STUDY ON HOST PREFERENCE AND MANAGEMENT OF RICE WEEVIL (*SITOPHILUS ORYZAE* L.) USING SOME BOTANICALS UNDER STORAGE CONDITION

MAHERA AKTER

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA

JUNE, 2020

STUDY ON HOST PREFERENCE AND MANAGEMENT OF RICE WEEVIL (*SITOPHILUS ORYZAE* L.) USING SOME BOTANICALS UNDER STORAGE CONDITION

BY

MAHERA AKTER
Reg. No.: 13-05352

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

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2020

APPROVED BY:

Prof. Dr. Md. Abdul Latif	**Prof. Dr. Mohammed Ali**
Department of Entomology	**Department of Entomology**
Supervisor	**Co-Supervisor**

Prof. Dr. S. M. Mizanur Rahman
Chairman
Examination Committee

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled, **'STUDY ON HOST PREFERENCE AND MANAGEMENT OF RICE WEEVIL (*SITOPHILUS ORYZAE* L.) USING SOME BOTANICALS UNDER STORAGE CONDITION'**, submitted to the Department of Entomology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in Entomology embodies the result of a piece of bona fide research work carried out by **MAHERA AKTER**, Registration No. **13-05352** 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, 2020

Dhaka, Bangladesh

Prof. Dr. Md. Abdul Latif

Supervisor

Department of Entomology

Sher-e-Bangla Agricultural University

Dhaka- 1207

Dedicated

To

My Beloved Parents

And

Dear Husband

ACKNOWLEDGEMENT

The author expresses all of her gratefulness to the almighty Allah who has enabled her to accomplish this thesis paper.

The author would like to express her heartiest respect, deepest sense of gratitude, and kindest thankfulness to her respected supervisor, **Prof. Dr. Md. Abdul Latif**, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.

The author would also like to express her heartiest respect and profound appreciation to her respected co-supervisor, **Prof. Dr. Mohammed Ali**, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his utmost cooperation and constructive suggestions to conduct the research work as well as preparation of the thesis.

The author would like to express her deepest respect and boundless gratitude to all her respected teachers of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work

The author is deeply indebted and grateful to her parents and her beloved husband who continuously prayed for her success and without whose love, affection, inspiration and sacrifice this work would not have been completed.

Finally, the author appreciates the assistance rendered by the staff members of the Department of Entomology and central farm, Sher-e-Bangla Agricultural University, Dhaka, who have helped her lot during the period of study.

Dated: June, 2020
Dhaka, Bangladesh

The Author

STUDY ON HOST PREFERENCE AND MANAGEMENT OF RICE WEEVIL (*SITOPHILUS ORYZAE* L.) USING SOME BOTANICALS UNDER STORAGE CONDITION

ABSTRACT

The study was conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka from May 2018 to October 2018 to find the most preferable grain by rice weevil (*Sitophilus oryzae* L.) based on its biology and the most effective botanical insecticide to control the rice weevil in storage condition. The experiment was laid out in the ambient condition of the laboratory following in a Completely Randomized Design (CRD) and the treatments were replicated for four times. Among the grains (wheat, husked rice, unhusked rice, maize and chick pea) considering wheat, rice weevil was given the highest number of progenies for all 1^{st}, 2^{nd} and 3^{rd} generation (90.33, 130.67 and 195.33). All the other grains resulted significantly different number of progeny but the lowest was obtained from unhusked rice grain (78.33 and 113.33) for 1^{st} and 2^{nd} generation and 185.33 from maize at 3^{rd} generation. The highest number of rice weevil larvae (5.67) was found in wheat grains. Number of adults were highest 35.33 in wheat grains while the lowest in husked rice (11.67). According to the observations, neem leaf powder (67.67 dead rice weevil) showed significantly very high insecticidal effect on *Sitophilus oryzae* adults at 1 day after treatment application. Mehogoni leaf T_1 (51.67 dead rice weevil), marigold leaf T_3 (48.67 dead rice weevil) and garlic powder T_4 (34.67 dead rice weevil) were followed by neem leaf. Percent mortality of some botanical insecticides, neem leaf T_2 (4% dead rice weevil), garlic powder T_4 (3% dead rice weevil) and marigold leaf T_3 (2.33% dead rice weevil). The highest weight of healthy seeds was recorded in T_2 (96.40 g) treatment which was statistically similar with T_1 (91.28 g), whereas the lowest in T_6 (79.76 g) untreated control treatment. In case of % infestation, the highest infestation was found from T_6 (19.96%) which was followed by T_5 (15.82%) treatment while the lowest in T_2 (3.18%) treatment. The highest percent infestation reduction over control was recorded in T_2 (84.07%) treatment and lowest from T_5 (20.84%) treatment. So, from the above findings, it can be said that neem leaf powder was found the best one to control rice weevil infestation as well as wheat grains were the most preferred host for rice weevil.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
CRD	=	Completely Randomized Design
cm	=	Centimeter
CV%	=	Percent Coefficient of Variation
°C	=	Degree Celceous
DMRT	=	Duncan’s Multiple Range Test
DAT	=	Days after treatment
d.f.	=	Degrees of freedom
etc.	=	Etcetra
et al.,	=	And others
°F	=	Degree Fahrenheit
g	=	Gram (s)
J.	=	Journal
LSD	=	Least Significant Difference
M.S.	=	Master of Science
mm	=	Millimeter
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
w/w	=	Weight by weight
%	=	Percent

CHAPTER I

INTRODUCTION

Cereals are the dominant sources of nutrition for developing and underdeveloped nations of Sub-Saharan Africa and South-east Asia. Among the cereals rice, wheat and maize constitute about 85% of total global production (Dayal *et al*. 2003). Among the cereals, wheat is the second most important staple food crop in Bangladesh after rice (BBS 2013). On the other hand, after rice and wheat, maize is an important cereal crop in Bangladesh serving as source of food, feed and industrial raw material. With the increase of population more food grain production is needed in the country. Wheat and maize can play a vital role in food requirement in nation perspective (BARI 1997). In storage, insect pests became important soon after men first learned to keep grains for seed and food purposes. Rice, wheat, maize and other cereals are stored in the government and public godown both in Bangladesh and other developing countries.

Insect infestation on stored grains and their products is a serious problem through the world. There are approximately 200 species of insects and mites attacking stored grains and stored products (Maniruzzaman 1981). According to Alam (1971), 5-8% of the food grain seeds and different food products are lost annually due to storage pests.

In Bangladesh, cereals are stored as raw parboiled in bamboo made container (dole and goals) or stored in earthen pot (motka) (BRRI 1984). Cereals are being damaged by a number of agents, such as, insects, rodents, fungi, mites, birds and moisture (Prakas and Rao 1983). Among them, storage insects are the major agents causing considerable losses each year. Nearly seventeen species of insects have been found to infest stored cereals (Prakas *et al*. 1987) of which rice weevil (*Sitophilus oryzae* L.), rice moth (*Sitotroga cerealella*) and red flour beetles (*Tribolium castaneum*) are the most serious insect pests.

The rice weevil *Sitophilus oryzae* L. is one of the most destructive insect pests of stored grains. It is almost cosmopolitan in distribution being more abundant in warm and humid areas but does not thrive in countries having cold winters (Prakash *et al*. 1987, Alam 1971). Both the adult and larva feed voraciously on a variety of stored cereal grains viz. rice, wheat, maize and other products causing serious losses. In tropical countries, outbreak of this pest may make the stored rice unfit for human consumption within eight months of storage both in unhusked and husked condition (Prakash *et al*. 1987). Rice weevil is the most common pest in all types of cereals stores in Bangladesh but loss estimates due to this pest are scanty. Bhuiya *et al*. (1992) reported 11-16% weight loss of husked rice during 4 months of storage in laboratory condition. At present different kinds of preventive and curative control has been used for a long time, but has serious drawbacks (Sharaby 1988). But the indiscriminate use of chemical pesticides in storage has given rise to many well known serious problems including resistance of pest species, toxic residues in stored products, increasing cost of application, enviromental pollution, hazards from handling etc. (Khanam *et al*. 1990, Ahmed *et al*. 1981). The residues of chemical insecticides remain in stored grain and also in the enviroment. Besides this, reports are also available on the efficacy of different plant products such as oils (Chander *et al*. 1991, Singh *et al*. 1990). But plant oils are not always available, not good in efficacy, have pungent smell. Hence, search for the alternative method of rice weevil control utilizing some non-toxic, enviroment friendly and human health hazard free methods are being persuaded now-a-days. In recent years it has been demonstrated that various insect species are affected in their growth activity and metamorphosis by treatment with botanicals like Mahogoni, Bishkatali, Neem products (khan 1991). It is well known that neem extract has proved to be one of the promising plant extract for insect control at the present time. These products do not leave harmfull residue with lower toxicity to mammals (Negahban *et al*. 2006). The efficacy of neem extracts on various insect pests species were noted earlier such as repellent, anti-feedant, growth-retardant, molt disrupting, progeny development disrupting and also oviposition deterrent (Schmutterer 1995, Saxena 1995, Sanguanpong and Schmutterer 1992). The practice of mixing neem materials especially neem oil with store products, food grain and other commodities showed an effective protection against the insect pests.

Considering the above facts, the present research work was undertaken with the following objectives:

- To find out the preferable host grain of rice weevil.
- To evaluate the efficacy of some botanicals for controlling rice weevil, *Sitophilus oryzae* L.

CHAPTER II

REVIEW OF LITERATURE

The insect, *Sitophilus oryzae* L. is a serious stored product pest which attacks several crops including rice, wheat and maize. The adults feed mainly on the grain endosperm thus reducing the carbohydrate content, while the larvae feed preferentially on the germ of the grain thus removing a large percentage of the proteins and vitamins (Belloa *et al*. 2000). A search in the literature revealed that the biology of this insect varied with environmental conditions, seasons and types of grains. Information about the biology of rice weevil on rice grains is not available in Bangladesh. Moreover, information is available pertaining to the contol of rice weevil is very limited and also not conclusive. It also reveals that very few studies have so far been done elsewhere in the world relevant to the control of rice weevil using neem products. Some literatures on such studies relevant to the present study available through literature and CD-ROM search have been reviewed here in brief under the following sub-headings.

2.1 Distribution of rice weevil

Sitophilus oryzae L. is worldwide in distribution but found in abundance in mountainous and coastal areas where the climate is rather humid.

2.2 Systematic position of rice weevil

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Curculionidae

Subfamily: Dryophthorinae

Genus: *Sitophilus*

Species: *Sitophilus oryzae* L.

2.3 Appearance of rice weevil

The rice weevil is small, 1/10 inch (2 to 3 mm) and stout in appearance. It is very similar in appearance to the granary weevil. However, the rice weevil is reddish brown to black in color with four light yellow or reddish spots on the corners of the elytra (the hard protective forewings). The snout is long (1 mm), almost 1/3 of the total length. The head with snout is as long as the prothorax or the elytra. The prothorax (the body region behind the head) is strongly pitted and the elytra have rows of pits within longitudinal grooves. The larva is legless and stays inside the hollowed grain kernel. It is fat with a cream colored body and dark head capsule (Koehler 2008).

2.4 Habits of rice weevil

The rice weevil is one of the most serious stored grain pests worldwide. This pest of stored grain was originated in India. It now has a cosmopolitan distribution. It is a serious pest in the southern United States. The rice weevil is replaced by the granary weevil in north of North Carolina and Tennessee. Both the adults and larvae feed on whole grains. They attack wheat, corn, oats, rye, barley, sorghum, buckwheat, dried beans, cashew nuts, wild bird seed, and cereal products, specially macaroni. The adult rice weevil can fly and is attracted to lights. When disturbed, adults pull in their legs, fall to the ground, and feign death. The larval rice weevil must complete its development inside a seed kernel or a man-made equivalent, like macaroni products. Larval rice weevils have been known to develop in hard caked flour. The adult female eats a cavity into a seed and then deposits a single egg in the cavity, sealing in the egg with secretions from her ovipositor. The larva develops within the seed, hollowing it out while feeding. The larva then pupates within the hollow husk of the grain kernel (Koehler 2008).

2.5 Biology of rice weevil

The adult female rice weevil lays an average of 4 eggs per day and may live for four to five months. The full life cycle may take only 26 to 32 days during hot summer months, but requires a much longer period during cooler weather. The eggs hatch in about 3 days.

The larvae feed inside the grain kernel for an average of 18 days. The pupa is naked and the pupal stage lasts an average of 6 days.

The new adult will remain in the seed for 3 to 4 days while it hardens and matures (Koehler 2008). The larvae, pupa and adult were shown in Plate 1 and 2.

Plate 1: Larvae of rice weevil

Plate 2: Pupa and adult of rice weevil

2.6 Control of rice weevil

The most important aspect of control is location of the source of the infestation. Place sticky traps around the room to locate the infestation, if not initially or easily located. Sticky traps with a higher density of rice weevils attached are probably closest to the infestation site. Common sources of infestations include decorative "Indian corn" from wild bird seed and dry plant arrangements that contain wheat seed heads, popcorn, beanbags, toys stuffed with grain, macaroni products, and seeds for sprouting. Infested materials should be destroyed or disposed of. All life stages can be killed by extreme heat (120°F for one hour) or cold (0°F for a week) (Jagjeet *et al*. 2005). The best control measure is to store products likely to be infested in pest-proof containers of plastic, glass, or metal. Seeds and nuts can be stored long term by adding a 1 inch cube of dry ice (solid carbon-dioxide) to a quart mason jar of seeds and sealing the lid. The carbon dioxide atmosphere discourages all stored product pests. Infestations in non-food areas can be treated with space sprays or crack and crevice treatments with residual insecticides having rice weevils listed on the label. Infestations in large quantities of grain are controlled by fumigation.

2.7 Control of rice weevil by using neem products

The harvested crops or grain are stored in storage. The stored grains suffer seriously from the attack of a number of insect pests. Now-a-days, pest control by botanicals has been proposed as potential pest control measures in the world. Several species of insects pests both in field and in storage have been reported to be controlled by the application of botanical products such as powder, extract and oil as potential source of anti-feedant, repellent and growth inhibitor (Islam 1984). Islam (1984) observed that oil of neem as well as its leaves and seeds extracts prepared in hexane, diethyl ether, 95% ethanol and acetone showed as potential feeding deterrents for the control of rice weevil. Yadav (1984) investigated the efficacy of neem seed kernel powder against pulse beetle and pulse seeds were protected from the attack of *Callosobrochus maculatus*. Several indigenous plant materials have traditionally been used as store grain protectants against insect pest in various parts of the world. Bowry *et al*. (1984) reported that oils and seed cake powders of neem, linseed, castor, mahua and mustard showed repellent action on *Sitophilus oryzae*. The neem preparation was most effective in reducing oviposition and linseed extracts. Long term studies were carried out in Poland on the stored grain pest *Sitophilus granarium* and on the behavior of the pest was tested with 54 extracts from 28 plant species for their repellent activity. The most effective repellent was found in Caraway extracts, the main component of which is Carbone (Nawrot 1985). Ahmed and Eapea (1986) screened plant extracts and found that those from gaultheria, dill (*Anethus graveoleus*), Japanese mint (*Mentha* sp.), eucalyptus, cineole and turpentine were promising as strong repellent against *Sitophilus oryzae* and *Callosobrochus chinensis.*

Neem (*Azadirachta indica*, *A. juss*) is a perennial plant belongs to the family Meliaceae. It is famous for its medicinal properties. The major active constituent is azadirachtin, which is well known for its anti-feedant, toxic and growth regulating effects on insects (Mordue and Blackwell 1993, Schmutterer 1990, Saxena 1989). However, neem compounds are too complex to be synthesized for practical purposes (Saxena 1989). The wood resembles mahogany and bark is very bitter (Hooker 1978). However, neem compounds are too complex to be synthesized for practical purpose (Saxena 1995).

Jilani (1986) conducted experiments with ethanolic extract of neem seed; hexane extract of sweet flag, *Acorus calamus* rhizome and thymol applied to *Tribolium castaneum*, *Rhyzopertha dominica*, *Sitophilus oryzae* L. and *Sitotroga cereallela* in wheat grain and observed significant control of the insect infestation.

Saxena (1986) reported that plant such as neem is important for their insect repellent properties in addition to other plant processing insecticidal and growth regulating properties.

Saljoqi *et al*. (2006) used ethanol extracts of six plant materials i.e. bakain drupes (*Melia azdarach*), habulas leaves (*Myrtus communis*), mint leaves (*Mentha longifolia*), bakain leaves, herbal shoots and seeds (*Pegnum harmala*) and lemon grass roots (*Cymbopogon citrates*) against rice weevil, *Sitophilus oryzae* L. to determine their insecticidal properties. The results revealed that all of the tested materials with some variations had repellent and lethal effects against the pest as compared with the untreated check. Considering the % of mortality of the insect as a main index, bakain drupes proved to be the most effective of these six plant materials, showed 61.2% mortality, followed by habulas (44. 40%), mint (47.40%) and bakain leaves (46.80%), while herbal (16.80%) was found less effective followed by lemon grass (35.20%).

Jilani and Saxena (1990) observed that neem, turmeric and sweet flag had repellent action on stored grain pests. Singh *et al*. (1987) evaluated six plant extracts against *Rhyzopertha dominica* in the laboratory, extracts of neem (*Azadirachta indica*), *Bassia longifolia* and *Pongamia glabra* were highly toxic. The crude extract of water hyacinth (*Eichhorrnia* *grassipes*) was evaluated for its biological activity against the *Tribolium castaneum*, *Sitophilus oryzae*, *Callosobrochus maculats* and *Corcyra cepheilanica*.

Tanzubil (1987) applied neem fruit dust, leaf dust and seed kernel oil on stored seed and observed that neem fruit dust at 105 protected seeds and found that 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 *Sitotroga cerealella* and prevented cross infestation by *Rhyzopertha dominica* (Dakshinamurthy 1988).

Makanjuola (1989) studied the effect of neem leaf and seed extracts on *Callosobrochus maculates*, *Sitophilus oryzae*, *Sitophilus zeamais* and *Cylospuncti collis*. The extracts were more effective as suppressants to *Callosobrochus maculates* than of *Sitophilus oryzae* and there was no effect on *Cylospuncti collis*. Repellency action of turmeric, sweet flag and neem oil against the lesser grain borer, *Rhyzopertha dominica* were observed by Jilani and Saxena (1990).

Adgesh *et al*. (1991) reported that oils and powder from neem and lagundi (*Vitex negundo*) mixed with grains at different storage intervals for 180 days effectively controlled the emergence of adults of *Sitophilus oryzae*, *Rhyzopert hadominica* and *Callosobnichus chinensis* and maintained viability of the seeds.

Azmi *et al*. (1993) observed in laboratory studies that the toxicity of a compound contained 10% cyfluthrin (Slofac) and a neem formulation contained crude extract from fruits of *Azadirachta indica* against *Sitophilus oryzae*. The tests were carried out by releasing the curculionids on treated filter papers seated with different concentration of the compounds. A mortality rate of 90% was obtained with a 0.5% concentration of cyfluthrin and a 1% concentration of the neem compound.

Talukder and Howse (1994) reported that the seed extract of *Aphanamixis poystachya* had strong repellent effects on red flour beetle and grain weevil. The repellency and toxicity of Azadirachtin and three neem extract to three stored product insects, *Cryptolestes ferrugineus*, *Sitophilus oryzae* and *Tribolium castaneum* investigated by Xie *et al*. (1995), when *Tribolium castaneum* was more sensitive to the repellent action of neem than the other 2 species.

Rouf *et al*. (1996) investigated the toxicity of the leaf powder of neem, nishinda and bishkatali, and their combinations against *Callosobrochus chinensis* on lentil seeds and reported that 4 g of bishkatali leaf powder/50g of lentil seeds was most effective in reducing oviposition, adult emergence, damage of seeds by the pest and seed weight loss; the combination of neem and bishkatali leaf powder ranked second followed by neem leaf powder alone. At low doses (1-2 g) these three plant materials applied either alone or in combination were found to be less effective germination of lentil seeds was not affected by bishkatali leaf powder. Application of the plant materials at intervals of 15 days up to 2 months storage did not give better protection of lentil seeds than a single application only.

Khan and Shahjahan (1998) reported that dried powdered *Eucalyptus teretocornis* leaves were extracted with hexane, acetone, ethanol and methanol and the extracts were tested to observe their effects on adults of *Sitophihis oryzae* and *Callosobrochus chinensis*. Results showed that *Sitophilus oryzae* was repelled and *Callosobrochus chinensis* was attracted by all the extracts. The percentages of repulsion for *Sitophilus oryzae* were 71.1, 74.7, 69.0 and 63.3 respectively.

Sharma (1999) reported that neem seed (*Azadirachta indica*) kernel powder (NSKP) at 4% and neem leaf powder (NPL) at 5% protected maize for 5 months against *Sitophilus oryzae*, *Sitotroga cerealella*, *Rhyzoperthado minica* and *Trogoderma granarium*. Neem oil (nimbcidine 1%) was toxic to the adults of *Sitophilus oryzae*, *Rhyzopertha dominica*, *Trogoderma granarium*, *Sitotroga cerealella* and *Triboliurn castaneum*. Neem oil (nimbicidine, 2%) effectively reduced the emergence of F_1 and F_2 progeny of all the pests and completely protected maize up to 9 months and suggested that neem products can be mixed with 15 stored maize to protect the grains up to 9 months from the attack of these major pests.

Shanmugapriyan and Kingly (2001) reported the effect of neem oil at 0.25, 0.5 and 1.5% on larvae of *Sitophilus oryzae*. Neem oil at 1.5% concentration caused the highest mortality of second and third instars (95.23%) and fourth instars (76.19%). Neem oil at 0.25% and 0.5% concentrations resulted in 57.10% and 85.7% mortality in second larval instars, 47.6% and 85.7% in third instars and 57.1% and 80.9% in fourth instars.

Islam and Talukder (2005) evaluated for direct and residual toxicities of seed extracts and leaf powders of the neem (*Azadirachta indica*), marigold (*Tageste serecta*) and durba (*Cynodon dactylon*) along with two commercial insecticides (malathion and carbaryl respectively) against red flour beetle (*Tribolium castaneum*), a major stored product pest. All seed extracts and leaf powders showed a certain degree of toxicity on the insects. Among the tested plant derivatives neem seed extract (100 µg/insect) showed highest direct toxicity (53.13% mortality) towards red flour beetle than marigold (46.88%) and durba (37.00%) seed extracts. Toxicity and protectant potential of chloroform extract of the leaves of the bishkatali (*Polygonum hydropiper*) and neem seed (*Azadirachta indica*) against the rice weevil *Sitophilus oryzae* L. were assessed using contact toxicity, progeny production, damage assessment and repellency assays. The extract of *Polygonum hydropiper* was moderately toxic to *Sitophilus oryzae* but that of *Azadirachta indica* was highly toxic to the weevils, evoking 95% mortality in rice treated with the highest dosage after 72 hour of exposure (Obeng-Ofori and Akuamoah 2007).

Experiments were carried out to evaluate the toxicity or six botanicals Mahogoni (*Swieteni mahagoni*) Neem (*Azadirachta indica*), Bazna (*Zanthoxy lumrhetsa*), Hijal (*Barringtonia acutangula*), Karanja (*Pongamia pinnata*), against red flour beetle (*Tribolium castaneum*). Leaf and seed extracts were prepared by using acetone, methanol and water as solvents. The results showed that extracts of all the six plants had direct toxic effect on red flour beetle. Among them, neem seed extract showed the highest toxic effect (mortality, 52.50%), whereas hijal leaf extract possessed the lowest toxic effect (mortality, 22.24%) (Mamun *et al*. 2009).

Fernando and Karunaratne (2012) investigates the effectiveness of the botanical *Olax zeylanica* in controlling infestations of the rice weevil. In two separate bioassays, contact/feeding and fumigant toxicity of powdered leaves of *Olax zeylanica* were tested against 1-7 days old adult *Sitophilus oryzae* under laboratory conditions. Contact/feeding toxicity was tested by directly exposing adult weevils to 1.0, 3.0, 5.0 and 7.5 g of leaf powder mixed with 100 g of rice grains while fumigant toxicity was evaluated by using the same doses where the adults were exposed to fumes emitted from the leaf powders. In both bioassays 100% mortality of the adult *Sitophilus oryzae* was observed within 18 hours of exposure to 3.0, 5.0 and 7.5 g doses of leaf powder. Percentage adult weevil mortality in treated rice tested with three doses of *Olax zeylanica* leaf powder at all the time intervals (except for 1.0 g) was significantly higher ($p < 0.05$) than that of the corresponding control. No Contact/feeding toxicity was recorded when adult weevils were directly exposed to 1.0 g leaf powder whereas only 14% adult weevil mortality was observed even after 24 hours of exposure to fumes of leaf powder. Results also revealed that mortality increased both with increasing dose and time of exposure. In both bioassays a 100% adult weevil mortality was obtained after18 hours of exposure to 3.0 g leaf powder of *Olax zeylanica* or to its fumes. Moreover, LD_{50} values of 2.55 g and 2.08 g for leaf powders obtained after 12 hours of exposure to adult *S. oryzae* in contact/feeding toxicity test and fumigation test respectively. The results indicated that leaf powder of *Olax zeylanica* is more toxic to adults *Sitophilus oryzae* when they were in direct contact with it. Findings of this study bears out the exceptionally high efficacy of *Olax zeylanica* leaves applied directly mixed with the rice grains or introduced as a fumigant to suppress weevil infestations in stored grains and strengthen the possibility of using powdered leaves of *Olax zeylanica* as an alternative to synthetic chemicals in storage insect pest management.

CHAPTER III

MATERIALS AND METHODS

Experiments were conducted at the Entomology laboratory of Sher-e-Bangla Agricultural University, Dhaka from May 2018 to October 2018 to find the most susceptible grain attacked by rice weevil, (*Sitophilus oryzae* L.) and the most effective botanical insecticide to control rice weevil (*Sitophilus oryzae* L.) in storage condition. A brief description of the experimental site, experimental design, treatments, data collection and analysis of different parameters under the following headings are presented below:

3.1: Host preference of rice weevil

3.1.1 Progeny determination

After 28 days of adult rice weevil release the insects of all container were sieved out to determine the F_1 progeny. Number of adult emergences was counted at 35, 40 and 45 days after adult release. Data collection was stopped after 45 days to avoid next generation.

3.1.2 Host preference

To find out the most suitable or preferable grain, 5 different grains (husked rice, unhusked rice, wheat, maize and chick pea) were used as food of rice weevil. All the grain was sterilized in hot water and dried. Two hundred and fifty gram of each grain was taken in plastic jar and 10 rice weevil adults were released in each plastic jar. The experiment was repeated 4 times.

3.1.3 No. of larva, pupa and adult

For counting the larva, pupa and adult population emerged from initial released weevil, 50 seeds were randomly selected at 35 days after adult rice weevil release. The selected grains were inspected and dissected to find out the larva, pupa and adult.

3.1.4 Incubation period, larval period, pupal period and adult longevity

Twenty grains of each type were taken in five petridish and 2 adult rice weevil was released into each petridish. After one day the adult of rice weevil were taken out and the grains were inspected under microscope to find out the egg containing grain. Five egg containing seeds were kept in the petridish and others were moved to another jar. Then the petridishes with 5 egg containing grains were observed every day. When a larva hatched from the egg the date was counted as incubation period. After that when the pupa found, the duration was counted as larval duration and the date of adult emergence was counted as pupal duration. Adult longevity was counted by keeping the newly emerged adult from the stock culture in isolated condition and the days were counted until the adult's death. The process was repeated 4 times.

Plate 3. Rice weevil infested wheat

Plate 4. Rice weevil infested unhusked and husked rice

Plate 5. Rice weevil infested maize and chick pea

3.2 Efficacy of some botanicals for controlling rice weevil

3.2.1 Experiment materials

Stored unhusked wheat (BARI Gom 24) were purchased and collected from the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka. Collected stored wheat (BARI Gom 24) were kept in 20 plastic pots maintaining one kg per pot and then these pots were in ambient room temperature in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University.

3.2.2 De-infestation of Wheat grains

Before artificial infestation of wheat grains with weevils, the parboiled wheat grains of BARI Gom 24 variety were dried in the sun for 2 days.

3.3 Collection and rearing of rice weevil

Rearing of rice weevil was necessary to ensure continuous supply of the test insects during the study. Initially, the insects with infested rice were collected from the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka. First, males and females were sorted out by using magnifying glass and simple microscope. The test insects were maintained in rice grain in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, at 27- 30°C temperature and 70-75% relative humidity. The insects were reared in the jars. Each jar was set up with 10 pairs of the adult rice weevil. Wheat grains were sterilized at 60°C for 30 minutes and then used as food for the insects. The mouth of the jars was covered by cheese-cloths fastened with rubber bands to prevent contamination and insect escape. After allowing them for free oviposition for a period of 7 days the adult insects were removed from each jar and the jars were put back into growth chamber for completing the generation of insects after development from the egg in the food. The wheat grains with eggs left on the sieve were kept for 30 days to develop into adults and then adult emergence was observed. One-day-old adults were sorted from the rice grains by sieving and transferred regularly into separate jars with wheat grains. Jars along with insects were then kept in the same place, temperature and relative humidity. Three to seven days old insects were used for the study. The rearing procedure was repeated with different batches to ensure continuous supply of the adults of required ages.

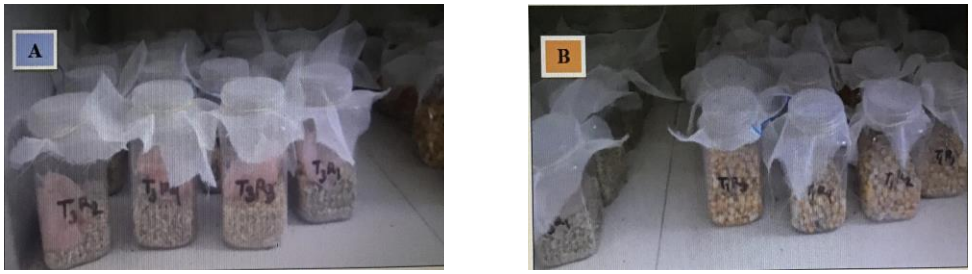


Plate 6. Set of the experiment in laboratory condition

3.4 Treatment materials

Five different plant materials and one untreated control were used as treatment. They are as follows:

T_1 = Mehogoni (*Swietenia macrophylla*) leaf powder at 10 gkg^{-1} of stored wheat grains

T_2 = Neem (*Azadirachta indica*) leaf powder at 10 gkg^{-1} of stored wheat grains

T_3 = Marigold (*Tagetes erecta* L.) leaf powder at 10 gkg^{-1} of stored wheat grains

T_4 = Garlic (*Allium sativum* L.) powder at 10 gkg^{-1} of stored wheat grains

T_5 = Bel (*Aegle marmelos*) leaf powder at 10 gkg^{-1} of stored wheat grains and

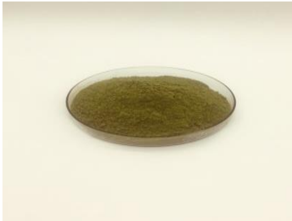
T_6 = Untreated control

Wheat grains were used as culture media. Before the treatment the wheat grains were washed with hot water and dried for 2 days.

3.5 Preparation of plant materials

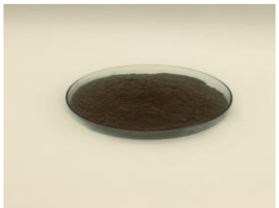
The plant leaves were collected from the Sher-e-Bangla Agricultural University campus and the garlic powder were collected from the local market. The plant materials were washed and air-dried for two weeks in a well-ventilated place. The powders were prepared by milling the plant materials using a grinder in the Entomology Laboratory, Sher-e-Bangla Agricultural Universit, Dhaka.

Mahogoni leaf



Powder of dried mahogoni leaf

Neem leaf

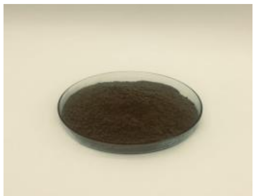


Powder of dried neem leaf

Marigold leaf

Powder of dried marigold leaf

Bel leaf



Powder of dried bel leaf

Garlic

Powder of dried garlic

Plate 7. Plant materials

3.6 Percent infestation

The grains kept in each plastic jar were infested with holes by insects were considered as damaged. To evaluate the damage percentage of the grain, 50 seeds were taken randomly from each jar and finally the number of holed seeds were counted and expressed as percentage at 30 days after adult rice weevil release. The percentage of infestation was calculated by the following formula:

$$\text{Percent infestation} = \frac{\text{No. of infested seeds}}{\text{No. of total seeds Consumed}} \times 100$$

3.7 Percent mortality at different rate of the treatments

Six plastic containers were filled with 100 g of the sterilized wheat grains. To each plastic container except the untreated container, 1 g of each powder was added and mixed thoroughly by manual agitation. 40 rice weevil adults were released in all the 6 container and the containers were covered with the lid to prevent the escape of the insect. The number of the dead insects were counted at 7, 14 and 28 days after the release, from the counted data percent mortality was calculated. The experiment was replicated for 4 times. Similar process was done with 3g and 5 g of the treatments.

The adult mortality was recorded and converted into percentage. The original data were corrected by the adopting Abbott's (1925) formula.

$$\text{Percent mortality} = \frac{\text{No. of dead insects}}{\text{Total no. of insects treated}} \times 100$$

3.8 Weight Loss

The seed weight loss caused by the feeding of weevils. The weight of the grains of each jar was measured at 30, 60 and 90 days after the release of adult rice weevil. Then percent weight loss was calculated to count the most preferable grains by rice weevil.

$$\text{Percent weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.9 Statistical analysis of data

The data obtained for different parameters were statistically analyzed using MSTAT-C software. The mean values of all the characters were calculated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the difference among the treatment means was estimated by the LSD at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSIONS

Experiments were conducted at the Entomology laboratory of Sher-e-Bangla Agricultural University, Dhaka from May 2018 to October 2018 to find the most susceptible grain attacked by rice weevil, (*Sitophilus oryzae* L.) and the most effective botanical insecticide to control rice weevil (*Sitophilus oryzae* L.) in storage condition. A brief description of analysis of different parameters under the following headings are presented below:

4.1 Preferable host range of rice weevil

Host rage of rice weevil was tested to find out the most suitable or preferable grain, 5 different grains (wheat, unhusked rice, husked rice, maize and chick pea) were used as food of rice weevil. All the grains were sterilized in hot water and dried.

4.1.1 Progeny determination

Status of selected grains in terms of progeny determination 1^{st}, 2^{nd} and 3^{rd} generation showed statistically significant variation under the present trial for the progeny determination of rice weevil in 5 grains. (Appendix IV).

Considering 1^{st} generation, the maximum number of progenies was found in wheat grain (90.33) followed by husked rice (84.67), chick pea (84.67) and maize (80.67) where husked rice and chick pea results were statistically similar (Tab.1) and the lowest number of progenies found in unhusked rice grain (78.33).

In case of 2^{nd} germination, the maximum number of progenies was found in wheat grain (130.67) followed by husked rice (125.33), chick pea (125.33) and maize (120.67) where husked rice and chick pea results were statistically similar (Tab.1) and the lowest number of progenies found in unhusked rice grain (113.33).

In case of 3rd generation, the maximum number of progenies was found in wheat grain (195.33) followed by husked rice (190.67), chick pea (190.67) and maize (185.33) where husked rice and chick pea results were statistically similar (Tab.1) and the lowest number of progenies found in unhusked rice grain (177.00).

Rice weevil prefers a wide range of grains among them wheat was the most affected one second to husked rice (polished) brought from store as the adults feed mainly on the grain endosperm thus reducing the carbohydrate content, while the larvae feed preferentially on the germination of the grain thus removing a large percentage of the proteins and vitamins. But in Bangladesh, both the adults and larvae feed on whole grains and also infested grains.

Table 1. Progeny determination of rice weevil population in different grains in laboratory condition

Grains	1st generation	2nd generation	3rd generation
Wheat	90.33 a	130.67 a	195.33 a
Unhusked rice	78.33 d	113.33 d	177.00 e
Husked rice	84.67 b	125.33 b	190.67 b
Maize	80.67 c	120.67 c	185.33 d
Chick pea	84.67 b	125.33 b	190.67 c
LSD (0.05)	1.12	2.06	2.13
CV%	0.71	0.89	0.61

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.

4.1.2 No. of larva, pupa, adult and incubation period

Status of selected grains in terms of rice weevil population showed statistically significant variation under the present trial for the population of the different stages of rice weevil in 5 grains (Tabe 2).

At larval stage, the highest number of rice weevil larva (5.67) was found in wheat grains which was statistically different from all other treatments (grains).

In contrast, the minimum number of rice weevil larva (1.00) was recorded from chick pea grains which was statistically identical to maize grains (1.67). The second highest number of rice grain larva (4.33) was found in unhusked rice grains which was followed by husked rice (3.00) grains and they were statistically different (Tab. 2).

At pupal stage, the highest number of rice weevil pupa (4.00) was found in wheat grains which was statistically different from all other treatments (grains).

In contrast, the minimum number of rice weevil pupa (0.67) was recorded from chick pea grains which was statistically identical to maize grains (1.00). The second highest number of rice weevil pupa (3.00) was found in unhusked rice grains which was followed by husked rice (2.00) grains and they were statistically different (Tab. 2).

At adult stage, the highest number of rice weevil adult (35.33) was found in wheat grains which was statistically different from all other treatments (grains).

In contrast, the minimum number of rice weevil adult (11.67) was recorded from husked rice grains which was statistically identical to chick pea grains (12.33). The second highest number of rice weevil adult (25.33) was found in unhusked rice grains which was followed by maize (13.67) grains and they were statistically different (Tab. 2).

At incubation period, the highest number of rice weevil incubation period (15.67 days) was found in husked rice grains which was statistically similar with the chick pea grains (15.00 days).

In contrast, the minimum number of rice weevil incubation period (8.33 days) was recorded from wheat grains which was followed by unhusked rice grains (10.33 days) and maize (12.67 days) grains (Tab. 2).

Data revealed that rice weevil mostly prefer wheat grains (around 80% infestation was occurred) and then rice grains. Other grains were moderately infested. So, wheat and rice grains require special care during storage and some eco-friendly management can be undertaken to control rice weevil infestation.

Table 2. Development of rice weevil population in different grains in laboratory condition

Grains	No. of larvae	No. of pupa	No. of adult	Incubation
Wheat	5.67 a	4.00 a	35.33 a	8.33 d
Unhusked rice	4.33 b	3.00 b	25.33 b	10.33 c
Husked rice	3.00 c	2.00 c	11.67 d	15.67 a
Maize	1.67 d	1.00 d	13.67 c	12.67 b
Chick pea	1.00 d	0.67 d	12.33 d	15.00 a
LSD (0.05)	0.90	0.48	1.19	1.37
CV%	15.42	12.10	3.22	5.89

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.

4.1.3.a. Larval period and pupal period

Status of selected grains in terms of the different stages duration of rice weevil population showed statistically significant variation under the present trial for the population of rice weevil in 5 grains. (Tab. 3)

Rice weevil larval duration significally vary from grain to grain. The maximum longer larval period was found in maize (27.33 days) grain which was followed by chick pea (25.33 days), husked rice (25.67 days) and unhusked rice (21.67 days) grains where chick pea and husked rice were statistical identical. The lowest larval duration of rice weevil was found in wheat (20.33 days) grain.

Rice weevil pupal duration significally vary from grain to grain. The maximum longer pupal period was found in husked rice (11.33 days) grain which was statistically identical to chick pea (11.33 days) grain. The second maximum longer pupal periods were found in unhusked rice (9.67 days) and maize (9.67 days) grains. The lowest pupal duration of rice weevil was found in wheat (7.67 days) grain.

Table 3. Biology of rice weevil population in different grains in laboratory condition

Grains	Larval period (days)	Pupal period (days)
Wheat	20.33 d	7.67 c
Unhusked rice	21.67 c	9.67 b
Husked rice	25.67 b	11.33 a
Maize	27.33 a	9.67 b
Chick pea	25.33 b	11.33 a
LSD (0.05)	1.13	1.03
CV%	2.46	5.51

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.

4.1.3.b. Adult longevity

In case of adult longevity rice weevil adult live highest (144.3 days) on husked rice followed by chick pea (140.67 days) and maize (133.67 days). On the other hand. the lowest duration was on wheat grain (115.7 days) followed by unhusked rice (120. 67 days). So, the data on the biology of the rice weevil revealed that the insect require least time to complete its life cycle on wheat grains (Figure 1).

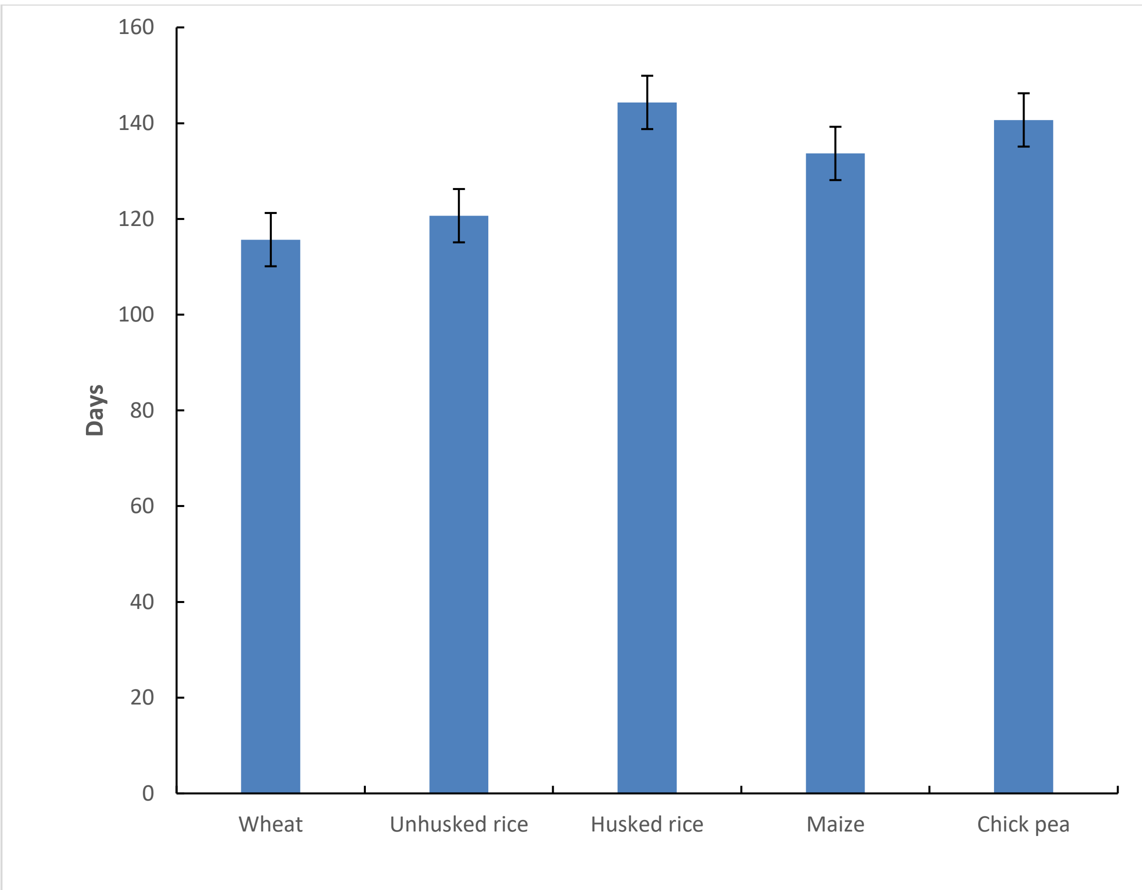


Figure 1. Adult longevity (days) of rice weevil population in different grains in laboratory condition

4.2 Efficacy of some botanicals for controlling rice weevil, *Sitophilus oryzae* L.

Botanical insecticides have long been stated as attractive alternatives to synthetic chemical insecticides for pest management because botanicals reputedly pose little threat to the environment or to human health (Isman 2006). Therefore, the present study was initiated to find and recommend possibly the most effective plant material against *Sitophilus oryzae* in the stored wheat grains.

4.2.1 Number of dead rice weevil observations

The effect of some botanical insecticides on *Sitophilus oryzae* at the rate of 10 g dose at 24, 48 and 72 hours after treatment are shown in Table 4. According to the observations, the highest number of dead rice weevil was found in neem leaf powder T_2 (67.67 dead rice weevil) showed significantly very high insecticidal effect on *Sitophilus oryzae* adults at 1 day after treatment. Mehogoni leaf T_1 (51.67 dead rice weevil), marigold leaf T_3 (48.67 dead rice weevil), garlic powder T_4 (34.67 dead rice weevil). T_1, T_3 and T_4 were followed by neem leaf powder and they were statistically different. Significantly the lowest number of dead rice weevil was observed in case of untreated control treatment T_6 (23.00 dead rice weevil)). More or less similar trend was found in all data recording days (at 48 hours and 72 hours). Talukdar (2005) reported similarly that, neem leaf powder reduced the loss of grain weight and percentage of infested grain of rice moth (*S. cerealella*) infestation in unhusked rice grain during storage. Isman (2006) reported that the antifeedant activities of the neem products might be responsible for lower damage of grains. These results were different from the findings observed by some others researchers (Islam 2000). Tanzubil (1987) applied neem fruit dust, leaf dust and seed kernel oil on stored seed and observed that neem fruit dust at 105 protected seeds and found that neem seed kernel oil also gave effective control.

Table 4. Number of adult dead rice weevil observations under different botanicals

Treatments	24 Hours	48 Hours	72 Hours	Mean
T_1	51.67 b	55.33 b	59.00 b	55.33 b
T_2	67.67 a	74.67 a	80.33 a	74.20 a
T_3	48.67 c	50.33 c	59.33 b	52.78 c
T_4	34.67 d	37.67 d	40.33 c	37.57 d
T_5	30.67 e	34.67 e	38.67 d	34.67 e
T_6	23.00 f	25.67 f	30.33 e	26.33 f
LSD (0.05)	1.54	1.08	1.44	0.62
CV%	1.99	1.29	1.55	0.73

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.

[Treatments: T_1 = Mehogoni leaf powder, T_2 = Neem leaf powder, T_3 = Marigold leaf powder, T_4 = Garlic powder, T_5 = Bel leaf powder and T_6 = Untreated control]

4.2.2 Effect of different treatments on percent mortality of rice weevil

Insect mortality showed statistically significant variation for different botanical products for the management of rice weevil in stored condition.

Percent mortality of some botanical insecticides on *Sitophilus oryzae* at the rate of 10 g dose at 24, 48 and 72 hours after treatment are shown in Table 5. According to the observations, neem leaf powder T_2 (4.00%) showed the highest percent mortality and gave the very high insecticidal effect on *Sitophilus oryzae* adults at 1 day after treatment. In contrast, the lowest percent mortality was found in untreated control T_6 (0.67%). The second highest percent mortality was observed in mehogoni leaf powder T_1 (3.33 %) which was followed by garlic powder T_4 (3.00%) (Tab. 5).

Table 5. Percent mortality of rice weevil at different times after treatment application

Treatments	% Mortality		
	24 Hours	48 Hours	72 Hours
T_1	3.33 b	7.67 b	10.33 b
T_2	4.00 a	11.67 a	15.33 a
T_3	2.33 c	5.33 c	8.67 c
T_4	3.00 b	4.33 c	7.67 d
T_5	2.00 c	2.67 d	6.33 e
T_6	0.67 d	0.67 e	1.67 f
LSD (0.05)	0.63	1.03	0.99
CV%	13.64	10.53	6.57

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.

[Treatments: T_1 = Mehogoni leaf powder, T_2 = Neem leaf powder, T_3 = Marigold leaf powder, T_4 = Garlic powder, T_5 = Bel leaf powder and T_6 = Untreated control]

4.2.3 Mortality rate

For cumulative percentage of mortality, the highest mortality (62%) was observed in T_2 treatment which was followed by T_1, T_3 and T_4 treatments and these treatments were statistically different. In contrast, the lowest mortality T_6 (6%) was found in untreated control (Figure 2).

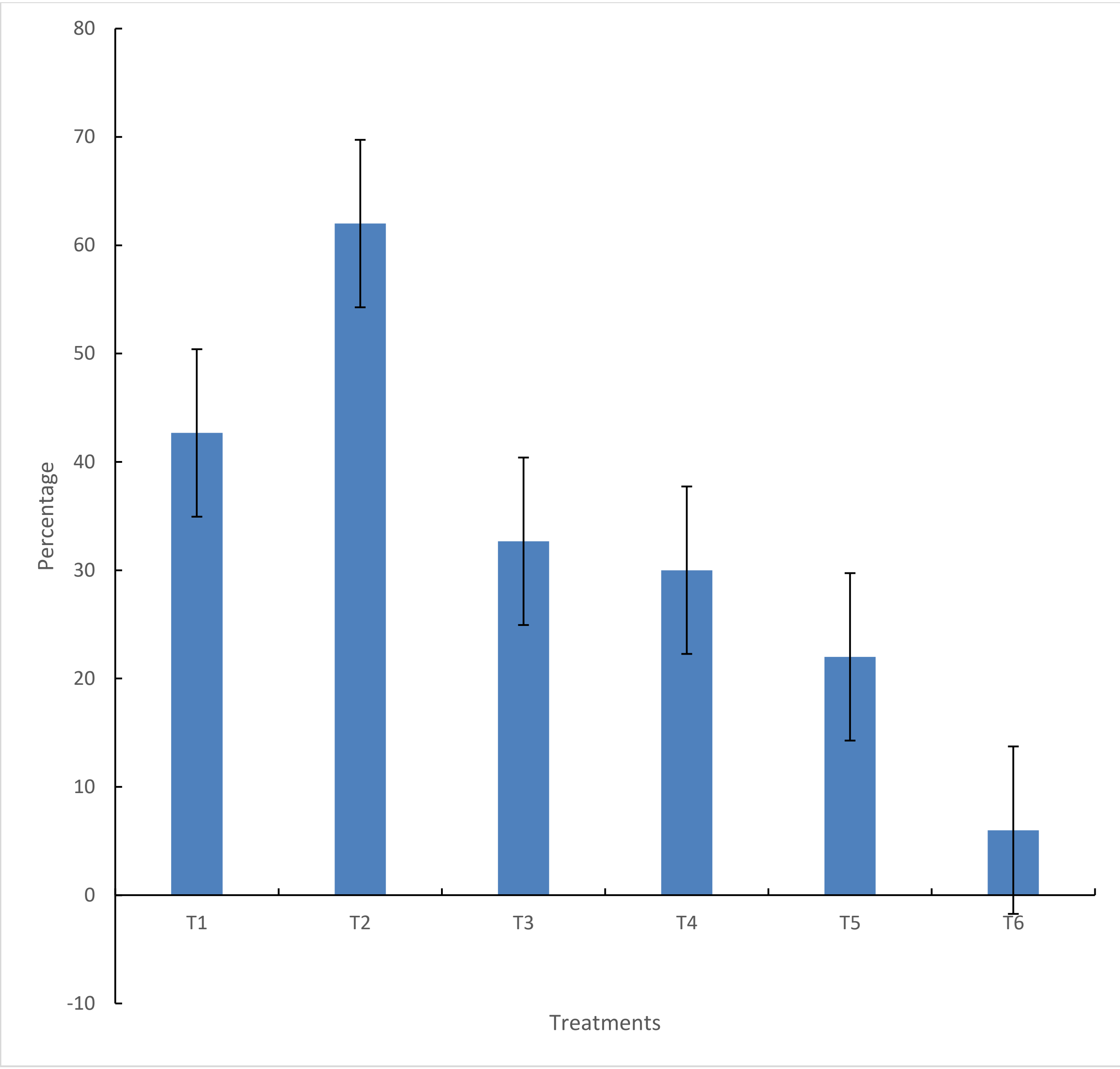


Figure 2. Cumulative percentage of mortality of rice weevil different in different botanicals

4.2.4 Effect of different botanical components on rice weevil infestation

Weight by g the highest weight of healthy seeds was recorded in T_2 (96.40 g) treatment which was followed by T_1, T_3 and T_4 treatments and they were statistically different. Whereas the lowest weight of healthy seed wes found in untreated control T_6 (79.76 g) which was significantly lower than treatment T_5 (83.53 g). In case of infested seeds, the lowest infested seeds obtained from T_2 (3.16 g) which was followed by T_1 (8.42 g) and the highest number was recorded in T_6 (19.90 g) treatment which was followed by T_5 (15.70 g). In case of % infestation, the highest infestation was found from T_6 (19.96%) which was followed by T_5 (15.82%) treatment while the lowest in T_2 (3.18%) treatment. The highest infestation reduction over control was recorded in T_2 (84.07%) treatment and the lowest from T_5 (20.84%) treatment.

Table 6. Effect of different botanicals on rice weevil infestation at reduction of weight loss

Treatments	Healthy (g)	Infested (g)	%Infestation	% Weight loss	% Infestation Reduction over control
T_1	91.28 b	8.42 e	8.45 e	8.71 e	57.66
T_2	96.40 a	3.16 f	3.18 f	3.60 f	84.07
T_3	88.41 c	10.66 d	10.76 d	11.58 d	41.98
T_4	85.60 d	13.73 c	13.82 c	14.40 c	27.85
T_5	83.53 e	15.70 b	15.82 b	16.46 b	20.84
T_6	79.76 f	19.90 a	19.96 a	20.23 a	
LSD (0.05)	0.46	0.45	0.44	0.46	--
CV%	0.29	2.10	2.05	2.03	--

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.

[Treatments: T_1 = Mehogoni leaf powder, T_2 = Neem leaf powder, T_3 = Marigold leaf powder, T_4 = Garlic powder, T_5 = Bel leaf powder and T_6 = Untreated control]

These results also support the findings of Talukdar (2005) who reported that, neem leaves powder reduced the loss of grain weight and percentage of infested grain of rice moth (*S. cerealella*) infestation in unhusked rice grain during storage. Isman (2006) reported that the antifeedent activities of the neem products might be responsible for lower damage of grains. These results were different from the findings observed by some others researchers (Islam 2000). Tanzubil (1987) applied neem fruit dust, leaf dust and seed kernel oil on stored seed and observed that neem fruit dust at 105 protected seeds and found that neem seed kernel oil also gave effective control.

CHAPTER V

SUMMERY AND CONCLUSION

The Experiment was conducted at the Entomology laboratory of Sher-e-Bangla Agricultural University, Dhaka from May 2018 to October 2018 to find the most susceptible grain attacked by rice weevil, (*Sitophilus oryzae* L.) and the most effective botanical insecticide to control rice weevil (*S. oryzae*) in storage condition. The experiment was laid out in the ambient condition of the laboratory following in a Completely Randomized Design (CRD) and the treatments were replicated for five times. Among the grains (wheat, husked rice, unhusked rice, maize and chick pea).

The adult female rice weevil lays an average of 4 eggs per day and may live for four to five months. The full life cycle may take only 26 to 32 days during hot summer months, but requires a much longer period during cooler weather. The eggs hatch in about 3 days. The larvae feed inside the grain kernel for an average of 18 days. The pupa is naked and the pupal stage lasts an average of 6 days. The new adult will remain in the seed for 3 to 4 days while it hardens and matures.

Considering wheat grain, rice weevil give highest number of progenies for all 1st, 2nd and 3rd generation (90.33, 130.67 and 195.33). All the other grains resulted significantly different number of progeny but the lowest was obtained from unhusked rice grain (78.33 and 113.33) for 1st and 2nd generation and 185.33 from maize at 3rd generation. The highest number of rice weevil larva (5.67) was found in wheat grains, which was followed by unhusked rice grains (4.33) and similar result was found in all data recording type (also the number of pupa and adult). Least number of pupa (0.67) was recorded on chick pea. Number of adult was highest 35.33 in wheat grains while the lowest in husked rice (11.67). Data revealed that rice weevil mostly prefer wheat grains (around 80% infestation was occurred) and then rice grains.

Rice weevil larval duration was the lowest in wheat (20.33 days) followed by unhusked rice (21.67 days). Similar trend was found in pupal duration of rice weevil, highest 11.33 days was required both in husked rice and chick pea. The lowest in 7.67 days in wheat grains. In case of adult longevity rice weevil adult live highest 144.3 days on husked rice followed by chick pea (140.67 days) and maize (133.67 days).

On the other hand, the lowest adult longevity was on wheat grains (115.67 days) followed by unhusked rice (120.67 days). So, the data on the biology of the rice weevil revealed that the insect require least time to complete its life cycle on wheat grains. (Figure 2).

The effect of some botanical insecticides on *Sitophilus oryzae* at the rate of 10 g dose at 24, 48 and 72 hours after treatment are shown in Table 4. According to the observations, neem leaf powder T_2 (67.67 dead rice weevil) showed significantly very high insecticidal effect on *Sitophilus oryzae* adults at 1 day after treatment. Mehogoni leaf T_1 (51.67 dead rice weevil), marigold leaf T_3 (48.67 dead rice weevil) and garlic powder T_4 (34.67 dead rice weevil) were followed by neem leaf. Significantly the lowest number of dead rice weevil was observed in untreated control T_6 (23.00 dead rice weevil). More or less similar trend was found in all data recordings (at 48 hours and 72 hours respectively). In percent mortality observation the highest % mortality was found in neem leaf T_2 (4% dead rice weevil) which was followed by garlic powder T_4 (3% dead rice weevil) and marigold leaf T_3 (2.3% dead rice weevil). Significantly the lowest number of dead rice weevil was observed in untreated control T_6 (0.67% dead rice weevil). More or less similar trend was found in all data recording days (at 48 hours and 72 hours respectively). Weight by g, the highest weight of healthy seeds was recorded in T_2 (96.40 g) treatment which was followed by T_1 (91.28 g), T_3 (88.41 g) and T_4 (85.60 g) treatment. Whereas the lowest weight of healthy seed was recorded in untreated control T_6 (79.76 g) which was significantly lower that treatment T_5 (83.53 g). In case of infested seeds, the lowest weight of infested seeds obtained from T_2 (3.16 g) and the highest infested weight was recorded in T_6 (19.90 g) treatment which was followed by T_5 (15.70). In case of % infestation, the highest infestation was found from T_6 (19.96%) which was followed by

T_2 (15.82%) treatment while the lowest in T_2 (3.18%) treatment. The highest infestation reduction over control was recorded in T_2 (84.07%) treatment and lowest from T_5 (20.84%) treatment.

Conclusion

Considering the results of the study, it could be concluded that wheat grain is the most preferable host grain of rice weevil (*Sitophilus oryzae* L.). In most cases, the infestation of rice weevil, *Sitophilus oryzae* L. could be minimized by use of neem leaf dusts. Among the other botanical products on 100 g of stored wheat grains was more effective followed by neem leaves dusts @ 10 gkg^{-1} of stored wheat grains (90 ml alcohol + 10 g leaves dusts) for controlling rice weevil.

Recommendations considering the findings of the present experiment, further studies in the following areas may be suggested;

1. Host preference practices may be introduced for effective control of rice weevil.
2. Such study needs to be carried out with using other botanicals with different concentration.

CHAPTER VI

REFERENCES

Adgesh, B.J. and Rajesus, B.M. (1991). Residual toxicity of three plant materials against three storage insect pests. College Laguna Philippines. Dept. of Entomology. 29p.

Ahmad, S. and Koppel, B. (1985). Plant extracts for pest control, village-level processing and use by limited resource farmers. Paper presented in Amer. Assoc. Advanem. Sci. Annual Meeting, Los Angeles, CA. p. 2631.

Ahmed, S. and Grainger, M. (1986). Potential of the neem tree (*Azadirachta indica*) for pest control and rural development. *Econ. Botany*. **40**(2): 201-209.

Ahmed, S.M. and Eapea, M. (1986). Comparative efficacy of indigenous plant materials as repellent against *Sitophilus oryzae* L. *Bangladesh J. Agril. Res.* **5**(2): 31-35.

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

Alam, M.Z. (1971). Pest of stored grains and other stored products and their control. *Agril. Inf. Serv*. Publ. Dacca. p. 61.

Ansari, A.R. (2003). Host preference, varietal screening and management of the rice weevil, *S. oryzae* (Coleoptera: Curculionidae). M.Sc. Thesis (unpublished). Master of Science in the Faculty of Agriculture. Maharana Pratap University of Agriculture and Technology, Udaipur, India. p. 89.

Azmi, M.A., Naqvi, S.N.H., Akter, K., Jahan, M., Habib, R. and Tavassum, R. (1993). Toxicological studies of solfae and neem formulation against *Sitophilus oryzae*. *National Academy Sci. Lett.* **16**(5-6): 187-190.

Baloch, U.K. (1992). Integrated Pest Management in Food Grains. Food and Agriculture Organization of the United Nations and Pakistan Agricultural Research Council, Islamabad, Pakistan. pp. 117.

BARI (Bangladesh Agricultural Research Institute) (1997). Annual report for 1996. Wheat Division. Joydevpur, Gazipur.

BBS (Bangladesh Bureau of Statistics) (2013). Statistical Yearbook of Bangladesh. Ministry of Planning, Dhaka, Bangladesh. 56-62.

Belmain, S. and Stevenson, P. (2001). Ethno-botanicals in Ghana: reviving and modernizing age-old farmer practice. *Pestic. Outlook.* **12**: 233–38.

Belloa, G.D., Padina, S., Lastrab. C.L. and Fabrizio, M. (2000). Laboratory evaluation of chemical biological control of rice weevil (*Sitophilus oryzae* L.) in store grain. *J. Stored Prod. Res.* **37**: 77-84.

Bhuiyan, 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**(1): 13-18.

Bowry, S.K., Pandey, N.D. and Triparthi, R.A. (1984). Evaluation of certain oilseed cake powders as grain protectant against *Sitophilus oryzae* L. *Indian J. Entomol*. **46**(2): 196-200.

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

Campbell, J.F. (2002). Influence of seed size on exploitation by the rice weevil, *Sitophilus oryzae*. *J. Insect Behav.* **15**(3): 420-445.

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

Chandra, S., Khare, B.P. and Sharma, V.K. (1989). Efficacy of some selected fumigants on rice-weevil, *Sitophilus oryzae* L. *Indian J. Agril. Res*. **12**(2): 79-84.

Cogan, P. M. and Highley, E. (2003). Effect of Neemazal and other neem products on mortality, fecundity and frass activity of the larger grain borer *Prostephanustruncatus* (Horn) (Coleoptera: Bostrichidae) infesting maize. Advances in stored product protection proceedings of the 8th international working conference on stored product protection York. U. K. 22-26 July. 588-595.

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

Das, G.P. and Karim, M.A. (1986). Effectiveness of neem seed kernel oil as surface protectant against the pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). *Rev. Appl. Entomol*. **76**(8): 30-31.

David, B.V., Sukumaran, D. and Kandasamy, C. (1988). The Indian privet, *Vitex negundo* L. a plant possessing promising pesticidal activity. *Pesticides*. **22**(2): 27-30.

Dayal, R., Tripathi, R.A. and Renu, R. (2003). Comparative efficacy of some botanicals as protectant against *Sitophilus oryzae* in rice and its palatability. *Annual Plant Protect. Sci*. **11**(1): 160-162.

Dey, D. and Sarup, P. (1993). Feasibility of protection maize varieties with vegetable oils to save losses in storage due to *Sitophilus oryzae* L. *J. Entomol. Res*. **17**(1): 1-15.

Dilwari, V.K., Dhaluiwal, D.G. and Mahar, M.S. (1991). Toxicity of allyl isothiocyanate to rice weevil, *Sitophilus oryzae* L. *J. Ins. Sci*. **4**(1): 101-102.

Dubey, N.K., Srivastava, B., and Kumar, A. (2008). Current Status of Plant Products as Botanical Pesticides in storage pest management. *J. Biopest.* **1**(2): 182 – 186.

El-Atta, H.A. and Ahmed, A. (2002). Comparative effects of some botanicals for the control of the seed weevil *Caryedon serratus* (Col. Bruchidae). *J. Appl. Entomol.* **126**(10): 577-582.

Fernando, H.S.D. and Kaurantee, M.M.C.D. (2012). Ethrobotanicals for Storage Insect Pest Management: Effect of powdered leaves of *Olax zeylanica* in suppressing infestations of rice weevil *Sitophilus oryzae* L. (Coleoptera: Curculionidae). *J. Tropic. Forest. Env.* **2**(1): 20-25.

Hassanali, A. and Lwande, W. (1989). Antipest secondary metabolites from African plants. **In:** Arnason, J.A., Philogene, B.J.R. and Morand, P. (ed.). Insecticides of Plant Origin. ACS Symposium Series No.387, U.S.A. 78-94.

Hooker, J.O. (1978). Flora of British India. Periodical Expert Book Agency. D-42, Vivek Vihar, Delhi-110032. 543-544.

Igantowicz, S. (1997). Repellency of powdered plant material of the Indian neem tree, the Labrador tea and the sweet flag to some stored product pests. *Entomology*. **65**(1-2): 75-79.

Imtiaz, A., Farzana, S., Azmi, M.A., Kahkashan, A., Rizvi, S.A., Muzaffer, A. and Shakoori, A.R. (2001). Comparative toxicological studies of neem leaf extract and cyhalothria (Pyrethroid) against *Sitophilus oryzae* and their effects on alkaline phosphatase activity. *Proc. Pakistan Congr. Zool*. **21**: 255-261.

Islam, B.N. (1984). Pesticidal action of neem and certain indigenous plants and weeds of Bangladesh. In Proc. 2nd Int. Neem Conf. Rauischholzhausen 1983. 263-290.

Islam, M.S. and Shahjahan, M. (2000). Insecticidal effects of some plant extracts against rice weevil, *Sitophilus oryzae* L. and red flour beetle, *Tribolium castaceum* Herbst. *Progress Agric*. **11**(1-2): 123-129.

Islam, M.S. and Talukder, F.A. (2005). Toxic and residual effects of Azadirachta indica, Tagetes erector and *Cynodon dactylon* seed extracts and leaf powders on *Tribolium castaneum*. *J. Plant Dis. Protet.* **112**(6): 594-601.

Isman, M.B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual Rev. Entomol*. **51**: 45–66.

Jagjeet, S., Chhillar, B.S. and Kashyap, R.K. (2005). Effectiveness of various seed protectants on adult mortality of pulse beetle, *Callosobrchus maculates* (F.) infesting pigeon pea seeds. *Annal. Biol.* **21**(1): 65-67.

Jenkins, D.A., Dunkel, F.V. and Gamby, K.T. (2003). Storage temperature of neem kernel extract: differential effects on oviposition deterrency and larval toxicity of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *Environ. Entomol.* **32**(6): 1283-1289.

Jilani, G. (1986). Evaluation of some botanical products as grain protectants against insect pests at farm level in Pakistan (Philippines). College Laguna (Philippines). p. 101.

Jilani, G. and Saxena, R.C. (1990). Derivatives of neem, turmeric and sweet flag as protectant against stored grain insect pest. International Rice Res. Inst. Los Banos, Manila, Philippines. p. 186.

Jilani, G., Saxena, R.C. and Rueda, B.P. (1988). Repellent and growth inhibiting effect of turmeric, sweet flag and neem oil on red flour beetle (Coleoptera: Tenebrionidae). *J. Econ. Entomol*. **81**(4): 1226-1230.

Jood, S., Kapoor, A.C. and Singh, R. (1993). Evaluation of some plant products against *Trogoderma granarium* in stored maize and their effects on nutritional composition and organoleptic characteristics of kernels. *J. Agril. Food Chem.* **41**(10): 1644-1648.

Khaliq, A., Nawaz, A., Ahmad, M.H. and Sagheer, M. (2014). Assessment of insecticidal potential of medicinal plant extracts for control of maize weevil, *Sitophiluszeamais* (Coleoptera: Curculionidae). *J. Agric. Sci. Rev.* **3**: 100-104.

Khan, M. and Shahjahan, R.M. (1998). Evaluation of eucalyptus leaf extracts as repellent for adult of *Sitophilusoryzae* L. (Coleoptera: Curculionidae) and attractant for *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). *Bangladesh J. Entomol.* **8**(1-2): 81-88.

Khan, R.A. (1991). Crop loss and waste assessment. USAID/BRAC Cheechi and Company Consulting Inc. Dhaka.

Khanam, L.A.M., Talukder, D., Khan, A.R. and Rahman, S.M. (1990). Insecticidal properties of Royna, *Aphanamixis polystachya* against *Tribolium confusum*. D. *J. Asiat. Soc. Bangladesh Sci*. **16**: 71-74.

Koehler, P.G. (2008). Rice Weevil, Sitophilus oryzae (Coleoptera: Curculionidae). Entomology and Nematology Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

Makanjuola, W.A. (1989). Evaluation of extracts of neem, *Azadirachta indica*, A. Juss for the control of some stored product pests. *J. Stored Prod. Res*. **25**(4): 231-237.

Maniruzzaman, F.M. (1981). Plant protection in Bangladesh. Nation Book Centre, 67/a, Purana Paltan. 270-276.

Metcalf, R.L. and Luckman, W.H. (1982). **In:** Insecticides in pest management: Introduction to Insect Pest Management (2nd ed.). John Wiley, New York, USA. 235 – 273.

Mulungu, L.S., Lupenza, G., Reuben, S.O.W.M. and Misangu, R.N. (2007). Evaluation of botanical products as stored grain protectant against maize weevil, *Sitophilus zeamais* (L.) on maize. *J. Entomol*. **4**(3): 258-262.

Nawaz, A. (1990). Appraisal of weight losses in stored grains by *Oryzaephilussurinamensis*(L.) (Coleoptera: Cucujidae) and its mortality by plant extracts. M.Sc. (Hons) Thesis. Department of Entomology, NWFP Agricultural University, Peshawar. pp. 39.

Negahban, M., Moharramipour, S. and Sefidkon, F. (2006). Chemical Composition and Insecticidal Activity of Artemisia scoparia essential oil against three Coleopteran stored-product insects. *J. Asia-Pacific Entomol*. **9**: 381-388.

Obeng-Ofori, D. and Akuamoah, R.K. (2007). Biological effects of plant extracts against the rice weevil *Sitophilus oryzae* in stored rice. *J. Ghana Sci. Assoc*. **2**(2): 62-69.

Ogunleye, R.F., Ogunkoya, M.O. and Abulude, F.O. (2010). Effect of the seed oil of three Botanicals, Jatrophacurcas, Helianthus annus and Cocosnucifera on the maize weevil, *Sitophilus zeamais*. *Plant Prod. Res. J*. **14**: 14 – 18.

Oni, M.O. and Ileke, K.D. (2008). Fumigant toxicity of four botanical plant oils on survival, egg laying and progeny development of the dried yam beetle, *Dinoderusporcellus* (Coleoptera: Bostrichidae). *J. Agril. Res*. **4**: 31-36.

Perveen, B., Malek, M.A., Talukder, D., Khanam, L.A.M., Dey, K.C. and Rafiqul, I. (1998). Effectiveness of two indigenous plant extracts against three stored product insect pests. *Bangladesh J. Sci. Ind. Res*. **33**(2): 287-289.

Prakash, A, and Rao, J. (1983). Insect pests and their management in rice storage in India, presented in National Symposium on Maximizing Stabilizing of yields on rain feed rice production system held at CSRRI, Cuttack (India). 23-25.

Prakash, A., Rao, J., Gupta, S.P. and Behr, J. (1993). Evaluation of botanical pesticides as grain protectants against rice weevil, *Sitophilus oryzae* L. *Bot. pestic. Integ. Pest Manage*. **17**: 360-365.

Rahman, L.M. (1998). Laboratory evaluation of Urmoi, Neem and Turmeric for controlling the rice weevil, *Sitophilus oryzae* L. and the grain weevil, *S. granaries* L. *Tropical Agric. Res. Exten*. **11**: 34-39.

Rajapakse, R.H.S., and Ratnasekera, D. (2008). Pesticidal potential of some selected tropical plant extracts against *Callosobruchus maculates* (F.) and *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae). *Tropical Agric. Res. Exten*. **11**: 69-71.

Ranjana, S., Beenam, S., Saxena, R. and Saxena, B. (2000). Bioactivity of certain plant extracts against *Callosobruchus maculates* (F.). *J. App. Zool. Res.* **11**(1): 29-32.

Rouf, F.M.A., Sardae, M.A. and Ahmed, K.S. (1996). Individual and combined effects of some plant materials for protection of lentil seeds against pulse beetle, *Callosobruchus chinensis* (L.). *Bangladesh J. Entomol*. **6**(1-2): 13-21.

Roy, B., Amin, R. and Uddin, M.N. (2005). Leaf extracts of Bishkatali (*Polygonum hydropiper*) as botanical insecticides against lesser grain borer and rice weevil. *J. Biological Sci.* **5**: 201-204.

Sanguanpong, U. and Schmutterer, H. (1992). Laboratory trials on the effects of neem oil and neem-seed based extracts against the two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae). *J. Plant Dis. Protect.* **99**(6): 637-646.

Saxena, R.C. (1989). Insecticides of plant origin. American Chemical Society, Washington, DC. ACS Symposium Series 387. 110-135.

Saxena, R.C. (1995). Pests of stored Products in H. Schmutterer (Eds.). The neem tree: Source of unique natural products for integrated pest management, medicine, industry and other purposes. VCH Publishers, Weinheim, Germany. 418-432.

Saxena, R.C., Jilani, G. and Kareem, A.A. (1988). Effects of neem on stored grain insects. Focus on Phytochemical Pesticides. Florida. **1**: 97-111.

Schumutterer, H. (1990). Properties and potential of natural pesticides from the neem tree, *Azadirachta indica. Annal. Rev. Entomol*. **18**: 286-292.

Schmutterer, H. (1995). Properties and potential of natural pesticides from the neem tree, *Azadirachta indica. Annual Rev. Entomol*. **35**: 271-297.

Shanmugapriyan, R. and Kingly, S. (2001). Bioefficacy of neem oil on larvae of bitter gourd beetle *Epilachna vigintioctopunctata* (Coleoptera: Coccinellidae). *J. Entomol. Environ. Monitoring*. **11**(3-4): 10-13.

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

Sharma, R. K. (1999). Efficacy of Neem products against storage pests in maize. *Annals Agril. Res*. **20**(2): 198-201.

Shazali, M.E.H., Smith, R.H. (1985). Life history studies of internally feeding pests of stored sorghum: *Sitotroga cerealella* and *Sitophilus oryzae* (L.). *J. Stored Prod. Res.* **21**(4): 171-178.

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

Singh, D., Stoyanova, S. and Shikerenov, D. (1987). Use of phosphene preparation for the de-infestation of wheat and flour. *Rasticlna Zaschita*. **31**(2): 30-33.

Singh, H., Mrig, K.K. and Mahla, J.C. (1996). Efficacy and persistence of plant products against lesser grain borer, *Rhizopertha dominica* in wheat grain. *Annals Biol*. *Ludhiana*. **12**(1): 99-103.

Singh, J., Dhaliwal, G.S., Kumar, I. and Sidhu, G.S. (1990). Evaluation of eliterice genotypes against whorl, aggot and rice hispa. *J. Insect Sci*. **3**(1): 102-105.

Singh, P.K. (2003). Effect of some oils against oils against pulse beetle, *Callosobruchus chinensis* in infesting pigeon pea. *Indian J. Entomol*. **64**(1): 55-58.

Talukder, F.A. (2006). Plant products as potential stored-product insect management agents - A mini review. *Emir. J. Agric. Sci*. **18** (1): 17-32.

Talukder, F,A. and Howse, P.E. (1993). Deterrent and insecticidal effects of extract of *Aphanamixis polystachya* against *Tribolium castaneum* in storage. *J. chem. Ecol.* **19**(11): 2463-2471.

Talukder, F.A. and Howse, P.E. (1994). Laboratoryevaluation of toxic and repellent properties of the pithraj tree *Aphanamixis polystachya* against *Sitophilus oryzae* L. *Intl. J. Pest Manage.* **41**(3): 274-279.

Tanzubil, P.B. (1987). The use of neem products in controlling the cowpea weevil, *Callosobruchus maculates* (F.). Nyankpala Agric. Exp. Sta. Crops Res. Inst. Tamale, Ghana. 517-523.

Tripathi, A.K., Prajapati, V., Verma, N., Bahl, J.R., Bansal, R.P., Khanuja ,S.P.S., and Kumar, S. (2002). Bioactivities of the leaf essential oil of *Curcuma longa* on three species of stored product beetles. *J. Econ. Entomol.* **95**: 183-189.

Yadav, T.D. (1983). Seed fumigation as an aspect to seed storage technology. *Seed Res*. **11**(2): 240-247.

Yadav, T.D. (1984). Efficacy of neem, *Azadirachta indica*, *A. Juss* kernel powder as seed treatment against pulse beetle. *Neem Newsl*. **1**(1): 6-7.

CHAPTER VII

APPENDICES

Appendix I. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (May, 2018 to October, 2018) at Sher-e-Bangla Agricultural University campus

Month	Air temperature (°c)		Average Relative humidity (%)	Rainfall (mm) (total)	Average Day length (hr)
	Maximum	Minimum			
May,2018	32.9	24.5	59	339.4	13.3
June, 2018	32.1	26.1	72	340.4	13.6
July, 2018	31.4	26.2	72	373.1	13.4
August, 2018	31.6	26.3	74	316.5	12.9
September, 2018	31.6	25.9	71	300.4	12.3
October, 2018	30.6	24.9	70	288.6	11.5

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka – 1212.

Appendix II: Mean Square value 1st, 2nd and 3rd generation of rice weevil

Source of variance	Degree of freedom	Mean Square value of		
		1st generation	2nd generation	3rd generation
Replication	2	0.266	4.867	0.200
Grains	4	62.900**	126.400**	139.433**
Error	8	0.350	1.200	1.283

** Significant at 1% level of significance.

Appendix III: Mean Square value of number of larvae pupa adult in different grains

Source of variance	Degree of freedom	Mean Square value of			
		number of larvae	number of pupa	number of adult	Incubation period
Replication	2	0.066	0.066	0.067	0.200
Grains	4	10.933**	5.766**	323.500**	28.733*
Error	8	0.233	0.066	0.400	0.533

** Significant at 1% level of significance.
* Significant at 5% level of significance.

Appendix IV: Mean Square value of larval period, pupal period & adult longevity

Source of variance	Degree of freedom	Mean Square value of		
		Larval period	Pupal period	Adult longevity
Replication	2	0.266	0.466	0.200
Grains	4	25.900**	6.900**	465.267*
Error	8	0.350	0.300	0.867

** Significant at 1% level of significance.

Appendix V: Mean Square value of present infestation of rice weevil on Wheat as host

Source of variance	Degree of freedom	Mean Square value of			
		24 Hours	48 Hours	72 Hours	Mean
Replication	2	0.056	0.222	0.530	0.080
Treatments	5	820.056**	930.856**	1011.730**	907.267**
Error	10	0.722	0.356	.630	0.117

** Significant at 1% level of significance.

Appendix VI: Mean Square value of present mortality of rice weevil on Wheat as host

Source of variance	Degree of freedom	Mean Square value of			
		24 Hours	48 Hours	72 Hours	% Mortality
Replication	2	0.388	0.388	0.500	0.890
Treatments	5	4.088**	45.255**	61.200**	1075.42**
Error	10	0.122	0.322	0.300	1.960

** Significant at 1% level of significance.

Appendix VII: Mean Square value of present weight loss of rice weevil on Wheat as host

Source of variance	Degree of freedom	Mean Square value of			
		Healthy(g)	Infested(g)	%Infestation	% Weight loss
Replication	2	0.020	0.030	0.007	0.020
Treatments	5	104.108**	102.996**	10.3.993**	104.108**
Error	10	0.065	0.063	0.060	0.065

** Significant at 1% level of significance.