BIO-ECOLOGY, DAMAGE ASSESSMENT AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* OLIVIER

MD. MONSUR ALAM

A DISSERTATION

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA, BANGLADESH

JUNE, 2017

BIO-ECOLOGY, DAMAGE ASSESSMENT AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* OLIVIER

BY

MD. MONSUR ALAM

REGISTRATION NO. 13-05791

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

DOCTOR OF PHILOSOPHY

IN

ENTOMOLOGY

SUBMITTED TO

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA, BANGLADESH

JUNE, 2017

BIO-ECOLOGY, DAMAGE ASSESSMENT AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* OLIVIER

MD. MONSUR ALAM
REGISTRATION NO. 13-05791

A DISSERTATION

DOCTOR OF PHILOSOPHY
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2017

Certificate of Approval

....
Prof. Dr. Md. Razzab Ali
Chairman
Advisory Committee

....
Prof. Dr. Md. Ramiz Uddin Miah
Member
Advisory Committee

....
Prof. Dr. Md. Abdul Latif
Member
Advisory Committee

....
Prof. Dr. M. Salahuddin M. Chowdhury
Member
Advisory Committee

DEPARTMENT OF ENTOMOLOGY
Sher-e-Bangla Agricultural University (SAU)
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that Dissertation entitled **"BIO-ECOLOGY, DAMAGE ASSESSMENT AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* OLIVIER"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN ENTOMOLOGY**, embodies the result of a piece of bonafide research work carried out by **MD. MONSUR ALAM, Registration no. 13-05791** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017
Place: Dhaka, Bangladesh

Prof. Dr. Md. Razzab Ali
Chairman, Advisory Committee
Department of Entomology
SAU, Dhaka

DEDICATED
TO
MY BELOVED
PARENTS

BIBLIOGRAPHIC SKETCH

The author Md. Monsur Alam was born on November 10, 1969 at the then a small sub-divisional town Thakurgaon, under Dinajpur district, Bangladesh. He is the ninth child of late Mashir Uddin Ahmed advocate and late Mrs. Sufia Khatun.

Md. Monsur Alam passed his SSC examination from Thakurgaon Government Boys' High School under Rajshahi board in 1984 and HSC examination from Thakurgaon Government College under the same Board in 1986. He obtained his B.Sc.Ag. (Hons.) in 1990 (held in 1993) from Bangladesh Agricultural University (affiliated BAI, Sher-e-Bangla Nagar, Dhaka). He did MS in Entomology from Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur in 2000. During his MS, he worked on, "Synchrony Evaluation of Plant Age, Aphid Performance and Insecticide Application in Controlling *Lipaphis erysimi* Kalt. in Mustard." He enrolled at the SAU, Sher-e-Bangla Nagar, Dhaka in July-December 2012 Semester as a PhD student in the Department of Entomology. He completed 32 credit hours of course work and 33 credit hours of Dissertation Research.

After graduation, the author joined first in a multinational chemical company named Ciba Geigy in 1995. During his service in Ciba Geigy Md. Monsur Alam had visited more than 120 Tea gardens of Bangladesh. He had been working there for two and half years before enrolled for MS degree. After completion of MS degree he joined to the DAE with dignified BCS (Agriculture). At present, he is serving as Deputy Director (Operation, Monitoring and Evaluation) at National Agricultural Technology Project (NATP 2), PIU, DAE, Khamarbari, Dhaka. He is happily married to Mst. Aysha Sultana and blessed with a beautiful daughter Junayna Tahseen.

BIO-ECOLOGY, DAMAGE ASSESSMENT AND MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* OLIVIER

ABSTRACT

Md. Monsur Alam

Seven sets of experiment including survey in farmers' household storage in 16 districts of the northern region of Bangladesh and six laboratory experiments at central laboratory of Sher-e-Bangla Agricultural University were conducted to evaluate bio-ecology, damage assessment and protection status of stored rice grains and management practices of Angoumois grain moth *Sitotroga cerealella* Olivier from June 2013 to May 2016. The bio-ecology study in laboratory revealed that mean duration of incubation period of Angoumois grain moth was 5.67 to 8 days, larval period 15.6 to 17.6 days, pupal period 4.50 to 6.50 days, adult longevity 7.17 to 8.58 days and total life cycle 32.92 to 40.67 days. The highest reproduction rate per female was found in June (139.20) and the lowest reproduction rate recorded in December (39.08). The field survey revealed that about 96.3% farmers stored unhusked rice grains in their household and among them 99% faced the problem of Angoumois grain moth infestation. In storage, 100% farmers took preventive measures to protect grains from infestation, among them, 91% reported sun-drying of grains and 72% dried neem leaf powder for prevention of this pest. It was also observed that in case of curative measures 96% farmers adopted sun drying of grains again and 67% used Aluminium phosphide tablet with sun drying. About 73% farmers learnt with precautionary measures of fumigation and 44% emphasized on air tight containers during fumigation. Most (83%) of the farmers reported that sun drying of rice grains was important as ecofriendly management practice and this perception was followed by the use of neem leaf powder (73%). The results from varietal screening of free choice test revealed that BRRI dhan 52 had the lowest incidence of infested grain, lower weight loss and lower seed germination reduction which was identical with BRRI dhan 60 and BRRI dhan 29. Varietal screening of no choice test was consistent with the results. The susceptibility of hybrid rice grains to grain moth was very high. Plastic pot was the most suitable container for storage grains showing lowest infestation (26%) and highest seed germination (31.75%) at 180 DAIR. The results on the control of Angoumois grain moth using botanicals revealed that the neem leaf powder @ 2g/kg rice grains was the most effective botanical reported lowest infestation (16.25%) and highest seed germination (81%) at 180 DAIR. Among the fumigants used, Aluminium phosphide @ 200mg/kg rice grains was the most effective for grain moth control. The integrated management approach of Angoumois grain moth with Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg grains was the most effective management package. This package resulted lower grain infestation (1.50%), lower grain weight loss (0.15%) and higher seed germination (83.75%) at 180 DAIR.

ACKNOWLEDGEMENTS

All the praises due to the Almighty Allah, the cherisher and sustainer of the world. His blessings have enabled the author to complete his dissertation leading to Doctor of Philosophy degree.

The author expresses his heartiest gratitude sincere appreciation, indebtedness and deep sense of respect to his adorable teacher, venerable Chairman, Advisory Committee Dr. Md. Razzab Ali, Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his planning, painstaking and scholastic guidance, support, extraordinary kind concern, everlasting encouragement, inestimable cooperation and intellectual encircling the till final preparation of the thesis.

Cordial thank giving due to the scholar member of the Advisory Committee, Dr. Md. Abdul Lalif, Professor, Department of Entomology Sher-e-Bangla Agricultural University, for his valuable suggestions, comments and advice during the entire period of study.

He expresses his profuse gratitude, cordial appreciation and gratefulness to his thoughtful, creative members of the Advisory Committee Dr. Md. Ramiz Uddin Miah, Professor, Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh and Dr. M. Salahuddin M. Chowdhury, Professor, Department of Plant Pathology, Sher-e-Bangla Agricultural University,for their valuable suggestions, guidance constant encouragement and inestimable during the entire period of study.

The author acknowledges his sincere gratitude to the NATP (National Agricultural Technology Project-Phage 1), DAE (Department of Agricultural Extension) authority for providing a fellowship for PhD study.

With due regards, he thanks the Chairman, Department of Entomology, Sher-e-Bangla Agricultural University, for the facilities provided, in carrying out this work. He also acknowledges with deep regards the help and cooperation received from his respected teachers and staff of the Department of Entomology, Sher-e-Bangla Agricultural University while carrying out this work.

He expresses his heartiest gratitude sincere appreciation, indebtedness and deep sense of respect to his late parents for their sincere and affectionate support and love, extraordinary kind concern, everlasting encouragement and inestimable cooperation during the entire period of study.

Last but not the least his dearest thanks goes to his beloved wife ‘Aysha Sultana for her interest in his work, her encouragement and love, which immensely contributed to his success.

Finally the author is deeply indebted to his loving daughter ‘Junayna Tahseen’ who might have missed his warm company and total attention during the whole study period. Their big sacrifice, patience and cooperation made it possible to complete his degree successfully.

Dated: June, 2017 **The Author**

SAU, Dhaka

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

et al.	:	And others
%	:	Percent
BBS	:	Bangladesh Bureau of Statistics
BRRI	:	Bangladesh Rich Research Institute
cm	:	Centimeter
CRD	:	Completely Randomized Design
CV	:	Coefficient of variation
d.f	:	Degrees of freedom
DAIR	:	Days After Insect Release
EC	:	Emulsifiable Concentrate
etc.	:	Et cetera
FAO	:	Food and Agriculture Organization
Fig.	:	Figure
g	:	Gram
ha	:	Hacter
J.	:	Journal
Kg	:	Kilogram
L	:	Liter
LSD	:	Least Significant Difference
m	:	Meter
m^2	:	Square meter
mm	:	Millimeter
MS	:	Mean sum of square
no.	:	Number
^oC	:	Degree Celsius
p^H	:	Hydrogen ion conc.
RH	:	Relative Humidity
SAU	:	Sher-e-Bangla Agricultural University
t	:	Ton

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice is the main food crop for more than half of the worlds' population. It is the major source of carbohydrate and plays a vital socio-economic role in the diet of the common people of Bangladesh. The rice occupies about 75% of the total cultivable land of the country. Bangladesh produces a total of 26.53 million tons of rice from an area of 26.02 million acres (BBS, 2016). About 90% of the population of Bangladesh depends on rice for their major food intake. The farmers store more than 65% of the total rice produces till the next season for their food, feed and seed purposes. Rice is stored as paddy (unhusked rice), brown and polished milled rice. In Bangladesh, rice is stored as raw parboiled in bamboo made container (called *dole* and *golas*) or stored as parbolied milled rice in earthen pot (called *motka*).

Rice is damaged by a number of agents, such as insects, rodents, fungi, mites, birds and moisture (Prakash and Rao, 1983). Among them, storage insects are the major agents causing considerable losses every year. Nearly seventeen species of insects have been found to infest stored rice (Praksh *et al.,* 1987) of which grain moth (*Sitotroga cerealella*), rice weevil (*Sitophilus oryzae* Linn.) and redflour beetle (*Tribolium castaneum*) predominant. On the other hand, moth and beetles predominate in raw rice and weevils predominate in milled rice (BRRI, 1984). Among all the insects, *Sitotroga cerealella* is often placed at the top of the list of major insect pest of stored rice. The grain moth, *S. cerealella* Olivier known as the Angoumois grain moth or paddy moth is one of the most dominant species in the stored paddy (Prakash *et al.,* 1984). The grain moth is also able to infest the grains in bulk storage structures and bags. Cogburn (1977) experimentally assessed weight losses during rice storage and concluded that one gravid female of *S. cerealella* in 50 g of stored rice could destroy the grain completely during three subsequent generations. Grain moth, *S. cerealella* Oliv. is cosmopolitan throughout the tropical and subtropical parts of the world.

Loss of rice due to the infestation by Angoumois grain moth has been increasing along with the higher production and amount of cereal grains being stored in farmer households. 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 stored at farmer level 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 it can keep itself concealed in the grains and 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 (Khatun, 2014).

The adult is a small, buff to yellowish brown or straw colored moth measuring about one-third of an inch long with a wing span 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. Angoumois grain moth larvae feed on a number of whole kernel grains. Larval feeding produces large cavity within the infested grain and causes a reduction in grain weight and quality. The newly hatched larvae bores directly into the grain and typically remains inside the grain for both larval and pupal development. They feed on the inside contents of grains leaving the grains unfit for human consumption. The larvae of this pest make tunnel inside the kernels causing substantial damage and rendering the grain more susceptible to secondary insect pests (Weston and Rattlingourd, 2000). 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). Larval feeding inside the grain cause an appreciable amount of damage which has been stated about 8.1% (Shahjahan, 1974). This insect alone can account for over 40% of the total losses in stored grain in some areas (Khatun, 2014).

Most of the farmers of Bangladesh store small quantities of rice, wheat and maize for consumption, seed 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 damages caused by this pest in rice, wheat and maize grains. On the other hand, this grain moth causes damage the unhusked rice grains round the year which varies depending on the variations of ambient temperature and relative humidity from season to season.

Due to lack of proper warehouse facilities, stored grain insects largely damage food grains in stores as well as during shipping and transportation (Upadhyay and Ahmad, 2011). Insects, pathogens and mites cause the greatest proportion of damage and cause the deterioration of grains by producing entomotoxins and mycotoxins (Morgan and Aldred, 2007). Many farmers suffer heavy losses of stored grains due to insect pests. There are about 39 species of pests, which attack the stored grains and grain products (Priya *et al.*, 2016).Most insect pests belong to the orders Coleoptera and Lepidoptera, which accounts for about 60% and 10%, respectively, of the total number of species of stored-product insect pests (Atwal and Dhaliwal, 2008).

Food grain losses due to insect infestation during storage are serious problem, particularly in the developing countries. Rice is stored as paddy (unhusked rice), brown and polished milled rice. In Bangladesh, rice is stored as raw parboiled in bamboo made container called bamboo *dul* and *gola* or stored as parboiled milled rice in earthen pot called *motka* (Anon, 1984). But the severity of infestation in stored unhusked rice caused by rice moth depends on the type of containers where the grains are stored. Therefore, it was felt to undertake the present study to find out the suitability of the container(s) available in the market for preserving rice grains against *S. cerealella* in the laboratory condition.

Recently, much attention has been paid to develop resistant varieties against the attack of the pest. But there is little information about the varietal responses of rice against Angoumois grain moth in Bangladesh. Therefore, it is felt to conduct this study to find out the tolerant/resistant rice varieties against infestation caused by Angoumois grain moth in storage condition

Plant essential oils have traditionally been used to kill or repel insects (Isman, 2006) being considered as an alternative to stored-grain conventional pesticides because of their low toxicity to warm-blooded mammals and their high volatility (Shaaya *et al*., 1997; Li and Zou, 2001). The toxicity of essential oils to stored-product insects is influenced by the chemical composition of the oil, which in turn depends on the source, season and ecological conditions, method of extraction, time of extraction and plant part used (Don-Pedro, 1996; Lee *et al*., 2001).

Extracts and components from more than 75 plant species belonging to different families have essential oils. Among them Anacardiaceae, Apiaceae (Umbelliferae), Araceae, Asteraceae (Compositae), Brassicaceae (Cruciferae), Chemopodiaceae, Cupressaceae, Graminaceae, Lamiaceae (Labiatae), Lauraceae, Liliaceae, Myrtaceae, Pinaceae, Rutaceae and Zingiberaceae are most important for fumigant toxicity. The essential oils were extracted from the rhizomes, bulbs, leaves, fruits, fruit peels, seeds, dried fruits or multiple parts (Rajendran and Sriranjini, 2008). In some studies, essential oils procured from commercial sources were used (Ahmed and Eapen, 1986; Sim *et al*., 2006). In addition to essential oils, specific compounds isolated from plant extracts/essential oils were tested for fumigant activity. Tests have also been carried out with pure compounds obtained from commercial sources (Auger *et al*., 1999; Huang *et al*., 1999; Lee *et al*., 2003a) or synthesized in the laboratory (Park *et al*., 2004).

Control of this pest is primarily dependent on repeated application of synthetic insecticides (Hasan and Reichmuth, 2004). Methyl bromide and phosphine fumigants have been used for decades to control stored pests (Islam,*et al*., 2009) and belong to the most effective treatments to protect stored food, feedstuffs, and other agricultural commodities. Currently, phosphine (from metal phosphide preparations, cylinderized formulations and on-site generators) and methyl bromide (available in cylinders and metal cans) are the two common fumigants used for stored-product protection worldwide. Insect resistance to phosphine is a global issue now and control failures have been reported in field situations in some countries (Taylor, 1989; Collins *et al*., 2002). Methyl bromide, a broad-spectrum fumigant, has been declared an ozone-depleting substance and therefore, is being phased out completely. In view of the problems with the current fumigants, there is a global interest in alternative strategies including development of chemical substitutes, exploitation of controlled atmospheres and integration of physical methods. In order to control this kind of species without disturbing the environment, natural products have been screened for their insecticidal activity (Sukumar *et al*., 1991). Botanical insecticide composed of essential oils may be a sound alternative to more persistent synthetic pesticides for managing the major pests of stored product insects (Sahaf and Moharramipour, 2008).

Chemical control, however as an alternative method has got great value. Several reports are available on the efficacy of different chemicals (Chandra *et al.*, 1989; Prakash and Rao, 1983; Stoyanova and Shikrenov, 1983; Yadav, 1983; Singh *et al*., 1989; Dilwari *et al.*, 1991). But the use of chemical insecticides against the attack of paddy moth in storage may cause serious health hazards. The residues of the chemical insecticides remain in the stored grains and also in the environment (Srivastava, 1980; Prakash and Kauraw, 1982). Moreover, serious environmental imbalance results due to development of resistance in pest population and subsequent resurgence as well as destruction of beneficial insects. Besides this, reports are also available on the efficacy of plant oils (Singh *et al.*, 2002; Chander *et al.*, 1991; Su, 1991). But the oils are not always available, not good in efficacy, have pungent smell and cannot disinfest the seeds. Hence, search for the alternative method of paddy moth control utilizing some non-toxic, environment friendly and human health hazard free methods are being pursued now a day.

Plant products liberally available as indigenous source of insecticides and insect repellents had been used more than one century in India. The insecticidal property is not very quick (except natural pyrethrins) as compared to that of synthetic insecticides and fumigants. The plant products certainly possess surface persistence for a long period, have least or no adverse effect on germination ability of seed, cooking quality and milling, less expensive, easily available and some of the products like natural pyrethrums have rapid killing action (Prakash *et al.*, 1981). A number of plant products have been reported as being in use against insect pest in stored grains including rice to minimize storage losses due to insects. Neem *(Azardirachta indica*) products like leaves, seed, bark from which oil cake and extracts are prepared have been reported to possess fungicidal, nematicidal, insecticidal, insect repellent and antifeedent properties (Ketkar *et al.*, 1976). Neem *(Azardirachta indica*) products have been reported by many workers as grain protectants against rice storage insects. Mixing dried leaves with grains repel the insect pests (Fry, 1938; Pruthi and Singh, 1950; Jilani and Su, 1983).The neem leaves act as an insecticide (Krisnamurthy and Rao, 1950).

However, for better protection appropriate methods for disinfecting the food grains are required. Farmers, through a long history of battle against stored product pests, have learnt to exploit natural resources, or to implement accessible methods, that would lead to a degree of population suppression of pests (Upadhyay and Ahmad, 2011). Intense use of insecticides and pesticides results in the evolution of resistant strains in addition to environmental contamination and various health hazards (Prakash & Rao, 2006; Rahman *et al.,* 2009).

However, the use of quality insecticide and its proper management is a burning issue in respect of agro socio economic and environmental aspect. At present situation in Bangladesh, there is a great need of information about appropriate insecticide based management to pest in rice. Considering the conditions mentioned above the study was undertaken based on the following objectives

Research objectives

The objectives of the research work are given below:

1. To assess the farmers perception on damage assessment of stored rice grains by Angoumois grain moth, *Sitotroga cerealella* in northern region of Bangladesh;
2. To study the bioecology of grain moth, *S. cerealella* on unhusked rice grains in laboratory conditions;

3. To develop integrated management approach of Angoumois grain moth in storage, evaluation of suitability of containers, varietal preference of different rice varieties, efficacy of available botanicals, determine efficacy and dosage rate of fumigants;

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

The review of literature on the relevant field of bio-ecology of Angoumois grain moth (*Sitotroga cerealella*), its responses on rice varieties, damages in storage conditions and management in Bangladesh and elsewhere of the world were searched and discussed under the following sub headings.

2.1. Nomenclature of Angoumois grain moth

The Angoumois grain moth (*Sitotroga cerealella*) is a species of gelechioid moth. It is the type species of its genus *Sitotroga*, placed in the subfamily Pexicopiinae of the twirler moth family (Gelechiidae). Formerly, it was included in the Chelariinae, which more recent authors do not separate from the Pexicopiinae and usually even do not consider a distinct tribe (Chelariini) within them (Pitkin & Jenkins, 2004). The 'Angoumois' was named after the French province which experienced an outbreak of the moth in 1760. Besides this it is also known as grain moth, rice grain moth, rice moth.

2.2. Origin and distribution

Angoumois grain moth was first scientifically described by G. A. Olivier in 1789 in a former province of France known as Angoumois. It has almost worldwide distribution. This is due to its synanthropic habits, which allow it to be easily transported in international grain shipments. Having a broad range of hosts also enables it to become a cosmopolitan insect pest of stored grains. It is sensitive to cold temperatures and prefers a moderate climatic condition. Angoumois grain moth is a primary colonizer of stored grain in subtropical and warm temperate regions of the world (Germanov, 1982).

2.3. Life cycle of Angoumois grain moth

The Angoumois grain moths a day after their emergence start mating. The female moth is capable of laying 150-400 eggs. The eggs hatch in about a week. The tiny caterpillar crawls about and penetrates the grain, effecting entrance generally through a crack or abrasion in the pericarp. It feeds on the kernel and remains there for the rest of its life. The full grown caterpillar is about 5.0 mm long. It eats out a small channel to the outside of the seed leaving, however, a thin layer of the coat intact. A silken cocoon is spun, inside which reddish-brown pupa is formed. The larval stage lasts for 2-3 weeks. After one week of the pupation period, the young moth emerges through the thin seed-coat left by the caterpillar. In this way, the larva and pupa are found entirely inside the grain. On an average the pest has 3-4 broods in a year, but sometimes 8 broods have also been reported (Samiksha, 2016).

Although the ideal environmental conditions for *S. cerealella* growth and development lie within the range of 25-30°C and 60-75% RH, the ability of this insect to complete development at 15 or 35°C and 43% RH enables this pest to infest stored grain not only in tropical and subtropical climates but also in cooler climates (Mendoza *et al., 2004*).

2.3.1. Mating and oviposition

The Angoumois grain moth, *S. cerealella* adults used to start their mating after passing 24 hrs of emergence. On rice grains, a single female moth laid eggs from 42 to 213 with an average of 109 eggs throughout its life. The eggs were laid singly or in groups of 4-7 depending upon the season and ovipositional site (Akter *et al.*, 2013).

Dhotmal and Dumbre (1982) reported that, 41 to 58 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.

The fecundity of Angoumois grain moth was 126.35 eggs/female in rice and 128.75 eggs/female in maize grains (Saikia *et al*., 2014).

Adults are short-lived, do not feed, and are attracted to light. Oviposition occurs on the exterior of the seed, usually during the overnight hours (Cox and Bell, 1991). Prakash *et al*. (1981) reported that for egg lying female prefers a rough surface than a smooth one in stored rice. Akter *et al*. (2013) observed that, the oviposition period was found to be on an average 3.67 ± 0.01 days.

Plate 2.1: Mating of male and female adults of Angoumois grain moth

2.3.2. Eggs

The eggs are laid singly or in clumps of variable numbers. They are white when first laid and quickly change to a reddish color. The egg is oval with the anterior (micropylar) end truncate and bearing longitudinal ridges and weaker transverse ridges.

The eggs are laid at night on the outside of cereal grains, in cracks, grooves or holes made by other insects (Hammad *et al.,* 1967). Eggs are laid singly or in clumps; the number laid is variable. The female may lay up to 200 eggs although 40 is a more average number (Dobie *et al.,* 1984).

Plate 2.2: Freshly laid egg of Angoumois grain moth (Source: SAU Lab 2014)

These are deposited in depression, cracks, and crevices, in floor or holes in the grains. The eggs are white in color when fresh, but soon become bright red in color. They are oval in shape and measures 0.5 mm in length, with both the ends rounded (Samiksha, 2016). The eggs are measured about 0.5 mm in diameter. The egg was oval shaped and hatched within a week (Akter *et al*., 2013).

2.3.3. Incubation of egg

Akter *et al*. (2013) observed that, an average incubation period of Angoumois grain moth was 5.5 ± 0.03 days.

2.3.4. Larval period

Larvae bore into the grain after hatching, entering sorghum kernels primarily in the germ end and its periphery (Wongo, 1990). Larvae complete their development in a single grain; two or three larvae may develop in single grains of maize, but only one adult is produced from single grains of other hosts (Cox and Bell, 1981).

The nature of the host may also affect the rate of larval development, with development times of 20 days reported for wheat (Cocurt X-71) and 22.4 days for barley (Cleaper) (Mahdi *et al*., 1988). Even under laboratory conditions, there may be wide variation in life cycles, with adults emerging after 20 to 90 days (Grinberg and Palii, 1981).

The larvae developed through five instars. The newly hatched larvae of all instars were yellowish white in color with light brown head. The stadia of the 1st, 2nd, 3rd, 4th and 5th instar larvae were 3.2 ± 0.09, 4.0 ± 0.11, 10.0 ± 0.23, 6.0 ± 0.07 and 3.0 ± 0.03 days, respectively. The lengths of all five larval instars were 1.0 ± 0.00, 2.0 ± 0.02, 4.0 ± 0.06, 5.0 ± 0.03 and 4.0 ± 0.06 mm, respectively and the widths were 0.1 ± 0.0, 0.4 ± 0.0, 0.6 ± 0.01, 0.8 ± 0.02 and 1.0 ± 0.09 mm, respectively (Akter *et al.*, 2013).

Duration of larva was found to be from 13.66 to 19.33 days in different rice varieties and development was faster in fine-grained varieties (Dhotmal and Dumbre, 1982).

a) First inster larva

b) Last inster larva

Plate 2.3: Larvae of Angoumois grain moth

Larval migration is reported as being up to 10 cm horizontally and 5 cm vertically (Germanov, 1982). Germanov (1982) described that, four larval stages during his studies under conditions of mass rearing and reported that larval stages I, II, III and IV were observed on the 9th, 12th, 18th and 20th days respectively after grain infestation at 22.3º C temperature and 65.8% RH.

2.3.5. Pupal period

Pupa is brown coloured, develops inside silken cocoon. Total 3.0 ± 0.05 days were required for pre-pupal stage and 5 ± 0.08 days for pupal stage under the laboratory condition. The pre-pupa measured 4.0 ± 0.02 mm in length and 1.20 ± 0.05 mm width and the pupa measured 3.5 ± 0.01 mm in length and 1.50 ± 0.03 mm width in rice grain (Akter *et al*., 2013). Generally, pupal period is 4-7days.

Plate 2.4: Pupa of Angoumois grain moth

Germanov (1982) reported that, pupation on the 15th day after infestation at 22.3ºC temperature and 68.8% relative humidity.

2.3.6. Adult longevity

The moth is small, pale brown, 5-7 mm long with wings folded, wingspan 10-16 mm. The head, thorax and filiform antennae are pale brown; labial palpi are long, slender, sharply pointed and upcurved, pale brown with dark tips, terminal segment longer than second, second segment rough-scaled beneath. The forewing is elongate, pale brown or ochreous-brown, with a few black scales at the base of the dorsum and a concentration of black scales towards the apex. The wing fringes are concolorous with the wing or a little paler, with a central black band. Vein CuP is absent, and veins R_4, R_5 and M_1 are stalked. The hindwing is greyish-brown, apex greatly produced. Abdomen is brown.

a) Ventral view

b) Dorsal view

Plate 2.5: Adult of Angoumois grain moth

Angoumois grain moths are non-feeding, short-lived, wingspan 5 to 6 mm (½ to ⅝ inch), dark spot on wings, long fringe on fore and hind wing, hind wing margin taper to a fingertip projection on tip (Mason and McDonough, 2011). The adult lifespan may be up to 15 days (Mondragon and Almeida, 1988).

The total life cycle of female was 43.2 days in rice and 44.3 days in maize, whereas the total life cycle of male was 37.4 days in rice and 43.3 days in maize (Saikia *et al.*, 2014). It was reported 8.9 days in male and 9.8 days in female respectively for adult longevity (Koleva and Ganeva, 2009; Ashamo, 2009).

The longevity of females was more than that of males. The adult longevity was 8 ± 0.13 days for male and 10 ± 0.32 days for female. The length of male was 11.2 ± 0.09 mm and 12.07 ± 0.06 mm for female in rice grain (Akter *et al.,* 2013). There are generally four to five generations per year, although in heated warehouses there may be as many as 10 to 12 generations (Mason, 2010).

2.4. Effect of weather factors on the population of *S. cerealella*

The rate of development is dependent on temperature. Mondragon and Almeida (1988) found that development was favored at 25°C, and that at this temperature, with 70 ±2% RH and a diet of maize, the mean period of development for the larval stage was 29.4 days. Although larvae will hatch at temperatures down to 12°C and up to 36°C (Cox and Bell, 1981), 16°C and 30% RH are cited as the minimum conditions for population increases (Evans, 1987) and the upper temperature limit is 35°C. Humidity in the range 50-90% RH has little effect on the development rate (Boldt, 1974).

The effect of different rearing temperatures (21, 24, 27 and 30°C) at 65% RH and different relative humidities (30, 40, 50, 60, 70, 80 and 90%) at 26°C on the biology of *S. cerealella* reared on wheat grains was investigated in Egypt. The duration of the egg stage, pre-oviposition, oviposition and post-oviposition periods, and adult lifespan was negatively correlated with temperature. The highest number of eggs was laid by Angoumois grain moth at 27°C (155/female). In summer season incubation period was from 2 to 3 days and in winter season it ranged from 5 to more (overall, incubation period depends on temperature and relative humidity (Akter *et al.*, 2013).

Egg development can last 5 to 6, 6 to 7, or 10 days at 30°C (86°F), 25°C (77°F), or 20°C (68°F), respectively (Boldt, 1974; Cox and Bell, 1991). Hatching of eggs of Angoumois grain moth was reported to take 11 days at 17.3°C temperature and 68.3% RH (Germanov, 1982). Eggs can hatch at temperatures as low as 12°C and as high as

36°C. Larvae are 5 mm (¼-inch long) and are yellow-white with brown heads. Larvae spend their entire lifetime within the kernel. In cold climates, larvae become dormant for four to five months. Pupation occurs within the kernel, lasting 8, 10 to 12, or 20 days at 30°C, 24°C to 27°C, and 20°C, respectively. Adults are short-lived, generally less than one week. Minimum temperature for population development is 16°C, optimum development occurs at 30°C, and maximum temperature for population development is 35°C to 37°C (Cox and Bell, 1991).

The larvae of Angoumois grain moth is dormant for four to five months during the winter in colder climates (Mason, 2010).

Akter *et al.*, (2013) showed that, the highest developmental period of *S. cerealella* was found 25.05 days at 20ºC temperature and the lowest developmental period was found 17.42 days at 32ºC temperature.

According to Hill (1990), total larval development of *S. cerealella* can be completed by 19 days at 30ºC and 80% relative humidity. Temperature limits for the development are 16ºC and 35ºC and humidity between 50 - 90 % which seem to have little effect on the rate of development.

Grewal and Atwal (1967) concluded that, 25 - 30ºC and 80% RH are most favorable for development, survival and reproduction of the Indian strain of *S. cerealella*.

The highest population increase of *S. cerealella* occurred at 30ºC. High relative humidity and temperatures higher than 30ºC are not suitable for development of this pest (Hansen *et al*., 2004).

The effects of different rearing temperatures (26ºC, 30ºC, 32ºC and 35ºC) and of different relative humidities (55, 65, 70 and 85 per cent) on the development and survival of Angoumois grain moths, *Sitotroga cerealella* (Olive.) were investigated on maize under laboratory conditions during the period from May 2013 to January 2014.

Temperature was the main factor affecting egg incubation period, larval-pupal development time, and adult survivorship. The highest number of eggs was laid at 30ºC (172.50/female). The shortest incubation period occurred at temperatures of 32ºC and higher, but they increased sharply as temperature decreased. Larval-pupal development time was shortest at 30ºC. Survivorship was optimal at 30-32ºC, but decreased sharply at 26 and 35ºC. Male longevity was significantly more (7.17 days) at 26°C, and the least (4.17 days) was at 35°C; likewise, female longevity was significantly more (10.33 days) at 26°C, and the least (7.83 days) at 35°C. The relative humidity had no apparent effect on the duration of larval-pupal development; however, 70-85 percent was optimal for hatching (Demissie *et al.,* 2014).

Survivorship was most variable at the more extreme temperatures of 15 and 35°C but was stable and high at 20-30°C.Information on immature development and survivorship at these more extreme temperatures is important to include in simulation models because control might be achieved by manipulating grain temperatures to conditions that result in reduced population growth. From a practical perspective, the lower temperatures are beneficial because they greatly increase immature development times. Thus, the data indicate that lowering grain temperature to 15°C would be a good management tool for Angoumois grain moth in stored corn, and this is a feasible option for most of the corn-growing regions of the United States (Arthur *et al.*, 2001).

Grewal and Atwal (1967) reported that, at 30°C and 60% RH, it took 4.1 and 19.8 d in their study compared with 6.8 and 31.1 d in our study for duration of development for the egg and larval-pupal stages, respectively. They reported that the most suitable environmental conditions for development from egg to adult occurred at 25-30°C and 80% RH (28.1 d). The study by Shazali and Smith (1985) on sorghum also indicates longer immature development times than reported by Grewal and Atwal (1967). In the study by Shazali and Smith (1985), the optimum conditions for immature development also were found to be 25-30°C and 60-80% RH.

The length of this life cycle depends on temperature with completion in 30 days at 86º F and 40 days at 77º F. Minimum temperature and relative humidity for development is 61º F/30% RH while the optimum is 86º F/75% RH and the maximum is 95ºF. Generally, Angoumois Grain Moth will have four to five generations per year with the larvae being dormant in the coldest winter months; but may have as many as 10-12 generations in heated warehouses (Mason, 2010).

2.5. Hosts of Angoumois grain moth

S. cerealella is a pest of stored products (grains). Some varieties are resistant to attack by this moth; varietal resistance in rice has been the subject of much research.

S. cerealella has also been found to infest stored spices, bell pepper (*Capsicum annuum*), coriander (*Coriandrum sativum*), black pepper (*Piper nigrum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*) and the weed *Echinochloa colonum* (Dakshinamurthy and Regupathy, 1988), although there are fewer documented cases of this. Plants are attacked at a postharvest stage, although some are also attacked at the fruiting stage.

Dakshinamurthy and Regupathy (1988) studied the infestation of various food plants by *S. cerealella* in Tamil Nadu, India, in order to determine possible sources of infestation for the next rice crop. *S. cerealella* was found to infest rice, sorghum, maize, pearl millet and the weed *E. colonum.*

2.6. Nature of damage

Although Angoumois grain moth is called stored grain pest, infestation may start from field on standing crop. Larval stage of Angoumois grain moth is the destructive stage. Adults do not feed on commodity. Immediate after hatching larvae bore into rice grain and start feeding on internal contents of grains. In fact larvae complete their development and start pupation within that grain. Infested grains usually have an unpleasant odor thus leave the grains unfit for human consumption. The newly hatched caterpillar bores directly into the grain and usually remains inside the grain for both larval and pupal development. The larvae of this pest tunnel inside the kernels, causing substantial damage and rendering the grain more susceptible to secondary insect pest attack.

Before pupation the larva constructs a chamber just under the grain seed coat, forming a small circular translucent window. Pupation takes places within the chamber inside a delicate cocoon. Adults fly well and cross-infestation occurs readily; but they are short-lived and generally survive only 5-12 days and in suitable stores breeding may be continuous throughout the year (Hill, 1990). Flour dust from internal feeding can spill from the grain once the grain moth has emerged. Besides this infestation produces abundant heat and moisture that may encourage mold growth and attract secondary pests.

2.7. Detection and inspection of *S. cerealella* in storage

S. cerealella larvae complete their development inside a single grain; damage is therefore not visible externally until the late stages of the infestation when translucent windows appear in the grain as the larva carves out a chamber beneath the surface of the grain.

Grain moth can be readily trapped by Z, E-7-11-hexadecadien-1-yl acetate (or HDA). Cogburn (1977) monitored the distribution of *S. cerealella* in rice fields and rice stores in Texas, USA, using pheromone-baited adhesive traps. The use of pheromones in monitoring *S. cerealella* adults has been reported in flour mills (Buchelos, 1980) and in storage and field situations (Vick *et al*., 1988). Stockel and Sureau (1981) determined the optimum dose of pheromone for sex trapping applications in maize. Majumder and Singh (1989) studied the factors affecting the efficiency of sticky traps for capture of *S. cerealella*.

2.8. Damage assessment of rice grains by grain moth in storage

According to Schulten (1973) there are two kinds of factors implicated in the onset and spread of infestation by *S. cerealella*: (1) conditions in the field; and (2) conditions during storage.

S. cerealella is a major pest of stored grains, causing weight loss to grains by hollowing them out. Its impact is greater in the tropics and subtropics where it attacks grain in the field as well as in storage. In the tropics, cereal and leguminous grains need continual protection against insect attack at all stages from the growing plant in the field up to the time of consumption, since field-to-storage infestation is common by stored grain insects such as *S. cerealella*. Inadequate storage methods immediately after harvest and before processing add to the problem, and infestation continues to increase during processing, transportation and long-term or seasonal storage, causing an estimated overall yield loss of up to 30% (Singh and Benazet, 1975).

S. cerealella is often found alongside other pests, with which it may act synergistically. In Tanzania, a complex of pests was responsible for dry weight loss of

31.8% for maize cobs and 7.85% for grains after 9 months of storage (Henckes, 1992).

S. cerealella causes a considerable amount of damage to unhusked stored rice in Bangladesh. The studies reported by Shahjahan (1974) showed that 3-12% of rice kernels are attacked over a period of 6-9 months. This causes a total weight loss varying from 4.2 to 11.9%.

Plate 2.6: Damaged rice grains caused by Angoumois grain moth

In Bangladesh during 4 months of infestation, *S. cerealella* caused 4-5% weight loss in husked rice and 1% in unhusked rice (Bhuiyah *et al*., 1992). This is similar to losses reported from Malaysia, where losses due to insects (including *Sitotroga*) were estimated at 3-7 and 5-14% in paddy and milled rice, respectively (Muda, 1985) and to reports from Thailand, where losses ranged from 1-25% (Sukprakam, 1985).

Insect species (including *S. cerealella*) and population densities in stored japonica rice in Taiwan were reported by Yao and Lo (1992). Stored rice (unhusked) samples drawn from India were found infested with *S. cerealella* to the extent of 88%, *R.*

dominica (76.38%), *S. oryzae* (69%), *Tribolium confusum* (13.88%) and *Oryzae philussurinamensis* (2.78%). Seed germination was also affected (to a maximum of 71.88%) and the average weight loss in storage was in the range 1.09-3.10% (Thakur and Sharma, 1996).

In laboratory studies, the effect of *S. cerealella* attack on stored grain of 9 rice genotypes was evaluated by Ferreira *et al.* (1997). After 14 months, the percentage of infested seeds and weight loss ranged from 10.5-61.5% and 5.5-26.1%, respectively. Genotype and level of infestation had significant effects on seed germination.

Grain from commercially grown varieties of rice from the USA, France and the Philippines showed significantly different levels of infestibility (Russell, 1976). In India, the resistance of 20 varieties was evaluated (Chatterji *et al.,* 1977). The data showed that insect infestation and subsequent weight loss increased with the moisture content during storage. Varieties with low protein content or a strong odour were the most resistant. Upadhyay *et al.* (1979) reported a study carried out on the relative resistance of grains of 12 rice varieties grown in the same country; a correlation was found between numbers of damaged seeds and percentage weight loss. In tests undertaken by Pandey *et al*. (1980) at Kanpur on 10 different rice varieties, the results indicated that none of the varieties was completely immune to *Sitotroga.*

In the USA, losses caused by *S. cerealella*, *S. oryzae* and *R. dominica* in 6 commercial varieties of rough rice were assessed as weight loss of rough rice, loss of milling yield, and loss of monetary value (Cogburn, 1977). Over three insect generations, damage attributable to *S. cerealella* or *R. dominica* was approximately equal; *S. oryzae* caused the least damage.

In Bangladesh, the populations of *S. cerealella*, *S. oryzae* and *R. dominica* in stored rice, and the percentage weight loss due to infestation by each species was studied over a 12-month period (Rubbi and Begum, 1986). The population of *S. cerealella* was highest, followed by *S. oryzae* and then *R. dominica*, and the percentage loss in weight of the rice followed the same order.

Resistance to *S. cerealella* was also assessed in 38 genotypes by Irshad *et al.* (1989); Wu (1990) reported that of 38 hybrid rice combinations evaluated, one was resistant and 8 were moderately resistant. Medina and Heinrichs (1986) reported that the susceptibility indices and grain weight loss differed significantly among varieties. According to Ragumoorthy and Gunathilagaraj (1988), in general resistant varieties had thick husks, low alkali values, coarse grain, higher 100-grain weight, and high silica, total protein and total amylose contents compared with less resistant ones.

In India, a survey of the losses of grain that occurred during storage, due to insect pests including *S. cerealella, S. oryzae, R. dominica, T. castaneum, O. surinamensis, T. granarium* and *E. cautella* is reported by Girish *et al.* (1974). The loss in weight after storage for six months varied from 0.06 to 9.7%, and the loss in viability from 7.0 to 22.0%.

Only larvae of *S. cerealella* cause serious damage to grain. The newly hatched caterpillar bore directly into the grain and typically remains inside the grain for both larval and pupal development. They feed on the inside contents of grains leaving the grains unfit for human consumption. The larvae of this pest tunnel inside the kernels are causing substantial damage and are rendering the grain more susceptible to secondary insect pests (Weston and Rattlingourd, 2000). Before pupation the larva constructs a chamber just under the grain seed coat, forming a small circular translucent window. Pupation takes places within the chamber inside a delicate cocoon. Adults fly well and cross-infestation occurs readily, but they are short-lived and generally survive only for 5-12 days, and in suitable stores breeding may be continuous throughout the year (Hill, 1990).

The studies reported by Shahjahan (1974) showed that 3-12% of rice kernels are attacked over a period of 6-9 months. This causes a total weight loss varying from 4.2 to 11.9%. Only about 56•3 per cent of each infested kernel is needed for complete larval development. The extent of the pest attack was increased by high moisture content.

Mukherjee *et al*. (1970) observed the extent of damage due to insect pest in 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 the damage to vary between 0 to 70 %, 0 to 75 %, 0 to 22.7 %, 0 to 11 % and 0 to 9% respectively.

Angoumois grain moth, *S. cerealella* also known as the rice moth or paddy moth is one of the most dominant species in the stored paddy (Prakash *et al*., 1984).

A report from Malaysia, showed losses due to stored grain insects (including *Sitotroga*) were estimated at 3-7 and 5-14% in paddy and milled rice, respectively (Muda, 1985) and another report from Thailand, showed losses ranged from 1-25% (Sukprakam, 1985).

Aviles and Guilbert (1986) noted 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.

Stored rice (unhusked) samples drawn from India were found infested with *S. cerealella* to the extent of 88%, *R. dominica* (76.38%), *S. oryzae* (69%), *Tribolium confusum* (13.88%) and *Oryzaephilussuri namensis* (2.78%). Seed germination was also affected (to a maximum of 71.88%) and the average weight loss in storage was in the range 1.09-3.10% (Thakur and Sharma, 1996).

Shafique and Ahmad (2003) determined losses in rice varieties from 4.09 to 12.61 %. Togola *et al*. (2010) recorded infestations by the Angoumois grain moth *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae) in many rice-producing zones in the country, causing an estimated 3-18% damage to grain, depending on the area and length of storage.

Lal *et al.*, (2000) observed the storage losses in unhusked rice assessed in farmer's stores of district Kangra, Himachal Pradesh, India. 180 samples are collected from the selected area, which are infested with rice weevil (*Sitophilus oryzae*), lesser grain borer (*Rhizopertha dominica*), rust red flour beetle (*Tribolium castaneum*), saw-toothed grain beetle (*Oryzaephilussuri namensis*), Angoumois grain moth (*Sitotroga cerealella*) and rice moth (*Corcyra cephalonica*). The maximum infestation was of *S. oryzae* (66.14%) followed by *T. castaneum* (23.53%), *O. surinamensis* (4.59%), *C. cephalonica* (3.80%), *S. cerealella* (1.14%), and *R. dominica* (0.79%). On an average 18.09% grains were found damaged and there was 3.96% weight loss due to insect feeding in unhusked rice.

The number of rice moths per pack in all the three rice varieties stored at 8% grain moisture level in paper and polythene was less than 10, throughout the study period compared to 1000 in the most susceptible variety, At 405 was stored with higher grain moisture level of 12.5% and 16%. This indicates that these two packing materials act as a good barrier in minimizing rice moth damage in stored rough rice of low grain moisture level. Furthermore, these results indicate that poly sack, the most popular packing material presently used in Sri Lanka results in the highest number of rice moths when rough rice is stored with normal (12.5%) and high (16%) seed moisture levels (Dharmasena and Abeysiriwardena, 2003).

2.9. Varietal performance of rice grains for resistance against *S. cerealella*

Insect species (*S. cerealella*) and population densities in stored japonica rice in Taiwan were reported by Yao and Lo (1992).

In laboratory studies, the effect of *S. cerealella* attack on stored grain of 9 rice genotypes was evaluated by Ferreira *et al*. (1997). After 14 months, the percentage of infested seeds and weight loss ranged from 10.5-61.5% and 5.5-26.1%, respectively. Genotype and level of infestation had significant effects on seed germination.

Rizwana *et al.* (2011) observed that, in Pakistan variety Basmati-370 was most resistant and Basmati-Pak and G-7 were most susceptible. The level of insect resistance among other varieties is in the order: IRRI-6 ≥ G-6 ≥ Basmoti-2000 ≥ Pak-Basmoti-385 ≥ Super Kernel Basmoti.

Shafique and Chaudry (2007) also observed in Pakistan that, in laboratory condition (27 + 2^{o}C and 60 + 5% RH) the resistance genome was IR 6-25A and the susceptible genome was Basmati 2.0. The level of insect resistance among other varieties in the order: IR-6 ≥ Shadab ≥ Sarshar ≥ Shua-92 ≥ Basmoti 15-14 ≥ Super Basmati.

So far many scientists in different countries have sorted out countless varieties of cereals against this insect to incorporate useful information in breeding program. Podoler and Applebaum (1968) stated that the thicker seed coat reduced the damage to various genotypes.

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

Grain from commercially grown varieties of rice from the USA, France and the Philippines showed significantly different levels of infestibility (Russell, 1976). In India, the resistance of 20 varieties was evaluated (Chatterji *et al*., 1977). The data showed that insect infestation and subsequent weight loss increased with the moisture content during storage. Varieties with low protein content or a strong odor were the most resistant.

In the USA, losses caused by *S. cerealella*, *S. oryzae* and *R. dominica* in 6 commercial varieties of rough rice were assessed as weight loss of rough rice, loss of milling yield, and loss of monetary value (Cogburn, 1977). Over three insect generations, damage attributable to *S. cerealella* or *R. dominica* was approximately equal; *S. oryzae* caused the least damage.

Upadhyay *et al*. (1979) carried out a study on the relative resistance of grains of 12 rice varieties where a correlation was found between numbers of damaged seeds and percentage weight loss. In tests undertaken by Pandey *et al.* (1980) at Kanpur on 10 different rice varieties, the results indicated that none of the varieties was completely immune to *Sitotroga*.

Development of Angoumois grain moth could possibly be managed by altering nutritive and physical characteristics of cereals (Gomez *et al.*, 1983; Tipping *et al*., 1988). The carbohydrate or protein content of grains affects, among other things, the developmental period, adult weight, fecundity and also the future progeny of insects (Scriber and Slansky, 1981; Slansky and Scriber, 1985).

In an experiment conducted by Cogburn *et al*. (1983) susceptible commercial varieties of rice were compared with resistant World Collection varieties by using Angoumois grain moths, *Sitotroga cerealella* (Olivier), and lesser grain borers, *Rhyzopertha dominica* (F.). Imperfect hulls favored infestation by the moth, but planting date did not. Wild and domesticated strains of moths varied in fecundity, but the relative resistance of varieties was unaffected. Varieties resistant to the moth were also less susceptible to the lesser grain borer (r = 0.96). Morphological differences in the central vascular bundle in the abscission scar affect the ability of the moth to penetrate grains that have intact hulls. Moth larvae penetrated through the vascular bundle of Vista (S) but not CI 12273 (R).

Variations in the susceptibility of cereals were caused by due to their physical and chemical nature. In general, the protein, fat, and carbohydrate content have been responsible for their varied susceptibility to insects (Khattak and Shafique, 1981; Ragumoorthy and Gunathilagaraj, 1988).

In Bangladesh, the populations of *S. cerealella*, *S. oryzae* and *R. dominica* in stored rice, and the percentage weight loss due to infestation by each species was studied over a 12-month period (Rubbi and Begum, 1986). The population of *S. cerealella* was highest, followed by *S. oryzae* and then *R. dominica*, and the percentage loss in weight of the rice followed the same order.

Medina and Heinrichs (1986) reported that the susceptibility indices and grain weight loss differed significantly among varieties.

According to Ragumoorthy and Gunathilagaraj (1988), in general resistant varieties had thick husks, low alkali values, coarse grain, higher 100-grain weight, and high silica, total protein and total amylose contents compared with less resistant ones.

Resistance to *S. cerealella* was also assessed in 38 genotypes by Irshad *et al*. (1989); Wu (1990) reported that of 38 hybrid rice combinations evaluated, one was resistant and 8 were moderately resistant.

Stored wheat of 10 varieties was assessed for susceptibility to *S. cerealella* in Pakistan (Khattak and Shafique, 1981). Resistance was studied in 8 varieties by Gillani and

Irshad (1990), while 15 hybrids were tested by Wu (1990). None of the varieties was completely immune to infestation by this pest, but susceptibility varied significantly.

Takeshita and Imura (1990) reported the loss assessment by adult insect number, rice moisture content, germination rate, percentages of grains stained by the TZ method, fat acidity value, 1000-grain weight, and weight of a 200-ml volume of grains indicated resistance of Nankin-II rough rice which had a thicker and more intact husk than Shinpo- 38 to *S. cerealella*.

Adeyemo, *et al.* (2015) observed in laboratory condition in Nigeria that, nine varieties named Cisdane, FARO 12, FARO 36, FAROX-228-4-1-1, BG 90/2, NERICA 1, WITA 4, IRAT 133 and ITA 230 are susceptible for *Sitotroga cerealella*. Among these varieties less susceptible varieties are Cisdane, FARO 36, FAROX-228-4-1-1 and BG 90/2 varieties and more susceptible varieties are NERICA 1, WITA 4, FARO 12, IRAT 133 and ITA 230 varieties.

The Angoumois grain moth, *Sitotroga cerealella* (Oliv.), is a serious pest of stored rice in Africa. Thus, eleven rice varieties including 6 upland NERICA, 2 *Oryza glaberrima* and 3 *O. sativa* were grown at four agro ecological zones of Benin. After harvest, samples of 1500 grains of each genotype were infested with 50 eggs of *S. cerealella*. Results showed significant effect of agro ecological zones on pest incidence and on varietal resistance as well. *O. glaberrima* varieties (TOG 5681 and CG 14) were the most resistant in each location whereas the resistance of NERICA and *O. sativa* varieties varied from tolerant to susceptible according to the growing ecology. This result highlights the impact of growing environment on rice resistance status and will provide the best advice to farmers on how to choose best genetic material according to cropping ecology (Santos *et al*., 2015).

S. cerealella progeny and more feeding damage were produced on cultivars from IITA except CG 14. Damage and adult progeny among varieties that were relatively susceptible varied widely in Glazoue, Malanville and Lokossa in Africa. Thus, NERICA varieties and parent *O. sativa* (WAB 5650, WAB 56104 and WAB 18118) ranged from susceptible to tolerant in the remaining locations (Cogburn *et al*., 1980 and Arthur *et al*., 2007).

Cogburn *et al*. (1980) reported that environmental influences more strongly in susceptible varieties than resistant ones. This seems to be strong evidence for a genetic basis for resistance. The *O. glaberrima* parents CG14 and TOG 5681 were found to be resistant to infestation by *S. cerealella* in all locations confirming the relatively good resistance of *O.glaberrima* previously reported by Sauphanor (1989).

Rai, *et al.* (2011) observed that feeding effect of different rice varieties on biology of Angoumois grain moth (*Sitotroga cerealella* Oliver.) in terai region of West Bengal in India at laboratory condition. Among the twenty four different genotypes the insect took minimum time to complete its development when the rearing grain was PNR-519 during post-monsoon, Tulsimanjuri, Tulsibhog and Kanak during autumn and in UBSR-2 during winter. The duration was found to be longer in Swarna Mashuri during winter, IR-68 and Kanak during post-monsoon and during autumn in Nauda and IR-68. With respect to fecundity Mashuri, Swarna Mashuri and China Boro, were found to be suitable for the infestation of *Sitotroga cereallela* during post monsoon, Swarna Mashuri, Nauda and Ajaya during autumn and Swarna Mashuri and IET 4786 during winter months in terai region of West Bengal.

Cohen and Russell (1970) reported a positive correlation between the presence of fissures in grains and infestation by *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) in rice varieties.

Differential responses of rice varieties to *S. cerealella* were observed. Of the 18 NERICA tested, NERICA6, 14, 4, 3, 15 and 16 were tolerant in increasing order, whereas only NERICA9 and 11 were susceptible (Santos *et al.*, 2014).

With *S. cerealella,* the technique of egg infestation was appropriate as shown by the high percentage of egg hatched. Percentage of weight loss and number of adult progeny appeared to be good indications of paddy rice resistance (El-Dessouki and El-Kifl, 1976; Sardar, 1976; Chatterji*et al*., 1977; Cogburn, 1977; Khattak and Shafique, 1981; Mohapatra and Khare, 1989). On the number of emerged adult progenies and grain damage basis, paddy NERICA9, NERICA8, NERICA7, NERICA11, NERICA12 and O. sativa parent WAB 56-50 showed the highest susceptibility among the tested cultivars. Conversely, it appeared that NERICA15, NERICA16 and CG14 (*O. glaberrima*), all with red caryopsis, had a good resistance. Of the eggs hatched only few had reach adult level on these varieties, suggesting again that rice glumes serve as barrier for entry of larvae into the grains (Cogburn, 1974).

Ashamo, M. O. (2010) studied the relative resistance of paddy varieties to the Angoumois grain moth, *Sitotroga cerealella* in the laboratory at a temperature of 28 ± 1.0°C and relative humidity of 65 ± 1.5%. The study was carried out on Indian Agricultural Research Institute (IARI), New Delhi, India varieties and a Taiwan variety. Results showed that the performance of *S. cerealella* was least in T (N)-1 (Taichung Native-1), with the longest developmental time (26.3 days) and egg to adult survival of 38% making the variety the most resistant. The performance was best in Pusa 44 with the shortest developmental time (23.0 days) and egg to adult survival of 68.7% making the variety the least resistant.

Ashamo and Khanna (2006b) observed that varieties of paddy with low amylose content tend to be more susceptible to infestation by *S. cerealella* than those with high amylose content. The most resistant variety is T (N)-1 which had small-sized seeds. This might be due to in sufficient endosperm to support maximum development of the moth. Many of the larger seeds were very susceptible therefore larger seeds enhanced survival.

A laboratory experiment was conducted by Jha *et al.* (2006) to assess the susceptibility of eleven promising cultivars of rice (Bali-1, Dwarf Mahasuri, Pusa-205-9-4, Pusa-44-33, Jaya, IR-72, Lalnakanda, Pusa 743-1-1-23, IARI-144, Chan-Xiang-Xian and Pusa-150-21-1) to *Sitotroga cerealella* under storage conditions at 30+or-1.5 degrees C and 70% RH. Based on the adult emergence and mean development period (MDP), the growth index (GI) of *S. cerealella* was evaluated. The results revealed that cultivar Bali-1 was least susceptible amongst all the cultivars with 0.00428 GI, while the most susceptible cultivar was Pusa-150-21-1 with 0.08156 GI. The GI for rest of the cultivars ranged between 0.03441 (Dwarf Mahasuri) and 0.08145 (Chan-Xiang-Xian).

Studies were conducted by Verma *et al.* (2010) to determine the resistance of different rice cultivars against *Sitotroga cerealella*. Seeds of the husked rice cultivars CSR-10, USAR-1, Pant-10, IR-36, Prasad, Kernal-local, Kalanamak, Kasturi, T-9, T-3, PB-1, CSR-4, Narendra-2, NDR-359, Pant-4, Pokkali and Saket-4 were sterilized in an oven at 55 degrees C for 4 h and placed in desiccators at 75+or-50% RH, with potassium hydroxide for 15 days, to maintain the constant level of moisture. A total of 25 grains of each cultivar were initially weighted and kept in specimen tubes. Five pairs of newly emerged male and female insects were introduced in each tube. All the tubes were placed in desiccators at 75+or-1 degrees C for 3 months. For determination of fecundity, one pair of male and female was introduced in specimen tubes having 25 g of grains of each cultivar. All the jars were kept under controlled conditions without disturbing them for 7 days and adults were removed and grains were left in the jars until the emergence of the F_1 generation and were counted regularly up to the end of the F_1 generation and, after each counting, the average period for complete development in each treatment was calculated by taking the weighted means of the time required for the ova, larval and pupal periods. The color and shape of grains was based on visual observation and the breaking strength (hardness) was measured. Pant-4, Pokkali, Usar-1 and CSR-10 were the least preferred by the pest and showed lesser fecundity and adult emergence, i.e. 101.25-116.09 ova and 62.2-70.4%, respectively. Higher developmental periods were also recorded in these cultivars ranging from 48.47 to 44.68 days. The lesser weight loss of 5.5-8.3% and percent damaged grains were 99-190%, respectively, showed that these cultivars were resistant against *S. cerealella*.

The growth and development of Angoumois grain moth, *S. cerealella*, on 18 rice cultivars were studied under controlled laboratory conditions (at 27+or-2 degrees C with 75+or-5% relative humidity). Observations on fecundity, hatching, pupation, adult emergence, developmental periods, number of generations, adult longevity, F< sub>1</ sub> progeny and index of suitability indicated Sona and T-26 as the most preferred, and Pant-4 and IR-8 as the least preferred hosts for *S. cerealella* (Yadav *et al.*, 2003).

2.10. Management of rice moth in stored rice grain

2.10.1. Use of botanicals against *S. cerealella*

The plant products certainly possess surface persistence for a long period, have least or no adverse effect on germination ability of seed, cooking quality and milling, less expensive, easily available and some of the products like natural pyrethrums have rapid killing action (Prakash and Mathur, 1981).

A number of plant products have been reported as being in use against insect pest in stored grains including rice to minimize storage losses due to insects. Neem 3 (*Azardirachta indica*) products like leaves, seed, bark from which oil cake and extracts are prepared have been reported to possess fungicidal, nematicidal, insecticidal, insect repellent and antifeedent properties (Ketkar, 1976).

The effects of 10 grain protectant oils, namely toria (*Brassica campestris var. toria*), mustard (*Brassica juncea*), linseed (*Linum usitatissimum*), sunflower (*Helianthus annuus*), soyabean (*Glycine max*), til (*Sesamum indicum*), castor (*Ricinus communis*), neem (*Azadirachta indica*), groundnut (*Arachis hypogaea*), and mahua (*Madhuca longifolia*) on the growth and development of Angoumois grain moth (*Sitotroga cerealella*) on rice cv. Saket-4 were studied under controlled laboratory conditions (at 75+or-5% relative humidity and 27+or-2 degrees C temperature). All the oil treatments were effective in retarding the growth and developmental processes of *S. cerealella*. The neem oil, followed by castor and mahua oils, were the most effective in reducing fecundity (26.41/female), development period (26.67 days), number of generations (6), hatching (20.93%), pupation (52.33%), and eclosion (50%). The untreated control had fecundity of 224.68/female, developmental period of 37 days, generations of 10 hatching of 87.44%, pupation of 89.67%, and eclosion of 90.67% (Yadav, *et al.*, 2007).

Baskaran and Janarthanan (2000) observed that the effect of dust formulations and plant oils was evaluated on the development of *Sitotroga cerealella* (Olivier) and *Callosobruchus chinensis* on IR 20 paddy grain and cowpea, respectively. Among the seven dust formulations, Iluppai oil 10% D (2%) was more effective in prolonging the development period (38.67+or-1.53 days). Low adult emergence (79.0/100 g seeds) was recorded in palmarosa [*Cymbopogon martinii*] oil (PO)+neem oil (*Azadirachta indica*) (NO)+Iluppai oil (*Madhuca longifolia*) (IO) 10% D (2%) (1:2:2 v/v/v) which correspondingly reduced the per cent bored grains (12.6%) and weight loss (5.0%), whereas in the control, respectively, 165 adults/100 g seeds, 26.4% bored grains and 10.4% weight loss were recorded. Palmarosa oil 10% D (2%) was comparatively less effective. Dusts formulated with plant oils were more effective than the plant oils alone against *C. chinensis*. Cowpea grains treated with PO+NO 10% D (2%) revealed only 3.0 eggs/50 g seeds while plant oils, palmarosa oil and neem oil at 1% recorded 6.5 and 4.5 eggs/50 g seeds, respectively. In spite of seeds treated with neem oil (1%) and PO 10% D (2%) containing more eggs, complete protection of cowpea seeds was observed as evidenced by no adult emergence and weight loss. Iluppai oil 1% and IO 10% D (2%) were less effective against *C. chinensis*.

Singh, *et al.* (2002) reveled that petroleum ether, methanol and acetone extracts (at 1%), essential oil (at 1, 0.5, 0.25, 0.125, 0.062 and 0.031%) and 2 pure compounds (viridiflorol at 434 mg and agnuside at 2.3 g) isolated from *V. negundo* leaves were screened for insecticidal activity against *S. cerealella* infesting wheat seeds. Only the essential oil was effective against the pest and caused 100% mortality even at the minimum concentration of 0.062%. Emergence of new adults was completely prevented by 0.125% of the essential oil.

The leaf powder of goat weed *A. conyzoides* controlled the multiplication of *Sitotroga cerealella* up to 6 months at treatment dose of 1.0 and 2.0% w/w and showed no grain damage on rice. At lower doses this moth could cause grain damage, which increased with increase of storage periods. Similar results were obtained with adult emergence of *Rhyzopertha dominica* and *Oryzae philussurinamensis*. In case of both these test insects also, leaf powder of *A. conyzoides* could absolutely controlled their up to 6 months at treatment doses of 1.0 and 2.0% w/w. Grain damage caused by *R. dominica* was nil at both the higher treatment doses of 1.0 and 2.0% w/w but at lower doses this borer caused grain damage, which increased with increase of storage periods as recorded in case of *S. cerealella*. Protection of stored paddy and milled rice grains against these test insects under controlled conditions of their infestation by dried leaf powder of *A. conyzoides* has been reported for the first time (Rao and Prakash, 2001).

Yadu, *et al*. (2000) conducted a laboratory experiment to evaluate certain indigenous plant products against *Sitotroga cereallea* as grain protectants under controlled conditions. Mixing of 5 botanical products, i.e. neem (*Azadirachta indica*) kernel powder, neem leaf powder, eucalyptus leaf powder, sarifa leaf powder and lantana leaf powder, at 1.0 and 2.0 parts (w/w) per 100 parts of maize and paddy grains proved to be protectants against *S. cerealellea* causing adverse effects on development, which resulted in less percentage of adult emergence and grain damage. The grain damage done by 200 eggs during their development was found to be 59.96 (in maize) and 10.89% (in paddy), which was protected from 63.94 to 96.61 and 76.58 to 94.49% when maize and paddy grains, respectively, were treated with various plant products. Neem kernel powder proved to be the most effect, while leaves of lantana, the least. The germination of treated seeds was not impaired in any case during the exposure period of about 8 months.

Srinivasan and Nadarajan (2004) observed that the insecticidal activity of extracts of notchi (*Vitex negundo*), kottaikaranthai (*Sphaeranthus indicus*), jamaica mountain sage (*Lantana camara*), dry chillies (*Capsicum annuum*), soap nut tree (*Sapindus emarginatus*), curry leaf (*Murraya koenigii*), kolingi (*Nigella sativa*), crotons (*Croton sparsiflorus*) and candle stick (*Cassia alata*) was investigated against Angoumois grain moth, *Sitotroga cerealella*, attacking stored rice. The extracts were mixed with rice grains and exposed to the Angoumois grain moth. The toxicity level varied among the plants. The percentage infestation at 10 days after treatment (DAT) showed that all the botanical treatments reduced the infestation (27.6-29.6%) compared to the untreated control (50.0%). The overall mean percentage infestation was lowest in notchi and kottaikaranthai (30.06 and 30.30%, respectively), followed by jamaca mountain sage (30.60%), soap nut tree (31.20%), dry chilli (31.20%) and curry leaf (31.30%). Kolingi, croton and candle stick showed the maximum infestation of 34.73, 34.86 and 36.26%, respectively, but distinctly superior than the control (60.10%). At 50 DAT, the lowest infestation was observed in notchi (31.6%) and kottaikaranthai (32.0%), which were on par with the extracts from jamaica mountain sage (32.6%), curry leaf (33.6%), soap nut tree (33.3%) and dry chilli (33.3%). The highest infestation (65.3%) was recorded in the untreated lot, which was statistically more significant than all other treatments.

Jamir, *et al.* (2013) observed that, *Sitotroga cerealella* (Olivier) is one of the most destructive insect-pests of Nagaland. Highest efficacy among 12 plant materials was shown by *L. citrata* seed powder @ 10g kg-1 throughout the period of study; lowest result was in *A. indica* oil cake @ 5 g kg-1 at 2 months, *Z. oxyphyllum* leaf powder@ 5 g kg-1 at 4 and 6 months of storage. Malathion @ 1.5 g kg-1 was the best treatment in all the months of storage. Ahning with Tsakvong indicated that the pest result out of 8 storage structures whereas gunny bag storage showed the highest infestation in all the months of storage. Best germination was presented in Ahning with Tsakvong. Analysis of correlation coefficient (r) of percent germination of seeds with infestation percentage of *Sitotroga cerealella* had indicated inverse relation infestation with germination percentage. Estimates on linear regression coefficient (b) for germination percentage of rice seeds with infestation percentage of *Sitotroga cerealella* was carried out in all the parameters.

Yadav, *et al*. (2003) reported that the growth and development of Angoumois grain moth, *S. cerealella*, on 18 rice cultivars were studied under controlled laboratory conditions (at 27+or-2 degrees C with 75+or-5% relative humidity). Observations on fecundity, hatching, pupation, adult emergence, developmental periods, number of generations, adult longevity, F₁ progeny and index of suitability indicated Sona and T-26 as the most preferred, and Pant-4 and IR-8 as the least preferred hosts for *S. cerealella*.

Yevoor (2003) recorded zero percent grain damage and weight loss at 90 DAS and cent percent mortality at 60 DAS against *S. cerealella* in this work, the application of sub-lethal dose of neem oil-based pellets.

Tanzubil (1987) applied neem fruit dust, leaf dust and seed kernel oil on stored seed and observed that neem fruit dust at 10%, protected seeds for at least 4 months. Neem seed kernel oil also gave effective control. In a study, eucalyptus powder mixed with rice was effective in reducing the number of adults of *S. cerealella* and prevented cross infestation by *R. dominica* (Dakshinamwithy, 1988).

Jilani (1986) conducted experiments with ethanolic extract of neem seed; hexane extract of sweetflag, Acorns calamus rhizome and thymel applied to *T. castaneum*, *R.*

Dominica, *S. oryzae* and *S. cereallela* in wheat grain and observed significant control of the insect infestation.

Hossain (2011) conducted a study in laboratory condition in Bangladesh to find out the efficiency of some botanicals applied against Angoumois grain moth, *Sitotroga cerealella* Olivier on stored paddy. Five botanicals viz. dried leaf powder of neem @ 2.5 g/kg paddy, bishkatali @ 2.5 g/kg paddy, marigold @ 2.5 g/kg paddy, mahogany @ 2.5 g/kg paddy, chopped garlic bulb @ 1.0 g/kg paddy along with one untreated control were evaluated. Among five promising botanicals, neem leaf powder reduced the highest grain infestation by number and weight (72.77% & 62.07%, respectively) as well as the lowest reduction of (10%) germination percentage than control (65%).

Shaaya *et al*. (1997) tested the biological activity of edible oils against *Callosobruchus maculatus*, *S. oryzae*, *S. zeamais* and *S. cerealella*. The edible oils, soya bean oil, cotton seed oil, crude rice bran oil and crude palm kernel oil where applied as contact insecticides in field and storage as well. Tests with *S. oryzae* were conducted on wheat, *C. maculatus* on mung beans, *C. maculatus* on chickpeas, *S. cerealella* on paddy and those with *S. zeamais* on maize. It was found that edible oils can control *C. maculatus* more significantly when compared with *S. zeamais*, *S. oryzae* and *S. cerealella*. The results revealed that edible oils can play an important role in controlling major stored grain pests without health and environmental risks associated with the use of synthetic insecticides.

Getu (1993) tested the local materials, including wood ash, sand, tobacco dust and sawdust for screening of maize varieties against *S. cerealella*. These local materials were compared to different combination of synthetic insecticides. Insecticides, primiphos-methyl, deltamethrin, permethrin and malathion were used in this experiment. It was found that application of tobacco dust significantly reduced the level of *S. cerealella* population and its damage in 22 tested cultivars. When free and no-choice tests were performed, variety UCB and Hybrid H-8151 showed a significant level of resistance to *S. cerealella* under free-choice test. In insecticide screening for *S. cerealella* control, it was found that primiphos-methyl, deltamethrin, (primiphos-mythyl + permethrin) and (malathin + permethrin) resulted in complete eradication of *S. cerealella*.

Gemu, *et al*. (2013) tested the efficacy of agricultural wastes against *S. zeamais* and *S. cerealella* in maize grains. In this experiment, sawdust, coffee husk and wood ash were used in 10, 15, 20 and 30% (w/w). Pirimiphos-methyl 2% (w/w) was used as untreated control. It was found that coffee husk and wood ash was effective to control *S. zeamais* and *S. cerealella*at all dosages. Among all the agricultural wastes to be tested, sawdust gave the best control of *S. cerealella*. The results revealed that agricultural trash can be a useful byproduct, if we use it to control stored grain insects.

Yang, *et al*. (2012) tested the efficacy of garlic, *A. sativum* essential oil and its two major components, diallyldisulphide and diallyltrisulphide against *S. cerealella*. These components were applied as a fumigant to study the impact on behaviour, survival and oviposition of *S. cerealella* in rice grains. It was found that these garlic components have a significant fumigant activity against *S. cerealella*. At doses (1.33 and 0.99) µL/25 g, the Lc was found 50% in 1.02 µL/L air space, respectively. In no-choice or two-choice tests, the ovipositional inhibition was found above 70% at 1.5 µL/25 g concentration. In Y-tube olfactometer bioassays, these components produced high behavioural deterrent activity in adult *S. cerealella*. The results revealed that garlic essential oil, diallyldisulphide and diallyltrisulphide act as behavioural deterrent and ovipositional inhibitor against *S. cerealella*. Inspite of synthetic fumigants, these components can be used as potential alternatives for grain protectants.

Iqbal, *et al*. (2010) studied on the formulations of plant extracts *Acorus calamus* (sweet flag), *A. indica* (neem) and *Curcuma longa* (turmeric) in petroleum ether, acetone and ethanol. The efficacy of these formulations was tested as growth inhibitor against *S. cerealella*. It was found that petroleum ether extract of sweet flag at 1000, 500 and 250 μg/g and its acetone extract at 1000 and 500 μg/g completely inhibited emergence of adults. Petroleum ether extract of neem was next to sweet flag. Turmeric was less effective when compared with other formulations. The results revealed that *A. calamus* and *A. indica* can significantly control the *S. cerealella* population in stored grains. But plant extracts to be used at mass scale have a lot of limitations. More research work and resources are required for efficient and economical use of plant extracts.

Prakash, *et al*. (1987) reported that 17 insect species infest stored rice. Out of these species, rice moth (*S. cerealella*), rice weevil (*S. oryzae*) and beetles (*T. castaneum*) are top of the list. Different rice varieties show different degree of pest resistance (Rizwana*et al*. 2011). To overcome the weight and viability loss in cereal grains by *S. cerealella*, scientists are working on resistant rice varieties (Khattak & Shafique, 1981; Ragumoorthy & Gunathilagaraj, 1988). Ashamo and Akinnawonu (2012) reported that when rice varieties are treated with *Aristolochia ringens* plant extract, the grain loss percentage due to *S. cerealella* infestation can be reduced up to a significant level when compared to pesticide use.

Akter and Jahan (2013) tested the toxicity of neem, biskataly and karanja extracts against *S. cerealella* in stored rice grain. Parboiled de-infested rice variety BR-11 was used in this experiment. Five per cent concentration of neem, biskataly and karanja leaves extract were applied at 0.5 ml/50 g in rice grain. Similarly, 10% concentration of neem, biskataly and karanja leaves extract were applied at 0.5 ml/50 g in rice grain. All plant extracts had toxic effects against *S. cerealella*. It was found that neem plant extracts showed the highest toxic effect when compared with biskataly and karanja at 5% concentration. The result revealed that degree of effectiveness of all the plant extracts increases with increase in doses applied.

Prakash and Rao (2006) tested 28 plant derivatives i.e. oil, leaf powder and fruit powders as paddy grain protectants against *S. cerealella* under controlled conditions. Under prophylactic treatment of plant oils, spearmint, cottonseed, linseed, raja mircha and eucalyptus at 0.50 and 1.00% v/w showed significant results. Under post-phylactic treatment, eucalyptus oil showed the significant results at 0.5 and 1.0% v/w up to 90 days. Spearmint oil (1.0% v/w) showed 100% inhibition in *S. cerealella* multiplication up to 180 days. Leaf powders of *Hyptis suaveolens* and *Mikania cordata* at 0.5 and 1.0% w/w showed significant reduction in population level for 180 days, but pest emergence could not be controlled. Whereas *S. cerealella* population was controlled 100% with the use of dried fruit of raja mircha and eucalyptus leaf powders.

Gemechu, *et al*. (2013) tested the efficacy of botanicals against *S. cerealella* in maize grains. For this purpose, *A. indica*, *Cymbopogon citrates*, *Tageteserecta*, *A. sativum*, *Brassica carinata*, *Gossypium hirsutum*, *Chenopodium ambrosioides* and *Maesa lanceolata* were used as botanicals. Malathion was used as control. It was found that after 20-day exposure to botanicals, maximum mortality was found 61.1% by *A. indica* bark powder and *C. ambrosioides* leaves. Similarly, among cooking oils, maximum mortality was found 77.8% by *B. carinata* and *G. hirsutum*. Malathion resulted in significantly higher *S. cerealella* mortality (94.4%) in controls. The results revealed that two cooking oil components *B. carinata* and *G. hirsutum* are most potent biopesticides to control *S. cerealella*.

2.10.2. Use of fumigants against *S. cerealella*

Research studies on plant essential oils and their constituents as fumigants, i.e., compounds acting on target insects in the vapour or gaseous phase, against stored-product insects have been reviewed. Fumigant toxicity tests conducted with essential oils of plants (mainly belonging to Apiaceae, Lamiaceae, Lauraceae and Myrtaceae) and their components (cyanohydrins, monoterpenoids, sulphur compounds, thiocyanates and others) have largely focused on beetle pests such as *Tribolium castaneum*, *Rhyzopertha dominica*, *Sitophilus oryzae* and *Sitophilus zeamais* but little or no attention has been paid towards moths such as *Corcyra cephalonica* and *Sitotroga cerealella*. Adults were generally susceptible, whereas, eggs were either tolerant or highly susceptible depending on insect species and the type of essential oil or component. The essential oils proved effective in mixture with CO< sub>2</ sub> or ethyl formate. Mode of action studies on monoterpenoids indicates inhibition of acetylcholinesterase enzyme activity as the major site of action. Although, in laboratory tests with adult insects, some of the plant compounds have shown insect toxicity comparable to methyl bromide or chloropicrin, their physical properties such as high molecular weight as well as high boiling point and very low vapour pressure are barriers for application in large-scale fumigations. Plant products, therefore, have the potential for small-scale treatments, space fumigations and as adjuvants for conventional fumigants. The constraints including lack of data for single or multiple components of essential oils on sorption, tainting and residues in food commodities, and registration protocols have been highlighted. The use of egg and pupal stages or preferably mixed-age cultures of target insects in screening tests with any new plant essential oil/compound has also been stressed (Rajendran and Sriranjini, 2008).

Arivudainambi and Singh (2005) observed that the fumigant toxicity of neem volatiles has been evaluated for various biological effects on *Sitotroga cerealella*. Neem seed volatiles were isolated from neem seed oil and evaluated for their bioactivity against eggs, 2- and 15-day-old larvae, and adults of *S. cerealella*. All stages were susceptible to different doses of volatiles. The volatiles at 200-25 micro litres caused 100% adult and grub mortality. The eggs when exposed to 50-200 micro litre doses for 3 days failed to hatch. There was no ovicidal activity at lower doses (25, 10 and 5 micro litres). The time-dependent effects of the volatiles proved lethal to the adult insects.

Rahman *et al*. (2006) reported that three additives, i.e. white crystalline camphor, white lime powder and dried neem leaves, were evaluated for protection of unhusked rice in storage from the infestation of Angoumois grain moth, *Sitotroga cerealella*, in three successive generations. The additives significantly reduced the emergence of adult moths, loss of grain weight and percentage of infested grain with the best result found with camphor. Lime powder and neem leaves showed 41.94-75.19% and 59.68-64.62% infestation reduction, respectively, whereas camphor kept the infestation reduction from 78.46-89.14%. The overall results revealed the best performance of camphor at a rate of 4.5 g/kg rice grain in suppressing the moth in storage. The other two additives, i.e. dried neem leaves at a rate of 71 g/kg grain and lime powder at a rate of 7.0 g/kg grain also showed satisfactory results.

Aluminium phosphide consisting 56% aluminium phosphide has been found to be effective against grain insects and their pre-adult stages, eggs, larvae and pupae.

These includes rain and rice weevils (S*itphilus oryzae)*, satooted grain beetle (*S. Granarius*), confused flour bettle (*Tribolium confusum*), lesser grain borer (*Rhizopertha dominica*), cadella beetle (*Tenebroides mauritanicus*), khapra beetle (*Trogoderma granarium*), grain moth (*Epthestia elutella*), indian meal moth (*Plodia interpunctella*), mediterranean flour moth (*Epthestia kuehniella*) and Angoumois grain moth (*Sitotroga cerealella*). The chemical phostoxin is aluminium phosphide, which is used as a rodenticide, insecticide, and fumigant for stored cereal grains (Mehrpour and Singh, 2010). As a pesticide, aluminium phosphide can be encountered under various brand names, e.g., Celphos, Fumitoxin, Phostoxin, and Quick Phos.

Hossain (2011) conducted a study in laboratory condition in Bangladesh to find out the efficiency of some fumigant based management. Three fumigants viz camphor @ 1.0gm/kg paddy, aluminium phosphide tablet @ 200mg/kg paddy, naphhalene @ 500mg/kg paddy along with one untreated control were evaluated. Among three promising fumigants, both camphor aluminium phosphide tablet reduced the highest percent of grain infestation (100%) by number and weight, Conversely, camphor saved the highest percent of seed germination over control (35.81%) than other fumigants. The camphor was also considered as the most economically viable tool for the management of rice moth, *S. cerealella* on rice gains in storage, which gave the highest (14.08) benefit cost ratio (BCR) than aluminium phosphide tablet (5.25).

Fields and White (2002) found that, methyl bromide as effective as it acts rapidly in less than 48h killing not only insects but also other pathogens such as microbes and nematodes.

Shankar and Abrol (2012) showed that, use of a controlled atmosphere for storage of grain involves the use of high CO_2 (9.0-9.5%) and low O_2 (2-4%) levels, conditions that are lethal to all insects.

Paneru*et al.* (1996) observed that, celphos (Zinc phosphide) used as fumigants against *S. cerealella* in storage condition for maize. Lee *et al.* (2003) conducted assays with the monoterpenoids (cineole, fenchone, perillaldehyde and pulegone) against *Tribolium castaneum* and *sitotroga cerealella* adults for 24-96h at 24 & 37^0 C and recorded higher mortalities at the higher temperature. Regnault-Roger and Hamraoui (1995) reported that, oxygenated monoterpinoids (e.g. carvacrol, linalool and terpinol) are more toxic than non-oxygenated compounds (*p*-cymene, cinnamaldehyde, anethole) against *S. cerealella* adults. Koul (2004) observed that, *S. cerealella* adults were more tolerant than *T. castaneum* adults.

In a 20h test, phosphine doses of 0.04mg/l (*S. oryzae*, *S. cerealella, S. Zeamais* and *T. castaneum*) and in 5h exposure with methyl bromide, doses of 6 mg/l (*S. oryzae, S. cerealella* and *S. Zeamais*) and 12 mg/l (*T. castaneum*) are known to produce 100% mortality of the adults (FAO, 1975).

In some reports, toxicity data on natural fumigants have been compared with those for dichlorvos and chloropicrin. Both dichlorvos and chloropicrin have very low vapor pressures (0.01 and 18.0 mm Hg at 20^0C, respectively) and therefore, they are used for space treatments but not for fumigants of commodities (Tsao *et al.*, 2002). Lee *et al*., (2004) observed that, phosphine- resistant strains of *T. castaneum* did not show any cross-resistance to 1,8-cineole, a major monoterpenoid.

Several reports indicate that monoterpenoids cause insect mortality by inhibiting acetylcholinesterase enzyme (AChE) activity (Houghton *et al*., 2006). However, with some monoterpenes, inhibition was noted in in vitro tests but not in vivo in insects

(Grundy and Still, 1985). In a comparative study on the fumigant action of terpenes (ZP51 and SEM76) from Labiatae plants and (+)- limonene, a component of plant essential oil, on AChE activity as well as octopamine systems in *R. dominica* adults, Kostyukovsky *et al*. (2002) noted that AChE inhibition was highest (65%) for highly toxic ZP51 but moderate for SEM76 (27%) and it was very low for (+)- limonene (2%) that was least toxic.

Fumigation plays a major role in insect pest elimination in stored products. Currently, phosphine (from metal phosphide preparations, cylinderized formulations and on-site generators) and methyl bromide (available in cylinders and metal cans) are the two common fumigants used for stored-product protection world over. Insect resistance to phosphine is a global issue now and control failures have been reported in field situations in some countries (Taylor, 1989; Collins *et al*., 2002).New fumigants such as carbonyl sulphide (Desmarchelier, 1994) and ethane dinitrile (Ryan *et al*., 2006) and the old fumigant ethyl formate (alone and in mixture with CO2) (Damcevski *et al*., 2003) have also been investigated as alternatives for food and non-food commodities.

Low-boiling chemicals such as methyl bromide and sulphuryl fluoride and volatile compounds available as solids (e.g. naphthalene and para-dichlorobenzene) and liquids (e.g. chloropicrin and ethyl formate) that act on *S. cerealella* in the gaseous or vapour state are considered as fumigants (Banks, 1984).

Eventhough EDCT (ethylene dichloride- carbon tetrachloride) mixture has been approved for fumigation of bag-stacks under airtight cover at the dosage of 300 to 400 g/m3 for 2-3 days and godown (warehouse) fumigations at 150 g/m3 for 7 d (Anon., 2009), the demand for the mixture is very less and is used for small scale treatment of seeds, cereals and pulses.

In India, use of CO_2 for long term storage of basmati rice in a private industry proved successful with regard to insect control and preservation of grain quality (Rajendran *et al*., 2002).

Mortality of *S. cerealella* is high in grains stored in silo bags due to natural changes in composition of air inside i.e., decreased O_2 and increased CO_2 levels. On the contrary, it has been reported that 100% insect kill will not be achieved in silo bags as CO_2 will never reach insecticidal level of ≥30% and O_2 concentration to a low level of ≤1%. In silo bags expected range of CO_2 is 3 to 10% and O_2 18 to 10% when dry grain is stored and with wet grain CO_2 range is 15 to 25% and O_2 about 5% (Bartosik, 2012).

Table 2.1 Suggested phosphine dosages and target terminal concentrations for effective fumigation

Commodity	Pest type	Temperature conditions	Dosage (g phosphine/ m^3)	Exposure Days (minimum)	Target end concentration (ppm)
All cereals except paddy rice	All insects except khapra beetle	≥ 25^0 C	3	7	500
		10-24^0 C	3	10	500
	Phosphine resistant insects and khapra beetle	≥ 25^0 C	6	10	1000
		10-24^0 C	6	14	1000
Paddy rice	All insects	≥ 25^0 C	4-8	7	500
		10-24^0 C	4-8	10	500
	Phosphine resistant insects	≥ 25^0 C	4-8	10	1000
		10-24^0 C	4-8	14	1000

Source: Rajendran, 2007

Sulfuryl fluoride, an inorganic gas available as a liquid (99.8%) under pressure has been registered for use on food commodities and/or in food facilities in more than 20 countries against stored grain insects (rice moth, Angoumois grain moth, khapra beetle etc.) (Buckley and Thoms, 2012).

Sulfuryl fluoride against mixed-age cultures of seven stored product insect species, high mortality showed in *S. cerealella* and *E. cautella* to the fumigant has been established (Sriranjini and Rajendran, 2008). Fumigation trials have been conducted with sulfurylfluoride from China on wheat (170 Mt each) and milled raw rice (150 Mt each) stacks at 32±7°C and a dosage of 40 g/m3 for 24 hr has been found effective (Rajendran *et al*., 2008).

Ethyl formate, a liquid fumigant with pleasant aroma, has been extensively studied as a fumigant for food commodities in India against *S. oryzae, S. cerealella, S. Zeamais, Tribolium castaneum* (Rajendran, 2016).

Allyl acetate, a liquid fumigant, has been examined as a fumigant for small scale treatments. Laboratory tests revealed that a dose of 200 mg/l with 72 hr exposure period was necessary for complete insect control in stored grains. The toxicity of allyl acetate to stored product insects could be enhanced by adding CO_2. The latter not only potentiates insect toxicity of allyl acetate but also helps reducing the flammability risk of allyl acetate and improves the penetration as well as distribution of the fumigant through the grain mass (Leelaja*et al*., 2007).

Shukla *et al.* (2007) reported that fumigant formulation using *Eucalyptus camaldulensis* oil was suitable for stored grain insect control. Monoterpenoids, cyanohydrins and cyanates, sulphur compounds (dimethyl disulphide, diethyl trisulphide, di-n-propyl disulphide, allyldisulphide, diallyltrisulphide, allylthiosulfinates), alkaloids (Z-asarone) and others (methyl salicylate, benzene derivatives, bornyl acetate, terpinolene) are the active components from plant sources showing fumigant action against *S. cerealella, S. oryzae* and *T. castaneum* in India.

2.5.3. Integrated approach for combating *S. cerealella*

A number of natural products have also been used to control *S. cerealella*. These include biogas derived from cattle manure (Jin and Pan, 1983), consisting of 60% methane, 30-35% carbon dioxide and traces of other gases (Palaniswamy and Dakshinamurthy, 1986). Dried leaves of wild sage (*Lippia geminata*) have also been found to be an effective repellent against *S. cerealella* for rice stored in India for up to 9 months (Prakash and Rao, 1984).

The economic loss due to pest attack in stored commodities is a serious problem worldwide. About 200 insect species attack stored commodities. These insect pests are responsible for quantitative and qualitative losses in cereal grains. Among the stored grain pests, Angoumois grain moth, *Sitotroga cerealella* is considered as common, top of the list and most destructive pest of cereal grains. Its infestation starts in the standing crop and continues in storage. Although there are many control strategies, our need is some effective, cheap and readily available strategy for safe storage. This review presents different ways by which *S. cerealella* can be controlled. In this paper, a list of approaches is given which are used to improve the protection of stored grains against *S. cerealella* attack. These approaches include use of edible oils, containers, synthetic chemicals, agricultural waste materials, plant derivatives, bacterial protoxins, biopesticides, biocontrol enhancers and semiochemicals. If these tactics are followed as combined strategies in a compatible manner, they can provide us an integrated pest management programme for the efficient control of *S. cerealella* in cereal grains (Bushra and Aslam, 2014).

Fadamiro, H. Y. and Baker, T. C. (2002) observed that the efficacy of pheromone mating disruption was investigated in a 7x6x3 m corn storage room harboring a high population density of Indian meal moth, *Plodia interpunctella* (Hubner) and

Angoumois grain moth, *Sitotroga cerealella* (Olivier). Pheromones were released from a controlled release dispenser, the metered semiochemical timed release system (MSTRSTM) at emission rates of ~0.6 micro g min-1 (Z9,E12:14:Ac for Indian meal moth) and ~0.2 micro g min-1 (Z7,E11-16:Ac for Angouimois grain moth). Mating disruption efficacy was evaluated using three parameters: male capture in pheromone traps, visual examination of mating behaviour, and the incidence and frequency of mating as measured by spermatophores. In three trials, comparisons were made between data collected before pheromone treatment and during treatment. Disruption of pheromone source location by males averaged 70% and 40% for *P. interpunctella* and *S. cerealella*, respectively, in the three trials. In addition, reduced levels of copulation by both species were recorded during pheromone treatment. More importantly, significant reductions were recorded in the incidence and frequency of mating by females of both species collected during the treatment period. While ~85% of *P. interpunctella* females collected before pheromone treatment in three trials had mated at least once, only 50% of the females collected during treatment had mated. The mean number of matings, as measured by spermatophores, ranged between 0.8-1.1 and 0.5-0.7 before and during pheromone treatment, respectively. Similarly, a ~20-30% reduction in the proportion of mated *S. cerealella* females was recorded during pheromone treatment. In the three trials, mean number of spermatophores per *S. cerealella* female averaged 1.0 and 0.7 during the pretreatment and treatment periods, respectively. Additional tests conducted in small boxes also recorded significant mating disruption of both species.

Control effects of deltamethrin and phoxim on insect pests in stored rice were evaluated in concrete bins at Tunglo, central Taiwan. Deltamethrin applied at two concentrations (0.73 or 1.1 ppm) were found valid for control of *Rhyzopertha* *dominica* (Fabricius) and *Sitotroga cerealella* (Olivier), respectively. The number of adults of these two insects decreased by >96%. The control effect could last for 5 months for these two specied of insects when phoxim was mixed rough rice at 10 ppm. Populations of these two insects increased rapidly thereafter. *R. dominica* and *S. cerealella* were the two dominant species of insects in grains with no insecticides. Totally two species of predatory insects and ten species of pest insects were found during the experimental period. Those two predators were found in deltamethrin-treated grains; however, no predator was found in phoxim-treated grains. Therefore it's recommended that deltamethrin be mixed with rough rice in bagged storage to control *R. dominica* and S. *cerealella* (Chi and Chen, 2000).

The Angoumois grain moth, *Sitotroga cerealella* (Oliver), is one of the major storage pests of cereals. Midgut proteases are vital to insects that digest food in the midgut and have been considered as targets for the control of insect pests. Protease inhibitors are attractive for their potential use in developing insect-resistant plant varieties via genetic engineering. Characterization of the midgut proteases of *S. cerealella* larvae revealed the major digestive proteases were trypsin-like and alpha-chymotrypsin-like serine proteases. The partial inhibition of proteolytic activity by pepstatin A, however, suggested the presence of another protease in the midgut sensitive to this inhibitor. The potential value of naturally occurring plant protease inhibitors as resistance factors for *S. cerealella* was assessed in bioassays using artificial seeds prepared by freeze-drying a flour paste in Teflon moulds and then coating the seeds with gelatin. Soyabean trypsin inhibitor (Kunitz inhibitor) had an adverse effect on the development of the insect and suggested a protease inhibitor might serve as a transgenic resistance factor. To evaluate the potential value of seed resistance in conjunction with an egg parasitoid on *S. cerealella* population dynamics a predictive model was developed. The model was directed toward grain storage in developing countries. While the model was hypothetical, outputs supported the use of resistant seed in conjunction with parasitoids to control the population growth of *S. cerealella* in a small seed storage room (Shukle and Wu, 2003).

Nualvaatna, *et al.* (2003) studies on the use of light traps for attracting stored product insects in a rice mill and in paddy seed stores. In these stores the light traps were placed near the products. Light traps with 6 W blacklight-blue alone could effectively attract Angoumois grain moth (*Sitotroga cerealella*), lesser grain borer (*Rhyzopertha dominica*), maize weevil (*Sitophilus zeamais*) and red flour beetle (*Tribolium castaneum*). When the light traps with blacklight-blue, fluorescent lamps, green colour incandescent lamps, and blacklight lamps were operated simultaneously in a store containing paddy seeds, there was no significant difference between these three kinds of light in attracting maize weevil, but Angoumois grain moth was attracted more to blacklight-blue and blacklight than to the green incandescent lamp. The lesser grain borer preferred the blacklight to the blacklight-blue and the green incandescent lamps. In the experiments, only adult insects were caught in the traps.

Rahman *et al.* (2006) reported that three additives, i.e. white crystalline camphor, white lime powder and dried neem leaves, were evaluated for protection of unhusked rice in storage from the infestation of Angoumois grain moth, *Sitotroga cerealella*, in three successive generations. The additives significantly reduced the emergence of adult moths, loss of grain weight and percentage of infested grain with the best result found with camphor. Lime powder and neem leaves showed 41.94-75.19% and 59.68-64.62% infestation reduction, respectively, whereas camphor kept the infestation reduction from 78.46-89.14%. The overall results revealed the best performance of camphor at a rate of 4.5 g/kg rice grain in suppressing the moth in storage. The other two additives, i.e. dried neem leaves at a rate of 71 g/kg grain and lime powder at a rate of 7.0 g/kg grain also showed satisfactory results.

Demissie *et al.* (2015) observed that the efficacy of fly ash, rice husk ash, cow-dung cake ash and diatomaceous earth as postharvest grain protectants against Angoumois grain moth, *Sitotroga cerealella*. Diatomaceous earth and rice husk ash were the most effective. The diatomaceous earth at all its application rates of 0.5 and 1.0% w/w of grains showed the minimum days (5.0) to achieve >80% mortality. This also resulted in lowest number (13.83) of F1 adults emerged, maximum percentage (>70%) mortality of F1 progenies, maximum inhibition (>90%) of F1 progenies, minimum grain damage (<2%) and minimum weight loss (<1%) similar to the standard check without affecting seed germination followed by rice husk ash. However, higher rate of cow-dung ash gave better control while fly ash at all its application rates and lower rate of cow-dung cake ash were less effective. Therefore, diatomaceous earth, rice husk ash and higher rate of cow-dung ash are considered as potential components of an integrated pest management strategy against *S. cerealella* in stored maize.

Rajasri *et al.* (2014) showed that the efficacy of different indigenous inert materials viz., Cow dung cake ash, Paddy husk ash, and two commercially available diatomaceous earth formulations viz., diatomaceous earth and indispron P406 @ 2.5g and 5 g /kg seed were evaluated against stored grain pests of rice. The freshly harvested rice with high germ inability and vigor was treated with these inert materials and kept under ambient conditions for further storability studies. Among the different inert materials, indispron P406 @ 2.5 and 5g/kg and diatomaceous earth @ 5g/kg were found to be effective against *sitotroga cerealell* upto Twelve months of storage of rice with less insect damage (<0.5%) compared to deltamethrin (6.38%) and untreated control(8.73%). Germinability of seed also maintained for 12 months which is above certification standards (>80%) in the indispron P406 treated rice seeds. These eco-friendly inert dusts can be recommended as seed protectants to save the rice seed against stored grain pests for longer periods.

Gemu *et al.* (2013) evaluated that the effectiveness of locally available inert materials including sawdust, coffee husk and wood ash at different proportions against *Sitophilus zeamais* and *Sitotroga cerealella* in laboratory. The treatments were 10%, 15%, 20% and 30% of coffee husk, 10%, 15%, 20% and 30% of saw dust, 10%, 15%, 20% and 30% of wood ash and 2% of Pirimiphos-methyl as standard check and untreated control. The efficacy of each treatment was evaluated with respect F_1 progeny emergence of the pests, mean number of damaged kernels and germination percentage of maize kernels. Coffee husk and wood ash at all dosages were found to be effective in controlling *S. zeamais* and *S.cerealella*. Wood ash at all proportions gave the best control of the pests during the study period. Wood ash and coffee husk at higher rates were more effective in controlling the pests. Sawdust at all dosages was not different from the untreated control in controlling *S. zeamais*. However, sawdust at some dosages showed superior performance against *S. cerealella*.

Emana (1993) reported that the highest dose of the local materials such as wood ash and tobacco dust was better than the lowest dose in controlling *S. cerealella* except sawdust.

Fenvalerate and malathion have been found to be effective against *S. cerealella* on rice in India (Dakshinamurthy and Regupathay, 1992). Deltamethrin and permethrin are also reported to give good levels of protection against a number of stored-grain pests including *S. cerealella* (Hung *et al.*, 1990). Repeated sprayings of carbaryl dust and tetrachlorvinphos have been used to control *S. cerealella* in Bangladesh (Bhuiyah *et al.*, 1992). Fenoxycarb prevents reproduction of *S. cerealella* (Cogburn, 1988).

Sheribha *et al.* (2010) assessed possibilities for the management of *S. cerealella* on stored products using colored lighting systems. They found that red light is not preferred by *S. cerealella* adults. Thus, if storage area were lit red, *S. cerealella* could be managed without the use of chemical pesticides.

Shankar and Abrol (2012) showed that, use of a controlled atmosphere for storage of grain involves the use of high CO_2 (9.0-9.5%) and low O_2 (2-4%) levels, conditions that are lethal to all insects. This technology for control of stored pests has been extensively used in the field.

Shankar and Abrol (2012) also reported that, some desiccants such as earth, silica gel and non-silica and diatomaceous earth can be used as combined with stored grains to provide protection against insect damage.

Spinosad is a commercial bacterial insecticide derived from metabolites of the actinomycete bacterium *Saccharopolyspora spinosa*. It is highly effective in controlling insects associated with stored wheat (Flinn *et al.,* 2004). Spinosad applied to wheat at 1.0 mg/kg was effective in killing all adults and preventing population growth of *S. cerealella* (Toews and Subramanyam, 2003).

Reed and Arthur (2000) observed that, aeration is used mainly to prevent spoilage due to high moisture in USA and Canada, whereas in Europe and Australia, aeration is used mainly to reduce insect damage.

Fields, (2006) observed that, the lower the temperature, the faster the insects die. The shape of the curve is usually a "J" shaped. There have been a number of models developed to predict mortality at low temperature (Jian *et al,* 2006).

Most grain storage structures have many avenues of entry for insects into the grain mass; cracks in the concrete, openings metal sections of bolted steel silos or ventilation ducts. With care, silos can be made to prevent the entry of insects, but also to be so welled sealed, even gas cannot enter. These types hermetic storage are widely used in Australia, China and Israel for controlling stored grain insects (Andrews *et al.*, 1994; Banks and Fields, 1995 and Alder *et al.*, 2000).

Plarre and Reichmuth (2000) observed that, the impact machines are most effective for controlling stored grain pests. Where the grain drops onto a rapidly spinning disk studied with pins. Infested grains hit the pins and the insects are killed on impact.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

EXPERIMENT 1

3.1.1 Name of the Experiment: Farmers' Perception on Damage Assessment of Stored Rice Grains and Control of Angoumois Grain Moth in Northern Regions of Bangladesh.

3.1.2 Experiment Outline

This sub-section covers the approach, strategy and design of the study, preparation of the study tools, implementation of the study including review of secondary documents, primary data collection through field visits and discussions, survey of relevant stakeholders, processing and analysis of the collected data regarding farmers' perception on damage assessment of stored rice grains by Angoumois grain moth in northern regions of Bangladesh.

The methodology was drawn in line with the objectives of the study. The suitable tools for survey had been developed on particular parameters in respect of perception of farmers regarding rice moth infesting rice grains in storages; level of infestation of rice grains by grain moth, perception of traditional management practices and health hazard effects of chemical control measures practiced by the farmers. The specific methodologies for different activities such as study design, review of secondary documents, field visits and field survey and discussion with the farmers, processing and analysis primary survey data were summarized in the following sub-headings:

3.1.2.1 Sources of data

The study had been conducted to generate stipulated primary data. Prior to generation of primary data, the relevant secondary information on the rice moth (Angoumois grain moth) and its extent of damage in storage, traditional management practices and their cross cutting issues as well as the perception of farmers who frequently store the rice grains and face problem by the grain moth infestation and subsequently these secondary documents had been reviewed meticulously. To develop the study instruments accurately and comparison with major indicators of the study, the secondary data were carefully scanned and had been collated according to the objectives of the study. For generating the desired primary data, the proposed sample study had been conducted using an appropriate sampling design and a formatted questionnaire.

3.1.2.2 Study duration

The present survey study was conducted in the northern regions of Bangladesh during February to June 2014 aiming to collect information from the farmers regarding damage assessment of rice moth on stored paddy in the farmers' households.

3.1.2.3 Study location

The survey study had been conducted from 16 districts in the northern regions of Bangladesh namely Chapainawabganj, Rajshahi, Natore, Naogaon, Pabna, Sirajgaonj, Joypurhat, Bogra, Gaibandha, Rangpur, Dinajpur, Nilphamari, Thakurgaon, Panchagar, Kurigram and Lalmonirhat, where the rice is intensively grown and stored in the farmers' house. Two upazilas were covered for respondent selection from each of the sampled districts and 20 farmers were chosen for data collection from each of districts considering 10 farmers from each upazila. Thus, the sample size of the study considered 320 farmers. The district and upazila wise distribution of respondents have been presented below:

Table 3.1.1 District and upazila wise distribution of the respondents

Division	District	Upazila	No. of farmers
Rajshahi	Chapainawabganj	Sadar	10
		Gomostapur	10
	Rajshahi	Putia	10
		Poba	10
	Natore	Sadar	10
		Boraigram	10
	Naogaon	Badalgachi	10
		Ranigonj	10
	Pabna	Sadar	10
		Ishwardi	10
	Sirajganj	Sadar	10
		Roygonj	10
	Joypurhat	Sadar	10
		Khetlal	10
	Bogra	Sadar	10
		Dupchachia	10
Rangpur	Gaibandha	Gobindagonj	10
		Sadullapur	10
	Rangpur	Sadar	10
		Mithapukur	10
	Dinajpur	Sadar	10
		Fulbari	10
	Nilphamari	Sadar	10
		Syedpur	10
	Thakurgaon	Sadar	10
		Ranisankail	10
	Panchagar	Atowari	10
		Boda	10
	Kurigram	Sadar	10
		Ulipur	10
	Lalmonirhat	Sadar	10
		Hatibanda	10
Total	**16**	**32**	**320**

3.1.2.4 Sample Design

Two types of analysis had been made to gather information about the study and those were quantitative and qualitative.

Quantitative Analysis

In order to ensure representativeness of the data and information collected, the proposed sampling strategy was delineated below:

The populations under the study were constituted to assess the farmers' perception on the extent of damage caused by grain moth; commonly used management practices and their health hazard issues; as well as identify and suggestions for more economic and eco-friendly management issues. Using 95% confidence level with 5% margin of error it was needed to obtain a representative sample size of farmers 320 for this study. For such purpose a sound statistical formula with Finite Population Correction (FPC) recommended by Daniel (1999) had been adopted to determine the appropriate sample size as given below;

$$n = \frac{NPQZ^2}{(N-1)e^2 + Z^2PQ}$$

Or,

$$n = \frac{Z^2PQ}{e^2}$$

Where,

n = Sample size without finite population correction (FPC),

P = Proportion/Probability of success (If the prevalence is 30%, P=0.3),

Q = 1-P,

Z = Z statistic for a level of confidence,

e = Precision or allowable margin of error (If the precision is 2%, then e=0.02)

Assumptions:

Z=1.96 (The value of the standard variation at 95% Confidence level)

P=0.5

Q=0.5

e=0.055 (Allowable margin of error at 5.5%)

Therefore, using this formula the sample size (n) for respective stakeholders had been calculated as follows:

$n = (1.96)^2*0.5*0.5/(0.055)^2 = 3.8416*0.25/0.003025 = 0.9604/0.003025 = 318.$

The sample size became 320 by using round figure of 318 for respondents. The respondents/farmers had been selected by using simple random sampling technique.

However, in order to reach such respondents two-stage random sampling procedure were adopted. At the first stage selected districts had been chosen under the study areas. According to the assumption, sixteen (16) districts of northern region of Bangladesh namely Chapainawabganj, Rajshahi, Natore, Naogaon, Pabna, Sirajgaonj, Joypurhat, Bogra, Gaibandha, Rangpur, Dinajpur, Nilphamari, Thakurgaon, Panchagar, Kurigram and Lalmonirhat had been considered as area coverage. At the second stage, 320 samples had been distributed in study areas of 16 sampled districts, where the rice are being grown intensively and storing was a common practice. However, the determined number of respondents had been proportionately allotted to the sampled districts. In order to reach stipulated respondents at sampled districts a census had been done in the chosen respondents before the study. Such census was aimed at identifying targeted population of respondents in the districts.

3.1.2.5 Variables/indicators covered

The following variables were considered during development of questionnaire for data collection from the respondents.

1. Demographic **:** Name, Age, Sex
2. Social **:** Education, Profession and Experience
3. Study related indicators:
   - Kinds of agricultural products stored
   - Problems faced during storage of agricultural products
   - Insect problems, extent of damage and measures taken to prevent damage
   - Perception grain moth infestation rice grains in storage
   - Ecological aspects of grain moth incidence in storage
   - Measures taken to prevent grain moth infestation
   - Measures taken to cure the grain moth infestation
   - Precautionary measures taken at treatment

- Hazardous issues of chemical control measures
- Perception of eco-friendly management of V moth in storage
- Perception of suitable containers to preserve rice grains
- Use of botanicals for the management of grain moth
- Information from service providers on grain moth and its control measure issues
- Best practices followed by the stakeholders.

3.1.2.6 Development of study tools/questionnaire

The questionnaire (Appendix I) of the study had been prepared based on the objectives and indicators determined for the survey study and methodologies. The study questionnaire was pre-tested in the study location and thereafter it had been finalized with due care to include appropriate questions for collection of necessary information from different levels and types of respondents to reflect the indicators relevant to the objectives of the study.

3.1.2.7 Method of data collection

The face to face interview of the rice farmers under the sampled districts had been conducted to collect the data for the study and those were given below:

- Direct personal interview approach had been adopted for collection of primary data. That method was effectively related to the collection of data directly from the farmers and people relevant with the storage of paddy in their houses.
- The researcher recorded the data only after fully being satisfied that he had been able to make the respondents understood the question, and the respondentswere offering any of the probable answers in his own perception.
- The investigators had made all efforts to have a friendly and open-minded interaction with the respondent. All questions had been asked one by one, and data were filled up on the spot.

- As per sample design, the 320 survey respondents had been interviewed for 32 upazilas, where 2 upazila for each of 16 sampled districts.

3.1.2.8 Data Analysis

The filled up questionnaire were coded according to the respective upazila and district. Then the entry of data had been performed using SPSS 20.0 version computer package and accordingly frequency analysis was done to generate objective wise desired information.

EXPERIMENT 2

3.2.1 Name of the experiment: Bioecology of Angoumois Grain Moth, *S. Cerealella* Olivier on Stored Rice Grains in Laboratory

3.2.2 Experiment Location and Duration

The study was conducted in the Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during 01 June 2013 to 30 May 2014 to evaluate growth and development of Angoumois grain moth (*Sitotroga cerealella*) reared on rice grains and its variations affected by ambient weather factors. The detail methodology of the study has been presented under the following sub-headings:

3.2.2.1 Materials used

Rice grain available in the market BR11 variety had been used for the infestation of grain moth. Other than unhusked rice grain a rearing cage made of stainless steel sheet and net, a number of Petridish has for infestation and several transparent glass cylinders had been used for egg laying of grain moth.

3.2.2.2 Stock culture of Angoumois grain moth

Prior investigation about the bio-ecology, the adult grain moths were collected from stored unhusked rice grains of godown under the Central Farm of Sher-e-Bangla Agricultural University. Aiming to rear the Angoumois grain moths, the collected grain moths were released on disinfested and sun-dried wheat grains in a number of plastic trays and covered by fine meshed mosquito net to facilitate the adults for laying eggs on the wheat grains. These trays were then kept in the Laboratory under the Department of Entomology, SAU since 31st March 2013. After laying eggs for 5 to 7 days, the infested wheat grains were kept in the specially made metallic rearing cage and maintained to collect newly emerged adult moth in time.

3.2.2.3 Design of the experiment

The experiment was conducted following the Completely Randomized Design (CRD) with four replications.

3.2.3 Data recorded

The parameters for data collection under this study were incubation period, larval period, pupal period, adult longevity, abundance of different growth and developmental stages of the Angoumois grain moth, *S. cerealella;* and ambient temperature and relative humidity in the laboratory.

3.2.3.1 Incubation period: Approximately hundreds of newly emerged male and female adults produced from rearing cage had been used to keep in a number of transparent glass cylinders for laying eggs. At the beginning of every month from June 2013 to May 2014 freshly laid 20 eggs were kept in each Petridishh with four replications. The hatching of larvae from egg had been observed at 10 am every day for recording data on days required from egg laying to hatching of larvae aiming to find out the incubation period. Transformation of larvae from eggs had been properly recorded as primary data. This experiment was started with keeping 20 fresh laying eggs in a Petridish and had ended with hatching of 20 larvae. A simple microscope with light source, Petridish and needle had been used to perform this experiment.

3.2.3.2 Larval period and pupal period: On the starting day of "incubation period" study, 65 grams i.e. nearly 2500 unhusked rice grains of BR 11 variety had been kept on a flat tray altogether with more than 3000 newly laid eggs of grain moth. The natural environment was maintained for utmost hatching of larva and accordingly infestation of unhusked rice through the experiment period. From the day of larva hatching in search of "larval period" and "pupal period" had been started at first dissection of pupae in the grain. These studies were done with four replications consisting 20 samples in each replication. Sample rice grains had been collected randomly from "bulk infestation pot" where infested grains were transferred from flat tray. Precautions had been taken to keep the flat tray as well as the bulk infestation pot free from any other insect pests. Every day, dissection of 20 sampled rice grains for each replication had been done to produce data over larval and pupal period of life cycle of grain moth.

3.2.3.3 Adult Longevity: At the completion of pupal stage observed at emergence of adults that occurred in the bulk infestation pot. Twenty adults for each replication were randomly collected in a test tube from the bulk infestation pot on the day of hundred percent adult emergences. A test tube was treated as a replication and the open end of a test tube was tied with fine net for aeration. Data of adult longevity and mortality had been recorded accordingly.

3.2.3.4 Abundance of egg and hatching: At the completion of pupal stage observed at emergence of adults was occurred in the bulk infestation pot. Twenty female adults with some males for each replication were randomly collected in a test tube from the bulk infestation pot on the day of hundred percent adult emergences. The open end of a test tube treated as a replication was tied with fine net for aeration and egg collection. Laid eggs were kept separately of each replication for counting larva after hatching and data had been collected accordingly. Larva came out from insect mummy's inlaid eggs had also been recorded.

3.2.3.5 Ambient temperature and relative humidity: Ambient temperature and relative humidity inside the laboratory had been recorded at 10 am every day.

3.2.4 Data analysis

The data recorded in this study had been analyzed using MSTAT-C computer package considering CRD and the means were separated using DMRT at 1% level of significance.

Plate 3.2.1: Metallic rearing cage for Angoumois grain moth

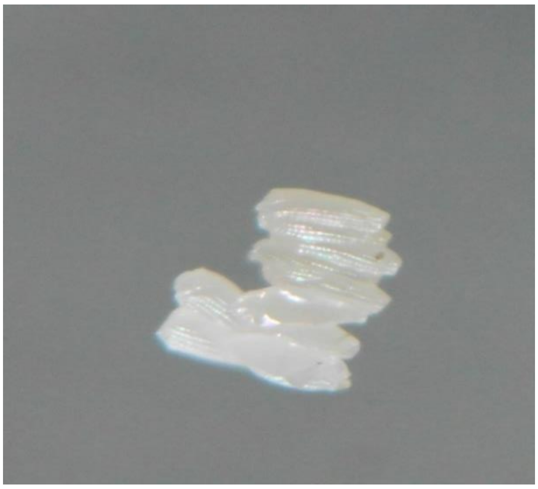

Plate 3.2.2: Freshly laid eggs of Angoumois grain moth

Plate 3.2.3: Larva of Angoumois grain moth

Plate 3.2.4: Pupa of Angoumois grain moth

Plate 3.2.5: Adult of Angoumois grain moth

Plate 3.2.6: Angoumois grain moth at mating

Plate 3.2.7: Adult moths captured in plastic boyam from rearing cage

Plate 3.2.8: Adult moth capturing technicique from the plastic boyam

EXPERIMENT 3

3.3.1 Name of the Experiment: Varietal Preference of Rice Grains for Resistance Sources against Angoumois Grain Moth *S. Cerealella*

3.3.2 Study location and Duration

The study was conducted in the Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during January 2014 to June 2014 to evaluate the varietal performance of available rice grains/seeds against Angoumois grain moth (*Sitotroga cerealella*) in the storage condition. The detail methodology of the study has been presented under the following sub-headings:

3.3.2.1 Materials used

The seeds of 12 high yielding varieties including 3 hybrid rice available in the market had been evaluated for screening to indentify the resistant/tolerant variety(ies) against grain moth. The selected rice varieties were T_1=Bina 7, T_2=BR 11, T_3=BRRI dhan 28, T_4=BRRI dhan 29, T_5=BRRI dhan 48, T_6 =BRRI dhan 52, T_7=BRRI dhan 60, T_8=BRRI dhan 61, T_9=BRRI dhan 62, T_{10}=Hybbrid Balia 1, T_{11}=Hybrid Balia 2 and T_{12}=Hybrid Tia 2. Each of the rice variety had been treated as an individual treatment for this study.

3.3.2.2 Sources of rice seeds

The rice seeds of T_1 were collected from Seed Processing Division at Gabtoli of Bangladesh Agricultural Development Corporation (BADC); whereas the rice seeds of T_2 to T_9 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur and the rice seeds of T_{10} to T_{12} were collected from local market of Dhaka city.

3.3.2.3 Stock culture of Angoumois grain moth

Prior investigation, the adult grain moths were reared on the stored unhusked rice grains in the laboratory under the Department of Entomology at Sher-e-Bangla Agricultural University. Aiming to rear the Angoumois grain moths, the collected grain moths were released on disinfested and sun-dried wheat grains in a number of plastic trays and covered by fine meshed mosquito net to facilitate the adults for laying eggs on the wheat grains. These trays were then kept in the Laboratory under the Department of Entomology, SAU since 31st March 2013. After laying eggs for 5 to 7 days, the infested wheat grains were kept in the specially made metallic rearing cage and maintained to collect newly emerged adult moth in time.

3.3.2.4 Methodology

The experiment had been conducted in the laboratory under the Department of Entomology at Sher-e-Bangla Agricultural University (SAU), Dhaka for screening the gains of selected rice varieties against Angoumois grain moth, *S. cerealella.* For this study free choice and no choice tests were carried out against grain moth.

3.3.2.4.a Free choice test: In case of free choice test, 200 g of unhusked rice grains had been kept in open mouth plastic pots for each variety (treatment) separately and the pots were kept around the periphery of circled tin cage, where an another open mouth plastic pot containing adult grain moths had been kept at the centre of the tin cage. Then the whole tin cage was covered with a fine meshed mosquito net and had been maintained the position at least for seven days to facilitate the adults to lay eggs randomly on the grains preserved in the plastic pots (Treatments). After seven days, the mouths of the plastic pots were covered with their respective lids and the rice grains containing pots had been transferred from the tin cage. All plastic pots containing rice grains along with their covered lids had been preserved in the ambient temperature of the laboratory for infestation.

3.3.2.4.b No choice test: In case of no choice test, 200 g of unhusked rice grains had been kept in plastic pots for each variety (Treatment) separately and the 20 pairs of adult grain moths were released to each plastic pot. Then all plastic pots had been covered with a fine meshed mosquito net to facilitate the adults to lay eggs on the grains preserved in the plastic pots (Treatments). After seven days, the mouths of the plastic pots had been covered with their respective lids and preserved in the ambient temperature of the laboratory for proper infestation (plate 3.3.3).

3.3.2.5 Design of the experiment

The experiment was conducted following the Completely Randomized Design (CRD) with maintaining four replications for each treatment.

3.3.2.6 Data recorded

The data had been collected at 30 days interval starting from 30 days after insect release and were continued upto 180 days to cover at least 5 generations. The parameters considered during data collection were weight of randomly selected 100 seeds at initial stage of the study, number of damaged grains per randomly 100 selected grains, weight of damaged grains per randomly 100 selected grains, total weight of rice grains at initial stage and after completion of the study and the percent germination of the seeds at initial stage and after completion of the study.

From the experiment data on different parameters were collected and calculated using the following formulas:

3.3.2.6. a Percent damaged grains: In the second set of experiment, 300 grains for each variety of rice were randomly collected from each pot and number of damaged grain was counted by observing the hole of larval entrance under simple microscope and the visible damage of grains. Then damage % was calculated by following formula:

$$\% \text{ damaged grain} = \frac{\text{Number of damaged grains found}}{\text{Total number of grains observed (300)}} \times 100$$

3.3.2.6. b Percent sampled grain weight loss: During the progress of infestation and adult emergence, the weight of sampled grains from each treatment was recorded separately. Then the percent sampled grain weight loss was measured in respect of initial weight of sampled grains using the following formula:

$$\% \text{ Sample grain content loss} = \frac{\text{Sample weight loss}}{\text{Initial weight of sampled grains}} \times 100$$

Weight loss = Initial weight of sampled grains – Weight of sampled grains after loss.

3.3.2.6. c Percent seed germination: To calculate percent germination numbers of germinated grains were counted. Seeds were considered germinated when radicle was 2mm long. The germination percentage was determined counting the number of germinated seeds in the petridishh out of randomly collected hundred seed every day. After the final count germination percentage was calculated by following formula:

$$\% \text{ germination} = \frac{\text{Number of germinated grains}}{\text{Total number of grains set for germination}} \times 100$$

3.3.2.7 Data analysis

The data had been recorded in this study which was analyzed using MSTAT-C computer package considering CRD and the means had been separated using Duncan Multiple Range Test at 1% level of significance.

Plate 3.3.1: Rice seeds for germination test due to Angoumois moth infestation after 180 DAIR

Plate 3.3.2: Seedling germinated from 180 DAIR seeds

Plate 3.3.3: Different rice variety seeds were kept for no choice test

Plate 3.3.4: Checking of infested seeds and collection of data

EXPERIMENT 4

3.4.1 Name of the Experiment: **Damage Assessment of Rice Grain by Angoumois Grain Moth Stored in Commonly Used Containers in Bangladesh**.

3.4.2 Location and duration

The study was conducted in the Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during 25 December 2013 to 24 June 2014 to evaluate the suitability of the market available containers for storing rice grains in storage against Angoumois grain moth (*Sitotroga cerealella*). The detail methodology of the study has been presented under the following subheadings:

3.4.2.1 Materials used

The seeds of BR 11 rice variety had been used for conducting this study. The seeds of this variety had been collected from the Seed Processing Division of BADC at Gabtoli, Dhaka. Two kg of sun dried rice grains of BR 11 variety had been used for each of the treatments.

3.4.2.2 Treatments

Four types of containers were used for this experiment, where each of the containers had been treated as an individual treatment. The containers were T_1=Earthen pot, T_2= Metal (tin) pot, T_3=Plastic pot, T_4= Internally laminated gunny bag. Two kg of rice grains of BR 11 variety had been stored in each of the above mentioned containers.

3.4.2.3 Methodology

The study had been conducted in the laboratory at SAU, Dhaka to assess the extent of damage of rice grain caused by grain moth storing in above mentioned containers. Two kg of rice grains sun dried for three consecutive days were stored in each type of container and preserved for six months in the laboratory to evaluate their suitability for storing unhusked rice grains against *S. cerealella*. Approximately hundred pairs of newly emerged adult grain moths counted through aspirator were collected from the stock culture as maintained continuously in the laboratory and released into each of the containers as inoculums for infesting the grains. The containers with two kg of rice grains and hundred pairs of adult moths covered with their own lids were then kept in the ambient conditions of the laboratory for six months.

3.4.2.4 Design of the experiment

The experiment was conducted following the Completely Randomized Design (CRD) with maintaining four replications for each treatment.

3.4.2.5. Data recorded

The data had been collected at 30 days interval starting from 30 days after insect release and were continued upto 180 days to cover at least 5 generations. The parameters considered data collection were weight of randomly selected 100 seeds at initial stage of the study; number of damaged grains per randomly 100 selected grains; weight of damaged grains per randomly 100 selected grains; total weight of rice grains at initial stage and after completion of the study and the percent germination of the seeds at initial stage and after completion of the study.

From the experiment data on different parameters were collected and calculated using the following formulas:

3.4.2.6.a Percent damaged grains: In the second set of experiment, 300 grains for each variety of rice were randomly collected from each pot and number of damaged grain was counted by observing the hole of larval entrance under simple microscope and the visible damage of grains. Then damage % was calculated by following formula:

$$\% \text{ damaged grain} = \frac{\text{Number of damaged grains found}}{\text{Total number of grains observed (300)}} \text{ x } 100$$

3.4.2.6.b Percent sampled grain weight loss: During the progress of infestation and adult emergence, the weight of sampled grains from each treatment was recorded separately. Then the percent sampled grain weight loss was measured in respect of initial weight of sampled grains using the following formula:

$$\% \text{ Sample grain content loss} = \frac{\text{Sample weight loss}}{\text{Initial weight of sampled grains}} \text{ x } 100$$

Weight loss = Initial weight of sampled grains – Weight of sampled grains after loss.

3.4.2.6.c Percent seed germination: To calculate percent germination numbers of germinated grains were counted. Seeds were considered germinated when radicle was 2mm long. The germination percentage was determined counting the number of germinated seeds in the petridishh out of randomly collected hundred seed every day. After the final count germination percentage was calculated by following formula:

$$\% \text{ germination} = \frac{\text{Number of germinated grains}}{\text{Total number of grains set for germination}} \text{ x100}$$

3.4.2.7 Data analysis

The data recorded in this study had been analyzed using MSTAT-C computer package considering CRD and the means were separated using Least Significance Difference test at 1% level of significance.

Plate 3.4.1: Rice seeds stored in four types of containers in the laboratory

Plate 3.4.2: Rice seeds stored in four types of containers in the laboratory

Plate 3.4.3: Fresh rice seeds in the bag before storage in the containers

Plate 3.4.4: A damaged wheat grain showing hole made by grain moth

Plate 3.4.5: Dissection of a damage rice grain showing hole made by grain moth

EXPERIMENT 5

3.5.1 Name of the Experiment: Damage Assessment of Rice Grain by Angoumois Grain Moth in Storage with Commonly Used Botanicals.

3.5.2 Study Location and Duration

The study was conducted in the Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla nagar, Dhaka, Bangladesh, during 22 August 2014 to 26 February 2015 to evaluate the effectiveness of botanicals for the management of Angoumois grain moth (*Sitotroga cerealella*) infesting rice grains in storage. The detail methodology of the study has been presented under the following sub-headings:

3.5.2.1 Materials used

The seeds of BR 11 rice variety had been used for conducting this study. The seeds of this variety had been collected from the Seed Processing Division of BADC at Gabtoli, Dhaka. Two kg of sun dried rice grains of BR 11 variety was used for each of the treatments.

3.5.2.2 Treatments

Six botanicals available in the nature and one untreated control treatments were considered for this experiment and these were T_1=neem leaf powder of neem @-2g/kg rice seeds, T_2=dried alamanda leaf powder@ 2g/kg rice seeds, T_3 = dried leaf powder of castor@2g/kg rice seeds, T_4 =dried leaf powder of mehogoni@ 2g/kg rice seeds, T_5=fine wood ash @ 2g/kg rice seeds, T_6=dried leaf powder of bishkatali @ 2g/kg rice seeds and T_7 =untreated control.

3.5.2.3 Methodology

The study was conducted in the laboratory at SAU, Dhaka to assess the efficacy of botanicals in controlling Angoumois grain moth on rice grains stored in the laboratory condition. Two kg of rice grains sun dried for three consecutive days were stored in plastic container that was found effective for storing rice grains against grain moth Approximately hundred pairs of newly emerged adult grain moths counted through aspirator were collected from the stock culture as maintained continuously in the laboratory and released in the three liter size containers for each treatment and replications as inoculums for infesting the grains. As per treatment each container with two kg of rice grains and hundred pairs of adult moths covered with their own perforated lids were then kept in the ambient conditions of the laboratory for six months.

3.5.2.4 Design of the experiment

The experiment was conducted following the Completely Randomized Design (CRD) with maintaining four replications for each treatment.

3.5.2.5. Data recorded

The data had been collected at 30 days interval starting from 30 days after insect release and were continued upto 180 days to cover at least 5 generations. The parameters considered in data collection were weight of randomly selected 100 seeds at initial stage of the study; number of damaged grains per randomly 100 selected grains; weight of damaged grains per randomly 100 selected grains; total weight of rice grains at initial stage and after completion of the study and the percent germination of the seeds at initial stage and after completion of the study.

From the experiment data on different parameters were collected and calculated using the following formulas:

3.5.2.6.a Percent damaged grains: In the second set of experiment, 300 grains for each variety of rice were randomly collected from each pot and number of damaged grain was counted by observing the hole of larval entrance under simple microscope and the visible damage of grains. Then damage % was calculated by following formula:

$$\% \text{ damaged grain} = \frac{\text{Number of damaged grains found}}{\text{Total number of grains observed (300)}} \times 100$$

3.5.2.6.b Percent sampled grain weight loss: During the progress of infestation and adult emergence, the weight of sampled grains from each treatment was recorded separately. Then the percent sampled grain weight loss was measured in respect of initial weight of sampled grains using the following formula:

$$\% \text{ Sample grain content loss} = \frac{\text{Sample weight loss}}{\text{Initial weight of sampled grains}} \times 100$$

Weight loss = Initial weight of sampled grains – Weight of sampled grains after loss.

3.5.2.6.c Percent seed germination: To calculate percent germination numbers of germinated grains were counted. Seeds were considered germinated when radicle was 2mm long. The germination percentage was determined counting the number of germinated seeds in the petridishh out of randomly collected hundred seed every day. After the final count germination percentage was calculated by following formula:

$$\% \text{ germination} = \frac{\text{Number of germinated grains}}{\text{Total number of grains set for germination}} \times 100$$

3.5.2.7 Data analysis

The data recorded in this study had been analyzed using MSTAT-C computer package considering CRD and the means had been separated using DMRT at 1% level of significance.

EXPERIMENT 6

3.6.1 Name of the Experiment: Efficacy of Commonly Used Fumigants for the Management of Angoumois Grain Moth in Stored Rice Grain.

3.6.2 Location and Duration

The study was conducted in the Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla nagar, Dhaka, Bangladesh, during 20 April 2015 to 26 August 2015 to evaluate the effectiveness of fumigants for the management of Angoumois grain moth (*Sitotroga cerealella*) infesting rice grains in storage. The detail methodology of the study has been presented under the following sub-headings:

3.6.2.1 Materials used

The seeds of BR 11 rice variety had been used for conducting this study. The seeds of this variety were collected from the Seed Processing Division of BADC at Gabtoli, Dhaka. Two kg of sun dried rice grains of BR 11 variety were used for each of the treatments.

3.6.2.2 Treatments

Four fumigants available in the nature or market and one untreated control treatments were considered for this experiment and these were T_1=camphor @1 g/kg grain, T_2= Garlic bulb @ 2 g/kg grain, T_3 = aluminium phosphide @ 200 mg/kg grain, T_4= Naphthalene @ 500 mg/kg grain, T_5 = Untreated control.

3.6.2.3 Methodology

The study had been conducted in the laboratory at SAU, Dhaka to assess the efficacy of fumigants in controlling Angoumois grain moth on rice grains stored in the laboratory condition. Two kg of rice grains sun dried for three consecutive days were stored in plastic container that was found effective for storing rice grains against grain moth Approximately hundred pairs of newly emerged adult grain moths counted through aspirator were collected from the stock culture as maintained continuously in the laboratory and released in the containers for each treatment and replication as inoculum for infesting the grains. The treatment wise each container with two kg of rice grains and hundred pairs of adult moths covered with their own lids were then kept in the ambient conditions of the laboratory for six months. Fumigants were treated just before covering the lids.

3.6.2.4 Design of the experiment

The experiment was conducted following the Completely Randomized Design (CRD) with maintaining four replications for each treatment.

3.6.2.5 Data recorded

The data had been collected at 30 days interval starting from 30 days after insect release and were continued up to 180 days to cover at least 5 generations. The parameters considered in data collection were weight of randomly selected 100 seeds at initial stage of the study; number of damaged grains per randomly 100 selected grains; weight of damaged grains per randomly 100 selected grains; total weight of rice grains at initial stage and after completion of the study and the percent germination of the seeds at initial stage and after completion of the study.

From the experiment data on different parameters were collected and calculated using the following formulas:

3.6.2.6.a Percent damaged grains: In the second set of experiment, 300 grains for each variety of rice were randomly collected from each pot and number of damaged grain was counted by observing the hole of larval entrance under simple microscope and the visible damage of grains. Then damage % was calculated by following formula:

$$\% \text{ damaged grain} = \frac{\text{Number of damaged grains found}}{\text{Total number of grains observed (300)}} \times 100$$

3.6.2.6. b Percent sampled grain weight loss: During the progress of infestation and adult emergence, the weight of sampled grains from each treatment was recorded separately. Then the percent sampled grain weight loss was measured in respect of initial weight of sampled grains using the following formula:

$$\% \text{ Sample grain content loss} = \frac{\text{Sample weight loss}}{\text{Initial weight of sampled grains}} \times 100$$

Weight loss = Initial weight of sampled grains – Weight of sampled grains after loss.

3.6.2.6.c Percent seed germination: To calculate percent germination numbers of germinated grains were counted. Seeds were considered germinated when radicle was 2mm long. The germination percentage was determined counting the number of germinated seeds every day. After the final count germination percentage was calculated by following formula:

$$\% \text{ germination} = \frac{\text{Number of germinated grains}}{\text{Total number of grains set for germination}} \times 100$$

3.6.2.7 Data analysis

The data recorded in this study had been analyzed using MSTAT-C computer package considering CRD and the means had been separated using DMRT at 1% level of significance.

EXPERIMENT 7

3.7.1 Name of the Experiment: Development of an Integrated Control Approach for Managing Angoumois Grain Moth

3.7.2 Location and Duration

The study was conducted in the Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla nagar, Dhaka, Bangladesh, during 1st January 2016 to 30th June 2016 to evaluate the effectiveness of different IPM packages for the management of Angoumois grain moth (*Sitotroga cerealella*) infesting rice grains in storage. The detail methodology of the study has been presented under the following sub-headings:

3.7.2.1 Materials used

The seeds of BR 11 rice variety were used for conducting this study. The seeds of this variety were collected from the Seed Processing Division of BADC at Gabtoli, Dhaka. Two kg of sun dried rice grains of BR 11 variety was used for each of the treatments.

3.7.2.2 Treatments

A number of combinations of the effective botanical dried neem leaf identified in the botanical based previous experiment and three effective fumigants viz. camphor, aluminium phosphide and garlic bulb identified in the fumigant based earlier experiment and had been evaluated for combating the infestation by grain moth in stored rice grains in the laboratory at SAU, Dhaka. **P_1**=Only sundried rice grain, **P_2**=Stored grain + dried neem leaf 2g/kg, **P_3**=Stored grain + dried Neem leaf 2g/kg + 0.5g of Camphor, **P_4**=Stored grain + neem leaf powder 2g/kg, **P_5**=Stored grain + neem leaf powder 2g/kg + 0.5g of Camphor, **P_6**=Stored grain + dried Neem leaf 2g/kg

+ 100g of Aluminium Phosphide, **P_7**=Stored grain + neem leaf powder 2g/kg + 100g of Aluminium Phosphide, **P_8**=Stored grain + dried neem leaf 2g/kg + 1g garlic bulb, **P_9**=Stored grain + dried neem leaf powder 2g/kg + 1g garlic bulb, **P_{10}**=Use only stored unhusked BR 11 rice grain (untreated control).

3.7.2.3 Methodology

The study had been conducted in the laboratory at SAU, Dhaka to assess the efficacy of different IPM packages in controlling Angoumois grain moth on rice grains stored in the laboratory condition. Two kg of rice grains sun dried for three consecutive days were stored in plastic container that was found effective for storing rice grains against grain moth Approximately hundred pairs of newly emerged adult grain moths counted through aspirator were collected from the stock culture as maintained continuously in the laboratory and released in the containers for each treatment and replication as inoculum for infesting the grains. The treatment wise each container with two kg of rice grains and hundred pairs of adult moths covered with their own lids were then kept in the ambient conditions of the laboratory for six months.

3.7.2.4 Design of the experiment

The experiment was conducted following the Completely Randomized Design (CRD) with maintaining four replications for each treatment.

3.7.2.5 Data recorded

The data had been collected at 30 days interval starting from 30 days after insect release and were continued up to 180 days to cover at least 5 generations. The parameters considered data collection were weight of randomly selected 100 seeds at initial stage of the study; number of damaged grains per randomly 100 selected grains; weight of damaged grains per randomly 100 selected grains; total weight of rice grains at initial stage and after completion of the study and the percent germination of the seeds at initial stage and after completion of the study.

From the experiment data on different parameters were collected and calculated using the following formulas:

3.7.2.6.a Percent damaged grains: In the second set of experiment, 300 grains for each variety of rice were randomly collected from each pot and number of damaged grain was counted by observing the hole of larval entrance under simple microscope and the visible damage of grains. Then damage % was calculated by following formula:

$$\% \text{ damaged grain} = \frac{\text{Number of damaged grains found}}{\text{Total number of grains observed (300)}} \times 100$$

3.7.2.6.b Percent sampled grain weight loss: During the advancement of infestation and adult emergence, the weight of sampled grains from each treatment was recorded separately. Then the percent sampled grain weight loss was measured in respect of initial weight of sampled grains using the following formula:

$$\% \text{ Sample grain content loss} = \frac{\text{Sample weight loss}}{\text{Initial weight of sampled grains}} \times 100$$

Weight loss = Initial weight of sampled grains – Weight of sampled grains after loss.

3.7.2.6.c Percent seed germination: To calculate percent germination numbers of germinated grains were counted. Seeds were considered germinated when radicle was 2mm long. The germination percentage was determined counting the number of germinated seeds every day. After the final count germination percentage was calculated by following formula:

$$\% \text{ germination} = \frac{\text{Number of germinated grains}}{\text{Total number of grains set for germination}} \times 100$$

3.7.2.7 Data analysis

The data recorded in this study had been analyzed using MSTAT-C computer package considering CRD and the means had been separated using DMRT at 1% level of significance.

Chapter IV

Results and Discussions

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Experiment 1: Farmers' Perception on Damage Assessment of Stored Rice Grains and control of Angoumois Grain Moth in Northern Regions of Bangladesh.

This study was conducted during February to June 2014 in 16 districts of the northern regions of Bangladesh aiming to assess the farmers' perception on damage assessment of stored rice grains by Angoumois grain moth, *Sitotroga cerealella* and the management practices by the farmers. The survey was conducted among 320 farmers in 32 upazila under 16 districts of northern regions of Bangladesh where almost all (99.4%) of the farmers were male. Most of the farmers (72.5%) in the survey were within 31 to 50 years of age. The educational level of the majority farmers (42.5%) was class-I to class-V, 26.3% farmers read from class-VI to SSC, 15.9% farmers attain HSC, 3.1% farmers have higher education. Among the respondents 12.2% farmers have no formal education but everyone can write their name. The findings of the survey study have been interpreted and discussed in the following sub-headings:

4.1.1 Size of the farmers

Significant variation was observed among the size of land under crop cultivation of farmers who participated in the field survey. Out of 320 farmers, majority (57%) of the farmers (183) were medium size followed by small (28%) size (89). Whereas, the lowest proportion of the participated farmers were large (15.0%) (48) (Figure 4.1.1.)

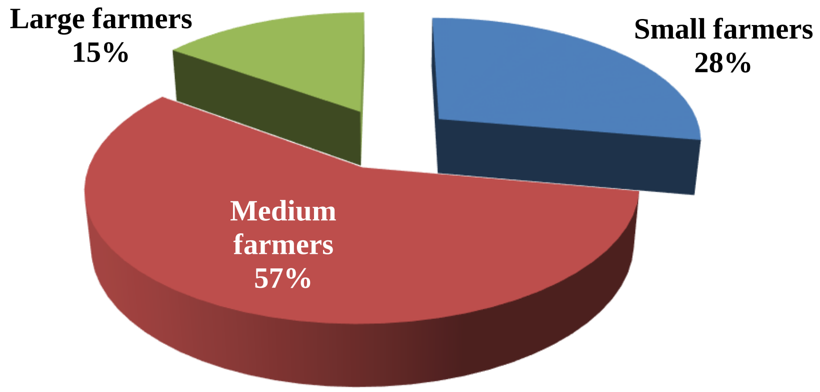

Figure 4.1.1. Category of farmers based on their farm size

4.1.2 Types of crops cultivated by the farmers

Different types of crops were cultivated by the farmers who participated in the survey. Out of 320, all (100%) of the farmers (320) cultivated cereal crops in their field, which was closely followed by vegetables (90.6%). This was succeed by fruits (20.6%), whereas the lowest number of farmers (4.1%) cultivated fiber crops, which was preceded by sugarcane farmers (6.6%). On the other hand, 6.88% farmers cultivated other crops and they mentioned tht they cultivated oil seed crops (such as mustard, sesame etc.), potato, tobacco etc (Table 4.1.2)

Table 4.1.2 Farmers' response on the type of agricultural production

Types of crops	Number of respondents [N=320]	% response
Cereals	320	100.0
Vegetables	290	90.6
Fruits	66	20.6
Sugarcane	21	6.6
Fiber crops	13	4.1
Other like oil seed crops, tobacco, potato etc	22	6.88
Multiple response*		

*Multiple response indicates one respondent provided his opinion on more than one answer of given options

4.1.3 Types of Cereal Crops Produced by Farmers

From the findings, it revealed that, 100% of respondent farmers produced rice crop in their field and wheat (51.9%) and also maize (37.8%). Beside this very few (0.9%) respondent farmers produced foxtail millet in their fields (Table 4.1.3.)

Table 4.1.3 Farmers' response on the type of cereal crops production

Types of cereal	Number of respondents [N=320]	% response
Rice	320	100.0
Wheat	166	51.9
Maize	121	37.8
Foxtail millet	3	0.9
Multiple response*		

4.1. 4. Storage of agricultural products after production

It revealed that all respondent farmers (100%) stored their agricultural products after production for future usage or sale.

4.1.5. Types of cereal products stored for future use

From the findings it revealed that most of the respondent farmers (96.3%) stored unhusked rice grain for their future usage or food which was succeed by the farmers (34.1%) who stored husked rice grain for food, 21.6% respondent farmers stored wheat for future use or food and 16.6% respondent farmers stored maize for future use or food purposes. On the other hand, few respondent farmers (1.9%) stored other cereals like foxtail millet in the survey area (Table 4.1.3)

Table 4.1.4 Farmers' response on the type of product storage for future use

Types of cereal storage	Number of respondents [N=320]	% response
Unhusked rice	308	96.3
Husked rice	109	34.1
Wheat	69	21.6
Maize	53	16.6
Others	6	1.9
Multiple Response		

4.1.6 Quantity of rice stored in previous two years before survey

The farmers' response on the quantity of rice grain stored in previous two years before survey was statistically similar but numerically different. In 2013, highest percentage of respondent farmers (22.81%) stored 501-600 kg rice grain, which was followed by 16.25% farmers who stored 601-700 kg rice grain, 15.31% farmers who stored above 800 kg and 13.13% respondent farmers stored 701-800 kg rice grain respectively. On the other hand, 2.11% respondent farmers stored 101-200 kg rice grain, which was followed by the farmers (3.13%) who stored 201-300 kg rice grain and 12.81% respondent farmers stored 301-400 kg rice grain (Figure 4.1.2).

In 2014, highest percentage of farmers (21.88%) stored 501-600 kg. About 601-700 kg rice grain, which was followed by 20.00% respondent farmers who stored 401-500 kg rice grain by 16.88% and 10.94% farmers who stored 301-400 kg rice grain and 9.88% farmer stored grain above 800 kg. Again, lowest percentage of farmers (3.44%) stored 101-200 kg rice grain, which was followed by 6.25% farmers who stored above 701-800 kg rice grain, 6.25% respondent farmers stored 701-800 kg rice grain and 8.75% respondent farmers stored 201-300 kg rice grain respectively (Figure 4.1.2).

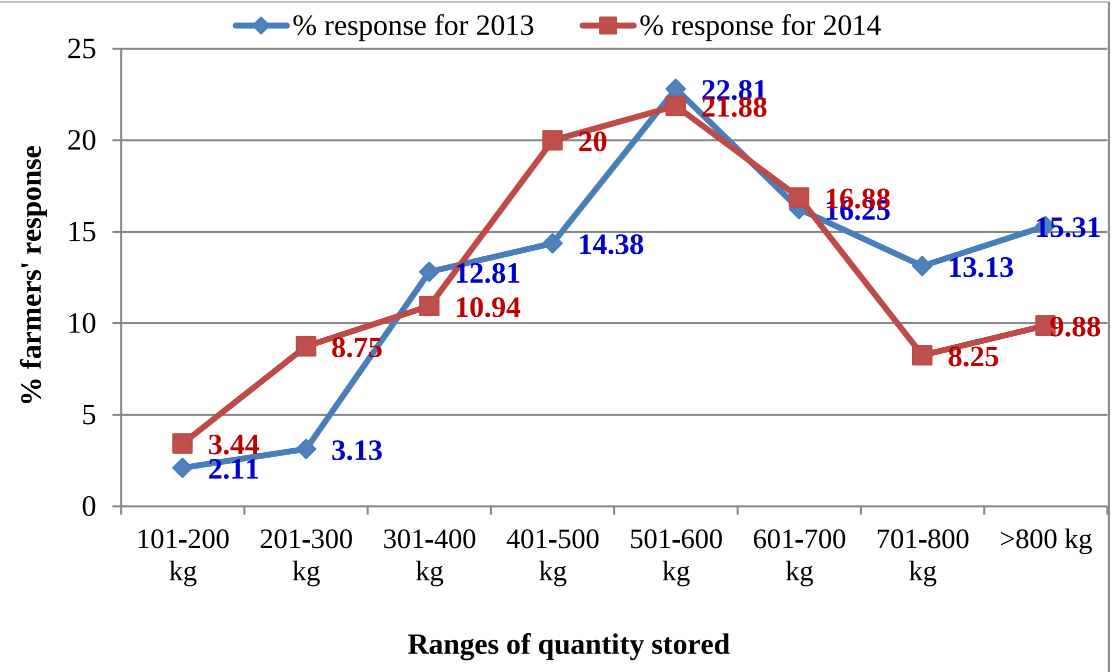

Figure 4.1.2. Percent farmers' response on the quantity of paddy stored in their households

From the above finding, it was observed that, the maximum number of farmers (about 60%) stored 400-800 kg rice grain and lowest number of farmers stored 101-200 kg rice grain in the previous two years in the survey area.

In 2013, maximum 1200 kg and minimum 140 kg rice was stored for further usage or food in the survey area. Whereas, maximum 1120 kg and minimum 200 kg rice stored for further usage or food in 2014. The average quantity of rice grain stored in 2013 was 641.72 kg and 657.50 kg rice grain in 2014 respectively in the survey area (Table 4.1.5).

Table 4.1.5 Farmers' response on the quantity of rice storage in previous two years

Range	Grain stored 2013 (Kg)	Grain stored 2014 (Kg)
Minimum	140	200
Maximum	1200	1120
Mean	641.72	657.50
Std. Deviation	215.829	180.094

4.1.7 Problems faced by the farmers in storage

During survey respondent farmers expressed that they faced different types of problem during storage. From the findings it revealed that, 97.5% farmers faced problem caused by insects in storage and the rodent problem faced by 91.3% respondent farmers. On the other hand, 6.3% respondent farmers faced problem caused by different diseases in their products during storage due to lack of farmer's knowledge on storage (10.3%), lack of appropriate storage pots (25.9%), lack of suitable godowns for rice grain storage (26.3%) and 26.3% farmers faced moisture problem during rice grain storage (Table 4.1.6).

Table 4.1.6 Farmers' response about the problems faced in storage

Types of problem	Farmers' response	
	No. of respondents	% response
Insects	312	97.5
Diseases	20	6.3
Rodents	292	91.3
Moisture	84	26.3
Lack of appropriate storage pots	83	25.9
Lack of suitable godowns	84	26.3
Lack of storage knowledge	33	10.3
Multiple Response		

4.1.7.1 Incidence of insect pest infestation on storage

Level of insect pest infestation in the storage of rice grain was statistically different on the basis of farmers' responses. Different types of insects attacked rice grains in storage. From the findings, 98.8% farmers found that grain moth was the most damaging insect pest in storage and 95.3% farmers found that rice weevil was also a major pest of storage products. On the other hand, 25% farmers found red flour beetle infestation and very little number of farmers (0.3%) mentioned about other insect pests infestation (Table 4.1.7).

Table 4.1.7 Farmers' response on the incidence of insect pest infestation in the storage

Types of insects	Farmers' response	
	No. of respondents	% Response
Grain moth	316	98.8
Rice weevil	305	95.3
Red flour beetle	80	25.0
Khapra beetle	0	0
Multiple Response		

4.1.7.2 Farmers knowledge about grain moth

From the survey it was found that all farmers (100%) had knowledge about grain moth (Table 4.1.8).

Table 4.1.8 Farmers' knowledge about the grain moth

Type of response	Number of respondents [N=320]	% response
Yes	320	100
No	0	0
Total	320	100

4.1.7.3 Grain moth infestation in different stored grain

Level of infestation of grain moth in different cereal crops at storage was significantly different on the basis of responses of farmers. From table it was observed that 99.4% respondent farmers found rice as the major host of grain moth in storage which was followed by 60.3% farmers' on wheat and 37.2% farmers on maize. A very low percentage of farmers (0.6%) expressed other cereal crops as the host of grain moth(Table 4.1.9).

Table 4.1.9 Commonly stored grains infested by grain moth

Types of grain	Number of respondents [N=320]	% response
Rice	318	99.4
Wheat	193	60.3
Maize	119	37.2
Others	2	0.6
Multiple Response		

4.1.7.4. Infestation status of grain moth in unhusked rice during storage

Infestation status of grain moth in unhusked rice during storage was significantly different on the basis of responses of 320 farmers. 64.4% farmers (206 respondent) mentioned that the infestation status of grain moth in unhusked rice during storage was about 10-20%. 19.1% farmers (61 respondent) expressed that infestation status of grain moth was 21-50% and 16.6% mentioned 01-10% infestation status (Table 4.1.10).

Table 4.1.10 Infestation status of grain moth in unhusked rice in storage condition

Infestation status	Response on the infestation of unhusked rice	
	Respondents	% response
01-10 %	53	16.6
11-20 %	206	64.4
21-50 %	61	19.1

4.1.7.5. Information about environmental condition of grain moth infestation in storage

It was observed that all (100%) farmers respond positive about the information regarding environmental condition of grain moth infestation in storage.

4.1.7.6 Grain moth infestation initiation seasons

Farmers' response on grain moth infestation initiation seasons was significantly different. According to the 99.4% farmers the infestation started in summer for grain moth in storage and only 0.6% farmers mentioned it to be the spring season (Table 4.1.11).

Table 4.1.11 General season of infestation initiation

Seasons for infestation initiation	Number of respondents [N=320]	% response
Spring	2	0.6
Summer	318	99.4
Total	320	100

4.1.7.7 Pick period of grain moth infestation in unhusked rice

Farmers response about the peak seasons of grain moth infestation was significantly different. It was found that summer with incissent rainfall was the peak season for grain moth infestation during storage according to the 99.4% farmers and only 0.6% farmers mentioned it to be the early summer when rainfall is not common (Table 4.1.12).

Table 4.1.12. Peak period of grain moth infestation

Seasons	Number of respondents [N=320]	% response
Summer	2	0.6
Summer with rainfall	318	99.4
Total	320	100

4.1.8 Information about the preventive measures taken by the farmers against grain moth

The farmers usually adopted poisonous preventive measures against grain moth before infestation in the storage

4.1.8.1. Farmers knowledge about the preventive measures against grain moth

Among 320 farmers, all the farmers (100% respondent) expressed positive responses about the preventive measures against grain moth.

4.1.8.2 Types of preventive measures taken by the famers against grain moth

From the table, it revealed that maximum 90.6% farmers' (290) used frequently sun drying as the most effective preventive measure taken against grain moth which was followed by using neem leaf powder 71.6% farmers' (229 respondents); 55.9% farmers (179 respondents) used better quality seed for storage, 47.8% farmers' (153 respondents) used chemical poison eg. Malathion, 41.9% farmers' (134 respondents) used plastic container, 37.5% farmers' (120 respondents) stored rice grain in metal container, 32.8% farmers' (105 respondents) used dried bishkatali leaf powder and 18.1% famers stored their storage in earthen pot. On the other hand, very few farmers as 1.9%, 1.3% and 4.4% used neem oil, neem seed kernel and camphor (Table 4.1.13).

Table 4.1.13. Types of preventive measures taken by farmers against grain moth

Type of measures	Number of respondents [N=320]	% response
Better quality seed used	179	55.9
Frequently sun drying	290	90.6
Storage in Plastic container	134	41.9
Storage in metal container	120	37.5
Storage in earthen pot	58	18.1
Use of neem leaf powder	229	71.6
Use of dried biskatali leaf powder	105	32.8
Use of neem oil	6	1.9
Use of neem seed kernel	4	1.3
Use of camphor	14	4.4
Use of chemical poisons	153	47.8
Multiple Response		

4.1.8.3 Best and easy preventive measures against grain moth

All the farmers who were participated in the survey practised different types of preventive measures to protect their paddy against grain moth infestation in storage. But maximum (73.4%) farmers said that frequently sun drying was the best and easy method to protect the grain from the grain moth infestation. After sun drying, using neem leaf powder was also the best and easy way to protect the grain from infestation by 60.9% farmers. According to 36.6% and 34.7% farmers seed storage in plastic container and storage of better quality seed were also effective against grain

Table 4.1.14 Best and easy preventive measures against grain moth

Type of measures	Number of respondents [N=320]	% response
Better quality seed storage	111	34.7
Frequently sun drying	235	73.4
Storage in Plastic container	117	36.6
Storage in metal container	47	14.7
Storage in earthen pot	22	6.9
Use of neem leaf powder	195	60.9
Use of biskatali leaf powder	47	14.7
Use of neem oil	6	1.9
Use of neem seed kernel	0	0
Use of camphor	3	0.9
Use of chemical poisons	115	35.9
Multiple Response		

4.1.8.4 Information about the curative measures taken by the farmers against grain moth

The farmers applied curative measures after infestation by grain moth in the stored condition

4.1.8.5 Curative measures against grain moth

Out of 320 farmers who were participated in the survey, almost all the farmers (95.6%) had the knowledge about the curative measures against grain moth infestation. On the other hand, very little 4.4% farmers had no knowledge on it (Fig 4.1.3).

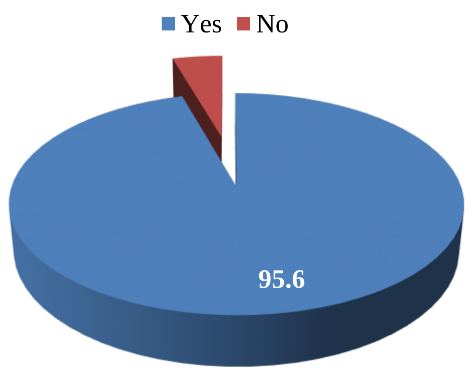

Figure 4.1.3. Farmers response about the curative measures against grain moth infestation

4.1.8.6 Types of curative measures taken by the farmers against grain moth infestation

Almost all the farmers who were respondent in the survey had the knowledge on curative measures against grain moth infestation. Generally they had used different types of curative measures. Out of 306 respondents, maximum 83.4% used sun drying as a curative measures against grain moth. On the other hand, 66.6% farmers used aluminium phosphide tablet as a curative measures, 57.5% used hand winnowing and 30.0% farmers used naphthalene as a curative measures against grain moth infestation. Very negligible percentage of farmers responded to liquid poisons.

Table 4.1.15 Types of curative measures taken against grain moth

Type of measures	Number of respondents [N=306]	% response
Use of phosphide tablet	213	66.6
Use of liquid poisons	9	2.8
Use of camphor	30	9.4
Use of naphthalene	96	30.0
Hand winnowing	184	57.5
Sun drying	267	83.4
Multiple response		

4.1.8.7 Better and easy curative measures against grain moth

Almost all the farmers in the survey used different curative measures to protect their storage against grain moth. But maximum 62.2% farmers expressed that using poisonous tablets was the easiest curative measures to protect grain moth infestation. On the other hand, 60% farmers said that sun drying was also better and easy curative measures against grain moth. Besides this, 34.7% farmers added that hand winnowing also a better and easy way to cure the grain moth after infestation.

Table 4.1.16 Better and easy curative measures against grain moth

Type of measures	Number of respondents [N=306]	% response
Use of tablet poisons	199	62.2
Use of liquid poisons	5	1.6
Use of camphor	3	0.9
Use of naphthalene	41	12.8
Hand winnowing	111	34.7
Sun drying	192	60.0
Multiple Response		

4.1.9 Method of chemicals applied in storage condition

Almost all (100%) the farmers in the survey practised different methods during chemical product application to protect the grain moth infestation in storage condition. But maximum 64.1% farmers expressed that using air tight container during chemical application was the best method in storage condition. On the other hand, 50.3% farmers said that chemical application in closed godown was also effective method in storage condition and 26.9% expressed that covering storage product with plastic sheet also a effective method to protect the grain moth infestation in storage.

Table 4.1.17. Method of chemicals applied against grain moth in storage condition

Type of methods	Number of respondents [N=320]	% response
By air tight container	205	64.1
By closed godown	161	50.3
By covering grains with plastic sheet	86	26.9
By spreading poisons at different level	18	5.6
By direct spraying	53	16.6
Multiple response		

4.1.9.1 Knowledge about chemical method to control grain moth

Farmers of the sampled area had been asked whether they were introduced with the chemical methods to control grain moth. All (100%) of them answered positively regarding this aspect.

4.1.9.2 Awareness of precautionary measures about chemical application during storage

Out of 320 respondents majority (72.5%) farmers had awareness of precaution during application of chemical method in case of unhusked rice storage. On the other hand 27.5% farmers had no knowledge regarding precautions required at the time of application.

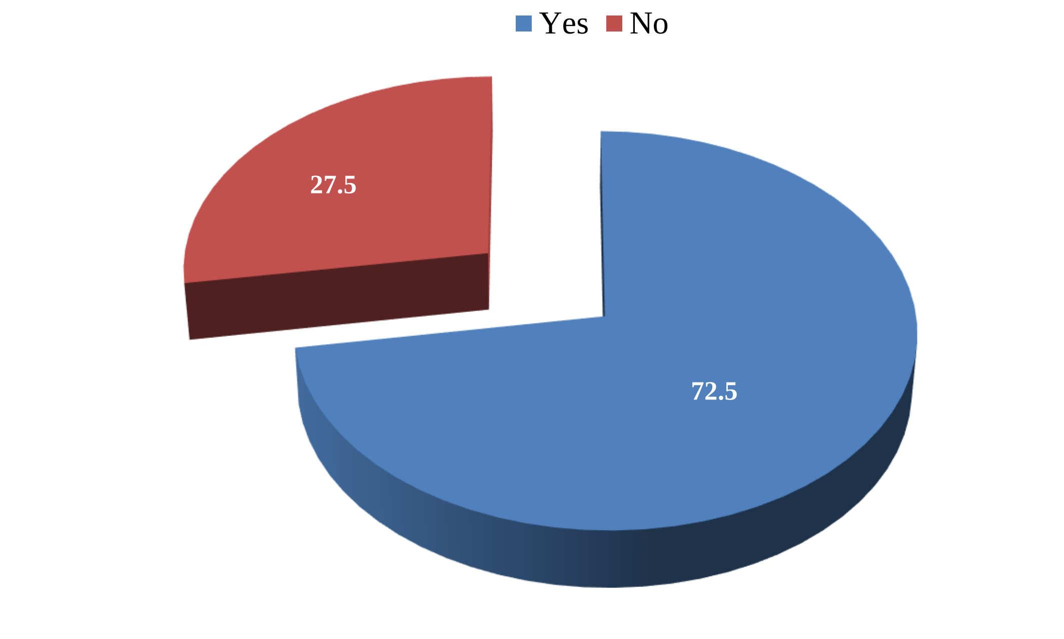

Figure 4.1.4. Awareness of precaution about chemical application during storage

4.1.9.3 Types of precautionary measures needed against application of chemicals

Out of 232 respondents on the query to desirable precautions needed in case of chemical application during unhusked rice grain storage, 44.1% emphasized on use of air tight container/warehouse to a certain period followed by airtight container/warehouse 42.5%. On the other hand 37.2% said keeping the children away from chemical application site, 35.3% said that no handling of store product immediate after chemical application and according to 26.6% Ensure ventilation followed by chemical application were the precautions methods that farmers followed during chemical application in storage condition.

Table 4.1.18 Types of precaution needed during storage

Type of precautions	**Number of respondents [N=232]**	**% response**
Air tight container/warehouse	141	44.1
Use of hand gloves and musk	50	15.6
Ensure ventilation followed by chemical application	85	26.6
No handling of store products immediate after chemical application	113	35.3
Keep the children away from chemical application site	119	37.2
No food should be taken during application of chemical insecticides	136	42.5
Multiple Response		

4.1.9.4 Knowledge about eco-friendly management of grain moth

In response to any knowledge about eco-friendly management tactics against grain moth, most of the respondents (90.9%) answered positively. Only 9.1% of the respondents had no idea about eco-friendly management tactics to prevent grain moth

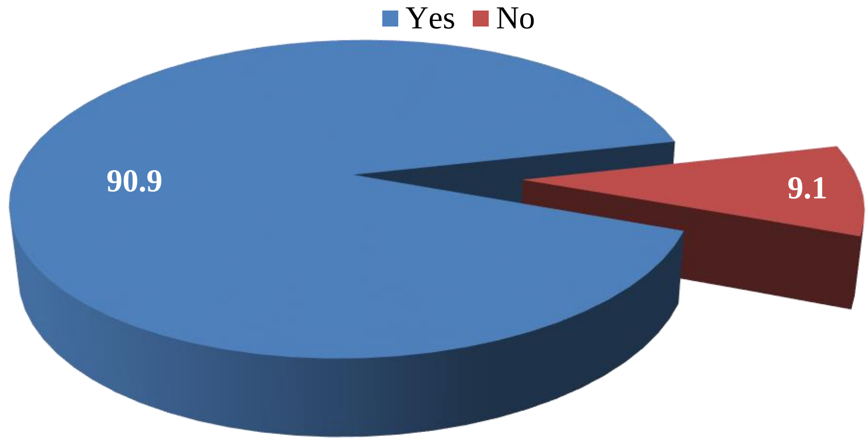

Figure 4.1.5 Farmers' Knowledge about eco-friendly management of grain moth in storage

4.1.9.5 Method of the eco-friendly management tactics against grain moth

In response to the knowledge about different methods of eco-friendly management tactics of grain moth infestation, most of the farmers (82.5%) mentioned the method, which was frequently used to manage the grain moth infestation was sun drying. Following that method, a large number of respondents (73.4%) expressed that they practised with use of neem (*Azadirachta indica*) leaf powder. A moderate percentage of farmers (39.1) had their dependence to face grain moth by storing better grade seed produced by them or collected from reliable sources. Storage of rice grain in plastic container and use of dried bishkatali (*Persicariahydro piper* L.) leaf powder were the management tactics of 34.7% and 32.2% farmers respectively. Only 21.6% farmers had the ability to store unhusked rice grain partially or completely in metal container. A small portion of farmers (16.3%) had been maintaining grain storage in earthen pot. Also a very small number of farmer usage camphor, neem oil and neem seed kernel about 5.6%, 3.4% and 2.2% respectively.

Table 4.1.19 Types of eco-friendly management practiced used against grain moth

Type of eco-friendly management	Number of respondents [N=291]	% response
Better grade seed storage	125	39.1
Frequently sun drying	264	82.5
Storage in Plastic container	111	34.7
Storage in metal container	69	21.6
Storage in earthen pot	52	16.3
Use of neem leaf powder	235	73.4
Use of biskatali leaf powder	103	32.2
Use of neem oil	11	3.4
Use of neem seed kernel	7	2.2
Use of camphor	18	5.6
Multiple Response		

4.1.9.6 Knowledge about the adverse effect about chemical uses

Farmers were asked about the adverse effect of chemical usage known to them. All (100%) of 320 farmers reported that they had knowledge about it.

4.1.9.7 Experience of any accident occurred as a result of chemical use

While the farmers were asked about their experiences of any accidental incidences occurred as a result of chemicals used during the management of grain moth, majority of them (63.1%) reported that they had no knowledge about this kind of incidence. On the other hand, 36.9% farmers reported that they had knowledge about accidental incidences occurred during the use of chemicals against pest management.

Table 4.1.20. Experiences of the farmers of any accident occurred as a result of chemical use

Type of response	Number of respondents [N=320]	% response
Yes	118	36.9
No	202	63.1
Total	320	100.0

4.1.9.8 Types of accident occur as a result of chemical use

In response to a question regarding the type of accident occurred as a result of chemical use during grain moth management in storage condition; majority (39.58%) of them answered about the death of domestic animals. About 33.85% of respondents informed about skin diseases. Some sort of damage of skin was answered by 14.58% and different type of injury other than damage of skin was noticed by 10.94%. But most dangerous thing was death of a human being during chemical poison use was informed by 1.04% respondents.

Table 4.1.21 Types of accident occur as a result of chemical use

Types of accident	Number of respondents [N=118]	% response
Death of human being due to poison	2	1.04
Injury of human being due to poison	21	10.94
Damage of skin	28	14.58
Skin diseases	65	33.85
Death of domestic animal	76	39.58
Multiple response		

4.1.9.9 Knowledge about storage container for preserving rice grains

The sampled farmers were interviewed about the available pots which were suitable for storing of unhusked rice grain. They mentioned their likings and usage regarding suitability and availabilityof containers/bags.

4.1.10 Suitable container for storing unhusked rice

Out of 320 interviewed farmers more than half of them (58.8%) told their suitable container as Bamboo Duli and approximately same number of farmers (57.8%) reported gunny bag was the suitable containers for storing rice grains. This was followed by 45.3% famers chose for plastic container. Demand for metal container and earthen pot was 37.2% and 35% respectively. Only 16.3% farmers told that used chemical fertilizer bag (plastic bag) was also usable for unhusked rice grain storing.

Table 4.1.22. Suitable container for storing unhusked rice

Types of container	Number of respondents [N=320]	% response
Earthen pot	112	35.0
Bamboo duli	188	58.8
Metal container	119	37.2
Plastic container	145	45.3
Gunny bag	185	57.8
Used chemical fertilizer bag	51	16.3
Multiple Response		

4.1.11 Commonly available container used for storing rice grains

In respect of most available container or bag used for unhusked rice grain storage; 40.6% farmers answered as Gunny jute bag. Next to gunny jute bag 34.7% informed about Bamboo Duli was also available container for rice storage. Plastic container, Gola and used chemical fertilizer bag were available and used by about 24% of respondents separately. Metal container and earthen pot were answered by 16.6% and 13.4% farmers respectively. A small number of respondents (5.6%) informed their availability of rice grain storage pot/bag was other than formatted options and those were simple jute bag, used rice (husked) bag and Aluminium pot (*dekchi*).

Table 4.1.23 Types of commonly available containers used for storing rice grains

Types of container	Number of respondents [N=320]	% response
Earthen pot	43	13.4
Bamboo duli	111	34.7
Gola (godown)	77	24.1
Metal container	53	16.6
Plastic container	74	23.1
Gunny jute bag	130	40.6
Used chemical fertilizer bag	78	24.4
Others	18	5.6
Multiple Response		

4.2. Experiment 2: Study on the Bio-Ecology of Angoumois Grain Moth, *Sitotroga Cerealella* Olivier on Stored Rice Grains in Laboratory

This section represents the growth, development and reproduction of *Sitotroga cerealella* Oliver as well as the effect of weather factors on the performance of these characteristics during 01 June 2013 to 30 May 2014 in the laboratory of the Department of Entomology at Sher-e-Bangla Agricultural University, Dhaka. The interpretations of the results on variations among the growth and developmental periods of *Sitotroga cerealella* observed in experimental months of study had been represented under the following sub-headings:

4.2.1 Incubation period

Significant variations were observed of incubation period among different months (June, 2013 to May, 2014) of *Sitotroga cerealella*. From the findings it was observed that the incubation period ranged 4.65 to 9.25 days. Maximum incubation period was observed 9.25 days of *Sitotroga cerealella* in January, 2014 which was statistically similar with 9.20 days incubation period in February, 2014 and different from other months and followed by 7.55 days incubation period in June, 2013 which was statistically similar with December, 2013 of 7.55 days of incubation period. In July, 2013 incubation period of *Sitotroga cerealella* was 7.00 days which was statistically similar with 6.95 days incubation period in November, 2013 and different with others and followed by 6.5 days incubation period in t October, 2013. Minimum incubation period was 4.65 days of *Sitotroga cerealella* in April, 2014 which was statistically different with others and followed by 5.867 days incubation period in September, 2013 which was statistically similar with 5.90 days incubation period in August, 2013, 5.95 days incubation period in May, 2014 and 6.00 days incubation period of *Sitotroga cerealella* in March, 2014 (Table 4.2.1)

Table 4.2.1 Variations of incubation period in the months from June 2013 to May 2014

Year	Month	Incubation period (days)		
		Mean ± SD	Range	Mean (days)
2013	June	7.5±1.84	5-8	7.550 b
	July	7±0.71	6-8	7.000 c
	August	5.9±0.78	5-7	5.900 e
	September	5.87±0.80	5-7	5.867 e
	October	6.5±1.06	5-8	6.500 d
	November	6.95±0.74	6-8	6.950 c
	December	7.55±1.03	6-9	7.550 b
2014	January	9.25±0.18	8-9	9.250 a
	February	9.2±0.14	8-10	9.200 a
	March	6±1.41	5-8	6.000 e
	April	4.65±0.25	4-5	4.650 f
	May	5.95±0.74	5-7	5.950 e
Average		6.85±0.81	5.67-8	-
CV (%)		**-**	**-**	**2.30**
LSD $_{(0.01)}$		**-**	**-**	**0.3516**

From the above findings it was revealed that among the different range of incubation period of *Sitotroga cerealella* were statistically different from each other among twelve months range from June, 2013 to May, 2014. The average incubation period was found at 5.67 to 8 days of *Sitotroga cerealella*. As a result the increasing trend of the incubation period among different experimental months was April > September > August > May > March > October > November > July > June > December > February > January. The duration of incubation period depends on temperature and relative humidity. Similar research was also conducted by several researchers. Khatun, (2014) reported that average incubation period of grain moth is 5.50 days in storage of rice grain.

4.2.2 Effect of monthly temperature and relative humidity on incubation period

Duration of the egg hatching varied significantly with temperature, relative humidity (Figure 4.2.1). The higher incubation periods (9.25 days) occurred at 17.21°C, while the lower incubation periods (4.65 days) occurred at 30.27°C, and incubation period increased as temperatures decreased below 20°C. Similar trends were observed in case of relative humidity. Higher incubation period (9.25 days) was observed at 62.26 per cent RH which was significantly different from all other levels of RH. Lower levels of relative humidity viz., 44.73 and 48.85 per cent resulted in lower incubation period of 6 and 4.65 days, respectively, and were statistically at par (Figure 4.2.1).

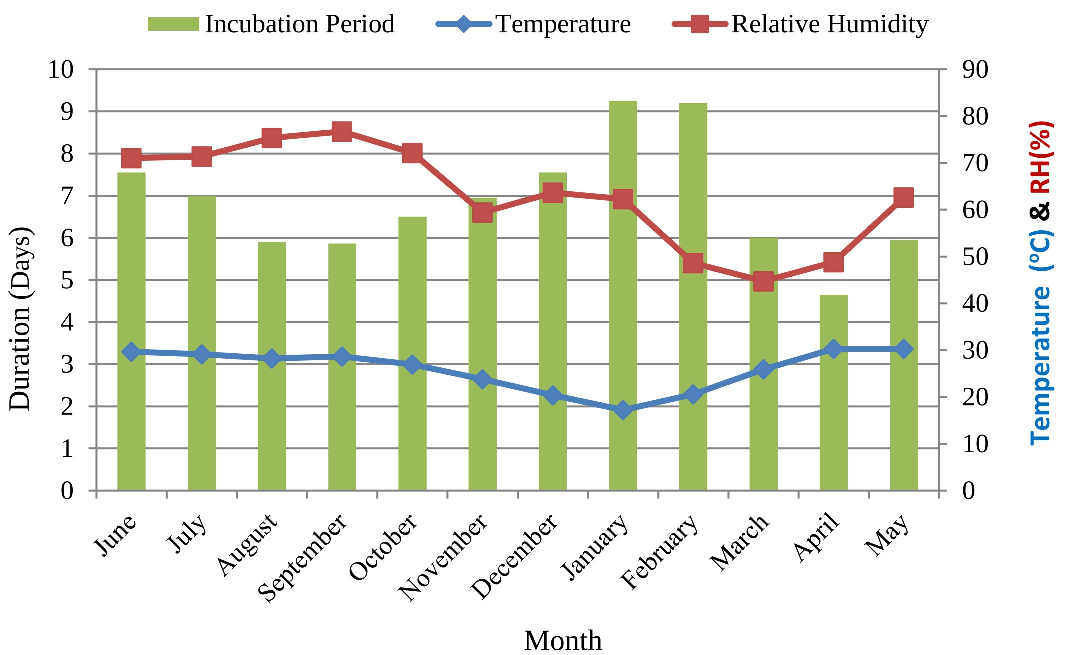

Figure 4.2.1. Effect of monthly temperature and relative humidity on incubation period.

4.2. 3 Larval period

Significant variations among the larval period were observed in different months of the study ($P < 0.01$). The larval period of grain moth, *Sitotroga cerealella* ranged from 13.67 to 20.83 days from the month of June to May (Table 4.2.2). The longest larval period was recorded in January 2014 (20.83 days) which was statistically similar to the month of December 2013 and 2nd highest larval period in November (18.57 days) and significantly decreased in june (17.20 days), February (16.77 days) and October (16.57 days). Later two months showing identical period. The larval period was the lowest in March-May with mean 13.67-13.72 days but this period was shorter than above three months.

Table 4.2.2 Variations of larval period in the months from June 2013 to May 2014

Year	Month	Larval period (days)		
		Mean ± SD	Range	Mean (days)
2013	June	17.20±0.90	16-19	17.20 c
	July	14.62±0.61	13-16	14.62 f
	August	15.67±0.51	15-17	15.67 e
	September	15.75±0.47	15-17	15.75 e
	October	16.57±0.65	15-18	16.57 d
	November	18.57±0.53	18-20	18.57 b
	December	20.80±0.58	20-22	20.80 a
2014	January	20.83±0.49	20-22	20.83 a
	February	16.77±0.53	16-18	16.77 d
	March	13.67±0.48	13-14	13.67 g
	April	13.72±0.45	13-14	13.72 g
	May	13.67±0.48	13-14	13.67 g
Average		16.48±0.56	15.6-17.6	-
CV (%)		**-**	**-**	**1.08**
LSD $_{(0.01)}$		**-**	**-**	**0.3978**

From the above findings, it revealed that the larval period of grain moth was the lowest in March, April, May and then it being increased gradually before reach to highest in January. The mean larval period of *Sitotroga cerealella* was 15.6 days to

17.6 days. As a result the increasing order of the larval period among different experimental months was March > May > April > July > August > September > October > February > June > November > December > January. More or less similar research was also conducted by several researchers. Akter *et al.* (2013) reported that average larval period of grain moth is 25.2 days in storage of rice grain.

4.2.4 Effect of monthly temperature and relative humidity on larval period

Duration of the larval period differed significantly with temperature and relative humidity (Figure 4.2.2). The longest larval periods (20.83 days) occurred under low temperature at 17.21°C. Lower temperature and moderate relative humidity prevailed in the month of December and January. With the increase of temperature but decrease of relative humidijty the larval period decreases (16.77 and 13.67) in March – May.

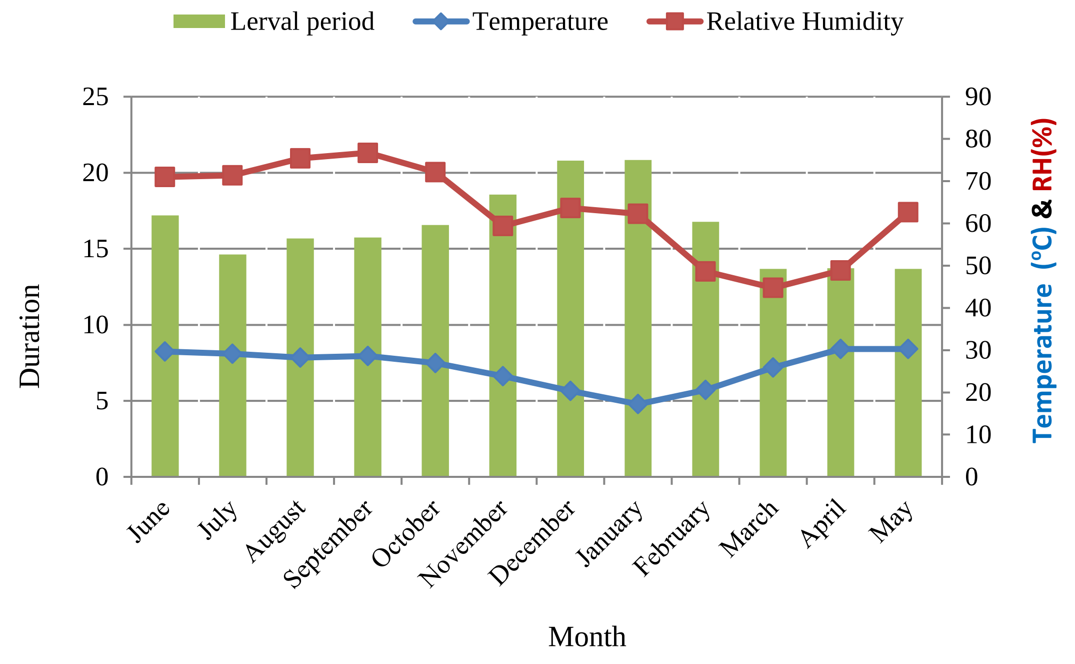

Figure 4.2.2 Effect of monthly temperature and relative humidity on larval period.

4.2.5 Pupal period

The significant difference among pupal period was observed in different months of the study (P <0.01). The pupal period of grain moth, *Sitotroga cerealella* ranged from 3.83 to 9.61 days from the month of June, 2013 to May, 2014 (Table 4.2.3). Pupal period recorded highest in January 2014 (9.61 days). Shortest pupal period was occurred in May (3.83 days) which was statistically similar with July, August and September. Moderate long pupal duration was observed in October (5.55 days), November (6.01 days) and longer duration was observed in statistically similar December (7.51 days) and February (7.56 days).

Table 4.2.3. Pupal period of *S. cerealella* in the months from June 2013 to May 2014

Year	Month	Pupal period (days)		
		Mean ± SD	**Range**	**Days**
2013	June	4.48±0.77	3-6	4.483 f
	July	3.98±0.13	3-4	3.983 gh
	August	4.05±0.50	3-5	4.050 gh
	September	4.03±0.45	3-5	4.033 gh
	October	5.55±0.72	4-7	5.550 d
	November	6.02±0.60	5-7	6.017 c
	December	7.52±0.57	6-9	7.517 b
2014	January	9.62±0.72	9-11	9.617 a
	February	7.57±0.72	7-9	7.567 b
	March	5.12±0.32	5-6	5.117 e
	April	4.20±0.58	3-5	4.200 g
	May	3.83±0.38	3-4	3.833 h
Average		5.50±0.54	4.50-6.5	-
CV (%)		-	-	**2.27**
$LSD_{(0.01)}$		-	-	**0.28**

From the above findings it revealed that from April to September lower range of pupal period observed (3.83 – 4.48 days). Trend of pupal period become increasing from October, reaches to peak in January (9.61 days) and decreases again. As a result the increasing order of the pupal period among different experimental months was May > July > September > August > April > June > March > October > November > December > February > January. More or less similar research was also conducted by several researchers. Akter *et al.* (2013) reported that average pupal period of grain moth is 5.0 days in storage of rice grain.

4.2.6 Effect of temperature and relative humidity on pupal period

Duration of the pupal period varied significantly with temperature and relative humidity (Figure 4.2.3). The longest pupal periods (9.61 days) occurred at 17.21^{o}C, while the shortest pupal periods (3.83days) occurred at 30.27^{o}C, and pupal period increased as temperatures decreased below 20^{o}C. Similar trends were observed in case of relative humidity. Longest pupal period (9.61 days) was observed at 62% RH which was significantly different from all other levels of RH. Lower relative humidity viz., 44% and 48% resulted in shorter pupal period of 5.12 and 4.2 days, respectively, and were statistically identical (Figure 4.2.3)

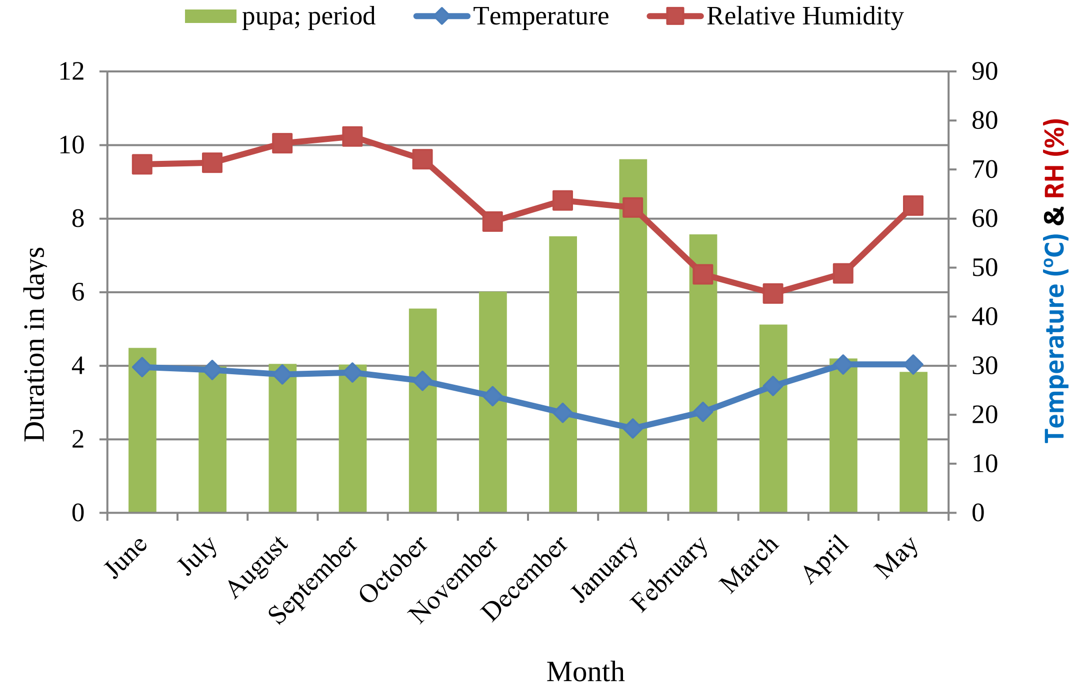

Figure 4.2.3 Effect of monthly temperature and relative humidity on pupal period of Angoumois grain moth.

4.2.7 Adult longevity

Significant variations among the adult longevity observed in different months of the study. The adult longevity of grain moth, *Sitotroga cerealella* ranged from 6.31 days to 8.68 days from the month of June, 2013 to May, 2014 (Table 4.2.4). The highest adult longevity found in March, April, June and October (8 days). Lowest adult longevity found in December (6.31 days). The average period of adult longevity of *Sitotroga cerealella* observed 7.17 days to 8.58 days.

Table 4.2.4. Adult longevity of *S. cerealella* in the months from June 2013 to May 2014

Year	Month	Adult longevity (days)		
		Mean ± SD	**Range**	**Days**
2013	June	8.62±0.49	8-9	8.617 a
	July	7.95±0.67	7-9	7.950 bc
	August	7.45±0.65	6-8	7.450 d
	September	7.97±0.61	7-9	7.967 bc
	October	8.48±0.50	8-9	8.483 a
	November	7.55±0.50	7-8	7.550 d
	December	6.32±0.47	6-7	6.317 e
2014	January	7.42±0.50	7-8	7.417 d
	February	7.67±0.54	7-9	7.667 cd
	March	8.68±0.47	8-9	8.683 a
	April	8.30±0.46	8-9	8.300 ab
	May	7.47±0.65	7-9	7.467 d
Average		7.82±0.54	7.17-8.58	-
CV (%)		-	-	**2.15**
LSD $_{(0.01)}$		-	-	**0.37**

4.2.8 Effect of temperature and relative humidity on adult longevity

Duration of the adult longevity differed significantly with temperature and relative humidity (Figure 4.2.4). The longest adult longevity (8.61 days) occurred under high (29 °C) temperature and high relative humidity (70%). The shortest adult longevity (6.31 days) occurred under low (20 °C) temperature and moderate relative humidity (63%) in December. From January to April increased adult longevity occurred with the increase of temperature and decrease of relative humidity. But from June to August adult longevity decreases (8.61-7.45) with reduction of temperature (30 °C - 28 °C) and increase (above 70%) of relative humidity (Figure 4.2.4).

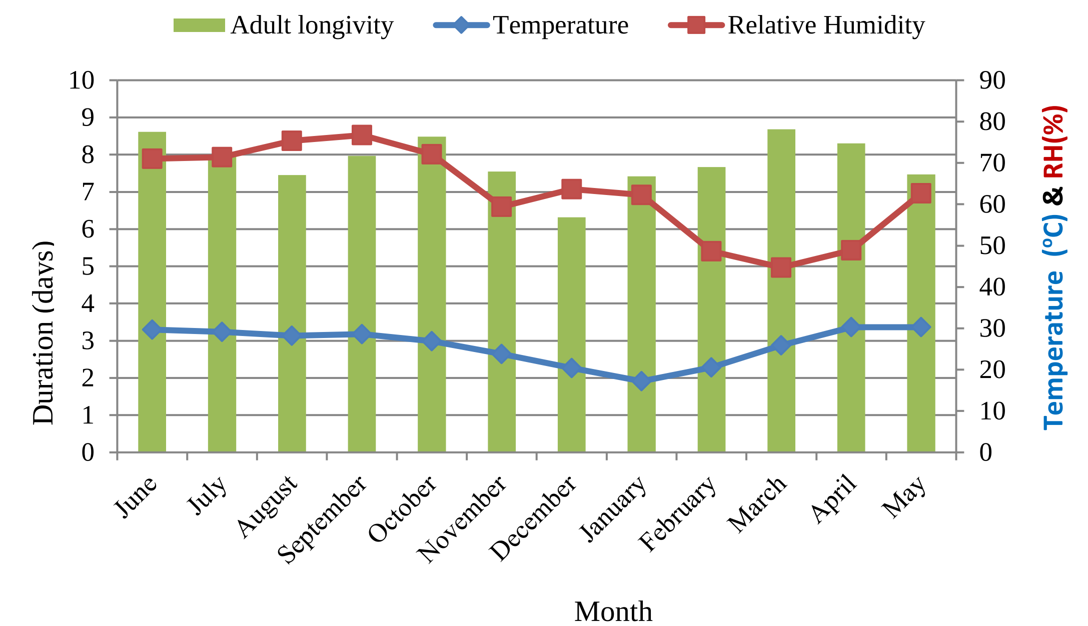

Figure 4.2.4 Relationship between adult longevity of grain moth and monthly temperature and relative humidity.

4.2.9 Total life span

The significant variations were observed among the total life span, i.e., the period between eggs laying to the death of the adult of *Sitotroga cerealella* was recorded from the cumulative results of the incubation, larval and pupal period, and adult longevity in different months of the study. The total life span of *S. cerealella* ranged from 30.87 days to 47.12 days from the month of June, 2013 to May, 2014 (Table 4.2.5). The longest life span of *Sitotroga cerealella* was observed in January 2014 (47.12 days). The second longest life span was observed in December (42.18 days) and the third longest in February (41.20 days). The shortest life span of grain moth found in the month of April (30.87 days) which was statistically similar to May (30.92 days). From the month June to October adult life span comes dwon from 33.07 (August) to 37.10 (October) days.

Table 4.2.5 Total life span of Angoumois grain moth from June 2013 to May 2014

Year	Month	Total life span (days)		
		Average ± SD	Range	Days
2013	June	37.70±4.00	32-44	37.85 e
	July	33.55±2.12	29-37	33.55 g
	August	33.07±2.44	29-37	33.07 h
	September	33.62±2.33	30-38	33.62 g
	October	37.10±2.94	32-42	37.10 f
	November	39.08±2.37	36-43	39.08 d
	December	42.18±2.64	38-47	42.18 b
2014	January	47.12±1.88	44-50	47.12 a
	February	41.20±1.94	38-46	41.20 c
	March	33.47±2.68	31-37	33.47 gh
	April	30.87±1.74	28-33	30.87 i
	May	30.92±2.24	28-34	30.92 i
Mean		36.66±2.44	32.92-40.67	-
CV (%)		-	-	**0.51**
$LSD_{(0.01)}$		-	-	**0.41**

From the above findings, it was revealed that the total life span of *S. cerealella* was the shortest when incubation was started on 1st of April and it was increased gradually, whereas life span was the longest when incubation started on 1st of January. The average longevity of total life span of *Sitotroga cerealella* was 32.92 days to 40.67 days. As a result the increasing order of the total life span of *S. cerealella* among different experimental months was April > May > August > March > July > September > October > June > November > February > December > January. Similar research was also conducted by several researchers. Khatun (2014) reported that total lifespan of male and female grain moth are 49.3 days and 51.2 days respectively in storage of rice grain.

4.2.10 Reproduction dynamics

Twenty female adults with some males for each replication were randomly collected in a test tube on the day of hundred percent adult emergences. Each test tube was treated as a replication. The open end of a test tube was tied with fine net for aeration and egg collection. Laid eggs were kept separately of each replication for counting egg hatching and data had been collected accordingly. Larvae came out from insect mummies abdomen were also recorded.

The significant variation were observed among different months of this study for number of egg per 20 adults, larva from egg per 20 adults, larva from mummy per 20 adults, total larva per 20 adults and reproduction rate per adult. In case of number of eggs per adult, highest number of eggs per 20 adults was recorded in June 2013 (2646 eggs) which was statistically different with other months of the study and followed by July 2013 (2220 eggs), May 2014 (2213 eggs), August 2013 (2117 eggs), March 2014 (1829 eggs), April 2014 (1753 eggs), February 2014 (1627 eggs) and September 2013 (1603 eggs). On the other hand, the lowest number of eggs per 20 adults were recorded in December 2013 (745.7 eggs) which was statistically similar with January 2014 (748.7 eggs) and November 2013 (861.3 eggs) which made difference with other months of the study and followed by October 2013 (1104 eggs) (Table 4.2.6.). As a result the increasing order of number of eggs of *S. cerealella* per 20 adults among different experimental months was December > January > November > October > February > September > March > April > August > May > July > June.

In case of number of larva from egg per 20 adults was recorded and observed that the highest number of larva from egg per 20 adults was found in June 2013 (2618 larva) which was statistically different with other months of the study and followed by July 2013 (2161 larva), May 2014 (2155 larva), August 2013 (2078 larva), March 2014 (1821 larva), April 2014 (1730 larva), February 2014 (1586 larva) and September 2013 (1584 larva). On the other hand, the lowest number of larva from egg per 20 adults was recorded in December 2013 (728.7 larva) which was statistically similar with January 2014 (730.7 larva), November 2013 (836 larva) and different from other months of the study and followed by October 2013 (1066 larva) (Table 4.2.6).As a result the increasing order of number of larva from eggs of *S. cerealella* per 20 adults among different experimental months was December > January > November > October > September > February > April > March > August > May > July > June.

In terms of number of larva from mummy per 20 adults was recorded and observed that the highest number of larva from mummy per 20 adults was found in July 2013 (463 larva) which was statistically similar with May 2014 (386.3 larva) and followed by August 2013 (321.7 larva), September 2013 (247 larva) and October 2013 (172.3 larva). On the other hand, the lowest number of larva from mummy per 20 adults was recorded in March 2014 (51.33 larva) which was statistically similar with April 2014 (53 larva), December 2013 (53 larva), January 2014 (53 larva), February 2014 (59.67 larva) and November 2013 (63.67 larva) and followed by June 2013 (166 larva) (Table 4.2.6). As a result the increasing order of number of larva from mummy of *S.*

cerealella per 20 adults among different experimental months was March >April > December > January > February > November > June > October > September > August > May > July.

Total number of larvae per 20 adults was recorded and the highest number of larva found in June 2013 (2784 larva) which was statistically different from other months of the study and followed by July 2013 (2624 larva), May 2014 (2541 larva), August 2013 (2399 larva), March 2014 (1872 larva), September 2013 (1831 larva) and April 2014 (1783 larva). On the other hand, the lowest number of larva from 20 adults was recorded in December 2013 (781.70 larva) which was statistically similar with January 2014 (783.70 larva) and November 2013 (899.70 larva). The lowest number of larvae was produced in December (39.08) which was statistically identical with January. Increasing order of larva of *S. cerealella* per 20 adults produced in different months was December > January > November > October > February > April > September > March > August > May > July > June.

From the table 4.2.6. it was observed that the highest reproduction rate per female adult of *Sitotroga cerealella* was in June 2013 (139.20) and production decreased gradually upto November. December and January was lowest production month and it increases gradually in the preceeding months.

Table 4.2.6. Reproduction dynamics of *S. cerealella* round the year

Months	No. of eggs/20 adults	Larvae from eggs/20 adults	Larvae from mummy/20 adults	Total larvae/20 adults	Reproduction rate/adult
June 13	2646.0 a	2618.0 a	166.0 e	2784.0 a	139.20 a
July 13	2220.0 b	2161.0 b	463.0 a	2624.0 b	131.20 b
August 13	2117.0 b	2078.0 b	321.7 bc	2399.0 c	120.00 c
September 13	1603.0 d	1584.0 d	247.0 cd	1831.0 d	91.55 d
October 13	1104.0 e	1066.0 e	172.3 de	1238.0 f	61.90 f
November 13	861.3 f	836.0 f	63.67 f	899.70 g	44.98 g
December 13	745.7 f	728.7 f	53.00 f	781.70 g	39.08 g
January 14	748.7 f	730.7 f	53.00 f	783.70 g	39.18 g
February 14	1627.0 d	1586.0 d	59.67 f	1646.0 e	82.30 e
March 14	1829.0 c	1821.0 c	51.33 f	1872.0 d	93.60 d
April 14	1753.0 c	1730.0 c	53.00 f	1783.0 d	89.17 d
May 14	2213.0 b	2155.0 b	386.3 ab	2541.0 b	127.10 b
CV (%)	**3.15**	**3.13**	**19.87**	**3.18**	**3.18**
$LSD_{(0.01)}$	**113.70**	**110.90**	**76.95**	**124.90**	**6.243**

On the other hand, the lowest number of reproduction rate per adult was recorded in December 2013 (39.08) which was statistically similar with January 2014 (39.18) and November 2013 (44.98) and followed by October 2013 (61.90), February 2014 (82.30). As a result the increasing order of reproduction rate of *S. cerealella* per female from lowest to highest among experimental months was December > January > November > October > February > April > September > March > August > May > July > June.

4.3 Experiment 3: Varietal Preference of Rice Grains for Resistance Sources Against Angoumois Grain Moth *S. Cerealella.* Olivier

The present study was conducted aiming to find the varietal resistance to varieties for management of Angoumois grain moth *Sitotroga cerealella* Oliver infesting rice grains stored in the plastic container. The experiment included 12 varieties of unhusked rice and the detailed methodology on free choice and no choice tests are presented in pages 72-76. The results and discussion are given.

This study was conducted in the laboratory condition under the Department of Entomology at Sher-e-Bangla Agricultural University, Dhaka during the period from 1st January 2014 to 30th June 2014. The seeds of twelve (12) high yielding varieties, of which three (3) hybrid rice varieties available in the market had been evaluated for screening to indentify the resistant/tolerant variety(ies) against grain moth.

Free Choice Test

This was a varietal screening of free choice test as mentioned in the methodology where 200 g of unhusked rice grains had been kept in open mouth plastic pots for each variety (Treatment) separately. The pots were kept around the periphery of a circled tin cage, where an another open mouth plastic pot containing about 600 adult Angoumois grain moths had been kept at the centre of the tin cage infest varieties according to choice. The selected rice varieties were T_1=Bina 7, T_2=BR 11, T_3=BRRI dhan 28, T_4=BRRI dhan 29, T_5=BRRI dhan 48, T_6 =BRRI dhan 52, T_7=BRRI dhan 60, T_8=BRRI dhan 61, T_9=BRRI dhan 62, T_{10}=Hybbrid Balia 1, T_{11}=Hybrid Balia 2 and T_{12}=Hybrid Tia 2.

The findings of the study had been interpreted and discussed in the following sub-headings:

4.3.1 Effect of rice varieties on grain infestation by number by Angoumois grain moth on free choice test

The significant differences were observed among different varietal treatments used in this study in terms of percent grain infestation by number at different days after insect release (DAIR) during storage in plastic container of *S. cerealella* in laboratory condition. Irrespective of any variety, the percent grain infestation had been increased with the increase of the duration of storage of rice grains. At 30 DAIR, the highest percentage of grain infestation was observed in T_{12} (8.50%) which was statistically similar to T_{10} (8.33%) and preceeded by T_{11} (7.20%) and T_9 (7.00%) T_2 (6.25%), T_3 (6.25%) and T_5 (6.00%) (Table 4.3.1). On the other hand, the percentage of infestation of grain moth was identical in other HYV varieties. Lowest percent of grain infestation observed in T_6 (0.75%) which was statistically similar to T_7 (1.00%), T_4 (2.00%) and preceed to T_1 (5.00%) and T_8 (5.00%).

In case of mean range of percent grain infestation by number, the highest percent of infested grains was observed in T_{12} (36.96%) which was statistically different from other treatments and succeed by T_{11} (33.20%), T_{10} (31.44%), T_9 (25.29%), T_2 (22.71%), T_3 (21.58%), T_5 (20.62%) and T_1 (20.04%). On the other hand, the lowest percent of infested grains was observed in T_6 (3.25%) which was similar to T_7 (4.83%) and followed by T_4 (7.08%) (Table 4.3.1).

Table 4.3.1 Grain infestation of rice varieties throughout the study period on free choice test against *S. cerealella*

Treatment	% damaged grains by number at different DAIR*						
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean
T_1	5.00 c	7.50 e	12.00 c	18.00 e	27.75 e	27.75 e	20.04 de
T_2	6.25 bc	9.00 cde	14.00 bc	21.25 de	31.25 de	31.25 de	22.71 cd
T_3	6.25 bc	9.75 cd	14.50 bc	22.50 de	31.00 de	31.00 de	21.58 de
T_4	2.00 d	3.00 f	4.75 d	7.00 f	9.75 f	9.75 f	7.08 f
T_5	6.00 bc	9.50 cde	14.50 bc	21.75 de	28.00 e	28.00 e	20.62 de
T_6	0.75 d	1.75 f	2.00 d	3.25 f	4.75 f	4.75 f	3.25 g
T_7	1.00 d	1.75 f	2.75 d	4.25 f	7.00 f	7.00 f	4.83 fg
T_8	5.00 c	7.75 de	12.00 c	18.00 e	25.00 e	25.00 e	18.79 e
T_9	7.00 ab	10.75 bc	16.75 ab	24.75 cd	34.75 d	34.75 d	25.29 c
T_{10}	8.33 a	13.00 a	19.33 a	29.00 bc	43.00 c	43.00 c	31.44 b
T_{11}	7.20 ab	12.60 ab	19.40 a	29.80 b	50.40 b	50.40 b	33.20 b
T_{12}	8.50 a	12.50 ab	19.75 a	35.50 a	60.5 a	60.50 a	36.96 a
CV (%)	16.41	12.80	15.42	12.63	10.87	6.54	8.52
LSD (0.01)	1.65	2.02	3.75	4.75	6.18	6.18	3.36

*DAIR=Days After Insect Release; The numerical values in the column indicates the average values of four replications; [T_1 = Bina 7, T_2 = BR 11,T_3 = BRRI dhan 28, T_4 =BRRI dhan 29, T_5 =BRRI dhan 48, T_6 = BRRI dhan 52, T_7 = BRRI dhan 60, T_8 = BRRI dhan 61, T_9 = BRRI dhan 62, T_{10} = Hybbrid Balia 1, T_{11} = Hybrid Balia 2 and T_{12} =Hybrid Tia 2]

The result showed that the order damage to rice grain of the varietal performance against Angoumois grain moth was BRRI dhan 52 (T_6) > BRRI dhan 60 (T_7) > BRRI dhan 29 (T_4) > BRRI dhan 61 (T_8) > BRRI dhan 48 (T_5) > Bina 7 (T_1) > BRRI dhan 28 (T_3) > BR 11 (T_2) > BRRI dhan 62 (T_9) > Hybrid Balia-1 (T_{10}) > Hybrid Balia-2 (T_{11}) > Hybrid Tia-2 (T_{12}).

It appeared from the test that hybrid varieties (T_{10}, T_{11}, T_{12}) were highly susceptible to Angoumois grain moth and HYV Bina 7, BR 11, BRRI dhan 28, BRRI dhan 48 and BRRI dhan 62 less or moderate susceptible and BRRI dhan 52, BRRI dhan 60, BRRI dhan 61 seems to be tolerant to grain moth attack. In a similar area, Rizwana, *et al.* (2011) reported that the maximum insect damage by grain moth was recorded in Basmati-Pak (33.3%) followed by G-7 (32.7%) whereas the minimum in Basmati-370 (7.8%) followed by Super Kernel Basmati (13.3-13.5%).

4.3. 2 Effect of rice varieties on weightloss of damaged grain due to attack of Angoumois grain moth through free choice test

The significant differences were observed among different varietal treatments used in this study in terms of weight loss of damaged grains at different days after insect release (DAIR) during storage in plastic container infested by *S. cerealella* in laboratory condition. Irrespective of variety, the weight reductions of damaged grains increased with time (Table 4.3.2). At 30 DAIR, the highest percentage of weight reduction of damaged grains were observed in T_{12} (3.45%) which was statistically similar to T_{10} (3.50%), T_{11} (2.93%), T_9 (2.91%), T_3 (2.83%), T_2 (2.66%) and T_5 (2.46%). The percent weight loss of rice grain was identical in varieties which was less than that of T_{12} and T_{10} varieties. Weight loss was lowest in T_6 (0.41%) which was statistically similar to T_7 (0.46%) and T_4 (0.79%), T_8 (2.01%) and T_1 (2.05%) varieties were equally and less infested by this grain moth. Similar trends of percent weight loss of damaged grains were recorded at 60, 90, 120, 150 and 180 DAIR.

The highest percentage mean weight loss of damaged grains at 180 DAIR was observed in T_{12} (20.86%) which was statistically different from other treatments such as T_{11} (18.12%), T_{10} (16.72%), T_9 (12.03%), T_3 (10.84%), T_2 (10.68%), T_5 (9.45%) and T_1 (9.42%). On the other hand, the lowest mean weight loss of damaged grain was observed in T_6 (1.69%) which was statistically similar to T_7 (2.12%) and T_4 (2.63%)

Table 4.3.2. Percent weight loss of damaged grain infested by Angoumois grain moth through free choice test

Treatment	% weight loss of damaged grains at different DAIR*						
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean
T_1	2.05 c	5.69 a	5.07 d	15.90 a	13.06 cde	25.24 ef	9.42 de
T_2	2.66 bc	3.76 de	5.90 cd	9.56 cd	14.48 cd	27.68 de	10.68 cd
T_3	2.83 ab	4.38 cd	6.76 bcd	10.75 c	15.66 cd	24.67 ef	10.84 cd
T_4	0.79 d	1.10 f	1.73 e	2.53 e	3.59 f	6.05 g	2.63 f
T_5	2.46 bc	3.91 de	6.16 cd	9.84 cd	12.78 de	21.59 f	9.45 de
T_6	0.41 d	0.84 f	1.05 e	1.86 e	2.388 f	3.60 g	1.69 f
T_7	0.46 d	0.75 f	1.11 e	2.06 e	2.69 f	5.63 g	2.12 f
T_8	2.01 c	3.11 e	4.93 d	7.84 d	10.76 e	21.59 f	8.37 e
T_9	2.91 ab	4.48 bcd	7.26 abc	10.84 c	16.26 c	30.39 d	12.03 c
T_{10}	3.50 a	5.69 a	8.66 a	13.81 b	21.93 b	46.71 c	16.72 b
T_{11}	2.93 ab	5.31 ab	8.46 ab	13.80 b	24.02 b	54.16 b	18.12 b
T_{12}	3.45 a	4.92 abc	8.18 ab	15.90 a	30.31 a	62.37 a	20.86 a
CV (%)	15.90	12.73	16.49	11.70	11.60	9.32	8.50
$LSD_{(0.01)}$	0.67	0.84	1.72	2.00	3.12	4.92	1.67

*DAIR=Days After Insect Release; The numerical values in the column indicates the average values of four replications[T_1 = Bina 7, T_2 = BR 11,T_3 = BRRI dhan 28, T_4 =BRRI dhan 29, T_5 =BRRI dhan 48, T_6 = BRRI dhan 52, T_7 = BRRI dhan 60, T_8 = BRRI dhan 61, T_9 = BRRI dhan 62, T_{10} = Hybbrid Balia 1, T_{11} = Hybrid Balia 2 and T_{12} =Hybrid Tia 2]

From these above findings it revealed that among the different varieties, T_6 comprised with BRRI dhan 52 reduced weight loss of damaged grains over highest at 180 DAIR at laboratory condition. As a result, the rank of efficacy of the varietal performance against weight loss of damaged grains infested by Angoumois grain moth *S. cerealella* was BRRI dhan 52 (T_6) > BRRI dhan 60 (T_7) > BRRI dhan 29(T_4) > BRRI dhan 61 (T_8) > BRRI dhan48 (T_5) > BRRI dhan 28 (T_3) > Bina 7 (T_1) > BR 11 (T_2) > BRRI dhan 62 (T_9) > Hybrid Balia-1 (T_{10}) > Hybrid Balia-2 (T_{11}) > Hybrid Tia-2 (T_{12}).

4.3.3 Variations on seed germination for rice varieties due to Angoumois grain moth infestation through Free Choice Test

Significant differences were observed among varietal treatments used in this study in terms of seed germination percentage of unhusked rice grain. At the beginning of this test the highest germination was in T_3 (95%) and lowest was in T_{11} (84%). At 180 DAIR, the highest percentage of seed germination was observed in T_6 (76.50%) which was statistically different from other treatments. Performance of other varieties such as T_7 (64.50%), T_4 (52.00%), T_1 (38.75%), T_5 (36.25%), T_8 (36.00%) and T_3 (35.50%). On the other hand, the lowest seed germination was observed in hybrid treatments such as T_{12} (6.00%), T_{11} (11.25%) and T_{10} (16.00%). Lower performance was observed in HYV varieties such as T_9 (31.75%) and T_2 (34.50%) (Table 4.3.3). Considering the percent of seed germination loss prevention at 180 DAIR, among different varieties, the highest percentage was observed in T_6 preceeded by T_7 and T_4.

It appeared from from germination test at free choice, hybrid varieties (T_{10}, T_{11}, T_{12}) were highly susceptible to Angoumois grain moth and seriously affected in germination ability. On the other hand BRRI dhan 52, BRRI dhan 60 seems to be tolerant in respect of germination ability when infested by Angoumois grain moth.

Table 4.3.3 Variations of seed germination for rice varieties due to infestation of angouimos grain moth at Free Choice Test

Varietal treatments for free choice test	% seed germination	
	0 DAIR	180 DAIR
T_1	90	38.75 d
T_2	91	34.50 f
T_3	95	35.50 ef
T_4	93	52.00 c
T_5	92	36.25 e
T_6	96	76.50 a
T_7	95	64.50 b
T_8	90	36.00 ef
T_9	94	31.75 g
T_{10}	85	16.00 h
T_{11}	84	11.25 i
T_{12}	86	6.00 j
CV (%)	0	2.09
LSD $_{(0.01)}$	-	1.468

*DAIR=Days After Insect Release; The numerical values in the column indicates the average values of four replications [T_1 = Bina 7, T_2 = BR 11,T_3 = BRRI dhan 28, T_4 =BRRI dhan 29, T_5 =BRRI dhan 48, T_6 = BRRI dhan 52, T_7 = BRRI dhan 60, T_8 = BRRI dhan 61, T_9 = BRRI dhan 62, T_{10} = Hybbrid Balia 1, T_{11} = Hybrid Balia 2 and T_{12} =Hybrid Tia 2]

No Choice Test

This was a screening of no choice test where 200 g of unhusked rice grains had been kept in open mouth plastic pots for each variety (Treatment) separately with four replications. Fifty adult moths have been placed into every plastic pot. All plastic pots containing rice grains along with their covered lids had been preserved in the ambient temperature of the laboratory for infestation. The findings of the study had been interpreted and discussed in the following sub-headings:

4.3.4 Grain infestation of *S. cerealella* on rice varieties throughout the study period for no choice test

Significant difference was observed among different varietal treatments used in this study in terms of percent damaged grains by number at different days after insect release (DAIR) during storage in plastic container of *S. cerealella* in laboratory condition. Irrespective of any variety, the percent damaged grains by number had been increased with the increase of the time duration of storage of rice grains in laboratory condition. At 30 DAIR, the highest range of percent damaged grains by number were observed in T_{12} (14.21%) which was statistically different from other treatment and preceeded by T_{10} (11.00%), T_{11} (8.75%), T_9 (7.25%), T_2 (7.00%), T_1 (6.75%) and T_8 (6.75%). On the other hand, the lowest range of percent damaged grains by number was observed in T_6 (1.25%) which was statistically similar with T_7 (1.75%) and T_4 (2.00%) and preceeded by T_3 (3.25%) and T_5 (4.75%). Similar trends of percent damaged grains were also recorded at 60, 90, 120, 150 and 180 DAIR (Table 4.3.4).

The highest percentage mean infestation of grains was observed in T_{12} (35.38%) which was statistically different from other treatments such as T_{10} (32.29%), T_{11} (24.83%), T_2 (22.71%), T_1 (22.67%) and T_9 (22.17%). On the other hand, the lowest percentage of infestation was observed in T_6 (3.16%) which was statistically similar with T_7 (4.33%). (Table 4.3.4).

From these above findings it revealed that among the different varieties, T_6 comprised with BRRI dhan 52 resists grain moth infestation from initial stage to 180 DAIR at laboratory condition. The order of rank of efficacy varietal resistance of other varieties against Angoumois grain moth *S. cerealella* was BRRI dhan 52 (T_6) > BRRI dhan 60 (T_7) > BRRI dhan 29 (T_4) > BRRI dhan 28 (T_3) > BRRI dhan 48 (T_5) > BRRI dhan 61 (T_8) > BRRI dhan 62 (T_9) > Bina 7 (T_1) > BR 11 (T_2) > Hybrid Balia-2 (T_{11}) > Hybrid Balia-1 (T_{10}) > Hybrid Tia-2 (T_{12}). Rizwana *et al.* (2011) observed that Basmati-Pak & G-7 were highly susceptible and significantly different from all other varieties.

Table 4.3.4 Grain infestation of rice varietiesb *S. cerealella* throughout the study period for no choice against

Treatment	% damaged grains by number at different DAIR*						
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean
T_1	6.75 d	4.05 c	6.31 b	21.75 b	31.25 b	52.25 e	22.67 cd
T_2	7.00 cd	3.42 d	5.71 b	20.00 b	30.00 b	57.75 cd	22.71 cd
T_3	3.25 ef	2.40 e	3.66 c	11.25 d	16.25 d	29.25 h	12.21 g
T_4	2.00 fg	0.95 f	1.58 d	6.00 e	9.00 e	19.00 i	7.16 h
T_5	4.75 e	2.40 e	3.94 c	13.25 d	19.00 d	35.00 g	14.50 f
T_6	1.25 g	0.72 f	1.17 d	3.00 e	4.25 f	7.00 j	3.16 i
T_7	1.75 fg	0.72 f	1.09 d	3.75 e	5.75 f	10.25 j	4.33 i
T_8	6.75 d	2.77 e	4.55 c	16.50 c	23.00 c	41.00 f	17.58 e
T_9	7.25 cd	3.66 cd	5.92 b	21.00 b	29.25 b	53.00 de	22.17 d
T_{10}	11.00 b	5.58 a	9.02 a	29.25 a	43.25 a	78.00 b	32.29 b
T_{11}	8.75 c	4.67 b	6.34 b	21.75 b	32.25 b	61.75 c	24.83 c
T_{12}	14.00 a	5.69 a	8.47 a	31.25 a	45.00 a	84.00 a	35.38 a
CV (%)	14.21	10.16	9.17	9.24	6.77	5.91	6.27
$LSD_{(0.01)}$	1.69	0.59	0.94	2.94	3.12	5.00	2.19

*DAIR=Days After Insect Release; The numerical values in the column indicates the average values of four replications; [T_1 = Bina 7, T_2 = BR 11,T_3 = BRRI dhan 28, T_4 =BRRI dhan 29, T_5 =BRRI dhan 48, T_6 = BRRI dhan 52, T_7 = BRRI dhan 60, T_8 = BRRI dhan 61, T_9 = BRRI dhan 62, T_{10} = Hybbrid Balia 1, T_{11} = Hybrid Balia 2 and T_{12} =Hybrid Tia 2]

4.3.5 Effect of rice varieties on grain infestation by weight due to attack of Angoumois grain moth through no choice test

Significant differences were observed among different varietal treatments used in this study in terms of percent weight loss at different days after insect release (DAIR) during storage in plastic container of *S. cerealella* in laboratory condition. Irrespective of variety, the percent weight reduction was increased with the increase of the duration of storage of rice grains in laboratory condition. At 30 DAIR, the highest percentage weight loss wass observed in T_{10} (4.77%) which was statistically similar to T_{12} (4.34%) and T_{11} (4.09%) (Table 4.3.5). Performance of other varieties such asT_9 (3.02%), T_2 (2.79%), T_1 (2.76%), T_8 (2.58%) and T_5 (1.96%). On the other hand, the lowest range of percent weight loss was observed in T_7 (0.48%) which was statistically similar to T_6 (0.67%) and T_4 (0.68%). Similar trend of percent weight loss was also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR. The highest percentage mean weight loss of damaged grains was T_{12} (16.85%)

In case of mean range of percent weight reduction, the highest range of percent weight loss was observed in T_{10} (17.42%) which was statistically similar with T_{12} (16.85%) and succeed by T_{11} (12.33%), T_1 (10.66%), T_2 (10.66%), T_9 (10.53%), T_8 (7.63%) and T_5 (6.49%). On the other hand, the lowest range of percent weight reduction was observed in T_6 (1.64%) which was statistically similar to T_7 (1.76%) and T_4 (2.70%) and Preceeded by T_3 (5.93%) (Table 4.3.5).

From these above findings it was revealed that among the different varieties, T_6 comprised with BRRI dhan 52 reduced weight reduction. As a result, the order of rank of efficacy of the varietal performance against weight reduction by Angoumois grain moth *Sitotroga cerealella* was BRRI dhan 52 (T_6) > BRRI dhan 60 (T_7) > BRRI dhan 29 (T_4) > BRRI dhan 28 (T_3) > BRRI dhan 48 (T_5) > BRRI dhan 61 (T_8) > BRRI dhan

62 (T_9) > Bina 7 (T_1) > BR 11(T_2) > Hybrid Balia-2 (T_{11}) > Hybrid Tia-2 (T_{12}) > Hybrid Balia-1 (T_{10}).

Table 4.3.5 Grain infestation of rice varieties by weight throughout the study period for no choice test against *S. cerealella*

Treatment	% damaged grains by weight at different DAIR*						
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean
T_1	2.76 bc	4.04 c	6.31 b	9.42 b	14.63 b	26.79 c	10.66c
T_2	2.79 bc	3.41 d	5.71 b	8.73 b	13.67 b	29.60 c	10.66c
T_3	1.60 de	2.40 e	3.66 c	5.32 d	7.77 d	14.84 e	5.93e
T_4	0.68 ef	0.95 f	1.58 d	2.25 e	3.38 e	7.37 f	2.70f
T_5	1.96 cd	2.40 e	3.94 c	5.64cd	8.43 cd	16.60 de	6.49de
T_6	0.67 ef	0.72 f	1.17 d	1.60 e	2.16 e	3.50 f	1.64f
T_7	0.48 f	0.72 f	1.09 d	1.58 e	2.37 e	4.30 f	1.76f
T_8	2.58 bc	2.77 e	4.55 c	6.83 c	9.88 c	19.16 d	7.63d
T_9	3.02 b	3.66 cd	5.92 b	9.39 b	13.81 b	27.39 c	10.53c
T_{10}	4.77 a	5.58 a	9.02 a	14.00a	22.38 a	48.73 a	17.42a
T_{11}	4.09 a	4.67 b	6.34 b	9.73 b	15.46 b	33.64 b	12.33b
T_{12}	4.34 a	5.69 a	8.47 a	13.78 a	20.96 a	47.86 a	16.85a
CV (%)	19.47	10.04	10.19	10.13	8.22	8.73	7.54
$LSD_{(0.01)}$	0.92	0.59	0.94	1.43	1.77	3.91	1.26

*DAIR=Days After Insect Release; The numerical values in the column indicates the average values of four replications[T_1 = Bina 7, T_2 = BR 11,T_3 = BRRI dhan 28, T_4 =BRRI dhan 29, T_5 =BRRI dhan 48, T_6 = BRRI dhan 52, T_7 = BRRI dhan 60, T_8 = BRRI dhan 61, T_9 = BRRI dhan 62, T_{10} = Hybbrid Balia 1, T_{11} = Hybrid Balia 2 and T_{12} =Hybrid Tia 2]

4.3.6 Variations on seed germination for rice varieties due to Angoumois grain moth infestation through No Choice Test

Significant differences were observed among varietal treatments used in this study in terms of seed germination percentage of unhusked rice grain. At the beginning of this test the highest germination was in T_3 (95%) and lowest was in T_{11} (84%).

At 180 DAIR, the highest transformation of seed germination was observed in T_6 (75.50%) which was statistically different from other treatments. Performance of other varieties such as T_7 (71.25%), T_4 (64.25%), T_3 (57.50%), T_5 (50.75%), T_8 (44.75%) and T_1 (35.75%). On the other hand, the lowest seed germination was observed in hybrids like T_{12} (7.25%) which was statistically different from other hybrids T_{10} (15.75%) (Table 4.3.6).

Table 4.3.6 Variations of seed germination for rice varieties due to attack of angouimos grain moth at Free Choice Test

Varietal treatments of no choice test	% seed germination	
	0 DAIR	180 DAIR
T_1	90	35.75 g
T_2	91	28.25 i
T_3	95	57.50 d
T_4	93	64.25 c
T_5	92	50.75 e
T_6	96	75.50 a
T_7	95	71.25 b
T_8	90	44.75 f
T_9	94	33.25 h
T_{10}	85	15.75 k
T_{11}	84	21.50 j
T_{12}	86	7.25 l
CV (%)	0	1.57
$LSD_{(0.01)}$	-	1.27

*DAIR=Days After Insect Release; The numerical values in the column indicates the average values of four replications [T_1 = Bina 7, T_2 = BR 11,T_3 = BRRI dhan 28, T_4 =BRRI dhan 29, T_5 =BRRI dhan 48, T_6 = BRRI dhan 52, T_7 = BRRI dhan 60, T_8 = BRRI dhan 61, T_9 = BRRI dhan 62, T_{10} = Hybbrid Balia 1, T_{11} = Hybrid Balia 2 and T_{12} =Hybrid Tia 2]

As a result, the order of rank of efficacy of the varietal performance against seed germination of sample grain from initial stage by Angoumois grain moth *Sitotroga cerealella* was BRRI dhan 52 (T_6) > BRRI dhan 60 (T_7) > BRRI dhan 29 (T_4) > BRRI dhan 28 (T_3) > BRRI dhan 48 (T_5) > BRRI dhan 61 (T_8) > BRRI dhan 62 (T_9) > Bina 7 (T_1) > BR 11(T_2) > Hybrid Balia-2 (T_{11}) > Hybrid Balia-1 (T_{10}) > Hybrid Tia-2 (T_{12}).

4.4. Experiment 4: Damage Assessment of Rice Grain by Angoumois Grain Moth Stored in Commonly Used Containers in Bangladesh

The present study was conducted aiming to find the effective container(s) for management of Angoumois grain moth *Sitotroga cerealella* Oliver infesting rice grains for storage. This study was conducted in the laboratory condition under the Department of Entomology at Sher-e-Bangla Agricultural University, Dhaka during the period from 25 December 2013 to 24 June. The findings of the study had been presented and discussed in the following sub-headings:

4.4.1 Suitability of containers on grain infestation by number

The significant variations were observed among different containers used as treatments against the grain infestation throughout the storing period of days after insect release (DAIR). At 30 DAIR, highest percentage of damaged grains by number was observed in gunny bag (2.75%) which was statistically similar to earthen pot (2.25%), metal pot (1.25%). On the other hand, lowest percentage of damaged grains was observed in plastic pot (0.50%). Similar trends of percent of damaged grains were also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR (Table 4.4.1).

In case of mean percent of damaged grains, the highest percentge of damaged grain was observed in T_4 (17.61%) which was statistically different from other treatments and preceeded to T_3 (15.54%). On the other hand, the lowest percent of damaged grains was observed in T_1 (9.25%) which was statistically different from other treatments and preceeded to T_2 (12.22%) (Table 4.4.1).

Table 4.4.1 Grain infestation of unhusked rice by number throughout the study period stored in the commonly used containers against *S. cerealella*

Treatment	% damaged grains at different DAIR						
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean
T_1	0.50 c	2.50 b	5.25 c	11.00 b	18.50 d	26.00 d	9.25 d
T_2	1.25 bc	3.50 ab	6.50 bc	13.00 b	22.75 c	36.50 c	12.22 c
T_3	2.25 ab	4.00 a	7.75 ab	16.00 a	33.00 b	42.75 b	15.54 b
T_4	2.75 a	4.50 a	8.75 a	17.50 a	36.00 a	49.75 a	17.61 a
CV(%)	30.84	17.81	9.37	6.66	3.59	3.20	2.98
$LSD_{(0.01)}$	1.12	1.39	1.42	2.06	2.13	2.68	0.88

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=Plastic pot, T_2=Metal (tin) pot, T_3=Earthen pot, T_4=Internally laminated gunny bag]

From these above findings it was revealed that among the different treatments, T_1 comprised with plastic pot reduced damaged grain over lowest performed container at 180 DAIR at laboratory condition. As a result, the order of rank of efficacy of the commonly used container at storing period of grains to reduce percent damaged grains infesed by Angoumois grain moth *S. cerealella* was plastic pot (T_1) > metal (tin) pot (T_2) > Earthen pot (T_3) > jute bag (gunny) (T_4). Similar research was also conducted by several researchers. Mollah, *et al.* (2017) reported that the performance of different containers showing reduction of grain infestation by number, plastic container showed highest reduction (69.51%) followed by tin pot (55.05%) and earthen pot (37.88%) over polyester bag.

4.4.2 Suitability of containers on weight loss of damage grain throughout the storage period

Significant differences were observed among different containers used as treatments on the grain infestation by weight throughout the storing period of days after insect release (DAIR). At 30 DAIR, highest percent of damaged grains by weight was observed in T_4 (1.10%) which was statistically similar with T_3 (0.96%) and followed by T_2 (0.78%). On the other hand, lowest percent of damaged grains by weight was observed in T_1 (0.54%). More or less similar trends of percent of damaged grains by weight were also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR (Table 4.4.2).

In case of mean percent of damaged grains by weight, the highest percent of damaged grains by weight was observed in T_4 (7.28%) which was statistically different from other treatments and preceeded to T_3 (5.04%). On the other hand, the lowest percent of damaged grains by weight was observed in T_1 (3.26%) which was statistically similar with T_2 (4.08%) (Table 4.4.2).

From these above findings it was revealed that among the different treatments, T_1 comprised with plastic pot reduced damaged grain by weight over lowest performed container at 180 DAIR at laboratory condition. As a result, the order of rank of efficacy of the commonly used container at storing period of grains to reduce percent damaged grains by weight against Angoumois grain moth *S. cerealella* was plastic pot (T_1) > metal (tin) pot (T_2) > Earthen pot (T_3) > jute bag (gunny) (T_4). Similar research was also conducted by several researchers. Mollah *et al.* (2017) reported that the performance of different containers in reducing the grain content loss by weight, plastic container reduced the highest percentage of grain content loss

(46.49%) over polyester bag followed by tin pot (24.87%) and the lowest reduction (8.87%) was recorded in earthen pot.

Table 4.4.2 Grain infestation of unhusked rice by weight throughout the study period stored in the commonly used containers against *S. cerealella*

Treatment	% grain infestation by weight at different DAIR						
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean
T_1	0.54 c	1.07 b	1.68 c	2.73 c	4.32 c	9.23 c	3.26 c
T_2	0.78 b	1.14 b	1.82 bc	3.45 b	5.36 bc	11.91 bc	4.08 c
T_3	0.96 ab	1.46 b	2.31 b	4.02 b	7.03 b	14.49 b	5.04 b
T_4	1.10 a	1.93 a	3.17 a	5.49 a	11.80 a	20.17 a	7.28 a
CV (%)	**12.26**	**13.08**	**11.55**	**7.58**	**13.04**	**10.97**	**8.08**
$LSD_{(0.01)}$	**0.2265**	**0.3983**	**0.5591**	**0.6407**	**2.009**	**3.306**	**0.858**

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=Plastic pot, T_2=Metal (tin) pot, T_3=Earthen pot, T_4=Internally laminated gunny bag]

4.4.3 Effect of containers on variations of seed germination

Significant variations were observed among different container used as treatments in this study in terms of percent seed germination of unhusked rice due to Angoumois grain moth infestation at 180 DAIR. In case of the day of insect infestation the percent seed germination of unhusked rice grain was recorded 90% in all the treatments i.e. no significant variation observed in all the treatments at 0 DAIR. At 180 DAIR, significant variation were observed in the treatments, the highest percent of seed germination was recorded 31.75% in T_1 which was statistically different from all other treatments and followed by T_2 (21.00%). On the other hand, the lowest percent of seed germination was recorded 4.50% in T_4 which was statistically different from all other treatments and followed by T_3 (11.00%) (Table 4.4.3).

Table 4.4.3 Variations of seed germination for rice grains due to attack of Angoumois grain moth stored in commonly used containers

Treatment	% seed germination		% prevention of seed germination over 180 DAIR
	0 day	180 day	
T_1	90	31.75 a	58.25
T_2	90	21.00 b	69.00
T_3	90	11.00 c	79.00
T_4	90	4.50 d	85.50
CV (%)	**0**	**4.06**	**-**
$LSD_{(0.01)}$	**-**	**1.495**	**-**

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=Plastic pot, T_2=Metal (tin) pot, T_3=Earthen pot, T_4=Internally laminated gunny bag]

From these above findings it revealed that, lowest percent of seed germination reduction over 0 DAIR was observed in T_1 (58.25%) which comprise with plastic pot. On the other hand, the highest percent of seed germination reduction over 0 DAIR in T_4 (85.50%) which comprise with jute bag (gunny). As a result, the order of container performance against seed germination rate after 180 DAIR by Angoumois grain moth *S. cerealella* was plastic pot (T_1) > metal (tin) pot (T_2) > Earthen pot (T_3) > jute bag (gunny) (T_4). Similar research was also conducted by several researchers. Mollah, *et al.* (2017) reported that the seed germination performance of plastic container supersede the highest percentage of seed germination (43.13%) succeeded by tin pot (40.43%).

4.5. Experiment 5: Damage Assessment of Rice Grain by Angoumois Grain Moth Stored in Commonly Used Botanicals in Bangladesh

The present study was conducted to find the more effective botanical(s) for management of Angoumois grain moth *Sitotroga cerealella* Oliver infesting rice grains stored in the plastic container as suitable for storage found from the previous experiment. This study was conducted in the laboratory condition under the Department of Entomology at Sher-e-Bangla Agricultural University, Dhaka during the period from 22 August 2014 to 26 February 2015. The results of the study had been explained and discussed in the following sub-headings:

4.5.1 Efficacy of botanicals on grain infestation by number

Significant variation was observed among six botanical treatments used in this study in terms of percent grain infestation at different days after insect (*S. cerealella*) release (DAIR) during storage in plastic container in laboratory condition. At 30 DAIR, the highest percentage of infested grain was observed in T_7 (5.50%) which was statistically similar with T_5 (4.50%) and succeed by T_2 (4.25%). On the other hand, the lowest percent of infested grain by number was observed in T_1 (0.75%) which was statistically similar with T_3 (1.50%) and succeed by T_4 (2.75%) and T_6 (3.00%) (Table 3.5.1). Similar trends of percent infested grain were also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR (Table 4.5.1).

In case of mean percent of infested grain, the highest percentage of infested grain was observed in T_7 (27.50%) which was statistically different from other treatments and followed by T_5 (20.67%), T_2 (16.54%) and T_4 (14.25%). On the other hand, the lowest percentage of infested grain was observed in T_1 (6.95%) which was statistically different from other treatments and followed by T_3 (10.04%) and T_6 (11.00%) (Table

5.5.1). Considering the percent reduction of infested grain among different treatments the highest (74.41%) reduction of infested grain over control at 180 DAIR in T_1 followed by T_3 (62.20%) and T_6 (56.30%). On the other hand, the minimum reduction of infested grain over control at 180 DAIR was found in T_5 (24.02%).

Table 4.5.1 Grain infestation of unhusked rice by number throughout the study period stored using botanicals against *S. cerealella*

Treatment	% damaged grains by number at different DAIR*							% reduction over control at 180 DAIR
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean	
T_1	0.75d	2.25e	4.25f	6.750e	11.50f	16.25f	6.95f	74.41
T_2	4.25b	6.75b	10.00c	14.50c	22.75c	41.00c	16.5c	35.43
T_3	1.50d	2.75de	5.50ef	11.00d	15.50e	24.00e	10.0e	62.20
T_4	2.75c	5.25c	8.50cd	11.00d	18.75d	39.25c	14.2d	38.19
T_5	4.50ab	8.75a	13.50b	20.50b	28.50b	48.25b	20.6b	24.02
T_6	3.00c	3.75d	7.00de	9.250d	15.25e	27.75d	11.0e	56.30
T_7	5.50a	8.50a	16.00a	28.50a	43.00a	63.50a	27.5a	0.00
CV (%)	**18.49**	**12.39**	**9.36**	**8.58**	**6.01**	**4.47**	**4.37**	**-**
LSD (0.01)	**1.17**	**1.34**	**1.73**	**2.49**	**2.66**	**3.32**	**1.33**	**-**

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=neem leaf powder of neem @ 2g/kg rice seeds, T_2=dried alamanda leaf powder @ 2g/kg rice seeds, T_3 = dried leaf powder of castor @ 2g/kg rice seeds, T_4 =dried leaf powder of mehogoni @ 2g/kg rice seeds, T_5=fine wood ash @ 2 g/kg rice seeds, T_6=dried leaf powder of bishkatali @ 2g/kg rice seeds and T_7 =untreated control]

From these above findings it revealed that among the different treatments of botanicals, T_1 comprised with leaf powder of neem reduced infested grain over control at 180 DAIR at laboratory condition. As a result, the order of rank of efficacy of the botanicals used at storing period of grains to reduce percent infested grain against Angoumois grain moth *S. cerealella* was leaf powder of neem (T_1) > dried mature leaf and seed powder of castor (T_3) > leaf powder of bishkatali (T_6) > leaf powder of mehogoni (T_4) > leaf powder of alamanda (T_2) > wood ash (T_5) > untreated control (T_7). Similar research was also conducted by several researchers. Mollah *et al.* (2017) reported that dried neem leaf showed the highest reduction (74.31%) over control followed by garlic bulb (68.51%) and dried mahogany leaf (66.03%), whereas the lowest reduction of grain infestation was recorded in dried mango leaf (50.28%) over control.

4.5.2 Efficacy of botanicals on percent weight reduction dynamics of damaged grains compared to uninfested grain over time

Significant variation was observed among different Botanical treatments used in this study in terms of percent weight reduction of infested grain at different days after insect release (DAIR) during storage in plastic container of *S. cerealella* in laboratory condition. At 30 DAIR, the highest percent reduction of weight of infested grain was observed in T_7 (0.75%) which was statistically similar with T_5 (0.61%) and followed by T_2 (0.57%). On the other hand, the lowest percent reduction of weight of infested grain was observed in T_1 (0.10%) which was statistically similar with T_3 (0.20%) and followed by T_4 (0.37%) and T_6 (0.40%). More or less similar trends of percent reduction of weight of infested grain were also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR (Table 4.5.2).

In case of mean percent reduction of weight of infested grain, the highest percent reduction of weight of infested grain was observed in T_7 (4.44%) which was statistically different from other treatments and followed by T_5 (3.14%), T_2 (2.46%) and T_4 (2.11%). On the other hand, the lowest percent reduction of weight of infested grainwas observed in T_1 (0.97%) which was statistically different from other treatments and followed by T_3 (1.43%) and T_6 (1.57%) (Table 3.5.2). Considering the percent reduction of weight of infested grain, among different treatments the highest 79.38% reduction of weight of infested grain over control at 180 DAIR in T_1 followed by T_3 (68.57%) and T_6 (63.04%). On the other hand, the minimum percent reduction of weight of infested grain over control at 180 DAIR was found in T_5 (29.20%).

Table 4.5.2 Grain infestation of unhusked rice by weight throughout the study period stored using botanicals against *S. cerealella*

Treatment	% grain infestation by weight at different DAIR*							% reduction over control at 180 DAIR
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean	
T_1	0.10d	0.30e	0.58f	0.92e	1.60f	2.31e	0.97f	79.38
T_2	0.57b	0.93b	1.38c	2.05c	3.32c	6.50c	2.46c	41.96
T_3	0.20d	0.37de	0.75ef	1.53d	2.20e	3.52d	1.43e	68.57
T_4	0.37c	0.72c	1.17cd	1.53d	2.69d	6.18c	2.11d	44.82
T_5	0.61ab	1.20a	1.90b	2.96b	4.27b	7.93b	3.14b	29.20
T_6	0.40c	0.50d	0.96de	1.27de	2.16e	4.14d	1.57e	63.04
T_7	0.75a	1.17a	2.27a	4.27a	6.89a	11.20a	4.44a	0.00
CV (%)	18.74	12.55	9.80	9.32	6.88	5.32	4.69	-
$LSD_{(0.01)}$	0.1675	0.1899	0.2532	0.3903	0.4565	0.6363	0.2193	-

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=neem leaf powder of neem @ 2g/kg rice seeds, T_2=dried alamanda leaf powder @ 2g/kg rice seeds, T_3 = dried leaf powder of castor @ 2g/kg rice seeds, T_4 =dried leaf powder of mehogoni @ 2g/kg rice seeds, T_5=fine wood ash @ 2 g/kg rice seeds, T_6=dried leaf powder of bishkatali @ 2g/kg rice seeds and T_7 =untreated control]

From these above findings it revealed that among the different treatments of botanicals, T_1 comprised with leaf powder of neem reduced weight of infested grain over control at 180 DAIR at laboratory condition. As a result, the order of rank of efficacy of the botanicals used at storing period of grains to reduce percent weight of infested grain against Angoumois grain moth *Sitotroga cerealella* was leaf powder of neem (T_1) > leaf and seed powder of castor (T_3) > leaf powder of bishkatali (T_6) > leaf powder of mehogoni (T_4) > leaf powder of alamanda (T_2) > wood ash (T_5) > untreated control (T_7). Similar research was also conducted by several researchers. Mollah *et al.* (2017) reported that neem leaf showed the highest reduction (67.46%) over control followed by garlic bulb (58.77%) and dried mahogany leaf (53.72%), whereas the lowest reduction of grain infestation was recorded in dried mango leaf (42.19%) over control.

4.5.3 Effect of botanicals on variations of seed germination

Significant variation were observed among different botanical treatments used in this study in terms of percent seed germination of unhusked rice due to Angoumois grain moth infestation at 180 DAIR. In case of the day of insect initiation the percent seed germination of unhusked rice grain was recorded 91% in all the treatments i.e. no significant variation observed in all the treatments at 0 DAIR. At 180 DAIR, significant variation were observed in the treatments, the highest percent of seed germination was recorded 81.00% in T_1 which was statistically different from all other treatments and followed by T_3 (70.75%). On the other hand, the lowest percent of seed germination was recorded 31.75% in T_7which was statistically different from all other treatments and followed by T_5 (42.25%) (Table 4.5.3).

Table 4.5.3 Variations of seed germination using botanicals against Angoumois grain moth

Treatment	% seed germination		% reduction of seed germination at 180 DAIR over initial germination	% increase of seed germination over control at 180 DAIR
	Initial (before insect release)	180 (DAIR)		
T_1	91%	81.00 a	10.00	155.12
T_2		48.75 e	42.25	53.54
T_3		70.75 b	20.25	122.83
T_4		53.50 d	37.50	68.50
T_5		42.25 f	48.75	33.07
T_6		65.50 c	25.50	106.30
T_7		31.75 g	59.25	-
CV(%)	**-**	**1.03**	**-**	**-**
LSD (0.01)	**-**	**1.155**	**-**	**-**

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=neem leaf powder of neem @ 2g/kg rice seeds, T_2=dried alamanda leaf powder @ 2g/kg rice seeds, T_3 = dried leaf powder of castor @ 2g/kg rice seeds, T_4 =dried leaf powder of mehogoni @ 2g/kg rice seeds, T_5=fine wood ash @ 2 g/kg rice seeds, T_6=dried leaf powder of bishkatali @ 2g/kg rice seeds and T_7 =untreated control]

From these above findings it revealed that, lowest percent of seed germination reduction over initial germination was observed in T_1 (10.00%) but increased over control at 180 DAIR was also in T_1 (155.12%) which comprised with dried leaf powder of neem. On the other hand, the highest percentage of seed germination reduction over initial germination was observed in T_7 (59.25%), which was comprised with untreated control. As a result, the order of botanicals performance against seed germination rate after 180 DAIR by Angoumois grain moth *S. cerealella* was leaf powder of neem (T_1) > dried mature leaf and seed powder of castor (T_3) > dried leaf powder of bishkatali (T_6) > leaf powder of mehogoni (T_4) > leaf powder of alamanda (T_2) > wood ash (T_5) > untreated control (T_7).

Similar research was also conducted by several researchers. Mollah, *et al.* (2017) reported that the performance of different botanicals in increasing the percent seed germination over control, dried neem leaf increased the highest percentage of seed germination (41.00%) followed by garlic bulb (35.47%) and dried mahogany leaf (35.03%), whereas the lowest seed germination (23.00%) were increased for dried mango leaf treated grains.

4.6. Experiment 6: Damage Assessment of Rice Grain By Angoumois Grain Moth Stored in Commonly Used Fumigants in Bangladesh

The present study was conducted to find the more effective fumigant(s) for management of Angoumois grain moth *Sitotroga cerealella* Oliver infesting rice grains stored in the plastic container as suitable for storage found from the previous experiment. This study was conducted in the laboratory condition under the Department of Entomology at Sher-e-Bangla Agricultural University, Dhaka during the period from 20 April 2015 to 26 August 2015. The findings of the study had been interpreted and discussed in the following sub-headings:

4.6. 1 Efficacy of fumigants on grain infestation percentage

Significant variation was observed among different fumigant treatments used in this study in terms of percent grain infestation by number at different days after insect release (DAIR) during storage in plastic container of *S. cerealella* in laboratory condition. At 30 DAIR, the highest percent of infested grain by number was observed in T_5 (3.50%) which was statistically similar with T_2 (3.00%) and followed by T_4 (2.00%). On the other hand, the lowest percent of infested grain by number was observed in T_3 (0.25%) which was statistically similar with T_1 (0.75%) (Table 4.6.1). Similar trends of percent infested grain were also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR

In case of mean percent of infested grain, the highest percent of infested grain was observed in T_5 (22.96%) which was statistically different from other treatments and succeed by T_2 (14.79%) and T_4 (9.41%). On the other hand, the lowest percent of infested grain by number was observed in T_3 (1.95%) which was statistically different from other treatments and followed by T_1 (5.20%) (Table 4.6.1). Considering the percent reduction of infested grain by number, among different treatments the highest

93.07% reduction of infested grain over control at 180 DAIR in T_3 followed by T_1 (77.23%). On the other hand, the minimum reduction of infested grain by number over control at 180 DAIR was found in T_2 (36.14%)

Table 4.6.1. Grain infestation of unhusked rice by number throughout the study period stored using fumigants against *S. cerealella*

Treatments	% damaged grains by number at different DAIR*							% Reduction of damaged grain over control at 180 DAIR
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean	
T_1	0.75c	2.00d	3.75d	5.75d	7.50d	11.50d	5.20d	77.23
T_2	3.00a	6.25b	10.25b	16.00b	21.00b	32.25b	14.79b	36.14
T_3	0.25c	1.00e	1.50e	2.25e	3.25e	3.50e	1.95e	93.07
T_4	2.00b	4.00c	6.50c	10.50c	13.25c	20.25c	9.41c	59.90
T_5	3.50a	8.75a	14.50a	25.00a	35.50a	50.50a	22.96a	0.00
CV(%)	**21.49**	**7.19**	**7.50**	**5.53**	**4.94**	**3.87**	**4.12**	**-**
$LSD_{(0.01)}$	**0.8515**	**0.6589**	**1.141**	**1.371**	**1.658**	**1.902**	**0.9318**	**-**

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=camphor @ 1g/kg rice seeds, T_2=garlic bulb @ 2g/kg rice seeds, T_3 = aluminium phosphide @ 200 miligram/kg rice seeds, T_4 = Naphthalene @ 500 miligram/kg rice seeds, T_5= untreated control]

From these above findings it was revealed that among the different treatments of fumigants, T_3 comprised with aluminium phosphide 200 miligram/kg grain reduced infested grain over control at 180 DAIR at laboratory condition. As a result, the order of rank of efficacy of the Fumigants used at storing period of grains to reduce percent infested grain by number against Angoumois grain moth *S. cerealella* was Aluminium phosphide 200 mg/kg grain (T_3) > Camphor 1 gm/kg grain (T_1) > Naphthalene 500 mg/kg grain (T_4) > Garlic bulb 2 gm/kg grain (T_2) > untreated control (T_5).

4.6. 2 Effect of fumigants on weight loss of damaged grains

Significant variation was observed among different fumigant treatments used in this study in terms of percent weight reduction of infested grain at different days after insect release (DAIR) during storage in plastic container of *S. cerealella* in laboratory condition. At 30 DAIR, the highest percent reduction of weight of infested grain was observed in T_5 (0.42%) which was statistically similar with T_2 (0.38%) and followed by T_4 (0.26%). On the other hand, the lowest percent reduction of weight of infested grain was observed in T_3 (0.05%) which was statistically similar with T_1 (0.11%) (Table 4.6.2). Ssimilar trends of percent reduction of weight of infested grain were also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR (Table 4.6.2).

In case of mean percent reduction of weight of infested grain, the highest percent reduction of weight of infested grain was observed in T_5 (3.53%) which was statistically different from other treatments and followed by T_2 (2.14%) and T_4 (1.32%). On the other hand, the lowest percent reduction of weight of infested grain was observed in T_3 (0.26%) which was statistically different from other treatments and followed by T_1 (0.71%) (Table 4.6.2). Considering the percent reduction of weight of infested grain, among different treatments the highest 94.39% reduction of weight of infested grain over control at 180 DAIR in T_3 followed by T_1 (81.03%). On the other hand, the minimum percent reduction of weight of infested grain over control at 180 DAIR was found in T_2 (41.53%).

From these above findings it revealed that among the different treatments of fumigants, T_3 comprised with aluminium phosphide 200 mg/kg grain reduced weight of infested grain over control at 180 DAIR at laboratory condition. As a result, the order of rank of efficacy of the Fumigants used at storing period of grains to reduce percent weight of infested grain against Angoumois grain moth *Sitotroga cerealella* was Aluminium phosphide 200 mg/kg grain (T_3)> Camphor 1 gm/kg grain (T_1) > Naphthalene 500 mg/kg grain (T_4) > Garlic bulb 2 gm/kg grain (T_2) > untreated control (T_5).

Table 4.6.2 Grain infestation of unhusked rice by weight throughout the study period stored using fumigants against *S. cerealella*

Treatment	% grain infestation by weight at different DAIR*							% reduction over control at 180 DAIR
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean	
T_1	0.11 c	0.26 d	0.50 d	0.78 d	1.02 d	1.59 d	0.71 d	81.03
T_2	0.38 a	0.85 b	1.41 b	2.26 b	3.03 b	4.90 b	2.14 b	41.53
T_3	0.05 c	0.13 e	0.20 e	0.30 e	0.43 e	0.47 e	0.26 e	94.39
T_4	0.26 b	0.53 c	0.88 c	1.45 c	1.85 c	2.93 c	1.32 c	65.04
T_5	0.42 a	1.20 a	2.04 a	3.68 a	5.47 a	8.38 a	3.53 a	-
CV (%)	**19.56**	**7.45**	**7.53**	**5.84**	**5.73**	**4.64**	**4.45**	**-**
LSD (0.01)	**0.093**	**0.093**	**0.161**	**0.208**	**0.279**	**0.354**	**0.147**	**-**

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=camphor @ 1g/kg rice seeds, T_2=garlic bulb @ 2g/kg rice seeds, T_3 = aluminium phosphide @ 200 miligram/kg rice seeds, T_4 = Naphthalene @ 500 miligram/kg rice seeds, T_5= untreated control]

4.6.3 Effect of fumigants on variations of seed germination

Significant variations were observed among different fumigant treatments used in this study in terms of percent seed germination of unhusked rice due to Angoumois grain moth infestation at 180 DAIR. In case of the day of insect initiation the percent seed germination of unhusked rice grain was recorded 91% in all the treatments i.e. no significant variation observed in all the treatments at 0 DAIR. At 180 DAIR, significant variation were observed in the treatments, the highest percent of seed germination was recorded 83.75% in T_3 which was statistically different from all other treatments and followed by T_1 (72.50%). On the other hand, the lowest percent of seed germination was recorded 32.25% in T_5 which was statistically different from all other treatments and followed by T_2 (46.00%) (Table 4.6.3).

Table 4.6.3 Variations of seed germination using fumigants against Angoumois grain moth

Treatment	% seed germination		% reduction of seed germination at 180 DAIR over initial germination	% increase of seed germination over control at 180 DAIR
	Initial (before insect release)	180 (DAIR)		
T_1	91	72.50 b	18.50	125.19
T_2		46.00 d	45.00	42.77
T_3		83.75 a	7.25	160.19
T_4		62.50 c	28.50	94.09
T_5		32.25 e	58.75	-
CV (%)	**-**	**4.38**	**-**	**-**
LSD $_{(0.01)}$	**-**	**5.42**	**-**	**-**

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [T_1=camphor @ 1g/kg rice seeds, T_2=garlic bulb @ 2g/kg rice seeds, T_3 = aluminium phosphide @ 200 miligram/kg rice seeds, T_4 = Naphthalene @ 500 miligram/kg rice seeds, T_5= untreated control]

From these above findings it revealed that, lowest percentage of seed germination reduction over 0 DAIR was observed in T_3 (7.25%) which comprised aluminium phosphide 200 mg/kg grain. On the other hand, the highest percent of seed germination reduction over 0 DAIR in T_5 (58.75%) which comprise with untreated control. As a result, the order of fumigant performance against seed germination rate after 180 DAIR by Angoumois grain moth *S. cerealella* was Aluminium phosphide 200 mg/kg grain (T_3) > Camphor 1 gm/kg grain (T_1) > Naphthalene 500 mg/kg grain (T_4) > Garlic bulb 2 gm/kg grain (T_2) > untreated control (T_5).

4.7. Experiment 7: Development of Integrated Management Approach for Combating Angoumois Grain Moth

The present study was conducted to find the most effective package(s) for integrated management of *S. cerealella* infesting rice grains stored in the plastic container as suitable for storage found from the previous experiment. This study was conducted in the laboratory condition under the Department of Entomology at Sher-e-Bangla Agricultural University, Dhaka during the period from 1st January 2016 to 30th June 2016. The details of Materials and Methods are given in pages 86-88.

4.7. 1 Efficacy of IPM packages on grain infestation by number

The significant variation was observed among different IPM packages as treatments used in this study in terms of percent grain infestation by number at different days after insect release (DAIR) during storage in plastic container of *S. cerealella* in laboratory condition. At 30 DAIR, the highest percentage of infested grain by number was observed in P_{10} (3.75%) which was statistically different from other treatments and followed by P_1 (2.75%), P_2 (1.75%) and P_3 (1.75%). On the other hand, the lowest percent of infested grain by number was observed in P_7 (0.75%) which was statistically similar to P_6 (0.25%), P_4 (0.25%), P_5 (0.75%), P_8 (0.75%) and P_9 (0.75%) (Table 4.7.1). Similar trends of percent infested grain were also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR (Table 4.7.1).

In case of mean infestation percentage, the highest percentage of infested grain was observed in P_{10} (22.79%) which was statistically different from other treatments and succeed by P_1 (21.37%), P_2 (8.29%), P_3 (7.96%) and P_8 (5.75%). On the other hand, the lowest percentage s of infested grain was observed in P_7 (0.67%) which was statistically similar to P_6 (0.83%) and succeed by P_4 (2.46%), P_5 (2.46%) and P_9 (4.04%) (Table 4.7.1). Considering the percent reduction of infested grain among different treatments the highest (97.22%) reduction of infested grain over control at 180 DAIR in P_6 followed by P_7 (97.18%) and P_5 (90.14%). On the other hand, the minimum reduction of infested grain over control at 180 DAIR was found in P_1

(5.16%). As a result, the order of performance of IPM packages against grain infestation rate after 180 DAIR by Angoumois grain moth *S. cerealella* was Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg grains (P_7) > Aluminium phosphide @ 200 mg/kg grains along with dried neem leaf power @ 2 g/kg grains(P_6) > Camphor @ 1000 mg/kg grains along with neem leaf powder @ 2 g/kg grains (P_4) > Camphor @ 500 mg/kg grains along with neem leaf powder @ 2 g/kg grains (P_5) > Garlic bulb (1/2 dosage rate of prev. exp.) along with neem leaf powder @ 2 g/kg grains (P_9) > Garlic bulb (1/2 dosage rate of prev. exp.) along with neem leaf powder @ 2 g/kg grains (P_8) > Stored BR11 unhusked rice grain with dried neem leaf powder @ 2g/kg (P_3) > Stored BR11 unhusked rice grain with dried neem leaf @ 2g/kg (P_2) > unhusked BR11 rice grain sundried for two hours (P_1) > Stored unhusked BR11 rice grain (Untreated control) (P_{10}).

From the above findings it revealed that the P_6 comprised with the use of Aluminium phosphide @ 200 mg/kg grains along with neem leaf powder @ 2 g/kg grains performed as the best IPM package in reducing the infestation (97.22%) of Angoumois grain moth in storage of rice grains, which was statistically similar to P_7 (97.18%) that was comprised with the use of Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg grains. But considering the eco-friendly point of view, P_7 is better than P_6, because P_7 was comprised with half the dosage rate of Aluminium phosphide than P_6. Considering the less health hazardous management, P_5 comprised with the use Camphor @ 500 mg/kg grains along with neem leaf powder @ 2 g/kg grains is better than P_7, because P_5 was comprised with botanical based package (both camphor and neem leaf) that ensured the less hazardous for human health and reduced more or less higher percentage (90.14%) of grain infestation in storage condition. Similar research was also conducted by several researchers. Rahman *et al.* (2006) reported that 78.46-89.14% rice grain infestation was found against grain moth in storage during the use of camphor at a rate of 4.5 g/kg rice grain management package.

Table 4.7.1 Grain infestation of unhusked rice by number throughout the study period stored using IPM packages against *S. cerealella*

Treatments	% damaged grains by number at different DAIR*							% Reduction of damage grain over control at 180 DAIR
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean	
P_1	2.75b	7.25a	15.00a	21.50b	31.25b	50.50b	21.37b	5.16
P_2	1.75c	3.25b	5.50b	8.75c	13.00c	17.50c	8.29c	67.14
P_3	1.75c	3.50b	5.75b	8.75c	12.25c	15.75c	7.96c	70.42
P_4	0.25d	0.75cd	1.50de	2.25f	3.50f	6.50f	2.46f	87.79
P_5	0.75cd	0.75cd	1.75de	2.50f	3.75f	5.25f	2.46f	90.14
P_6	0.25d	0.50cd	0.50e	1.00g	1.25g	1.48g	0.83g	97.22
P_7	0.25d	0.25d	0.50e	0.75g	0.75g	1.50g	0.67g	97.18
P_8	0.75cd	1.50c	3.50c	6.00d	9.25d	13.50d	5.75d	74.65
P_9	0.75cd	1.25cd	2.25cd	3.75e	5.75e	10.50e	4.04e	80.28
P_{10}	3.75a	7.75a	16.00a	23.00a	33.00a	53.25a	22.79a	0.00
CV (%)	**38.46**	**19.60**	**13.65**	**8.00**	**6.47**	**5.62**	**5.48**	-
$LSD_{(0.01)}$	**0.97**	**1.02**	**1.38**	**1.21**	**1.43**	**1.92**	**0.81**	-

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [P_1= unhusked BR11 rice grain sundried for two hours, P_2= Stored BR11 unhusked rice grain with dried neem leaf @ 2g/kg, P_3 = Stored BR11 unhusked rice grain with dried neem leaf powder @ 2g/kg, P_4 = P_3 + 1g/kg of camphor P_5= P_3 + 0.5g/kg of camphor, P_6= P_3 + 200 mg of Aluminium Phosphide, P_7 = P_3 + 100 mg of Aluminium Phosphide, P_8 = P_3 + 2g/kg garlic bulb, P_9= P_3 + 2g/kg garlic bulb, P_{10}= Stored unhusked BR11 rice grain (Untreated control)]

4.7. 2 Effect of IPM packages on weight reduction of damaged grains

Significant variation was observed among different IPM packages used in this study in terms of less weight percentage reduction at different days after insect release (DAIR) during integrated management of *S. cerealella* in laboratory condition. Irrespective of any management package, the percentage weight loss of infested grains had been increased with the increase of the duration of storage of rice grains in laboratory condition. At 30 DAIR, the highest percentage weight loss of damaged grains for P_{10} was 0.41% which was statistically similar to P_1 (0.41%) and succeed by P_3 (0.22%) and P_2 (0.12%). On the other hand, the lowest range of percent weight loss of damaged grains were recorded in P_6 (0.00%) and P_7 (0.00%) which were statistically similar to P_9 (0.09%), P_8 (0.10%), P_5 (0.10%) and P_4 (0.10%). Similar trends of percent weight loss of infested grain were also recorded at 60 DAIR, 90 DAIR, 120 DAIR, 150 DAIR and 180 DAIR for other IPM packages.

In case of mean percentage weight reduction of infested grain, the highest percent reduction of weight loss of infested grain was observed in P_{10} (3.54%) which was statistically different from other treatments and followed by P_1 (3.28%), P_2 (1.13%), P_3 (1.09%) and P_8 (0.80%). On the other hand, the lowest percent reduction of weight loss of infested grain was observed in P_7 (0.06%) which was statistically similar to P_6 (0.09%) and succeed by P_5 (0.33%), P_4 (0.34%) and P_9 (0.56%) (Table 4.7.2). Considering the percentge weight loss of infested grain among different treatments the highest 98.36% reduction of weight loss of infested grain over control at 180 DAIR in P_7 followed by P_6 (97.92%), P_5 (92.21%) and P_4 (90.35%). On the other hand, the minimum percent reduction of weight loss of infested grain over control at 180 DAIR was found in P_1 (8.11%). As a result, the order of performance of IPM packages against seed germination rate after 180 DAIR by Angoumois grain moth *S. cerealella* was Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg grains (P_7) > Aluminium phosphide @ 200 mg/kg grains along with dried neem leaf power @ 2 g/kg grains(P_6) > Camphor @ 500 mg/kg grains along with neem leaf powder @ 2 g/kg grains (P_5) > Camphor @ 1000 mg/kg grains along with neem leaf powder @ 2 g/kg grains (P_4) > Garlic bulb (1/2 dosage rate of prev. exp.) along with neem leaf powder @ 2 g/kg grains (P_9) > Garlic bulb (1/2 dosage rate of prev. exp.) along with neem leaf powder @ 2 g/kg grains (P_8) > Stored BR11 unhusked rice grain with dried neem leaf powder @ 2g/kg (P_3) > Stored BR11 unhusked rice grain with dried neem leaf @ 2g/kg (P_2) > unhusked BR11 rice grain sundried for two hours (P_1) > Stored unhusked BR11 rice grain (Untreated control) (P_{10})

Table 4.7.2 Grain infestation of unhusked rice by weight throughout the study period stored using different IPM packages against *S. cerealella*

Treatment	% grain infestation by weight at different DAIR*							% reduction over control at 180 DAIR
	30 DAIR	60 DAIR	90 DAIR	120 DAIR	150 DAIR	180 DAIR	Mean	
P_1	0.41a	0.95a	2.12a	3.12b	4.73b	8.38b	3.28b	8.11
P_2	0.12bc	0.43b	0.74b	1.20c	1.79c	2.49c	1.13c	72.70
P_3	0.22b	0.47b	0.81b	1.23c	1.60d	2.22d	1.09c	75.66
P_4	0.10cd	0.10cd	0.20de	0.30fg	0.46g	0.88g	0.34f	90.35
P_5	0.10cd	0.09cd	0.23de	0.33ef	0.50g	0.71g	0.3f	92.21
P_6	0.00d	0.00d	0.06e	0.13gh	0.14h	0.19h	0.09g	97.92
P_7	0.00d	0.00d	0.03e	0.09g	0.13h	0.15h	0.06g	98.36
P_8	0.10cd	0.26c	0.47c	0.81d	1.31e	1.89e	0.80d	79.28
P_9	0.09cd	0.16cd	0.30cd	0.50e	0.80f	1.51f	0.56e	83.44
P_{10}	0.41a	1.06a	2.26a	3.35a	5.06a	9.12a	3.54a	0.00
CV (%)	**34.85**	**23.10**	**14.16**	**8.58**	**4.62**	**4.59**	**5.32**	
$LSD_{(0.01)}$	**0.10**	**0.16**	**0.20**	**0.18**	**0.15**	**0.24**	**0.12**	

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [P_1= unhusked BR11 rice grain sundried for two hours, P_2= Stored BR11 unhusked rice grain with dried neem leaf @ 2g/kg, P_3 = Stored BR11 unhusked rice grain with dried neem leaf powder @ 2g/kg, P_4 = P_3 + 1g/kg of camphor P_5= P_3 + 0.5g/kg of camphor, P_6= P_3 + 200 mg of Aluminium Phosphide, P_7 = P_3 + 100 mg of Aluminium Phosphide, P_8 = P_3 + 2g/kg garlic bulb, P_9= P_3 + 2g/kg garlic bulb, P_{10}= Stored unhusked BR11 rice grain (Untreated control)]

From the above findings it revealed that the P_7 comprised with the use of Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg grains performed as the best IPM package in reducing the percentage weight loss of infested grain (98.36%) of Angoumois grain moth in storage of rice grains, which was statistically similar to P_6 (97.92%) that was comprised with the use of Aluminium phosphide @ 200 mg/kg grains along with neem leaf powder @ 2 g/kg grains. Considering the less health hazardous management, P_5 comprised with the use Camphor @ 500 mg/kg grains along with neem leaf powder @ 2 g/kg grains is better than P_7, because P_5 was comprised with botanical based package (both camphor and neem leaf) that ensured the less hazardous for human health and reduced more or less higher percentage (92.21%) of weight loss of infested grain in storage condition.

4.7. 3 Effect of IPM packages on variations of seed germination

Significant variation were observed among different IPM packages used in this study in terms of percent seed germination of unhusked rice due to Angoumois grain moth infestation at 180 DAIR. Since the day of insect initiation the percent seed germination of unhusked rice grain was recorded 91% in all the treatments i.e. no significant variation observed in all the treatments at 0 DAIR. At 180 DAIR, significant variation were observed in the treatments, the highest percent of seed germination was recorded 83.75% in P_6 which was statistically different from all other treatments and followed by P_7 (81.25%), P_5 (77.25%), P_4 (70.50%) and P_8 (62.00%). On the other hand, the lowest percent of seed germination was recorded 30.00% in P_{10}which was statistically different from all other treatments and followed by P_1 (34.00%), P_2 (54.50%), P_3 (56.50%) and P_9 (60.00%) (Table 4.7. 3).As a result, the order of performance of IPM packages against seed germination rate after 180 DAIR by Angoumois grain moth *S. cerealella* was Aluminium phosphide @ 200 mg/kg grains along with dried neem leaf power @ 2 g/kg grains(P_6) > Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg grains (P_7) > Camphor @ 500 mg/kg grains along with neemleaf powder @ 2 g/kg grains (P_5) >

Camphor @ 1000 mg/kg grains along with neem leaf powder @ 2 g/kg grains (P_4) > Garlic bulb (1/2 dosage rate of prev. exp.) along with neem leaf powder @ 2 g/kg grains (P_8) > Garlic bulb (1/2 dosage rate of prev. exp.) along with neem leaf powder @ 2 g/kg grains(P_9) > Stored BR11 unhusked rice grain with dried neem leaf powder @ 2g/kg (P_3) > Stored BR11 unhusked rice grain with dried neem leaf @ 2g/kg (P_2) > unhusked BR11 rice grain sundried for two hours (P_1) > Stored unhusked BR11 rice grain (Untreated control) (P_{10}).

Table 4.7.3 Variations of seed germination using fumigants against Angoumois grain moth

IPM packages	% seed germination		% reduction of seed germination at 180 DAIR over initial germination	% increase of seed germination over control at 180 DAIR
	Initial (before insect release)	180(DAIR)		
P_1	91	34.00 i	62.64	13.33
P_2		54.50 h	40.11	81.67
P_3		56.50 g	37.91	88.33
P_4		70.50 d	22.53	135.00
P_5		77.25 c	15.11	157.50
P_6		83.75 a	7.97	179.17
P_7		81.25 b	10.71	170.83
P_8		62.00 e	31.87	106.67
P_9		60.00 f	34.07	100.00
P_{10}		30.00 j	67.03	
CV (%)	**-**	**1.56%**	**-**	**-**
LSD (0.01)	**-**	**1.85**	**-**	**-**

*DAIR=Days after insect release; The numerical values in the column indicates the average values of four replications; [P_1= unhusked BR 11 rice grain sundried for two hours, P_2= Stored BR11 unhusked rice grain with dried neem leaf @ 2g/kg, P_3 = Stored BR11 unhusked rice grain with dried neem leaf powder @ 2g/kg, P_4 = P_3 + 1g/kg of camphor P_5= P_3 + 0.5g/kg of camphor, P_6= P_3 + 200 mg of Aluminium Phosphide, P_7 = P_3 + 100 mg of Aluminium Phosphide, P_8 = P_3 + 2g/kg garlic bulb, P_9= P_3 + 2g/kg garlic bulb, P_{10}= Stored unhusked BR11 rice grain (Untreated control)]

From these above findings it revealed that, lowest percent of seed germination increased over 0 DAIR was observed in P_1 (13.33%) which comprised with unhusked BR11 rice grain sundried for two hours. On the other hand, the highest percent of seed germination increased over 0 DAIR in P_6 (179.17%) which comprised with Aluminium phosphide @ 200 mg/kg grains along with neem leaf power @ 2 g/kg grains. Considering the less health hazardous management, P_5 comprised with the use Camphor @ 500 mg/kg grains along with neem leaf powder @ 2 g/kg grains is better than P_7, because P_5 was comprised with botanical based package (both camphor and neem leaf) that ensured the less hazardous for human health and reduced more or less higher percentage (90.14%) of grain infestation in storage condition.

Chapter V

Summary

CHAPTER V

SUMMARY

Seven experiments were conducted, one of which field survey in 16 districts of the Northern regions of Bangladesh, and six in the Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh were conducted during June 2013 to May 2016 to evaluate bio-ecology, damage assessment and management practices of Angoumois grain moth (*S. cerealella*). Based on the findings of the seven sets of experiments the study has been summarized as follows:

The study revealed for the field survey that out of 320 farmers 96.3% stored unhusked rice grains and 34% stored husked rice in their household storage. Most of the farmers (98%) faced insect pest infestation problem during storage of rice grains, among which 99% faced the problem of the infestation Angoumois grain moth. The infestation of rice grains by grain moth was around 10-20% as reported by 64% farmers. Most of the farmers (99%) reported that the grain moth infestation in storage generally initiated during summer season in stored rice and 99% farmers also reported that pick infestation was occurred during incissent rain. During preservation of rice grains in the storage, 100% farmers took preventive measures to protect the grains against infestation of grain moth, of which 91% farmers sun-dried the grains and 72% used neem leaf powder, 56% farmers stored better quality seeds and 42% stored in plastic container; among these preventive measures sun drying of the unhusked rice was the best method against grain moth for storing. In case of high infestation of rice grains caused by grain moth, 96% farmers took curative measures; among which 83% farmers sun-dried the rice grains and 67% used dry fumigant tablet like aluminium phosphide. Almost all (100%) of the farmers were aware about the method of application of fumigants during the storage of rice grains, of which 64% farmers reported that air tighten of the container was the best method during application of fumigants. Out of 320 farmers, 73% farmers were aware about the precautionary measures need to be taken during the application of fumigants, of which 44% farmers reported that air tighten was the most important precautionary measure. About 91% famers were aware about the eco-friendly management of grain moth in stored rice and most (83%) of them reported that sun-drying of the rice grains was the most important one followed by use of neem leaf powder as reported by 73% farmers. Among the locally available containers, 59% farmers reported that the bamboo duli was the most suitable container for preserving rice grains in storage followed by gunny bag as reported by 59% farmers.

The overall results for the study of bio-ecology of Angoumois grain moth, *S. cerealella* revealed that maximum duration for egg incubation were observed in January and February, larval period in December and January, pupal period in January and adult longevity of grain moth in June, October and March were observed in**.** Mean incubation period of Angoumois grain moth was 5.67 to 8 days, mean larval period was 15.6 days to 17.6 days, mean pupal period was 4.50 to 6.50 days, mean period of adult longevity was 7.17 to 8.58 days and mean longevity of total life span was 32.92 to 40.67 days. The highest reproduction rate per female adult of *S. cerealella* was found in June 2013 (139.20) and the lowest number of reproduction rate per adult was recorded in December 2013 (39.08).

The results for the study of varietal screening of rice grains indicated that the BRRI dhan 52 decreased the incidence of *Sitotroga cerealella*. Infested grain by number

(3.25%), percent weight loss of infested grain (1.69%) and increased percent seed germination (76.50%).

The results for the study on the suitability of commonly used containers for the protection of rice grain infestation against Angoumois grain moth revealed that the plastic pot was the most suitable container for storing rice grains in storage where the lowest grain infestation of rice by number (26%) and weight (9.23%) were recorded after 180 days storage against *Sitotroga cerealella.* Whereas highest infestation was recorded in gunny bag (49.75% and 20.17%, respectively), Simlarly, the lowest grain weight loss (21.68%) of infested grain but highest seed germination (31.75%) were also recorded in plastic containers. Conversely, lowest seed germination (4.50%) was recorded in gunny bag.

The results for the study of management of Angoumois grain moth on stored rice grains using botanicals revealed that the neem leaf powder @ 2g/kg rice grains was the most effective botanicals for the management of *Sitotroga cerealella* on rice grains in storage, where the lowest grain infestation by number (16.25%) and weight (9.23%) were recorded at 180 days after insect release (DAIR) in storage against *Sitotroga cerealella* and reduced 74.41% and 79.38% grain infestation by number and weight respectively over control at 180 DAIR. Whereas highest infestation was recorded in untreated control by number (63.50%) and weight (11.20%). Similarly, highest seed germination (81.0%) was also recorded in neem leaf powder @2g/kg rice grains, where highest increase (155.12%) of seed germination at 180 DAIR over control was also recorded. Conversely, lowest seed germination (31.75%) was recorded in untreated control.

The overall results from the study of management of Angoumois grain moth on stored rice grains using fumigants revealed that the Aluminium phosphide tablet @ 200/kg rice grains was the most effective fumigant for the management of *Sitotroga cerealella* on rice grains in storage, where the lowest grain infestation by number (3.50%) and weight (0.47%) were recorded at 180 days after insect release (DAIR) in storage against *S. cerealella* and reduced 93.07% and 94.39% grain infestation by number and weight respectively over control at 180 DAIR. Whereas highest infestation was recorded in untreated control by number (50.50%) and weight (8.38%). Similarly, the lowest grain weight loss (1.78%) of infested grain, but highest seed germination (83.75%) was also recorded in aluminium phosphide @ 200 mg/kg rice grains, where the highest reduction (91.14%) of grain content loss and the highest increase (160.19%) of seed germination at 180 DAIR over control was also recorded for aluminium phosphide. Conversely, the highest grain content loss (20.09%) but lowest seed germination (32.25%) was recorded in untreated control.

The overall results from the study of Integrated Management of Angoumois grain moth on stored rice grains revealed that the Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg rice grains was the most effective IPM packages for the management of *S. cerealella* on rice grains in storage, where the lowest grain infestation by number (1.50%) and weight (0.15%) were recorded at 180 days after insect release (DAIR) in storage against *Sitotroga cerealella* and reduced 97.18% and 98.36% grain infestation by number and weight respectively over control at 180 DAIR. Whereas highest infestation was recorded in untreated control by number (53.25%) and weight (9.12%). Similarly, the lowest grain weight loss (0.58%) of infested grain, but highest seed germination (81.25%) was also recorded in Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg rice grains, where the highest reduction (97.30%) of grain content loss at 180 DAIR over control was also recorded for Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg rice grains. But the highest increase (179.17%) of seed germination at 180 DAIR over control was also recorded for Aluminium phosphide @ 200 mg/kg grains along with dried neem leaf power @ 2 g/kg grains. Conversely, the highest grain content loss (21.49%) but the lowest seed germination (30.00%) was recorded in untreated control.

Chapter VI

Conclusion and Recommendation

CHAPTER VI

CONCLUSION AND RECOMMENDATION

CONCLUSIONS

Based on the findings of the seven sets of experiments, the following conclusions can be made:

- Most of the farmers of the Northern region of Bangladesh stored unhusked rice grains and small numbers stored husked rice in their household storage, of which all faced the problem of the infestation Angoumois grain moth.
- During preservation of rice grains in the storage, all farmers took preventive measures to protect the grains against infestation of grain moth, and majority used neem leaf powder.
- In case of high infestation of grain moth, almost all the farmers took curative measures such as sun-drying and not many of them used poisonous tablet like aluminium phosphide. The later being better and easy curative measure on their opinion
- Majority of the farmers were concerned with precautionary measures during the application of fumigants and use of airtight containers, the later being the most important precautionary measures.
- Most of the farmers practiced sun-drying of the rice grains as the most important eco-friendly management of grain moth in stored rice and they also follow use of neem leaf powder.
- The survey indicated that among the locally available containers, the bamboo duli and gunny bag were the most suitable container for preserving rice grains by farmers.

- The life cycle from egg to adult death averaged 32.92 to 40.67 days depending on the season which the durations from egg to pupal development ranged from 25.77 to 30.67 days. The highest and lowest egg laying was found in June and December respectively and showed the highest and lowest grain damage in summer and winter season.
- Three rice varieties such as BRRI dhan 52, BRRI dhan 60 and BRRI dhan 29 decreased the attack of *S. cerealella* resulting lowest grain damage, weight loss and increased seed germination. These varieties might be resistant to grain moth infestation and three hybrid varieties appeared to be highly susceptible.
- The plastic pot was the most suitable container for storing rice grains in storage where the grain infestation of rice and loss recorded lowest after 180 days storage against *S. cerealella,* whereas most common containers used by the farmers such as duli and and gunny bags were favourable for easy infestation of this insect pest.
- The neem leaf powder @ 2g/kg rice grains was the most effective botanical for the control of *S. cerealella* on rice grains in storage, where the lowest grain infestation by and weight loss were recorded at 180 days after insect release (DAIR) and reduced the highest grain infestation and weight loss over contro. The seed germination was not affected by this treatment.
- The Aluminium phosphide tablet @ 200 mg/kg rice grains was the most effective fumigant for the management of *S. cerealella* on rice grains in storage, where negligible grain infestation and weight loss were recorded at 180 days after insect release (DAIR). This fumigant was not favourable for seed germination.
- The Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg rice grains was the most effective package for the management of *Sitotroga cerealella* on rice grains in storage, where the lowest grain infestation and weight

loss were recorded at 180 days after insect release by reducing grain infestation and weight loss respectively over control.

- Neem leaf powder along with camphor @0.5 g/kg grains might be used as an alternative package. Neem leaf powder and garlic bulb might also be used as package for grain moth protection. Seed germination percentages with these packages of IPM were also acceptable.

RECOMMENDATIONS

Based on the findings and conclusions of the present study, the following recommendations can be made:

- Further intensive survey can be made by the inclusion of indepth investigation of storded rice and other agricultural stored products at household level as well as commercial purpose all over the country.
- Plastic containers should be recommended to preserve the grains at household level against Agoumois grain moths and other insect pests;
- Further investigation may be made to find out the resistance factor(s) of rice varieties against *S. cerealella;*
- Neem leaf powder and Camphor should be recommended as botanical products to prevent the infestation of Angoumois grain moth during storage of rice grains in airtight containers;
- The Aluminium phosphide @ 100 mg/kg grains along with neem leaf powder @ 2 g/kg rice grains may be recommended as effective integrated package for the management of *Sitotroga cerealella* on rice grains in storage.

Chapter VII

References

CHAPTER VII

REFERENCES

Abivardi, C. 1977. Effect of camphor on embryonic and post-embryonic development *Callosobruchus chinensis* (L.) *J. Econ. Entomol.* **6**(3): 818-820.

Adeyemo, A.C., Ashamo, M.O. and Odeyemi, O.O. (2015). Screening of selected properties of some paddy rice varieties for their resistance against *Sitotroga cerealella* (Olivier) attack in storage. *FUTA J. Res. Sci.* **11**(ii): 210-216.

Akter, T. and Jahan, M. (2013). Toxicity effect of commonly used indigenous plant extracts in controlling grain moth, *Sitotroga cerealella* Oliv. in stored rice grain. *Intl. J. Sust. Agric*. **5**: 10–15.

Akter, T., Jahan, M. and Bhuiyan, M.S.I. (2013). Biology of the Angoumois grain moth, *Sitotroga cerealella* (Oliver) on stored rice grain in laboratory condition. *J. Asiatic. Soc. Bangladesh Sci.* **39**(1): 61-67.

Alder, C., Corinth, H. and Reichmuth, C. (2000). Modified atmospheres. **In:** Alternatives to pesticides in stored-product IPM. Subramanyam, B. H. and Hagstrum, D. W. (Eds.). Kluwer Academic Publishers, Boston. pp. 105-146.

Andrews, A.S., Annis, P.C. and Newman, C.R. (1994). Sealed storage technology on Australian farms. Proc. Int.symp. on stored-product protection. Highley, E., Wright, E. J., Banks, H. J. and Champ, B. R. (Eds.). CABI International, Wallingford. pp.: 27-36.

Anon., (2009). Major uses of pesticides registered under the Insecticides Act, 1968. Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, Directorate of Plant Protection, Quarantine and Storage, Central Insecticide Board and Registration Committee. pp.66.

Arivudainambi, N.M. and Singh, R.P. (2005). Fumigant toxicity of neem (*Azadirachta indica*) seed oil volatiles against grain moth, *Sitotroga cerealella*. *J. Ecotox. Environ. Moni.* **15**(i): 91-98.

Arthur, F.H., Throne, J.E., Maier, D. E. and Montross, M.D. (1998). Feasibility of aeration for management of maize weevil populations in corn stored in the southern United States: model simulations based on recorded weather data. *American. Entomol*. **44**: 118–123.

Arthur, F.H., Throne, J.E., Maier, D.E. and Montross, M.D. (2001). Impact of aeration on maize weevil (Coleoptera: Curculionidae) populations in corn stored in the northern United States: simulation studies. *American. Entomol*. **47**: 104–110.

Arthur, F.H., Bautista, R.C. and Siebenmorgen, T.J. (2007). Influence of Growing Location and Cultivar on *Rhyzopertha dominica* (Coleoptera: Curculionidae)

Infestation of Rough Rice. *J. Compil. Intl. Zool.* Chinese Academy of Sciences, **14**: 231-239.

Ashamo M.O. and Khanna S.C. (2006b). Resistance to the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) in some paddy varieties. *Annals. Plant Protect. Sci.* **14** (ii): 368–373.

Ashamo, M.O. (2009). Relative resistance of paddy varieties to *Sitotroga cerealella* (Lepidoptera: Gelechiidae), Division of Entomology, Indian Agricultural Research Institute (IARI). *New Delhi Biologia.* **65**(ii): 333-337.

Ashamo, M.O. (2010). Relative resistance of paddy varieties to *Sitotroga cerealella* (Lepidoptera: Gelechiidae). *Biologia*. **65**(ii): 333-337.

Ashamo, M.O. and Akinnawonu, O. (2012). Insecticidal efficacy of some plant powders and extracts against the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *Arch. Phytopathol. Plant Protect*. **45**: 1051–1058.

Aviles, R. and Guilbert, G. (1986). Crop residues as a reservoir of pest of stored rice. *Rev. Appl. Entomol*. **79**(xii): 1098.

Banks, H.J.(1984). Fumigation and the properties of gases. Proc. Australian Development Assistance Course on the Preservation of Stored Cereals, vol. 2. CSIRO Division of Entomology, Canberra, Australia, pp.739–753.

Banks, H.J. and Fields, P.G. (1995). Physical methods for insect control in stored grain ecosystem. **In**: Stored-grain Ecosystems. Jayas, D.S., White, N.D.G. and Muir, W. E. (Eds.). Marcel-Dekker Inc, New York. pp.353-410.

Bartosik, R. (2012). An inside look at the silo-bag system. In: Navarro, S., Banks, H.J., Jayas, D.S., Bell, C.H., Noyes, R.T., Ferizli, A.G., Emekci, M., Isikber, A.A., Alagusundaram, K. (eds.). Proceedings 9th international conference on controlled atmosphere and fumigation in stored products, Antalya, Turkey. 15-19 October 2012, ARBER Professional Congress Services, Turkey. pp.117-128.

Baskaran, R.K.M. and Janarthanan, R. (2000). Effect of dust formulations of certain plant oils against important pests of paddy and cowpea in storage. *J. Entomol. Res.* **24**(iii): 271-278.

BBS (Bangladesh Bureau of Statistics). 2012. Statistical Yearbook of Bangladesh (32^{nd} ed.). Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Government of the people's republic of Bangladesh, Dhaka. 132 pp.

Bhuiyah, M.I.M., Alam, S. and Karim, A.N.M.R. (1992). Losses to stored rice caused by rice weevil and Angoumois grain moth, and their control in Bangladesh. *Bangladesh J. Agric. Sci.* **19**(i): 13-18.

Boldt, P.E. (1974). Effects of temperature and humidity on development and oviposition of *Sitotroga cerealella* (Lepidoptera: Gelechiidae). *J. Kansas Entomol. Soci*. **47**(i): 30-36.

BRRI (Bangladesh Rice Research Institute). 1984. Annual Report. Bangladesh Rice Research Institute, Joydebpur, Gazipur, pp. 135-139.

Buckley, S. and Thoms, E. (2012). Current status of ProFume® gas fumigant for disinfestation of commodities. **In**: Proc. 9th intl conference on controlled atmosphere and fumigation in stored products, Antalya, Turkey. Status of fumigation in stored grains in India. 15-19 October 2012, ARBER Professional Congress Services, Turkey. pp. 241-246.

Bushra, S. and Aslam, M. (2014). Management of *Sitotrogacerealella* in stored cereal grains: a review. *Arch. Phytopath. Plant Protect.* **47**(19): 2365-2376.

Canadian Grain Commission (CGC). (2013). Angoumois grain moth (*Sitotroga cerealella*) Olivier. https://www.grainscanada.gc.ca/storage-entrepose/pip-irp/agm-adg-eng.htm. PP.26-27.

Chander, H., S. G. Kulkarni and S.K. Berry. 1991. Effectiveness of turmeric powder and mustard oil as protectant in stored milled rice against the rice weevil, *Sitophilus oryzae* Linn. *Intl. Pest Control*. 33(4): 94-97.

Chandra, S., B.P. Khare and V.K. Sharma. 1978. Efficacy of some selected fumigants on rice-weevil, *Sitophilus oryzae* Linn. *Indian J. Agril. Res.* 12(2): 79-84.

Chatterji, S.M., Dani, R.C. and Govindaswami, W. (1977). Evaluation of rice varieties for resistance to *Sitotroga cerealella* oliv. (Lepidoptera: Gelechiidae). *J. Entomol. Res*. **1**(i): 74-77.

Chi, Y.M. and Chen, L.K. (2000). Evaluation of deltamethrin and phoxim dust mixed with bagged rough rice for control of storage insects. *Chinese J. Entomol.* **20**(4): 255-266.

Cogburn, R.R. (1974). Domestic rice varieties: Apparent resistance to rice weevils, lesser grain borers and Angoumois grain moths. *Environ. Entomol*. **3**: 681-685.

Cogburn, R.R. 1975. Stored rice insect research, *The Rice J*. 7:78

Cogburn, R.R. (1977). Resistance to the Angoumois grain moth in some varieties of rough rice from the USDA world collection. *J. Econ. Entomol*. **70**: 753-754.

Cogburn, R.R. (1977). Susceptibility of varieties of stored rough rice to losses caused by storage insects. *J. Stor. Prod. Res*. **13**(1): 29-34.

Cogburn, R., Bollich, C.N., Johnston, T.H. and Mcilrath, W.O. (1980). Environmental Influences on Resistance to *Sitotroga cerealella* in Varieties of Rough Rice. *Environ. Entomol*. **9** (5): 689-693.

Cogburn, R.R., Bollich, C.N. and Meoln, S. (1983). Factors that affect the relative resistance of rough rice to Angoumois grain moths and lesser grain moth. *Environ. Entomol*. **12**(3): 936-942.

Cogburn, R.R. (1988). Fenoxycarb as a long term protectant for stored rough rice. *J. Econ. Entomol.* **81**(2): 722-726.

Cohen, L.M. and Russell, M.P. (1970). Some effects of rice varieties on the biology of the Angoumois grain moth, *Sitotroga cerealella*. *Ann. Entomol. Soci. American.* **63**: 930–931.

Collins, P.J., Daglish, G.J., Pavic, H., Lambkin, T.M. and Kapittke, R.(2002). Combating strong resistance to phosphine in stored grain pests in Australia. In: Wright, E.J., Banks, H.J., Highley, E. (Eds.), Stored Grain in Australia 2000. Proceedings of the Australian Postharvest Technical Conference, Adelaide, 1–4 August 2000. CSIRO Stored Grain Research Laboratory, Canberra, Australia, pp.: 109–112.

Cox, P.D. and Bell. C.H. (1991). Biology and Ecology of Moth Pests of Stored Food, 181-193. **In**: J. R. Gorham (Ed). Ecology and Management of Food-Industry Pests. FDA Technical Bulletin 4. VA: Association of Analytical Chemists.

Crombie, A.C. (1943). The development of Angoumois grain moth *Sitotroga cerealella* Oliv. *Nature*. **152** (3852): 246.

Dakshinamurthy, A. (1988). Effect of certain plant products on storage pests of paddy. Tropical Sci. **28**(2): 119 - 122.

Dakshinamurthy, A. and Regupathy, A.(1992). Pre-harvest spray of insecticides for the management of *Sitotroga cerealella* Olivier on rice. **In**: Bioecology and control of insect pests, Proc.National Symposium on Growth, Development and Control Technology of Insect Pests [edited by Goel, S. C.] Muzaffarnagar, India; Uttar Pradesh Zoological Society. pp. 218-224.

Damcevski, K., Dojchinov, G. and Haritos, V.S.(2003). VAPORMATETM, a formulation of ethyl formate with CO_2, for disinfestation of grain. **In**: Stored Grain in Australia 2003. Proc. Australian Postharvest Technical Conference, Canberra, 25–27 June 200. Wright, E.J., Webb, M. C., Highley, E. (Eds.). 3. CSIRO Stored Grain Research Laboratory, Canberra, pp. 199–204.

Demissie, G., Rajamani, S. and Ameta, P.O. (2014). Effect of temperature and relative humidity on development and survival of Angoumois grain moth, *Sitotroga cerealella* (olivier) (Lepidoptera: Gelechiidae) on stored maize. *Intl. J. Sci.: Basic and Applied Res.* **15**(2): 9-21.

Demissie, G., Swaminathan, R. and Ameta, O.P. (2015). Efficacy of inert dusts against Angoumois grain moth in stored maize. *Indian J. Entomol.* **77**(3): 255-261.

Desmarchelier, J. M.(1994). Carbonyl sulphide as a fumigant for control of insects and mites. **In**: Highley, E., Wright, E.J., Banks, H.J., Champ, B. R. (Eds.). Stored Product Protection, Proceedings of the Sixth International Working Conference on Stored-product Protection, 17–23 April 1994, Canberra, Australia, CAB International, Wallingford, UK, pp.: 75–81.

Dharmasena, C.M.D. and Abeysiriwaedena, D.S. de Z. (2003). Effect of variety, grain moisture and packing material on weight and storage pests of rough rice during storage. *Annal. Sri Lanka Dept. Agic.* **5**: 57-67.

Dhotmal, N.J. and Dumbre, R.B. (1982). Laboratory studies on the bionomics of Angoumois grain moth, *Sitotroga cerealella* Oliv. on different rice varieties (Lepidoptera: Gelechiidae). *Bull. Grain Tech*. **20**(i): 220 -222.

Dilwari, V.K., D. G. Dhaluiwal and M. S. Maha. (1991). Toxicity of allylisothiocyanate to rice weevil, *Sitophylus oryzae* Linn. *J. Ins. Sci.* **4**(1): 101-102.

Douglas, W. A. (1941). Field infestation of insects that injure rice in storage. *Circ. USDP*, No. 602, p. 8.

El-Dessouki, S.A. and El-Kifl, A.H. (1976). *Sitotroga cerealella* infestation and its influence on certain chemical and physical properties of stored wheat in Egypt. *Zeitschrift Angewandte Entomologie.* **80**: 83-88.

Emana, G. (1993). Studies on the distribution and control of Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) in Sidama administrative region. M. Sc. Thesis, Alemaya University of Agriculture, Alemaya, Ethiopia. 11-23.

Evans, D.E. (1987). Stored Products. In: Burn, A.J., Coaker, T.H., Jepson, P.C. eds. Integrated Pest Management. London: Academic Press. pp. 18-25.

Fadamiro, H.Y. and Baker, T.C. (2002). Pheromone puffs suppress mating by *Plodiainter punctella* and *Sitotroga cerealella* in an infested corn store. *Entomologia Experimentaliset Applicata.* **102**(3): 239-251.

FAO (Food and Agricultural Organisation).(1975). Recommended methods for the detection and measurement of resistance of agricultural pests to pesticides. Tentative method for adults of some major pest species of stored cereals, with methyl bromide and phosphine—FAO Method No. 16. FAO Plant Protection Bulletin 23, pp. 12–25.

Ferreira, E., Vieira, N.R. and Castro, E.M. (1997). Intensity of the attack of *Sitotroga cerealella* (Olivier) in rice genotypes and its effect on seedling emergence. *Intl. Rice Res*. **22**: 25.

Fields, P. (2006). Alternatives to chemical control of stored-product insects in temperate regions. **In**: Proceedings of the ninth international working conference on stored-product protection. Lessard, F. F., Tomasini, B., Kostine, L. and Fuzeau, B. (Eds.). CABI International, Wallingford. pp.: 653-662.

Fields, P.G. and White, N.D.G. (2002). Alternatives to methyl bromide treatments for stored product and quarantine insects. *Annal. Rev. Entomol.* **47**: 331-359.

Fletcher, T.B. and Ghosh, C.C. (1919). Stored grain pest. *Proc. III entomol. Meetg*. pp. 712 – 761.

Flinn, P.W., Subramanyam, B. and Arthur, F.H. (2004). Comparison of aeration and spinosad for suppressing insects in stored wheat. *J. Econ. Entomol.* **97**: 1465-1473.

G. C., Y. (2006). Efficacy of indigenous plant materials and modified storage structures to insect pests of maize seed during on-farm storage. *J. Inst. Agric. Anim. Sci.* **27**: 69-76.

Gemechu, F., Waktole, S. and Santiago, D.R. (2013). Efficacy of botanical powders and cooking oils against Angoumois grain moth, *Sitotroga cereallela* Oliv. (Lepidoptera: Gelechiidae) in stored maize. *Afr. J. Biotech*. **12**: 1978–1986.

Gemu, M., Getu, E., Yosuf, A. and Tadesse, T. (2013). Management of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) and *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) using locally available agricultural wastes in Southern Ethiopia. *J. Agric. Crop Res*. **1**: 10–16.

Germanov, A. (1982). Development and behavior of larvae of Angoumois grain moth, *Sitotroga cerealella* Oliv. under conditions of mass rearing. *Rasteniev dni Naeuki*. **19**(5): 87 -95.

Getu, E. (1993). Studies on the distribution and control of Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) in Sidamo Administrative Region [thesis (MSc, Crop Protection)]. 14 Tables; 4 Figs.; 107 Ref. Summary (En). Addis Ababa: Information Serices, IAR, POB 2003.

Gillani, W.A. and Irshad, M. (1990). Reactions of rice varieties to rice moth *Sitotroga cerealella. Intl. Rice Res. Newsl.* **15**: 8.

Girish, G. K., Tripathi, B.P., Tomer, R.P.S. and Krishnamurthy, K. (1974). Studies on the assessment of losses of conventional grain storage practices and losses in rural areas in Uttar Pradesh. *Bull. Grain Tech*. **12**(3): 199-210.

Golob, P. and Muwalo, E. (1984). Pirimiphos-methyl as a protectant of stored maize cobs in Malawi. *Intl. Pest Control.* **26**(4): 94-96.

Gomez, L.A., Rodriguez, J.G., Poneleit, C.G., Blake, D.F. and Smith, C.R.J. (1983). Influence of nutritional characteristics of selected corn genotypes on food utilization by the rice weevil (Coleoptera:Curculionidae). *J. econ. Entomol.* **76**: 728-732.

Grewal, S.S. and Atwal, A.S. (1967). The influence of temperature and humidity on the development of *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *J. Res*. **6**: 353–358.

Grinberg, S.M. and Palii, M.V. (1981). Increasing the yield of eggs of the grain moth. *Zashchita Rastenii.* **12**: 32-33.

Grundy, D.L. and Still, C.C.(1985). Inhibition of acetylcholinesterases by pulegone-1,2-epoxide. pesticide biochemistry and physiology 23. pp. 383–388.

Hammad, S.M., Shenouda, M.G.H. and El-Deeb, A.L. (1967). Studies on the biology of *Sitotroga cerealella*. *Bull. Soci. Entomol. d'Egypte*. **51**: 257-268.

Hansen, L.S., Henrik, S. and Hell, K. (2004). Life Table Study of *Sitotroga cerealella* (Lepidoptera: Gelechiidae), a strain from West Africa. *J. Econ. Entomol*. **97**(4): 1484 - 1490.

Hasan, M.I. (2011). Eco-friendly management of Angoumois grain moth, *Sitotrogam cerealella* Olivier using some botanicals and fumigants on stored paddy. M. S. thesis. Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. p. V.

Henckes, C. (1992). Investigations into insect population dynamics, damage and loss of stored maize: an approach to IPM on small farms in Tanzania with special reference to *Prostephanus truncatus* (Horn). Thesis, Deutsche Gesellschaft fur Technische Zusammenarbeit, Projekt fur Nacherntefragen (GTZ), Hamburg, Germany. pp. 124.

Hill, D.S. (1990). Pests of stored products and their control. S.K. Jain for CBS Publishers & Distributors (Pvt.) Ltd. New Delhi, India. pp. 152-153.

Hossain, M.I. (2011). Eco-friendly management of Angoumois grain moth, *Sitotroga cerealella* Olivier using some botanicals and fumigants on stored paddy. M. S. thesis. Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. p. V.

Houghton, P.J., Ren, Y. andHowes, M.J. (2006). Acetylcholinesterase inhibitors from plants and fungi. *Natural Products Reports.* **23:** 181–199. https://www.agric.wa.gov.au/sites/all/modules/custom/seed_tools/pestweb/-667089907.html

Hung, C.C., Hsieh, F.K. and Hwang, J.S. (1990). Stored grain insects monitoring and their chemical control. *Chinese J. Entomol.* **10**(2): 169-179.

Imdorf, A., V. Kilchenman, S. Bogdanor; B.Bachofen and C. Beretta. 1995. Toxic effects of thymol, camphor, menthol and eucalyptol on *Varroa jacobsoni* Oud. and *Apis mellifera* Linn. in a laboratory test. *Apidologie.* **26**(1): 27-31.

Iqbal, J., Jilani, G. and Aslam, M. (2010). Growth inhibiting effects of plant extracts against the grain moth, *Sitotroga cerealella* (Oliv.) (Gelechiidae: Lepidoptera). *Pakistan. J. Zool*. **42**: 597–601.

Irshad, M., Talpur, S. and Gillani, W.A. (1989). Resistance in different rice genetic lines to rice moth *Sitotroga cereallela* (Oliv.). *Intl. Rice Res. Newsl*. **14**(5): 16.

Jamir, I.T.A., Ao, M.A. and Khound, J.N. (2013). Management practices against Angoumois grain moth, *Sitotroga Cerealella* (Olivier) in stored paddy in Nagaland, India. *Intl. J. Bio-Res. Stress Manage.* **4**(1): 58-63.

Jha, A.N., Palta, R.K. and Singh, V.S. (2006). Relative susceptibility of some promising cultivars of rice to *Sitotroga cerealella* (Olivier) under storage conditions. *Indian J. Entomol.* **68**(3): 304-306.

Jilani, G. (1986). Use of botanicals for protection of stored food grains against insect pests: A review. *Grain Storage Research Laboratory*. PARC, Karachi, Pakistan. pp. 30 - 35.

Jilani, G. and Saxena, R.C. (1987). Derivatives of neem, turmeric and sweetflag as grain protectant against stored grain insect pests. International Rice Research Institute, Los Nanos, Manila (Philippines). pp.1.

Jin, L. Z. and Pan, X. F. (1983). A new measure on the control of grain storage insects by marsh gas. *Insect Knowledge (Kunchong Zhishi).***20**(3):118-119.

Ketkar, C.M. (1976). Utilization of neem (*Azadirachta indica* A. Juss) and its by products. VIC, Bombay, India. pp. 234.

Khatak, S.U. and Shafique, M. (1981). Susceptibility of some wheat varieties to Angoumois grain moth, *Sitotroga cerealella* (Olive.) (Lepidoptera: Gelechiidae). *Pakistan J. Zool*. **13**: 99-103.

Koleva, L. and Ganeva, G. (2009). A Study on the Life Cycle of Angoumois Grain Moth *Sitotroga cerealella* Oliv. (Lepidoptera: Gelechiidae) during Feeding on different wheat genotypes (*Triticum aestivum* L.). *Plant Science.* **46**(2).

Kostyukovsky, M., Rafaeli, A., Gileadi, C., Demchenko, N. and Shaaya, E. (2002). Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. *Pest Manage. Sci.* **58:** 1101–1106.

Koul, O.(2004). Biological activity of volatile di-n-propyl disulfide from seeds of neem, *Azadirachta indica* (Meliaceae), to two species of stored grain pests, *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst). *J. Econ. Entomol.* **97:** 1142–1147.

Krishnamurthi, B. and S. D. Rao, 1950. Some important insect pests of stored grains and their control, *Entomol. Series Bull*., No. 14, Agric. College & Research Institute, Mysore, Bangalore. pp. 123-138.

Lal, R., Vaidya, D.N. and Mehta, P.K. (2000). Relative abundance and extent of losses in unhusked rice due to stored grain insect pests in Kangra district of Himachal Pradesh. *Pest Manage. Econ. Zool.* **8**(2): 129-132.

Lee, S., Peterson, C.J. and Coats, J.R. (2003). Fumigation toxicity of monoterpenoids to several stored product insects. *J. Stored Products Res.* **39:** 77–85.

Lee, B.H., Annis, P.C., Tumaalii, F. and Lee, S.E. (2004). Fumigant toxicity of *Eucalyptus blakelyi* and *Melaleucafulgens* essential oils and 1,8-cineole against different development stages of the rice weevil *Sitophilus oryzae*. *Phytoparasitica.* **32:** 498–506.

Leelaja, B.C., Rajashekhar, Y., Reddy, V.P., Begum, K. and Rajendran, S. (2007). Enhanced fumigant toxicity of allyl acetate to stored-product beetle pests in the presence of carbon dioxide. *J. Stored Products Res.* **43**: 45-48.

Mahdi, M.T. and El-Najjar, S.J.T. (1988). The effect of certain varieties of wheat and barley on the biology of the laboratory reared first generation of Angoumois grain moth, *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae). *Arab J. Plant Protect*. **6**(2): 64-70.

Mason, L.J. (2010). Angoumois Grain Moth. Purdue Extension, E-236-W. http://extension.entm.purdue.edu/publications/E-236.pdf

Mason, L. and McDonough, M. (2011). Biology, behavior and ecology of stored grain and legume insects. K- State Research & Extension. **156**(2): 1-14.

Medina, E.B. and Heinrichs, E.A. (1986). Reaction of IR varieties to Angoumois grain moth. *Intl. Rice Res. Newsl*. **11**(2): 10.

Mendoza, P.J., Weaver, K.D. and Thorn, E.J. (2004). Development and survivorship of immature Angoumois grain moth (Lepidoptera: Gelechiidae) on stored corn. *Environ. Entomol*. **33**(4): 807-814.

Mohapatra, H. and Khare, B.P. (1989). Effect of some wheat cultivars on the growth and development of Angoumois grain moth, *Sitotroga cerealella* Olivier. *Indian J. Plant Protect*. **14**: 259-262.

Mondragon, I. and Almeida, A.A. (1988). Influencia de dos temperaturas en el desarrollo de *Sitotroga cerealella* (Olivier, 1819) (Lepidoptera, Gelechiidae) en maiz almacenado. *Annal. Soci. Entomol. do Brasil*, **17**: 397-407.

Muda, A.R. (1985). Pest problems and the use of pesticides in grain storage in Malaysia. **In:** ACIAR Proceedings Series, Australian Centre for International Agricultural Research. **14**: 11-16.

Mukherjee, P.B., Jotwaqni, M.G., Sircar, P. and Yadav, T.D. (1970). Studies on the insecticides and extent of damage due to insect pest in stored seeds. *Biol. Abst.* **51**(17): 9497.

Nualvatna, K., Makathan, N., Chavapradit, C., Kitkuandee, K. and Uraichuan, J. (2003). The use of light traps for attracting stored-product insects in a rice mill and paddy seed stores. **In:** Advances in stored product protection Proceedings of the 8th International Working Conference on Stored Product Protection, UK, 22-26 July, 2002. pp. 244-247.

Palaniswamy, P.T. and Dakshinamurthy, A. (1986). Biogas to control rice storage pests. *Intl. Rice Res. News.* **11**(6): 25.

Pandey, V., Nigam, P.M., Awasthi, B.K. and Ram, S. (1980). Comparative resistance of paddy varieties to *Sitotroga cerealella* Olivier. *Bulletin Entomol*. **21**(1/2): 132-134.

Paneru, R. B., Duwadi, V.R., Khanal, R. and Bhandari, M.R. (1996). Testing of the efficacy of some materials against weevil in stored rice grain. PAC working paper no. 139, Dhankuta, Nepal. pp. 32-48.

Pitkin, B. and Jenkins, P. (2004). Butterflies and Moths of the World, Generic Names and their Type-species – Sitotroga.Version of 2004-Nov-05. Retrieved 2010-Apr-30.pp. 115-128.

Plarre, R. and Reichmuth, F. (2000). Impact. **In**: Alternatives to pesticides in stored-product IPM. Subramanyam, B.H. and Hagstrum, D.W. (Eds.). Kluwer Academic Publishers, Boston. pp.: 401-428.

Podoler, H. and Applebaum, S.W. (1968). Physiological aspects of host specificity in *Bruichidae* Varietal differences in the resistance of *Vicia faba* L. to *Callosobrochus chinensis* L. *J. Stored Prod.Res*. **4**(1): 9-11.

Prakas, A., I. C. Mathur. 1981. Plant products in insect pests management of stored grains. Bull. *Grain Technol*. **19**(3): 213-219.

Prakash, A., Pasalu, I.C. and Mathur, K.C. (1981). Plant products in insect pests management of stored grains. Bull. *Grain Technol*. **19**(3): 213-219.

Prakash, A. and I. P. Kauraw, 1982. A package of practices for pest management in rice storage. Farmers and Parliament. 17(11): 15-16.

Prakas, A, and J. Rao. 1983. Insect pests and their management in rice storage in India, presented in National Symposium on Maximising and Stabilising of yields on rain fed rice production system held at CSRRI, Cuttack (India) on Feb. 23-25, 1983.

Prakas, A., I. C. Pasalu and Jagadiswari Rao. 1984. The pest status of insects infesting rice stored in Orissa (India). *Tropical Stored Prod. Inf.* **47**(1): 15-20.

Prakash, A., Pasalu, I.C. and Jagadiswar, R. (1984). The pest status of insects infesting rice stored in Orissa (India). *Tropical Stored Prod Inf*. **47**: 15-20.

Prakash, A. and Rao, J. (1984). Wild sage, *Lippiageminata*: a paddy grain protectant in storage. *Oryza*. **21**(4): 209-212.

Prakas, A., Jagasdiswari Rao and J. P. Kulsthrestha. 1986. Evaluation of Plant products for management of rice storage insects, Presented in Research Planning Works on Botanical Pest Control in rice based cropping system on 9-13 June (1986) at International Rice Res. Inst., Manila, Philippines, p. 15.

Prakash, A, J. Rao, I. C. Pasalu and K. C. Mathur. 1987. Rice Storage and insect pest management. B. R. Publishing Corporation. Delhi, pp. 15-60.

Prakash, A., Rao, J., Pasalu, I.C. and Mathur, K.C. (1987). Rice storage and insect pest management. Delhi: B.R. Publishing Corporation; pp. 15–60.

Prakash, A. and Rao, J. (2006). Exploitation of newer botanicals as rice grain protectants against Angoumois grain moth, *Sitotroga cerealella* Oliv. *Entomol*. **31**: 1–8.

Ragumoorthy, K.N. and Gunathilagaraj, K. (1988). Field incidence of and host resistance to Angoumois grain moth (AGM). *Intl. Rice Res. News*. **13**(4): 12.

Rahman, S.M.M., Siddika, A., Kundu, R. and Akter. T. (2006). Efficacy of some additives for suppression of Angoumois grain moth infestation in stored rice grain. *Intl. J. Sustainable Agril.Tech*. **2**(3): 27-31.

Rai, A., Chaudhuri, N. and Ghosh, J. (2011). Effect of feeding of different rice varieties on biology of Angoumois grain moth (*Sitotroga cerealella* Olivier.) in terai region of West Bengal, India. *Intl. J. Bio-Res. Stress Manage.* **2**(4): 397-402.

Rajasri, M., Rao, P.S. and Kumari, M.K.V.S. (2014). Inert dust-better alternatives for the management of Angoumois grain moth, *Sitotroga cerealella* in stored rice. *Intl. J. Sci. Res.* **3**(10): 278-283.

Rajendran, (2007). Benchmarking- what makes a good fumigation? **In**: Donahaye, E.J., Navarro, S., Bell, C., Jayas, D.S., Noyes, R., Phillips, T. W. (Eds.). Proc. Intl. conference on controlled atmosphere and fumigation in stored products, Gold- Coast Australia. 8-13th August 2004. FTIC Ltd. Publishing, Israel. pp.: 345-365.

Rajendran, S. and Sriranjini, V. (2008). Plant products as fumigants for stored-product insect control. *J. Stored Products Res.* **44**(2): 126-135.

Rajendran, S., Lalith Kumar, V. and Sriranjini, V. (2008). Fumigation of grain stacks with sulfuryl fluoride. *Intl. Pest Control.* **50**(4): 192-195.

Rajendran, S. (2016). Status of fumigation in stored grains in India. *J. Grain Storage Res.* (Status paper). pp.: 28-38.

Rao, J. and Prakash, A. (2001). Goat weed, *Ageratum conyzoides* Linn. (Asteraceae): a rice grain protectant against storage insects. *J. Appl. Zool. Res.* **12**(2/3): 152-156.

Reed, C. and Arthur, F.H. (2000). Aeration. In: Alternatives to pesticides in stored-product IPM. Subramanyam, B.H. and Hagstrum, D.W. (Eds.). Kluwer Academic Publishers, Boston. pp. 51-72.

Regnault-Roger, C. and Hamraoui, A. (1995). Fumigant toxic activity and reproductive inhibition induced by monoterpenes on *Acanthoscelidesobtectus* (Say) (Coleoptera), a bruchid of kidney bean (*Phaseolus vulgaris* L.). *J. Stored Products Res.***31:** 291–299.

Rizwana, S., Hamed, M., Naheed, A. and Afghan, S. (2011). Resistance in stored rice varieties against Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *Pakistan J. Zool.* **43**(2): 343-348.

Rubbi, S.F and Begum, S.S. (1986). Effect of insect infestation on stored IRRI-8 paddy. *Bangladesh J. Zool*. **14**(2): 181-182.

Russell, M.P. (1976). Resistance of commercial rice varieties to *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *J. Stored Prod. Res*. **12**(2): 105-109.

Ryan, R., Grant, N., Nicolson, J., Beven, D. and Harvey, A. (2006). Sterigas TM and Cosmic TM: update on proposed new fumigants. **In**: Lorini, I., Bacaltchuk, B., Beckel, H., Deckers, D., Sundfeld, E., dos Santos, J.P., Biagi, J.D., Celaro, J.C., Faroni, L.R.D'A., Bartolini, L. de O. F., Sartori, M.R., Elias, M.C., Guedes, R.N.C., De-Fonseca, R.G., Scussel, V.M. (Eds.). Proceedings of the Ninth International Working Conference on Stored Product Protection, 15–18 October 2006, Sao Paulo, Brazil, Brazilian Post-harvest Association, Campinas, Brazil, pp. 624–629.

Saha, S. K. 1999. Determination of fumigation toxicity, vertical mobility and protection efficacy of camphor against different stages of *Callosobruchus chinensis* Linn. on chickpea. M. S. Thesis, 74p.

Saikia, J., Goswami, M.M. and Bhattacharyya, B. (2014). Biology and detection technique of Angoumois grain moth, *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae) on stored rice and maize grains. *J. Entomol. Zool. Studies.* **2**(6): 09-11.

Santos, C. Agbangla, C. Chougourou, D. Togola, A. Cisse, B. Akintayo, I. and Nwilene, F.E. (2014). Resistance of Upland NERICAs and Parents to Rice Weevil and Angoumois Grain Moth. *J. Entomol*. **11**(6): 345-354.

Santos, C., Agbangla, C., Chougourou, D., Missihoun, A. and Ahanhanzo, C. (2015). Influence of Agro Ecology on Rice Varietal Resistance to *Sitophilus oryzae* (Coleoptera: Curculionidae) and *Sitotroga cerealella* (Lepidoptera: Gelechiidae) in Benin. *American J. Plant Sci.* **6**(18)**:** 2832-2843.

Sardar, M. A. (1976). Susceptibility of certain varieties of stored rice to rice moth, *S. cerealella*. *Indian J. Entomol*. **34**(4): 388-390.

Sauphanor, B. (1989). Possibilités d'amélioration de la résistance variétale du riz aux insectes des stocks. In: AUPELF- UREF, Ed., Céréales en régions chaudes, John Libbey Eurotext, Paris, 131-140.

Schulten, G.G.M. (1973). Beginning and progression of maize infestation. *Trop. Stor. Prod. Info*. **25**: 16-17.

Scriber, J.M. and Slansky, Jr. F. (1981). The nutritional ecology of immature insects. *Annal. Rev. Entomol*. **26**: 183-211.

Shaaya, E., Kostjukovski, M., Eilberg, J. and Sukprakarn, C. (1997). Plant oils as fumigants and contact insecticides for the control of stored-product insects. *J. stored Prod. RCS*. **33**: 7–15.

Shafique, M. and Ahmad, M. (2003). Susceptibility of milled rice genotypes to Angoumois grain moth, *Sitotroga cerealella* Oliv. (Lepidoptera: Gelechiidae). *SAARC J. Agric*. **1**: 193-197.

Shafique, M. and Chaudry, M.A. (2007). Screening of rice genotype for resistance to storage insects. *Pakistan Entomol*. **29**(1): 19-21.

Shahjahan, M. (1974). Extent damage of unhusked stored rice by *Sitotroga cerealella* Oliv. (Lepidoptera, Gelechiidae) in Bangladesh. *J. Stor. Prod. Res*. **10**(1): 23-26.

Shankar, U. and Abrol, D.P. (2012). Integrated pest management in stored grains. In: Integrated pest management principles and practice. CABI. pp. 386-407.

Shazali, M.E.H. and Smith, R.H. (1985). Life history studies of internally feeding pests of stored sorghum: *Sitotroga cerealella* (Ol.) and *Sitophilus oryzae* (L.). *J. Stored Prod. Res*. **21**: 171–178.

Sheribha, P.R.B., Jinham, A.P., Das, S.S.M. and Jasmine, K.R. (2010). Management of *Tribolium castaneum* (Herbst) based on hue response. *Turkish J. Zool.* **34**: 367-375.

Shrivastava, J. L. 1980. Pesticide resistance in food grain and pest resistance to pesticide. *Bull. Grain Tech.* **18**(1): 65-78.

Shukla, A.C., Shukla, A., Mishra, R.C. and Dikshit, A. (2007). Broadspectrum herbal fumigant formulation for the management of stored grain pests. Donahaye, E.J., Navarro, S., Bell, C., Jayas, D.S., Noyes, R., Phillips, T.W. (Eds.). Proceedings international conference on controlled atmosphere and fumigation in stored products. Gold-Coast Australia. 8-13th August 2004. FTIC Ltd. Publishing, Israel. p.117.

Shukle, R.H. and Wu, L. (2003). The role of protease inhibitors and parasitoids on the population dynamics of *Sitotroga cerealella* (Lepidoptera: Gelechiidae). *Environ. Entomol.* **32**(3): 488-498.

Singh, D., M.S. Siddiqui and S. Sharma. 1989. Reproduction retardant and fumigant properties of essentials oils against rice weevil (Colleoptera: Cuuculionidae), in stored wheat. *J. Econ. Entomol*. **82**(3): 727-733.

Singh, S.R. and Benazet, J. (1975). Chemical intervention on all stages and on all scales of tropical storage practice. Brady, E.U., Brower, J.H., Hunter, P.E., Jay, E.G., Lum, P.T.M., Lund, H.O., Mullen, M.A., Davis, R. (Organisers): Proceedings of the First International Working Conference on Stored-Product Entomology, Savannah, Georgia, USA, October 7-11, 1974. Stored-Product Insects Research and Development Laboratory, ARS, USDA & Department of Entomology, Georgia University. Savannah & Athens, Georgia USA. 41-46.

Singh, V., Dayal, R. and Bhandari, R.S. (2002). activity of essential oil of *Vitex negundo* leaves against *Sitotroga cereallela*. *Shashpa*. **9**(1): 71-75.

Slansky, J.R.F. and Scriber, J.M. (1985). Food consumption and utilization. In: Comprehensive insect physiologv, biochemistry and pharmacology (eds. Kerkut, G.A. and Gilbert, L.I.). **4**: 87-163.

Srinivasan, D. and Nadarajan, L. (2004). Preliminary studies on plant extract as grain protectant against Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *Insect environ.* **10**(1): 9-11.

Sriranjini, V. and Rajendran, S. (2008). Efficacy of sulfuryl fluoride against insect pests of stored food commodities. *Pestology*. **32**: 32-38.

Stoyanova, S. and D. Shikerenov. 1983. Use of phosphene preparation for the de-infestation of wheat and flour. *Rasticlna Zaschita*. **31**(2): 30-33.

Sukprakarn, C. (1985). Pest problems and the use of pesticides in grain storage in Thailand. ACIAR Proceedings Series, Australian Centre for International Agricultural Research. **14**: 31-35.

Takeshita, H. and Imura, O. (1990). Loss assessment of stored rice infested by *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *Appl. Entomol. Zool*. **25**(2): 239-249.

Tanzubil, P.B. (1987). The use of neem products in controlling the cowpea weevil, *Callosobruchus maculates* Fab. *Nyankpala Agril. Exp. Sta. Crops Res. Inst*. pp. 517 - 523.

Taylor, R.W.D. (1989). Phosphine—a major fumigant at risk. *Inter. Pest Control.* **31:** 10–14.

Thakur, A.K. and Sharma, J.K. (1996). Assessment of storage losses in rice in Himachol Pradesh. *Pest Management Econ. Zool.* **4**(1/2): 97-100.

Tipping, P.W., Rodriguez, J.G., Poneleit, C.G. and Legg, D.E. (1988). Feeding activity of the maize weevil (Coleoptera: Curculionidae) on two dense corn lines and some of their mutants. *J. econ. Entomol*. **81**: 830-833.

Toews, M.D. and Subramanyam, B. (2003). Contribution of contact toxicity and wheat condition to mortality of stored-product insects exposed to spinosad. *Pest Manage. Sci.* **59**: 538-544.

Togola, A., Nwilene, F.E., Chougourou, D.C. and Agunbiade, T. (2010). Presence, populations and damage of the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera, Gelechiidae), on rice stocks in Benin. *Cah. Agric*. **19**: 205-209.

Tsao, R., Peterson, C.J., Coats, J. R. (2002). Glucosinolate breakdown products as insect fumigants and their effect on carbon dioxide emission of insects. *BMC Ecology*. **2:** 1–7.

Upadhay, V.R., Shah, A.H. and Desai, N.D. (1979). Varietal resistance of paddy varieties to *Sitotroga cerealella* Oliv. *Indian J. Entomol*. **41**(2): 190-192.

Verma, R.A., Pal, A. and Lal, D. (2010). Screening of husked rice varieties against *Sitotroga cerealella*. *Annal. Plant Protect. Sci.* **18**(1): 244-245.

Weston, P.A. and Rattlingourd, P.L. (2000). Progeny production by *Tribolium castaneum* (Coleoptera: Tenebrionidae) and *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) in maize previously infested by *Sitotroga cerealella* (Lepidoptera: Gelichiidae). *J. Econ. Entomol*. **93**: 533-536.

Wongo, L.E. (1990). Factors of resistance in sorghum against *Sitotroga cerealella* (Oliv.) and *Sitophilus oryzae* (L.). Insect. Sci. Appli. **11**(2): 179-188.

Wu, R.Z. (1990). Evaluation of hybrid rice combinations for resistance to *Sitotroga cerealella* Olivier in stored grain. *Chinese J. Rice Sci*. **4**(2): 63-68.

Yadav, T. D. 1983. Seed fumigation as an aspect to seed storage technology. *Seed Res.* **11**(2): 240-247.

Yadav, U.S., Prasad, S.S., Ram, M. and Kumar, N. (2007). Effect of certain grain protectant oils on growth and development of Angoumois grain moth, *Sitotroga cerealella* Olivier. *Res. Crop.* **8**(2): 442-445.

Yadav, U.S., Prasad, S.S., Upadhyay, K.D. and Ram, M. (2003). Growth and development of Angoumois grain moth, *Sitotroga cerealella* Olivier on different rice varieties. Proc. *National Aca. Sci. India Sec. Biol. Sci. Publ*. **73**(3/4): 283-290.

Yadu, Y.K., Saxena, R.C., Dubey, V.K. and Rana, D.K. (2000). Evaluation of certain plant products against *S. cereallea* (Oliv.) in stored maize and paddy. *Indian J. Agric. Res.* **34**(4): 261-263.

Yang, F., Zhu, F. and Lei, C. (2012). Insecticidal activities of garlic substances against adults of grain moth, *Sitotroga cerealella* (Lepidoptera: Gelechiidae). *Insect Sci*. **19**: 205–212.

Yao, M.C. and Lo, K.C. (1992). Insect species and population densities in stored japonica rice in Taiwan. *Chinese J. Entomol*. **12**(3): 161-169.

Yevoor. (2003). Biology and management of rice weevil, *Sitophilus oryzae* (Linn.) in maizegrains. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.

Appendix

কীটতত্ত্ব বিভাগ
শেরেবাংলা কৃষি বিশ্ববিদ্যালয়
শেরেবাংলা নগর, ঢাকা-১২০৭।

কোড নং --------

"বাংলাদেশের উত্তরাঞ্চলে গুদামজাত ধানে সুরুই পোকা/ফুতি পোকা/ রাইস মথ আক্রমনে ক্ষতির ধরণ ও পরিমাপ" শীর্ষক কার্যক্রমের নিমিত্তে ধান চাষীদের জন্য প্রশ্নাবলীঃ

১.০. **উত্তর দাতার ব্যক্তিগত তথ্যাদি:**

১.১. **নামঃ**...

১.২.

মোবাইল:	০	১									

১.৩. **ঠিকানা:** ক. গ্রাম/বাজার: ...., খ. ইউনিয়ন: ....
গ. উপজেলা: ...., ঘ. জেলা: ....

১.৩. **লিঙ্গঃ** (কোড: ১=পুরুষ, ২=মহিলা) ☐

১.৪. **বয়স:** (কোড: ১= ২০ বছর বা তার কম, ২= ২১-৩০ বৎসর, ৩= ৩১-৪০ বৎসর, ৪= ৪১-৫০ বৎসর, ৫= ৫১ বা বেশী) ☐

১.৫. **আনুষ্ঠানিক শিক্ষা:** (কোড: ১= নিরক্ষর, ২= প্রাথমিক, ৩= এসএসসি, ৪=এইচএসসি, ৫= স্নাতক, ৬= স্নাতকোত্তর) ☐

১.৬. **পেশার ধরণ:** (কোড: ১=ক্ষুদ্র কৃষক, ২=মাঝারী কৃষক, ৩=বড় কৃষক, ৪=বীজ উৎপাদনকারী, ৫=বীজ ব্যবসায়ী, ৬=ধান গুদামের মালিক, ৭=ধান গুদামের কর্মচারী, ৮=অন্যান্য...................................... (উ.ক.) ☐

২.০. **কৃষি পণ্য উৎপাদন সম্পর্কিত তথ্যাদিঃ**

২.১. আপনি সাধারণত: কি কি ফসল চাষ করেন?
(কোড: ১=দানাদার ফসল, ২=শাক-সজি, ৩=ফলমূল, ৪=আখ, ৫=আশঁ জাতীয় শষ্য, ৬= অন্যান্য..উ.ক.) ☐

২.২. আপনি দানাদার শষ্যের মধ্যে কোন কোন ফসল আবাদ করেন?
(কোড: ১=ধান, ২=গম, ৩=ভুট্টা, ৪= কাউন/চিনা, ৫=অন্যান্য................................. উল্লেখ করুন) ☐

৩.০. **শষ্য সংরক্ষণ সম্পর্কিত তথ্যাদিঃ**

৩.১. আপনি উৎপাদিত শষ্য ভবিষ্যতের জন্য সংরক্ষণ করেন কি? [কোড: ১=হ্যাঁ, ২=না] ☐

৩.২. যদি উত্তর হ্যাঁ হয়, তাহলে কোন কোন শষ্য/পণ্য সংরক্ষণ করেন?
(কোড: ১=ধান, ২=চাউল, ৩=গম, ৪=ভূট্টা, ৫= অন্যান্য.. .. .. উল্লেখ করুন) ☐

৩.৩. যদি ধান সংরক্ষণ করে থাকেন, তাহলে গত দুই বছর কি পরিমান সংরক্ষণ করেছেন? [মণ (৪০ কেজি) হিসেবে উল্লেখ করুন]
ক. গত বছর (২০১৩): --------------------------- মণ
খ. চলতি বছর (২০১৪):-------------------------- মণ

৪.০. শষ্য সংরক্ষণে সমস্যা সম্পর্কিত তথ্যাদিঃ

৪.১ শষ্য সংরক্ষণে আপনি কি ধরণের সমস্যার সম্মুখীন হয়েছেন?
(কোডঃ ১=পোকা, ২=রোগ, ৩=ইঁদুর, ৪=আর্দ্রতা, ৫=উপযুক্ত পাত্রের অভাব, ৬=নিম্নমানের গুদাম, ৭=শষ্য সংরক্ষণে প্রয়োজনীয় জ্ঞানের অভাব, ৮=অন্যান্য....................................উ.ক.)

৪.২ সংরক্ষিত দানাদার শষ্যে সাধারণত: কোন কোন পোকার আক্রমণ হয়?
(কোডঃ ১= ফুতি পোকা/ সুরুই পোকা (রাইস মথ), ২= চালের কেড়ি/ হাতীয়া/শুড় পোকা, ৩=ময়দার লাল বিটল, ৪= খাপড়া বিটল, ৫=অন্যান্য ....উ.ক.)

৪.৩ ধানের সুরুই/ ফুতি পোকা সম্পর্কে ধারণা আছে কি? [কোডঃ ১=হ্যাঁ, ২=না]

৪.৪ সুরুই/ফুতি পোকা সাধারণত: গুদামে সংরক্ষিত কোন কোন শষ্যে আক্রমণ করে
[কোডঃ ১=ধান, ২=গম, ৩=ভুট্টা, ৪=অনান্য........... ....(উ. ক.)]

৪.৫ সুরুই/ফুতি পোকা দ্বারা সাধারণত: ধান/ গম/ ভুট্টার কি পরিমাণ ক্ষতি হয়?
(কোডঃ ১= ০১- ১০%, ২= ১০-২০%, ৩= ২১-৫০%, ৪= ৫১-৮০%, ৫= ৮১-১০০%)

৫.০ ধানে সুরুই/ফুতি পোকা আক্রমনকালে জৈব প্রতিবেশ অবস্থাঃ

৫.১ ধানে সুরুই/ফুতি পোকার আক্রমনের মৌসুম সম্পর্কে আপনার কোন ধারণা আছে কি?
[কোডঃ ১=হ্যাঁ, ২=না]

৫.২ যদি উত্তর হ্যাঁ হয়, তাহলে সাধারণত: বছরের কোন সময় ধানের সুরুই পোকার আক্রমন শুরু/আরম্ভ হয়?
(কোডঃ ১= শীত, ২= বসন্ত, ৩= গ্রীষ্ম, ৪= বর্ষা, ৫= শরৎ, ৬= হেমন্ত)

৫.৩ সাধারণত: বছরের কোন সময় সুরুই/ফুতি পোকার আক্রমন সবচেয়ে বেশী হয়?
(কোডঃ ১= শীত, ২= বসন্ত, ৩= গ্রীষ্ম, ৪= বর্ষা, ৫= শরৎ, ৬= হেমন্ত)

৬.০ ধানের সুরুই পোকা প্রতিরোধক ব্যবস্থাপনার তথ্যাদি

৬.১ ধানের সুরুই/ফুতি পোকার দমনে প্রতিরোধ ব্যবস্থা সম্পর্কে আপনার কোন ধারণা আছে কি?
[কোডঃ ১=হ্যাঁ, ২=না]

৬.২ যদি উত্তর হ্যাঁ হয়, তাহলে সুরুই/ফুতি পোকা দমনে সাধারণত: কোন কোন প্রতিরোধ ব্যবস্থা গ্রহণ করে থাকেন?
[কোডঃ ১=উত্তম গ্রেডের বীজ সংরক্ষণ, ২= বারংবার রোদে শুকানো, ৩= প্ল্যাস্টিকের কনটেইনারে সংরক্ষণ, ৪= ধাতব ড্রামে সংরক্ষণ, ৫= মাটির পাত্রে/মটকায় সংরক্ষণ, ৬= শুকনো নিম পাতার গুড়া ব্যবহার, ৭= শুকনো বিষকাটালী পাতার গুড়া ব্যবহার, ৮= নিমের তেল ব্যবহার, ৯=নিম বীজের সাঁস ব্যবহার, ১০=কর্পূর ব্যবহার, ১১=রাসায়নিক বিষ ব্যবহার (যেমন বিষাক্ত গ্যাস টেবলেট), ১২= অন্যান্য.................................(উ.ক.)]

৬.৩ সুরুই/ফুতি পোকা দমনের প্রতিরোধ ব্যবস্থাগুলোর মধ্যে কোন পদ্ধতিগুলো সহজ এবং উত্তম বলে মনে করেন?
[কোডঃ ১=উত্তম গ্রেডের বীজ সংরক্ষণ, ২= বারংবার রোদে শুকানো, ৩= প্ল্যাস্টিকের কনটেইনারে সংরক্ষণ, ৪= ধাতব ড্রামে সংরক্ষণ, ৫= মাটির পাত্রে/মটকায় সংরক্ষণ, ৬= শুকনো নিম পাতার গুড়া ব্যবহার, ৭= শুকনো বিষকাটালী পাতার গুড়া ব্যবহার, ৮= নিমের তেল ব্যবহার, ৯=নিম বীজের সাঁস ব্যবহার, ১০=কর্পূর ব্যবহার, ১১=রাসায়নিক বিষ ব্যবহার (যেমন বিষাক্ত গ্যাস টেবলেট), ১২= অন্যান্য.................................(উ.ক.)]

৭.০ ধানের সুরুই/ফুতি পোকা প্রতিশেধক ব্যবস্থাপনার তথ্যাদিঃ

৭.১ ধানের সুরুই/ফুতি পোকার দমনে প্রতিশেধক ব্যবস্থা সম্পর্কে আপনার কোন ধারণা আছে কি?
[কোডঃ ১=হ্যাঁ, ২=না]

৭.২ যদি উত্তর হ্যাঁ হয়, তাহলে সুরুই/ফুতি পোকা দমনে সাধারণত: কোন কোন প্রতিশেধক ব্যবস্থা গ্রহণ করে থাকেন?
[কোড: ১=বিষাক্ত গ্যাস টেবলেট (যেমন ফসটক্সিন), ২= বিষাক্ত তরল, ৩=কর্পূর ব্যবহার, ৪=ন্যাফথালিন ব্যবহার, ৫=কুলায় ঝাড়া, ৬=রোদে শুকানো, ৭=অন্যান্য.. (উ.ক.)]

৭.৩ সুরুই/ফুতি পোকা দমনের প্রতিরোধ ব্যবস্থাগুলোর মধ্যে কোন পদ্ধতিগুলো সহজ এবং উত্তম বলে মনে করেন?
[কোড: ১=বিষাক্ত গ্যাস টেবলেট (যেমন ফসটক্সিন), ২= বিষাক্ত তরল, ৩=কর্পূর ব্যবহার, ৪=ন্যাফথালিন ব্যবহার, ৫=কুলায় ঝাড়া, ৬=রোদে শুকানো, ৭=অন্যান্য.. (উ.ক.)]

৭.৪ এই এলাকায় গোলাঘর/ গুদামে রাসায়নিক দ্রব্য ব্যবহারের প্রচলিত পদ্ধতি কি কি?
[কোডঃ ১=পাত্রকে বায়ুরোধী করে প্রয়োগ, ২= গোলাঘর/গুদাম বন্ধ রেখে প্রয়োগ, ৩=গুদামজাত শষ্য ত্রিপল দিয়ে ঢেকে বিষ ব্যবহার, ৪= সংরক্ষিত শষ্যের বিভিন্ন স্তরে বিষ ছিটিয়ে, ৫= সংরক্ষিত শষ্যে সরাসরি বিষ স্প্রে করে, ৬=অন্যান্য .... (উ.ক.)]

৮.০ রাসায়নিক পদ্ধতিতে ধানের সুরুই/ফুতি পোকা দমনের অভিজ্ঞতা

৮.১ রাসায়নিক পদ্ধতিতে গুদামজাত শষ্য সংরক্ষণকালে কোন সতর্কতা অবলম্বন করতে হয় কি?
[কোডঃ ১=হ্যাঁ, ২=না]

৮.২ যদি উত্তর হ্যাঁ হয়, তাহলে সাধারণত: কি কি সতর্কতা অবলম্বন করতে হয়?
[কোডঃ ১= বায়ুরোধী পাত্র/গুদাম ব্যবহার, ২= দস্তানা (হ্যান্ড গ্লাভস) ও মাস্ক ব্যবহার, ৩= নির্দিষ্ট সময় পর্যন্ত গুদামের/পাত্রের বায়ুরোধ করা, ৪=রাসায়নিক ব্যবহার করার নির্দিষ্ট সময় পর উপযুক্ত বায়ু চলাচলের ব্যবস্থা করা, ৫= রাসায়নিক ব্যবহার করার সাথে সাথে সংরক্ষিত দানা শষ্য খাবারের জন্য ব্যবহার না করা, ৬=রাসায়নিক ব্যবহার স্থল থেকে শিশুদের দূরে রাখা, ৭=অন্যান্য...(উ.ক.)]

৮.৩ ধানের সুরুই/ফুতি পোকা দমনে পরিবেশ বান্ধব কোন পদ্ধতি সম্পর্কে আপনার জানা আছে কি?
[কোডঃ ১=হ্যাঁ, ২=না]

৮.৪ জানা থাকলে ধানের সুরুই/ফুতি পোকা দমনে পরিবেশ বান্ধব পদ্ধতিগুলো কি কি?
[কোড: ১=উত্তম গ্রেডের বীজ সংরক্ষণ, ২= রোদে শুকানো, ৩= প্ল্যাস্টিকের কনটেইনারে সংরক্ষণ, ৪= ধাতব ড্রামে সংরক্ষণ, ৫= মাটির পাত্রে/মটকায় সংরক্ষণ, ৬= শুকনো নিম পাতার গুড়া ব্যবহার, ৭= শুকনো বিষকাটালী পাতার গুড়া ব্যবহার, ৮= নিমের তেল ব্যবহার, ৯=নিম বীজের সাঁস ব্যবহার, ১০=কর্পূর ব্যবহার, ১১=অন্যান্য..................................(উ.ক.)]

৯.০ রাসায়নিক পদ্ধতি অবলম্বনের ফলে তিক্ত অভিজ্ঞতা (যদি থাকে)ঃ

৯.১ রাসায়নিক পদ্ধতি ব্যবহারের কারণে বিপদ হয়েছে এমন কোন দূর্ঘটনার কথা আপনার জানা আছে কি?
[কোডঃ ১=হ্যাঁ, ২=না]

৯.২ যদি উত্তর হ্যাঁ হয়, তাহলে রাসায়নিক পদ্ধতি ব্যবহারকালে কি ধরণের দূর্ঘটনা ঘটেছিল?
[কোডঃ ১=বিষক্রিয়ায় লোক মারা গেছে, ২=বিষক্রিয়ায় লোক আহত হয়েছে, ৩=শরীরে ক্ষত হয়েছে, ৪=শরীরে চুলকানী রোগ হয়েছে, ৫=হাঁস-মুরগী মারা গেছে, ৬=অন্যান্য.. (উ.ক.)]

১০.০ ধান সংরক্ষনের জন্য পাত্র/ব্যাগের তথ্য

১০.১ ধান সংরক্ষণে আপনাদের এলাকায় সাধারণত: বেশী কার্যকর কোন কোন পাত্র/ব্যাগ ব্যবহার করা হয়?
[কোডঃ ১=মাটির মটকা, ২= বাঁশের ডুলি, ৩= ধানের গোলা, ৪= ধাতব ড্রাম, ৫= প্লাস্টিক ড্রাম, ৬= পলিথিন প্রলেপসহ চটের বস্তা, ৭= ব্যবহৃত রাসায়নিক সারের বস্তা, ৮= অন্যান্য.....................................উ.ক.]

১০.২ ধান সংরক্ষনে কোন কার্যকর পাত্রটি সহজলভ্য বলে মনে করেন ?
[কোডঃ ১=মাটির মটকা, ২= বাঁশের ডুলি, ৩= ধানের গোলা, ৪= ধাতব ড্রাম, ৫= প্লাস্টিক ড্রাম, ৬= পলিথিন প্রলেপসহ চটের বস্তা, ৭= ব্যবহৃত রাসায়নিক সারের বস্তা, ৮= অন্যান্য.....................................উ.ক.]

সার্বিক সহযোগীতার জন্য আপনাকে ধন্যবাদ।