ASSESSMENT OF DIFFERENT NEEM PRODUCTS FOR THE MANAGEMENT OF RICE WEEVIL (*SITOPHILUS ORYZAE* L.) IN STORED RICE GRAIN

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CERTIFICATE

*This is to certify that thesis entitled, **'Assessment of Different Neem Products for the Management of Rice Weevil (Sitophilus oryzae L.) in Stored Rice Grain'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of Master of Science in Entomology, embodies the result of a piece of bona fide research work carried out by **Sajib Talukder**, Registration No. **11-04728** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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ABSTRACT

The experiment was conducted to study the damage assessment and effect of different neem products for the management of rice weevil (*Sitophilus oryzae* L.) in stored rice grain during the period from July to December 2013. Stored husked and unhusked rice of BR 27 were used as the experimental materials. The experiment consists of the treatments: T_1: Neem leaves dust 10 gm/kg of stored rice grains; T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains; T_3: Neem leaves extract @ 10 ml/kg of stored rice grains; T_4: Neem oil 5 ml/kg of stored rice grains and T_5: Untreated control. The experiment was laid out in the ambient condition of the laboratory following in a Completely Randomized Design (CRD) and the treatments was replicated four times for each. In case of unhusked rice, the highest mortality (100.00%) was observed in T_4 treatment, while the lowest 5.25% mortality was recorded in T_5 treatment. For husked rice, the highest mortality (100.00%) was observed in T_4, while the lowest mortality (9.00%) was recorded in T_5 treatment. At 1st generation for unhusked rice, in weight basis, the highest infestation was recorded from T_5 (9.49%) treatment while the lowest in T_4 (1.32) and for husked rice, the highest infestation was recorded from T_5 (10.68%), while the lowest in T_4 (2.79%) treatment. On the other hand, by number basis in unhusked rice, the highest infestation was found from T_5 (11.57%), while the lowest in T_4 (2.47%) treatment and for husked rice, the highest infestation was found from T_5 (14.72%) while the lowest in T_4 (3.86%) treatment. Similar trend of results were revealed from the 2nd and 3rd generations. At 1st generation, for unhusked rice, the highest weight loss was found in T_5 (18.21%), while the lowest was found in T_4 (3.89%) treatment and for husked rice grain, the highest weight loss was recorded in T_5 (21.45%), whereas the lowest was observed in T_4 (4.38%) treatment. Similar trend of result also recorded in 2nd and 3rd generation. In case of repellency effect for unhusked rice, after 5 hours of treatment application the highest repellency rate was found from T_4 and T_3 (100.00%), whereas the lowest repellency rate (80.00%) was recorded in T_1 treatment. In case of repellency effect for husked rice, after 5 hours of treatment application the highest repellency rate was found from T_4 and T_3 (100.00%) treatments which was followed by T_1 and T_2 (90.00%) treatments. Among the neem products neem oil 5 ml/kg of stored rice grains was more effective for controlling rice weevil.

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CHAPTER I

INTRODUCTION

Rice is the most important food for majority of people around the world. It is the staple food for more than two billion people in Asia (Hien*et al.*, 2006). In Bangladesh, the geographical, climatic and edaphic conditions are favorable for year round rice cultivation. About 75% of the total cropped area and more than 80% of the total irrigated area is cultivated for rice (Hossain and Deb, 2003).Bangladesh produces a total of 27.04 million tons of rice from an area of 25.56 million acres (BBS, 2012). Preservation of reserve food grain stocks is necessary to ensure a continuous supply at stable price around the year. The farmers store more than 65% of the total rice produced till the next season for their food, feed and seed purposes. Rice is stored as paddy (unhusked rice) after harvest and also polished milled rice (husked rice).

About 10,000 years ago, agricultural practices began and that of storing grain started about 4,500 years ago as a safeguard against poor farmers from famines (Saxena*et al.*, 1988). In Bangladesh, rice is stored as raw parboiled in bamboo made container (dole and golas) or stored as parbolied milled rice 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. Rice is 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 rice (Prakas*et al.* 1987) of which rice weevil (*Sitophilusoryzae* Linn.), rice moth (*Sitotrogacerealella*); and beetles (*Triboliumcastaneum*) predominate in parboiled rice. In India losses caused by insects accounted for 6.5% of stored grain (Raju, 1984). In Bangladesh, the annual grain losses cost over taka 100 crores (Alam, 1971). If these losses could be saved and food grains are properly distributed, famine in most of the countries of Asia and Africa could be averted.

The rice weevil *Sitophilusoryzae* 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). In Bangladesh rice is 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 rice 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 rice grain. 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 and 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 and 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 *et al*., 1991). Indo-Pakistani farmers use neem leaves, bishkatali for controling 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, antifeedant, 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; the present research work was undertaken with the following objectives:

- To determine the damage assessment of unhusked and husked stored rice grains by rice weevil.
- To find out the effect of different neem products on adult mortality and development of rice weevil.
- To evaluate the effect of different neem products on grain weight loss by rice weevil.
- To evaluate the repellent effect of different neem products against rice weevil.

CHAPTER II

REVIEW OF LITERATURE

The insect, *Sitophilusoryzae* 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

Sitophilusoryzae 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: ***S. oryzae***

2.3Appearance 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).

2.4Distribution and habitsof rice weevil

The rice weevil is one of the most serious stored grain pests worldwide. This pest of whole grain originated in India and has been spread worldwide by commerce. 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 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).

2.5Biology 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).

2.6Control 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" saved from Thanksgiving, wild bird seed, dry plant arrangements that contain wheat or other seed heads, popcorn, beanbags or 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). 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 have 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 antifeedant, 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. 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 *Sitophilusoryzae*. 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 *Sitophilusgranarium* and on the behaviour 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 carvone (Nawrot, 1985). Ahmed and Eapea (1986) screened plant extracts and found that those from Gaultheria, dill (*Anethusgraveoleus*), Japanese mint (*Mentha sp*.) and Eucalyptus and cineole and turpentine, were promising as strong repellent against *Sitophilusoryzae*and *Callosobruchuschinensis*.

Neem (*Azadirachtaindica, 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 antifeedant, 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 (Jacobson, 1986).The wood resembles mahogany and bark is very bitter (Hooker, 1978).However, neem compounds are too complex to be synthesized for practical purpose (Jacobson, 1986).

Ahmed and Eapea (1986) screened plant extracts and found that those from Gaultheria, dill (*Anethusgravevieus*), Japanese mint (*Mentha*sp.) and Eucalyptus were promising as strong repellent against *Sitophilusorvzae* and *Callosobruchuschinensis.*

Jilani (1986) conducted experiments with ethanolic extract of neem seed; hexane extract of sweet flag, Acoruscalamus 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.

Ahmed and Eapea (1986) screened some essential plant extracts and found that gaultheria, dill (*Anethumgraveoleus*), Japanese mint (*Mentha*), eucalyptus, cineole and turpentine were promising as strong repellents against *S. oryzae*and *C. chinensis.*

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 *Callosobruchuschinensis*.

Seventeen plant extracts in Pakistan were tested for their repellency to *Triboliumcastaneum*. Seed extracts of *Intsiabijuga* and neem oil both had highest repellency. Vegetable oils from *Olimumbasilieum, Tageteserecta, Momordicacharantia*, Celery and garlic were less repellent than *I. bijuga* oil, but more repellent than oils from *Cuminumcyminum*, bottle guards or Indian mustard (Mohiuddin*et al*., 1987).

Jilani and Saxena (1987) observed that neem, turmeric and sweet flag has repellent action on stored grain pests. Singh *et al*. (1987) evaluated six plant extracts against*R. dominica* in the laboratory, extracts of neem, *Azadirachtaindica*, *Bassialongifolia* and *Pongamiaglabra*were highly toxic. The crude extract of water hyacinth (*Eichhorrniagrassipes*) was evaluated for its biological activity against the *T. cactanium. S. oryzae, Callosobruchusmaculats*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* (Dakshinamwithy, 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 *Triboliumcastaneum*. 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. maculatus, S. oryzae, S. zeamais and Cylospuncticollis.* The extracts were more effective as suppressants to *C. maculates* than of *S. oryzae* and the there was no effect on *Cylospuncticollis.* Repellency action of turmeric, sweet flag and neem oil against the lesser grain borer, *R. dominica* were observed by Jilani and Saxena (1990).

Adgeh*et al.* (1991) reported that oils and powder from neem and lagundi (*Vitexnegundo*) mixed with grains at different storage intervals for 180 days, effectively controlled the emergence of adults of *Sitophilusoryzae, Rhyzoperthadominica*and *Callosobnichuschinensis* and maintained viability of the seeds.

Adgesh and Rejesus (1991) reported that oils and powders from neem, lagudi (*Vetexnegundo*) mixed with grains at different storage intervals for 180 days effectively controlled the emergence of adults of *Sitophilusoryzae*, *Sitophilusgarnarius, Rhizoperthadominica*and *Callosobruchuschinensis* and maintained viability of the seeds.

Jood*et al*. (1993) reported that neem kernel powder and oil provided, complete protection to hatching of *Trogodermagranarium* in wheat grain for 6 months. DeyandSarup (1993) tested eight vegetable oils viz. mustard, soybean, coconut, neem, groundnut, cotton, sesame and castor at 5 doses against adults, *Sitophilusoryzae*, 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 containing 10% cyfluthrin (Slofac) and a neem formulation containing crude extract from fruits of *Azadirachtaindica* 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 (*Menthaspicata*) leaf on maize kernels at 1 and 2% level (w/w) to control the larvae of *T. granarium*. Neem kernel powder and oil provided complete protection to grains for 6months, whereas, substantial insect infestation was noticed after 3 months in other treatments.

Prakash *et al.* (1993) evaluated that twenty plant products against *Sitophilusoryzae.* 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 *Vitexneganda*, leaves of *Andrographospaniculata,* 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. oryzaeand R. clominica*and damage to paddy grain stored in 40 kg jute bags for 3 months (Muda, 1994).

Talukder and Howse (1994) reported that the seed extract of *Aphanamixispoystachya* had strong repellent effects on red flour beetle and grain weevil. The repellency and toxicity of Azadirachtin and three neem extracts to three stored product insects, *Crypiatlestesferrugineous, 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, NishindaandBiskatali 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 and Wesolowska (1996) 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 and (*Eucallyptushydrida*), *L. camara* and *V. negundo* against *R. dominica* on wheat in the laboratory. *A. indica, L. camera* 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 (*Melilotusofficinalis*) and the white melilot (*M. albus*) were found to be strongly repellent to *Sitophilusgrainarius,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 *Sitophihisoryzae*and *C. chinensis*. Results showed that in *S. oryzae* was raepelled 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, *Calotropisgiganteani*, inn. (Akando) and *Ipomoea nil* Linn (Kaladanah) [*Pharbitis nil*] for their toxicity against the adults of *Sitophilusoryzae* Linn.*Trboliumcastanium*Herbst and *Cryptolestesferrugineus*(Stephens) after 24 hours of treatment. The LD_{50} 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. gigantean* 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 *Sitophilusoryzae*. In choice experiments insects were allowed to feed either on untreated rice or on rice treated with extracts of the leaf bud exudate 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 (*Azadirachtaindica*), the botanical most commonly used by farmers for storage protection in south Asia. Preliminary High Performance Liquid Chromatography analyses (HPLC) 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 F_1 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 significantly dose dependent.

Sharma (1999) reported that neem seed (*Azadirachtaindica*) kernel powder (nskp) at 4% and neem leaf powder (npl) at 5% protected maize for 5 months against *Sitophilusoryzae, Sitotrogacerealella, Rhyzoperthadominica*and *Trogodermagranarium*. Neem oil (nimbcidine 1%) was toxic to the adults of *Sitophilusoryzae, R. dominica, Trogodermagranarium, Sitotrogacerealella*and *Triboliurncastaneum.* 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 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 0.5and 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 *Azadirachtaindica* kernels, *Allium sativuim* bulbs, *Citrus sinensis* peels, *Citrus Limon* peels and *Mangiferaindica* 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% and61.11% mortality, respectively.

Islam and Shahjahan (2000) conducted experiments to evaluate the toxicity of five botanicals, viz. neem (*A. indica*), marigold (*Tagesteserecta*) and durba (*Cynodondactylon*) and found a significant effect in controlling insect pests.

Four laboratory experiments were conducted with the leaves of three plant species viz. biskatali (*Polygonumhydropiper*), akanda (*Asclepiascalotropis*), and neem (*Azadirachtaindica*) for studying their relative efficacy against the lesser grain borer, *Rhyzoperthadominica* (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 F_1 progeny emergence and grain infestation rates (Amin *et a1*., 2000).

Shanmugapriyan and Kingly (2001) reported the effect of neem oil at 0.25,0.5 and 1.5% on larvae of *Sitophilusoryzae*. Neem oil at 1.5% concentrationcaused the highest mortality of second and third instars (95.23%) andfourth instars (76.19%). Neem oil at 0.25% and 0.5% concentrationsresulted 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, *Sitophilusoryzae.* Glass film method was adopted to determine the Lc50 rate. After ploting a graph between mortality and concentration, the Lc50 was found to be 0.44 µg/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 Neamleaf 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 *Sitophilusoryzae* 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).

Ogemah*et al.* (2003) tested two Neemazal products from Trifolio 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 mgazadirachtin 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 .0 ml/kg), diflubenzuron (10 mg/kg), neem seed oil (0.5 ml/kg) tulsiseed oil (0.5 ml/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. Tenpairs (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 flavour, texture and taste scores varied significantly between treatments and were highest in rice treated with cloveoil.

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 *Sitophilusoryzae* on stored maize grains. Processed cardamom and Mick pepper 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 7.5 ml, turmeric powder at 3.5 g, mustard oil + turmeric powder at3.75 ml + 1.75 g, ground nut oil + turmeric powder at 3.75 ml + 1.75 g each per one kg of seed, 4 m 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 only1633% adult mortality. Al the other treatments were not effective.

Two experiments were conducted in the laboratory with leaves of one plant species bishkatali (*Polygonumhydropiper*) for studying their repellency and toxicity test against the rice weevil (*Sitophilus of oryzae* L.) and lesser grain borer(*Rhyzoperthadominica* 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 *Polygonumhydropiper* 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 (*Tagesteserecta*) and durba (*Cynodondactylon*) 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 (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 (*Polygonumhydropiper*) and neem seed (*Azadirachtaindica*) against the rice weevil *Sitophilusoryzae* (L.) were assessed using contact toxicity, progeny production, damage assessment and repellency assays. The extract of *Polygonumhydropiper*was moderately toxic to *S. oryzae* but that of *Azadirachtaindica* 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 (*Callosobruchuschinensis*). 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 (*Swietenimahagoni*)Ncem (*Azadirachtaindica*), Ghora-ncern(*Meliasempervirens*), Bazna (*Zanthoxylumrhetsa*), Hijal (*Barringtoniaacutangula*), Karanja (*Pongamiapinnata*), against red flour beetle, *Triboliumcastaneum*. Leaf and seed extracts were prepared by using acetone, methanoland water as solvents. The results showed that extracts of all the six plants haddirect toxic effect on red flour beetle. Among them, Neem seed extract showedthe highest toxic effect (mortality, 52.50%), whereas Hijal leaf extract possessedthe lowest toxic effect (mortality, 22.24%) (Mamun*et al.*, 2009).

A laboratory experiment was conducted to investigate the insecticidal activitiesof seven plant against *Sitophilusoryzae* developmental durations and damage inrice. Plant materials were evaluated at 1 g/20 g rice (0.1 g PMD/20 g rice).Theresults showed that MWA was more effective in causing adult *Sitophilusoryzae*mortality, but CPP was significantly more effective in reducing adultemergence, percentage hatching inhibition rate and per cent holed rice (Yusuf,2009).

In Bangladesh, most of the farmers are poor and marginal and they store small quantities of seed for edible rice and cannot offer expensive control measures. Therefore, use of neem products can be effective methods for safe storing of rice.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the damage assessment and effect of different neem products for the management of rice weevil (*Sitophilusoryzae* L.) in stored rice grainduring the period from July to December 2013. A brief description of the experimental site, experimental design, treatments, data collection and analysis of different parameters under the following headings are presented below:

3.1Experimental material

Stored husked and unhusked rice (BR 27) were purchased and collected from the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka. Collected stored rice (BR 27) 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. De-infestation of rice grains

Before artificial infestation of rice grains (unhusked and husked) with weevils, the parboiled rice grains of BR 27 variety was dried in the sun for 2 days. Nawab Ali *et al*. (1980) reported that solar heat treatment of paddy grains destroys the initial insect infestation in the grains before storage.

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^{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.

3.4 Experimental treatment

The experiment consists of the following different neem products:

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

Plate 1. Set of the experiment in laboratory condition

3.5 Description of neem

It has been an age old practice in rural areas of Bangladesh to mix dried neem leaves with stored rice to control stored-stored rice insects. A variety of preparations based on neem extracts have been tasted against stored product insects. Azadirachtin-rich commercial "Margosan-O" is already produced in developing countries for controlling pests.

3.5.1 Morphology

Neem is perennial tree, 15-20 m height with a straight trunk; leaves are simple, number of leaflets 9-15, opposite, sub-opposite or alternate, lanciolate, acuminate or sub-falcate, flowers are white, fruit (droup) oblong.

3.5.2 Distribution

Neem is a common tree of Bangladesh and throughout the greater part of India, Planted in the hot climate. It is known by different names in different areas, such as neem, nem (Hindi and Bangla), timba (Gujrati), bevu (Kannada), vepe (Malayalam), limba (marati) and vepa (Tamil).

3.5.3 Uses

Neem is famous for its medicinal properties. The major active constituent is azadirachtin which is well known for its toxic, antifeedent and growth regulating effect on insects.

3.6 Preparation of neem products

3.6.1Neem leaf dust

Fresh leaves of neem(Plate 2A) were collected from the field area of SAU, Dhaka. After bringing to the laboratory, they were washed in running water and dried in shade. Dust was prepared by pulverizing the dried leaves in a magnetic stirrer. A 25-mesh diameter sieve was used to obtain fine dust (Plate 2B).

Plate 2.Twig ofneemleaf (A) and neem leaf dusts in petridish (B)

3.6.2Neemkernel dust

Neemkernel were collected from the field area of Sher-e-Bangla Agricultural University, Dhaka. After bringing to the laboratory, they were washed in running water and dried in shade. Dust was prepared by pulverizing the kernel in a magnetic stirrer. A 25-mesh diameter sieve was used to obtain fine dust (Plate 3A).

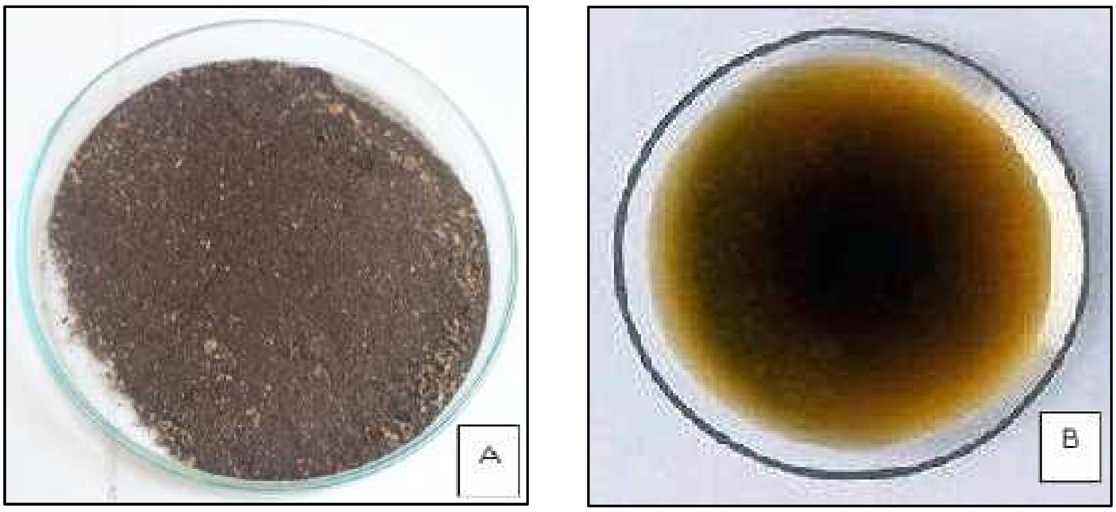

Plate 3.Dusts of neemseed kernel (A) and neem oil in petridish (B)

3.6.3Neem leaf extract

Fresh neem leaves were collected from the campus of Sher-e-Bangla Agricultural University, Dhaka. Then the collected leaves were washed with tap water. Air dried fresh 10 g of leaves were taken into an electric blender with 100 ml of water. For obtaining fine extract, the blended mixture was filtered with fine cloth and the extract was considered as 10% neem leaf extract. The prepared extract was mixed with equal volume of water to obtain 5% neem leaf extract.

3.6.4Neem oil

Neem oil that used in this experiment was collected from the Department of Entomology, SAU, Dhaka with 100% concentration. Two millilitres of 100% neem oil was taken in flask with a small amount of distilled water and a few drops of ethyl alcohol for well mixing and then the volume was made 100m1 by adding distilled water into the mixture. The mixture was considered as 2% neem oil. Fifty millilitres of the prepared 2% neem oil and 50 ml of distilled water was mixed to prepare 1% neem oil solution (Plate 2).

3.7 Experimental design and layout

The experiment was laid out in the ambient condition of the laboratory following Completely Randomized Design (CRD) and the treatments was replicated four times for each.

3.8Assessment of different neem productsagainst rice weevil

The effects of different neem products as grain protectant against *S. oryzae*were evaluated considering adult mortality, adult emergence, adult life span, number of damaged seeds, grain weight loss and repellency test from treated and untreated grains both for unhuskedand husked rice. Data were collected on the bellow mentioned parameters:

3.8.1 Observation on adult mortality and emergence

50 gm of insect free rice grains were taken into Petri dishes. At the rate of 10 gm. /kg of each treatment was added in each Petri dish excluding control mixed thoroughly.

Then 5 pairs of newly emerged adult rice weevil were released carefully into each Petri dish. Insect mortality was recorded at 24 hours intervals up to 3 days.

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

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

After 24 – 28 days, new adults started emerging from those grains. The number of emerged rice weevil at different days from each treated Petri dish including control was recorded. The counting of emergent adult was made by opening the lid. At the beginning, few weevilcame out from the Petri dish at first and the rest of them came out after gently shakings the Petri dish.

3.8.2 Observation on adult life span

After release of 5 pairs of adult weevils, they were observed daily up to the death. From this mortality data, adult life span was calculated.

3.8.3Observation on damage and weight loss

When the emergence of the weevil was completed the seeds were cleaned and the numbers of damaged and normal seeds were counted for both unhusked and husked rice grain. Grains with hole were considered as damaged or infested seeds (Plate 4). To determine the percentage of damaged rice seeds, number of seeds having hole and normal seeds were counted per Petri dish or replicate and percentage of damaged seeds were calculated by using the following formula-

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

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

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

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

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

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

Plate 4.Rice weevil infested unhusked and husked rice

3.8.4 Observation on repellency test

Repellency test were conducted according to the method of Talukder and Howse (1994) with slight modifications. A petridish (9 cm) was divided into 3 parts, treated, untreated portion (3.5 cm each) and neutral centre portion (without grain) 2 cm. Two grams of rice grain were taken in treated and untreated portion of Petri dishes for unhusked and husked rice grain. Then each treatment was applied on treated grain side portion separately of each petridishand other untreated grain side portion. Ten insects were released at the center portion of each Petri dish and a cover was placed on the Petri dish. For each treatment, four replications were used. Then the insect present on each portion (treated and untreated) were counted at hourly intervals up to fifth hour for unhusked and husked rice grain.

The data were expressed as percentage repulsion (PR %) by the following formula as described by Talukder and Howse (1994).

PR (%) = (NC – 50) × 2

Where,

NC = The percentage of insect present in the control half. Position (+) values expressed repellency and negative values express attractions. Data (PR %) was analyzed using analysis of variance (ANOVA) after transforming them into percentage. The average values were then categorized according to the following classes (McDonald *et al.* 1970).

Class	Repellency rate (%)
0	>0.01 to 0.1
I	0.1 to 20.0
II	20.1 to 40.0
III	40.1 to 60.0
IV	60.1 to 80.0
V	80.1 to 100.0

3.9 Statistically analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the damage assessment and effect of different neem products for the management of rice weevil (*Sitophilus oryzae* L.) in stored rice grain both in unhusked and husked condition. The results have been presented and discussed, and possible interpretations were given below under the following headings:

4.1 Number of dead insects

Number of cumulative dead insects after 24, 48 and 72 hours showed statistically significant variation due to different neem products for management of rice weevil in unhusked and husked stored rice grain (Appendix I).

4.1.1 Adult mortality in unhusked rice

After 24 hours of treatment application the highest number of dead insects (7.50) was recorded in T_4 treatment (Neem oil 5 ml/kg of stored rice grains) which closely followed (6.25) by T_3 treatment (Neem leaves extract @ 10 ml/kg of stored rice grains) and then by T_1 (Neem leaves dust 10 gm/kg of stored rice grains). On the other hand, no dead insects were found in T_5 (untreated control) treatment which was followed by T_2 (Neem seed kernel dusts @ 10 gm/kg of stored rice grains) treatments (Table 1). After 48 hours the cumulative the highest numbers of dead insects were observed in T_4 (13.25) treatment which closely followed by T_3 (11.50) whereas there were no dead insects in T_5 treatment. T_2 (8.75) and T_1 (9.50) treatments were statistically similar in respect of dead insects after 48 hours. After 72 hours of treatment the cumulative highest number of dead insects were found in T_4 (14.25) treatment which was closely followed by T_3 (12.50) and then by T_1 (11.75) treatments and by T_2 (10.25) treatments while there were no dead insects in T_5 treatment after 24 hours for unhusked rice grain.

Table 1. Effect of different neem products on the number of dead insects after different times in unhusked and husked rice

*Treatment(s)	No. of dead insects for					
	Unhusked rice grain after			Husked rice grain after		
	24 hours	48 Hours	72 Hours	24 hours	48 Hours	72 Hours
T_1	5.25 c	9.50 c	11.75 c	6.25 c	11.25 d	14.00 d
T_2	3.25 d	8.75 c	10.25 d	4.25 d	10.50 c	11.50 c
T_3	6.25 b	11.50 b	12.50 b	7.50 b	12.75 b	13.75 b
T_4	7.50 a	13.25 a	14.25 a	8.75 a	14.00 a	15.50 a
T_5	0.00 e	0.00 d	0.00 e	0.00 e	0.00 e	0.00 e
Level of Significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	5.66	4.11	6.89	4.48	7.23	5.44

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.1.2 Adult mortality in husked rice

After 24 hours of treatment application the highest number of dead insects (8.75) was recorded in T_4 treatment which was closely followed by T_3 (7.50) treatment and then by T_1 (6.25). On the other hand, no dead insects were found in T_5 treatment which was followed by T_2 (4.25) treatments (Table 1). After 48 hours the highest cumulative numbers of dead insects were observed in T_4 (14.00) treatment which was closely followed by T_3 (12.75), whereas there were no dead insect in T_5 treatment which followed by T_2 (10.50) and T_1 (11.25) treatments. After 72 hours of treatment the cumulative highest number of dead insects were found in T_4 (15.50) treatment which closely followed by T_3 (13.75) and then by T_1 (14.00) treatments and by T_2 (11.50) treatments while there were no dead insects in T_5 treatment after 24 hours for husked rice grain.

4.2 Adult emergence

Adults emerged for 1st, 2nd, 3rd generations and also total varied significantly for the application of different neem products for the management of rice weevil in stored rice grain for unhusked and husked condition (Appendix II).

4.2.1 Unhusked rice

For unhusked rice, at 1st generation no adults emerged in T_4 treatment which was followed by T_3 (2.50), while the highest number of adults were recorded in T_5 (78.25) treatment which was followed by T_2 (8.50) treatment and T_1 (6.25) and they were statistically identical (Table 2). At 2nd generation there were no emerged adults was recorded in T_4 treatment which was followed by T_3 (4.25) treatment, while the highest adult was recorded in T_7 (112.25) which was followed by T_2 (12.50) treatment. At 3rd generation no adults emerged in T_4 treatment which was followed by T_3 (5.00) while the highest adult was obtained in T_5 (178.50) treatment which was followed by T_2 (19.00) treatment. In case of total adult emergence for 1st, 2nd and 3rd generation no adults emerged in T_4 treatment which was followed by T_3 (11.75) treatment while the highest adult was recorded in T_5 (369.00) which was followed by T_2 (40.00) treatment.

Table 2. Effect of different neem products on adult emergence at 1st, 2nd, 3rd generation & total adult emerged in unhusked and husked rice

*Treatment(s)	Adult emerged at							
	Unhusked rice grain				Husked rice grain			
	1st generation	2nd generation	3rd generation	Total	1st generation	2nd generation	3rd generation	Total
T_1	6.25 b	9.25 c	14.00 c	29.25 c	7.75 b	11.75 b	15.50 b	35.00 c
T_2	8.50 b	12.50 b	19.00 b	40.00 b	9.25 b	14.25 b	21.50 b	45.00 b
T_3	2.50 c	4.25 d	5.00 d	11.75 d	3.50 c	7.50 c	8.25 c	19.25 d
T_4	0.00 d	0.00 e	0.50 e	0.00 e	0.00 d	0.00 e	0.00 d	0.00 e
T_5	78.25 a	112.25 a	178.50 a	369.00 a	84.50 a	125.50 a	189.50 a	399.50 a
Level of Significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	3.98	6.78	5.45	7.33	5.95	6.34	4.55	7.02

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.2.2 Husked rice

In case of husked rice, at 1st generation no adults emerged in T_4 treatment which was followed by T_3 (3.50), while the highest number of adults were recorded in T_5 (84.50) treatment which was followed by T_2 (9.25) treatment and T_1 (7.75) treatment and they were statistically similar (Table 2). At 2nd generation there were no emerged adults was recorded in T_4 treatment which was followed by T_3 (7.50) treatment, while the highest adult was recorded in T_7 (125.50) which was followed by T_2 (14.25) treatment and T_1 (11.75) and they were statistically identical. At 3rd generation no adults emerged in T_4 treatment which was followed by T_3 (8.25) while the highest adult was obtained in T_5 (189.50) treatment which was followed by T_2 (21.50) treatment and T_1 (15.50) and they were statistically similar. In case of total adult emergence for 1st, 2nd and 3rd generation no adults emerged in T_4 treatment which was followed by T_3 (19.25) treatment, whereas the highest adult was recorded in T_5 (399.50) which was followed by T_2 (45.00) treatment.

4.3 Insect mortality

Insect mortality showed statistically significant variation for different neem products for the management of rice weevil in unhusked and husked stored rice grain (Appendix II).

4.3.1 Unhusked rice

In case of unhusked rice, the highest mortality (100.00%) was observed in T_4 treatment which was statistically identical (98.50%) with T_3 treatment and closely followed by T_1 (85.25%), while there were 5.25% mortality was recorded in T_5 treatment (Figure 1).

4.3.2 Husked rice

For husked rice, the highest mortality (100.00%) was observed in T_4 treatment which was statistically identical (99.00%) with T_3 treatment and closely followed by T_1 (89.50%), while the lowest mortality (9.00%) was recorded in T_5 treatment (Figure 1).

Ranjana *et al.* (2000) reported that 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 and found that neem (*A. indica*) had a significant effect in controlling insect pests. Shanmugapriyan and Kingly (2001) reported that 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. 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). Ogemah *et al.* (2003) reported that neem seed oil at high rates caused more than 80% mortality compared with 4% in the control. Islam and Talukder (2005) reported that 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.

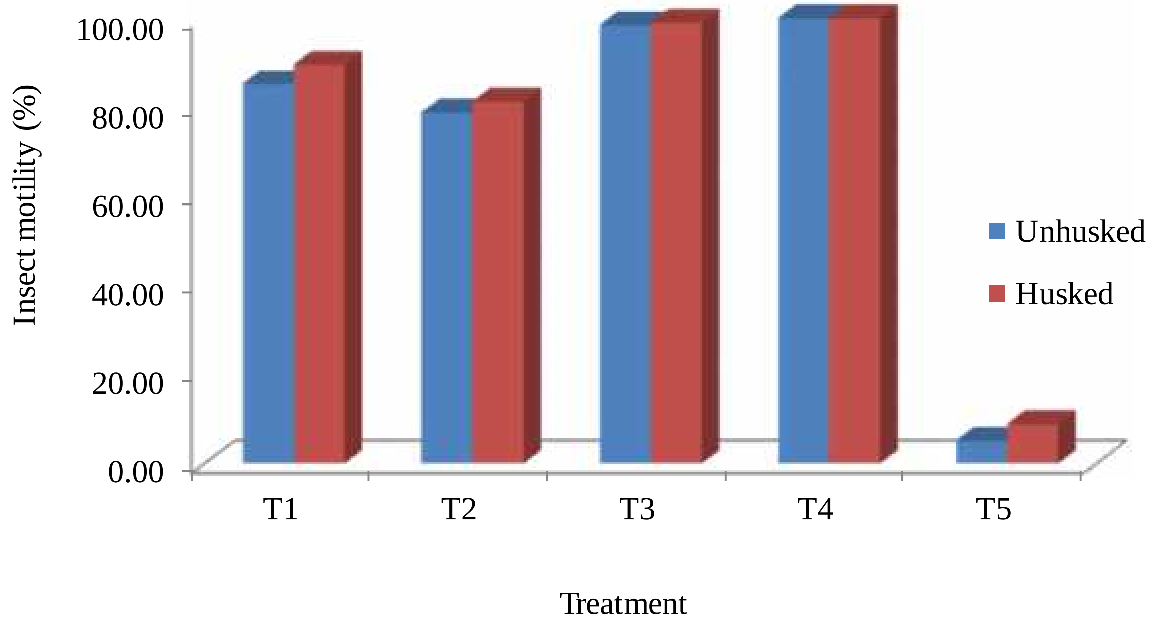

Figure 1. Effect of different neem product for controlling of *S. oryzae* in percentage of insect mortality

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.4 Status of rice grain in 1st, 2nd and 3rd generation by weight and number basis

Status of rice grain in terms of healthy, infested seeds and % infestation by weight and number for 1st, 2nd and 3rd generation showed statistically significant variation under the present trial for different neem products for the management of rice weevil in unhusked and husked stored rice grain (Appendix III to VIII).

4.4.1 At 1st generation

4.4.1.1 Unhusked rice in weight basis

At 1st generation for unhusked rice, in weight basis, the highest healthy seeds was recorded in T_4 (98.70 g) treatment which was closely followed with T_3 (97.17 g) treatments, whereas lowest in T_5 (91.33 g) which was closely followed by T_2 (96.12 g) and T_1 (96.78 g) treatment, respectively and they were statistically identical. In case of infested seeds, the lowest infested seeds were recorded from T_4 (1.30 g) treatment which was followed by T_3 (2.83 g) treatment and the highest was observed in T_5 (8.67 g) treatment which was followed by T_2 (3.88 g). In case of % infestation, the highest infestation was recorded from T_5 (9.49%) which was closely followed by T_2 (4.04%) treatment while the lowest in T_4 (1.32) which was followed by T_3 (2.91%). The highest infestation reduction over control was recorded in T_4 (86.13%) treatment and lowest from T_2 (57.48%) treatment (Table 3).

4.4.1.2 Husked rice in weight basis

At 1st generation for husked rice, in weight basis, the highest healthy seeds was recorded in T_4 (116.52 g) treatment which was statistically similar with T_3 (115.09 g) treatments, whereas lowest in T_5 (107.24 g) treatment which was closely followed by T_2 (110.54 g) T_1 and (110.87 g) treatment, respectively and they were statistically identical. In case of infested seeds, the lowest infested seeds were recorded from T_4 (3.25 g) which similar to T_3 (4.76 g) treatment and the highest was observed in T_5 (11.45 g) which was followed by T_2 (8.02 g) treatment. In case of % infestation, the highest infestation was recorded from T_5 (10.68%) which was closely followed by T_2 (7.26%), while the lowest in T_4 (2.79%) which was followed by T_3 (4.14%) treatment. The highest infestation reduction over control was recorded in T_4 (73.88%) and lowest from T_2 (32.058%) treatment (Table 3).

Table 3. Effect of different neem products for the management of rice weevil in stored unhusked and husked rice grain at 1st generation by weight basis

*Treatment(s)	Total weight of seeds for							
	Unhusked rice grain				Husked rice grain			
	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control (%)	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control (%)
T_1	96.78 c	3.22 c	3.33 c	64.95	110.87 b	7.67 b	6.92 b	35.21
T_2	96.12 c	3.88 b	4.04 b	57.48	110.54 b	8.02 b	7.26 b	32.05
T_3	97.17 b	2.83 d	2.91 d	69.32	115.09 a	4.76 c	4.14 c	61.26
T_4	98.70 a	1.30 e	1.32 e	86.13	116.52 a	3.25 c	2.79 d	73.88
T_5	91.33 d	8.67 a	9.49 a	--	107.24 c	11.45 a	10.68 a	--
Significance level	0.01	0.01	0.01	--	0.01	0.01	0.01	--
CV (%)	10.44	5.66	8.99	--	4.56	6.57	8.99	--

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.4.1.3 Unhusked rice in number basis

At 1st generation by number, the highest number of healthy seeds was recorded in T_4 (486) treatment which was statistically similar with T_3 (481) and followed by T_1 (475), whereas lowest in T_5 (445) treatment which was closely followed by T_2 (469) treatment. In case of infested seeds, the lowest infested seeds obtained from T_4 (12.00) which was followed by T_3 (19.25) and the highest number was recorded in T_5 (51.50) treatment which was followed by T_2 (26.50) and T_1 (23.25) treatment and they were statistically similar. In case of % infestation, the highest infestation was found from T_5 (11.57%) which was followed by T_2 (5.65%) treatment while the lowest in T_4 (2.47%) treatment which was followed by T_3 (4.00%) treatment. The highest infestation reduction over control was recorded in T_4 (78.66%) treatment and lowest from T_2 (51.18%) treatment (Table 4).

4.4.1.4 Husked rice in number basis

At 1st generation by number, the highest number of healthy seeds was recorded in T_4 (479) treatment which was statistically similar with T_3 (473) and followed by T_1 (462), whereas lowest in T_5 (431) treatment. In case of infested seeds, the lowest infested seeds obtained from T_4 (18.50) which was followed by T_3 (24.75) and the highest number was recorded in T_5 (63.50) treatment which was followed by T_2 (38.50) and T_1 (34.75) treatment and they were statistically similar. In case of % infestation, the highest infestation was found from T_5 (14.72%) which was followed by T_2 (8.35%) treatment while the lowest in T_4 (3.86%) treatment which was followed by T_3 (5.23%) treatment. The highest infestation reduction over control was recorded in T_4 (73.76%) treatment and lowest from T_2 (43.27%) treatment (Table 4).

Table 4. Effect of different neem products for the management of rice weevil in stored unhusked and husked rice grain at 1st generation by number basis

*Treatment(s)	Total number of seeds for							
	Unhusked rice grain				Husked rice grain			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	475 b	23.25 b	4.89 c	57.71	462 c	34.75 b	7.52 b	48.91
T_2	469 c	26.50 b	5.65 b	51.18	461 c	38.50 b	8.35 b	43.27
T_3	481 a	19.25 c	4.00 d	65.42	473 b	24.75 c	5.23 c	64.46
T_4	486 a	12.00 d	2.47 e	78.66	479 a	18.50 d	3.86 c	73.76
T_5	445 d	51.50 a	11.57 a	--	431 d	63.50 a	14.72 a	--
Significance level	0.01	0.01	0.01	--	0.01	0.01	0.01	--
CV (%)	5.66	7.09	4.33	--	6.78	5.45	6.33	--

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.4.2 At 2nd generation

4.4.2.1 Unhusked rice in weight basis

At 2nd generation for unhusked rice, in weight basis, the highest healthy seeds was recorded in T_4 (97.86 g) treatment which was closely followed with T_3 (95.62 g) treatments, whereas lowest in T_5 (88.56 g) which was closely followed by T_2 (93.22 g) and T_1 (94.56 g) treatment, respectively and they were statistically identical. In case of infested seeds, the lowest infested seeds were recorded from T_4 (2.11 g) treatment which was closely followed by T_3 (3.85 g) treatment and the highest was observed in T_5 (10.67 g) treatment which was followed by T_2 (6.44 g). In case of % infestation, the highest infestation was recorded from T_5 (12.05%) which was closely followed by T_2 (6.91%) and T_1 (5.54%) treatment and they were statistically similar, while the lowest in T_4 (2.16) which was followed by T_3 (4.03%). The highest infestation reduction over control was recorded in T_4 (82.10%) treatment and lowest from T_2 (42.66%) treatment (Table 5).

4.4.2.2 Husked rice in weight basis

At 2nd generation for husked rice, in weight basis, the highest healthy seeds was recorded in T_4 (113.62 g) treatment which was statistically similar with T_3 (110.15 g) treatments, whereas lowest in T_5 (97.55 g) treatment which was closely followed by T_2 (104.34 g) and T_1 (105.65 g) treatment, respectively and they were statistically similar. In case of infested seeds, the lowest infested seeds were recorded from T_4 (4.33 g) which similar to T_3 (7.69 g) treatment and the highest was observed in T_5 (17.64 g) which was followed by T_2 (11.18 g) and T_1 (10.51 g) treatment and they were statistically identical. In case of % infestation, the highest infestation was recorded from T_5 (18.08%) which was followed by T_2 (10.71%) and T_1 (9.95%) and they were statistically identical, while the lowest was recorded in T_4 (3.81%) which was followed by T_3 (6.98%) treatment. The highest infestation reduction over control was recorded in T_4 (78.93%) and lowest from T_2 (40.75%) treatment (Table 5).

Table 5. Effect of different neem products for the management of rice weevil in stored unhusked and husked rice grain at 2nd generation by weight basis

*Treatment(s)	Total weight of seeds for							
	Unhusked rice grain				Husked rice grain			
	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control (%)	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control (%)
T_1	94.56 c	5.24 c	5.54 b	54.01	105.65 b	10.51 b	9.95 b	44.99
T_2	93.22 c	6.44 b	6.91 b	42.66	104.34 b	11.18 b	10.71 b	40.75
T_3	95.62 b	3.85 d	4.03 c	66.58	110.15 a	7.69 c	6.98 c	61.39
T_4	97.86 a	2.11 e	2.16 d	82.10	113.62 a	4.33 d	3.81 d	78.93
T_5	88.56 d	10.67 a	12.05 a	--	97.55 c	17.64 a	18.08 a	--
Significance level	0.01	0.01	0.01	--	0.01	0.01	0.01	--
CV (%)	5.89	7.77	4.35	--	5.56	7.99	4.55	--

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.4.2.3 Unhusked rice in number basis

At 2^{nd} generation by number, the highest number of healthy seeds was recorded in T_4 (479) treatment which was closely followed by T_3 (472) and T_1 (468) treatment and they were statistically identical, while the lowest in T_5 (434) treatment which was closely followed by T_2 (462) treatment. In case of infested seeds, the lowest infested seeds obtained from T_4 (19.00) which was followed by T_3 (28.25) and the highest number was recorded in T_5 (62.50) treatment which was followed by T_2 (33.50). In case of % infestation, the highest infestation was found from T_5 (14.40%) which was followed by T_2 (7.25%) treatment, while the lowest in T_4 (3.97%) treatment which was followed by T_3 (5.99%) treatment. The highest infestation reduction over control was recorded in T_4 (72.46%) treatment and lowest from T_2 (49.65%) treatment (Table 6).

4.4.2.4 Unhusked rice in number basis

At 2^{nd} generation by number, the highest number of healthy seeds was recorded in T_4 (471) treatment which was statistically similar with T_3 (467) and followed by T_2 (448) and T_1 (445) treatment and they were statistically similar, whereas lowest was recorded in T_5 (415) treatment. In case of infested seeds, the lowest infested seeds obtained from T_4 (24.25) which was statistically similar with T_3 (29.75) and the highest number was recorded in T_5 (79.75) treatment which was followed by T_2 (49.50) and T_1 (45.75) treatment and they were statistically similar. In case of % infestation, the highest infestation was found from T_5 (19.22%) which was followed by T_2 (11.05%) treatment, whereas the lowest in T_4 (5.15%) treatment which was followed by T_3 (6.37%) treatment. The highest infestation reduction over control was recorded in T_4 (73.21%) treatment and lowest from T_2 (42.50%) treatment (Table 6).

Table 6. Effect of different neem products for the management of rice weevil in stored unhusked and husked rice grain at 2nd generation by number basis

*Treatment(s)	Total number of seeds for							
	Unhusked rice grain				Husked rice grain			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	468 b	30.25 c	6.46 c	55.12	445 b	45.75 b	10.28 b	46.50
T_2	462 c	33.50 b	7.25 b	49.65	448 b	49.50 b	11.05 b	42.50
T_3	472 b	28.25 d	5.99 d	58.44	467 a	29.75 c	6.37 c	66.85
T_4	479 a	19.00 e	3.97 e	72.46	471 a	24.25 c	5.15 c	73.21
T_5	434 d	62.50 a	14.40 a	--	415 c	79.75 a	19.22 a	--
Significance level	0.01	0.01	0.01	--	0.01	0.01	0.01	--
CV (%)	6.09	4.55	7.93	--	5.88	6.09	5.22	--

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.4.3 At 3rd generation

4.4.3.1 Unhusked rice in weight basis

At 3rd generation for unhusked rice, in weight basis, the highest healthy seeds was recorded in T_4 (97.45 g) treatment which was closely followed with T_3 (94.82 g) treatments, whereas lowest in T_5 (85.34 g) which was followed by T_2 (91.54 g). In case of infested seeds, the lowest infested seeds were recorded from T_4 (2.49 g) treatment which was followed by T_3 (4.43 g) treatment and the highest was observed in T_5 (13.08 g) treatment which was followed by T_2 (8.35 g). In case of % infestation, the highest infestation was recorded from T_5 (15.33%) which was followed by T_2 (9.12%) treatment while the lowest in T_4 (2.56) which was followed by T_3 (4.67%). The highest infestation reduction over control was recorded in T_4 (83.33%) treatment and lowest from T_2 (40.33%) treatment (Table 7).

4.4.3.2 Husked rice in weight basis

At 3rd generation for husked rice, in weight basis, the highest healthy seeds was recorded in T_4 (109.45 g) treatment which was statistically similar with T_3 (107.43 g) treatments, whereas lowest in T_5 (91.89 g) treatment which was closely followed by T_1 (101.57 g) and T_2 (102.69 g) treatment, respectively and they were statistically identical. In case of infested seeds, the lowest infested seeds were recorded from T_4 (5.27 g) which was followed by T_3 (8.45 g) treatment and the highest was observed in T_5 (22.31 g) which was followed by T_2 (16.05 g) treatment. In case of % infestation, the highest infestation was recorded from T_5 (24.28%) which was closely followed by T_2 (15.63%) and T_1 (14.98%) treatment and they were statistically similar, while the lowest was recorded in T_4 (4.81%) which was followed by T_3 (7.87%) treatment. The highest infestation reduction over control was recorded in T_4 (80.17%) and lowest was recorded from T_2 (35.63%) treatment (Table 7).

Table 7. Effect of different neem products for the management of rice weevil in stored unhusked and husked rice grain at 3rd generation by weight basis

*Treatment(s)	Total weight of seeds for							
	Unhusked rice grain				Husked rice grain			
	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control (%)	Healthy (g)	Infested (g)	Infestation (%)	Infestation reduction over control (%)
T_1	93.86 b	5.82 c	6.20 c	59.54	101.57 b	15.22 b	14.98 b	38.28
T_2	91.54 c	8.35 b	9.12 b	40.49	102.69 b	16.05 b	15.63 b	35.63
T_3	94.82 b	4.43 c	4.67 d	69.52	107.43 a	8.45 c	7.87 c	67.60
T_4	97.45 a	2.49 d	2.56 e	83.33	109.45 a	5.27 d	4.81 d	80.17
T_5	85.34 d	13.08 a	15.33 a	--	91.89 c	22.31 a	24.28 a	--
Significance level	0.01	0.01	0.01	--	0.01	0.01	0.01	--
CV(%)	7.33	4.18	6.67	--	9.02	3.55	6.66	--

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.4.3.3 Unhusked rice in number basis

At 3rd generation by number, the highest number of healthy seeds was recorded in T_4 (473) treatment which was closely followed by T_3 (467), whereas the lowest in T_5 (424) treatment which was followed by T_2 (450) treatment. In case of infested seeds, the lowest infested seeds obtained from T_4 (25.00) treatment which was followed by T_3 (33.25) and the highest number was recorded in T_5 (72.50) treatment which was followed by T_2 (45.50). In case of % infestation, the highest infestation was found from T_5 (17.10%) which was followed by T_2 (10.11%) treatment, while the lowest in T_4 (5.29%) treatment which was followed by T_3 (7.12%) treatment. The highest infestation reduction over control was recorded in T_4 (69.09%) treatment and lowest from T_2 (40.87%) treatment (Table 8).

4.4.3.4 Unhusked rice in number basis

At 3rd generation by number, the highest number of healthy seeds was recorded in T_4 (464) treatment which was followed by T_3 (442) treatment, whereas the lowest in T_5 (372) treatment. In case of infested seeds, the lowest infested seeds obtained from T_4 (25.78) which was followed by T_3 (39.22) and the highest number was recorded in T_5 (94.33) treatment which was followed by T_2 (69.34) and T_1 (64.02) treatment and they were statistically similar. In case of % infestation, the highest infestation was found from T_5 (25.36%) which was followed by T_2 (16.39%) treatment while the lowest in T_4 (5.56%) treatment which was followed by T_3 (8.87%) treatment. The highest infestation reduction over control was recorded in T_4 (78.09%) treatment and lowest from T_2 (35.35%) treatment (Table 8).

Siddika (2004) 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. Akter (2005) 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 (Akter, 2009). 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 8. Effect of different neem products for the management of rice weevil in stored unhusked and husked rice grain at 3rd generation by number basis

*Treatment(s)	Total number of seeds for							
	Unhusked rice grain				Husked rice grain			
	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)	Healthy (No.)	Infested (No.)	Infestation (%)	Infestation reduction over control (%)
T_1	461 c	37.25 c	8.08 c	52.74	419 c	64.02 b	15.28 b	39.74
T_2	450 d	45.50 b	10.11 b	40.87	423 c	69.34 b	16.39 b	35.35
T_3	467 b	33.25 d	7.12 c	58.36	442 b	39.22 c	8.87 c	65.01
T_4	473 a	25.00 e	5.29 d	69.09	464 a	25.78 d	5.56 d	78.09
T_5	424 e	72.50 a	17.10 a	--	372 d	94.33 a	25.36 a	--
Significance level	0.01	0.01	0.01	--	0.01	0.01	0.01	--
CV(%)	5.66	8.99	3.57	--	5.90	4.04	5.55	--

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.5 Weight loss

Weight loss for 1st, 2nd and 3rd generation showed statistically significant variation under the present trial for different neem products for the management of rice weevil in unhusked and husked stored rice grain (Appendix IX).

4.5.1 Unhusked rice

At 1st generation in case of weight loss for unhusked rice grain, the highest weight loss was recorded in T_5 (18.21%) which was followed by T_2 (11.34%) treatment whereas the lowest was observed in T_4 (3.89%) treatment (Table 9). At 2nd generation, the highest weight loss was found in T_5 (33.26%) which was followed by T_2 (18.08%) treatment whereas the lowest was found in T_4 (8.78%) treatment. At 3rd generation, the highest weight loss was obtained in T_5 (48.55%) which was followed by T_2 (27.67%), whereas the lowest (14.34%) was found in T_4 treatment.

4.5.2 Husked rice

For husked rice grain, at 1st generation in case of weight loss, the highest weight loss was recorded in T_5 (21.45%) which was followed by T_2 (12.55%) treatment, while the lowest was observed in T_4 (4.38%) treatment (Table 9). At 2nd generation, the highest weight loss was found in T_5 (38.90%) treatment which was followed by T_2 (19.37%) treatment, whereas the lowest was found in T_4 (10.12%) treatment. At 3rd generation, the highest weight loss was obtained in T_5 (54.09%) which was followed by T_2 (32.457%), while the lowest (17.55%) was found in T_4 treatment which was followed by T_3 treatment (21.55%).

Prakash *et al.* (1993) found that neem seed oil was the most effective for reduced adult populations and weight loss of grain. Ogemah *et al.* (2003) reported that neem oil and neem seed cake powder reduced weight loss to less than 20% in the control. Umoetok (2004) reported that grains treated with the neem plant powders significantly lowered weight loss than the untreated grains.

Table 9. Effect of different neem products on weight loss of stored unhusked and husked rice grain at different generation

*Treatment(s)	Weight loss (%) for					
	Unhusked rice grain			Husked rice grain		
	1st generation	2nd generation	3rd generation	1st generation	2nd generation	3rd generation
T_1	7.96 c	16.45 b	25.49 b	9.21 c	17.95 b	29.56 c
T_2	11.34 b	18.08 b	27.67 b	12.55 b	19.37 b	32.45 b
T_3	6.45 d	13.78 c	21.55 c	7.08 d	14.78 c	26.89 d
T_4	3.89 e	8.78 d	14.34 d	4.38 e	10.12 d	17.55 e
T_5	18.21 a	33.26 a	48.55 a	21.45 a	38.90 a	54.09 a
Level of Significance	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	8.88	4.67	5.78	6.89	5.55	8.99

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

T_5: Untreated control

4.6 Repellency effect

Repellency effect showed statistically significant variation for different neem products for the management of rice weevil in unhusked and husked stored rice grain (Appendix X).

4.6.1 Unhusked rice

In case of repellency effect for unhusked rice, after 1 hour of treatment application the highest repellency rate was found from T_4 (80.00%) which was followed by T_3 (60.00%) treatments, whereas the lowest repellency rate was recorded in T_1 (30.00%) which was followed by T_2 (40.00) treatments (Table 10). After 2 hours of treatment application the highest repellency rate was observed from T_4 (90.00%) which was followed by T_3 (70.00%) treatment, while the lowest repellency rate was observed in T_1 and T_2 (60.00%) treatment. After 3 hours of application the highest repellency rate was obtained from T_4 (100.00%) which was followed by T_3 (80.00%), again the lowest repellency rate was recorded in T_1 (60.00%) which was followed by T_2 (70.00%) treatment. After 4 hours of treatment application the highest repellency rate was observed from T_4 (100.00%) which was followed by T_3 (90.00%), while the lowest repellency rate (70.00%) was recorded in T_1 which was followed by T_2 (80.00%). After 5 hours of treatment application the highest repellency rate was found from T_4 and T_3 (100.00%) which was followed by T_2 (90.00%), whereas the lowest repellency rate (80.00%) was recorded in T_1 treatment.

4.6.2 Husked rice

In case of repellency effect for husked rice, after 1 hour of treatment application the highest repellency rate was found from T_4 (80.00%) which was followed by T_3 (50.00%) treatments, whereas the lowest repellency rate was recorded in T_1 and T_2 (40.00%) treatments (Table 10). After 2 hours of treatment application the highest repellency rate was observed from T_4 (90.00%) which was followed by T_3 (80.00%) treatment, while the lowest in T_1 (60.00%) treatment. After 3 hours of application of treatment the highest repellency rate was obtained from T_4 (90.00%), while the lowest repellency rate was recorded in T_1, T_2 and T_3 (80.00%) treatment.

Table 10. Repellency effect of different neem products on rice weevil in stored unhusked and husked rice grain at different hours after treatment

*Treatment(s)	Percent of repelled after application of treatment for									
	Unhusked rice grain					Husked rice grain				
	1 hour	2 hour	3 hour	4 hour	5 hour	1 hour	2 hour	3 hour	4 hour	5 hour
T_1	30.00 d	60.00 c	60.00 d	70.00 d	80.00 c	40.00 c	60.00 d	80.00 b	80.00 c	90.00 b
T_2	40.00 c	60.00 c	70.00 c	80.00 c	90.00 b	40.00 c	70.00 c	80.00 b	80.00 c	90.00 b
T_3	60.00 b	70.00 b	80.00 b	90.00 b	100.00 a	50.00 b	80.00 b	80.00 b	90.00 b	100.00 a
T_4	80.00 a	90.00 a	100.00 a	100.00 b	100.00 a	80.00 a	90.00 a	90.00 a	100.00 a	100.00 a
Level of Significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	4.56	3.55	6.07	5.67	8.44	6.77	5.44	6.98	5.45	8.93

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

***Treatments**

T_1: Neem leaves dust 10 gm/kg of stored rice grains

T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains

T_3: Neem leaves extract @ 10 ml/kg of stored rice grains

T_4: Neem oil 5 ml/kg of stored rice grains

After 4 hours of treatment application the highest repellency rate was observed from T_4 (100.00%) which was followed by T_3 (90.00%), while the lowest repellency rate was recorded in T_1 and T_2 (80.00%). After 5 hours of treatment application the highest repellency rate was found from T_4 and T_3 (100.00%) which was followed by T_1 and T_2 (90.00%) treatment.

Igantowicz and Wesolowska (1996) 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. 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*. Eapea (1986) screened plant extracts and found that those from Gaultheria, dill (*Anethusgra veoleus*), Japanese mint (*Mentha sp*.) and Eucalyptus and cineole and turpentine, were promising as strong repellent against *Sitophilus oryzae* and *Callosobruchus chinensis*. Rahman (1998) evaluated the extracts and dust of Neem 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 had repellency, detergency and direct toxicity effect. Xie *et al*. (1995) reported that S. *oryzae* was more sensitive to the repellent action of neem products.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted to study the damage assessment and effect of different neem products for the management of rice weevil (*Sitophilus oryzae* L.) in stored rice grain during the period from July to December 2013. Stored husked and unhusked rice of BR 27 were used as the experimental materials. The experiment consists of the treatments: T_1: Neem leaves dust 10 gm/kg of stored rice grains; T_2: Neem seed kernel dusts @ 10 gm/kg of stored rice grains; T_3: Neem leaves extract @ 10 ml/kg of stored rice grains (90 ml alcohol + 10 gm leaves dusts); T_4: Neem oil 5 ml/kg of stored rice grains and T_5: Untreated control. The experiment was laid out in the ambient condition of the laboratory considering in a Completely Randomized Design (CRD) and the treatments was replicated four times for each. The effects of different neem products as grain protectant against *S. oryzae* were evaluated considering adult mortality, adult emergence, adult life span, number of damaged seeds, grain weight loss and repellency test from treated and untreated grains both for unhusked and husked rice.

In case of unhusked rice, after 24 hours of treatment application the highest number of dead insects (7.50) was recorded in T_4 treatment and no dead insects were found in T_5. After 48 hours the highest cumulative numbers of dead insects were observed in T_4 (13.25) treatment, whereas there were no dead insects in T_5 treatment. After 72 hours of treatment the cumulative highest number of dead insects were found in T_4 (14.25) treatment while there were no dead insects in T_5 treatment after 24 hours for unhusked rice grain. For husked rice after 24 hours of treatment application the highest number of dead insects (8.75) was recorded in T_4 treatment and no dead insects were found in T_5 treatment. After 48 hours the highest cumulative numbers of dead insects were observed in T_4 (14.00) treatment, whereas there were no dead insect in T_5 treatment. After 72 hours of treatment the cumulative highest number of dead insects were found in T_4 (15.50) treatment while there were no dead insects in T_5 treatment.

For unhusked rice, total adult emergence for 1st, 2nd and 3rd generation was zero in T_4 treatment, while the highest adult was recorded in T_5 (369.00) treatment. In case of husked rice, total adult emergence for 1st, 2nd and 3rd generation was observed in T_4 treatment, whereas the highest adult was recorded in T_5 (399.50) treatment. In case of unhusked rice, the highest mortality (100.00%) was observed in T_4 treatment, while the lowest 5.25% mortality was recorded in T_5 treatment. For husked rice, the highest mortality (100.00%) was observed in T_4, while the lowest mortality (9.00%) was recorded in T_5 treatment.

At 1st generation for unhusked rice, in weight basis the highest infestation was recorded from T_5 (9.49%) treatment, while the lowest in T_4 (1.32%) treatment. For husked rice, in weight basis, the highest infestation was recorded from T_5 (10.68%), while the lowest in T_4 (2.79%) treatment. At 1st generation for unhusked rice by number, the highest infestation was found from T_5 (11.57%) treatment, while the lowest in T_4 (2.47%) treatment. For 1st generation by number in husked rice, the highest infestation was found from T_5 (14.72%), while the lowest in T_4 (3.86%) treatment. At 2nd generation for unhusked rice, in weight basis, the highest infestation was recorded from T_5 (12.05%), while the lowest in T_4 (2.16%) treatment. At 2nd generation for husked rice, in weight basis, the highest infestation was recorded from T_5 (18.08%), while the lowest was recorded in T_4 (3.81%) treatment. At 2nd generation by number in husked rice, the highest infestation was found from T_5 (14.40%) treatment, while the lowest in T_4 (3.97%) treatment. At 2nd generation by number in husked rice, the highest infestation was found from T_5 (19.22%), whereas the lowest in T_4 (5.15%) treatment. At 3rd generation for unhusked rice, in weight basis, the highest infestation was recorded from T_5 (15.33%), while the lowest in T_4 (2.56) treatment. At 3rd generation for husked rice, in weight basis, the highest infestation was recorded from T_5 (24.28%), while the lowest was recorded in T_4 (4.81%) treatment. At 3rd generation by number in unhusked rice, the highest infestation was found from T_5 (17.10%), while the lowest in T_4 (5.29%) treatment. At 3rd generation by number in husked rice, the highest infestation was found from T_5 (25.36%), while the lowest in T_4 (5.56%)

treatment. At 1st generation in case of weight loss for unhusked rice grain, the highest weight loss was recorded in T_5 (18.21%), whereas the lowest was observed in T_4 (3.89%) treatment. At 2nd generation, the highest weight loss was found in T_5 (33.26%) treatment, whereas the lowest was found in T_4 (8.78%) treatment. At 3rd generation, the highest weight loss was obtained in T_5 (48.55%), whereas the lowest (14.34%) was found in T_4 treatment. For husked rice grain, at 1st generation in case of weight loss, the highest weight loss was recorded in T_5 (21.45%), while the lowest was observed in T_4 (4.38%) treatment. At 2nd generation, the highest weight loss was found in T_5 (38.90%) treatment, whereas the lowest was found in T_4 (10.12%) treatment. At 3rd generation, the highest weight loss was obtained in T_5 (54.09%), while the lowest (17.55%) was found in T_4 treatment. In case of repellency effect for unhusked rice, after 5 hours of treatment application the highest repellency rate was found from T_4 and T_3 (100.00%), whereas the lowest repellency rate (80.00%) was recorded in T_1 treatment. In case of repellency effect for husked rice, after 5 hours of treatment application the highest repellency rate was found from T_4 and T_3 (100.00%) which was followed by T_1 and T_2 (90.00%) treatment.

Considering the results of the study, it could be concluded that in most cases, the infestation of rice weevil, *S.oryzae* could be minimized by use of neem products. Among the neem products neem oil 5 ml/kg of stored rice grains was more effective followed by neem leaves extract @ 10 ml/kg of stored rice grains (90 ml alcohol + 10 gm leaves dusts) for controlling rice weevil.

Recommendations

Considering the findings of the present experiment, further studies in the following areas may be suggested:

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

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APPENDICES

Appendix I. Analysis of variance of the data on number of dead insects after different times in unhusked and husked rice as influenced by different neem products

Source of variation	Degrees of freedom	Mean square					
		No. of dead insects for					
		Unhusked rice grain after			Husked rice grain after		
		24 hours	48 Hours	72 Hours	24 hours	48 Hours	72 Hours
Between	4	15.310**	32.071**	42.988**	98.81**	20.726**	34.123**
Within	12	0.532	0.516	0.671	7.063	1.425	3.213

**: Significant at 1% level of probability

Appendix II. Analysis of variance of the data on for adult emerged at 1st, 2nd, 3rd generation & total adult emerged in unhusked and husked riceas influenced by different neem products

Source of variation	Degrees of freedom	Mean square							
		Adult emerged at							
		Unhusked rice grain				Husked rice grain			
		1st generation	2nd generation	3rd generation	Total	1st generation	2nd generation	3rd generation	Total
Between	6	983.82**	560.12**	189.87**	4305.07**	345.23**	140.071**	123.093**	89.112**
Within	14	1.806	3.897	9.948	35.040	21.345	6.103	3.098	3.891

**: Significant at 1% level of probability

Appendix III. Analysis of variance of the data on for management of rice weevil in stored unhusked and husked rice grain at 1st generation by weight basis as influenced by different neem products

Source of variation	Degrees of freedom	Mean square					
		Total weight of seeds for					
		Unhusked rice grain after			Husked rice grain after		
		Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)
Between	4	29.171**	2.582**	48.477**	47.314**	5.080**	75.413**
Within	12	2.382	0.049	0.704	2.727	0.080	0.516

**: Significant at 1% level of probability

Appendix IV. Analysis of variance of the data on for management of rice weevil in stored unhusked and husked rice grain at 1st generation by number basis as influenced by different neem products

Source of variation	Degrees of freedom	Mean square					
		Total number of seeds for					
		Unhusked rice grain after			Husked rice grain after		
		Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)
Between	4	168.518**	130.088**	47.233**	30.403**	32.916**	29.171**
Within	12	12.279	17.133	3.964	1.476	0.316	2.382

**: Significant at 1% level of probability

Appendix V. Analysis of variance of the data on for management of rice weevil in stored unhusked and husked rice grain at 2nd generation by weight basis as influenced by different neem products

Source of variation	Degrees of freedom	Mean square					
		Total weight of seeds for					
		Unhusked rice grain after			Husked rice grain after		
		Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)
Between	4	9.184**	27.274*	43.057*	2.348**	11.868**	12.421**
Within	12	0.436	8.243	13.535	0.068	0.428	0.511

**: Significant at 1% level of probability

Appendix VI. Analysis of variance of the data on for management of rice weevil in stored unhusked and husked rice grain at 2nd generation by number basis as influenced by different neem products

Source of variation	Degrees of freedom	Mean square					
		Total number of seeds for					
		Unhusked rice grain after			Husked rice grain after		
		Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)
Between	4	12.248**	16.723**	26.129*	10.905**	15.160**	39.604**
Within	12	0.268	0.421	7.097	0.214	0.391	5.872

**: Significant at 1% level of probability

Appendix VII. Analysis of variance of the data on for management of rice weevil in stored unhusked and husked rice grain at 3rd generation by weight basis as influenced by different neem products

Source of variation	Degrees of freedom	Mean square					
		Total weight of seeds for					
		Unhusked rice grain after			Husked rice grain after		
		Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)
Between	4	7.585*	12.277**	40.301**	31.104**	94.765**	34.78**
Within	12	2.855	3.290	7.784	8.045	7.613	4.567

**: Significant at 1% level of probability

Appendix VIII. Analysis of variance of the data on for management of rice weevil in stored unhusked and husked rice grain at 3rd generation by number basis as influenced by different neem products

Source of variation	Degrees of freedom	Mean square					
		Total number of seeds for					
		Unhusked rice grain after			Husked rice grain after		
		Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)
Between	4	3.734**	5.626**	5.729**	6.667**	6.667**	7.583**
Within	12	0.033	0.083	0.115	0.178	0.261	0.309

**: Significant at 1% level of probability

Appendix IX. Analysis of variance of the data on weight loss in stored unhusked and husked rice grain as influenced by different neem products

Source of variation	Degrees of freedom	Mean square					
		Weight loss (%) for					
		Unhusked rice grain after			Husked rice grain after		
		1st generation	2nd generation	3rd generation	1st generation	2nd generation	3rd generation
Between	4	18.772*	39.894*	100.381**	26.413**	44.159**	137.98**
Within	12	2.889	7.057	11.512	0.524	0.286	5.093

**: Significant at 1% level of probability

Appendix X. Analysis of variance of the data on repellency effect on unhusked and husked rice grain as influenced by different neem products

Source of variation	Degrees of freedom	Mean square									
		Percent of repelled after application of treatment for									
		Unhusked rice grain after					Husked rice grain after				
		1 hour	2 hour	3 hour	4 hour	5 hour	1 hour	2 hour	3 hour	4 hour	5 hour
Between	4	797.56**	5610.09	453.098**	443.159**	165.381**	1814.29**	1495.24**	2114.29**	1280.95**	1657.14**
Within	12	12.79	34.25	16.45	27.714	7.619	109.048	77.937	54.921	93.175	67.317

**: Significant at 1% level of probability