DAMAGE LOSS ASSESSMENT AND MANAGEMENT OF RICE WEEVIL (*SITOPHILUS ORYZAE* L.) IN WHEAT AND MAIZE GRAINS IN STORAGE

NARGIS AKTER

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

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BY

NARGIS AKTER

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Approved by:

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

Dr. Md. Mizanur Rahman
Professor
Department of Entomology
SAU, Dhaka
Co-Supervisor

Dr. Mohammed Sakhawat Hossain
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, '**DAMAGE LOSS ASSESSMENT AND MANAGEMENT OF RICE WEEVIL (*SITOPHILUS ORYZAE* L.) IN WHEAT AND MAIZE GRAINS IN STORAGE**', 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** in Entomology embodies the result of a piece of bona fide research work carried out by **NARGIS AKTER**, Registration No. **09-3693** 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 by him.

Dated:
Dhaka, Bangladesh

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

Dedicated to

My Beloved Parents

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DAMAGE LOSS ASSESSMENT AND MANAGEMENT OF RICE WEEVIL (*SITOPHILUS ORYZAE* L.) IN WHEAT AND MAIZE GRAINS IN STORAGE

ABSTRACT

In order to study the damage loss assessment and management of rice weevil (*Sitophilus oryzae* L.) in wheat and maize grains in storage, experiments were conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from May to October 2014. Results revealed that no loss of wheat and maize grain weight during storage was found in T_2 (Naphthalene 5 g/kg of stored grains) where highest loss of grain weight was found by T_3 (Neem oil 5 ml/kg of stored grains) for wheat stored grain and T_5 (Black pepper 5 g/kg of stored grains) for maize stored grain. In case of mortality of rice weevil, results also indicated that T_2 (Naphthalene 5 g/kg of stored grains) showed 100% mortality of rice weevil where lowest mortality was found from T_3 (Neem oil 5 ml/kg of stored grains) for wheat stored grain and T_5 (Black pepper 5 g/kg of stored grains) for maize stored grain.

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LIST OF ABBRIVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
CBR	=	Cost Benefit Ratio
cm	=	Centimeter
0C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others (at alii)
kg	=	Kilogram
kg/ha	=	Kilogram/hectare
g	=	gram(s)
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
pH	=	Hydrogen ion concentration
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	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). Wheat is established as a farmer's crop and is an important food supplement of the common people. On the other hand, after rice and wheat, maize (*Zea mays* L.) is an important cereal crop in Bangladesh serving as source of food, feed and industrial raw material. Over 85% of maize produced in the country is consumed as human food (Meseret, 2011). 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. Saxena *et al.* (1988) stated that agricultural practices began about 10,000 years ago and that of storing food grain started about 4,500 years ago as a safe guard against poor harvest and famines (Saxena *et al*., 1988). Wheat, maize and other cereals are stored in the government and public go-down both in Bangladesh and other developing countries.

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

In Bangladesh, cereals are stored as raw parboiled in bamboo made container (dole and golas) or stored in earthen pot (motka) (BRRI, 1984). Losses due to insect infestation are the most serious problem in grain storage, particularly in villages and towns of developing countries like Bangladesh. 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 un-husked and husked condition (Prakash *et al*., 1987). In Bangladesh any cereals are mostly stored in farm houses for several months or until the harvest of next crop; but stored for longer duration in public sector silos or large storages. 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 measures are practiced to protect insect pests of cereals. Among them, chemical control has been used for a long time, but has serious drawbacks (Sharaby, 1988). Several reports are available on the efficacy of different chemicals (Prakas and Rao, 1983; Yadav, 1983; Chandra *et al*. 1989; Singh *et al*., 1989; Dilwari *et al*., 1991). 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, environmental pollution, hazards from handling etc. (Ahmed *et al*., 1981; Khanam *et al*., 1990). The residues of chemical insecticides remain in stored grain and also in the environment. Besides this, reports are also available on the efficacy of different plant products such as oils (Singh *et al*., 1990; Chander *et al*., 1991). But plant oils are not always available, not good in efficacy, have pungent smell. Hence, search for the alternative method of paddy weevil control utilizing some non-toxic, environment 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, Neern products (Khan, 1991). Indo-Pakistani farmers use neem leaves, bishkatali for controlling stored grain pests, while various Nigerian tribes use roots, stems and leaves of plants (Ahmad and Koppel, 1985; Ahmed and Grainge, 1986). Our farmers are traditionally protecting their stored products with some herbal substances such as oil, leaves, roots, seeds etc. of different plants instead of chemical control (Talukder and Howse, 1993). 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 harmful 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 (Sanguanpong and Schmutterer, 1992; Saxena, 1995; Schmutterer, 1995). However the most practical use of these oils is to mix grains or seeds with oil or substances to provide the physical contact of oil with insect cuticle and resulting in behavioral responses. Even 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 study the extent of damage caused by rice weevil, *Sitophilus oryzae* L.
- To evaluate the efficacy of some botanicals and fumigant for controlling rice weevil, *S. oryzae* L.
- To find out the most effective management approach for controlling *S. oryzae* L.

CHAPTER II

REVIEW OF LITERATURE

The insect, *Sitophilus oryzae* L. is a serious stored product pest which attacks several crops, including wheat, rice, and maize. 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 control 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 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*

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 Distribution and 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, especially 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 insect's pests both infield 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 C. maculates. 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 *S. 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 *Callosobruchus 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 (Saxena, 1989; Schmutterer, 1990; Mordue and Blackwell, 1993). 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 *T. castaneum*, *R. dominica*, *S. oryzae* and *S. 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.

Das and Karim (1986) reported that neem oil was used an effective surface protectant of pulses in storage. They found that treated seeds were not infested after storage for 5 months by *Callosobruchus chinensis*. Seventeen plant extracts in Pakistan were tested for their repellency to *Tribolium castaneum*. Seed extracts of Ipil (*Intsia bijuga*) and neem oil both had highest repellency. Vegetable oils from *Olimum basilieum, Tagetes erecta, Momordica charantia,* celery and garlic were less repellent than *I. bijuga* oil, but more repellent than oils from *Cuminum cyminum*, bottle guards or Indian mustard (Mohiuddin *et al.*, 1987).

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 *R. 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 *T. cactanium, S. oryzae, C. maculats* and *C. 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 *S. cerealella* and prevented cross infestation by *R. dominica* (Dakshinamurthy, 1988).

David *et al*. (1988) showed the repellent activity of *V. negundo* against several species of stored product pests. Jilani *et al*. (1988) reported that turmeric, sweet flag and neem oil acted as repellent against *Tribolium castaneum.*

Ketker (1989) observed that neem oil was the best surface protectant for stored legumes against *C. chinensis* and *C. maculatus*.

Makanjuola (1989) studied the effect of neem leaf and seed extracts on *C. maculates, S. oryzae, S. zeamais* and *C. collis*. The extracts were more effective as suppressants to *C. maculates* than of *S. oryzae* and there was no effect on *Cylospuncti collis*. Repellency action of turmeric, sweet flag and neem oil against the lesser grain borer, *R. 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.

Jood *et al*. (1993) reported that neem kernel powder and oil provided complete protection to hatching of *Trogoderma granarium* in wheat grain for 6 months.

Dey and Sarup (1993) tested eight vegetable oils viz. mustard, soybean, coconut, neem, groundnut, cotton, sesame and castor at 5 doses against adults, *Sitophilus oryzae*, in three varieties of stored maize in India and showed that highest weevil mortality was on one day after treatment.

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 *S. 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.

Jood *et al*. (1993) used neem oil and powder of leaf and seed kernel, citrus lemon leaf, garlic (*Allium sativum*) bulb, pudina (*Menthas picata*) leaf on maize kernel 1 and 2% level (w/w) to control the larvae of *T. granarium*. Neem kernel powder and oil provided complete protection to grains for 6 months, whereas, substantial insect infestation was noticed after 3 months in other treatments.

Prakash *et al*. (1993) evaluated that twenty plant products against *Sitophilus oryzae*. Only seven products significantly reduced adult populations and weight loss of grain. Neem seed oil was the most effective, followed by *Piper nigram* seed powder, leaves of *Vitex neganda*, leaves of *Androgra phospaniculata*, dried mandarin fruit peel, rhizome powder of turmeric and seed powder of *Cassia fistula*, respectively. In Malaysia, mixing neem leaves with paddy grain in a proportion of 2 to 100 parts (wt/wt), bag treatment with 2% neem leaf water extract (wt/wt), or placing barriers of neem leaves between bags and storage floor, significantly reduced the infestation by *S. oryzae* and *R. dominica* sand damage to paddy grain stored in 40kg jute bags for 3 months (Muda, 1994).

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*, *S. oryzae* and *T. castaneum* investigated by Xie *et al*. (1995), when *T. 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 biskatali, and their combinations against *C. chinensis* on lentil seeds and reported that 4 gm of bishkatali leaf powder/50 gm 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 biskatali leaf powder ranked second followed by neem leaf powder alone. At low doses (1-2 gm) 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.

Igantowicz (1997) confirmed and compared the repellency of several plant powders against three species or stored product pest (*C. chinensis*, *S. oryzae* and *S. granarius*) and reported that the powdered seed kernels of neem, *A.*

indica were more effective as repellents than the powders of dry leaves and seed shells; they further reported that the repellency of neem products increased with the increase of the concentration of the product and 5% concentration by weight, was the most effective.

Singh *et al*. (1996) studied the effects of extracts of neem. (*A. indica*), garlic, *Eucallyptus hydrida*, *L. camara* and *V. negundo* against *R. dominica* on wheat in the laboratory. *A. indica*, *L. camer*a and *V. negundo* were the most effective against the adult and reducing grain damage (number basis and weight basis).

Igantowicz (1997) reported that powdered aerial parts of the ribbed melilot (*Melilotus officinalis*) and the white melilot (*M. albus*) were found to be strongly repellent to *Sitophilus grainarius. S. oryzae* was repelled only by high doses (2-5%) of these powders. Coumarin, a characteristic and volatile constituent of melifots, is thought to produce the repellent effect against weevils.

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 *C. chinensis*. Results showed that *S. oryzae* was repelled and *C. chinensis* was attracted by all the extracts. The percentages of repulsion for *S. oryzae* were 71.1, 74.7, 69.0 and 63.3 respectively.

Perveen *et al*. (1998) evaluated the methanol extracts of two indigenous plants, *Calotropis gigantea* L. (Akando) and *Ipomoea nil* L. (Pharbitisnil) for their toxicity against the adults of *Sitophilus oryzae* L., *Trbolium castanium Herbst* and *Cryptolestes ferrugineus* (Stephens) after 24 hours of treatment. The LD50 for *C. ferrugineus* were 0.418, 0.420, 0.206 and 0.357, 0.422, 0.143 mg/cm^2, respectively. *C. ferrugineus* was more susceptible to *C. gigantea* and *P. nil* than *S. oryzae* and *T. castameurn*.

Kestenholz and Stevenson (1998) tested the alcohol extract of *Gardenia fosbergii* (Rubiaceae), an indigenous plant of eastern Sri Lanka and it was found to have a strong repellent activity to *Sitophilus oryzae*. In choice experiments insects were allowed to feed either on untreated rice or on rice treated with extracts of the leaf bud exudates of *G. fosbergii*. Treated rice was significantly more repellent to *S.oryzae* than untreated rice. Furthermore, the deterrent activity of Gardenia extracts was more potent than neem seed kernel extracts (*Azadirachta indica*), the botanical most commonly used by farmers for storage protection in south Asia. Preliminary High Performance Liquid Chromatography (HPLC) analyses of the *G. fosbergii* leaf bud exudates have shown several compounds to be associated with this activity. The bioactivity of Gardenia extracts was shown to break down after 3 days exposure to daylight.

Rahman (1998) evaluated the extracts and dust of Urmoi, Neem and Turmeric for their repellency, feeding detergency, direct toxicity, residual effects and their potentiality against the rice weevil, *S. oryzae*. The results showed that 100, 75, 50 and 25 mg/ml extracts of all three plants had repellency, detergency and direct toxicity effect. Ethanol and acetone extracts were more effective than water extracts. The emergence of F1 progeny, seed damage rate, percent weight loss and inhabitation rate of two weevil species were reduced significantly in almost all treatments compared to control. He also reported that reduction was significant lydose dependent.

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*, *R. dominica*, *Trogoderma granarium*, *Sitotroga cerealella* and *Triboliurn castaneum*. Neem oil (nimbicidine, 2%) effectively reduced the emergence of F1 and F2 progeny of all the pests and completely protected maize up to 9 months and suggested that neem products can be mixed with stored maize to protect the grains up to 9 months from the attack of these major pests.

Reddy *et al*. (1999) carried out an experiment with plant oils. Neem, karanja and palmolein oil at the dose of 0.5 and 1.0% level which effectively protected green gram from pulse beetle, *C. chinensis*. These oils exhibited contact toxicity, and no adults could survive in neem treated green gram at 50% concentration. In all treatments insect mortality ranged from 25 to 50%.

Umoetok (2000) investigated the toxicity of the powder of Acoruscalamus to three species of stored product insect pests namely *S. oryzae*, *T. castaneum* and *R. dominica* in the laboratory. A. calamus was applied at six doses of 0.0, 0.025, 0.05, 0.1 and 0.5 g/20 g of wheat grains. Only *S. oryzae* and *R. dominica* were susceptible to the test products.

Ranjana *et al*. (2000) tested fire plant extracts from *Azadirachta indica* kernels, *Allium sativuim* bulbs, *Citrus sinensis* peels, *Citrus limon* peels and *Mangifera indica* leaves each having three concentrations (1%, 1.5% and 2%) against pulse beetle, *C. maculates*. The petroleum ether extract of neem kernel was most effective as 1.5% and 2.0% concentrations showed 50% and 61.11% mortality, respectively.

Islam and Shahjahan (2000) conducted experiments to evaluate the toxicity of five botanicals, viz. neem (*A. indica*), marigold (*Tagestes erecta*) and durba (*Cynodon dactylon*) and found a significant effect in controlling insect pests. Four laboratory experiments were conducted with the leaves of three plant species viz. biskatali (*Polygonum hydro piper*), akanda (*Asclepias calotropis*), and neem (*Azadirachta indica*) for studying their relative efficacy against the lesser grainborer, *Rhyzopertha dominica* (Bostrychidac: Colcoptera). In the first three experiments, water extracts (2, 3 and 4% by volume) were used on the adult beetle to evaluate their repellency, feeding detergency and direct toxicity effects. In the fourth experiment, dried leaf dusts (2, 3 and 4% by weight) were mixed with wheat grain to assess their residual toxicity. Results from the first three experiments indicated that 2, 3 and 4% water extracts of all the three plant species had repellency as well as direct toxicity; while the 3% showed strong feeding detergency effect. In the last experiment, powdered leaves of 2, 3 and 4% dust provided adequate protection of wheat grains by reducing both the F1 progeny emergence and grain infestation rates (Amin *et al.*, 2000).

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.

Imtiaz *et al*. (2001) observed the effects of neem leaf extracts on adult rice weevil, *Sitophilus oryzae*. Glass film method was adopted to determine the Lc50 rate. After plotting a graph between mortality and concentration, the Lc50 was found to be 0.44 $\mu g/cm^2$. Leaf powder, seed kernel powder and oil extracted from the seeds of *A. indica* and leaf powder and oil extracted from the leaves of *E. canialdulensis* and benzene hexachloride (BHC) were tested at 1, 3 and 5% (w/w or v/w) against *S. oryzae*. Neem oil (NO) and Eucalyptus leaf oil (ELO) at 3 and 5% were as efficient as BHC and significantly (P=0.0001) reduced egg laying by *S. oryzae*, whereas Eucalyptus leaf powder (ELP) had no significant effect. Neem seed kernel powder (NSKP) at 5%, ELO (3 and 5%) and NO (3 and 5%) significantly reduced egg hatching more than BHC at all doses. NO (3 and 5%) and ELO (3 and 5%) significantly (P-0.0001) reduced larval development more than BHC, whereas ELP and Neam leaf powder had no significant effect (El-Atta *et al.*, 2002).

Neem kernel extract heated to 28^0C or above also lost effectiveness as an oviposition deterrent of rice weevil. However, the number of neem kernel extract treated eggs of rice weevil that survive to become adults was significantly reduced even neem kernel extract was exposed to 50^0C for 2 week (Jenkins *et al*., 2003).

A study was carried out to evaluate the efficacy of some botanical insecticides as protectants against *Sitophilus oryzae* infesting stored rice and to determine the effect of these botanical insecticides on the organoleptic traits of Basmati rice. The treatments were neem seed oil (0.5 ml/kg) mentha oil (0.5 ml/kg), mahogoni (0.5 ml/kg), diflubenzuron (10 mg/kg), tulsi seed oil (0.5 ml/kg) turmeric powder (1.0 g/kg), mercury tablet (0.25 tablet/kg), DDVP [dichlorvos] (0.05 ml/kg; encapsulated), camphor (0.5 g/kg), and control. Mortality was recorded after 10 days of treatments. After 2 months of storage, the organoleptic traits of treated rice were evaluated. Based on the cumulative percent mortality of adults, all treatments were significantly superior over the untreated control. Treatment with DDVP resulted in the highest adult mortality (91.8%) 10 days after application, followed by neem seed oil (73.5%) and camphor (66.6%) (Dayal *et al*., 2003).

Cogan *et al*. (2003) tested two NeemAzal products from Trifolio-M GmbH, Germany and neem oil and neem seed cake powder of the Kenyan neem tree for their efficiency against the storage pest *P. truncates* in the laboratory at (a) low, (b) medium and (c) high rates, containing approximately 1.5, 3 and 6 mg azadirachtin A/kg maize, respectively. They observed that NeemAzal PC kg 0.1 (0.1% azadirachtin A) at all the tested rates and neem seed oil at high rates caused more than 80% mortality compared with 4% in the control. The two compounds also reduced weight loss to less than 20% in the control.

Dayal *et al*. (2003) conducted a study was carried out to evaluate the efficacy of some botanical insecticides and fungicides as protectants against *S. oryzae* infesting stored rice and to determine the effect of these botanical insecticides on the organoleptic traits of Basmati rice. The treatments were mentha oil (0.5 ml/kg), clove oil (0.5 ml/kg), salt (1 .0 ml/kg), mustard oil (1 .0ml/kg), diflubenzuron (10 mg/kg), neem seed oil (0.5 ml/kg) tulsi seed oil (0.5ml/kg), turmeric powder (1.0 h/kg), mercury tablet (0.25 tablet/kg), DDVP [dichiorvos] (0.05 m1/kg; encapsulated), camphor (0.5 g/kg), and control. Ten pairs (1:1 sex ratio) of newly emerged adults were released in vials containing rice and the treatments. Mortality was recorded after 10 days of treatment. After 2 months of storage, the organoleptic traits of treated rice were evaluated. Based on the cumulative percent mortality of adults, all treatments were significantly superior over the untreated control. Treatment with DDVP resulted in the highest adult mortality (91.8%) 10 days after application, followed by neem seed oil (73.5%) and camphor (66.6%). Based on sensory panel evaluations, there were no significant differences in rice color between treatments, but flavor, texture and taste scores varied significantly between treatments and were highest in rice treated with clove oil.

Singh (2003) evaluated the effect of edible oil (coconut, mustard, sunflower, sesamum and mahua) non edible oil (neem, karanj, castor, tarpin and noorani) as well as hair oil of arnica, himtaj, amla, banphol and navratan as surface protectants for pigeon pea seeds against *C. chinensis* at 8 ml/kg seed. All oils proved highly effective in protecting the seed up to 9 months storage in terms of seed damage and weight loss.

Umoetok (2004) conducted laboratory experiments to assess the damage caused by *Sitophilus oryzae* on stored maize grains. Processed cardamom and Mickpepper powder (applied at 5%) were used as protectants. They observed that grains treated with the plant powders significantly lowered weight loss than the untreated grains.

Jagjeet *et al*. (2005) treated pigeon pea seeds with seed protectants, i.e. neem seed kernel powder at 20g, neem oil at 10 ml, mustard oil and groundnut oil each at 7.5ml, turmeric powder at 3.5 g, mustard oil + turmeric powder at 3.75 ml + 1.75 g, ground nut oil + turmeric powder at 3.75 ml + 1.75 g each per one kg of seed, covering with each of sand, dung cake ash, sawdust and wheat husk and mixed them with half kg of seed by shaking it manually. Neem oil was effective (64.33% adult mortality) up to 35 DAT and it was followed by mustard oil + turmeric powder, which recorded only 16.33% adult mortality. All the other treatments were not effective.

Two experiments were conducted in the laboratory with leaves of one plant species bishkatali *(Polygonum hydropiper*) for studying their repellency and toxicity test against the rice weevil (*Sitophilus oryzae* L.) and lesser grain borer (*Rhyzopert hadominica* F.). In the first experiment petroleum ether extract of dried leaves (1, 2 and 3% by volume) were used on the adult beetle of lesser grain borer and rice weevil to evaluate their repellency for mortality/direct toxicity effects. Results for the two experiments indicated that 1, 2 and 3% petroleum ether extract of leave of *Polygonum hydropiper* species had repellency as well as direct toxicity, while 3% showed strong repellency and toxicity effects among the other extracts on both lesser grain and rice weevil (Roy *et al*., 2005).

Islam and Talukder (2005) evaluated for direct and residual toxicities of seed extracts and leaf powders of the neem (*A. indica*), marigold (*Tageste serecta*) and durba (*Cynodon dactylon*) along with two commercial insecticides (malathion and carbaryl respectively) against red flour beetle (*T. 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 (100µg/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 *S. 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).

Plant oils obtained from leaves and other parts of 20 different plant species were bioassayed under laboratory conditions for their ability to protect stored rice from damage by rice weevil (*S. oryzae*) and pulse beetle (*Callosobruchus chinensis*). Three plant oil extracts showed some bioactivity, nine plant oil extracts caused significant adult mortality in both species and eight had none. Plant oil extracts such as mahogoni, lemon grass, clove seeds, neem, and custard apple inflicted between 41 to 100% egg mortality in both species in the order of 60, 60-67, 70, 90, 91 and 100% respectively (Rajapakse and Ratnasekera, 2008).

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).

A laboratory experiment was conducted to investigate the insecticidal activities of seven plants against *Sitophilus oryzae* developmental durations and damage in rice. Plant materials were evaluated at 1 g/20 g rice (0.1 g PMD/20 g rice). The results showed that MWA was more effective in causing adult *Sitophilus oryzae* mortality, but CPP was significantly more effective in reducing adult emergence, percentage hatching inhibition rate and per cent holed rice (Yusuf, 2009).

CHAPTER III

MATERIALS AND METHODS

Experiments were conducted to study the extent of damage caused by rice weevil, *Sitophilus oryzae* L. in wheat and maize grains in storage during the period from May to October 2014. A brief description of the experimental site, experimental design, treatments, data collection and analysis of different parameters under the following headings are presented below:

3.1 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^{0}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. Rice 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 rice 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 rice 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.

3.2 Experimental material

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

3.3 De-infestation of wheat and maize grains

Before artificial infestation of wheat and maize grains with rice weevil, the parboiled rice and the other test grains were dried in the sun for few days. Islam *et al*. (2000) reported that solar heat treatment of grains destroys the initial insect infestation in the grains before storage.

Plate 3: A - Experimental set up of Wheat grains with treatments and B - Experimental set up of Maize grain with treatments

3.4 Experimental treatment

The experiment consists of the following treatments:

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain

T_2 = Naphthalene @ 5 g/kg of grain on the upper layer

T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain

T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain

T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain

T_6 = Untreated control

3.5 Experimental design and layout

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

3.6 Observation on adult emergence

50 gm of insect free wheat and maize grains were taken into each Petri dish. Five pairs of newly emerged adult rice weevil were released carefully in each of the Petri dish. Insect mortality was recorded at 24 hours intervals up to 3 days. New adults started emerge from the grains after 24-28 days of infestation. The number of emerged rice weevil at different days from each of the treated Petri dishes including control was recorded. The emerged adult moths were counted by opening the lid. A few rice weevils became visible on the surface of grains at first but a gentle shake of the Petri dishes allowed the other adults to come out.

Plate 4: Dry leaf of Tobacco

Plate 5: Dust of dry Tobacco leaves

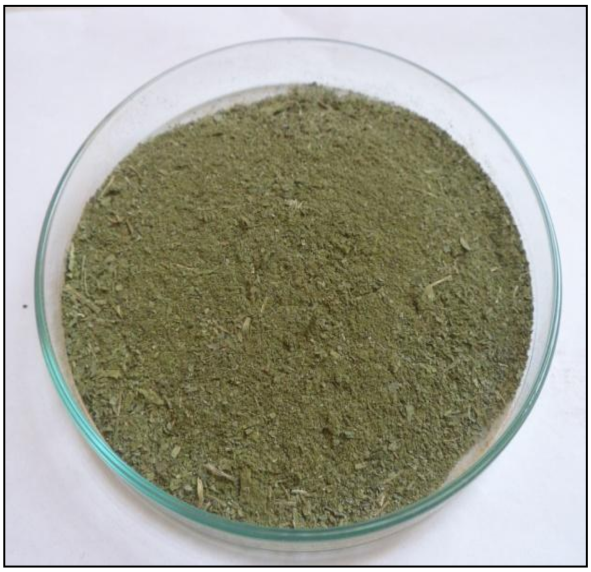

Plate 6: Twig of Lantana

Plate 7: Dust of Lantana leaves

Plate 8: Neem oil in jar

Plate 9: Neem oil wettable paper tissue

Plate 10: Seeds of Black pepper

Plate 11: Seeds dust of Black pepper

3.7 Number of death insect

Number of dead insect was observed intensively and collected from four replication of each treatment and average number of dead rice weevil was calculated

3.8 Percent (mortality)

Percent mortality was calculated by the following formula

$$\% \text{ mortality} = \frac{\text{Number of dead rice weevil}}{\text{Total number of rice weevil}} \times 100$$

3.9 Extent of damage and weight loss

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

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

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

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

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

3.10 Statistical analysis

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

Plate 12: Infested Wheat grains with hole

Plate 13: Healthy wheat grains

Plate 14: Infested Maize grains with hole

Plate 15: Healthy Maize grains

CHAPTER IV

RESULTS AND DISCUSSION

Experiments were conducted to study the damage loss assessment and management of rice weevil (*Sitophilus oryzae* L.) in wheat and maize grains in storage. The results have been presented using different Table & Graphs and discussed with possible interpretations under the following headings and sub headings:

4.1 Number of dead insects

Number of cumulative dead insects showed statistically significant variation for different stored grains after 24, 48 and 72 hours of observation by the application of different treatments (Table 4.1 and 4.2).

After 72 hours of observations, in case of wheat stored grain, all insects (7.75, 2.25 and 0.00 at 24, 48 and 72 hours respectively) were dead and it was performed by T_2 (Naphthalene 5 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains) and minimum efficiency (3.00, 0.50 and 1.25 at 24, 48 and 72 hours respectively) was found by T_1 (Tobacco 7 g/kg of stored grains) whereas all the insects were found alive with T_6 (Untreated control) treatment (Table 4.1).

In terms of maize stored grain, After 72 hours of observations, all insects (8.75, 1.25 and 0.00 at 24, 48 and 72 hours respectively) were dead and it was performed by T_2 (Naphthalene 5 g/kg of stored grains) followed by T_3 (Neem oil 5 ml/kg of stored grains) and minimum efficiency (2.25, 1.25 and 1.50 at 24, 48 and 72 hours respectively) was found by T_4 (Lantana leaf 10 g/kg of stored grains) whereas all the insects were found alive with T_6 (Untreated control) treatment (Table 4.2).

Table 4.1: Number of death insect with different treatment in stored grain of wheat

Treatments	Number of dead insects for			
	24 hrs	48 hrs	72 hrs	Total
T_1	3.00 b	0.50 e	1.25 a	4.75
T_2	7.75 a	2.25 b	0.00 c	10.00
T_3	3.25 b	1.50 c	1.25 a	6.00
T_4	2.50 c	1.00 d	1.50 b	5.00
T_5	2.75 c	2.75 a	1.50 b	7.00
T_6	0.00	0.00	0.00	0.00
LSD (0.05)	0.284	0.267	0.317	--
Level of Significance	0.01	0.01	0.01	--
CV (%)	3.671	4.283	4.174	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

Table 4.2: Number of death insect with different treatment in stored grain of Maize

Treatments	Number of dead insects for			
	24 hrs	48 hrs	72 hrs	Total
T_1	2.25 c	1.25 c	1.50 b	5.00
T_2	8.75 a	1.25 c	0.00 e	10.00
T_3	5.75 b	1.75 b	1.25 c	8.75
T_4	1.75 d	1.75 b	1.00 d	4.50
T_5	1.75 d	2.25 a	1.75 a	5.75
T_6	0.00	0.00	0.00	0.00
LSD (0.05)	0.344	0.293	0.165	--
Level of Significance	0.01	0.01	0.01	--
CV (%)	3.264	4.228	3.847	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.2 Percent (%) mortality

Significant variation was found from the result of different treatment efficiency on % mortality of rice weevil in wheat and maize (Fig. 4.1 and 4.2).

Result revealed that in terms of wheat stored grain the highest mortality of rice weevil (100%) was performed by T_2 (Naphthalene 5 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains) where the lowest performance (47.50%) was found from T_1 (Tobacco 7 g/kg of stored grains) which was statistically identical with T_3 (Neem oil 5 ml/kg of stored grains). There was no mortality in control treatment (Fig. 4.1).

In case of maize stored grain, results also revealed that the highest mortality (100%) was performed by T_2 (Naphthalene 5 g/kg of stored grains) followed by T_3 (Neem oil 5 ml/kg of stored grains) where the lowest performance (50%) was found from T_1 (Tobacco 7 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains). There was no mortality in control treatment for maize stored grain (Fig 4.2).

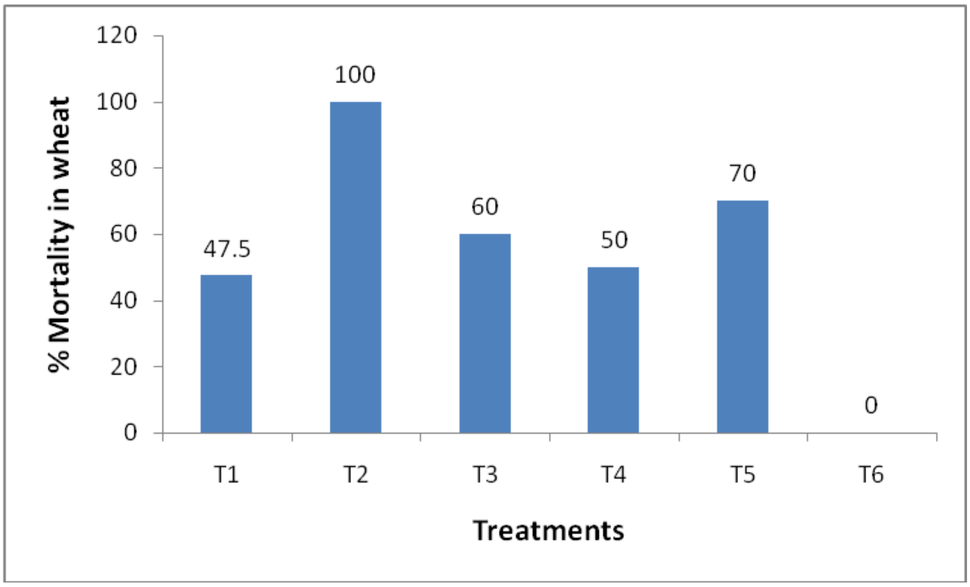

Fig. 4.1: Insect mortality (%) with the different treatment in wheat

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

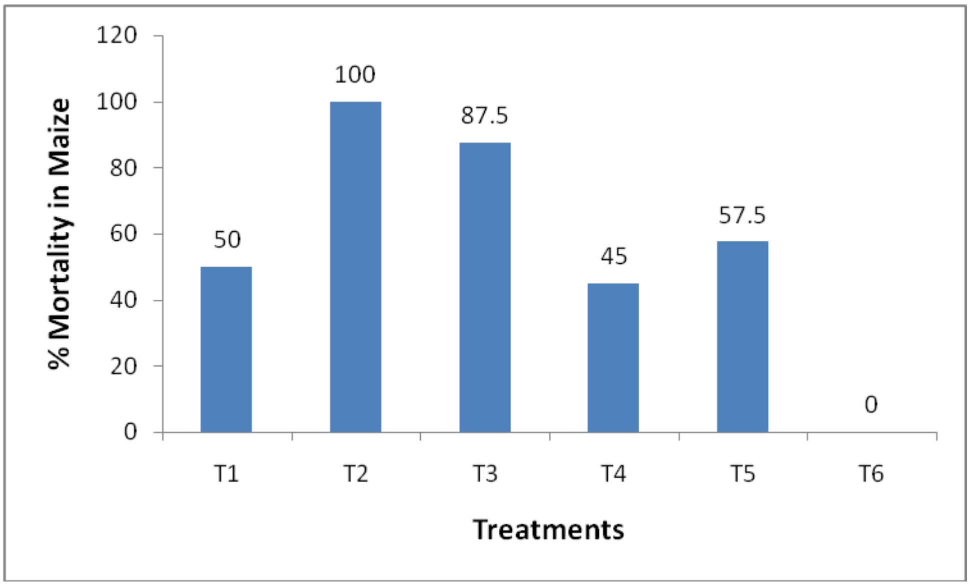

Fig. 4.2: Insect mortality (%) with the different treatment in maize

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer

T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.3 Infestation status of wheat seeds by number at the 1st generation

The experimental findings showed a statistical significant variation in number of healthy seed, infested seed and percent of infestation by number in wheat grain caused by rice weevil at 1st generation (Table 4.3). Result revealed the highest number of healthy seeds was recorded for wheat grain (2243) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) which was followed by T_5 (Black pepper 5 g/kg of stored grains) whereas the lowest was observed in case of wheat grain (2145) from T_6 (Untreated control) followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain).

Consequently, the highest number of infested seed was recorded for wheat grain (107.00) was recorded from T_6 (Untreated control) which was significantly different from those of the others followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) while the lowest number of wheat grain (00.00) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) which was highly significant among all treatments.

In case of % infestation, the highest infestation was recorded for wheat grains (4.75 %) was found in T_6 (Untreated control) followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) which were statistically different from those of all other test grains whereas the lowest infestation (00.00) was archived from T_2 (Naphthalene 5 g/kg of stored grains).

Table 4.3: Infestation of rice weevil in stored grains of wheat at 1st generation by number

Treatment	Infestation status of wheat seeds by number		
	Healthy	Infested	Infestation (%)
T_1	2191 c	67.00 c	2.97 c
T_2	2243 a	00.00 f	0.00 e
T_3	2170 e	84.00 b	3.73 b
T_4	2182 d	61.00 d	2.72 c
T_5	2200 b	52.00 e	2.31 d
T_6	2145 f	107.00 a	4.75 a
LSD (0.05)	4.365	4.729	0.468
Level of Significance	0.05	0.05	0.01
CV (%)	7.483	6.244	4.389

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.4 Infestation status of wheat seeds by weight at the 1st generation

Statistically significant variation was found in number of healthy seed, infested seed and percent of infestation by weight in wheat grain caused by rice weevil at 1st generation (Table 4.4). Findings revealed that the highest number of healthy seeds was recorded for rice grain (100.00) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) which was followed by T_4 (Lantana leaf 10 g/kg of stored grains) whereas the lowest was observed in case of wheat grain (80.40) from T_6 (Untreated control) followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain).

There was a significantly effect in number of healthy seed, infested seed and percent of infestation by weight in wheat grain caused by rice weevil at 1st generation (Table 4.4). Here, the highest weight of infested seed was recorded for wheat grain (10.30) was recorded from T_6 (Untreated control) which was significantly different from those of the others followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20×20 cm^2) on the upper layer of grain) and T_4 (Lantana leaves dust 10 g/kg of stored grains) while the lowest number of wheat grain (00.00) was recorded from T_2 (Naphthalene 5 g/kg of stored grains).

Treatments influenced by rice weevil significantly in number of healthy seed, infested seed and percent of infestation by weight in wheat grain caused by at 1st generation (Table 4.4). In case of % infestation, the highest infestation was recorded for wheat grains (11.36 %) was found in T_6 (Untreated control) followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) and T_4 (Lantana leaves dust 10 g/kg of stored grains) which were statistically different from those of all other test grains whereas the lowest infestation (00.00) was archived from T_2 (Naphthalene 5 g/kg of stored grains).

Table 4.4: Infestation of rice weevil in stored grains of wheat at 1st generation by weight

Treatment	Infestation status of wheat seeds by weight		
	Healthy (g)	Infested (g)	Infestation (%)
T_1	94.10 b	3.70 c	3.78 c
T_2	100.00 a	0.00 d	0.00 d
T_3	91.80 c	4.70 b	4.87 b
T_4	93.20 b	4.20 b	4.31 b
T_5	95.80 b	3.50 c	3.52 c
T_6	80.40 d	10.30 a	11.36 a
LSD (0.05)	3.014	0.459	0.701
Level of Significance	0.05	0.05	0.01
CV (%)	6.376	8.247	5.241

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.5 Infestation status of maize seeds by number at the 1st generation

Treatment findings showed a statistical significant variation in number of healthy seed, infested seed and percent of infestation by number in maize grain caused by rice weevil at 1st generation (Table 4.5). Result revealed that the highest number of healthy seeds was recorded for rice grain (402) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the lowest observed in case of maize grain (368) from T_6 (Untreated control) followed by T_4 (Lantana leaves dust 10 g/kg of stored grains).

Statistical significant variation was observed that the highest number of infested seed was recorded for maize grain (44.00) was recorded from T_6 (Untreated control) which was significantly different from those of the others followed by T_4 (Lantana leaf 10 g/kg of stored grains) while the lowest number of maize grain (8.00) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains).

Variation was revealed that, in case of % infestation the highest infestation was recorded for maize grains (10.68 %) was found in T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains) which were statistically different from those of all other test grains where the lowest infestation (1.95%) was archived from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains).

Table 4.5: Infestation of rice weevil in stored grains of maize at the 1st generation by number

Treatment	Infestation status of maize seeds by number		
	Healthy	Infested	Infestation (%)
T_1	398 b	16.00 d	3.86 e
T_2	402 a	8.00 e	1.95 f
T_3	392 c	17.00 c	4.16 d
T_4	384 d	27.00 b	6.57 b
T_5	391 c	19.00 c	4.63 c
T_6	368 e	44.00 a	10.68 a
LSD (0.05)	3.683	3.267	0.412
Level of Significance	0.05	0.05	0.05
CV (%)	6.542	8.267	9.385

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.6 Infestation status of maize seeds by weight at the 1st generation

Statistical significant variation was recorded in number of healthy seed, infested seed and percent of infestation by weight in maize grain caused by rice weevil at 1st generation (Table 4.6). Result revealed that the highest weight of healthy seeds was recorded for rice grain (97.20) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco leaves dust @ 7 g/kg of stored grains) where the lowest observed in case of maize grain (78.75) from T_6 (Untreated control) followed by T_4 (Lantana leaves dust 10 g/kg of stored grains).

Highly variation in statistical significant was observed that, the highest weight of infested seed was recorded for maize grain (13.25) was recorded from T_6 (Untreated control) which was significantly different from those of the others followed by T_4 (Lantana leaf 10 g/kg of stored grains) while the lowest number of maize grain (2.80) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains).

There was a variation for statistical significant in case of % infestation, the highest weight of infestation was recorded for maize grains (14.40 %) was found in T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains) which were statistically different from those of all other test grains where the lowest infestation (2.80) was archived from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains).

Table 4.6: Infestation of rice weevil in stored grains of maize at the 1st generation by weight

Treatment	Infestation status of maize seeds by weight		
	Healthy (g)	Infested (g)	Infestation (%)
T_1	91.10 b	6.30 c	6.47 c
T_2	97.20 a	2.80 e	2.80 d
T_3	90.80 b	6.40 c	6.58 c
T_4	84.40 d	8.70 b	9.34 b
T_5	88.80 c	6.80 c	7.11 c
T_6	78.75 e	13.25 a	14.40 a
LSD (0.05)	2.689	1.046	1.163
Level of Significance	0.05	0.01	0.01
CV (%)	8.375	4.592	5.746

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.7 Infestation status of wheat seeds by number at the 2nd generation

Treatments influenced for the experimental findings of healthy seed, infested seed and percent of infest station by number in wheat grain caused by rice weevil at 2nd generation (Table 4.7). Result revealed the highest number of healthy seeds was recorded for rice grain (2240) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) which was followed by T_5 (Black pepper 5 g/kg of stored grains) whereas the lowest was observed in case of wheat grain (2097) from T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) followed by T_1 (Tobacco 7 g/kg of stored grains).

Significantly variation was recorded in number of healthy seed, infested seed and percent of infestation by weight in wheat grain caused by rice weevil at 2nd generation (Table 4.7). Result revealed the highest number of infested seed was recorded for wheat grain (218.00) was recorded from T_6 (Untreated control) which was significantly different from those of the others followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) while the lowest number of wheat grain (77.00) was recorded from T_5 (Black pepper 5 g/kg of stored grains) followed by T_2 (Naphthalene 5 g/kg of stored grains).

In case of % infestation, the highest infestation was recorded for wheat grains (9.70 %) was found in T_6 (Untreated control) followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) which were statistically different from those of all other test grains whereas the lowest infestation (00.00) was archived from T_2 (Naphthalene 5 g/kg of stored grains) and T_1 (Tobacco 7 g/kg of stored grains).

Table 4.7: Infestation of rice weevil in stored grains of wheat at the 2nd generation by number

Treatment	Infestation status of wheat seeds by number		
	Healthy	Infested	Infestation (%)
T_1	2136 d	107.00 c	4.77 c
T_2	2240 a	00.00 f	0.00 d
T_3	2097 e	146.00 b	6.51 b
T_4	2147 c	96.00 d	4.28 c
T_5	2166 b	77.00 e	3.43 c
T_6	2030 f	218.00 a	9.70 a
LSD (0.05)	4.367	3.592	1.438
Level of Significance	0.05	0.05	0.05
CV (%)	11.293	10.568	7.359

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.8 Infestation status of wheat seeds by weight at the 2nd generation

The experimental findings showed a statistical significant variation in number of healthy seed, infested seed and percent of infestation by weight in wheat grain caused by rice weevil at 2nd generation (Table 4.8). Result revealed that the highest number of healthy seeds was recorded for rice grain (100.00) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) which was followed by T_1 (Tobacco 7 g/kg of stored grains) and T_5 (Black pepper 5 g/kg of stored grains) whereas the lowest was observed in case of wheat grain (74.73) from T_6 (Untreated control).

Consequently, the highest weight of infested seed was recorded for wheat grain (13.27) was recorded from T_6 (Untreated control) which was significantly different from those of the others followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) and T_4 (Lantana leaves 10 g/kg of stored grains) while the lowest number of wheat grain (00.00) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains).

Highly significant variation in case of % infestation, the highest infestation was recorded for wheat grains (15.08 %) was found in T_6 (Untreated control) followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) and T_4 (Lantana leaf 10 g/kg of stored grains) which were statistically different from those of all other test grains whereas the lowest infestation (00.00) was archived from T_2 (Naphthalene 5 g/kg of stored grains).

Table 4.8: Infestation of rice weevil in stored grains of wheat at the 2nd generation by weight

Treatment	Infestation status of wheat seeds by weight		
	Healthy	Infested	Infestation (%)
T_1	95.40 b	1.60 d	2.65 b
T_2	100.00 a	0.00 e	0.00 c
T_3	91.40 c	3.60 b	3.79 b
T_4	93.30 c	2.70 c	2.81 b
T_5	96.00 b	1.20 d	1.23 b
T_6	74.73 d	13.27 a	15.08 a
LSD (0.05)	2.284	0.526	2.631
Level of Significance	0.05	0.05	0.05
CV (%)	12.597	6.322	8.261

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.9 Infestation status of maize seeds by number at the 2^{nd} generation

Statistically significant variation was in number of healthy seed, infested seed and percent of infestation by number in maize grain caused by rice weevil at 2^{nd} generation (Table 4.9). Result revealed that the highest number of healthy seeds was recorded for rice grain (398) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the lowest observed in case of maize grain (368) from T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains).

In number of healthy seed, infested seed and percent of infestation by weight in wheat grain caused by rice weevil at 2^{nd} generation in significant (Table 4.9). The highest number of infested seed was recorded for maize grain (48.00) was recorded from T_6 (Untreated control) which was significantly different from those of the others followed by T_4 (Lantana leaf 10 g/kg of stored grains) while the lowest number of maize grain (7.00%) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains).

Significantly variation was recorded in case of % infestation, the highest infestation was recorded for maize grains (11.82 %) was found in T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains) which were statistically different from those of all other test grains where the lowest infestation (1.73 %) was achieved from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains).

Table 4.9: Infestation of rice weevil in stored grains of maize at the 2nd generation by number

Treatment	Infestation status of maize seeds by number		
	Healthy	Infested	Infestation (%)
T_1	390 b	15.00 c	3.70 c
T_2	398 a	7.00 d	1.73 d
T_3	389 b	16.00 c	3.95 c
T_4	380 c	25.00 b	6.17 b
T_5	389 b	16.00 c	3.95 c
T_6	358 d	48.00 a	11.82 a
LSD (0.05)	3.845	2.380	1.149
Level of Significance	0.05	0.05	0.01
CV (%)	13.756	9.674	4.763

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.10 Infestation status of maize seeds by weight at the 2^{nd} generation

In number of healthy seed, infested seed and percent of infestation by weight in wheat grain caused by rice weevil at 2^{nd} generation showed a statistical significant variation (Table 4.10). Result revealed that the highest weight of healthy seeds was recorded for rice grain (96.80) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_3 (Neem oil 5 ml/kg of stored grains) where the lowest observed in case of maize grain (74.26%) from T_6 (Untreated control) followed by T_4 (Lantana leaves dust 10 g/kg of stored grains).

Consequently, the highest weight of infested seed was recorded for maize grain (15.77) was recorded from T_6 (Untreated control) which was significantly different from those of the others followed by T_4 (Lantana leaves 10 g/kg of stored grains) while the lowest number of maize grain (2.50) was recorded from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains), T_5 (Black pepper 5 g/kg of stored grains) and T_2 (Naphthalene 5 g/kg of stored grains).

In case of % infestation, the highest weight of infestation was recorded for maize grains (17.52 %) was found in T_6 (Untreated control) followed by T_4 (Lantana leaves 10 g/kg of stored grains) which were statistically different from those of all other test grains where the lowest infestation (2.52%) was archived from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains), T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain) and T_2 (Naphthalene 5 g/kg of stored grains).

Table 4.10: Infestation of rice weevil in stored grains of maize at the 2nd generation by weight

Treatment	Infestation status of maize seeds by weight		
	Healthy	Infested	Infestation (%)
T_1	91.40 c	3.90 d	4.09 c
T_2	96.80 a	2.50 e	2.52 d
T_3	93.60 b	4.10 c	4.20 c
T_4	87.20 d	6.70 b	7.14 b
T_5	91.80 c	3.60 d	3.77 c
T_6	74.26 e	15.77 a	17.52 a
LSD (0.05)	1.371	0.519	0.724
Level of Significance	0.05	0.05	0.05
CV (%)	12.570	8.381	7.934

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability and numeric data represents the mean value of 4 replications.

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

4.11 Percent (%) weight loss by rice weevil

Percent weight loss was statistically significantly due cause of rice weevil infestation. (Fig. 4.3 and 4.4).

In terms of % weight loss of stored grain wheat regarding 1st generation of rice weevil, no loss of wheat grain weight was found in T_2 (Naphthalene 5 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains) where the highest loss of wheat grain weight (9.30%) was found in T_6 (Untreated control) followed by T_3 (Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain). In case of % weight loss of stored grain maize regarding 1st generation of rice weevil, no loss of maize grain weight was found in T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the highest loss of maize grain weight (8.00%) was found in T_6 (Untreated control) followed by T_4 (Lantana leaves dust 10 g/kg of stored grains) (Fig. 4.3).

In terms of % weight loss of stored grain wheat regarding 2nd generation of rice weevil, no loss of wheat grain weight was found in T_2 (Naphthalene 5 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains) where the highest loss of wheat grain weight (12.00%) was found in T_6 (Untreated control) followed by T_3 (Neem oil 5 ml/kg of stored grains). In case of % weight loss of stored grain maize regarding 2nd generation of rice weevil, lowest loss of maize grain weight (0.70%) was found in T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the highest loss of maize grain weight (9.97%) was found in T_6 (Untreated control) followed by T_4 (Lantana leaves 10 g/kg of stored grains) (Fig. 4.4).

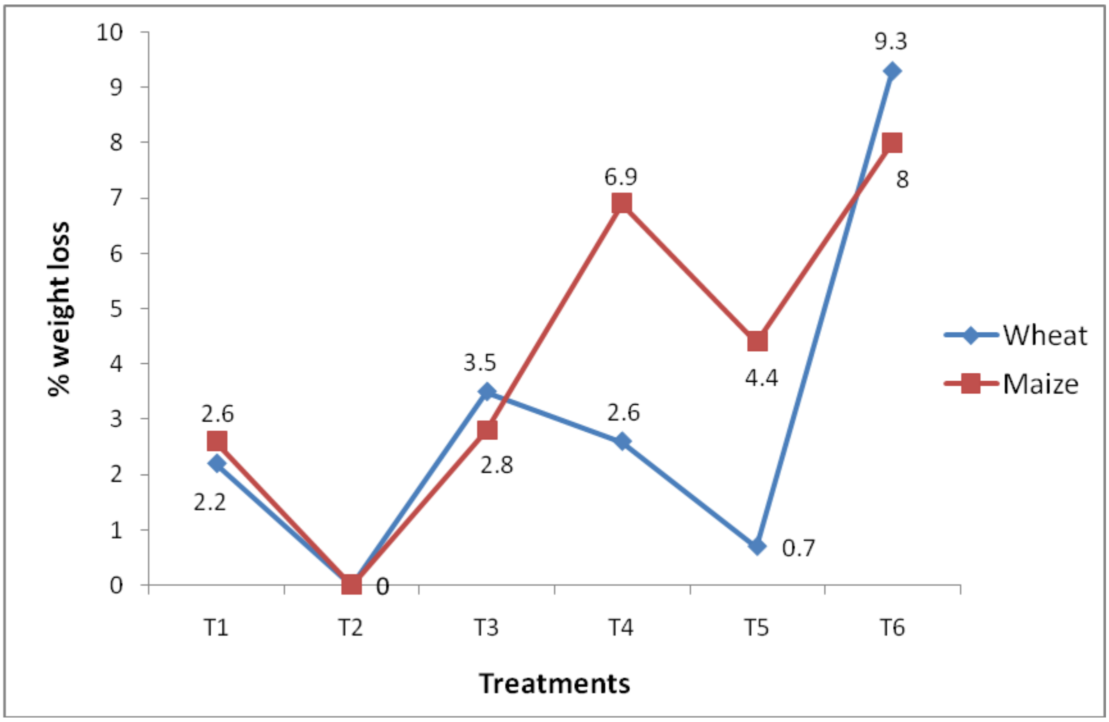

Fig. 4.3: Weight loss due to 1st generation rice weevil infestation of stored grains of wheat and maize

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

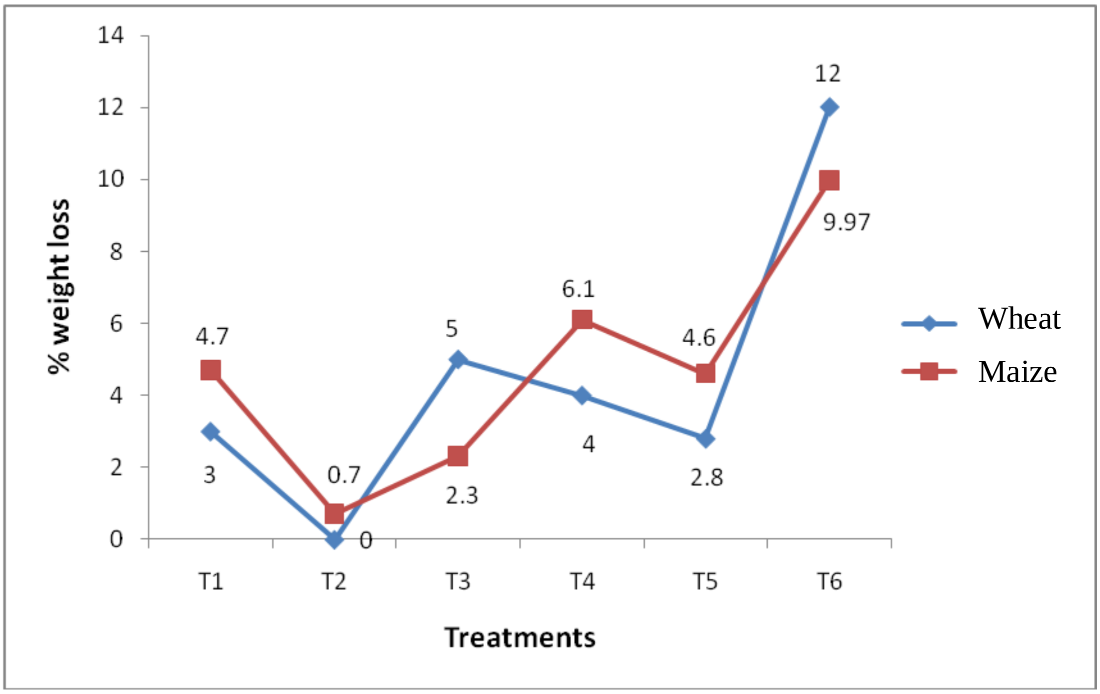

Fig. 4.4: Weight loss due to 2nd generation rice weevil infestation of stored grains of wheat and maize at different generation

T_1 = Tobacco leaves dust @ 7 g/kg of grain mixing with stored grain
T_2 = Naphthalene @ 5 g/kg of grain on the upper layer
T_3 = Neem oil wettable cloth @ 1.0 ml / tissue paper (20x20 cm^2) on the upper layer of grain
T_4 = Lantana leaves dust @ 10 g/kg of grain mixing with stored grain
T_5 = Black pepper dust @ 5g / Kg of grain mixing with stored grain
T_6 = Untreated control

CHAPTER V

SUMMARY AND CONCLUSION

Experiments were conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from May to October 2014 to study the damage loss assessment and management of rice weevil (*Sitopilus oryzae* L.) in different wheat and maize grains in storage. Wheat and maize seeds were used as experimental materials.

5.1 Damage loss assessment of wheat and maize grains in storage caused by rice weevil by number and weight

1^{st} generation of rice weevil by number caused significant infestation in wheat and maize grain. Results signified that the highest healthy seed by number (2243) was found from T_2 (Naphthalene 5 g/kg of stored grains) where the lowest was from T_6 (Untreated control). Similarly, the lowest (2145) infested seed by number was found in T_2 (Naphthalene 5 g/kg of stored grains) where T_6 (Untreated control) gave highest number of infested seed (107). In terms of percent (%) infestation, no infestation was found from T_1 (Tobacco 7 g/kg of stored grains) but control treatment gave the highest infestation (4.75%) by number.

1^{st} generation of rice weevil by weight also caused significant infestation in wheat. Results indicated that the highest healthy seed by weight (100 g) was found from T_2 (Naphthalene 5 g/kg of stored grains) where the lowest was from T_6 (Untreated control) followed by T_3 (Neem oil 5 ml/kg of stored grains). Similarly, no infested seed was observed in T_2 (Naphthalene 5 g/kg of stored grains) where T_6 (Untreated control) gave highest infested seed (10.30 g) followed by T_3 (Neem oil 5 ml/kg of stored grains). In terms of percent (%)

infestation, no infestation was found from T_1 (Tobacco 7 g/kg of stored grains) but control treatment gave the highest infestation (11.36%) by weight.

In case of maize stored grain, rice weevil affect significantly by number. Results revealed that the highest number of healthy seed (402), lowest number of infested seed (8.00) and lowest % infestation (1.95%) by number was observed from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the lowest number of healthy seed (368), highest number of infested seed (44.00) and highest % infestation (10.68%) by number was found from T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains).

Again, in case of maize stored grain, rice weevil affect significantly by weight. Results showed that the highest weight of healthy seed (97.20 g), lowest weight of infested seed (2.80 g) and lowest % infestation (2.80%) by weight was observed from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the lowest weight of healthy seed (78.75 g), highest weight of infested seed (13.25 g) and highest % infestation (14.40%) by weight was found from T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains).

2nd generation of rice weevil by number caused significant infestation in wheat grain. Results revealed that in case of wheat stored seed the highest number of healthy seed (2240), lowest number of infested seed (0.00) and lowest % infestation (0.00%) by number was observed from T_2 (Napthalin 5 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains) where the lowest number of healthy seed (2030), highest number of infested seed (77.00) and highest % infestation (9.70%) by number was found from T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains).

Again, 2nd generation of rice weevil by weight caused significant infestation in wheat grain. Results showed that regarding wheat stored seed the highest weight of healthy seed (100 g), lowest weight of infested seed (0.00 g) and lowest % infestation (0.00%) by weight was observed from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains) where the lowest weight of healthy seed (74.73 g), highest weight of infested seed (13.27 g) and highest % infestation (15.08%) by weight was found from T_6 (Untreated control) followed by T_3 (Neem oil 5 ml/kg of stored grains).

Considering maize stored seed, for 2nd generation rice weevil, results revealed that the highest number of healthy seed (398), lowest number of infested seed (7.00) and lowest % infestation (1.37%) by number was observed from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the lowest number of healthy seed (358), highest number of infested seed (48.00) and highest % infestation (11.82%) by number was found from T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains). Again, Results showed that the highest weight of healthy seed (96.80 g), lowest weight of infested seed (2.50 g) and lowest % infestation (2.52%) by weight was observed from T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the lowest weight of healthy seed (74.26 g), highest weight of infested seed (15.77 g) and highest % infestation (17.52%) by weight was found from T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains).

In terms of % weight loss of stored grain wheat regarding 1st generation of rice weevil, no loss of wheat grain weight was found in T_2 (Naphthalene 5 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains) where the highest loss of wheat grain weight (9.30%) was found in T_6 (Untreated control) followed by T_3 (Neem oil 5 ml/kg of stored grains). In case of % weight loss of stored grain maize regarding 1st generation of rice weevil, no loss of maize grain weight was found in T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the highest loss of maize grain weight (8.00%) was found in T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains).

In terms of % weight loss of stored grain wheat regarding 2nd generation of rice weevil, no loss of wheat grain weight was found in T_2 (Naphthalene 5 g/kg of stored grains) followed by T_5 (Black pepper 5 g/kg of stored grains) where the highest loss of wheat grain weight (12.00%) was found in T_6 (Untreated control) followed by T_3 (Neem oil 5 ml/kg of stored grains). In case of % weight loss of stored grain maize regarding 2nd generation of rice weevil, lowest loss of maize grain weight (0.70%) was found in T_2 (Naphthalene 5 g/kg of stored grains) followed by T_1 (Tobacco 7 g/kg of stored grains) where the highest loss of maize grain weight (9.97%) was found in T_6 (Untreated control) followed by T_4 (Lantana leaf 10 g/kg of stored grains).

From the above discussion, it can be concluded that the treatment of T_2 (Naphthalene 5 g/kg of stored grains) gave the best performance for both wheat and maize stored grain in terms of seed infestation and % weight loss compared to control.

5.2 Management of wheat and maize grains in storage affected by rice weevil

Death and % mortality of rice weevil by the application of different treatments in wheat stored grain showed significant difference. Results showed that the highest death of rice weevil (10.00) with 100% mortality was found in T_2 (Naphthalene 5 g/kg of stored grains) where the minimum death of rice weevil (4.75) by number with lowest mortality rate (47.50%) was found in T_1 (Tobacco 7 g/kg of stored grains). Death and % mortality of rice weevil by the application of different treatments in stored maize seeds also showed significant difference. Results showed that the highest death of rice weevil (10.00) with 100% mortality was found in T_2 (Naphthalene 5 g/kg of stored grains) where the minimum death of rice weevil (4.50) by number with lowest mortality rate (45.00%) was found in T_4 (Lantana leaf 10 g/kg of stored grains). In both case no death and mortality was found from T_6 (Untreated control).

From the above findings it can be conclude that for experiment 2 the best performance of was given by T_2 (Naphthalene 5 g/kg of stored grains) regarding death of insect and mortality rate compared to all other treatments including control.

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APPENDICES

Appendix 1: Monthly records of Temperature, Rainfall, and Relative humidity of the experiment site during the period from May 2014 to October 2014

Year	Month	Air Temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2014	May	34.90	27.00	30.95	61.00	2.00	221.50
2014	June	35.60	29.30	32.45	72.65	2.50	229.40
2014	July	35.80	29.60	32.70	75.70	2.70	230.50
2014	August	36.30	30.50	33.40	74.60	3.00	227.80
2014	September	32.70	28.60	30.65	68.50	1.50	123.50

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix 2: The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (µ gm/gm)	:	18.49
Exchangeable K (meq)	:	0.07
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.32
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix 3: Infestation of rice weevil in stored grains of wheat at 1st generation by number

Sources of variation	Degrees of freedom	Infestation status of wheat seeds by number		
		Healthy	Infested	Infestation (%)
Replication	3	212.36	0.20	0.600
Factor A	5	108.74*	7.68*	0.97**
Error	15	7.044	0.538	0.411

Appendix 4: Infestation of rice weevil in stored grains of wheat at 1st generation by number

Sources of variation	Degrees of freedom	Infestation status of wheat seeds by number		
		Healthy	Infested	Infestation (%)
Replication	3	11.167	0.407	0.016
Factor A	5	305.31*	4.71*	0.34**
Error	15	12.45	2.75	0.52

Appendix 5: Infestation of rice weevil in stored grains of wheat at 1st generation by weight

Sources of variation	Degrees of freedom	Infestation status of wheat seeds by weight		
		Healthy (g)	Infested (g)	Infestation (%)
Replication	3	9.515	0.712	0.030
Factor A	5	204.03*	6.834*	2.480**
Error	15	9.542	2.884	1.630

Appendix 6: Infestation of rice weevil in stored grains of maize at 1st generation by number

Sources of variation	Degrees of freedom	Infestation status of maize seeds by number		
		Healthy	Infested	Infestation (%)
Replication	3	13.056	0.089	0.068
Factor A	5	82.346*	7.016*	2.400*
Error	15	6.326	1.571	1.281

Appendix 7: Infestation of rice weevil in stored grains of maize at 1st generation by weight

Sources of variation	Degrees of freedom	Infestation status of maize seeds by weight		
		Healthy (g)	Infested (g)	Infestation (%)
Replication	3	12.434	0.809	1.367
Factor A	5	74.39*	8.31**	1.342**
Error	15	7.601	1.825	2.366

Appendix 8: Infestation of rice weevil in stored grains of wheat at 2nd generation by number

Sources of variation	Degrees of freedom	Infestation status of wheat seeds by number		
		Healthy	Infested	Infestation (%)
Replication	3	9.536	1.241	1.562
Factor A	5	67.35*	9.289*	3.336*
Error	15	8.244	2.268	1.392

Appendix 9: Infestation of rice weevil in stored grains of wheat at 2nd generation by weight

Sources of variation	Degrees of freedom	Infestation status of wheat seeds by weight		
		Healthy	Infested	Infestation (%)
Replication	3	12.389	1.237	0.842
Factor A	5	66.348*	8.599*	4.297*
Error	15	7.647	1.529	1.759

Appendix 10: Infestation of rice weevil in stored grains of maize at 2nd generation by number

Sources of variation	Degrees of freedom	Infestation status of maize seeds by number		
		Healthy	Infested	Infestation (%)
Replication	3	9.761	0.256	0.162
Factor A	5	56.244*	9.247*	3.739**
Error	15	5.274	2.215	0.274

Appendix 11: Infestation of rice weevil in stored grains of maize at 2nd generation by weight

Sources of variation	Degrees of freedom	Infestation status of maize seeds by weight		
		Healthy	Infested	Infestation (%)
Replication	3	3.281	1.844	0.854
Factor A	5	60.732*	9.344*	3.249*
Error	15	7.361	3.278	1.168

Appendix 12: Weight loss due to rice weevil infestation of stored grains of wheat and maize at different generation

Sources of variation	Degrees of freedom	First generation (%)		Second generation (%)	
		Wheat	Maize	Wheat	Maize
Replication	3	0.267	0.162	0.214	0.356
Factor A	5	8.548**	10.739**	9.374**	12.247**
Error	15	1.261	2.274	1.268	1.356

Appendix 13: Number of death insect with different treatment in stored grain of wheat

Sources of variation	Degrees of freedom	Number of dead insects for		
		24 hrs	48 hrs	72 hrs
Replication	3	0.387	0.003	0.001
Factor A	5	8.289**	3.247**	0.261**
Error	15	2.231	1.277	0.006

Appendix 14: Number of death insect with different treatment in stored grain of Maize

Sources of variation	Degrees of freedom	Number of dead insects for		
		24 hrs	48 hrs	72 hrs
Replication	3	0.014	0.041	0.006
Factor A	5	7.426**	0.312**	0.156**
Error	15	0.359	0.109	0.107

Appendix 15: Insect mortality (%) with the different treatment of stored grain pest

Sources of variation	Degrees of freedom	Percent mortality (%)	
		Wheat	Maize
Replication	3	0.072	0.124
Factor A	5	8.429**	9.367**
Error	15	2.238	3.127