize grains and width was 11.9 ± 0.03, 12.4 ± 0.01 and 12.8 ± 0.01 mm, respectively for rice, wheat and maize grains. In consideration of female adult wing span, length was 12.7 ± 0.04, 12.9 ± 0.06 and 13.01 ± 0.04 mm, respectively for rice, wheat and maize grains, whereas the width was 13.1 ± 0.04, 14.1 ± 0.01 and 14.4 ± 0.06 mm, respectively for rice, wheat and maize grains.

Experiment-2: Damage assessment of different stored grains caused by angoumois grain moth

After 24 hours of observations, the highest number of dead insects (1.00) was recorded in rice grain whereas no dead insect was observed for wheat and maize stored grains. After 48 hours of observations, the highest number of dead insects (2.00) was recorded in rice grain followed (1.00) by wheat grain but no dead insect was observed for stored maize grains. After 72 hours of observations, the highest number of dead insects (4.00) was recorded in rice grain but the lowest (1.00) for maize grains.

At 1st, 2nd and 3rd generation, the highest number of adults emerged (81.75, 122.00 and 203.00, respectively) in wheat grains, while the lowest number of adults (9.50, 14.00 and 23.00, respectively) was recorded for rice grains. At 1st generation in weight basis, the highest (92 g) weight of healthy seeds was recorded for rice grains, while the lowest (84 g) was found for wheat grains by weight basis. In case of infested seeds, the highest (12 g) weight of infested seeds was recorded for wheat grains, while the lowest (8 g) weight of infested seeds was found for rice grains. The highest (14.29%) infestation level was recorded in wheat stored grains, whereas the lowest (8.70%) infestation was observed for rice grains seeds.

At 2nd generation, the highest (88 g) weight of healthy seeds was recorded for rice grains, while the lowest (78 g) weight of healthy seeds was found for wheat grains by weight basis. In case of infested seeds, the highest (17 g) weight of infested seeds was recorded for wheat grains, while the lowest (12 g) weight of infested seeds was found for rice grains. The highest (21.79%) infestation was recorded in wheat grains but the rice had the lowest (13.64%) infestation. Considering the weight of the healthy seeds, rice was found best, but the wheat was the worst in this respect at the time of 3rd generation of the pest. On the contrary, the weight of the infested seed was found highest (22 g) in wheat grains, while rice showed the lowest weight of infested seeds. Consequently wheat showed the highest level (33.85%) of infestation.

At 1st generation in case of weight loss, the highest (16.50%) weight loss was observed in wheat seeds, whereas the lowest (10.15%) weight loss was recorded in rice seeds. At 2nd generation in case of weight loss, the highest (30.25%) weight loss was observed in wheat seeds, whereas the lowest (21.63%) weight loss was recorded in rice seeds. At 3^{rd} generation in case of weight loss, the highest (43.50%) weight loss was observed in wheat seeds, whereas the lowest (15.20%) weight loss was recorded in rice seeds.

Conclusion:

The Angoumois grain moth, *Sitotroga cerealella* (Oliver) is one of the most serious pests of different stored grains at post harvest level. The moth develops through egg, five larval instars, pupa, pre-pupa and adult stages. The duration for different developmental stages of the moth varied for different stored grains. The grain weight loss increased with the increase in percentage of infestation levels.

Considering the adult mortality, adult emergence, weight of healthy and infested rice, wheat and maize grains and percent infestation, the present study showed that positive co-relation (significant correlation) existed between percent of infestation of test grains at the 1^{st}, 2^{nd} and 3^{rd} generations and weight loss (%) of the grains.

Recommendation:

Considering the situation of the present experiment, further studies in the following areas may be conducted:

1. Influence or impact of different environmental factors may be studied studying the biology of the pest in different seasons of the year;

2. Studies on the efficiency of different control measures of stored grain pests.