VARIETAL SCREENING OF RICE FOR RESISTANCE AGAINST ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* (OLIVIER)

SAJIA HOQUE MISHU

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR, DHAKA-1207

JUNE, 2015

VARIETAL SCREENING OF RICE FOR RESISTANCE AGAINST ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* (OLIVIER)

BY

SAJIA HOQUE MISHU

Registration No. 09-03554

A Thesis

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

MASTER OF SCIENCE
IN
ENTOMOLOGY

SEMESTER: JANUARY- JUNE, 2015

Approved by:

Supervisor

Dr. Md. Razzab Ali
Professor
Department of Entomology

Co-supervisor

Dr. Tahmina Akter
Associate Professor
Department of Entomology

Dr. Mohammed Sakhawat Hossain
Chairman
Department of Entomology

CERTIFICATE

This is to certify that the thesis entitled, "**VARIETAL SCREENING OF RICE FOR RESISTANCE AGAINST ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* (OLIVIER)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **SAJIA HOQUE MISHU** bearing **Registration No. 09-03554** 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 been duly acknowledged.

Prof. Dr. Md. Razzab Ali
Supervisor
Department of Entomology

Dated: June, 2015

ACKNOWLEDGEMENT

The author first wants to express her enormous sense of gratitude to the Almighty Allah for His countless blessing, love, support, protection, guidance, wisdom and assent to successfully complete her M.S. degree.

The author feels proud to expresses her deepest gratitude, deep sense of respect and immense indebtedness to his research supervisor, Prof. Dr. Md. Razzab Ali, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207, for his constant supervision, invaluable suggestion, scholastic guidance, continuous inspiration, constructive comments, constructive criticism and encouragement during her research work and guidance in preparation of manuscript of the thesis.

The author also likes to express expresses her sincere appreciation, profound sense, respect and immense indebtedness to her respected co-supervisor Associate Prof. Tahmina Akter, the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207, for extending her generous help, scholastic guidance and valuable suggestions during the research work and preparation of the manuscript of the thesis.

The author would like to express her deepest respect and boundless gratitude to all respected teachers of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 for their sympathetic co-operation and inspirations throughout the course of this study and research work. Cordial thanks are also due to all stuffs of the Dept. of Entomology for their co-operation to complete the research work in the laboratory.

Words are not enough to express the author's gratitude to her beloved family for their blessings, financial support and dedicated efforts for their endless sacrifice for building her academic career, which can never be repaid.

June, 2015 The author

VARIETAL SCREENING OF RICE FOR RESISTANCE AGAINST ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* (OLIVIER)

ABSTRACT

The study was conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July, 2014 to February, 2015 to find out the varietal response of rice on growth and development of Angoumois grain moth, *Sitotroga cerealella* (Oliv.) and to find out the resistant/tolerant varieties in storage. The experiments were laid out in Completely Randomized Design (CRD) with four replications. The rice varieties tested were BR 11, BR 22, BR 26, BRRI dhan 28, BRRI dhan 29, BRRI dhan 49, BRRI dhan 50, BINA 7, ACI-1 (hybrid) and Chamak-1 (hybrid). It was found that none of the varieties were completely immune to *S. cerealella*. But Significant differences were observed among ten rice varieties on larval incidence, adult emergence, grain damage percentage, seed germination percentage and grain content loss by *S. cerealella*. The highest larval incidence was found in BRRI dhan 50 (83.33 %) and the lowest was in BR 11 (30.00 %). Highest number of adult emergence occurred in BRRI dhan 50 (77.67) and lowest number of adult emergence was found in BR (27.67). The highest grain content loss was observed in BRRI dhan 50 (6.89 %) and the lowest was in BR 11 (0.61 %). Moreover highest number of seed germination was found in BR 11 (73.33) and the lowest number was in BRRI dhan 50 (18.67 %). In no choice, test highest grain damage was found in BRRI dhan 50 (10.00 %) and lowest grain damage was in BR 11 (1.11 %). The highest grain content loss was in BRRI dhan 50 (10.02 %) and the lowest grain content loss was in BR 11 (1.16 %). In free choice, test highest grain damage occurred in BRRI dhan 50 (9.00 %) and the lowest damage occurred in BR 11 (1.00 %). The highest grain content loss was observed in BRRI dhan 50 (9.02 %) and the lowest grain content loss was in BR 11 (1.02 %). Among the rice varieties BRRI dhan 50 was found the most susceptible host for *S. cerealella* in respect of both growth and development and food consumption. On the other hand, BR 11 was the resistant variety for *S. cerealella*.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is an essential cereal crop and plays an important role in the socio-economic stability of Bangladesh. It is the staple food accounting for about 93 percent of the total food produced, about 70% of average calorie intake and 35% of household expenditure. Rice production is the largest contributor to farm income, while related trade and commerce are important sources of rural non-farm income (Ahmed, 2001). The demand for rice is constantly rising in Bangladesh as nearly 2.3 million people being added each year with about 120 million of the population (Anon., 2001). About 90% of the population of Bangladesh depends on rice as their major food (Anon., 1981). Over many years, rice has been the dominant crop in Bangladesh and it currently accounts for 77% of agricultural land use. Bangladesh is now the fourth largest rice producer in the world (FAO, 2010). The total area and production of rice is about 11.5 million hectares and over 35.0 million metric tons respectively (BBS, 2013). A large portion (more than 65% of the production) of this rice produced is stored up to the next season to ensure food, feed and seed where a portion of it is subjected to damage by insect pests. Out of the common biological agents, beetles and moths are the main rice storage pests found in the tropical countries responsible for the losses and deterioration of stored rice (Hall, 1970). It is estimated that 5-10% of world's grain production is lost due to ravages of insects (Adam, 1998). The losses may reach 50% in tropical countries where summer is hot and humid and storage facilities are improper and inadequate (Ahmad and Ahmad, 2002). Varieties vary in susceptibility and attraction to stored grain insects depending upon their physico-chemcial structures.

The Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae), is one of the serious insect pests found in stored grains (unhusked) at postharvest level. The insect is small in size and can conceal itself in grain facilitating their exportation by commerce to all parts of the world. It is cosmopolitan in distribution and a primary colonizer of stored grain in subtropical and warm temperate regions of the world. The insect is more or less active throughout the year but less active during the period from December to first part of March. At the time of harvest the panicle shows no sign of infestation usually, and the first adult emerges takes place after few weeks of storage. A sizeable quantity of unhusked rice is stored at farmer's level which is badly damaged by Angoumois grain moth. It is an extremely efficient seed penetrator (Cogburn, 1975). *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%. 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. Another study shows, during 4 months of infestation, *S. cerealella* caused 4-5% weight loss in husked rice and 1% in unhusked rice (Bhuiyah *et al*., 1992).

Only larvae of *S. cerealella* cause serious damage to grain. The newly hatched caterpillar 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 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).

To avoid the toxic hazards of chemical control, it is urgent need to find out a safe and sound alternative to chemical insecticides to protect the stored products in storage. Recently, much attention has been paid to develop resistant varieties against the attack of the pest. But there is a 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 considering the following objectives.

Objectives

- To determine the level of infestation caused by *S. cerealella* among different rice varieties.

- To determine the resistance response of different rice varieties against *S. cerealella* in storage.

CHAPTER II
REVIEW OF LITERATURE

The Angoumois grain moth, *Sitotroga cerealella* (Olivier), is a cosmopolitan and most destructive primary insect pest of several stored grains. It is found throughout the warmer parts of the world. It is commonly known as rice moth and a very broad range of other stored products. The degree of damage differed in different stored grains including rice causing serious economic loss nationally. Emphasis has given to control the pest by evolving resistant varieties. Some important literatures related to work are pertained.

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 name '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 a nearly 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

There are about five generations per year in southern Europe, but in warmer climates *S. cerealella* is continuously brooded with up to 12 generations per year. In temperate countries, it overwinters in the larval stage in stored grain kernels or in scattered wheat in litter, straw piles or baled straw.

2.3.1. Egg

A female moth can lay up to 200 eggs. The number of eggs is dependent on food, season, or temperature. The eggs are laid singly or in clumps on the surface of grain. Eggs are oval, ivory in color and about 1/12 inch long. 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). The adult life span may be up to 15 days (Mondragon and Almeida, 1988) and one female may lay up to 200 eggs (Dobie *et al*., 1984) although 40 is a more average number (ARS, USDA, 1978).

2.3.2. Larvae

The larvae of Angoumois grain moths are creamy white, brown head capsule, and legless. They are internal feeders of grains. Soon after hatching each larva hollows out the inside of grain where it completes its development. 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).

2.3.3. Pupae

Pupation occurs inside the grain. Light brownish colored pupa skins may be visible on emergence. Before pupation, the larva extends the anterior of its chamber to just beneath the surface of the grain, forming a small circular 'window' of translucent seed coat, which is the first visible sign of infestation. Mondragon and Almeida (1988) recorded an average pupal stage of 10.4 days, but this may be as short as 5 days (Dobie *et al*., 1984). In very small grains (e.g. some sorghum grains), pupation may occur between two or more grains held together by the silken threads of a thin cocoon.

2.3.4. Adult

Adults are up to 0.5 inch long with light grey to buff colored wings. There may be tiny spots on the forewing. The hind wings have a unique curved edge with pointed tip. The newly emerged adult pushes through the window of the seed coat, leaving a small, but characteristic, round hole, usually in the crown end of the grain. Adults are strong fliers and can disperse easily. Upon adult emergence, females move to a surface above the food to release the sex pheromone. Males are attracted to this pheromone for mating.

2.4. Ecology

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 (Dobie *et al*., 1984). 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 humidity levels (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 numbers of eggs were laid at 27°C (155/female).

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*) (Padwal-Desai *et al*., 1987) 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. According to Douglus (1941) it not only infests the grains in storage, but also in field conditions, which enhances its ability to damage. 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 contentsof 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 pests attack (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 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.

Food-bait traps have proved the most effective method of detecting pests of stored-food products in the Ukrainian SSR (Ustinov *et al*., 1986). Adult males can be also detected using sticky traps baited with synthetic, female sex-attractant (Vick *et al*., 1979). Detection using X-ray imaging (Keagy and Schatzki, 1991) and sound detection (Vick *et al*., 1988) has also been investigated.

S. cerealella can be readily trapped by Z, E-7-11-hexadecadien-1-yl acetate (or HDA). Cogburn and Vick (1981) 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; Levinson and Buchelos, 1981) and in storage and field situations (Vick *et al*., 1987). 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. Extent of damage

Several researches within the country and outside showed the extent of damage caused by Angoumois grain moth. 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.

These grains can have either one or all deficiencies that include weight loss, reduction in nutritional value, contamination or tanning, rendering the cereal food unfit for human consumption. A large quantity of unhusked rice is stored at farmer's level which is badly damaged by *S. cerealella*, which is an extremely efficient seed penetrator (Cogburn, 1975).

According to Pandey and Pandey (1978), the contents of protein, total and reducing sugars, starch, ash and oil of damaged grain of 15 varieties and on losses caused by *S. cerealella* indicated that the chemical constituents of the grain were not related to losses. It is thought that the losses in the different varieties may be related to the combined effects of the chemical and physical properties of the grain.

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.

Infestations of *S. cerealella* occur during storage, or pre-harvest (Howlander and Matin, 1988) or postharvest (Seck, 1991a). In the field, *S. cerealella* is able to attack whole (unhusked) grains (Evans, 1987), which poses a greater problem in tropical and subtropical countries than elsewhere (ARS, USDA, 1978).

Another study shows, during 4 months of infestation, *S. cerealella* caused 4-5% weight loss in husked rice and 1% in unhusked rice (Bhuiyah *et al*., 1992).

Hassan *et al*. (1994) surveyed and reported that weight loss due to insect pests in Multan and Bahawalpur go-downs ranged between 0.45 and 0.72%.

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. But 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.

As a general rule, *S. cerealella, S. oryzae, S. zeamais, R. dominica* and *Prostephanus truncatus* (Horn) are the major insect pests that make up the core of the parasitical complex that has a major economic impact on grain stocks over the world (Grenier *et al*., 1994; Hansen *et al*., 2004). They are cosmopolitan pests (Cotton, 1960; CABI, 2005; Bamaiyi *et al*., 2007; Plague *et al*., 2010; Arthur *et al*., 2012), able to attack many types of cereal grain (Sedaghat *et al*., 2011; Hamed and Nadeem, 2012). Their dispersal over large areas has come not just from changes to population feeding habits caused by drought-making farmers abandon their dryland crops to grow rice and maize (Meikle *et al*., 1998; Hansen *et al*., 2004) but also from uncontrolled cross border movements of grain produce fostered by regional or international trade (Youm *et al*., 2011).

2.9. Varietal preferences

So far many scientists in different countries have sorted out countless varieties of cereals against this insect to incorporate useful information in breeding program. Badhera (1944) carried out an experiment on susceptibility of 12 different varieties of stored rice seeds and he stated that oviposition preference by the pyralid was highest on BK-814-15 and lowest on Ratna.

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 (1991). 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.*

CHAPTER III
MATERIALS AND METHODS

The study has been conducted to find out resistance source(s) among the ten rice varieties against Angoumois grain moth, *Sitotroga cerealella* during July, 2014 to February, 2015 in the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207,Bangladesh.

Experiment 1: Screening of varietal resistance of rice through growth and development of *S. cerealella*

Experiment 2: Varietal screening of rice against *S. cerealella* infestation in storage

Details of the experiments are furnished below:

3.1. Rearing of *S. cerealella*

The homologous stock culture of *S. cerealella* were maintained on wheat grain (for rearing purpose only) in special mass rearing chamber with perforated wall in the same laboratory at ambient temperature of 30°C±0.82 and 87.22 % relative humidity. Male and female moths were sorted out under simple microscope by observing their abdominal tergites. In males, the abdomen is thinner, pointed and blackish when viewed from the ventral side whereas in females, the abdomen is bulky and long without any blackish coloration and size of the body (male is smaller than female). From *S. cerealella* mass rearing chamber, thousands of adults were collected and kept them in a glass cylinder. The top of the cylinder was covered by 32 mesh net. Adults were kept in a cylinder for one day for mating and subsequent egg laying on the glass cylinder. In the consecutive days the eggs laid on the wall of the cylinder were brushed and sieved to collect fresh eggs along with body parts of moth. Then the body parts of moth were cleaned and fresh eggs were obtained. The collected eggs of *S. cerealella* were kept into a glass tube with labeling and stored in a refrigerator at 4°C temperature to ensure continuous supply for future study. The rearing procedure was repeated to ensure continuous supply of the adults with required eggs.

Plate 1: Adult female moth

Plate 2: Adult male moth

3.2. De-infestation of rice grains

Grains of different rice varieties were spread separately on black polythene sheets and sun-dried from 10.00 a.m. to 3.00 p.m. in direct sunlight with air temperature ranging from 32-42°C for 5 consecutive days. The sun-dried grains were kept in the laboratory for few hours and packed in polythene bags and sealed to avoid future infestation.

3.3. Treatments of the experiment

Grains of ten rice varieties were collected from different sources that were used under the study are given in Table 1 and each of which was considered as an individual treatment.

Table 1. Name and source of the grains of rice varieties under present study

Rice variety	Source of grains
V_1 = BR 11	Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur
V_2 = BR 22	
V_3 = BR 26	
V_4 = BRRI dhan 28	
V_5 = BRRI dhan 29	
V_6 = BRRI dhan 49	
V_7 = BRRI dhan 50	
V_8 = BINA 7	Local market (Siddik Bazar, Dhaka)
V_9 = ACI-1(Hybrid)	
V_{10} = Chamak-1(Hybrid)	

3.4. Detail procedure of the experiments

3.4.1. Experiment 1: Screening of varietal resistance of rice through growth and development of *S. cerealella*

The experiment was conducted in the laboratory from July to August, 2014. The experiment was laid out in a Completely Randomized Design (CRD) with four replications.

Twenty grams of de-infested healthy grains of each rice variety were taken in individual plastic pot (6cm dia x 9cm height). Then 5 pairs of one-day-old (0-24 hours) healthy adults of *S. cerealella* from the stock culture were released in each pot and covered with their respective lids. The pots were then stored under room condition. Data were recorded on larval incidence, adult emergence and grain weight loss.

Germination tests were performed with four replications to evaluate the germination percentage of healthy grains before the experiment and germination loss of infested grains by *S. cereallella* after completion of the experiment. For that twenty five grains from each variety were randomly selected and placed in petri dishes (9 cm diameter) over newspaper sheets maintaining equal distance. These petridishes were then placed in room condition. Regular and proper watering was done and data were collected.

Plate 3: Germination test of different rice varieties

3.4.2. Experiment 2: Varietal screening of rice against *S. cerealella* infestation in storage

The experiment was laid out in a Completely Randomized Design (CRD) with four replications. Two types of tests like free choice test and no choice test were conducted. Both the tests were carried out for five consecutive generations of *S. cerealella* as follows:

3.4.2.1. Free choice test

This test was conducted from August to December, 2014. Two hundred grams of de-infested healthy grains of each rice variety were taken in individual plastic pot (6cm dia x 9cm height). Then the pots were placed randomly at equal distances around a central circle in the mosquito netted topped tin cage (60 cm dia x 90cm height). Then 150 pairs of one-day-old (0-24 hours) healthy adults of *S. cerealella* from the stock culture were taken in a petridish (90 mm dia) and placed it center of the cage. The lids of all plastic pots and petridish were removed and covered the cage quickly with mosquito net tightly. After three days (72 hours) of release, both dead and alive insects were removed from the plastic pots. The pots with the lids were then stored under room condition. Data were recorded on grain damage percentage and grain weight loss.

Plate 4: Free choice test of varietal screening of rice against *S. cerealella* infestation in a tin cage covered by mosquito net

3.4.2.2. No choice test

This test was conducted from September, 2014 to January, 2014. Two hundred grams of de-infested healthy grains of each rice variety were taken in individual plastic pot (6cm dia x 9cm height). Then 5 pairs of one-day-old (0-24 hours) healthy adults of *S. cerealella* from the stock culture were released in each pot and covered with their respective lids.The pots were then stored under room condition. Data were recorded as previous parameters.

Plate 5: No choice test of varietal screening of rice against *S. cerealella* infestation in the plastic pots covered by lids

3.5. Data collection and calculation

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

3.5.1. Percent larval incidence

Data on larval incidence were recorded in terms of presence of larvae in observed grains. After fifteen days of insect release twenty grains from each replication of each variety were randomly sampled and observed for signs of infestation like hole of larval entrance on seed coat using magnifying glass. The numbers were then recorded and percent larval incidence was calculated by following formula:

$$\% \text{ larval incidence} = \frac{\text{Number of infested grain observed}}{\text{Number of grain sampled}} \times 100$$

3.5.2. Adult emergence

Data on the total number of adults emerged were recorded by visual observation. The number of adults emerged were counted from the first date of adult emergence to last day of emergence. The emerged adults were removed from the pot every day to avoid double counting.

3.5.3. Percent grain content loss

After the complete emergence of adults, the total weight of grains for each pot or variety was recorded separately. Then the percent grain content loss was measured in respect of initial weight of grains using the following formula:

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

Weight loss = Initial weight of grains – final weight of grains.

3.5.4. Percent 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:

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

3.5.5. 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 entranceunder simple microscope and the visible damage of grains. Then damage % was calculated by following formula:

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

3.6. Statistical analysis

Data were analyzed by ANOVA-1 in CRD (Completely Randomized Design) for each set of tests separately and the means were separated by DMRT (Duncan's Multiple Range Test).

CHAPTER IV
RESULTS AND DISCUSSION

Two sets of experiments were conducted to evaluate different rice varieties against Angoumois grain moth for resistance source(s) during July, 2014 to February, 2015 in the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The results have been presented and discussed and possible interpretations have been given under following headings.

4.1. Experiment 1: Screening of varietal resistance of rice through growth and development of *S. cerealella*

The experiment was carried out to observe the varietal preference of ten rice varieties through the growth and development of *S. cerealella* considering percent larval incidence, adult emergence, grain content loss and percent germination loss of infested grains. The findings of these parameters are presented here.

4.1.1. Larval incidence

Significant variations (P>0.01) were found among the different varieties of rice grains in terms of larval incidence percentage (Table 2). The highest number of larvae was found in BBRI dhan 50 (83.33) which was statistically similar to Chamak-1 (75.00). Chamak-1 itself was also statistically similar to ACI-1 (68.33), BRRI dhan 28 (68.33). There was no significant variations among these to BR 22 (65.00), BR 26 (61.67). Again these are similar to BRRI dhan 49 (55.00) and BRRI dhan 29 (53.33). On the other hand, lowest number was found in BR 11 (30.00) which was statistically similar to BINA 7 (38.33). Therefore the order of larval development was BBRI dhan 50 = CHAMAK-1 (hybrid) = ACI-1 (hybrid) = BRRI dhan 28 = BR 22 =BR 26 = BRRI dhan 49 = BRRI dhan 29 > BINA 7 = BR 11.

The result thus observed showed a significant influence of different rice grains on the development of larvae of *S. cerealella*. The variations in the orientation of moths towards different varieties of rice may be attributed to the characteristics of the seed in respect of the surfaces of the grains (Chavan *et al.*, 1997) or to the odor emitted from the grains (Schoonhoven, 1972).

Table 2. Larval incidence of *S. cerealella* among ten rice varieties

Varieties	Number of larvae per 20 grains	larval incidence (%)
BR 11	6.00 e	30.00 e
BR 22	13.00 c	65.00 c
BR 26	12.33 cd	61.67 cd
BRRI dhan 28	13.67 bc	68.33 bc
BRRI dhan 29	10.67 d	53.33 d
BRRI dhan 49	11.00 d	55.00 d
BRRI dhan 50	16.67 a	83.33 a
BINA 7	7.67 e	38.33 e
ACI-1 (Hybrid)	13.67 bc	68.33 bc
Chamak-1 (Hybrid)	15.00 ab	75.00 ab
$LSD_{(0.01)}$	1.80	8.99
CV (%)	6.47	6.47

[In a column, numeric data represents the mean value of 4 replications. In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.]

4.1.2. Adult emergence

Significant variation in respect to the adults emerged from different varieties of rice grains was found. Total number of emergence moths ranges from 25 to 82 per 20 g of rice grains in ten varieties (Table 3). The mean of total number differed significantly among the varieties ($P>0.01$). The highest number of adults were emerged from BRRI dhan 50 having mean 77.67. This was statistically similar to Chamak-1 (73.00), ACI-1 (69.33), BRRI dhan 28 (66.67), BR 22 (62.67) and BR 26 (61.00) respectively. There was no significant difference among the adult emergence from these varieties.

The lowest number of adult emergence was observed from BR 11 (27.67) which was statistically different from all other varieties. This was followed by BINA 7 (41.33), and statistically similar BRRI dhan 29 (52.33) and BRRI dhan 49 (55.00) respectively. Variability of emergence adults might be related to different factors. BRRI dhan 50 was long and fine, hybrid ACI-1 (hybrid) and Chamak-1 (hybrid) were flattened and fine, BRRI dhan 28 and BR 22 were medium and fine. BR 26, BRRI dhan 29 and BRRI dhan

49 were medium in characteristics. On the other hand, BR 11 and BINA 7 were felt medium and course in character. These inherent characters could modify the grain physical structure like texture, shape and amount of endosperm. These alterations might have affected the host-pest relationship (Gomez *et al.*, 1983).

Table 3. Adult emergence of *S. cerealella* from ten rice varieties

Varieties	Adult emergence (no./20 gm)
BR 11	27.67 g
BR 22	62.67 d
BR 26	61.00 d
BRRI dhan 28	66.67 cd
BRRI dhan 29	52.33 e
BRRI dhan 49	55.00 e
BRRI dhan 50	77.67 a
BINA 7	41.33 f
ACI-1 (Hybrid)	69.33 bc
Chamak-1 (Hybrid)	73.00 ab
$LSD_{(0.01)}$	5.98
CV (%)	4.39

[In a column, numeric data represents the mean value of 4 replications. In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.]

The results indicated the order of suitable host for *S. cerealella* that was BRRI dhan 50 = Chamak-1 (hybrid) = ACI-1 (hybrid) = BRRI dhan 28 =BR 22 = BR 26 > BRRI dhan 49 = BRRI dhan 29 > BINA 7 > BR 11. The results reported by Pajni *et al.* (1980) and Chen *et al.* (1998) supported the results of present study.

4.1.3. Percent grain content loss

The percent grain content loss percentages of ten rice varieties ranged from 0.61 to 6.89 % (Table 4). Mean content loss percentage of damaged rice grains of BRRI dhan 50 were significantly different from other varieties (P>0.01). In case of BRRI dhan 50 grain content loss percentage was 6.89 % which was the highest. The lowest grain content loss percentage of 0.61 was found on the variety BR 11. In other varieties descending order of grain content loss percentages were Chamak-1 (5.61), ACI-1 (4.94), BRRI dhan 28 (4.44), BR 22 (3.61), BR 26 (3.17), BRRI dhan 49 (2.45), BRRI dhan 29 (2.22) and BINA 7 (1.28) respectively. There was no statistical significant difference between BRRI dhan 49 and BRRI dhan 29. This result indicated that BRRI dhan 50 was more susceptible to *S. cerealella* and BR 11 was least susceptible to the same insect.

According to these findings the order in terms of susceptibility of rice varieties to the damage by *S. cerealella* was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) > BRRI dhan 28 > BR 22 > BR 26 > BRRI dhan 29 = BRRI dhan 49 > BINA 7 > BR 11.

Table 4. Grain content loss of ten rice varieties by *S. cerealella*

Varieties	Initial grain weight (g)	Loss of grain content (g)	% grain content loss
BR 11	20	0.12 i	0.61 i
BR 22	20	0.72 e	3.61 e
BR 26	20	0.63 f	3.17 f
BRRI dhan 28	20	0.89 d	4.44 d
BRRI dhan 29	20	0.44 g	2.22 g
BRRI dhan 49	20	0.49 g	2.45 g
BRRI dhan 50	20	1.38 a	6.89 a
BINA 7	20	0.26 h	1.28 h
ACI-1 (Hybrid)	20	0.99 c	4.94 c
Chamak-1 (Hybrid)	20	1.12 b	5.61 b
$LSD_{(0.01)}$		0.14	0.39
CV (%)		4.73	4.73

[In a column, numeric data represents the mean value of 4 replications. In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.]

The grain content loss might be related to grain damage. Grain damage might be more or less due to different nutrient contents in different rice varieties. Seed coat structure, morphological and physiological characteristics were also major factors for grain damage and content losses caused by *S. cerealella*. This result agreed with those of Takeshita and Imura (1990) who observed the thicker coat reduced the damage to two rice varieties.

4.1.4. Effect on germination percentage

Assessment of percent germination loss caused by *S. cerealella* on rice grains was determined on the basis of germination percentage before and after the experiment. The mean germination percentage at the beginning of the experiment ranged from 97.33 to 90.67 percentages (Table 5). There was no statistically significant difference among the mean germination percentages of ten rice varieties (P>0.01). But after completion the experiment, when final germination test was performed there was significant differences among the mean germination percentages of rice varieties (P>0.01).

Table 5: Variation in germination percentages among ten rice varieties

Varieties	Germination % at the beginning of the study	Germination % at the end of the study
BR 11	97.33 a	73.33 a
BR 22	93.33 abc	53.33 c
BR 26	94.67 abc	56.00 c
BRRI dhan 28	93.33 abc	42.67 d
BRRI dhan 29	96.00 ab	65.33 b
BRRI dhan 49	96.00 ab	61.33 b
BRRI dhan 50	90.67c	18.67 g
BINA 7	97.33 a	70.67 a
ACI-1 (Hybrid)	92.00 bc	33.33 e
Chamak-1 (Hybrid)	90.67 c	25.33 f
$LSD_{(0.01)}$	4.49	5.09
CV (%)	2.06	4.38

[In a column, numeric data represents the mean value of 4 replications. In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.]

The highest germination percentage reduction was observed in BRRI dhan 50 where mean initial germination percentage was 90.67 but after the experiment it reduced to 18.67. That is a reduction of 70 percentages occurred due to infestation by *S. cerealella*.

With mean final germination percentage this was followed by Chamak-1 (25.33), ACI-1 (33.33), BRRI dhan 28 (42.67). There were no statistically significant difference between the pairs BR 22 (53.33) and BR 26 (56.00), BRRI dhan 29 (65.33) and BRRI dhan 49 (61.33). On the other hand the lowest reduction (24 % and 26.66%) in germination percentage was observed in BR 11 and BINA 7 with a mean final germination percentage 73.33 and 70.67 respectively.

As a result the order of percent germination loss of infested grains of ten rice varieties was BR 11 = BINA 7 > BRRI dhan 29 = BRRI dhan 49 > BR 22 = BR 26 > BRRI dhan 28 > ACI-1(hybrid) > Chamak-1(hybrid) > BRRI dhan 50.

Feeding by the moth larvae on germ and endosperm of rice was responsible for the drastic loss of germinability in the infested rice. Present study results indicated that BRRI dhan 50 was the most susceptible grain to the damage caused by *S. cerealella*, BINA 7 and BR 11 was the least susceptible to thedamage by this insect. This result was supported by those of Takeshita and Imura (1990) who observed germination percentage loss in infested S-38 rough and brown rice and N-11 brown rice was more than 90% at week 13.

4.1.5. Relationship between larval incidence and grain content loss

Correlation study was done to establish a relationship between larval incidence and grain content loss percentage. From the study it was revealed that significant correlations existed between the characters (Figure 1). The regression equation $y = 0.1175x - 3.51$ gave a good fit to the data and the value of the co-efficient of determination ($R^2 = 0.9368$). From this it can be concluded that the larval incidence percentage was positively related to the grain content loss percentage, i. e. with the increase in larval incidence grain content loss percentage increased.

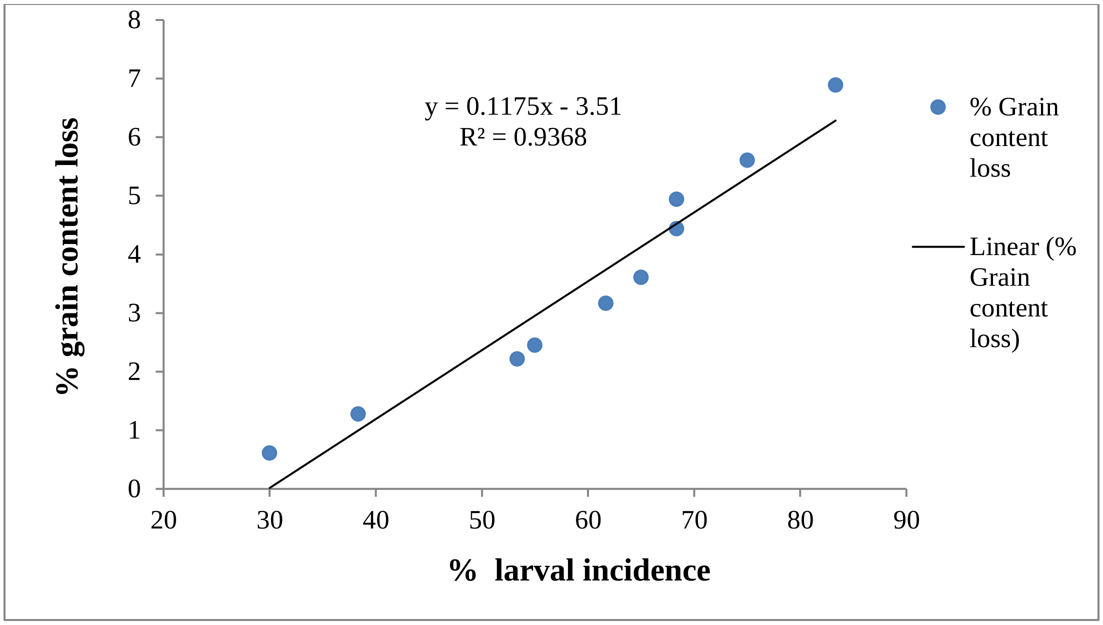

Figure 1: Relationship between larval incidence and grain content loss

4.1.6. Relationship between the larval incidence and seed germination

The significant relationship was found between the larval incidence and percent seed germination when correlation was made between the parameters (Figure 2). The highly significant ($p<0.01$), very strong (R^2= 0.8491) and negative (slope = -1.087) correlation was found between the larval incidence and percent seed germination, i.e. the germination percentage decreased with the increase of larval incidence.

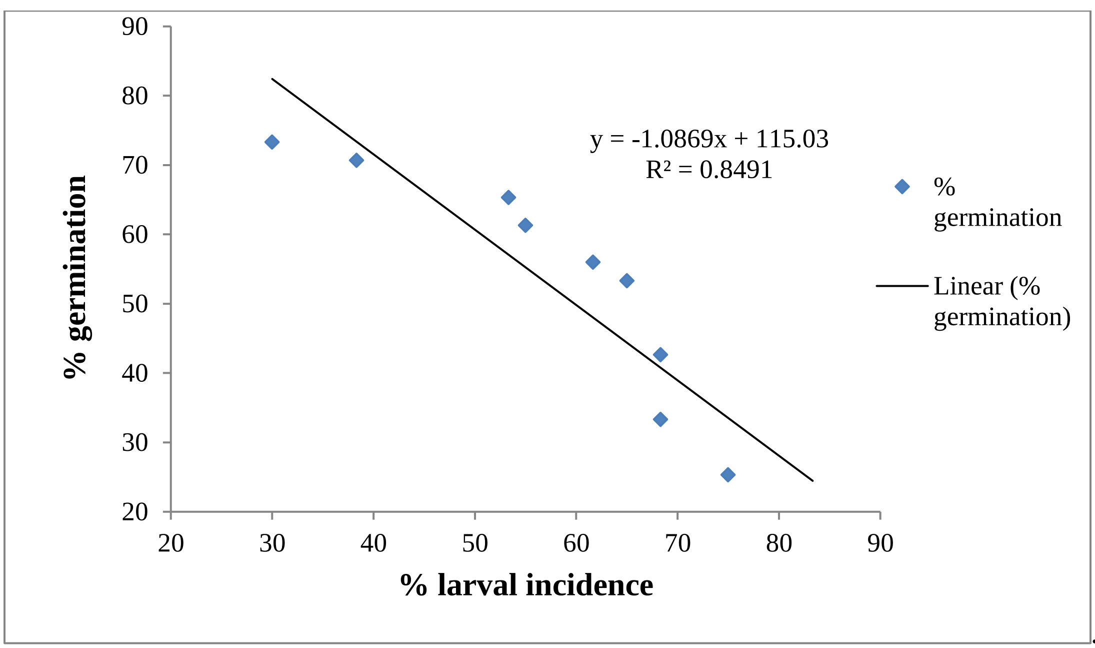

Figure 2: Relationship between larval incidence and seed germination

4.1.7. Relationship between adult emergence and grain content loss

Correlation study was done to establish a relationship between the number of adult emergence and grain content loss percentage. From the study it was revealed that significant correlations existed between the characters (Figure 3). The regression equation y = 0.1214x - 3.59 gave a good fit to the data and the value of the co-efficient of determination (R^2 = 0.9073). From this it can be concluded that the number of adult emergence was positively related to the grain content loss percentage, i. e. with the increase in number of adult emergence percent grain content loss increased.

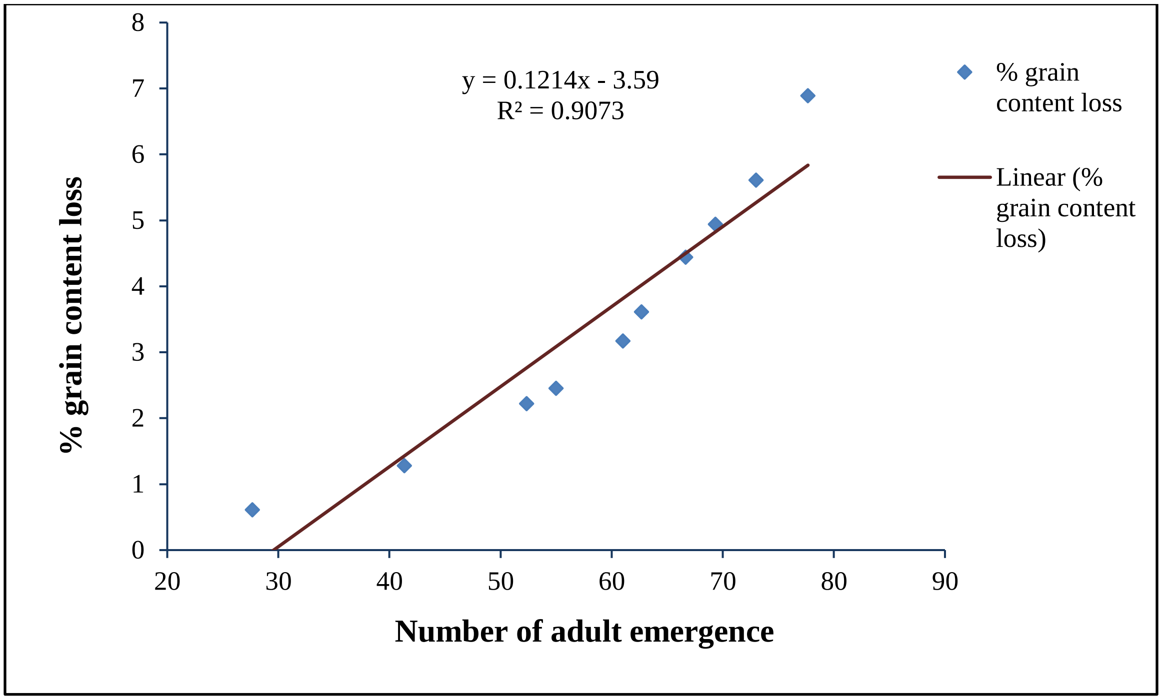

Figure 3: Relationship between number of adult emergence and percent grain content loss

4.1.8. Relationship between adult emergence and seed germination

The significant relationship was found between the number adult emergence and percent germination when correlation was made between the parameters (Figure 4). The highly significant ($p<0.01$), very strong (R^2 =0.8228) and negative (slope = -1.143) correlation was found between the number adult emergence and percent germination, i.e. the germination percentage decreased with the increase of number of adult emergence.

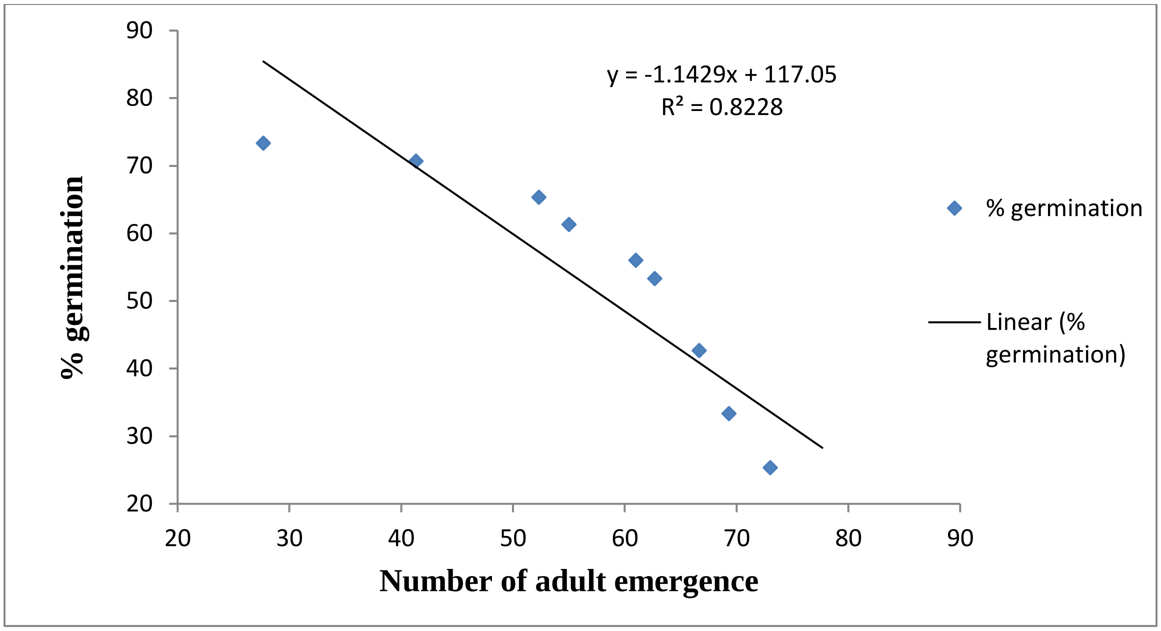

Figure 4: Relationship between number of adult emergence and seed germination

4.1.9. Relationship between the grain content loss and seed germination

The significant relationship was found between the grain content loss percentage and percent germination when correlation was made between the parameters (Figure 5). The highly significant ($p<0.01$), very strong (R^2 =0.9729) and negative (slope=-9.557) correlation was found between the grain content loss percentage and percent germination, i.e. the seed germination decreased with the increase of grain content loss.

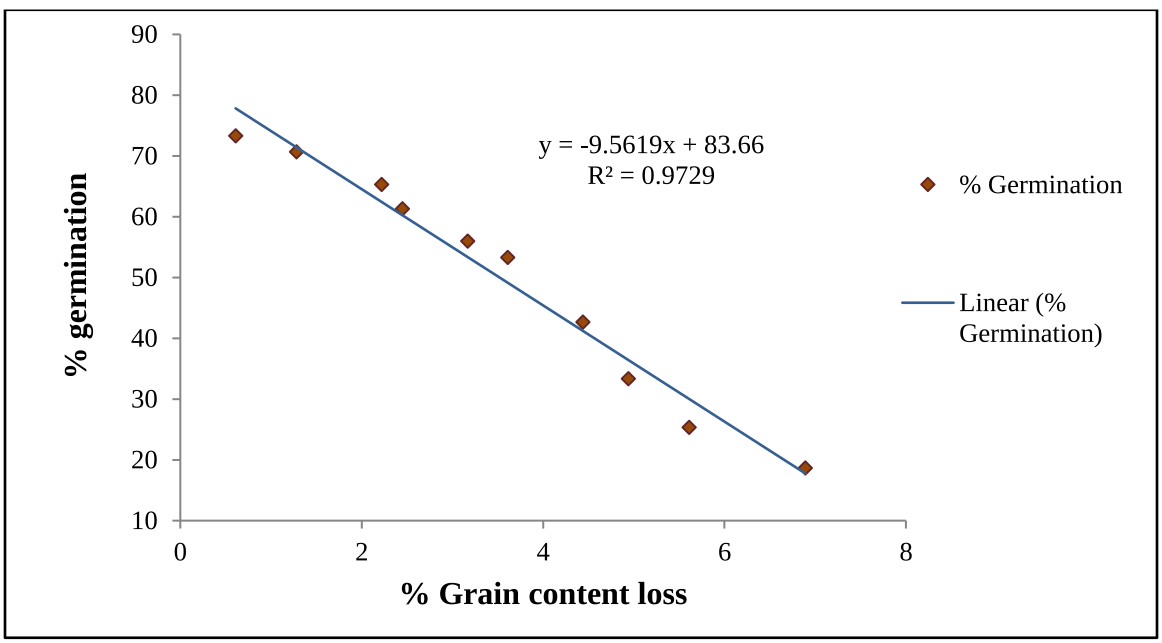

Figure 5: Relationship between the grain content loss and seed germination

4.2. Experiment 2: Varietal screening of rice against *S. cerealella* infestation in storage

The experiment was carried out to observe the varietal screening of ten rice varieties against *S. cerealella* considering grain damage percentage and grain content loss of infested grains. The findings of these parameters are presented here.

4.2.1. No choice test

Evaluation of ten rice varieties was done against *S. cereallella* for five consecutive generations. Five pairs of adult moth were released in each pot. After completion of each generation assessment of grain damage was done by taking care of adult moth. At the end of fifth generation total weight loss was measured and percent grain content loss was calculated.

4.2.1.1. Grain damage by *S. cerealella*

Assessment of damaged grains caused by *S. cerealella* on rice grains was determined on the basis of number of rice grains eaten by the developing larvae and making hole through which the adult emerged. Data was collected after the completion of each generation. Statistical variations were observed among damage percentages by *S. cerealella* on ten rice varieties (Table 6).

First generation: The highest mean damage percentage was observed in BRRI dhan 50 (6.45) which was statistically different from all other varieties (P>0.01). This was followed by Chamak-1 (5.44), ACI-1 (4.89), BRRI dhan 28 (4.33) although there was no statistical difference among these three varieties, followed by BR 22 (3.56) and BR 26 (3.11). On the other hand, the lowest mean damage percentage was observed in BR 11 (0.56) which is statistically different from all other varieties. This was followed by BINA 7 (1.22), BRRI dhan 29 (2.11) and BRRI dhan 49 (2.33).

Second generation: BRRI dhan 50 (7.56) showed highest mean damage percentage which was statistically different from all other varieties (P>0.01) followed by Chamak-1 (6.22), ACI-1 (5.56), BRRI dhan 28 (5.11), BR 22 (4.44) and BR 26 (3.78). The lowest mean damage percentage was observed in BR 11 (0.78) which is statistically different from all other varieties, followed by BINA 7 (1.56), BRRI dhan 29 (2.56) and BRRI dhan 49 (2.89).

Table 6: Grain infestation of rice varieties at different generations of *S. cerealella*

Variety	% grain infestation at different generations				
	1st (30 DAIR)	2nd (60 DAIR)	3rd (90 DAIR)	4th (120 DAIR)	5th (150 DAIR)
BR 11	0.56 g	0.78 h	0.89 i	1.11 g	1.11 h
BR 22	3.56 d	4.44 d	4.78 e	5.11 d	5.44 d
BR 26	3.11 d	3.78 e	4.22 f	4.56 d	4.78 e
BRRI dhan 28	4.33 c	5.11 c	5.68 d	6.22 c	6.67 c
BRRI dhan 29	2.11 e	2.56 f	2.89 g	3.11 e	3.33 f
BRRI dhan 49	2.33 e	2.89 f	3.22 g	3.56 e	3.67 f
BRRI dhan 50	6.45 a	7.56 a	8.44 a	9.33 a	10.00 a
BINA 7	1.22 f	1.56 g	1.89 h	2.00 f	2.22 g
ACI-1 (Hybrid)	4.89 bc	5.56 c	6.22 c	6.78 bc	7.11 c
Chamak-1 (Hybrid)	5.44 b	6.22 b	7.00 b	7.33 b	7.78 b
$LSD_{(0.01)}$	0.58	0.45	0.52	0.56	0.60
CV (%)	7.41	4.78	5.01	4.95	4.95

[DAIR = Days after Insect Release

In a column, numeric data represents the mean value of 4 replications. In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.]

Third generation: The highest mean damage percentage was observed in BRRI dhan 50 (8.44) which was statistically different from all other varieties (P>0.01), followed by Chamak-1 (7.00), ACI-1 (6.22), BRRI dhan 28 (5.68), BR 22 (4.78) and BR 26 (4.22). On the other hand, the lowest mean damage percentage was observed in BR 11 (0.89) which is statistically different from all other varieties. This was followed by BINA 7 (1.89), BRRI dhan 29 (2.89) and BRRI dhan 49 (3.22).

Fourth generation: In fourth generation also the highest mean damage percentage was observed in BRRI dhan 50 (9.33) which was statistically different from all other varieties (P>0.01). There was no statistical difference among Chamak-1 (7.33), ACI-1 (6.78) and

BRRI dhan 28 (6.22), followed by BR 22 (5.11) and BR 26 (4.56). The lowest mean damage percentage was observed in BR 11 (1.11) which is statistically different from all other varieties. This was followed by BINA 7 (2.00), BRRI dhan 29 (3.11) and BRRI dhan 49 (3.56).

Fifth generation: Alike first four generations BRRI dhan 50 having mean damage percentage 10.00 ranks in first position which was statistically different from all other varieties (P>0.01), followed by Chamak-1 (7.78), ACI-1 (7.11), BRRI dhan 28 (6.67), BR 22 (5.44), BR 26 (4.78), BRRI dhan 49 (3.67), BRRI dhan 29 (3.33), and BINA 7 (2.22). On the other hand, with damage percentage of 1.11, BR 11 ranks in last position which is also statistically different from all other varieties.

After observing the results for five consecutive generations, it can be concluded that the damage percentage caused by *S. cerealella* on ten rice varieties was more or less same in pattern and the order in terms of susceptibility of rice varieties to the damage by *S. cerealella* was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) > BRRI dhan 28 > BR 22 > BR 26 > BRRI dhan 29 = BRRI dhan 49 > BINA 7 > BR 11.

4.2.1.2. Grain content loss

The statistical variations were observed among the effect of *S. cerealella* on ten rice varieties in terms of grain content loss percentage (Table 7). After five consecutive generations the highest percent grain content loss was found in BRRI dhan 50 (10.02) which is statistically different from all other varieties followed by Chamak-1 (7.81). There was no statistical significant difference between ACI-1 (7.13) and BRRI dhan 28 (6.70). This was followed by BR 22 (5.47) and BR 26 (4.82). On the other hand, the lowest amount of content loss was found in BR 11 (1.16). This was followed by BINA 7 (2.25). Here between BRRI dhan 29 (3.36) and BRRI dhan 49 (3.69) there was no statistical difference in terms of grain content loss percentage.

As a result the order of percent grain content loss of rice varieties was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) = BRRI dhan 28 > BR 22 > BR 26 > BRRI dhan 49 = BRRI dhan 29 > BINA 7 > BR 11.

The grain content loss might be related to grain damage. Grain damage might be more or less due to different nutrient contents in different rice varieties. Seed coat structure, morphological and physiological characteristics were also major factors for grain damage and content losses caused by *S. cerealella*. This result agreed with those of Takeshita and Imura (1990) who observed the thicker coat reduced the damage to two rice varieties.

Table 7: Effect of *S. cerealella* on grain content loss of ten rice varieties

Variety	Initial weight (g)	Final weight (g)	Weight loss (g)	% grain content loss
BR 11	200	197.68 a	2.32 h	1.16 h
BR 22	200	189.07 e	10.93 d	5.47 d
BR 26	200	190.36 d	9.64 e	4.82 e
BRRI dhan 28	200	186.61 f	13.39 c	6.70 c
BRRI dhan 29	200	193.29 c	6.71 f	3.36 f
BRRI dhan 49	200	192.61 c	7.39 f	3.69 f
BRRI dhan 50	200	180.96 h	20.04a	10.02 a
BINA 7	200	195.50 b	4.50 g	2.25 g
ACI-1 (Hybrid)	200	185.73 f	14.27 c	7.13 c
Chamak-1 (Hybrid)	200	184.39 g	15.61 b	7.81 b
$LSD_{(0.01)}$		1.20	1.68	0.60
CV (%)		0.27	4.92	4.92

[In a column, numeric data represents the mean value of 4 replications. In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.]

4.2.2. Free choice test

Evaluation of ten rice varieties was done against *S. cereallella* for five consecutive generations where moths were allowed to choose their host (rice variety) according to their preference. After completion of each generation assessment of grain damage was done by taking care of adult moth as no choice test. At the end of fifth generation total weight loss was measured and percent grain content loss was calculated.

4.2.2.1. Grain damage by *S. cerealella*

Alike no choice test assessment of damaged grains caused by *S. cerealella* on rice grains was done in case of free choice test. Obtained results are presented in table 8. Varieties having same lettering are not statistically different from each other.

In first generation the highest mean grain damage was observed in BRRI dhan 50 (7.33) that was statistically different from all other varieties followed by Chamak-1 (5.78). There was no significant difference between ACI-1 (5.00) and BRRI dhan 28 (4.56) and among BR 22 (3.67), BR 26 (3.22), BRRI dhan 49 (2.56) and BRRI dhan 29 (2.33). The least mean grain damage was found in BR 11 (0.67) which is statistically different from all other varieties and followed by BINA 7 (1.33)

Table 8: Grain infestation of rice varieties at different generations of *S. cerealella*

Variety	% grain infestation at different generations				
	1st (30 DAIR)	2nd (60 DAIR)	3rd (90 DAIR)	4th (120 DAIR)	5th (150 DAIR)
BR 11	0.67 h	0.89 g	1.00 g	0.89 g	1.00 g
BR 22	3.67 d	4.11 d	4.33 d	4.44 d	4.56 d
BR 26	3.22 de	3.56 d	3.78 d	4.00 d	4.00 d
BRRI dhan 28	4.56 c	5.00 c	5.33 c	5.67 c	5.78 c
BRRI dhan 29	2.33 f	2.67 e	2.78 e	2.78 e	2.78 e
BRRI dhan 49	2.56 ef	2.89 e	3.11 e	3.22 e	3.22 e
BRRI dhan 50	7.33 a	8.11 a	8.56 a	8.89 a	9.00 a
BINA 7	1.33 g	1.67 f	1.78 f	1.56 f	1.67 f
ACI-1 (Hybrid)	5.00 c	5.56 c	5.78 c	5.89 c	6.00 c
Chamak-1 (Hybrid)	5.78 b	6.33 b	6.78 b	6.89 b	7.00 b
$LSD_{(0.01)}$	0.67	0.60	0.62	0.53	0.61
CV (%)	7.86	6.32	6.13	5.14	5.84

[DAIR = Days after Insect Release

In a column, numeric data represents the mean value of 4 replications. In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.]

Here in second generation the highest ranking variety in term of damaged grain percentage was BRRI dhan 50 (8.11). This was followed by Chamak-1 (6.33). There were no significant variation between the pair of ACI-1 (5.56) and BRRI dhan 28 (5.00), BR 22 (4.11) and BR 26 (3.56), BRRI dhan 49 (2.89) and BRRI dhan 29 (2.67). On the other hand the least mean grain damage percentage was observed in BR 11 (0.89) which was followed by BINA 7 (1.67).

Similar data was found in third, fourth and fifth generations where the top ranker variety in terms of grain damage was BRRI dhan 50 and was statistically different from all other varieties followed by Chamak-1 (hybrid). With no statistical difference similar pairs of varieties are ACI-1 and BRRI dhan 29, BR 22 and BR 26, BRRI dhan 49 and BRRI dhan 29. The bottom ranker variety was BR 11 which was followed by BINA 7.

At the end of five consecutive generations, it can be concluded that the damage percentage caused by *S. cerealella* on ten rice varieties was more or less same in pattern. According to these findings the order in terms of susceptibility of rice varieties to the damage by *S. cerealella* was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) = BRRI dhan 28 > BR 22 = BR 26 > BRRI dhan 29 = BRRI dhan 49 > BINA 7 > BR 11.

4.2.2.2. Grain content loss

The statistical variations were observed among the effect of *S. cerealella* on ten rice varieties in terms of grain content loss percentage (Table 9). After five consecutive generations the highest amount of grain content loss percentage was found in BRRI dhan 50 (9.02) which is statistically different from all other varieties followed by Chamak-1 (7.04). There was no statistical significant difference between the pairs of ACI-1 (6.02) and BRRI dhan 28 (5.80), BR 22 (4.59) and BR 26 (4.03), BRRI dhan 49 (3.24) and BRRI dhan 29 (2.80). On the other hand the lowest amount of content loss was found in BR 11 (1.02) which was statistically different from all other varieties. This was followed by BINA 7 (1.70).

As a result the order of grain content loss percentage of rice varieties was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) = BRRI dhan 28 > BR 22 = BR 26 > BRRI dhan 49 = BRRI dhan 29 > BINA 7 > BR 11.

Table 9: Effect of *S. cerealella* on grain content loss of ten rice varieties

Variety	Initial weight (g)	Final weight (g)	Weight loss (g)	% grain content loss
BR 11	200	197.96 a	2.04 g	1.02 g
BR 22	200	190.82 d	9.18 d	4.59 d
BR 26	200	191.94 d	8.06 d	4.03 d
BRRI dhan 28	200	188.39 e	11.61 c	5.80 c
BRRI dhan 29	200	194.40 c	5.6 e	2.80 e
BRRI dhan 49	200	193.51 c	6.49 e	3.24 e
BRRI dhan 50	200	181.96 g	18.04 a	9.02 a
BINA 7	200	196.60 b	3.4 f	1.70 f
ACI-1 (Hybrid)	200	187.96 e	12.04 c	6.02 c
Chamak-1 (Hybrid)	200	185.92 f	14.08 b	7.04 b
$LSD_{(0.01)}$		0.85	1.22	0.61
CV (%)		0.28	4.39	5.77

[In a column, numeric data represents the mean value of 4 replications. In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.]

4.2.3. Trend of percent grain content loss of ten rice varieties in no choice test and free choice test

Statistical variations found in percent grain content losses of ten rice varieties were almost similar in pattern in both tests but value was little lower in free choice test. It might be because this free choice test was performed a month after the no choice test was performed due to shortage of supply of moth population. For that last two generations that are fourth and fifth were during the months of December and January when temperature was lower. It might affect the biology of *S. cerealella* resulting in lower grain damage therefore lower grain content loss. The findings are supported by the report of Akter (2013) where mortality of egg, larvae; pupae, adult emergence and life span of rice moth were found increasing with the temperature and relative humidity decreasing.

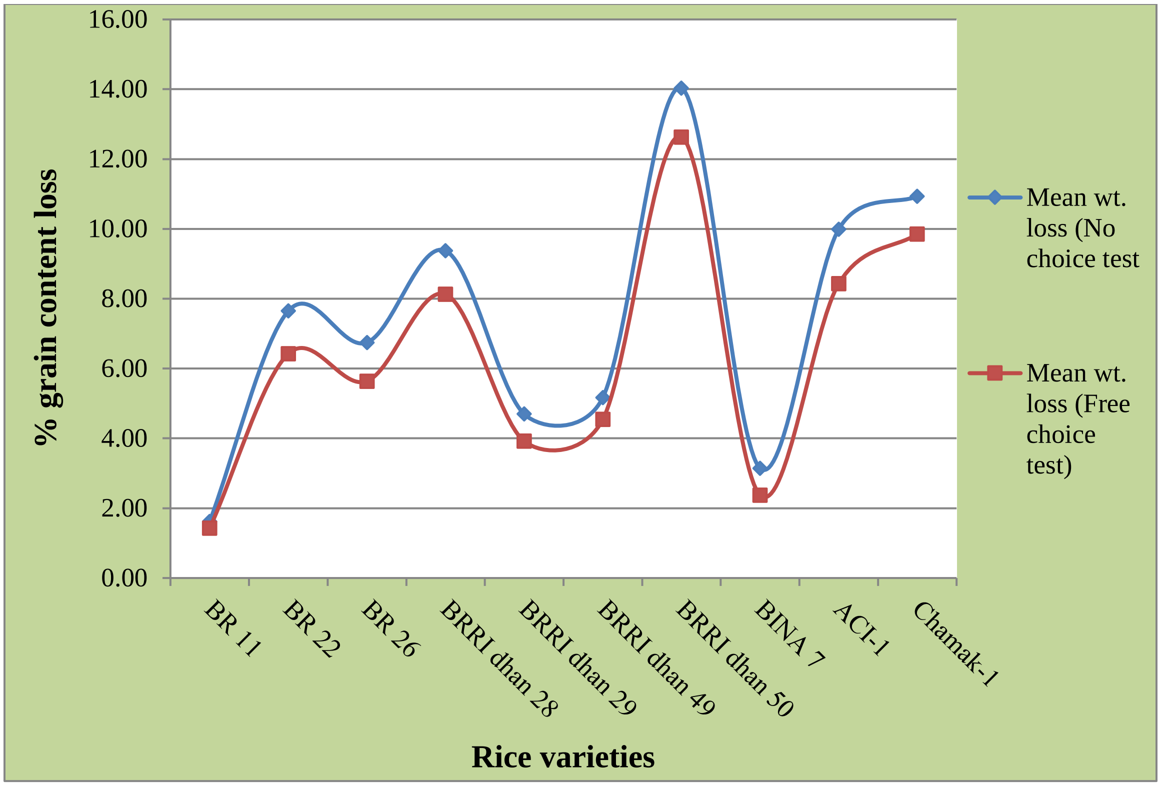

Figure 6: Trend of percent grain content loss of ten rice varieties in no choice test and free choice test.

CHAPTER V
SUMMARY AND CONCLUTION

In the laboratory, ten rice varieties were evaluated against Angoumois grain moth, *Sitotroga cerealella* Oliv. from July, 2014 to February, 2015. Two sets of experiment were conducted where in first set rice varieties were tested to find out varietal preference of rice through growth and development of *S. cerealella* and in second set varieties were tested against *S. cerealella* for five consecutive generations. The experiment was laid out in one factor Completely Randomized Design (CRD) with four replications. Data were taken in respect of percentage of larval incidence, number of adult emergence, percentage of grain damage, grain content loss and seed germination percentage. The obtained data of different parameters were statistically analyzed to find out the significance level of the treatments.

Considering the screening of ten rice varieties against Angoumois grain moth there was a significant influence of these varieties of rice on the larval incidence, adult emergent, grain content loss and seed germination percentage were observed.

Percentage of grain infestation in terms of larval incidence the order of host preference was BBRI dhan 50 = Chamak-1 (hybrid) = ACI-1 (hybrid) = BRRI dhan 28 = BR 22 =BR 26 = BRRI dhan 49 = BRRI dhan 29 > BINA 7 = BR 11

In case of adult emergence the order of host preference was BRRI dhan 50 = Chamak-1 (hybrid) = ACI-1 (hybrid) = BRRI dhan 28 =BR 22 = BR 26 > BRRI dhan 49 = BRRI dhan 29 > BINA 7 > BR 11.

According to the findings the order in terms of susceptibility of rice varieties to the grain content loss by *S. cerealella* was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) > BRRI dhan 28 > BR 22 > BR 26 > BRRI dhan 29 = BRRI dhan 49 > BINA 7 > BR 11.

As the result of seed germination percentage the order of germination percentage of infested seeds of different rice varieties was BR 11 = BINA 7 > BRRI dhan 29 = BRRI dhan 49 > BR 22 = BR 26 > BRRI dhan 28 > ACI-1 (hybrid) > Chamak-1 (hybrid) > BRRI dhan 50.

In the second set of experiment where no choice test and free choice test were performed, significant varietal effect on grain damage percentage and grain content loss by *S. cerealella* was observed.

In no choice test for grain damage percentage the order of preference was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) > BRRI dhan 28 > BR 22 > BR 26 > BRRI dhan 29 = BRRI dhan 49 > BINA 7 > BR 11.

As the result indicated the order of grain content loss of rice varieties was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) = BRRI dhan 28 > BR 22 > BR 26 > BRRI dhan 49 = BRRI dhan 29 > BINA 7 > BR 11.

In case of free choice test for *S. cerealella*, the order of host suitability among different rice varieties in terms of grain damage assessment and grain content loss was more or less similar to that found in no choice test.

The order of grain damage percentage in free choice test was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) = BRRI dhan 28 > BR 22 = BR 26 > BRRI dhan 29 = BRRI dhan 49 > BINA 7 > BR 11.

In case of grain content loss the order of rice varieties was BRRI dhan 50 > Chamak-1 (hybrid) > ACI-1 (hybrid) = BRRI dhan 28 > BR 22 = BR 26 > BRRI dhan 49 = BRRI dhan 29 > BINA 7 > BR 11.

Based on the findings of the present study the following conclusions may be drawn for further evaluation:

i. Significant response had been observed among ten rice varieties on larval incidence, adult emergence, grain damage percentage, seed germination percentage and grain content loss by *S. cerealella* in both sets of experiments.

ii. The highest larval incidence was found in BRRI dhan 50 (83.33 %) and the lowest was in BR 11 (30.00 %). Highest number of adult emergence occurred in BRRI dhan 50 (77.67) and lowest number of adult emergence was found in BR (27.67). The highest grain content loss was observed in BRRI dhan 50 (6.89 %) and the lowest was in BR 11 (0.61 %). Highest number of seed germination was found in BR 11 (73.33) and the lowest number was in BRRI dhan 50 (18.67 %).

iii. In no choice test, highest grain damage was found in BRRI dhan 50 (10.00 %) and lowest grain damage was in BR 11 (1.11 %). The highest grain content loss was in BRRI dhan 50 (10.02 %) and the lowest grain content loss was in BR 11 (1.16 %).

iv. In free choice test, highest grain damage occurred in BRRI dhan 50 (9.00 %) and the lowest damage occurred in BR 11 (1.00 %). The highest grain content loss was observed in BRRI dhan 50 (9.02 %) and the lowest grain content loss was in BR 11 (1.02 %).

v. Among the rice varieties BRRI dhan 50 was found the most suitable host for *S. cerealella* in respect of both growth and development and food consumption. On the other hand, BR 11 was the least suitable host for *S. cerealella*.

CHAPTER VI

REFERENCES

Adam, C. A. (1998). Deterioration of stored feed grains. *Poult. Int*. **37**: 32-36.

Ahmad, M. and ahmad, A. (2002). Storage of food grains. *Farming Outlook*. **1**: 16-20.

Ahmed, R. (2001). Retrospects and prospects of the rice economy of Bangladesh. The University Press Limited, Dhaka. pp. 128.

Ahmed, S. M.; Chander, H. and Pereira, J. (1981). Insecticidal potential and biological activity of Indian indigenous plant against *Musca domestica. Inf. Pest Control.* **23**: 170-175.

Akter, T. (2013). Effects of Temperature and Relative Humidity on The Angoumois Grain Moth, *Sitotroga cerealella* (Olivier) on Stored Rice Grain in Laboratory Condition. *Int. J. Agril. Crop Sci.* **6**(11): 648-653.

Anonymous (1981). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, p. 156.

Anonymous (2001). Year Book of Statistics of Bangladesh. Bureau of Statistics. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, p. 136.

Agricultural Research Service, United States Department of Agriculture (1978). Stored-grain insects, Agriculture Handbook No. 500. Washington, DC: Agricultural Research Service.

Arthur, F. H.; Ondier, G. O. and Siebenmorgen, T. J. (2012). Impact of *Rhyzopertha dominica* (F.) on quality parameters of milled rice. *J. Stored Prod. Res*. **48**: 137-142.

Aviles, R. and Guilbert, G. (1986). Crop residues as a reservoir of pest of stored rice. *Rev. Appl. Entomol.* **79**(12): 1098.

BBS. (2009). Statistical Year book of Bangladesh. Ministry of Planning. Government of the Peoples' Republic of Bangladesh. Dhaka.

BBS. (2013). Statistical Year book of Bangladesh. Ministry of Planning. Government of the Peoples' Republic of Bangladesh. Dhaka.

Bhuiyan, M. I. M.; Alam, S. and Karim, A. N. M. (1992). Losses to stored rice caused by rice weevil and angoumois grain moth and their control in Bangladesh. *Bangladesh J. Agric. Sci.***19**(1): 13-18.

Boldt, P. E. (1974). Effects of temperature and humidity on development and oviposition of *Sitotroga cerealella* (Lepidoptera: Gelechiidae). J. *Kansas Entomol. Society*. **47**(1): 30-36.

Buchelos, C. T. (1980). Moth populations at a typical flour mill. *Annales de l'Institut Phytopathologique Benaki*. **12**(2): 188-197.

CABI. (2005). Crop Protection Compendium. CAB International, Wallingford, UK.

Chavan, P. D.; Yeshbir, S.; Singh, S. P. and Singh, Y. (1997). Growth and development of *Callosobrochus chinensis* on cowpea lines. *Ind. J. Entomol*. **59**(3): 304-310.

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

Chen, S. C. and Peng, W. K. (1998). Emergence and longevity of rice moth, *Corcyra cephalonica* (Stainton) (Lepidoptera:Pyralidae). *Chinese J. Entomol.* **18**(2): 135-140.

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

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

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.

Cotton, R. T. (1960). Pests of Stored Grain and Stored Product. Burgess Publ. Co., Minneapolis, USA. p.34.

Cox, P. D. and Bell, C. H. (1981). A Review of the Biology of Moth Pests on Stored Products. Slough, UK: ADAS.

Dobie, P.; Haines, C. P.; Hodges, R. J.; Prevett, P. F. and Rees, D. P. (1984). Insects and Arachnids of Tropical Stored Products: Their Biology and Identification. Chatham, UK: Natural Resources Insitute.

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

Dakshinamurthy, A. and Regupathy, A. (1988). Alternate rice field hosts of the Angoumois grain moth. *Int. Rice Res. Newsletter*. **13**(3): 42-43.

Evans, D. E. (1987). Stored Products. In: Burn AJ, Coaker TH, Jepson PC, eds. Integrated Pest Management. London: Academic Press.

FAO. (2010). Food Outlook: Global Market Analysis, Global Information and Early Warning System. www.fao.org/docrep/012/ak349e/ak349e00.pdf.

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

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

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. Ent*. **76**: 728-732.

Grenier, A. M.; Pintareau, B. and Nardo, P. (1994). Enzymatic variability in three species of *Sitophilus oryzae* (Coleoptera: Curculionidae). *J. Stored Prod. Res*. **30**: 201-213.

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

Hall, D.W. (1970). Handling and Storage of Food Grains in Tropical and Subtropical Areas. Agricultural development. FAO. Rome, Italy. p. 90.

Hamed, M. and Nadeem, S. (2012). Effect of cereals on the development of *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) and subsequent quality of the egg parasitoid, *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae). *Pak. J. Zool*. **44**: 923-929.

Hammad., S. M.; Shenouda, M. G. H. and El-Deeb, AL (1967). Studies on the biology of *Sitotroga cerealella*. *Bulletin Societe Entomologique d'Egypte*, **51**: 257-268.

Hansen, L. S.; Skovgard, H. and Hell, K. (2004). Life table study of *Sitotroga cerealella* (Lepidoptera: Gelechiidae), a strain from West Africa. *J. Econ. Entomol.* **97**: 1484-1490.

Hassan, M.; Farooq, T. M.; Ahmad, F. and Khan, F. R. (1994). Assessment of storage losses in wheat due to insect pests in Multan and Bahawalpur wheat storages. *Grain Stor.Manag.Newsl*. **1**: 11.

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.

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

Keagy, P. M. and Schatzki, T. F. (1991). Effect of image resolution on insect detection in wheat radiographs. *Cereal Chemistry*. **68**(4): 339-343.

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.

Mahdi, M. T.; 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 Protec.* **6**(2): 64-70.

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

Meikle, W. G.; Markham, R. H.; Holst, N.; Djomamau, B.; Schneider, H. and Vowotor, K. A. (1998). Distribution and sampling of *prostephanus truncatus* (Coleoptera: Bostrichidae) and *Sitophilus zeamais* (Coleoptera: Cucurlionidae) in maize stores in Benin. *J. Econ. Entomol*. **91**: 1366-1374.

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

Muda, A. R. (1985). Pest problems and the use of pesticides in grain storage in Malaysia. ACIAR Proceedings Series, Australian Centre for International Agricultural Research, No. 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.

Pajni, H. R.; Rose, H. S. and Gill, K. M. (1980). Some observations on the biology of *Corcyra cephalonica* (Stainton). *Rev. Appl. Entomol.* **68**(12): 824.

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.

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.

Plague, G. R.; Gaelle, V.; Bridget, E. W. and Kevin, M. D. (2010). Rice weevils and maize weevils (Coleoptera: Curculionidae) respond differently to disturbance of stored grain. *Ann. Entomol. Soc. Am.* **103**: 683-687.

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.

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.

Ragumoorthy, K. N. and Gunathilagaraj, K. (1988). Field incidence of host resistance against Angoumois grain moths. *Intl. Rice. Res. Newsl*. **13**: 12.

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.

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

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

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.

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

Sharaby, A. (1988). Evaluation of some Myrtaceae plant leaves as protectants of rice against the infestation of *Sitophilus oryzae* L. and *Sitophilus granaries* (Coleoptera). *Polskie-Pismo-Entomologiczne.* **59**(2): 372-382.

Sedaghat, R.; Talebi, A. A. and Moharramipour, S. (2011). Effect of Ultra Violet Irradiation (UVC) on biological parameters of *Sitotroga cerealella* (Olivier) (Lep.,Gelechiidae). *J. Entomol. Res*. **2**: 259-269.

Slansky, JR. 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.). vol. 4.Pergamon Press, Oxford, U.K. pp. 87-163.

Stockel, J. and Sureau, F. (1981). Monitoring for the Angoumois grain moth in corn. In: Mitchell ER, Ed. Management of Insects Pest with Semiochemicals. New York, USA: Plenum Press, 63-67.

Sukprakarn, C. (1985). Pest problems and the use of pesticides in grain storage in Thailand. ACIAR Proceedings Series, Australian Centre for International Agricultural Research, No. 14: 31-35.

Takeshita, H. and Imura, O. (!990). Loss assessment of stored rice infested by *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae). *Applied Entomol. Zool*. **25**(2): 239-249.

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 dent corn lines and some of their mutants. *J. econ. Ent*. **81**: 830-833.

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.

Upadhay, V. R.; Shah, A. H.; Desai, N. D. (1979). Varietal resistance of paddy varieties to *Sitotroga cerealella* Oliv. *Indian J. Entomol*. **41**(2): 190-192.

Ustinov, I. D.; Dudarenko, G. P. and Lunochkin, S. M. (1986). For the detection of pests of food stores. Zashchita Rastenii, No. 2:35.

Vick, K. W.; Kvenberg, J.; Coffelt, J. A. and Steward, C. (1979). Investigation of sex pheromone traps for simultaneous detection of Indianmeal moths and Angoumois grain moths. *J. Econ. Entomol.* **72**(2): 245-249.

Vick, K. W.; Webb, J. C.; Weaver, B. A. and Litzkow, C. (1988). Sound detection of stored-product insects that feed inside kernels of grain. *J. Econ. Entomol.* **81**(5): 1489-1493.

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. App*. **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.

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.

Youm, O.; Vayssieres, J. F.; Togola, A.; Robertson, S. P. and Nwilene, F. E. (2011). International trade and exotic pests: The risks for biodiversity and African economies. *Outlook Agric*. **40**: 59-70.