INSECTICIDAL POTENCY OF SOME INDIGENOUS PLANT EXTRACTS AGAINST RICE WEEVIL, *Sitophilus oryzae* (L.) (CURCULIONIDAE: COLEOPTERA)

A THESIS
BY

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Examination Roll No. 1205001
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Semester: July – December, 2013

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

DECEMBER, 2013

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DEPARTMENT OF ENTOMOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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The author

INSECTICIDAL POTENCY OF SOME INDIGENOUS PLANT EXTRACTS AGAINST RICE WEEVIL, *Sitophilus oryzae* (L.) (CURCULIONIDAE: COLEOPTERA)

ABSTRACT

Experiments were conducted to study the bioefficacy of some indigenous plant extracts against rice weevil, *Sitophilus oryzae* L. in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period from April to October 2012. The petroleum ether extracts of seed of ata (*Annona reticulata*) and castor (*Ricinus communis*), leaf of karabi (*Nerium olender*), marigold (*Calendula officinalis*) and nishinda (*Vitex negundo*) at 0.5, 1.0 and 1.5 % concentration were evaluated for their repellent, direct toxic and residual effects against rice weevil. The results showed that all five plants extracts were effective in checking insect infestation and had different toxic, residual and repellent effects against rice weevil. Among the tested plant extracts, ata seed extract showed the highest toxic effect (64.18 % mortality) and lowest number of F1 adult (7.75 %) emergence but castor seed extract showed the lowest toxic effect (21.66 % mortality) and highest number of F1 adult (18.08 %) emergence. Mortality percentage was also found directly proportional to the level of concentrations of plant extracts and to the exposure period. The repellent effect of ata, castor, karabi, nisinda and marigold extracts showed that the five plant extracts had moderate repellent action on rice weevil. Ata seed extract also showed the highest repellency (49.45 %) while castor seed extract provided the lowest repellency (33.62 %). Residual effect of ata seed extract was also higher than all other plant extracts. Considering all the concentration and efficacy, the order of toxicity of plant extracts was ata › karabi › marigold › nishinda › castor.

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INTRODUCTION

1.1 General Background

The people of Bangladesh store different kinds of grains both for the seed and food purposes because preservation of reserve food grain stocks is necessary to ensure a continuous supply at stable price. It has gained much popularity among the farmers due to its higher production. Losses due to insect infestation are the most serious problem in grain storage, particularly in villages and towns of developing countries like Bangladesh. The climate and storage conditions, especially in the tropics, are often highly favourable for insect growth and development (Jacobson 1982).

A large number of insects and mites have been found to attack stored grains and grain products throughout the world (Hinton 1945). Storage losses can be significant in developing countries where more than 70% of cereal production is stored in Farms (Wright 1985). In India, losses caused by insects accounted for 6.5 % of stored grain (Raju 1984). Insect pests damage stored grains in Bangladesh causing serious loss to national economy. The annual grain losses of Bangladesh cost over taka 100 cores (Alam 1971).

The rice weevil *Sitophilus oryzae* L. is one of the most destructive insect pests of stored grains. It is almost cosmopolitan in distribution being more abundant in warm and humid areas but does not thrive in countries having cold winter (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. Though, 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 that 11-16 % weight loss of husked rice during 4 months of storage in the laboratory.

To minimize the loss of stored grain due to insect attack, Bangladesh has to import a large amount of chemical insecticides by spending costly foreign exchange in every year. Synthetic pesticides which have been in use for a long time for controlling insect pest, have got many limitations and undesirable side effects like development of pesticide resistance, pest resurgence, outbreak of secondary pests, increasing cost of production, health hazards, ecological imbalance, residue in food, feed and environment (Hussain

1984, Khanam *et al.* 1990, Haque and Hussain 1993). Thus effective and safe alternatives to chemical pesticides for controlling insect pest are in demand.

In many developing countries, researches are being conducted to minimize the use of insecticides in pest control programmes through the use of indigenous plant materials. These products may help to keep the draw-backs of conventional methods within bounds. The use of locally available plants and their products as bio-degradable components in the control of the storage pests is an ancient technology in many parts of the world. This has created a world wide interest in the development of alternative strategies including the search for new types of insecticides and use of age-old traditional botanical pest control agents (Heyde *et al.* 1983). Botanical plant products are environmentally safe, less hazardous and less expensive. The use of simple crude botanical extracts, oils and dusts is suited for grain protection by resource limited farmers in developing countries like Bangladesh. Those can be processed at village level by using simple methods.

However, a very few scientific and continuous research work have been done in Bangladesh to establish our locally available plant materials against stored product pests. Under these circumstances, an investigation was undertaken to determine the toxicity, repellency and residual effect of five indigenous plant extracts against rice weevil.

1.2 Research objectives

In view of the above perspectives the present experiments were, therefore, undertaken to find out the effectiveness of locally available botanical insecticides namely, ata, karabi, castor, nishinda and marigold against rice weevil. The objectives of' the present research works were as follows:

- to determine the direct toxicity of plant extracts against rice weevil.
- to determine the residual toxicity of plant extracts against rice weevil.
- to evaluate the repellent effect of plant extracts against rice weevil.

REVIEW OF LITERATURE

Stored grains suffer seriously from the attack of a number of insect pests. Control of insect pest by botanicals has been proposed as potential pest control measures all over the world. There were many reports published on the use of plant materials against stored pest but information against rice weevil is scanty. Relevant research works on the effect of different botanicals in various forms against stored grain pests including rice weevil, *Sitophilus oryzae* L. in home and aboard are reviewed below:

2.1 Toxic Effect

Adgesh and Rejesus (1991) showed that oils and powders from neem, lagudi (*Velez negundo*) mixed with grains at different storage intervals for 180 days effectively controlled the emergence of *Sitophilus ganarius*, *S. oryzae*, *Rhizopertha dominica* and *Callosobruchus chinensis* adults and maintained the viability of the seeds.

Niber *et al.* (1992) tested the extracts of *Azadirachta indica*, *Ricinus communis* and *Solanum nigrum* for their toxicity against *Acanthoscelides obtectus*, *Prostephanus tuncatus* and *Sitophilus oryzae* under laboratory condition. They used the crude ethanol extract at the concentration of 10 % (w/v) as topical application and found that the crude extract were most toxic to those three pest species.

Azmi *et al.* (1993) conducted a study in laboratory with the toxicity of a compound containing 10 % cyfluthrin (Slofac) and a neem formulation containing crude extract from ripe berries of *Azadirachta indica* against *S. oryzae.* They showed that the mortality rate of 90 % was obtained with a 0.5 % conc. of the cyfluthrin and at 1 % conc. of the neem compound.

Prakash *et al.* (1993) conducted an experiment to evaluate twenty plant products against *Sitophilus oryzae*. Only seven products significantly reduced adult populations and weight loss of grain. They found that neem seed oil was the most effective followed by *Piper nigram* seed powder, *Vitex neganda*, leaves of *Andrographis paniculata*, dried mandarin fruit peel, rhizome powder of turmeric and seed powder of *Cassia fistula*.

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

Sarac and Tunc (1995) found that oil of *Pimpinella anisum* caused 95% mortality of *Tribolium confusum* and *S. oryzae* within shorter exposure. Oils of *Tuymbra spicata* and *Satureja thymbra* showed higher toxicity only to *S. oryzae*.

Rahman (1998) conducted an experiment with extracts and dust of Urmoi, Neem and Turmeric for their repellency, feeding deterrency, direct toxicity, residual effects and their potentiality against the rice weevil, *S. oryzae* and grain weevil *S. granaries*. The results showed that 100, 75, 50 and 25 mg/ml extracts of all three plants had repellency, deterrency and direct toxic effect against these two species. Ethanol and acetone extracts were more effective than water extracts. The emergence of F_1 progeny, seed damage rate, percent weight loss and inhibition rate of two weevil species reduced significantly in almost all treatments compared to control and it was dose dependent.

Perveen *et al.* (1998) conducted an experimrnt with methanol extracts of two indigenous plants, *Calotropis gigantea* Linn. (Akando) and *Iponioea nil* Linn. (Kaladanah) for their toxicity against the adults of *Sitophilus oryzae* Linn, *Tribolium castaneum* Herbst and *Cryptoletes ferrugineus* Stephans after 24 hours of treatment. The LD_{50} of *C. gigantea* and *P. nil* for the mortality of *S. oryzae, T. castaneum* and *C. ferrugineus* were 0.418, 0.420, 0.206 and 0.357, 0.422, 0.143 mg/ cm^2, respectively.

Islam (1984) found that the extracts of *Azadirachta indica, A. ruhituka*, *Annona reticulate*, *Annona squamosa* caused higher mortality of *Callosobruchus chinensis* in their studies.

Salas (1985) opined that when soybean, castor, coconut, groundnut, sesame and olive oils were mixed with maize seeds gave cent per cent mortality of adult *Sitophilus oryzae.*

Mahgoub and Ahmed (1996) studied the effect of seed extracts of castor, *Ricinus communis* by using various solvents viz. petroleum ether, chloroform, acetone and methanol against *S. oryzae.* The petroleum ether extract was the most potent and had the highest toxicity.

Islam and Shahjahan (2000) conducted an experiment to evaluate the toxicity of five botanicals, neem (*A. indica*), marigold (*T. erecta*), Durba (*Cynodon dactylon*), castor (*R. communis*), Pithraj (*Aphanamixis polystachya*) and one insecticide (Malathion 57 EC) against rice weevil (*S. Oryzae* L.) and red flour beetle (*T. castaneum*). The results showed that the water extracts of all the five botanicals were effective in controlling the rice weevil and red flour beetle. Among the botanicals, neem was found to be the most toxic ranking next to Malathion.

Umoetok (2000) tested the toxicity of the powder of *Acorus calamus* to three species of stored product insect pests namely *S. oryzae, T. castaneum* and *Rhizopertha dominica* in the laboratory. *A. calamus* was applied at six doses of 0.0, 0.025, 0.05, 0.1, 0.2 and 0.5 µl/20 g of wheat grain. Only *S. oryzae* and *R. dominica* were susceptible to the test products.

Ahad *et al.* (2012) conducted an experiment in the laboratory of Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during June 2009 to June 2010. Ethanol solvent extract of 13 local plants were tested for screening of their insecticidal activity against pulse beetle, *Callosobruchus chinensis* L. All plants extracts were showed insecticidal activity by affecting through mortality, inhibition of F1 adult emergence, reduced seed damage and fecundity or acting repellency. 100% mortality achieved in *Annona reticulata* (at 2 and 3%) in 72 hours. Lowest seed damage and reduced of fecundity were found in the extracts of *Annona reticulata* (at 3%) followed by *Polygonum hydropiper* (at 3%).

Arannilewa *et al.* (2006) conducted an study on the petroleum ether extract of four medicinal plants; *Aristolochia ringens* (Vahl), *Allium sativum* (L), *Ficus exasperata* (L) and *Garcinia kola* (H), as grain protectant against the maize weevil, *Sitophilus zeamais* (Mots) in the laboratory at 0.5, 1.0 and 1.5% (w/v) concentrations. There was increase in adult mortality with days of exposure in all concentrations. *Aristolochia ringens* followed by *Allium sativum* were most potent both in adult mortality and adult emergence.

Chayengia *et al.* (2010) conducted an experiment to evaluate the efficacy of volatile oils, powders, ethanol extracts and water extracts on the basis of per cent mortality, final adult population of *Sitophilus oryzae* and grain weight loss of rice. Volatile oil of *Citrus* *reticulata* resulted in 100 % mortality after 24 hours of exposure followed by *Curcuma longa*, *Psidium guajava* and *Pogostemon cablin.*

The seeds of *A. squamosa* were reported to have insecticidal and abortifacient properties and the crude oils from seeds of *A. squamosa* at 2.5 percent concentrations significantly reduced the leaf damage caused by larvae (Babu *et al*. 1998).

Pandey and Brave (2011) opined that the ethanolic *Annona squamosa* extract showed potent activity against *Sitophilus oryzae* L. and cent percent mortality was achieved at 39.6±1.4 and 14.5±1.1 min for 1% w/v and 5% w/v concentration respectively.

Sivasrinivasu (2001) reported that custard apple seed powder at 5 per cent in rice and wheat grains showed cent percent mortality of *S. oryzae* at 7 days after adult release.

2.2. Repellent effects

Several indigenous plant materials have traditionally been used as stored grain protectants against insect pest in various parts of the world.

Bowery *et al.* (1984) reported that oils and seed cake powders of neem, linseed, castor, mahua and mustard showed repellent action on *Sitophilus oryzae*.

Mishra *et al.* (1992) found that wheat grains can be protected from the attack of *S. oryzae* by mixing custard apple seed powder at 5 per cent for 75 days.

The custard apple seed extract possess more olfactory repellency against normal susceptible strain of *S. oryzae* and *T. castaneum* as compared to soapnut (Quadri 1973).

Jilani (1984) reported that *Acorus calamus* as good grain protectant against *S. oryzae* and *R. dominica*.

Biradar (2000) studied the mortality of *S. oryzae* consequent to the impregnation of gunny bags with botanicals. Sweet flag rhizome extract at the rate of 5 per cent v/v at 30 days after storage offered 100 per cent mortality. Among different treatments tested sweet flag rhizome extract protected upto 90 days of storage.

Jilani (1986) conducted an experiment with ethanolic extract of neem seed; hexane extract of sweetflag, *Acorus calamus,* rhizome and thymol applied to *T. castaneum*; *R. dominica*; *S. oryzae* and *S. cerealella* in wheat grain and observed significant control of the insect infestation.

Tanzubil (1987) applied neem fruit dust, leaf dust and seed kernel oil on stored seed and observed that neem fruit dust at 10% protected seeds for at least 4 months. Neem seed kernel oil also gave effective control.

Su (1984) treated wheat with dill seed extract and found that it reduced the F_1 adult emergence of *S. oryzae*.

Talukder and Howse (1995) showed that the seed extracts of *Aphanamixis polystachya* had strong repellent effects on red flour beetle and rice weevil.

Hussain *et al.* (1995) reported that the extracts of *Ploygonum hydropiper* and *Annona squamosa* were strong repellent effect to adults of *T. castaneum*.

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

Rahman *et al.* (1999) reported that the extracts of urmoi (*Sapium sebiferum* L.) neem, (*Azadirachta indica*, *A. juss*), and turmeric (*Curcuma longa* L.) were evaluated for their repellency against the rice weevil, *S. oryzae* L. and the granary weevil, *S. granarius* L. in the laboratory. The results showed that 100, 75, 50 and 25 mg/ml extracts of all the three plants extracts had a repellent effect.

Fernando and Karunaratne (2013) conducted an experiment to evaluate the repellents effect of *Olax zeylanica* against rice weevil, *Sitophilus oryzae* L. Four different doses (1.0g, 3.0g, 5.0g and 7.0g) of powdered leaves were tested for fumigant repellency in a dual-choice bio-assay apparatus. Repellent effect of powdered leaves against the adult rice weevils was found to be significantly high ($P < 0.05$) at all doses. The highest repellent effect was produced by 7.0g of leaf powder resulting in repellency of 97%, while the lowest dose (1.0g) also elicited more than 50% repellency in weevils indicating a very strong repellent action of the powdered leaves.

2.3 Residual effects

Jilani (1986) conducted an experiment with ethanolic extracts of Neem seed, hexane extract of Sweet flag were applied to *T. castaneunm*; *R. dominica*; *S. oryzae* and *S. cerealella* in wheat grain and observed significant control of the insect infestation.

Rouf *et al.* (1996) investigated the toxicity of the leaf powder of neem, nishinda, and biskatali against *C. chinensis* on lentil seeds. Result showed that 4 g of bishkatali leaf powder/ 50g of lentil seeds were the most effective in reducing oviposition, adult emergence. At low doses (1-2g) those 3 plant materials applied either alone or in combination were found to be less effective.

Chakraborty and Ghose (1998) conducted a laboratory experiment with 15 powdered plant materials which were mixed with wheat grains at a wt/wt ratio of 2:100 to test their suitability as grain protectants against *S. oryzae*. *Mentha spicata* produced 100% mortality and protected the grain up-to 4 weeks.

Mishra *et al.* (1992) found that wheat grains can be protected from the attack of *S. oryzae* by mixing custard apple seed powder at 5 per cent for 75 days.

Sivasrinivasu (2001) opined that custard apple seed powder at 5 per cent in rice and wheat grains showed cent per cent mortality of *S. oryzae* at 7 days after adult release and recorded zero per cent weight loss after 90 days of storage.

Kumar (2003) concluded that custard seed powder at 1 per cent was effective in controlling *S. oryzae* on sorghum grains upto 90 days after storage.

Yevoor (2003) opined that custard apple seed powder at the rate of 0.2 per cent was highly effective and showed cent per cent upto 60 DAT and zero per cent grain damage and weight loss upto 90 DAT.

MATERIALS AND METHODS

3.1 Experimental site

The present study on efficacy of five indigenous plant extracts viz. ata (*Annona reticulata*), castor (*Ricinus communis*), nishinda (*Vitex negundo*), karabi (*Nerium oleander*) and marigold (*Tagetes erecta*) against rice weevil, *Sitophilus oryzae* (L.) were carried out in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period from April to October 2012.

3.2 Tested Plant Materials

The test plant materials (leaves and seeds) of five indigenous plants were collected from different areas of HSTU campus, Dinajpur. Both the leaves and seeds were used for this experiment. Short descriptions of the plants are presented here.

3.2.1 Ata

Scientific name **:** *Annona reticulata* Linn.

Family **:** Annonaceac

Morphology

Ata is a small, semi (or late) deciduous much branched shrub or small tree with a broad, open crown or irregularly spreading branches and a short trunk, not buttressed at base. The fruit of *A. reticulata* has delicious whitish pulp, and is popular in tropical markets. Branches with light brown bark and visible leaf scars; inner bark light yellow and slightly bitter; twigs become brown with light brown dots. Aggregate and soft fruits form the numerous and loosely united pistils of a flower which become enlarged and mature into fruits. The round or heart-shaped greenish yellow, ripened aggregate fruit is pendulous on a thickened stalk.

Distribution

Annona reticulata is native to the tropical America and West Indies, but the exact origin is unknown. It is now the most widely cultivated of all the species of *Annona*, being grown for its fruit throughout the tropics and warmer subtropics, such as Indonesia, Thailand and Taiwan; it was introduced to Southern Asia before 1590.

Uses

Heat-extracted oil from the seeds has been employed against agricultural pests. The poisonous seeds are insecticidal; the bark and root are cathartic. A paste of the seeds is used for extracting guinea-worms and for killing head lice (Kirtikar and Basu 1980).

3.2.2 Castor

Scientific name **:** *Ricinus communis* Linn.

Family **:** Euphorbiaceae

Morphology

Ricinus communis is a perennial remarkable for the size of its leaves and its majestic appearance. It is a shrub or small tree that can grow to 2-4 m., branched, completely glabrous, a glaucous green with yellow parts that are often reddish. The leaves are simple, alternate, downy and with a long petiole bearing shield-like epidermic glands. The limb is palmate-lobed, divided into 7-9 lanceolated, irregularly toothed, glandulous lobes. The flowers are apetalous, set in several groups to form a wide-panicled inflorescence. The fruit is a 2-3 cm. capsule composed of three prickly shells; each loculus contains a shiny seed about the size of a haricot bean, with a caruncle, covered with a very hard yellow/brown marbled integument. Flowering occurs between March and June (Kirtikar and Basu 1980).

Distribution

Probably it is in African origin but cosmopolitan species. Originally it comes from the east (India) and tropical Africa. It is naturalized all over the Mediterranean. Now it is widely cultivated in tropical countries.

Uses

This plant provides medicinal value. The leaf juice is given as an emetic in narcotic poisoning. The seeds contain the alkaloid ricinine; they also contain ricin, a potent vegetable toxin. Ricin is regarded as a blood poison. The oil is sweetish; cathartic, aphrodisiac, anthelmintic. The seeds and the in them have a bad taste: purgative (Kirtikar and Basu 1980).

3.2.3 Nishinda

Scientific name **:** *Vitex negundo*

Family **:** Lamiaceae

Morphology

Vitex negundo, commonly known as the five-leaved chaste tree, is a large aromatic shrub with quadrangular, densely whitish, tomentose branchlets. Nishinda is a small tree growing from 2 to 8 m (6.6 to 26 ft) in height. The bark is reddish-brown. The leaf edges are toothed or serrated and the bottom surface is covered with hairs. The numerous flowers are borne in panicles 10 to 20 cm (3.9 to 7.9 inch) in length. Each is around 6 to 7 cm (2.4 to 2.8 inch) long and is white to blue in color. The petals are of different lengths, with the middle lower lobe being the longest. Both the corolla and calyx are covered in dense hairs. The fruit is a succulent drupe, 4 mm (0.16 inch) in diameter, rounded to egg-shaped. It is black or purple when ripe.

Distribution and habitat

Vitex negundo is native to tropical Eastern and Southern Africa and Asia. It is widely cultivated and naturalized elsewhere. Countries it is indigenous to include Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Japan, Kenya, Madagascar, Malaysia, Mozambique, Myanmar, Nepal, Pakistan, The Philippines, Sri Lanka, Taiwan, Tanzania, Thailand, and Vietnam. *Vitex negundo* are commonly found near bodies of water, recently disturbed land, grasslands, and mixed open forests.

Uses

Vitex negundo is used for treating stored garlic against pests and as a cough remedy in the Philippines. Roots and leaves used in eczema, ringworm and other skin diseases, liver disorders, spleen enlargement, rheumatic pain, gout, abscess, backache; seeds used as vermicide.

3.2.4 Marigold

Scientific name **:** *Tagetes erecta*

Family **:** Compositae

Morphology

It flowers from July to September. The scented flowers are hermaphrodite (have both male and female organs). It is hardy to zone 6 and is frost tender. The lower leaves are broad and spatula shaped. Upper leaves may be oblong, are smooth at the edges, and are arranged alternately along the stem. Seeds are crescent to horseshoe shaped with the rough exterior. Its branching stem grows to the height of 30- 60 cm.

Cultivation

Marigold plant is propagated by the seeds. They are shown during the early spring. Marigold does not need cultivation but the soil should be free from the weeds. The seeds should be shown 2cm apart. Seeds should be planted in the sunny locations. Fertilizers should be added from time to time. They require damp to wet soil for the growth. The seeds are germinated in two to three weeks. It needs full sunlight for its growth.

Uses

Marigold is used for stomach upset, ulcers, menstrual period problems, eye infections, inflammations, and for wound healing. It is antiseptic. If the Marigold flower is rubbed on the affected part, it brings relief in pain and swelling caused by a wasp or bee. A lotion made from the flowers is most useful for sprains and wounds and a water distilled from them is good the sore eyes. The infusion of the freshly gathered flowers is beneficial in fever. Marigold flowers are mostly in demand foe children ailment.

Externally it is used in the treatment of alopecia. Internally it is used to treat bladder and kidney problems, blood in the urine, uterine bleeding and many more.

Other uses

Bright yellow and orange Marigold flowers are used to make garlands. They are even used to decorate the religious places. The leaves of its flowers are used as salads. Yellow dye has also been extracted from the flower, by boiling. The burning herb repels insects and flies. Pigments in the Marigold are sometimes extracted and used as the food colouring for humans and livestock

3.2.5 Karabi

Scientific name : *Nerium oleander* Linn.

Family : Apocynaccae

Morphology

Nerium oleander is an evergreen shrub or small tree in the family Apocynaceae, toxic in all its parts. Erect glabrous shrubs, leaves usually in whorls of three, narrow coriaceous; nerves slender, very close. Flowers large, in terminal racemose cymes. Calyx 5-partite, glandular within, segments narrow, Corolla tunnel shaped; tube cylindric, expanding above, with 5 fringed scales on the throat, lobes overlapping to the right. Stamens inserted near the mouth of the tube, filaments short; anthers conniving around and adhering to the stigma, tipped with long hairy appendages, each cell produced downwards into a rigid spur like appendage. Carpels 2, distinct, many ovuled; style filiform or dilated upwards; stigma with a reflected lobed membrane surmounted by 5 tubercles, tip sub-globose. Follicles cylindric, straight adpressed. Seeds oblong, villous; coma terminal, caducous; albumen fleshy, cotyledons flat (Kirtikar and Basu 1980).

Distribution

It is so widely cultivated that no precise region of origin has been identified, though Southwest Asia has been suggested. Upper Gangetic Plain, Himalaya from Nepal westwards to Kashmir Lip to 6,500 ft., salt Range, Waziristan, Baluchistan, Central and

South India. It is extensively cultivated throughout the greater part of India as well China and Japan.

Uses

Oleander is one of the most poisonous of commonly grown garden plants. The leaves are highly toxic. The leaves contain the glucocides nerrin and olenderin. The roots are a cardiac poison. The bark of the root and the sweet-smelling leaves of this shrub are considered by the Vydians as powerful repellents, applies externally. The oil extracted from the root-bark is locally used for scaly skin diseases like eczema, impetigo etc. and leprosy (Kirtikar and Basu 1980).

3.3 Collection and preparation of botanical powders

The fresh plant leaves of karabi (*Nerium olender*), Marigold (*Tagetes erecta*) and nishinda (*Vitex negundo* L.), Seeds of ata (*Annona reticulata*), and castor (*Ricinus communis*) were collected around the HSTU campus and neighboring areas. After collection, they were kept in the laboratory for 7 days for the purpose of air drying followed by one day sun drying before making powder. After dried they were made powder separately by an electric grinder in the laboratory and passed through a 60-mesh sieve to get fine powder. Later, the powder was stored separately at room temperature in air tight plastic pot (Plate 1) for experimental use.

Plate 1: Powder of five indigenous plants stored in plastic pots

3. 4 Preparation of plant extracts

The prepared powdered materials were extracted in petroleum solvent. Hundred grams of each category of powder were taken in a 600 ml beaker and separately mixed with 300 ml of petroleum ether. Then the mixture was stirred for 30 minutes in a magnetic stirrer (600 rpm). The mixture was then allowed to stand for 72 hours and shaking several intervals. Then, the mixture was filtered through a filter paper (Whatman no. 1) and allowed to evaporate the solvents. Finally, concentrated different coloured extracts as stock solution were obtained (Plate 2). The stock solutions were preserved in tightly corked vials and stored in a refrigerator for experimental use.

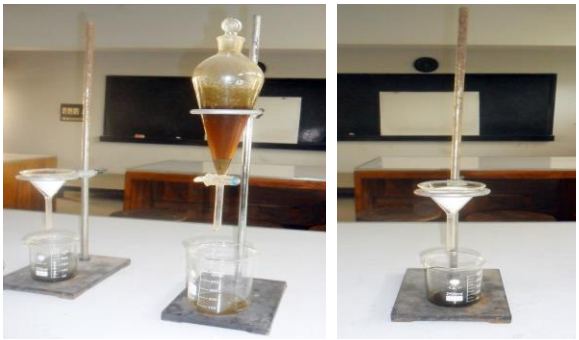

Plate 2: Extract preparation from five indigenous plant powder as stock solution

3. 5 Preparation of doses

Stock solutions were prepared separately by diluting the crude extracts with petroleum ether solvent. Different concentrations (1.5, 1.0 and 0.5%) of each category of plant extracts were prepared by dissolving the stock solution in the petroleum ether prior to insect bioassay (Plate 3). Pilot experiments were done to obtain the appropriate dose.

Plate 3: Dose preparation from the extracts

3.6 Collection of food for test insect

Healthy wheat grain *Triticum aestivum* (L.) was purchased from the local market of Dinajpur town. The grains were thoroughly cleaned, sun dried and cooled at 8-10% moisture level. Before setting up the experiment, the wheat grains were stored at room temperature in big air tight plastic bags for further use.

3.7 The test insects

The present study was conducted by using a major stored grain pests, rice weevil.

3. 7. 1 Rice weevil

Scientific name : *Sitophilus oryzae L.*

Family : Curculionidae

Order : Coleoptera

Morphological feature

The adults are small weevil of around 2.5 to 4 mm long. The adult has a long, distinctive snout. The body color appears to be brown/black, but on close examination, four orange/red spots are arranged in a cross on the wing covers. Elbowed antennae with basal segment of club oval, apex hardly wider than base. Rostrum is straight, not constricted basally in profile, swollen sub-basally, more coarsely punctured and sculptured in males. Abdomen basal sternite at narrowest point behind metacoxae is shorter than second. Males bear median lobe of aedeagus, which is evenly convex dorsally in cross-section, females bear lobes of internal, Y-shaped sclerite, which is broader and rounded apically, and more narrowly separated (Booth *et al*. 1990).The identifying characteristics of the male and female are the rostrum of male is rough and distinctly shorter and wider than that of female. But the rostrum of female is smooth and shinny and distinctly longer and narrower than that of the male (Halstead 1963).

Distribution

The rice weevil is one of the serious stored grain pests worldwide. It is distributed in tropical environments. However, it is becoming established in temperate environments due to changes in the transportation and storage of rice. It prefers temperate or sub-tropical climate and is a serious pest of stored grain in Bangladesh, India, Pakistan, Srilanka, Bhutan, Nepal and many other countries of the world.

Food habit

The insect is one of the most destructive pests of stored grains. Both the adults and larvae feed on whole grains. They attack wheat, corn, oats, rye, barley, sorghum, blackwheat, dried beans, cashew nuts, wild bird seed, and cereal products, especially macaroni.

Biology

The duration of various stages in the life cycle and the number of generation in a year vary with the prevailing temperature and humidity conditions. But the rice weevil breeds from April to October, and hibernates in winter as adults inside cracks, and crevices or under grain bags in the godown. A single female can lay as many as 250 eggs. Before laying eggs, the female bores a small hole in the grain with the help of mandibles. After lays an egg, it covers with a gelatinous fluid that seals the hole. It hatches in about 4 days during summer but takes 6-9 days during winter season. The grub is small white fleshy and legless with small yellowish brown head. It lives within the grain, feeding on the starchy contents. The larval stage lasts from 22 to 33 days. A full-grown grub measures 3 mm long and makes a pupal cell inside the grain and pupates after passing 1 or 2 days as a pre-pupa and the pupa is of exarate type. The pupal stage lasts from 3 to 7 days depending on the prevailing temperature. The duration of the life of adult, on an average, is about one and a half month in Bangladesh. There are about 5 to 7 generations in a year depending on the prevailing temperature and easy availability of food materials (Alam 1971).

3.7.2 Collection and rearing of insects

Rice weevil, *Sitophilus oryzae* L. adults were collected from naturally infested wheat grains from the local market of Dinajpur town and was mass reared in the laboratory at ambient room temperature (28±3^{o}C) in glass jars (47 cm height × 4 cm dia). Approximately 200 adults of the collected rice weevils were released in each glass jar containing 500 g of wheat seeds and the mouth was closed with nylon organza. The beetles were allowed for free mating and oviposition for a maximum period of 7 days. After oviposition, the beetles were separated from the seeds by sieving and seeds along with eggs were left in the container for emergence of next generation. After emergence, the newly emerged adults were collected and again allowed for oviposition with new seeds in different containers to maintain a stock culture of the test insect. The stock culture of the test insect was maintained throughout the experimental period. Only 1 to 7 days old adults were used for the subsequent experiments.

3.8 Insect bioassays

Insect bioassay were conducted in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur at 27 to 30^0C temperature and 70-75% relative humidity to determine the direct toxicity, residual and repellent effects against rice weevil.

3.8. 1. Direct toxicity tests (by topical application method)

Toxicity test of five indigenous plants extracts against *S. oryzae* were conducted according to the method as describe by Talukder and Howse (1993) with a minor modification. Different concentration (1.5 %, 1.0% and 0.5 %) of above mentioned 5 plant extracts were prepared with petroleum ether solvent. Before applying extracts to the thorax of the insect, 10 minutes chilling were done with 4ºC in refrigerator. One μl of prepared solution was applied to the dorsal surface of the thorax of each insect by the help of a micropipette. Ten insects per replication were treated and each treatment was replicated thrice. Equal number of insect with petroleum ether solvent only was treated as control. Insect mortality was recorded at 24, 48 and 72 hours after treatment (HAT). The percentage of the mortality was corrected using by Abbott's (1987) formula before analysis.

$$P = \frac{p' - C}{100 - C} \times 100$$

Where,

P= Percentage of corrected mortality

P'= Observed mortality (%)

C= Mortality (%) at control.

3.8.2. Evaluation of residual toxicity

For residual effect of plant extracts on insect mortality, the extracts were mixed with wheat grains separately (1ml / 50 gm wheat) followed by air dried for 10 minutes. Five pairs one day old adults were released into the bottle containing plant extracts treated wheat grain and bottle was covered with perforated lid. Three replications were maintained for each of the concentration of each individual plant extracts along with control. All treated bottles were kept at ambient room temperature (28±3^{o}C) in the laboratory for oviposition. After 7 days, dead and alive beetles were removed from each container and number of eggs was counted. For the determination of oviposition, 100 seeds were collected randomly from each bottle of each treatment and examined under magnifying glass (10x), counted and return to respective container for further development. After emergence the F1 adult, 100 seeds were counted up to the period of 48 days and inhibitin rate (% IR) was calculated by the following formula:

% IR= Cn-Tn/Cn x 100

Where, Cn= Number of insect on control treatment

Tn = Number of insect on treated treatment

3.9 Evaluation of repellency activities

The repellent activities of the five indigenous plant extracts were evaluated using the filter paper impregnation method (Talukder & Howse 1994) with minor modification (Plate 4). First of all, the Whatman no. 40 filter were cut into two half, and 1ml solution of each concentration dose was applied to each half uniformly with the help of micropipette. The treated and control papers then air dried for 20 minutes to evaporate the solvent. The treated half of the paper was attached with the untreated half one in the way that attachment did not interfere with the free movement of insects from one half to another. After attachment, the treated and control paper were placed in a glass Petridish (90 mm diameter) and then 5 pairs of adult beetles were released at the centre of the filter paper. Vaseline was applied to the inner vertical side of the petridish to prevent the beetles from climbing onto the side and lid of the petridish. The petridish was covered with its lid and kept in darkness in the laboratory. Each treatment was replicated thrice and the number of insects on each portion was counted at hourly intervals upto the 6th hour with control treatment. The data was expressed as percentage of repulsion (PR) using the following formula: PR= (Nc-50) x 2 where, Nc= % of insects present in the control half. Positive values expressed repellency and negative values attractancy. The average values were categorized according to the following scale (McDonald *et al.* 1970)

Class	Repellency (%)
0	0 > 0.01 to 0.1
I	0.1 to 20
II	20.1 to 40
III	40.1 to 60
IV	60.1 to 80
V	80.1 to 100

Plate 4: Repellency test of five indigenous plant extracts against rice weevil (with treated and untreated filter paper)

3.10. Statistical analysis:

The collected data were statistically analyzed by completely randomized design (CRD) using MSTAT statistical software in a microcomputer. The treatment mean values were adjusted by Duncan's New Multiple Range Test (DMRT). The corrected mortality data were then analysed by probit analyses designed by Finney (1971) using Mstat Statistical in a computer.

RESULTS AND DISCUSSION

The efficacy of five indigenous plant extracts was evaluated against rice weevil, *Sitophilus oryzae* L. The results of the experiment conducted during the study period are presented and discussed under the following subheadings.

4.1 Direct toxicity effects (mortality) on rice weevil

Average mortality percentage of rice weevil at 24, 48 and 72 hours after treatment (HAT) indicated that ata seed extract possessed the highest (mortality, 64.18%) toxic effect, whereas castor seed extract possessed the lowest (mortality, 21.66%) toxic effect (Table 1) against rice weevil. Mortality percentages were directly proportional to the time after treatment. The orders of the toxicity of five plant extracts against rice weevil were: ata>karabi>marigold> nishinda>castor and the average mortality percentage of rice weevil were differed statistically among all the plant extracts. Mortality percentage of rice weevil was also differed significantly among all the concentration level at different time interval (Table 2). The highest average mortality (79.11%) was observed at the highest concentration (1.5%) of plant extract. It was also found that the average mortality percentage directly proportional to the level of concentration of different plant extracts. The interaction effects of plant, dose and time is presented in the Table No. 3. Mortality percentage of rice weevil treated with different plant extracts of different dose level at different hours were found statistically significant. Average value indicated that the cent percent mortality was found in ata seed extracts at highest dose (1.5%) which was statistical different from all other plant extract at different concentration level.

From the above finding it was observed that among the tested five plant extracts, ata showed the most toxic effect against rice weevil and castor was the less effective. The seeds of *A. squamosa* were reported to have insecticidal and abortifacient properties and the crude oils from seeds of *A. squamosa* at 2.5 percent concentration significantly reduced the leaf damage caused by larvae of *Spodoptera litura* (Babu *et al.*1998). Adult mortality might be due to contact toxicity of the plant extracts. The mortality per cent recorded by Ali *et al.* (1981) supports the present findings. None of the other tested extracts at that dose although performed significant mortalities against rice weevil but can not provided cent percent mortality. It indicated that varied efficacies of different tested plant extracts of pest controlling properties are not uniformly distributed. The biological activity of ata seed extracts might be attributed to its alkaloids contents such as Anonaine, Squamocins B to N, Annotemoyin-1, Annotemoyin-2, squamocin &

cholesteryl, glucopyranoside etc. (Pandey and Brave 2011) which caused mortality to insects.

Table 1: Direct toxic effect of different plant extracts against rice weevil at different HAT (Interaction of plant extracts and time)

Plant extracts used	Mortality percentage at different time intervals			
	24 HAT	48 HAT	72 HAT	Average mortality
Ata	60.83 a	65.00 a	66.67 a	64.18 a
Karabi	50.00 b	60.00 a	62.50 a	57.50 b
Castor	18.33 e	21.67 d	25.00 c	21.66 e
Marigold	37.50 c	45.83 b	47.50 b	43.62 c
Nishinda	31.67 d	34.17 c	47.50 b	37.79 d
P- value	0.0001	0.0001	0.0001	0.0001
LSD	4.69	5.21	4.48	3.95
CV (%)	4.32	3.91	2.89	2.63
SE	1.64	1.82	1.56	1.38

HAT= Hour after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 2: Direct toxic effect of plant extracts of different doses against rice weevil at different HAT (Interaction of dose and time)

Dose (%)	Mortality percentage at different time intervals			
	24 HAT	48 HAT	72 HAT	Average mortality
0.0	0.00d	0.00d	0.00 d	0.00 d
0.5	32.67 c	35.33 c	44.00 c	37.34 c
1.0	56.00 b	65.33 b	68.67 b	63.35 b
1.5	70.00 a	80.67 a	86.67 a	79.11 a
P- value	0.0001	0.0001	0.0001	0.0001
lsd	4.20	4.66	4.01	3.53
CV (%)	4.32	3.91	2.89	2.63
SE	1.46	1.62	1.40	1.23

HAT= Hour after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 3: Direct toxic effect of different plant extracts of different doses against rice weevil at different HAT (Interaction of plant, dose and time)

Plant extracts used	Dose (%)	Percentage of insect mortality at different time intervals			
		24 HAT	48 HAT	72 HAT	Average mortality
Ata	0.0	0.00 j	0.00 h	0.00 h	0.00 j
	0.5	56.67 e	60.00 cd	66.67 d	61.13 e
	1.0	86.67 b	100.0 a	100.0 a	95.57 ab
	1.5	100.0 a	100.0 a	100.0 a	100.0 a
Karabi	0.0	0.00 j	0.00 h	0.00 h	0.00 j
	0.5	50.00 ef	53.33 de	63.33 d	55.57 ef
	1.0	70.00 d	86.67 b	86.67 c	81.10 c
	1.5	80.00b c	100.0 a	100.0 a	93.33 ab
Castor	0.0	0.00 j	0.00 h	0.00 h	0.00 j
	0.5	10.00 i	10.00 h	16.67 g	12.20 i
	1.0	26.67 h	33.33 fg	36.67 f	32.23 h
	1.5	36.67 g	43.33 ef	46.67 e	42.20 g
Marigold	0.0	0.00 j	0.00 h	0.00 h	0.00 j
	0.5	23.33 h	30.00 g	33.33 f	28.90 h
	1.0	53.33 e	60.00 cd	60.00 d	57.80 ef
	1.5	73.33 cd	93.33 ab	96.67 ab	87.77 bc
Nishinda	0.0	0.00 j	0.00 h	0.00 h	0.00 j
	0.5	23.33 h	23.33 g	40.00 ef	28.90 h
	1.0	43.33 fg	46.67 e	60.00 d	50.03 fg
	1.5	60.00 e	66.67 c	90.00 bc	72.23 d
	P- value	0.0001	0.0001	0.0001	0.0001
	LSD	9.39	10.42	8.97	7.90
	CV (%)	4.32	3.91	2.89	2.63
	SE	3.28	3.63	3.13	2.75

HAT= Hour after treatment

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

4.2 Probit analysis for direct toxic effect

The results of the probit analysis for the estimation of LD_{50} values and their 95 % feducial limits at 24, 48 and 72 HAT for the mortality of rice weevil are presented in Tables 4. Among the treatments, LD_{50} values at 24 HAT indicated that ata (0.45 mg) seed extract was the most toxic followed by karabi (0.50 mg) leaf extract while castor (2.16 mg) seed extract was the least toxic. Ata seed extract was also maintained its highest toxicity when the LD_{50} values were compared at 48 HAT (0.41 mg) and 72 HAT (0.36 mg). Similar trend of results was showed at 48 HAT and 72 HAT in all other plant extracts. The chi-square values of different plant extracts at different HAT were insignificant at 5% level of probability and did not show any heterogeneity of the mortality data.

From the above probit results it is clear that all the tested plants would be more or less effective for controlling rice weevil but ata and karabi will be the most effective. Pandey and Brave (2011) opined that the ethanolic *Annona squamosa* extract showed potent activity against *Sitophilus oryzae* L. and cent percent mortality was achieved at 39.6±1.4 min and 14.5±1.1 min for 1% w/v and 5% w/v concentration, respectively. Sivasrinivasu (2001) reported that custard apple seed powder at 5 per cent in rice and wheat grains showed cent per cent mortality of *S. oryzae* L. at 7 days after adult release.

Table 4: Relative toxicity (probit analysis) of different plant extracts treated against rice weevil after 24, 48 and 72 HAT

Plant extracts used	No. of insect used	LD 50 values (%)	95 % fiducially limits		χ^2 values
			Lower	Upper	
24 HAT					
Ata	90	0.45	0.3264015	0.6316205	0.20743
Karabi	90	0.50	0.2848516	0.9023578	0.00009
Castor	90	2.16	1.055749	4.426739	0.06769
Marigold	90	0.93	0.7455038	1.171104	0.00899
Nishinda	90	1.14	0.8321165	1.562745	0.04704
48 HAT					
Ata	90	0.41	0.2997458	0.5756118	1.09452
Karabi	90	0.48	0.3618938	0.638851	0.06141
Castor	90	1.67	1.069428	2.617227	0.22149
Marigold	90	0.73	0.6048285	0.8881281	2.18805
Nishinda	90	1.03	0.7958676	1.342043	0.07574
72 HAT					
Ata	90	0.36	0.2402006	0.5647698	0.88356
Karabi	90	0.38	0.2434323	0.6143315	0.39381
Castor	90	1.61	0.9496852	2.744131	0.05333
Marigold	90	0.70	0.5814081	0.8563526	3.82381
Nishinda	90	0.66	0.5151702	0.8595201	2.24758

HAT = Hour after treatment

Values were based on three concentrations, three replications of 10 insects each.

χ^2 = Goodness of fit

The tabulated value of χ^2 is 5.99 (d. f = 2 at 5% level)

4.3 Probit regression lines

The probit regression lines for the efficacy of five tested indigenous plant extracts (ata, karabi, castor, marigold and nishinda) against rice weevil at 24, 48 and 72 HAT are presented in figures 1-3.

The calculated probit regression equation lines for the efficacy of different plant extracts against rice weevil at 24 HAT were Y=3.4834x+2.7425, Y=1.7594x+3.7793, Y=2.0014x+2.352, Y=2.7921x+2.3216, Y=2.0312x+2.8402 for ata, karabi, castor, marigold and nishinda plants extracts, respectively (Figure 1). Among the five lines, the regression line for ata seed extract showed the highest probit mortality and castor seed extract showed the lowestty. The probit regression lines for five plant extracts against rice weevil at 48 HAT are given in figure 2. The regression equations were Y=3.6232x+2.8825, Y=3.7057x+2.4972, Y=2.3427x+2.1333, Y=3.9612x+1.627, Y=2.4181x+2.5681 for ata, karabi, castor, marigold and nishinda plant extracts, respectively. Comparing among the five plant extracts at 48 HAT for probit mortality, ata seed extract showed the highest probit mortality whereas castor seed extract showed the lowest. Ata was also maintained its highest probit mortality when the probit regression lines were compared at 72 HAT (Figure 3).

The insect mortality rate showed positive correlation with the doses in all treatments. The probit regression lines of five plant extracts showed a clear linear relationship between probit mortality and their log doses and the regression lines become sleeper as doses increased, because the adult insects were treated with more toxins for the same period at higher doses.

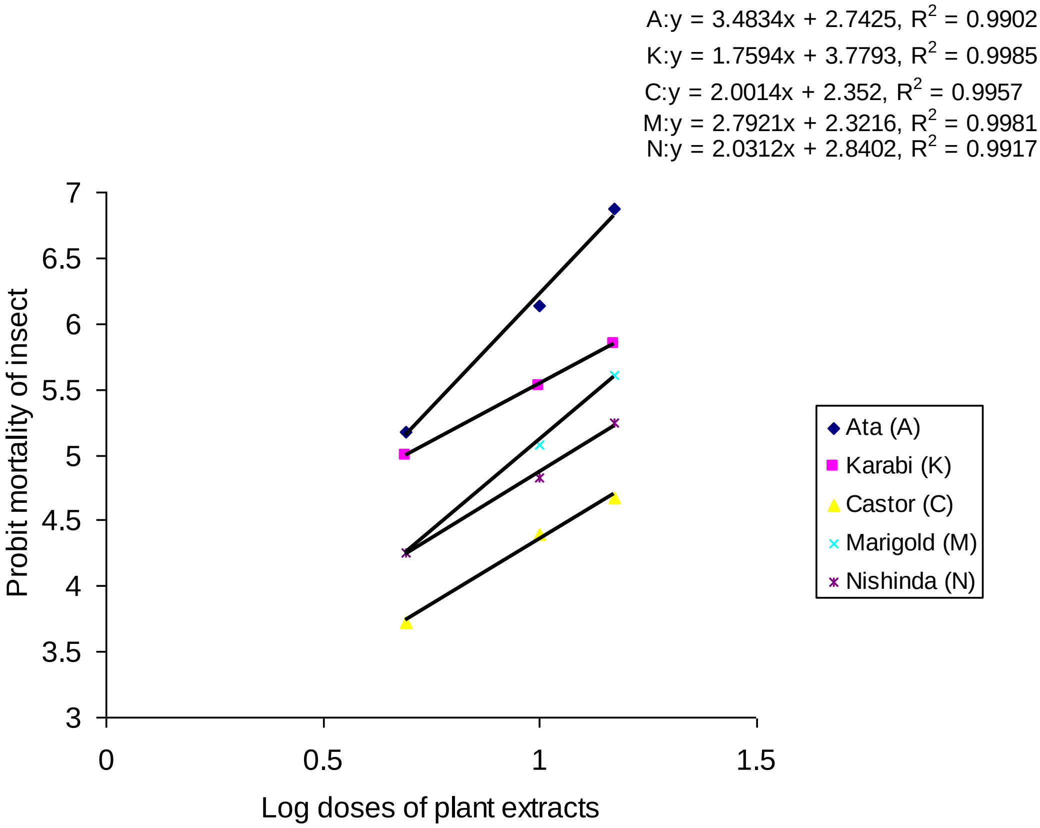

Fig.1. Relationship between probit mortality and log doses of different plant extracts on rice weevil at 24 HAT

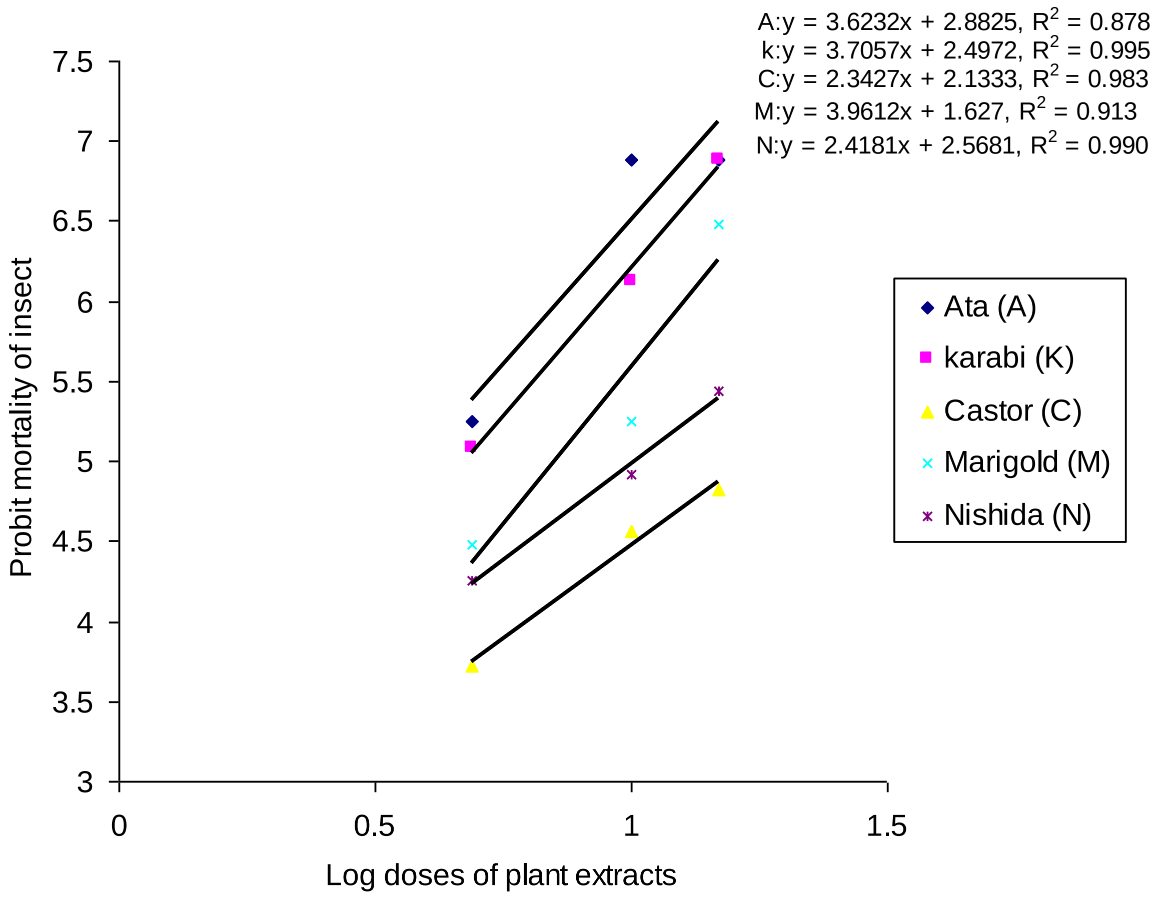

Fig.2. Relationship between probit mortality and log doses of different plant extracts on rice weevil at 48 HAT

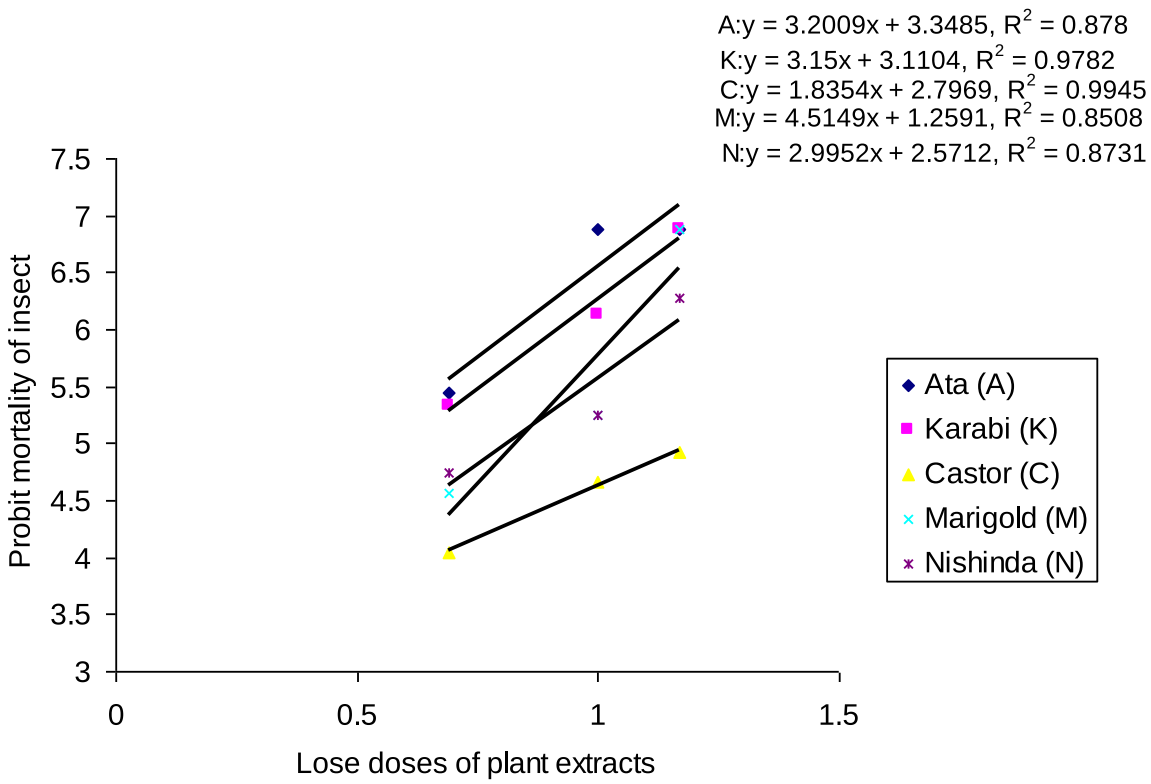

Fig.3. Relationship between probit mortality and log doses of different plant extracts on rice weevil at 72 HAT

4.4 Residual toxic effects on rice weevil

The efficacy of five plant extracts as protectants for wheat grain against rice weevil were evaluated. The data for residual toxicity test are shown in table 5-7. The number of eggs, punctures and F1 adult emergence were statistically differed among the plant extracts (Table 5). The lowest number of eggs and F1 adults per 100 seeds were observed in ata (13.5, 12.08 and 7.75) while the highest from castor seed extracts (23.17, 19.42 and 18.08). The highest infestation inhibition was found in Karabi (60.13%) followed by ata (58.04%) which was not statistically different (Table 5). On the contrary, the lowest inhibition was found in castor seed extract (28.08%). The number of eggs, holes and F1 adults statistically differed among all level of concentration. The lowest and highest number of eggs, number of holes and number of F1 adults were observed in control (28.53, 26.13 and 25.53) and 1.5% concentration (10.87, 7.20 and 3.88) respectively (Table 6). The reduction in adult population is probably due to egg mortality or larval mortality or even reduction in hatching of eggs and also might be due to the presence of toxic substances (Mathur *et al.* 1985).

The interaction of residual effects of plant and dose is highlighted in Table 7. The number of eggs, number of holes of F1 adults and percentage of infestation inhibition were statistically significant different among all the plant extracts in all level of concentration and the residual toxicity was directly proportional to the level of concentration.

From the above finding it was observed that the tested five plant extracts possessed residual toxic effect on rice weevil. The present study agreed with the previous finding of Mishra *et al.* (1992). They found that wheat grains can be protected from the attack of *S. oryzae* by mixing custard apple seed powder at 5 per cent for 75 days. Sivasrinivasu (2001) opined that custard apple seed powder at 5 per cent in rice and wheat grains showed cent per cent mortality of *S. oryzae* at 7 days after adult release and recorded zero per cent weight loss 90 days after storage. Kumar (2003) concluded that custard seed powder at 1 per cent was effective in controlling *S. oryzae* on sorghum grains upto 90 days after storage. Yevoor (2003) concluded that custard apple seed powder at the rate of 0.2 per cent was highly effective and showed cent per cent upto 60 DAT and zero per cent grain damage and weight loss upto 90 DAT.

Table 5. Residual toxicity of different plant extracts on rice weevil after grain treatment (plant effect)

Plant extracts used	No. of eggs / 100 seeds	No. of holes / 100 seeds	No. of F1 adults / 100 seeds	Inhibition rate (%)
Ata	13.50 c	12.08 c	7.75 c	58.04 a
Karabi	16.25 b	10.58 d	7.92 c	60.13 a
Castor	23.17 a	19.42 a	18.08 a	28.08 c
Merigold	18.00 b	15.17 b	12.83 b	39.33 b
Nishinda	17.58 b	15.25 b	11.92 b	38.00 b
LSD value	1.67	1.36	0.96	5.06
$s_{\bar{x}}$	0.58	0.47	0.33	3.70

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 6. Residual toxicity of different plant extracts at different dose levels on rice weevil after grain treatment (dose effect)

Concentrations (%)	No. of eggs / 100 seeds	No. of holes / 100 seeds	No. of F1 adults / 100 seeds	Inhibition rate (%)
0.0	28.53 a	26.13 a	25.53 a	0.00 d
0.5	17.47 b	13.60 b	9.87 b	48.76 c
1.0	13.93 c	11.07 c	7.53 c	57.72 b
1.5	10.87 d	7.20 d	3.88 d	72.39 a
LSD value	1.494	1.213	0.8629	4.52
$s_{\bar{x}}$	0.52	0.42	0.30	3.7

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

Table 7. Residual toxicity of different plant extracts at different concentrations on rice weevil, *Sitophilus oryzae* after grain treatment (interaction effect)

Plant extracts used	Concentrations (%)	No. of eggs / 100 seeds	No. of holes / 100 seeds	No. of F1 adults / 100 seeds	Inhibition rate (%)
Ata	0.0	29.33 a	28.67 a	27.00 a	0.00 j
	0.5	11.00 g-i	9.67 ij	2.33 h-j	66.66 cd
	1.0	7.67 ij	6.67 jk	1.67 h-j	77.01 bc
	1.5	6.00 f	3.33 l	0.67 j	88.50 a
Karabi	0.0	29.33 a	26.00 a-c	23.67 b	0.00 j
	0.5	15.67 ef	7.33 jk	3.67 h	75.12 bc
	1.0	12.00 gh	5.33 kl	2.33 h-j	79.49 ab
	1.5	8.00 ij	3.67 l	1.33 ij	85.89 ab
Castor	0.0	28.67 a	27.00 ab	27.00 a	0.00 j
	0.5	24.67 bc	20.33 d	18.67 c	24.69 i
	1.0	21.33 cd	18.33 de	16.00 d	32.09 hi
	1.5	18.00 de	12.00 hi	10.67 f	55.55 ef
Marigold	0.0	27.67 ab	25.00 bc	25.00 ab	0.00 j
	0.5	18.00 de	15.00 fg	13.00 e	40.00 gh
	1.0	14.67 efg	12.67 gh	10.00 f	49.33 fg
	1.5	11.67 gh	8.00 jk	3.33 hi	68.00 cd
Nishinda	0.0	27.67 ab	24.00 c	25.00 ab	0.00 j
	0.5	18.00 de	15.67 ef	11.67 ef	37.33 h
	1.0	14.00 f-h	12.33 g-i	7.67 g	50.67 f
	1.5	10.67 hi	9.00 j	3.33 hi	64.00 de
	LSD value	3.341	2.712	1.929	10.7
	$s_{\bar{x}}$	1.169	0.948	0.675	3.7

Within column values followed by different letter(s) are significantly different by DMRT at 5% level of probability.

4.5 Repellency effect

The repellency rate of five plant extracts at different HAT are presented in table 8. Among the tested five plant extracts ata extract showed the highest (49.45%) repellent effect followed by marigold (43.04%), nishinda (39.45%), karabi (38.63%) and castor (33.62%). On the basis of repellency rate, it was found that ata and marigold plant extracts were in the same repellency class i.e. Class III and other three plant extracts namely, nishinda, karabi and castor were in class II.

The repellency effect of different plant extracts in different dose level against rice weevil is presented in Table 9. The repellency rates of insects were influenced by the concentration of extracts. The highest mean repellency (64.45%) was found in 1.5% concentration and its bear repellency class IV and the lowest repellency (6.0%) was found in control treatment. Table 10 shows the interaction repellent effect of plant, dose and time. The repellent effect influenced by different level of concentrations at different HAT and had significant difference. Among different plant extracts ata seed extract showed the highest repellency rate (73.33 %) followed by nishinda (71.13%) at highest concentration (1.5%) level. The repellency class of different plant extracts at different concentration level varied between I to IV.

From the above result it was found that ata seed extracts showed strong repellent effect against rice weevil than other plant extracts. The present study agreed with the previous finding of Mishra *et al.* (1992). They found that wheat grains can be protected from the attack of *S. oryzae* by mixing custard apple seed powder at 5 per cent for 75 days. The custard apple seed extract possess more olfactory repellency against normal susceptible strain of *S. oryzae* and *T. castaneum* as compared to soapnut (Quadri 1973).

Table 8. Repellent effect of different plant extracts on rice weevil using treated wheat grain at different HAT (Interaction of plant extracts and time)

Plant extracts used		Repellency rate (%)						
	1HAT	2 HAT	3 HAT	4 HAT	5 HAT	6 HAT	% Mean repell.	Repell. classes
Ata	25.00 b	50.00 ab	51.67 a	41.67 ns	61.67 a	66.67 a	49.45 a	III
Karabi	30.00 b	50.00 ab	38.33 ab	43.33 ns	31.67 b	38.33 b	38.63 ab	II
Castor	23.33 b	33.33 b	21.67 b	46.67 ns	40.00 b	36.67 b	33.62 b	II
Marigold	46.67 a	56.67 a	33.33 ab	43.33 ns	35.00 b	43.33 b	43.04 ab	III
Nishinda	33.33 ab	35.00 b	43.33 ab	40.00 ns	43.33 ab	41.67 b	39.45 ab	II
P- value	0.011	0.084	0.055	-	0.028	0.013	0.057	
LSD	13.71	19.71	20.17	21.37	19.21	18.34	10.61	
CV (%)	2.38	3.00	4.78	4.13	4.89	4.96	3.43	
SE	4.78	6.88	7.04	7.46	6.70	6.40	3.70	

HAT= Hour after treatment

ns= not significant

Mean followed by the same letter(s) did not differ significantly at 5% level and ns indicate no significant by DMRT.

Table 9. Repellent effect of different plant extracts of different doses on rice weevil using treated wheat grain at different HAT (Interaction of dose and time)

Doses (%)	Repellency rate (%)							
	1HAT	2 HAT	3 HAT	4 HAT	5 HAT	6 HAT	% Mean repell.	Repell. classes
0.0	0.00 c	4.00 b	8.00 c	12.00 c	8.00 b	4.00 c	6.00 c	I
0.5	44.00 a	52.00 a	48.00 ab	45.33 b	49.33 a	45.33 b	47.33 b	III
1.0	26.67 b	56.00 a	36.00 b	42.67 b	49.33 a	62.67 a	45.56 b	III
1.5	56.00 a	68.00 a	58.67 a	72.00 a	62.67 a	69.33 a	64.45 a	IV
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
LSD	12.26	17.63	18.04	19.11	17.18	16.41	9.48	
CV (%)	2.38	3.00	4.78	4.13	4.89	4.96	3.43	
SE	4.28	6.15	6.30	6.67	6.00	5.73	3.31	

Mean followed by the same letter(s) did not differ significantly at 5% level by DMRT.

Table 10. Repellent effect of different plant extracts at different dose level on rice weevil using treated wheat grain at different HAT (Interaction of plant extracts, dose and time)

Plant extracts used	Repellency rate (%)								
	Doses (%)	1 HAT	2 HAT	3 HAT	4 HAT	5 HAT	6 HAT	% Mean repell.	Repell. classes
Ata	0.0	0.00 f	0.00 d	40.00 a-c	0.00 c	0.00 e	0.00 f	6.70 gh	I
	0.5	20.00 d-f	53.33 bc	53.33 ab	40.00 a-c	66.67 a-c	86.67 ab	53.33 a-d	III
	1.0	33.33 c-e	66.67 a-c	40.00 a-c	60.00 ab	93.33 a	93.33 a	64.43 a-c	IV
	1.5	46.67 b-d	80.00 ab	73.33 a	66.67 ab	86.67 ab	86.67 ab	73.33 a	IV
Karabi	0.0	0.00 f	20.00 cd	0.00 c	20.00 bc	0.00 e	0.00 f	6.700 gh	I
	0.5	40.00 b-d	60.00 a-c	33.33 a-c	20.00 bc	20.00 de	33.33 c-f	34.43 d-f	II
	1.0	33.33 c-e	60.00 a-c	46.67 a-c	53.33 ab	40.00 c-e	53.33 a-e	47.80 b-e	III
	1.5	46.67 b-d	60.00 a-c	73.33 a	80.00 a	66.67 a-c	66.67 a-d	65.57 ab	IV
Castor	0.0	0.00 f	0.00 d	0.00 c	40.00 a-c	40.00 c-e	0.00 f	13.30 f-h	I
	0.5	53.33 bc	33.33 b-d	26.67 a-c	40.00 a-c	40.00 c-e	46.67 b-e	40.00 c-e	II
	1.0	6.66 ef	46.67 bc	20.00 bc	26.67 bc	20.00 de	53.33 a-e	28.90 e-g	II
	1.5	33.33 c-e	53.33 bc	40.00 a-c	80.00 a	60.00 a-d	46.67 b-e	52.23 a-e	III
Marigold	0.0	0.00 f	0.00 d	0.00 c	0.00 c	0.00 e	20.00 ef	3.30 h	I
	0.5	60.00 a-c	60.00 a-c	53.33 ab	66.67 ab	60.00 a-d	26.67 d-f	54.43 a-d	III
	1.0	40.00 b-d	66.67 a-c	46.67 a-c	53.33 ab	46.67 b-d	73.33 a-c	54.43 a-d	III
	1.5	86.67 a	100.0 a	33.33 a-c	53.33 ab	33.33 c-e	53.33 a-e	60.00 a-c	III
Nishinda	0.0	0.00 f	0.00 d	0.00 c	0.00 c	0.00 e	0.00 f	0.00 h	0
	0.5	46.67 b-d	53.33 bc	73.33 a	60.00 ab	60.00 a-d	33.33 c-f	54.43 a-d	III
	1.0	20.00 d-f	40.00 b-d	26.67 a-c	20.00 bc	46.67 b-d	40.00 c-f	32.23 d-f	II
	1.5	66.67 ab	46.67 bc	73.33 a	80.00 a	66.67 abc	93.33 a	71.13 ab	IV
P- value		0.0773	-	0.3184	0.118	0.0263	0.0717	0.117	
LSD		27.41	39.42	40.33	42.73	38.41	36.69	21.21	
CV (%)		2.38	3.00	4.78	4.13	4.89	4.96	3.43	
SE		9.57	13.77	14.09	14.93	13.42	12.81	7.41	

HAT= Hour after treatment

Mean followed by the same letter(s) did not differ significantly at 5% level by DMRT

SUMMERY

The present experiment was undertaken to study the efficacy of five indigenous plant extracts against rice weevil, *Sitophilus oryzae* (L.) in the laboratory of the Department of Entomology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during the period from April to October 2012. The petroleum ether extracts of seed of ata (*Annona reticulata*) and castor (*Ricinus communis*), leaf of karabi (*Nerium olender,* marigold (*Tagetes erecta*) and nishinda (*Vitex negundo* L.) at 0.5, 1.0 and 1.5 % concentration were evaluated for their repellent, direct toxic and residual effect against rice weevil, *S. oryzae* L.

Average mortality percentage of rice weevil at 24, 48 and 72 hours after treatment (HAT) indicated that ata seed extract the highest (mortality, 64.18%) toxic effects, whereas castor seed extract the lowest (mortality, 21.66%) toxic effect. The average mortality percentages of rice weevil were differed statistically among all the plant extracts. Mortality percentages were directly proportional to the time after treatment. The orders of the toxicity of five plant extracts were: ata>karabi>marigold > nishinda >castor. The highest mortality (79.11%) was observed at the highest concentration (1.5%) of plant extract and it was also found that the mortality percentage directly proportional to the level of concentration of different plant extracts. Mortality percentage of rice weevil treated with different plant extracts of different dose level at different hours were also found statistically significant.

The LD50 values of ata, karabi, castor, marigold and nishinda were 0.45, 0.50, 2.16, 0.93 and 1.14 mg, respectively at 24 HAT indicated that ata was the most toxic followed by karabi and castor was the least toxic. Ata also maintained its highest toxicity when the LD50 values were compared at 48 HAT (0.41mg) and 72 HAT (0.36 mg). Similar trend of results in all other plant extracts was showed at 48 HAT and 72 HAT. The chi-square values of different plant extracts at different HAT were insignificant at 5% level of probability and did not show any heterogeneity of the mortality. The probit regression lines of plant extracts showed a clear linear relationship between probit mortality and their log doses and the regression lines become sleeper as doses increased. Among the five lines, the regression line for ata seed extract showed the highest probit mortality and castor seed extract showed the lowest probit mortality at 24, 48 and 72 HAT.

From the finding it was observed that the tested five plant extracts possessed residual toxic effect on rice weevil. The number of eggs, holes and F1 adult emergence were statistically differed among the tested plant extracts. The lowest and highest number of eggs, and F1 adults were observed in ata (13.5, 12.08 and 7.75) and castor seed extracts (23.17, 19.42 and 18.08). The highest infestation inhibition was found in karabi (60.13%) followed by ata (58.04%) which was statistically similar (Table 5). But the lowest infestation inhibition was found in castor seed extract (28.08%). The lowest and highest number of eggs, holes and F1 adults were observed in control (28.53, 26.13 and 25.53) and 1.5% concentration (10.87, 7.20 and 3.88), respectively (Table 6). The number of eggs, holes of F1 adults and percentage of inhibition were statistically significant different among all the plant extracts in all level of concentration and the residual toxicity was directly proportional to the level of concentration.

The repellency effects influenced by different level of concentrations at different HAT had significant difference. Among different plant extracts ata showed the highest repellency rate (73.33 %) followed by nishinda (71.13%) at the highest concentration (1.5%) level. The repellency class of different plant extracts at different concentration level varied between I to IV.

CONCLUSION

Some promising information was obtained from the present study. However, it has been observed from the result that the tested all five plants extract had repellent, direct and residual toxic effects against rice weevil, *S. oryzae* L. but ata seed extracts showed the most toxic, repellent and residual effects whereas castor seed extract showed the least toxic effect against rice weevil. The present study indicated the potentiality of our indigenous plant extracts (ata, karabi, castor, marigold and nishinda) as insecticidal potency against stored grain pests, rice weevil, *Sitophilus oryzae* L. The findings of new insecticidal activity are of great economic importance for sustainable grain protection. The reason for using natural insecticides is that those are active at highly acceptable readily biodegradable and free from residues while the commonly used synthetic insecticides pollute the environment. Every year Bangladesh imports a large quantity of insecticides to minimize the severe damage caused by insect pests. So they can use botanical materials as insecticides.

Therefore, the findings of the present study will be very useful to screen out some plant extracts in controlling our storage pest successfully and will enable us to save precious foreign currency from importing synthetic insecticides in this regards.

Recommendations

1. Farmers can use seed extract of ata as botanical insecticide against rice weevil as they showed toxic effect.
2. Farmers may use leaf extract of nishinda and seed extract of ata in their storage as repellent against rice weevil because they have moderate repellent effect.
3. Attempt may be undertaken to cultivate the indigenous test plants on cultivable wasteland throughout the country to ensure availability in large scale.

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APPENDICES

Appendix table 1: Doses mortality data of *Sitophilus oryzae* L. adult treated with ata seed extract in petroleum ether solvent at 24 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	29	96.66	97	6.88	6.829	6.909	5.4	6.780
1.0	1	30	26	86.66	87	6.13	6.209	6.077	11.1	6.176
0.5	0.698	30	17	56.66	57	5.18	5.150	5.165	19.02	5.143

Y = 2.745919 + 3.430325 X; χ^2 is 0.2074337 with 1 degrees of freedom; No sig. heterogeneity, LD-50 is 0.4540505 ; 95% Confidence limits are 0.3264015 to 0.6316205

Appendix table 2: Doses mortality data of *Sitophilus oryzae* L. adult treated with ata seed extract in petroleum ether solvent at 48 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	29	96.66	97	6.88	7.223	6.754	2.76	7.209
1.0	1	30	29	96.66	97	6.88	6.508	6.759	8.07	6.511
0.5	0.698	30	18	60	60	5.25	5.285	5.28	18.81	5.319

Y = 2.549366 + 3.962598 X; χ^2 is 1.094524 with 1 degrees of freedom; No sig. heterogeneity; LD-50 is 0.415376; 95% Confidence limits are 0. 2997458 to 0.5756118.

Appendix table 3: Doses mortality data of *Sitophilus oryzae* L. adult treated with ata seed extract in petroleum ether solvent at 72 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	29	96.66	97	6.88	7.149	6.789	3.3	7.146
1.0	1	30	29	96.66	97	6.88	6.524	6.759	8.07	6.527
0.5	0.698	30	20	66.66	67	4.55	5.456	5.429	18.03	5.467

Y = 3.006727 + 3.520298 X; χ^2 is .8835697 with 1 degrees of freedom; no sig heterogeneity; LD-50 is .3683179; 95% Confidence limits are 0.2402006 to 0.5647698

Appendix table 4: Doses mortality data of *Sitophilus oryzae* L. adult treated with karabi leaf extract in petroleum ether solvent at 24 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	24	80	80	5.85	5.843	5.8	15.09	5.799
1.0	1	30	21	70	70	5.52	5.530	5.5	17.43	5.500
0.5	0.698	30	15	50	50	5.00	4.996	4.99	19.02	4.989

Y = 3.803502 + 1.697163 X; χ^2 is -9.727478E-05 with 1 degrees of freedom; no sig heterogeneity; LD-50 is .5069893 ; 95% Confidence limits are .2848516 to .9023578

Appendix table 5: Doses mortality data of *Sitophilus oryzae* L. adult treated with karabi leaf extract in petroleum ether solvent at 48 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	29	96.66	97	6.88	6.844	6.909	5.4	6.837
1.0	1	30	26	86.66	87	6.13	6.185	6.132	12.12	6.182
0.5	0.698	30	16	53.33	53	5.08	5.059	5.075	19.11	5.063

Y = 2.464038 + 3.718472 X; χ^2 is 6.140518E-02 with 1 degrees of freedom; no sig heterogeneity; LD-50 is 0.4808287; 95% Confidence limits are 0.3618938 to 0.638851

Appendix table 6: Doses mortality data of *Sitophilus oryzae*L. adult treated with karabi leaf extract in petroleum solvent at 72 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	29	96.66	97	6.88	6.806	6.909	5.4	6.731
1.0	1	30	26	86.66	87	6.13	6.245	6.077	11.1	6.213
0.5	0.698	30	19	63.33	63	5.33	5.287	5.358	18.81	5.328

Y = 3.27216 + 2.941554 X; χ^2 is 0.3938055 with 1 degrees of freedom; no sig heterogeneity; LD-50 is .3867145; 95% Confidence limits are 0.2434323 to 0.6143315

Appendix table 7: Doses mortality data of *Sitophilus oryzae* L. adult treated with castor seed extract in petroleum ether solvent at 24 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	11	36.66	37	4.67	4.699	4.659	18.03	4.688
1.0	1	30	8	26.66	27	4.39	4.343	4.394	15.96	4.341
0.5	0.698	30	3	10	10	3.72	3.736	3.72	10.08	3.750

Y = 2.376729 + 1.965259 X; .χ^2 is 6.769657E-02 with 1 degrees of freedom; No sig heterogeneity; LD-50 is 2.161833; 95% 95% Confidence limits are 1.055749 to 4.426739

Appendix table 8: Doses mortality data of *Sitophilus oryzae* L. adult treated with castor seed extract in petroleum ether solvent at 48 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	13	43.33	43	4.82	4.880	4.838	18.81	4.889
1.0	1	30	10	33.33	33	4.56	4.464	4.57	16.74	4.478
0.5	0.698	30	3	10	10	3.72	3.755	3.72	10.08	3.776

Y = 2.145106 + 2.33339 X; χ^2 is .2214985 with 1 degrees of freedom; no sig heterogeneity

LD-50 is 1.673002; 95% Confidence limits are 1.069428 to 2.617227

Appendix table 9: Doses mortality data of *Sitophilus oryzae* L. adult treated with castor seed extract in petroleum ether solvent at 72 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	14	46.66	47	4.92	4.949	4.915	19.02	4.941
1.0	1	30	11	36.66	37	4.67	4.623	4.659	18.03	4.615
0.5	0.698	30	5	16.66	17	4.05	4.067	4.037	13.17	4.058

Y = 2.76681 + 1.84868 X; χ^2 is 5.333567E-02 with 1 degrees of freedom; no sig heterogeneity; LD-50 is 1.61433; 95% Confidence limits are 0.9496852 to 2.744131

Appendix table 10: Doses mortality data of *Sitophilus oryzae* L. adult treated with marigold leaf extract in petroleum ether solvent at 24 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	22	73.33	73	5.61	5.596	5.584	17.43	5.572
1.0	1	30	16	53.33	53	5.08	5.100	5.065	19.02	5.082
0.5	0.698	30	7	23.33	23	4.26	4.252	4.252	15.09	4.244

Y = 2.298249 + 2.78381 X; χ^2 is 8.996964E-03 with 1 degrees of freedom; no sig heterogeneity; LD-50 is 0.9343781; 95% Confidence limits are 0.7455038 to 1.171104

Appendix table 11: Doses mortality data of *Sitophilus oryzae* L. adult treated with marigold leaf extract in petroleum ether solvent at 48 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	28	93.33	93	6.48	6.123	6.408	12.15	6.161
1.0	1	30	18	60	60	5.25	5.481	5.24	18.03	5.503
0.5	0.698	30	9	30	30	4.48	4.384	4.49	15.96	4.380

Y = 1.770836 +3.732906X; χ^2 is 2.188059 with 1 degrees of freedom; no sig heterogeneity

LD-50 is .7329155; 95% Confidence limits are 0.6048285 to 0.8881281

Appendix table 12: Doses mortality data of *Sitophilus oryzae* L. adult treated with marigold leaf extract in petroleum ether solvent at 72 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	29	96.66	97	6.88	6.261	6.587	11.1	6.237
1.0	1	30	18	60	60	5.25	5.588	5.220	17.43	5.572
0.5	0.698	30	10	33.33	33	4.56	4.438	4.57	16.74	4.434

Y = 1.792746 + 3.779612 X; χ^2 is 3.823805 with 1 degrees of freedom; no sig heterogeneity; LD-50 is .7056134; 95% Confidence limits are 0.5814081 to .8563526

Appendix table 13: Doses mortality data of *Sitophilus oryzae* L. adult treated with nishinda leaf extract in petroleum ether solvent at 24 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	18	60	60	5.25	5.223	5.28	18.81	5.254
1.0	1	30	13	43.33	43	4.82	4.862	4.838	18.81	4.877
0.5	0.698	30	7	23.33	23	4.26	4.244	4.252	15.09	4.233

Y = 2.737602 +2.140322 X; $\chi 2$ is 4.704094E-02 with 1 degrees of freedom; no sig heterogeneity; LD-50 is 1.140345; 95% Confidence limits are 0.8321165 to 1.562745

Appendix table 14: Doses mortality data of *Sitophilus oryzae* L. adult treated with nishinda leaf extract in petroleum ether solvent at 48 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	20	66.66	67	5.44	5.405	5.429	18.03	5.395
1.0	1	30	14	46.66	47	4.92	4.975	4.915	19.02	4.965
0.5	0.698	30	7	23.33	23	4.26	4.239	4.252	15.09	4.228

Y = 2.51911 +2.445905 X; χ^2 is 7.574749E-02 with 1 degrees of freedom; no sig heterogeneity; LD-50 is 1.033484; 95% Confidence limits are 0.7958676 to 1.342043

Appendix table 15: Doses mortality data of *Sitophilus oryzae* L. adult treated with nishinda leaf extract in petroleum ether solvent at 72 HAT.

dose	logdose	number	kill	% kill	corr%	emp probit	expt probit	wrk probit	weight	final probit
1.5	1.176	30	27	90	90	6.28	5.984	6.25	14.13	6.028
1.0	1	30	18	60	60	5.25	5.489	5.24	18.03	5.515
0.5	0.698	30	12	40	40	4.75	4.643	4.74	18.03	4.638

Y=2.602109+2.913232X; $\chi 2$ is 2.24758 with 1 degrees of freedom; no sig heterogeneity; LD-50 is 0.6654315; 95% Confidence limits are 0.5151702 to 0.8595201

Appendix table 16. Repellency effects of ata seed extract against *Sitophilus oryzae* L. using treated filter paper

Duration of treatment	Replication	Doses (%)			
		1.5	1.0	0.5	0.0
1 HAT	R1	40	20	40	00
	R2	40	40	00	00
	R3	60	40	20	00
2 HAT	R1	60	40	80	00
	R2	80	60	20	00
	R3	100	100	60	00
3 HAT	R1	40	60	60	20
	R2	100	40	60	20
	R3	80	20	40	20
4 HAT	R1	40	40	40	00
	R2	100	100	20	00
	R3	60	40	60	00
5 HAT	R1	60	100	20	00
	R2	100	100	80	00
	R3	100	80	100	00
6 HAT	R1	60	100	60	00
	R2	100	100	100	00
	R3	100	80	100	00

Appendix table 17. Repellency effects of Karabi leaf extract against *Sitophilus oryzae* L. using treated filter paper

Duration of treatment	Replication	Doses (%)			
		1.5	1.0	0.5	0.0
1 HAT	R1	40	00	20	00
	R2	80	40	60	00
	R3	20	60	40	00
2 HAT	R1	80	40	00	00
	R2	40	60	80	00
	R3	60	80	100	00
3 HAT	R1	100	00	40	20
	R2	60	40	60	20
	R3	60	100	00	20
4 HAT	R1	100	20	40	00
	R2	80	60	00	00
	R3	60	80	20	00
5 HAT	R1	100	20	40	00
	R2	60	40	20	00
	R3	40	60	00	00
6 HAT	R1	100	20	00	00
	R2	60	40	40	00
	R3	40	100	60	00

Appendix table 18. Repellency effects of castor seed extract against *Sitophilus oryzae* L. using treated filter paper

Duration of treatment	Replication	Doses (%)			
		1.5	1.0	0.5	0.0
1 HAT	R1	00	00	40	00
	R2	40	20	60	00
	R3	60	00	60	00
2 HAT	R1	40	40	00	00
	R2	60	60	60	00
	R3	60	40	40	00
3 HAT	R1	40	60	00	20
	R2	60	00	60	20
	R3	20	00	20	20
4 HAT	R1	100	60	20	00
	R2	80	20	40	00
	R3	60	00	60	00
5 HAT	R1	80	00	00	00
	R2	60	20	60	00
	R3	40	40	60	00
6 HAT	R1	40	60	40	00
	R2	60	60	60	00
	R3	40	40	40	00

Appendix table 19. Repellency effects of marigold leaf extract against *Sitophilus oryzae* L. using treated filter paper

Duration of treatment	Replication	Doses (%)			
		1.5	1.0	0.5	0.0
1 HAT	R1	80	60	40	00
	R2	100	40	80	00
	R3	80	20	60	00
2 HAT	R1	100	80	80	00
	R2	100	60	60	00
	R3	100	60	40	00
3 HAT	R1	80	60	40	00
	R2	00	40	60	00
	R3	20	40	60	00
4 HAT	R1	00	40	100	00
	R2	100	60	40	00
	R3	60	60	60	00
5 HAT	R1	40	60	60	00
	R2	00	60	60	00
	R3	60	20	60	00
6 HAT	R1	00	60	00	20
	R2	60	60	60	20
	R3	100	100	20	20

Appendix table 20. Repellency effects of Nishinda leaf extract against *Sitophilus oryzae* L. using treated filter paper

Duration of treatment	Replication	Doses (%)			
		1.5	1.0	0.5	0.0
1 HAT	R1	60	40	60	00
	R2	80	20	40	00
	R3	60	00	40	00
2 HAT	R1	80	40	60	00
	R2	60	00	60	00
	R3	00	80	40	00
3 HAT	R1	60	60	100	00
	R2	100	20	60	00
	R3	60	00	60	00
4 HAT	R1	100	00	100	00
	R2	80	40	80	00
	R3	60	20	00	00
5 HAT	R1	60	100	60	00
	R2	60	40	60	00
	R3	80	00	60	00
6 HAT	R1	100	60	00	00
	R2	80	40	60	00
	R3	100	20	40	00