ECO-FRIENDLY MANAGEMENT OF ANGOUMOIS GRAIN MOTH, *SITOTROGA CEREALELLA* OLIVIER USING SOME BOTANICALS AND FUMIGANTS ON STORED PADDY

MD. ISMILE HOSSIEN

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

MD. ISMILE HOSSIEN
Reg. No. 05-1727

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Approved by:

(Prof. Dr. Md. Razzab Ali)	**(Prof. Dr. Md. Mizanur Rahman)**
Supervisor	**Co-Supervisor**

Prof. Dr. Md. Razzab Ali
Chairman
Examination Committee

DEDICATED

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MY BELOVED PARENTS

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/Entomology/2012/

CERTIFICATE

This is to certify that thesis entitled, **"Eco-friendly management of Angoumois grain moth, *Sitotroga cerealella* Olivier using some botanicals and fumigants on stored paddy"** 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 **Md. Ismile Hossien, Registration No. 05-1727** 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.

Dated: June, 2011

Place: Dhaka, Bangladesh

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(Prof. Dr. Md. Razzab Ali)

Supervisor

&

Chairman

Department of Entomology

SAU, Dhaka

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ABSTRACT

The study was conducted in the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from April to September, 2011 to find out the efficiency of some botanicals and fumigants applied against Angoumois grain moth, *Sitotrogra cerealella* Olivier on stored paddy. The study was conducted under the two separate experiments considering botanical and fumigant based management. In case of botanical based experiment, five botanicals viz., dried leaf powder of neem @ 2.5 g/kg paddy, bishkatali @ 2.5 g/kg paddy, marigold @ 2.5 g/kg paddy, mahogany @ 2.5 g/kg paddy, chopped garlic bulb @ 1.0 g/kg paddy along with one untreated control were evaluated. While in case of fumigant based experiment, three fumigants viz. camphor @ 1.0 gm/kg paddy, phostoxin tablet @ 200 mg/kg paddy, naphthalene @ 500 mg/kg paddy along with one untreated control were evaluated. The experiments were laid out in Completely Randomized Design (CRD) with 4 replications. Data were recorded on grain infestation by number and weight, seed germination and economic returns of the management practices in terms of benefit cost ratio (BCR). Among five promising botanicals,dried neem leaf powder reduced the highest grain infestation by number and weight (72.77% & 62.07%, respectively) as well as the highest % germination saved over control (28.74%) . The highest (11.65) benefit cost ratio (BCR) was also achieved by the dried neem leaf powder than other botanicals. Among three promising fumigants, both camphor phostoxin tablet reduced the highest percent of grain infestation (100%) by number and weight, Conversely, camphor saved the highest percent of seed germination over control (35.81%) than other fumigants. The camphor was also considered as the most economically viable tool for the management of rice moth, *S. cerealella* on rice gains in storage, which gave the highest (14.08) benefit cost ratio (BCR) than phostoxin tablet (5.25).

CHAPTER I

INTRODUCTION

Paddy is the main food crop for more than half of the worlds' population. It is the major source of carbohydrate and plays a vital socio-economic role in t he diet of the common people of Bangladesh. The paddy occupies about 70% of the total cultivable land of the country. Bangladesh produces a total of 3.13 million ton of rice from an area of 6.11 million hectare (BBS, 2010). About 90% of the population of Bangladesh depends on rice for their major food intake (Anon., 1981). The farmers store more than 65% of the total paddy produces till the next season for their food, feed and seed purposes. paddy is stored as paddy (unhusked rice), brown and polished milled rice. In Bangladesh, rice is stored as raw parboiled in bamboo made container (called dole and golas) or stored as parbolied milled rice in earthen pot (called motka) (BRRI, 1984). Prakash *et al*. (1987) reported that about 5-8% of rice was stored for seed. But rice is being damaged by a number of agents, such as insects, rodents, fungi, mites, birds and moisture (Prakash and Rao, 1983). Among them, storage insects are the major agents causing considerable losses every year. Nearly seventeen species of insects have been found to infest stored rice (Praksh *et al.,* 1987) of which rice moth (*Sitotroga cerealella*), rice weevil (*Sitophilus oryzae* Linn.) and beetles (*Tribolium castaneum*) predominate in parboiled rice. On the other hand, moth and beetles predominate in raw rice and weevils predominate in milled rice (BRRI, 1984). Among all the insects, *S. cerealella* is often placed at the top of the list as major insect pest of stored rice. The rice moth, *S. cerealella* Olive known as the Angoumois grain moth or paddy moth is one of the most dominant species in the stored paddy (Prakash *et al.,* 1987). In, stored it appeared to be the major and number one pest. It not only infests the grains in storage, but also in field conditions, which enhances its ability to damage (Douglus, 1941). In addition, *S. cerealella* is also able to infest the grains in bulk storage structures and bags. Cogburn

(1975) experimental assessed weight losses during paddy storage and concluded that one gravid female of *S. cerealella* in 50 g of stored paddy could destroy the grain completely for three subsequent generations. Rice moth is cosmopolitan throughout the tropical and subtropical parts of the world.

Chemical control method has got great value for the management of rice moth in storage. Several reports are available on the efficacy of different chemicals (Chandra *et al.*, 1989; Prakash an Rao, 1983; Stoyanova and Shikrenov, 1983; Yadav, 1983; Singh *et al*., 1989; Dilwari *et al.*, 1991). But the use of chemical insecticides against the attack of paddy moth in storage may cause serious health hazards. The residues of the chemical insecticides remain in the stored grain and also in the environment (Srivastava, 1980; Prakash and Kauraw, 1982). Moreover, serious environmental imbalance results due to development of resistance in pest population and subsequent resurgence as well as destruction of beneficial insects. Besides this, reports are also available on the efficacy of plant oils (Singh *et al.,* Chander *et al.*, 1991; Su,1991). Hence, search for the alternative method of paddy moth control utilizing some non-toxic, environment friendly and human health hazard free methods are being pursued now-a-days. In Bangladesh, most of the farmers are poor and marginal. They store small quantities of seed for edible rice and cannot practice expensive control measures. Therefore, they essentially need some cheap, easy to use, readily available but effective methods for safe storing of rice. Plant products are being liberally available as indigenous source of insecticides and insect repellents have been in use for more than one century. The insecticidal property is not very quick (except natural pyrethrins) as compared to that of synthetic insecticides and fumigants. The plant products certainly possess surface persistence for a long period, have least or no adverse effect on germination ability of seed, cooking quality and milling, less expensive, easily available and some of the products like natural pyrethrums have rapid killing action (Prakash *et al.*, 1981). A number of plant products have been reported as being in use against insect pest in stored grains including rice to minimize storage losses due to insects. Neem *(Azardirachta indica*) products like leaves, seed, bark from which oil cake and extracts are prepared have been reported to possess fungicidal, nematicidal, insecticidal, insect repellent and antifeedent properties (Ketkar *et al.*, 1976). Neem *(Azardirachta indica*) products have been reported by many workers as grain protectants against rice storage insects. Mixing dried leaves with grains repel the insect pests (Fry, 1938; Pruthi and Singh, 1950; Jilani and Su, 1983).The neem leaves act as an insecticide (Krisnamurthy and Rao, 1950). Some chemical like Nepthaline, Camphor and Phostoxin tablet are also being used as fumigants for the control of storage insect pests. The locally available indigenous source of insecticide with low mammalian toxicity or no adverse effect on seed germination, cooking quality and milling, have been in use for more than a century in India (Prakash *et al.*, 1987). Camphor, originally a natural component of essential oil having very low mammalian toxicity and was found highly effective against Rice moth (Abivardi, 197). Most of these reports are of laboratory based. Preliminary studies and are not conclusive regarding their performances in farmer`s storage conditions. Evidence suggests that a series of experiments were conducted, which will help to formulate appropriate future plan for developing suitable management approach for controlling rice moth. However, the use of quality insecticide and its proper management is a burning issue in respect of agro socio economic and environmental aspect. At present situation in Bangladesh, there is a great need of information about appropriate plant based insecticide for the management of stored grain pest in storage.

Objectives

Considering above points view in mind the objectives of the research work are given below:

i. To assess the extent of damage of stored rice grain by rice moth, *S. cerealella,*
ii. To evaluate the effectiveness of some promising botanicals against rice moth and,
iii. To evaluate the effectiveness of some promising fumigants against rice moth.

CHAPTER II

REVIEW OF LITERATURE

Stored grains suffer seriously from the attack of a number of insect pests. Now a day, the botanical products have been recognized as potential pests controlling measures all over the world. Most of the insects are controlled by using insecticides. Several species of insect pests both in field and in storage have been reported to be controlled by the application of botanical products such as powder, extract and oil as potential source of antifeedant, repellent and growth inhibitor (Islam 1984). But very few works have so far been done for their control in Bangladesh. Review of literatures cited here reveals some information about the use of chemical and botanical products at home and abroad. In this chapter, relevant research works on stored product insect pest management by botanical insecticides have been cited.

2.1.Taxonomy of Angouimous Grain Moth, *Sitotroga cerealella*

The Angouimous grain moth, popularly known as rice moth in Bangladesh, has a wing expanse of 13-19 mm and a length of 6-9 mm. The forewings are clay-yellow and without markings; the hind wings are grey. The rear edges of the forewings and hind wings have long fringes.

Kingdom : Animelia
Class : Insecta
Sub-order : Pterygota
Order : Lepidoptera
Family : Gelechiidae
Sub-family : Anacanpsinae
Genus : *Sitotroga*
Species : *Sitotroga cerealella*

2.2. Distribution of *S. cerealella*

Including temperate-zone countries and the tropics, *S. cerealella* has world wide distribution but found in abundance in mountainous and coastal area where the climate is rather humid. This pest derives its common name from the colossal depredations caused by it in the province of Angoumois, France in about 1736.

2.3. Biology of *S. cerealella*

The female lays an average of 150 eggs. The caterpillar bores into a grain kernel after emerging from the egg, remaining there until fully developed. The development period depends on temperature; in Central Europe one, in warmer countries several generations per year. Dhotmal and Dumbre (1982) reported 40.88 to 57.88 eggs laid by a female on different rice varieties in a laboratory and found that fine grain varieties were preformed for its egg laying. Fecundity was found to vary in the wild and domesticated strains of this moth. Ovipositing period was reported as being from 3.3 to5.0 days. Eggs are laying singly or in groups of 4-7 depending upon the season and ovipositional site. Larva is yellowish white a dark head and attains a length of 6-10 mm (plate. 1) depending upon grain length. Larval migration is reported as being up to 10 cm horizontally and 5 cm vertically (Germonav, 1982) after entering the grain, the larva often turns and practically closes the entry whole with a silken web.

Pupa is brown (plate. 2) colored, develop inside silken cocoon and 4-5 mm in length. Pupal period is 4-7 days (Crombie, 1943). The adult (plate. 3) is a good flier, short-lived (5-10 days), gray or buff colored moth, usually nocturnal in habit.

2.4. Extent of damage of stored rice by *S. cerealella*

Rice moth is a serious pest of rice and it attacks all cereals both in the field as well as in storage. The weight losses can be as much as 50% for wheat and 24% for corn. Badly infested grain has a sickening smell and taste that makes it unpalatable.

Rice moth *S. cerealella* is a serious pest of rice and it attacks all cereals both in the field as well as in storage, It is a major pest of stored rice, through it commonly attacks wheat, maize, sorghum, barley and oat (Flethcher and Ghosh, 1919), Bokder (1984) considered the attack of this moth as an index for judging the quality of rice grain.

2.5. Management practices of *S.cerealella*

Heating the grain to 60^0C will kill all stages of development of the grain moth, but the germinative capacity of the grain is highly decreased and the flour no longer suitable for baking. Improved storage structure can substantially reduce the pest infestation. Chemical control, however as an alternative method has got great value. Several reports are available on the efficacy of different chemicals (Chandra *et al*., 1978 Prokash and Rao, Stoyanova and Shikrenov, 1983; Yadav, 1983; Singh *et al*., 1989 Dilwari *et al*., 1991). But the use of chemical insecticides against the attack of paddy moth in storage may cause serious health hazards.

2.5.1. Botanicals as management practices

Haritha *et al*. (2000) reported that the average pre-oviposition and oviposition periods of *Corcyra cephalonica* on groundnut pods and kernels were 0.525 and 6 days, respectively. The average duration of egg, larval and pupal periods were 4.5, 49.4 and 15.62 days, respectively, on groundnut pods and 4.5, 46.54, and 13.68 days, respectively, on kernels. The total life cycle of the moth was completed earlier on groundnut kernels (65.08 days) than on pods (69.24 days). The average fecundity of the moth was higher on groundnut kernels (277 eggs) than on pods (229 eggs) The effects of 10 grain protectant oils, namely toria (*Brassica campestris* var. toria), mustard (*Brassica juncea*), linseed

(*Linum usitatissimum*), sunflower (*Helianthus annuus*), soyabean (*Glycine max*), til (*Sesamum indicum*), castor (*Ricinus communis*), neem (*Azadirachta indica*), groundnut (*Arachis hypogaea*), and mahua (*Madhuca longifolia*), on the growth and development of angoumois grain moth (*Sitotroga cerealella*) on rice cv. Saket-4 was studied under controlled laboratory conditions (at 75+or-5% relative humidity and 27+or-2 degrees C temperature). All the oil treatments used were effective in retarding the growth and developmental processes of *S. cerealella*. The neem oil, followed by castor and mahua oils, were the most effective in reducing fecundity (26.41/female), development period (26.67 days), number of generations (6), hatching (20.93%), pupation (52.33%), and eclosion (50%). The untreated control had fecundity of 224.68/female, developmental period of 37 days, generations of 10 hatching of 87.44%, pupation of 89.67%, and eclosion of 90.67%.

Bunker and Bhargava (2002) studied to determine the effect of vegetable oils on the eggs of *Corcyra cephalonica*. The treatments were castor bean (*Ricinus communis*), coconut (*Cocos nucifera*), groundnut (*Arachis hypogaea*), Indian mustard (*Brassica juncea*), sesame (*Sesamum indicum*), and sunflower (*Helianthus annuus*) oils at 0.5, 1.0, 2.0, 3.0, and 5.0%. All the vegetable oil concentrations were significantly superior than the control in reducing egg hatchability. The percentage of egg hatch inhibition in all the treatments increased with an increase in concentration. Castor oil was the most effective in reducing egg hatchability followed by Indian mustard, groundnut, sesame, coconut, and sunflower oils.

Dwivedi and Kumar (1999) evaluated leaf extracts of 6 plant species were evaluated for their ovicidal activity against *Corcyra cephalonica* under laboratory conditions. At S/10 dose level *Vinca rosea* (*Catharanthus roseus)* shows 40% ovicidal activity followed by *Chenopodium album* and *Helianthus annuus* 3-4%. At S/100 dose level *Withania* *somnifera* exhibit 100% inhibition of hatching whereas *Vinca rosea*, *Cassia occidentalis*, *Chenopodium album*, *Argemone mexicana* and *Helianthus annuus show* 96.7, 86.7, 70.0, 23.4 and 23.4% hatching, respectively.

Yadav *et al*. (2003) reported that the growth and development of angoumois grain moth, *S. cerealella*, on 18 rice cultivars were studied under controlled laboratory conditions (at 27+or-2 degrees C with 75+or-5% relative humidity). Observations on fecundity, hatching, pupation, adult emergence, developmental periods, number of generations, adult longevity, F< sub>1</ sub> progeny and index of suitability indicated Sona and T-26 as the most preferred, and Pant-4 and IR-8 as the least preferred hosts for *S. cerealella*.

Ansari *et al.* (2000) studied the effect of different plant products, i.e. powders and extracts of *Allium sativum, Gynandropsis gynandra* (*Cleome gynandra), Zingiber officinale, Tagetes indica* and *Centratherum anthelminticum*, on the egg laying rate of the rice moth *C. cephalonica* was studied in the laboratory. For this purpose, 10 newly emerged adults of the test insect were introduced into grain seed jars treated with 50 g powder and 1.0 ml extract of the different plant species. The results showed that T. indica was the most effective in reducing the egg laying rate of C. cephalonica. The powder and extract form of *T. indica* resulted in egg laying rates of 33.00 and 33.30%, respectively.

Singh *et al* .(2002) screened Petroleum ether, methanol and acetone extracts (at 1%), essential oil (at 1, 0.5, 0.25, 0.125, 0.062 and 0.031%) and 2 pure compounds (viridiflorol at 434 mg and agnuside at 2.3 g) isolated from *V. negundo* leaves for insecticidal activity against *S. cerealella* infesting wheat seeds. Only the essential oil was effective against the pest and caused 100% mortality even at the minimum concentration of 0.062%. Emergence of new adults was completely prevented by 0.125% of the essential oil.

Yadu *et al.* (2000) undertook a laboratory experiment to evaluate certain indigenous plant products against *Sitotroga cereallea* as grain protectants under controlled conditions. Mixing of 5 botanical products, i.e. neem (*Azadirachta indica*) kernel powder, neem leaf powder, eucalyptus leaf powder, sarifa leaf powder and lantana leaf powder, at 1.0 and 2.0 parts (w/w) per 100 parts of maize and paddy grains proved to be protectants against *S. cerealellea* causing adverse effects on development, which resulted in less percentage of adult emergence and grain damage. The grain damage done by 200 eggs during their development was found to be 59.96 (in maize) and 10.89% (in paddy), which was protected from 63.94 to 96.61 and 76.58 to 94.49% when maize and paddy grains, respectively, were treated with various plant products. Neem kernel powder proved to be the most effective, while leaves of lantana, the least. The germination of treated seeds was not impaired in any case during the exposure period of about 8 months.

Bhargava and Meena (2001) reported that the oils of cumin (*Cuminum cyminum)*, cinnamon (*Cinnamomum zeylanicum*), ajowan (*Carum copticum* (*Trachyspermum ammi*, and clove were applied on freshly laid eggs (0-24 h) of *Corcyra cephalonica* at 0.00, 0.10, 0.20, 0.50, 1.00 and 2.00% concentration. All spice oils at all concentrations inhibited egg hatch over control. Hatching inhibition increased as the oil concentrations increased. The minimum LC< sub>50</ sub> value (0.1561+or-0.0321) was found in ajowan oil, followed by cumin seed oil (0.2015+or-0.393), clove oil (0.2602+or-0.0298) and cinnamon leaf oil (0.3773+or-0.0368).

Srinivasan, and Nadarajan (2004) reported that the insecticidal activity of extracts of notchi (*Vitex negundo*), kottai karanthai (*Sphaeranthus indicus*), jamaica mountain sage (*Lantana camara*), dry chillies (*Capsicum annuum*), soap nut tree (*Sapindus *emarginatus*), curry leaf (*Murraya koenigii*), kolingi (*Tephrosia purpurea*), crotons (*Croton sparsiflorus*) and candle stick (*Cassia alata*) was investigated against Angoumois grain moth, *Sitotroga cerealella*, attacking stored rice. The extracts were mixed with rice grains and exposed to the Angoumois grain moth. The toxicity level varied among the plants. The percent infestation at 10 days after treatment (DAT) showed that all the botanical treatments reduced the infestation (27.6-29.6%) compared to the untreated control (50.0%). The overall mean percent infestation was lowest in notchi and kottai karanthai (30.06 and 30.30%, respectively), followed by jamaca mountain sage (30.60%), soap nut tree (31.20%), dry chilli (31.20%) and curry leaf (31.30%). Kolingi, croton and candle stick showed the maximum infestation of 34.73, 34.86 and 36.26%, respectively, but distinctly superior than the control (60.10%). At 50 DAT, the lowest infestation was observed in notchi (31.6%) and kottai karanthai (32.0%), which were on par with the extracts from jamaica mountain sage (32.6%), curry leaf (33.6%), soap nut tree (33.3%) and dry chilli (33.3%). The highest infestation (65.3%) was recorded in the untreated lot, which was statistically more significant than all other treatments.

Meena and Bhargava (2003) reported that the efficacy of 0.1, 0.5 and 1 ml/100 broken seeds of *Azadirachta indica*, *Pongamia glabra* [*P. pinnata*], *Calophyllum inophyllum*, *Cymbopogon flexuosus*, *Lawsonia inermis*, *Cocos nucifera*, castor, Indian mustard, sesame, groundnut, soyabean and sunflower extracts and/or oils in controlling *C. cephalonica* infesting rice was determined. The fecundity, egg viability and longevity of both males and female *C. cephalonica* decreased with increasing concentrations of the extracts and the oils. Male and female longevity was lowest with lemongrass oil treatment.

Yevoor (2003) recorded zero per cent grain damage and weight loss 90 DAS and cent per cent mortality at 60 DAS in this work, the application of sub-lethal dose of neem oil-based pellets.

Mahanti (2002) reported that neem seed powder at the rate of 2 g per kg of maize seed caused 100 per cent mortality of *S. oryzae* at 10 days after beetle release. Sunil (2003) reported that neem seed powder @ 1 percent showed less per cent of seed damage of 5 to 10% from 30 to 60 days after storage.

Imtiaz *et al.* (2001) observed the effects of neem leaf extracts on adult rice weevil, *Sitophilus oryzae.* Glass film method was adopted to determine the L_c 50. After plotting a graph between mortality and concentration, the L_c 50 was found to be 0.44µg/sq. cm.

Neem seed powder @ 5 percent caused cent per cent mortality of rice at 7 days after beetle release and weight loss was nil during 90 days of storage as per the observations (Sivasrinivas, 2001).

Rahman *et al.* (1999) reported that the extracts of urmoi *(Sapium sebiferum* L.) neem, *(Azadirachta indica, A. fuss),* 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 extract had a repellent effect. Ethanol and acetone were found to be better solvents for extracting greater amounts of toxic component from seeds and rhizomes. Significant positive correlation was found between extract concentration and insect response. Urmoi and neem were almost similar in their effectiveness. However, the potency of turmeric decreased more rapidly than that of neem and urmoi due to higher volatilization of the active components in turmeric.

Sahayaraj and Paulraj (1998) carried out an experiment in the laboratory to evaluate the effect of water extracts of different plant leaves in insect pest control. Various concentrations of the extracts (0.5, 1, 2, 4, and 6%) were used against last instar larvae of the groundnut pest *Spodoptera lotura*. *Calotropis gigantean* was found to be the most toxic plant product followed by *Vitex nigrndo*, *azakirachta indica* and *Pongamia glabra (P. pinnata).*

Rahman (1998) evaluated the extracts and dust of Urmoi, Neem and Turmeric for their repellency, feeding deterrence, 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 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 inhibition rate of two weevil species reduced significantly in almost all treatments compared to control and reduction was significantly dose dependent.

Perveen *et al.* (1998) used mithanol extracts of two indigenous plants, *Calotropis gigantean* Linn. (Akando) and *Ipomoea nil* Linn (Kaladanah) *[Pharbitis nil]* and evaluated for their toxicity against the adults of *Sitophilus oryzae* Linn, *Tribolium castanium* Herbst and *Cryptolestes ferrugineus* (Stephens) after 24 hours of treatment. The $LD5_0$ of *C. gigantean* 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. *C. ferrugineus* was more susceptible to *C. gigantean* and *P. nil* than *S. oryzae* and *T. castameum.*

Kalasagond (1998) noticed the mortality of *S. oryzae* at 60, 120, 180 and 240 days after treatment with 0.8, 1.0, 1.2 and 1.4 percent neem seed powder in wheat grains were 25.00, 8.33, 8.33 and 6.66 percent, 43.33, 26.66, 25.00 and 8.33 percent, 51.66, 41.66, 35.00 and 10.00 percent, 61.66, 53.33, 43.33 and 26.66 percent, respectively as against 0.00, 0.00. 6.66 and 5.00 in untreated control.

Rama and Sarangi (1998) reported neem seed powder (5%) as a effective grain protectant against *S. oryzae* with 87.70 per cent mortality which reduced to 82.50 per cent from 30.00 to 90.00 days after treatment. Neem seed kernel powder @ 4 per cent when mixed with maize grains effectively protected the grains for 5 months against *S. oryzae* attack (Sharma, 1999).

Khan and Shahjahan (1998) reported that dried powdered *Eucalyptus teretocornis* leaves were extracted with n-hexane, acetone, ethanol and methanol and the extracts were tested to observe their effects on adults of *Sitophilus oryzae* and *C. chinensis.* Results showed that in *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.

Hiremath *et al.* (1997) tested methanol extracts of 84 samples of 49 Indian plants species for insecticidal activities against *Nilaparvata lugens* by topical application method at a dose of 0.5µg/female. The identified significant and toxic plants species were *Adahota vasica* leaves (100% mortality), *Annanosa squamosa* seeds (100%), *Nerium indicum* stems (100%), *Clerodendrum inerme* whole plants (90%), *Azadirachta indica* seeds (89%), *Azadiracta indica* stems (85%) *Aegle marmelos* leaves (88%) and *Madhuca indica* seed oil (88%).

Sanguanpong (1996) formulated various essential oils and volatile substances were explored based on insecticidal properties and non-direct contamination method for protecting rice grain damage caused by rice weevil. Their biological activities against *Sitophilus oryzae* such as feeding deterrence, reproductive inhibition and progeny development disrupting were determined.

The repellency and toxicity of *Azadirachtin* and 3 neem extracts to 3 stored product insects, *Cryptolestes ferrugineous, 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.

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

Weaver *et al*. (1995) stated that volatile components of dried leaves of *Artemisia tridentata* (Nutt.) and *Monarda fistulosa* L. were terpenoids with camphor, (9.7 mg/g) and 1,8-cineole (4.0 mg/g) but abundant in *A. tridentata* and carvacrol (26..3 mg/g) largely available in *M. fistillosa*. Both plant species were less effective against the rice weevil in wheat. The maximal control achieved against *S. oryzae* was less than 50% at 3% w/w.

Talukder and Howse (1994 and 1995) reported that the seed extracts of *Aphanamixis polystachya* had strong repellent effects on red flour beetle and rice weevil. Hussain (1995) studied that the extracts of *Ploygonum hydropiper* and *Annona squamosa* were repellent effect on adults of *T. castaneum.*

Xu Hanhong and Zhao Shanhuan (1994) reported that cassia oil mixed with wheat flour completely inhibited the reproduction of *S. zeamais*, *R dominica* and *T. castaneum.* Sharma (1995) tested that neem leaf powder and cob ash to find out their efficacy on stored maize. Both the tested compounds at different dosages were effective in reducing grain damage and adult emergence of *R. dominica.*

Talukder and Howse (1994 and 1995) mixed leaf, bark and seed powders of pithraj with pulses, wheat grains and wheat flour and observed that the treated food effectively reduced the oviposition rate, egg hatching rates, emergence of F_1 adults of *C. Chinensis, S. granarius* and *T. castaneum.*

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 ripe berries of *Azadirachta indica* against *S. oryzae* was determined. The tests were carried out by releasing the curculionids on treated filter papers treated with different concentration of the compounds. A mortality rate of 90 % was obtained with a 0.5 % conc. of cyfluthrin and a 1 % conc. of the neem compound.

Prakash *et al.* (1993) observed that twenty plant products were evaluated against *Sitophilus oryzae.* Only seven products significantly reduced adult populations and weight loss of grain. Neem seed oil was the most effective, followed by *Piper nigram* seed powder, leaves of *Vitex neganda,* leaves of *Andrographis paniculata,* dried mandarin fruit peel, rhizome powder of turmeric and seed powder of *Cassia fistula,* respectively.

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

Valsamma and Patel (1992) tried the neem leaf powder (10%) against pulse beetle, *C. analis* on green gram and reported that at 30 and 60 days after treatment, the seed damage was 4.3 and 4.8 per cent as against 9.7 and 22.8 in untreated control.

Niber *et al.* (1992) tested plant extracts of *A. indica*, *Ricinus communis* and *Solanum nigrum* for their toxicity to three species, *Acanthoscelides obtectus, Prostephanus tuncatus* and *Sitophilus oryzae* under laboratory condition. Crude ethanol extract at concentration at 10 % (w/v) were used as topical application.

The effects of the plant extracts were compared with those of three extracts and the crude materials were most toxic to the three pest species.

Ryoo and Cho (1992) carried out an experiment and found that exposure of first instar nymphs of *Dysdercus koenigii* between 24 and 48 hours old in Eucalyptus oil odor for 2 hours resulted in greater mortality in the 3^{rd} instar.

Sharaby (1989) studied on the effects of powdered guava and eucalyptus leaves admixed with rice grains on adults of *S. oryzae* and *S. granaries.* Guava was found rather more toxic (LD_{50} value about 2.2g /100g rice grains in each case) than the eucalyptus (LD_{50} value about 4.1- 4.6g). Sub-lethal doses above the LD_{50} value suppressed the development of progeny sat doses 15 g rice grains.

Kashyap *et al.* (1992) determined the efficacy of powdered dry leaves of *V. negundo, Ageratum haustorianum, Mentha longifolia, Cinnamomum tamala, Cannabis sativa, Lantana camara, Murraya koenigii* and *Eucalyptus sp.* in controlling *Phthorimaea operculella* on stored potato. They found *A. haustorianum, V. negundo M. longifolia* protected potatoes for up to 120%.

Khalequzzaman and Islam (1992) stated that various extracts of leaves of *Datura metel* were tested for their effects on 2 stains of *Tribolium castaneum* when applied topically, all extracts were toxic to the pests, a methanol extracts was the most toxic.

Mishra *et al.* (1992) reported that seed powder at 0.5 percent (w/w) retained its effect for longer duration causing 100, 96.70, 83.30 percent adult weevil mortality at 30, 60 and 75 days after treatment. Neem seed powder at 0.5, 1.00 and 2.5 g per kg of maize seeds recorded cent per cent mortality within five days after treatment and protected seeds for six months without affecting the seed viability. Neem seed kernel powder at 2 percent (w/w) was found effective in protecting maize seeds against *S. oryzae* for two weeks (Sharma, 1995).

Chander *et al.* (1991) conducted laboratory studies to evaluate the efficacy of turmeric powder and mustard oil as protectants for milled rice against *S. oryzae* Linn. They observed that turmeric powder alone did not because significant mortality except at 2 or 4% concentration after 3 months storage interval. Mustard oil at 4 or 8 ml/kg dosage gave appreciable mortality of *S. oryzae* at all storage intervals. One or 2 ml/kg dosage reduced *S. oryzae* progeny by 40% even after 6 months of storage. The 4 ml/kg dosage of Mustard oil combining 1 - 2g of turmeric powder gave the best protection efficacy. Su (1991) reported that essential oil of *Chenopodium ambrosoides* was moderately toxic to *S. oryzae* (52.5% mortality at 50 mug/insects).

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

Bhuiah and Quinones (1990) treated the corn with leaf powder of biskatali and found effective on oviposition and adult emergence of *S. zeamais.* Adgesh and Rejesus (1991) observed the residual toxicity by the admixture treatment of oils and powders from neem, lagundi, *V. negundo against S. zeamais*, *R. dominica* and *C. chinensis* on stored grains.

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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. 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). Su (1989) treated wheat with dill seed extract and found that it reduced the F_1 adult emergence of *S. oryzae.*

Singh (1987) evaluated six plant extracts against *R. dominica* in the laboratory, extracts of neem, *Azadirachta indica, Bassia longifolia* and *Pongamia glabra* were highly toxic. The crude extract of water hyacinth *(Eichhornia rassipes)* was evaluated for its biological activity against the *T. castanium. S. oryzae*, *Callosobruchus maculates* and *C. cephalonica.*

Jilani and Saxena (1987) observed that neem, turmeric and sweetflag have repellent action on stored grain pests.

Das (1986) studied on the pesticidal properties of the oils of neem, coconut, sesame, mustard or soybean mixed with pulses and found that all *C. chinensis* adults died after four days of release into treated foods. He also reported that neem oil was found to be superior to til oil for its protectant activity. He checked the weight loss of treated seeds of khesari, lentil and chickpea. No adverse effect on the germination of the oil treated seed was observed.

Ahmed and Eapea (1986) screened plant extracts and found that those from Gaultheria, dill *(Anethus graveoleus),* Japanese mint *(Mentha sp.)* and Eucalyptus and cineole and turpentine were promoting and strong repellent against *Sitophilus oryzae* and *Callosobruchus chinensis.*

Karim (1986) reported that local botanicals like dholkolmi *(I. sepiara)* and dutura *(Datura fastuosa)* were found very effective in killing on an average 88 % of the hispa adult at 48 hours after application.

Jilani (1986) conducted experiments with ethanolic extract of neem seed; hexane extract of sweetflag, *Acorns calamus* rhizome and thymel 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 *(Anethum graveoleus),* Japanese mint *(Mentha),* eucalyptus, cineole and turpentine were promising as strong repellents against *S. oryzae* and *C. chinensis.*

Long term studies were carried out in Poland on the stored grain pest *Sitophilus granarium* and on the behavior of the pest was tested with 54 extracts from 28 plant species for their repellent activity. The most effective repellent was found in Caraway extracts, the main component of which is carvone (Nawrot, 1985).

Several indigenous plant materials have traditionally been used as stored grain protectants against insect pest in various parts of the world. Bowry *et al.* (1984) reported that oils and seed cake powders of neem, linseed, castor, mahua and mustard showed repellent action on *Sitophilus oryzae.* The neem preparation was most effective in reducing oviposition.

Stoyanova and Shikrenov (1983) reported that Phosphine preparations (Phostoxin and gastoxin) against rice weevil of stored wheat at the rate 6 and 10 tablets/ton caused 100%

mortality. Yadav (1983) advised 1.75 to 3.5g/1000 kg seed dose of aluminium phosphide fumigant with an exposure of 4-5days for effective control of *S. oryzae*. Laboratory study revealed that Ethylene dichloride was the best compound and carbon tetrachloride was the least effective against rice weevil (Chandra *et al.*, 1978).

Jilani and Su (1983) indicated the repellent activity of neem leaf powder to *S. granarius* and *R. dominica* on wheat seeds. It was reported that the average number of *R. dominica* adult emergence was 3.08, 5.16 and 20.16 with neem leaf powder used at 2.0 and 1.0 per cent and untreated control, respectively. This repellent activity of neem leaf powder was supported by Banarjee and Nigam (1985).

According to Abivardi (1976), adults of *Bruchus lentis*, *B. rufimanus*, *B. pisorunt, Callosobruchus chinensis*, *Sitophilus granarius* and *S. oryzae*, larvae of *Plodia interpunctella* and adults and larvae of *Trogoderma granarium* and *Tribolium confusum* were exposed to camphor (1,7,7 trimethylbicyclo (2.2.1) heptanc 2 one) at 5 concentrations in air tight containers in the laboratory. The result showed that the last 5 species were not controlled; there was 100% mortality *of B. lentis, C. chinensis*, *B. rufimanus* and *B. pisorum* at 12, 24, 48 and 96 ppm, respectively.

Ketkar (1976) reported that neem seed powder at 0.5 percent of grain reduced *S. oryzae* population. Chander and Ahmed (1983) reported that neem leaf powder at 5 per cent (w/w) protected the wheat seeds against *S. oryzae* infestation for three months.

Cotton (1963) reported that carbon disulphide was six times more toxic than carbon tetrachloride against *S. oryzae*. Complete mortality of larvae of rice weevil was achieved by using 1-3 aluminium phosphide tablets/ton for 15 days (Rai *et al.*, 1963).

2.5.2. Fumigants as management practices

Rajendran and Sriranjini (2008) studied a Research on plant essential oils and their constituents as fumigants, i.e., compounds acting on target insects in the vapour or gaseous phase, against stored-product insects have been reviewed. Fumigant toxicity tests conducted with essential oils of plants (mainly belonging to Apiaceae, Lamiaceae, Lauraceae and Myrtaceae) and their components (cyanohydrins, monoterpenoids, sulphur compounds, thiocyanates and others) have largely focused on beetle pests such as *Tribolium castaneum*, *Rhyzopertha dominica*, *Sitophilus oryzae* and *Sitophilus zeamais* but little or no attention has been paid towards moths such as *Corcyra cephalonica* and *Sitotroga cerealella*. Adults were generally susceptible, whereas, eggs were either tolerant or highly susceptible depending on insect species and the type of essential oil or component. The essential oils proved effective in mixture with CO< sub>2</ sub> or ethyl formate. Mode of action studies on monoterpenoids indicate inhibition of acetylcholinesterase enzyme activity as the major site of action. Although, in laboratory tests with adult insects, some of the plant compounds have shown insect toxicity comparable to methyl bromide or chloropicrin, their physical properties such as high molecular weight as well as high boiling point and very low vapour pressure are barriers for application in large-scale fumigations. Plant products, therefore, have the potential for small-scale treatments, space fumigations and as adjuvants for conventional fumigants. The constraints including lack of data for single or multiple components of essential oils on absorption, tainting and residues in food commodities, and registration protocols have been highlighted. The use of egg and pupal stages or preferably mixed-age cultures of target insects in screening tests with any new plant essential oil/compound has also been stressed.

Rahman *et al.*(2006) reported that three additives, i.e. white crystalline camphor, white lime powder and dried neem leaves, were evaluated for protection of unhusked rice in storage from the infestation of Angoumois grain moth, *Sitotroga cerealella*, in three successive generations. The additives significantly reduced the emergence of adult moths, loss of grain weight and percentage of infested grain with the best result found with camphor. Lime powder and neem leaves showed 41.94-75.19% and 59.68-64.62% infestation reduction, respectively, whereas camphor kept the infestation reduction from 78.46-89.14%. The overall results revealed the best performance of camphor at a rate of 4.5 g/kg rice grain in suppressing the moth in storage. The other two additives, i.e. dried neem leaves at a rate of 71 g/kg grain and lime powder at a rate of 7.0 g/kg grain also showed satisfactory results.

Arivudainambi *et al.* (2005) reported that the Fumigant toxicity of neem volatiles has been evaluated for various biological effects on *Sitotroga cerealella*. Neem seed volatiles were isolated from neem seed oil and evaluated for their bioactivity against eggs, 2- and 15-day-old larvae, and adults of *S. cerealella.* All stages were susceptible to different doses of volatiles. The volatiles at 200-25 micro litres caused 100% adult and grub mortality. The eggs when exposed to 50-200 micro litre dose for 3 days failed to hatch. There was no ovicidal activity at lower doses (25, 10 and 5 micro litres). The time-dependent effects of the volatiles proved lethal to the adult insects.

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Phostoxin

Phostoxin consisting 56% aluminium phosphide has been found to be effective against grain insects and their pre-adult stages, eggs, larvae and pupae. These includes rain and rice weevils *sitphilus oryzae*, s. Granarius, satooted grain beetle, confused flour bettle (*tribolium confusum*), lesser grain borer (*Rhizopertha dominica*), cadella beetle *Tenebroides mauritanicus*), khapra beetle (*trogoderma granarium*), grain moth (*epthestia elutella*), indian meal moth (*lodia interpunctella*), mediterranean flour moth (epthestia kuehniella) and angoumois grain moth (*sitotroga cerealella*). The chemical phostoxin is aluminium phosphide (Wayne *et al.*, 1953), which is used as a rodenticide, insecticide, and fumigant for stored cereal grains (Mehrpour and Singh, 2010). As a pesticide, aluminium phosphide can be encountered under various brand names, e.g., Celphos, Fumitoxin, Phostoxin, and Quick Phos.

Stoyanova and Shikrenov (1983) reported that Phosphine preparations (Phostoxin and gastoxin) against rice weevil of stored wheat at the rate 6 and 10 tablets/ton caused 100% mortality. Yadav (1983) advised 1.75 to 3.5g/1000 kg seed dose of aluminium phosphide fumigant with an exposure of 4-5days for effective control of *S. oryzae*. Laboratory study revealed that Ethylene dichloride was the best compound and carbon tetrachloride was the least effective against rice weevil (Chandra *et al.*, 1978).

Camphor

Camphor is a waxy, white or transparent solid with a strong, aromatic odor. It is a terpenoid with the chemical formula $C_{10}H_{16}O$. It is found in wood of the camphor laurel (*Cinnamomum camphora*), a large evergreen tree found in Asia (particularly in Borneo and Taiwan) and also of *Dryobalanops aromatica*, a giant of the Bornean forests. It also occurs in some other related trees in the laurel family, notably *Ocotea usambarensis*. Dried rosemary leaves (*Rosmarinus officinalis*), in the mint family, contain up to 20% camphor. It can also be synthetically produced from oil of turpentine. It is used for its scent, as an ingredient in cooking (mainly in India), as an embalming fluid, for medicinal purposes, and in religious ceremonies. A major source of camphor in Asia is camphor basil.

The biological activity of camphor, a major component of essential oil of the basil shrub, Ocimum kilimandscharicum, against the beetles, *Sitophilus granarius, S. zeamais, Tribolium castaneum* and *Prostephanus truncatus*, was investigated in the laboratory using contact toxicity, grain treatment and repellency assays. Camphor applied either topically, impregnated on filter papers or whole wheat and maize grains was highly toxic to all the four species. Beetle mortality was dosage-dependent with the highest doses of 100 mg/ filter paper and 100 mg/insect evoking over 93% and 100% mortalities, respectively, in *S. granarius, S. zeamais* and *P.truncatus* after 24 h exposure. Similar doses induced 70% and 100% mortality in *T. castaneum.* Camphor impregnated on the grain surface was more effective than on filter paper. There was, however, highly significant reduction in toxicity in grain after only 24 h following treatment. Development of eggs and immature stages within grain kernels, as well as progeny emergence, was completely inhibited in camphor-treated grain. Camphor was also highly repellent to the beetles with overall repellency in the range of 80 - 100%. The potential use of suitable products derived from *O. kilimandscharicum* as supplementary or alternative grain protectants against insect damage in traditional grain storage in developing countries is discussed.

It is widely used for medicinal purposes, and in religious ceremonies (Mann *et al.*, 1994). In extreme cases, even topical application of camphor may lead to hepatotoxicity

(Bishop and Sanders, 2000). Lethal doses in adults are in the range 50–500 mg/kg (orally). Generally, 2 g causes serious toxicity and 4 g is potentially lethal (Martin *et al.*, 2004). Abiverdi (1977) reported that the insecticidal efficacy of camphor. Chauvin *et al*. (1994) reported that the camphor has fumigation properties and has got a very low mammalian toxicity.

Naphthalene

Naphthalene, also known as naphthalin, is a crystalline, aromatic, white, solid hydrocarbon with formula $C_{10}H_8$ and the structure of two fused benzene rings. It is volatile, forming a flammable vapor, and readily sublimes at room temperature, producing a characteristic odor that is detectable at concentrations as low as 0.08 ppm by mass (Amoore and Hautala, 1983). The most familiar use of naphthalene is as a household fumigant, such as in mothballs. In a sealed container containing naphthalene pellets, naphthalene vapors build up to levels toxic to both the adult and larval forms of many moths that attack textiles (Bryn, 2002) and other stored cereals.

Weaver *et al.* (1995) stated that volatile components of dried leaves or *Artemisia tridentata* (Nutt.) and *Monarda fistulosa* L. were terpenoids with camphor, (9.7 mg/g) and 1,8-cineole (4.0 mg/g) but abundant in *A. tridentata* and carvacrol (26..3 mg/g) largely available in *M. fistillosa*. Both plant species were less effective against the rice weevil in wheat. The maximal control achieved against *S. oryzae* was less than 50% at 3% w/w.

2.5.3.. Insecticides as management practices

Farid *et al.* (2002) reported that the acaricides Agrifol (20% dicofol at 2 and 4 ml/litre), Ethion (10% hexythiazox at 3 and 6 ml/litre), Nissoron (46.5% phosphorodithioate at 1 and 2 g/litre) and sulfur (at 10 and 20 mg) were tested to determine which is the least toxic to *S. cerealella* (used as factitious host for mass rearing *Trichogramma*). Treating *S. cerealella* eggs with the acaricides did not have a significant effect on hatching. When the rearing medium of S. cerealella (wheat grains) was treated with acaricides, Ethion almost completely suppressed *S. cerealella* emergence, indicating its high toxicity to the moth. Agrifol at 4 ml/L also reduced moth emergence significantly. The effects of the rest of the acaricides and concentrations used were similar to those of the control. No acaricides exerted any selective sex-based mortality of *S. cerealella.* None of the acaricides reduced adult longevity. Agrifol at 2 or 4 ml/L and Nissoron at 1 g/L did not have adverse effects on *S. cerealella* fecundity. The higher concentration of Nissoron (2 g/L) and sulfur reduced the moth fecundity. Percent hatching did not differ among all treatments including the control. Based on the parameters of *S. cerealella* development, Nissoron at 1 g/L and Agrifol at 2 ml/L were the least toxic for moth development.

Pathak *et al.* (2001) treated maize and rice seeds with dust formulation of deltamethrin, chlorpyrifos-methyl, etrimfos and malathion at 3, 30, 10 and 40 ppm, respectively, were stored in jute and polypropylene bags at Delhi and Meghalaya, India up to 180 days. Amongst four insecticidal treatments, deltamethrin showed high kill of 93.3-96.7% against Sitophilus oryzae on maize in jute and polypropylene bags stored at Delhi and Meghalaya. Chlorpyrifos-methyl was also equally effective against *Sitophilus oryzae* at Delhi. However, at Meghalaya, it deteriorated in jute bags and only 36.7% kill was recorded. Etrimfos degraded drastically in polypropylene bags and showed only 10% kill at Delhi and 53.3% kill at Meghalaya. Malathion gave 46.7% kill in jute and 96.7% in polypropylene bags at Meghalaya. Deltamethrin was found superior against *Sitotroga cerealella* at both places and polypropylene bag provided better protection over jute bags.

Treatment of packing materials with celphos @ 56 g a.i./28 m^3 or with malathion @ 0.1 protected paddy seed stored in the structures prepared from these packing materials and grains from *Sitotroga cereslella* and *Sitophilus oryzae* (Borah and Mohan, 1981). Dichlorovos is considered as a fumigant because of its vapor action. It does not penetrate into commodities but is used to kill insects in empty space inside a storage structure or godown. It also acts as a contact, stomach poison and is one of the safest organophospate insecticides. DDVP was also reported as a n effective grain protectant against moth pests (Anon., 1978). Dichlorvos strips suspended in the over space in galvanized metal bins containing rough rice reduced the infestation of *Sitotroga cereslella* about 99% within six weeks and eliminated its population by 12 weeks (Cogburn *et al*., 1983). In galvanized metal bins storing rough rice for 12 months, fumigation with phosphene reduced infestation of *Sitotroga cereslella* by 99% but its population began to recover immediately after treatment (Cogburn *et al*., 1983).

CHAPTER III

MATERIALS AND METHODS

The study was conducted to explore the efficiency of easily available botanicals and fumigants for eco-friendly management of rice moth, *Sitotroga cerealella* on stored rice grain in the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka during the period of May, 2011 to November, 2011. The study was conducted under following two separate experiments.

Experiment 1: Efficacy of some botanicals for the management of rice moth, *Sitotroga cerealella* in stored paddy

Experiment 2: Efficacy of some fumigants for the management of rice moth, *Sitotroga cerealella* in stored paddy

The details of the procedure for two experiments have been described under the following sub-headings:

Experiment 1: Efficacy of some botanicals for the management of rice moth, *Sitotroga cerealella* in stored paddy

This experiment was conducted to evaluate the efficiency of five promising botanicals viz., dried neem, bishkatali, marigold, mehogoni leaves, bulb of garlic applied against rice moth, *S. cerealella* infesting stored rice in the laboratory condition. The detail procedure of the experiment has been described below:

3.1.1. Design of experiment

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

3.1.2. Materials used in the study

Twenty four kg of newly harvested paddy grains (BR 28) were purchased and collected from the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka. Collected seeds were sun dried on the cemented floor for three consecutive days in the month of April, 2011 and kept the rice grains in 24 plastic pots maintaining one kg per pot and the pots were kept in ambient room temperature in the laboratory under the Department of Entomology of Sher-e-Bangla Agricultural University. The moisture content of the grains was 10-12% measured by using a digital moisture meter with the technical help and support from the Seed treatment and preservation center of BADC, Gabtoli, Dhaka.

3.1.3. Viability test of the seeds

The germination test of collected paddy seeds were also conducted, where pre-soaked rice seeds were kept on the blotting papers placed on the petridishes and kept in the ambient temperature in the laboratory. Watering and other necessary practices were done and percent seed germination of the paddy seeds were counted and recorded.

3.1.4. Treatments

The five promising botanicals viz., dried leaf powders of neem, bishkatali, marigold, mehogoni and bulb of garlic were evaluated in this study, where each botanical was treated as an individual treatment. Besides these botanicals, one untreated control was also maintained. The treatments and their doses selected for the study have been furnished below:

Treatments	Botanicals	Dose of the botanicals
T_1	Dried neem leaf powder	2.5 g /kg paddy grains
T_2	Dried bishkatali leaf powder	2.5 g /kg paddy grains
T_3	Dried marigold leaf powder	2.5 g /kg paddy grains
T_4	Dried mahogoni leaf powder	2.5 g /kg paddy grains
T_5	Bulb of garlic	1 g /kg paddy grains
T_6	Untreated control	No botanicals were used

3.1.5. Collection and preparation of botanicals

The leaves of neem, bishakatali, marigold and mehogani were collected from the Jahangirnagar University and Shere-e-Bangla Agricultural University in February to March, 2011. The leaves were then directly sun dried on metal tray for 5 consecutive days until completely dried up. Each type of dried leaves was then crushed separately with the help of an electric grinder. Before crushing, the grinder was cleaned carefully for each type of plant leaves to avoid contamination. Each type of powdered leaf was then taken into a separate plastic pot and stored in cool dry place for use in the study. The bulb of garlic, *Allium sativum* Linn. was purchased from Agargaon bazaar, Dhaka. The scale leaves of garlic were removed from the bulbs, then the bulbs were chopped into pieces with the help of a sharp knife and kept in a petridish to use in the study.

3.1.6. Application of the botanicals

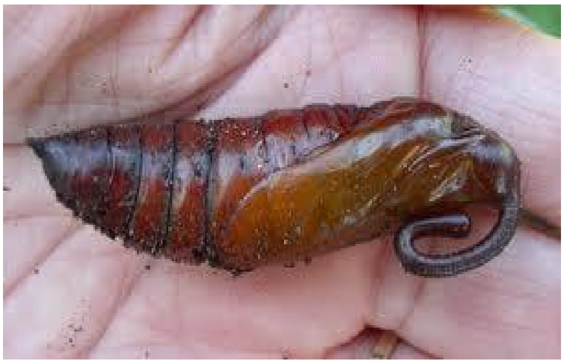
The 2.5 gm (0.25% w/w) of the grinded powders of the dried neem leaves were thoroughly mixed with 1 kg of the paddy seeds that were kept in a container of the plastic pot. Similarly, the rest 3 containers of the plastic pot for neem leaf based treatment were thoroughly mixed with 2.5 g of the grinded powders of the dried neem leaves in each container containing one kg of selected paddy grains. Similar procedures were also followed with same doses (2.5 g) of grinded powders of the bishkatali, marigold and mehagoni leaves for each container and replicate four times under the experiment for used of four replications. In case of bulb of garlic, chopped one g garlic bulb (0.10% w/w) was thoroughly mixed with each 1 kg of the paddy seeds that were already kept in each container of plastic pot. Similarly the rest 3 plastic pots were thoroughly mixed with same dose of chopped bulb of garlic which contains one kg of rice in each container. No botanicals were mixed in rest of four containers of each category that were also kept one kg of selected rice grains as untreated control.

3.1.7. Release of the rice moth, *S. cerealella*

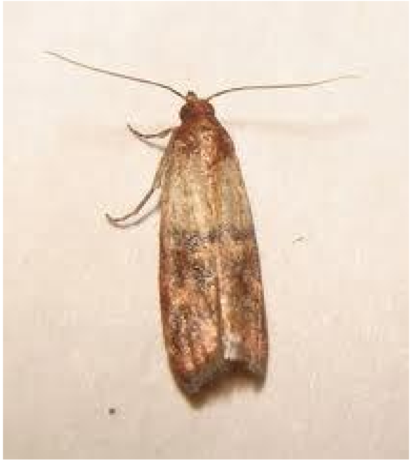
The eggs of rice moth collected from the laboratory under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka were released in the rice grains kept in plastic containers assigned for each treatment. About 500 newly laid eggs (10 mg) of rice moth were released on the rice grains kept in each container. Immediately after the release of the rice moth eggs, each container was covered with its lid. The plastic containers with rice grains for each treatment were preserved in ambient temperature in the laboratory up to 6 months that is 180 days after egg release (DAER) for recording data.

Plate#1a. Full grown larva of *Sitotroga cerealella*

Plate#1b. Full grown larva of rice moth inside the rice grain



Plate#02. Pupa of rice moth, *S. cerealella*



Plate#03. Adult rice moth

Plate#04. Infested rice grains showing holes caused by the adult emergence

3.1.8. Data sampling

The data on grain infestation by number and weight, grain content loss, and seed germinations were recorded. The data were collected and recorded at 30 days intervals started from 30 DAER and continued up to 180 DAER considering the sampling procedure. For each sample, 100 rice grains from each replicate of each of the treatment were randomly drawn at each data recording time. The sample was taken from the middle of each container (10-15 cm below from the surface) by inserting a spoon. From each of the samples, 100 grains were used to record the data for each time and each parameter.

3.1.9. Data collection and calculation

The data on the grain infestation by number and weight, grain content loss, and seed germinations were recorded.

3.1.9a. Data on grain infestation by number and weight

The number and weight of infested grains plate (4,5)was counted for each sample of 100 grains. The infested grains were identified by recognizing the bore grains caused by the rice moth after emerging (plate 2) adult from the grains. Magnifying lens and simple microscope were also used in that purpose. The percent grain infestation and percent reduction of grain infestation over control were then calculated using the following formulae (Khosla, 1997):

$$\text{Percent grain infestation} = \frac{\text{Number of infested grains}}{\text{Number of total grains observed}} \times 100$$

$$\text{\% reduction of grain infestation over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where X_1 = Mean value of treated pot

X_2 = Mean value of untreated pot

Plate#5. Infested rice grains showing holes caused by the adult emergence

3.1.9b. Data on grain content loss

The weight (g) of the 100 grains sample for each treatment were measured and recorded at initial stage of the experiment, i.e., before setting the experiment and the weight of 100 grains were measured and recorded for each treatment at each data recording time from 30 days after egg release. DAER to 180 DAER. Finally, the percent grain content loss was calculated using the following formula:

$$\%\ \text{grain content loss} = \frac{\text{Initial weight of grains} - \text{Weight of grains at data recording time}}{\text{Initial weight of the grains}} \times 100$$

$$\%\ \text{increase of grain content loss over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where X_1 = Mean value of treated pot
X_2 = Mean value of untreated pot

3.1.9c. Data on seed germination

The viability of stored rice grains were assessed through seed germination test (Plate 6). The viability test was done to determine whether or not the rice moth infestation can affect seed germination. The germination rate of the rice seeds was determined at each data recording time from 30 to 180 DAER. The 100 seed sample for each treatment was taken randomly and placed those in water soaked blotting papers in Petridish, and preserved for 5 days at room temperature ranging from $27^{o}C$ to $34^{o}C$ for maximum germination of the seeds. After complete germination, the number of germinated seeds was counted and recorded. Finally, the percent seed germination and percent increase of seed germination over control were calculated using the following formulae:

$$\text{Percent seed germination} = \frac{\text{Number of germinated seeds}}{\text{Number of total seeds tested for germination}} \times 100$$

$$\text{\% increase of seed germination over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where X_1 = Mean value of treated pot
X_2 = Mean value of untreated pot

Plate#6. Germination test of stored rice seed

3.1.10. Economic analysis of the botanical based management practices

Economic analysis in terms of Benefit Cost Ratio (BCR) was analyzed on the basis of total expenditure of the respective management treatment along with the total return from that particular treatment using different botanical based treatments against rice moth on rice grains in storage. In this study, BCR was analyzed for the weight (1 kg) of rice grains stored for each treatment considering following parameters given below:

Treatment wise management cost/variable cost: This cost was calculated by adding all costs incurred for labors and inputs for each management treatment along with untreated control during the entire storing period. The grain saved from rice moth infestation (kg/pot) for each treatment was achieved by subtracting the amount of grain content loss from the initial weight of the grains stored and then the amount (kg) of grain saved was converted into amount of grain saved in ton.

Gross Return (GR): The yield in terms of money that was measured by multiplying the total grains saved after the completion of the study by the unit price of rice grains (Tk 18/kg).

Net Return (NR) = The Net Return was calculated by subtracting treatment wise management cost from the gross return.

The Net Return was calculated by subtracting the cost of untreated treatment from treatment wise management cost of gross return.

Adjusted Net Return (ANR): The ANR was determined by subtracting the net return of the control treatment from the net return for a particular management treatment.

Benefit Cost Ratio (BCR): Finally, BCR was calculated for each management treatment using botanicals to justify the economic basis of the management practices using the following formula described by Elias and Karim (1984):

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Adjusted net return}}{\text{Total management cost}} \times 100$$

Experiment 2: Efficacy of some promising fumigants for the management of rice moth, *Sitotroga cerealella* in stored rice

This experiment was conducted to evaluate the efficiency of three promising fumigants viz. camphor, phostoxin and naphthalene applied against rice moth, *S. cerealella* infesting stored rice in the laboratory condition. The detail procedure of the experiment has been described below:

3.2.1. Design of the experiment

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

3.2.2. Materials used in the study

Sixteen (16) kg of newly harvested rice grains (BR 28) were purchased and collected from the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka. The collected rice seeds were then used in this experiment as mentioned earlier in the Experiment 1.

3.2.3. Viability test of the seeds

The germination tests of collected rice seeds were also recored and percent seed germination of the rice seeds were also counted and recorded as mentioned earlier in the Experiment 1.

3.2.4. Treatments

There were three promising fumigants viz., camphor, phostoxin and naphthalene evaluated in this experiment, where each fumigant was treated as an individual treatment. Besides these fumigants, one untreated control was also considered. The treatments and their doses selected for the experiment have been furnished below:

Treatments	Fumigants	Dose of the fumigants
T_1	Camphor	1.0 g /kg paddy grains
T_2	Phostoxin tablet	200 mg /kg paddy grains
T_3	Naphthalene	500 mg /kg paddy grains
T_4	Untreated control	No fumigants were used

3.2.5. Collection and description of the fumigants

The camphor, phostoxin tablet and naphthalene were from local market of the Agargaon bazaar, and Siddik bazaar, Dhaka. The brief description of the collected fumigants is furnished below:

3.2.5a. Camphor

Camphor is a white transparent waxy crystalline solid with a strong penetrating pungent aromatic odor. It is found in wood of the camphor laurel, *Cinnamonum camphora*, which is a large evergreen tree found in Asia (particularly in Borneo and Taiwan). It is widely used for medicinal purposes, and in religious ceremonies (Mann *et al.*, 1994). In extreme cases, even topical application of camphor may lead to hepatotoxicity (Bishop and Sanders, 2000). Lethal doses in adults are in the range 50–500 mg/kg (orally). Generally, 2 g causes serious toxicity and 4 g is potentially lethal (Martin *et al.,* 2004). Abiverdi (1977) reported that the insecticidal efficacy of camphor. Chauvin *et al*., (1994) reported that the camphor has fumigation properties and has got a very low mammalian toxicity.

3.2.5b. Phostoxin

Phostoxin is available in the market at its tablet or pellet form. The chemical name phostoxin is aluminium phosphide (Wayne *et al.,* 1953), which is used as a rodenticide, insecticide, and fumigant for stored cereal grains (Mehrpour and Singh, 2010). As a pesticide, aluminium phosphide can be encountered under various brand names, e.g. Celphos, Fumitoxin, Phostoxin, and Quick Phos.

3.2.5c. Naphthalene

Naphthalene, also known as naphthalin, is a crystalline, aromatic, white, solid hydrocarbon with formula $C_{10}H_8$ and the structure of two fused benzene rings. It is volatile, forming a flammable vapor, and readily sublimes at room temperature, producing a characteristic odor that is detectable at concentrations as low as 0.08 ppm by mass (Amoore and Hautala, 1983). The most familiar use of naphthalene is as a household fumigant, such as in mothballs. In a sealed container containing naphthalene pellets, naphthalene vapors build up to levels toxic to both the adult and larval forms of many moths that attack textiles (Bryn, 2002) and other stored cereals.

3.2.5d. Untreated control

The grains used as untreated control were never treated with any of the fumigants, but only the eggs of rice moth were released on the paddy grains, and stored in respective container and preserved for infestation from which necessary data were recorded.

3.2.6. Application of the fumigants

About 16 kg of the selected paddy grains were taken and distributed in 16 plastic pots each having one kg of the grains. One (1.0) gm of powdered camphor was thoroughly mixed with the grains of each of the pots and the same dose of camphor was mixed with the grains of other three pots to maintain 4 replications. Similarly, 200 mg of phostoxin tablet was thoroughly mixed with grains of 4 containers assigned for phostoxin. Similarly, 500 mg of naphthalene were also mixed with the grains of each container assigned for naphthalene. The last 4 plastic pots with grains were kept as untreated control, i.e. no fumigants were added with the grains.

3.2.7. Release of the rice moth, *S. cerealella*

The eggs of rice moth were released on the rice grains for each treatment and replication considering the similar procedure as mentioned in the earlier experiment. The containers were then covered with their respective lids and preserved in ambient temperature in the laboratory up to 6 months that is 180 days after egg release (DAER) for recording the data.

3.2.8. Data sampling, collection and recording

The data on grain infestation by number and weight, grain content loss, and seed germinations were recorded. The data were collected and recorded at 30 days intervals started from 30 DAER and continued up to 180 DAER considering the sampling procedure as mentioned earlier in the Experiment 1.

3.2.9. Economic analysis of the fumigant based management practices

Economic analysis in terms of Benefit Cost Ratio (BCR) was also analyzed on the basis of total expenditure of the respective management treatment along with the total return from that particular treatment using different fumigants based treatments against rice moth on rice grains in storage considering the procedure as mentioned earlier in the Experiment 1.

3.2.10. Data analysis

The data on above mentioned parameters for Experiment 1 & 2 were analyzed on one-factor CRD with the help of Computer based program MSTAT-C software. The means were 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 study was conducted to find out the extent of damage of stored paddy caused by rice moth, *Sitotroga cerealella* and its eco-friendly management using some promising botanicals and fumigants under two separate experiments in the laboratory under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from April, 2011 to November, 2011. The findings of the study have been interpreted and discussed under the following sub-headings:

Experiment 1. Effect of some botanicals for eco-friendly management of rice moth, *Sitotroga cerealella* Olivier on stored paddy

The significant variations were observed among five promising botanicals viz., dried neem leaf powder, dried bishkatali leaf powder, dried marigold leaf powder, dried dholkolmi leaf powder and bulb of garlic including untreated control applied against rice moth, *S. cerealella* Olivier and observed the effect on grain infestation by number and weight, grain content loss and viability of rice seeds.

4.1. Effect of botanicals on grain infestation by number

Significant variations among different botanicals were observed on the grain infestation by number during the management of rice moth, *S. cerealella* in the storage throughout the storing period from 30 to 180 days after egg release (DAER) on paddy (Table 1). In case of 30 DAER, the highest percent grain infestation (1.01%) was recorded in untreated control (T_6), where no botanicals were used followed by T_3 (0.74%) comprising dried marigold leaf powder @ 2.5 g/kg paddy, T_4 (0.66%) comprising dried mahogany leaf powder @ 2.5 g/kg paddy. On the other hand, the lowest percent grain infestation by number (0.41%) was recorded in T_1 comprised of dried neem leaf powder @ 2.5 g/kg paddy, which was statistically similar of that g T_5 (0.49%) comprising chopped bulb of garlic @ 1.0 g/kg paddy and T_2 (0.58%) comprising dried bishakatali leaf powder. In case of 60 DAER, the highest percent grain infestation (4.35%) was recorded in untreated control, which was statistically different from all other treatments followed by T_3 (2.58%) and T_2 (2.35%). On the other hand, the lowest percent grain infestation by number (1.60%) was recorded in T_1, which was statistically identical to that of T_5 (1.60%) followed by T_4 (2.10%). More or less similar trends of results were also observed for 90, 120, 150,180 DAER, but the level of infestations were increased with the increase of data recording time. In case of 180 DAER, the highest percent grain infestation (31.81%) was recorded in untreated control (T_6), which was statistically different from all other treatments followed by T_3 (17.84%) and T_2 (16.64%). On the other hand, the lowest percent grain infestation by number (9.39%) was recorded in T_1, which was statistically similar to that of T_5 (11.14%) followed by T_4 (11.89%).

Considering the grain infestation reduction over control, the highest reduction (72.77%) was recorded in T_1, followed by T_5 (69.13%), T_4 (66.16%). On the other hand, the lowest percent grain infestation reduction over control was recorded in T_3 (48.40%) and T_2 (52.43%). As a result, the trend of efficiency among different botanicals including untreated control in terms of percent grain infestation by number was T_1 (dried neem leaf powder) > T_5 (bulb of garlic) > T_4 (dried mahogany leaf powder) > T_2 (dried bishkatali leaf powder) > T_3 (dried marigold leaf powder) > T_6 (untreated control).

Table 1. Effect of botanicals on the grain infestation by number of stored paddy during the management of rice moth *S. cerealella* in storage

Treatment	Grain infestation (%) by number							% reduction of grain infestation over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Mean	
T_1	0.41e	1.60c	2.97d	4.52c	7.91c	9.39c	4.47d	72.77
T_2	0.58cd	2.35b	4.64b	8.44b	14.16b	16.64b	7.80bc	52.43
T_3	0.74b	2.58b	5.01b	9.34b	15.27b	17.84b	8.46bc	48.40

T_4	0.66bc	2.10bc	3.64cd	5.69c	9.32c	11.89c	5.55d	66.16
T_5	0.49de	1.60c	3.80c	5.11c	8.24c	11.14c	5.06d	69.13
T_6	1.01a	4.35a	11.64a	19.61a	29.99a	31.81a	16.40a	-
LSD $_{(0.05)}$	0.13	0.50	0.75	1.51	2.01	2.51	1.24	-
CV (%)	12.6	13.73	9.47	11.38	9.42	10.13	11.1	-

DAER = Days after egg release; In column, means followed by same letters are not significantly different at 5% level of significance by LSD. The values in the column are the means of 4 replications for each treatment.

[T_1= Dried neem leaf powder @ 2.5 g /kg paddy, T_2= Dried bishkatali leaf powder @ 2.5 g /kg paddy, T_3 = Dried marigold leaf powder @ 2.5 g /kg paddy, T_4 = Dried mahogany leaf powder @ 2.5 g /kg paddy, T_5 = Bulb of garlic @ 1.0 gm /kg paddy, T_6 = Untreated control]

4.2. Effect of botanicals on the grain infestation by weight

Significant variations among different botanicals were observed on the grain infestation by weight during the management of rice moth, *S. cerealella* in the storage throughout the storing period from 30 to 180 DAER on paddy (Table 2). In case of 30 DAER, the highest percent grain infestation (6.65%) was recorded in untreated control (T_6), which was statistically similar to that of g T_2 (6.44%) and T_3 (6.63%). On the other hand, the lowest percent grain infestation by weight (3.04%) was recorded in T_1, which was statistically different from all other treatments followed by T_5 (5.63%) that was statistically similar to that of T_4 (5.73%). In case of 60 DAER, the highest percent grain infestation (4.35%) was recorded in untreated control followed by T_3 (8.14%) and T_2 (7.75%). On the other hand, the lowest percent grain infestation by weight (5.78%) was recorded in T_1, which was statistically different from all other treatments followed by T_5 (7.25%) and T_4 (7.47%) (Table 2). More or less similar trends of results were also observed for 90, 120, 150,180 DAER, but the level of infestations were increased with the increase of data recording time. In case of 180 DAER, the highest percent grain infestation (38.82%) was recorded in untreated control, which was statistically different from all other treatments followed by T_3 (24.15%) and T_2 (23.21%). On the other hand, the lowest percent grain infestation by weight (13.06%) was recorded in T_1, which was statistically different from all other treatments followed by T_5 (17.14%) and T_4 (18.99%) (Table 1).

Considering the mean infestation of paddy by weight, the highest percent grain infestation (21.65%) was recorded in untreated control, which was statistically different from all other treatments followed by T_3 (13.4%) and T_2 (12.90%). On the other hand, the lowest percent grain infestation by weight (8.21%) was recorded in T_1, which was statistically different from all other treatments followed by T_5 (10.92%) and T_4 (11.48%). Similarly, in case of grain infestation reduction by weight over control, the highest reduction (62.07%) was recorded in T_1 followed by T_5 (49.56%), T_4 (46.95%). On the other hand, the lowest percent grain infestation reduction over control was recorded in T_3 (37.73%) and T_2 (40.10%). As a result, the trend of efficiency among different botanicals including untreated control in terms of reducing percent grain infestation by weight was T_1 (dried neem leaf powder) > T_5 (bulb of garlic) > T_4 (dried mahogany leaf powder) > T_2 (dried bishkatali leaf powder) > T_3 (dried marigold leaf powder) > T_6 (untreated control).

Table 2. Effect of botanicals on the grain infestation by weight of stored paddy during the management of rice moth *S. cerealella* in storage

Botanicals	Grain content loss by weight (%)							% reduction of grain infestation by weight over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Mean	

T_1	3.04c	5.78b	7.43d	7.26c	12.71d	13.06e	8.21d	62.07
T_2	6.44a	7.75a	9.87bc	11.73b	18.81b	23.21b	12.9b	40.10
T_3	6.63a	8.14a	11.13b	11.88b	18.97b	24.15b	13.4b	37.73
T_4	5.73b	7.47a	9.54c	11.41b	15.77c	18.99d	11.48c	46.95
T_5	5.63b	7.25a	9.15c	10.60b	15.76c	17.14c	10.92c	49.56
T_6	6.65a	8.71a	16.58a	26.11a	33.03a	38.82a	21.65a	-----
LSD $_{(0.05)}$	0.54	1.40	1.42	1.33	1.331	1.165	1.20	
CV (%)	6.25	12.39	8.88	6.73	4.59	3.44	7.05	

DAER = Days after egg release; In column, means followed by same letters are not significantly different at 5% level of significance by LSD. The values in the column are the means of 4 replications for each treatment.

[T_1= Dried neem leaf powder @ 2.5 g /kg paddy, T_2= Dried bishkatali leaf powder @ 2.5 g /kg paddy, T_3 = Dried marigold leaf powder @ 2.5 g /kg paddy, T_4 = Dried mahogany leaf powder @ 2.5 g /kg paddy, T_5 = Bulb of garlic @ 1.0 gm /kg paddy, T_6 = Untreated control]

From the above findings it was revealed that among five promising botanicals, T_1 (72.77% & 62.07%) comprising dried neem leaf powder @ 2.5 g/kg paddy provided the best results in reducing the grain infestation by number and weight, respectively, followed by T_5 (69.13% & 49.56%, respectively) comprising chopped bulb of garlic @ 1.0 g/kg paddy, T_4 (66.16% & 46.95%, respectively) comprising dried mahogany leaf powder @ 2.5 g/kg paddy, whereas T_3 (48.40% & 37.73%, , respectively) comprising dried marigold leaf powder @ 2.5 g/kg paddy showed the least performance among five botanicals followed by T_2 (52.43% & 40.10%, respectively) comprising dried bishkatali leaf powder @ 2.5 gm/kg paddy. As a result, the order of trend efficiency of five botanicals and untreated control in reducing the grain infestation during the management of rice moth, *S. cerealella* was T_1 (dried neem leaf powder) > T_5 (bulb of garlic) > T_4 (dried mahogany leaf powder) > T_2 (dried bishkatali leaf powder) > T_3 (dried marigold leaf powder) > T_6 (untreated control) (Table 2). About similar findings were also observed by other researchers. Jilani (1986) reported that the ethanolic extract of neem seed; hexane extract of sweet flag, *Acorns calamus* rhizome and thymel significantly controlled the level of infestation applied against *Sitrotroga cerealella*, *Tribolium castaneaum*, *R. dominica* and *Sitophilus oryzae* in wheat grain. Dakshinamwithy (1988) also reported that neem seed kernel oil and eucalyptus powder mixed with rice also gave effective control in reducing the number of adults of *S. cerealella*.

4.3. Effect of botanicals on the viability of stored rice seeds

Significant variations among different botanicals were observed on the germination of rice seeds by number during the management of rice moth, *S. cerealella* in the storage throughout the storing period from 30 to 180 DAER (Table 3). In case of 30 DAER, the highest percent seed germination (94.72%) was recorded in T_1, which was statistically different from all other treatments followed by T_5 (93.3%), T_4 (92.97%) and T_2 (92.13%). On the other hand, the lowest percent seed germination (90.3%) was recorded in T_3, which was statistically similar (91.22%) to that untreated control. In case of 60 DAER, the highest percent seed germination (93.27%) was recorded in T_1, which was statistically similar to that of T_5 (92.02%), T_4 (91.68%) and T_2 (92.18%). On the other hand, the lowest percent of seed germination (80.35%) was recorded in untreated control, which was statistically similar to T_3 (89.58%). More or less similar trends of results were also observed for 90, 120, 150, 180 DAER, but the percent seed germinations were decreased with the increase of data recording time. However, in case of 180 DAER, the highest percent seed germination (68.96%) was recorded in T_1, which was statistically different from all other treatments followed by T_5 (63.13%), T_4 (62.71%) and T_2 (53.04%). On the other hand, the lowest percent seed germination (41.04%) was recorded in untreated control, which was statistically different from all other treatments followed by T_3 (51.76%).

Considering the mean germination of rice seeds, the highest percent seed germination (85.41%) was recorded in T_1, which was statistically different from all other treatments followed by T_5 (82.37%), and T_4 (81.64%). On the other hand, the lowest percent seed germination (66.34%) was recorded in untreated control, which was statistically different from all other treatments followed by T_3 (76.69%) and T_3 (78.06%). Similarly, in case of seed germination reduction over control, the highest reduction (28.74%) was recorded in T_1 followed by T_5 (24.16%) and T_4 (23.07%). On the other hand, the lowest percent seed germination reduction over control was recorded in T_3 (15.60%) and T_2 (17.67%). As a result, the trend of efficiency among different botanicals including untreated control in terms of saving percent seed germination over control was T_1 (dried neem leaf powder) > T_5 (bulb of garlic) > T_4 (dried mahogany leaf powder) > T_2 (dried bishkatali leaf powder) > T_3 (dried marigold leaf powder) > T_6 (untreated control).

Table 3. Effect of botanicals on germination of stored paddy seeds during the management of rice moth, *S. cerealella* in storage

Botanical	Seed germination (%)							% germination saved over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Mean	
T_1	94.72a	93.27a	89.95a	85.85a	79.68a	68.96a	85.41a	28.745
T_2	92.13cd	91.18b	86.2b	79.03cd	66.77c	53.04c	78.06de	17.670
T_3	90.3e	89.58c	84.14c	77.76d	66.58c	51.76c	76.69e	15.602
T_4	92.97bc	91.68b	87.53b	81.28b	73.68b	62.71b	81.64c	23.072
T_5	93.3b	92.02ab	87.62b	82.53bc	75.6b	63.13b	82.37bc	24.165
T_6	91.22de	82.35d	72.87d	58.44e	52.1d	41.04d	66.34f	------
$LSD_{(0.05)}$	1.004	1.507	2.01	2.512	2.01	3.014	2.01	
CV (%)	3.27	2.11	1.57	2.15	1.93	3.52	2.50	

DAER = Days after egg release; In column, means followed by same letters are not significantly different at 5% level of significance by LSD. The values in the column are the means of 4 replications for each treatment.

[T_1= Dried neem leaf powder @ 2.5 g /kg paddy, T_2= Dried bishkatali leaf powder @ 2.5 g/kg paddy, T_3 = Dried marigold leaf powder @ 2.5 g /kg paddy, T_4 = Dried mahogany leaf powder @ 2.5 g /kg paddy, T_5 = Bulb of garlic @ 1.0 g /kg paddy, T_6 = Untreated control].

From the above findings it was revealed that among five promising botanicals, T_1 (28.74%) comprising dried neem leaf powder @ 2.5 g/kg paddy performed best results in increasing percent seed germination followed by T_5 (24.16) comprising chopped bulb of garlic @ 1.0 g/kg paddy, T_4 (23.07%) comprising dried mahogany leaf powder @ 2.5 g/kg paddy, whereas T_3 (15.60%) comprising dried marigold leaf powder @ 2.5 g/kg paddy showed the least performance among five botanicals followed by T_2 (17.67%) comprising dried bishkatali leaf powder @ 2.5 g/kg paddy. As a result, the order of trend efficiency of five botanicals and untreated control in saving percent seed germination of rice during the management of rice moth, *S. cerealella* was T_1 (dried neem leaf powder) > T_5 (bulb of garlic) > T_4 (dried mahogany leaf powder) > T_2 (dried bishkatali leaf powder) > T_3 (dried marigold leaf powder) > T_6 (untreated control). Very little findings were found directly to related with the effect of botanical on seed germination of rice seeds. Jilani (1986) reported that the ethanolic extract of neem seed; hexane extract of sweet flag, *Acorns calamus* rhizome and thymel significantly controlled the level of infestation applied to *Sitrotroga cerealella, Tribolium castaneaum, R. dominica* and *Sitophilus oryzae* in wheat grain. Dakshinamwithy (1988) also reported that neem seed kernel oil and eucalyptus powder mixed with rice also gave effective control in reducing the number of adults of *S. cerealella*.

4.4. Economic analysis of the botanical based management practices

Economic analysis of botanical based management practices applied against rice moth infesting paddy in storage is represented in Table 4. The untreated control treatment did not incur any pest management cost. The labor costs were involved in neem leaf; bishkatali leaf, marigold and

mahogany leaf based treatment for collecting, drying and grinding, and in case of garlic bulb the cost of garlic was only involved. Thus the highest benefit cost ratio (BCR) 11.65 was achieved by T_1 comprising dried neem leaf @ 2.5 g/kg paddy followed by T_4 (8.00) comprising dried mahogany leaf powder @ 2.5 g/kg paddy and T_5 (7.18) comprising chopped bulb of garlic @ 1.0 g/kg paddy and T_2 (5.81) comprising dried bishkatali leaf powder @ 2.5g/kg grains. On the other hand, the lowest BCR (4.35) was achieved in T_3 comprising dried marigold leaf powder @ 2.5 gm/kg paddy. As well as considering the environmental safety and human health hazards free point of view, neem based management practices against insect pests of stored products was also acceptable for the consumers (Table 4).

Table 4. Economic analysis of botanicals based management practices applied against rice moth on paddy in storage

Treatment	Cost of management (Tk/ton)	Grain saved (kg/pot)	Grain saved (ton)	Gross return (Tk)	Net return (Tk)	Adjusted net return(Tk)	BCR
T_1	370	0.9	900	16200	15830	4310	11.65
T_2	370	0.78	780	14040	13670	2150	5.81
T_3	370	0.75	750	13500	13130	1610	4.35
T_4	360	0.82	820	14760	14400	2880	8.00
T_5	440	0.84	840	15120	14680	3160	7.18
T_6	0	0.64	640	11520	11520	-	-

Market price of paddy 1 kg = 18.00 Tk during the study period

[T_1= Dried neem leaf powder @ 2.5 g /kg paddy, T_2= Dried bishkatali leaf powder @ 2.5 g /kg paddy, T_3 = Dried marigold leaf powder @ 2.5 g /kg paddy, T_4 = Dried mahogany leaf powder @ 2.5 g /kg paddy, T_5 = Bulb of garlic @ 1.0 g /kg paddy, T_6 = Untreated control]

From the economic analysis it may be concluded that the dried neem leaf based management treatment considered as the most economically viable tool for the management of rice moth on paddy in storage, which gave the highest BCR (11.65). As well as considering the environmental safety and human health hazards free, neem based management practices against insect pests of stored products was also acceptable for the consumers. Several worker`s results supported this findings. Plant-derived materials are more readily biodegradable. Some are less toxic to mammals, may be more selective in action, and may retard the development of pesticide resistance to insects. Their main advantage is that they may be easily and cheaply produced by farmers and small-scale industries as crude, or partially purified extracts. In the last two decades, considerable efforts have been directed at screening plants in order to develop new botanical insecticides as alternatives to the existing insecticides. It was reported that when mixed with stored-grains, leaf, neern seed powder, or oil extracts of plants reduced oviposition rate and suppress adult emergence of bruchids, and also reduced seed damage rate (Keita *et al*., 2001).

Experiment 2. Effect of some fumigants for eco-friendly management of rice moth, *Sitotroga cerealella* Olivier on stored paddy

The significant variations were observed among three promising fumigants viz., camphor, phostoxin and naphthalene were applied against rice moth, *S. cerealella* Olivier and evaluate the grain infestation by number and weight, grain content loss and viability of rice seeds and compared with the untreated control.

4.5. Effect of fumigants on grain infestation by number

Significant variations among different fumigants were observed on the grain infestation by number during the management of rice moth, *S. cerealella* attacking paddy in the storage throughout the storing period from 30 to 180 days after egg release (DAER) on paddy (Table 5). In case of 30 DAER, no infestation symptoms were observed on the treated grains of the treatments. Whereas, for 60 DAER, the highest percent grain infestation (3.99%) was recorded in untreated control (T_4) comprising untreated control, where no fumigants were used in the grains followed by T_3 (0.49%) comprising naphthalene @ 500 mg/kg paddy. On the other hand, none of the infested grains were observed in T_1 (0.00%) comprising camphor @ 1.0 gm/kg paddy and T_2 (0.00%) comprising phostoxin tablet @ 200 mg/kg paddy. More or less similar trends of results were also observed for 90, 120, 150,180 DAER, but the level of infestations were increased with the increase of data recording time. In case of 180 DAER, the highest percent grain infestation by number (37.27%) was recorded in (T_4) comprising untreated control followed by T_3 (15.85%) comprising naphthalene @ 500 mg/kg paddy. On the other hand, none of the infested grains were observed in T_1 (0.00%) comprising camphor @ 1.0 gm/kg paddy and T_2 (0.00%) comprising phostoxin tablet @ 200 mg/kg paddy.

Considering the mean infestation of grains, the highest percent grain infestation by number (17.62%) was recorded in untreated control followed by T_3 (5.48%). On the other hand, none of the infested grains were observed in T_1 (0.00%) and T_2 (0.00%). Similarly, grain infestation reduction over control, the highest reduction (100.00%) was recorded in T_1 and T_2 (100.00%). On the other hand, the lowest percent grain infestation reduction over control was recorded in T_3 (68.89%). As a result, the trend of efficiency among different fumigants including untreated control in terms of percent reduction of grain infestation by number was T_1 (Camphor), T_2 (Phostoxin) > T_3 (Naphthalene) > T_4 (Untreated control).

Table 5. Effect of fumigants on grain infestation of paddy during the management rice moth, *S. cerealella* in storage

Fumigant	Percent grain infestation by number							% grain infestation reduction over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Mean	
T_1	0	0c	0c	0c	0c	0c	0c	100
T_2	0	0c	0c	0c	0c	0c	0c	100
T_3	0	0.49b	1.59b	5.56b	9.41b	15.85b	5.48b	68.89
T_4	0	3.99a	14.99a	22.98a	26.49a	37.27a	17.62a	-
LSD (0.05)	0	0.05	0.11	0.65	1.96	1.60	0.73	
CV (%)	0	2.29	1.59	4.78	9.90	5.11	3.95	

DAER = Days after egg release; In column, means followed by same letters are not significantly different at 5% level of significance by LSD. The values in the column are the means of 4 replications for each treatment.

[T_1 = Camphor @ 1.0 g /kg paddy, T_2 = Phostoxin tablet @ 200 mg /kg paddy, T_3 = Naphthalene @ 500 mg /kg paddy, T_4 = Untreated control]

4.6. Effect of fumigants on grain infestation of by weight

Significant variations among different fumigants were also observed on the grain infestation by weight during the management of rice moth, *S. cerealella* in the storage throughout the storing period from 30 to 180 DAER on paddy (Table 6). In case of 30 DAER, the highest percent grain infestation (3.08%) was recorded in untreated control, where no fumigants were applied in the grains followed by T_3 (1.20%) comprising naphthalene @ 500 mg/kg paddy. On the other hand, none of the infested grains were observed in T_1 (0.00%) comprising camphor @ 1.0 gm/kg paddy and T_2 (0.00%)

comprising phostoxin tablet @ 200 mg/kg paddy. In case of 60 DAER, the highest percent grain infestation by weight (8.96%) was also recorded in T_4 comprising untreated control, followed by T_3 (3.14%) comprising naphthalene @ 500 mg/kg paddy. On the other hand, none of the infested grains were observed in T_1 (0.00%) comprising camphor @ 1.0 gm/kg paddy and T_2 (0.00%) comprising phostoxin tablet @ 200 mg/kg paddy. More or less similar trends of results were also observed for 90, 120, 150,180 DAER, but the level of infestations were increased with the progress of data recording time. In case of 180 DAER, the highest percent grain infestation by weight (39.01%) was recorded in T_4 comprising untreated control followed by T_3 (8.68%) comprising naphthalene @ 500 mg/kg paddy. On the other hand, none of the infested grains were observed in T_1 (0.00%) comprising camphor @ 1.0 gm/kg paddy and T_2 (0.00%) comprising phostoxin tablet @ 200 mg/kg paddy.

Considering the mean infestation of grains, the highest percent grain infestation by weight (20.98%) was recorded in untreated control followed by T_3 (8.68%). On the other hand, none of the infested grains were observed in T_1 (0.00%) and T_2 (0.00%). Similarly, grain infestation reduction over control, the highest reduction (100.00%) was recorded in T_1 and T_2. On the other hand, the lowest percent grain infestation reduction over control was recorded in T_3 (58.62%). As a result, the order of trend of efficiency among different fumigants including untreated control in terms of percent grain infestation reduction by weight was T_1 (Camphor), T_2 (Phostoxin) > T_3 (Naphthalene) > T_4 (Untreated control).

Table 6. Effect of fumigants on grain infestation by weight during the management of rice moth *S. cerealella* in storage

Fumigant	Percent grain infestation by weight							% grain infestation reduction over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Mean	
T_1	0c	0c	0c	0c	0c	0c	0c	100
T_2	0c	0c	0c	0c	0c	0c	0c	100
T_3	1.20b	3.14b	6.34b	12.64b	13.57b	15.20b	8.68b	58.62
T_4	3.08a	8.96a	17.94a	24.94a	31.94a	39.01a	20.98a	-
LSD $_{(0.05)}$	0.02	0.65	0.98	1.31	1.96	1.60	1.09	-
CV (%)	1.41	9.58	7.14	5.95	7.31	5.12	6.09	-

DAER = Days after egg release; In column, means followed by same letters are not significantly different at 5% level of significance by LSD. The values in the column are the means of 4 replications for each treatment.

[T_1 = Camphor @ 1.0 g /kg paddy, T_2 = Phostoxin tablet @ 200 mg /kg paddy, T_3 = Naphthalene @ 500 mg /kg paddy, T_4 = Untreated control]

From the above findings it was revealed that among three promising fumigants, T_1 (100% & 100%) comprising Camphor @ 1.0 g/kg paddy showed the best performance in reducing percent infestation by number and weight over control (100%) and T_2 (100%) comprising Phostoxin tablet @ 200 mg/kg paddy. On the other hand T_3 comprising Naphthalene @ 500 mg/kg paddy showed the least performance (58.62%). As a result, the order of trend efficiency of three fumigants and untreated control in reducing percent grain infestation by number and weight during the management of rice moth, *S. cerealella* was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene) > T_4 (Untreated control). About similar findings were also observed by several researchers. Stoyanova and Shikrenov (1983) reported that Phosphine preparations (Phostoxin and Gastoxin) against rice weevil of stored wheat at the rate 6 and 10 tablets/t caused 100% mortality. Yadav (1983) advised 1.75 to 3.5g/1000 kg seed dose of aluminium phosphide fumigant with an exposure of 4-5days for effective control of *S. oryzae*. Chandra *et al.* (1978) reported that Ethylene dichloride was the best compound and carbon tetrachloride was the least effective against rice weevil in storage.

4.7. Effect of fumigants on the viability of stored rice seeds

The rice seed germination was also varied significantly for different fumigants applied against rice moth in storage throughout the storing period of 30 to 180 DAER in storage (Table 7). In case of 30 DAER, the highest percent seed germination (95.82%) was recorded in T_1 comprising camphor @ 1.0 g/kg paddy followed by T_2 (95.23%) comprising phostoxin tablet @ 200 mg/kg paddy that was statistically similar with T_3 (94.07%) comprising naphthalene @ 500 mg/kg paddy. On the other hand, the lowest percent seed germination (90.96%) was recorded in untreated control (T_4), where no fumigants were used in the grains. In case of 60 DAER, the highest percent seed germination (93.75%) was also recorded in T_1, which was statistically similar with T_2 (93.58%) followed by T_3 (91.08%). On the other hand, the lowest percent seed germination (82.45%) was recorded in untreated control. More or less similar trends of results were also observed for 90, 120, 150,180 DAER, but the percent seed germinations were decreased with the progress of data recording time, particularly for untreated control, where the seed germination was drastically reduced (Table 7). In case of 180 DAER, the highest percent seed germination (83.28%) was recorded in T_1, which was statistically similar with T_2 (82.22%) and T_3 (81.87%). On the other hand, the lowest percent seed germination (36.58%) was recorded in untreated control (Table 7).

Considering the mean seed germination, the highest percent seed germination (89.12%) was also recorded in T_1, which was statistically similar with T_2 (88.62%) followed by T_3 (85.83%). On the other hand, the lowest percent seed germination (65.62%) was recorded in T_4 comprising untreated control (Table 7). Similarly, percent seed germination saved over control, the highest percent seed germination saved over control (35.81%) was also recorded in T_1, followed by T_2 (35.05%). On the other hand, the lowest percent seed germination saved over control (30.79%) was recorded in T_3. As a result, the order of trend of efficiency among different fumigants including untreated control in terms of percent seed germination saved over control was T_1 (Camphor), T_2 (Phostoxin) > T_3 (Naphthalene) > T_4 (Untreated control).

Table 7. Effect of fumigants on seed germination during the management of rice moth, *S. cerealella* infesting paddy in storage

Fumigant	Seed germination (%)							% seed germination saved over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Mean	
T_1	95.82a	93.75a	90.82a	87.78a	83.24a	83.28a	89.12ab	35.81
T_2	95.23ab	93.58a	90a	87.45a	83.24a	82.22a	88.62ab	35.05
T_3	94.07b	91.08b	86b	83.03b	78.9b	81.87a	85.83b	30.79
T_4	90.96c	82.45c	72.85c	61.85c	49.01c	36.58b	65.62c	-
$LSD_{(0.05)}$	1.296	1.949	2.601	3.242	3.874	4.549	2.92	-
CV (%)	1.86	1.35	1.92	2.53	3.29	4.01	2.49	-

DAER = Days after egg release; In column, means followed by same letters are not significantly different at 5% level of significance by LSD. The values in the column are the means of 4 replications for each treatment.

[T_1 = Camphor @ 1.0 g /kg paddy, T_2 = Phostoxin tablet @ 200 mg /kg paddy, T_3 = Naphthalene @ 500 mg /kg paddy, T_4 = Untreated control]

From the above findings it was revealed that among three fumigants, T_1 (35.81%) comprising Camphor @ 1.0 g/kg paddy performed best results in saving percent seed germination and T_2 (35.05%) comprising Phostoxin tablet @ 200 mg/kg paddy, where T_3 (30.79%) comprising naphthalene @ 500 mg/kg paddy showed the least performance. As a result, the order of trend efficiency of three fumigants and untreated control in increasing percent seed germination of rice during the management of rice moth, *S. cerealella* was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene) > T_4 (untreated control). Very little studies were found directly related with the effect of botanical on seed germination of rice seeds. Ahmed *et al*. (2006) reported that considering the combination of containers and materials, camphor with tin container and polythene lined gunny bag had almost no infestation (< 1.00%) after 270 days of storage and the germination percentage of stored seeds of mungbean was 87.82 - 88.73% against C.

chinensis and they suggested that mungbean seeds can be stored up to 270 days using camphor either in tin container or gunny bag lined with polythene.

4.8. Economic analysis of the fumigant based management practices

Economic analysis of fumigant based management practices applied against rice moth infesting paddy in storage is represented in Table 8. The untreated control treatment did not incur any pest management cost. The labor costs were involved in camphor, phostoxin tablet and naphthalene treatment for applying the treatments and the costs were also involved for the procurement of the items. Thus the maximum benefit cost ratio (BCR) 14.08 was calculated in Camphor @ 1.0 gm/kg paddy. This was followed (5.25) by Phostoxin tablet @ 200 mg/kg paddy. On the other hand, the minimum BCR (3.65) was calculated in naphthalene @ 500 mg/kg paddy (Table 8).

Table 8. Economic analysis of fumigant based management practices applied against rice moth on paddy in storage

Treatment	Cost of management (Tk/ton)	Grain saved (kg/pot)	Grain saved (ton)	Gross return (Tk)	Net return (Tk)	Adjusted net return(Tk)	BCR
T_1	370	0.95	950	17100	16730	5210	14.08
T_2	720	0.89	890	16020	15300	3780	5.25
T_3	620	0.8	800	14400	13780	2260	3.65
T_4	0	0.64	640	11520	11520	-	-

Market price of paddy 1 kg = 18.00 Tk. during the study period

[T_1 = Camphor @ 1.0 g /kg paddy, T_2 = Phostoxin tablet @ 200 mg /kg paddy, T_3 = Naphthalene @ 500 mg /kg paddy, T_4 = Untreated control]

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted to find out the effectiveness of some promising botanicals and fumigants applied against Angoumois grain moth/rice moth, *Sitorogra cerealella* Olivier on paddy in storage in the laboratory under the Department of Entomology of Sher-e-Bangla Agriculture University, Dhaka during April to September 2011. The study was conducted under two separate experiments. In first experiment, five botanicals along with one untreated control were used viz., (i) T_1 = Dried neem leaf powder @ 2.5 g/kg paddy, (ii) T_2 = Dried bishkatali leaf powder @ 2.5 g/kg paddy, (iii) T_3 = Dried marigold leaf powder @ 2.5 g/kg paddy, (iv) T_4 = Dried mahogany leaf powder @ 2.5 g/kg paddy, (v) T_5 = Chopped garlic bulb @ 1 g/kg paddy, (vi) T_6 = Untreated control. While in second experiment, three fumigants along with untreated control treatments were used viz., (i) T_1 = Camphor @ 1 g/kg paddy, (ii) T_2 = Phostoxin tablet @ 200 mg/kg paddy, (iii) T_3 = Naphthalene @ 500 mg/kg paddy and (iv) T_4 = Untreated control. Both the experiments were laid out in Completely Randomized Design (CRD) with 4 replications. Data were collected on grain infestation by number and weight, viability of rice seeds and economic analysis of the management practices.

SUMMARY

Considering the efficacy of botanical based management practices applied against *S. cerealella*, the findings of the results have been summarized below:

In terms of percent grain infestation by number, among five promising botanicals, T_1 (72.77%) comprising dried neem leaf powder @ 2.5 g/kg paddy performed the best in reducing the grain infestation by number and weight followed by T_5 (69.13%) comprising chopped bulb of garlic @ 1.0 g/kg paddy, T_4 (66.16%) comprising dried mahogany leaf powder @ 2.5 g/kg paddy, whereas T_3 (48.40%) comprising dried marigold leaf powder @ 2.5 g/kg paddy showed the least performance among five botanicals followed by T_2 (52.43%) comprising dried bishkatali leaf powder @ 2.5 gm/kg paddy. As a result, the order of trend efficiency of five botanicals and untreated control in reducing the grain infestation during the management of rice moth, *S. cerealella* was T_1 (dried neem leaf powder) > T_5 (bulb of garlic) > T_4 (dried mahogany leaf powder) > T_2 (dried bishkatali leaf powder) > T_3 (dried marigold leaf powder) > T_6 (untreated control).

In case grain infestation reduction by weight, T_1 (62.07%) comprising dried neem leaf powder @ 2.5 g/kg paddy performed best results in reducing the grain infestation by number and weight, respectively, followed by T_5 (49.56%, respectively) comprising chopped bulb of garlic @ 1.0 g/kg paddy, T_4 (46.95%, respectively) comprising dried mahogany leaf powder @ 2.5 g/kg paddy, whereas T_3 (37.73%) comprising dried marigold leaf powder @ 2.5 g/kg paddy showed the least performance among five botanicals followed by T_2 (40.10%) comprising dried bishkatali leaf powder @ 2.5 g/kg paddy. As a result, the order of trend efficiency of five botanicals and untreated control in reducing the grain infestation during the management of rice moth, *S. cerealella* was T_1 (dried neem leaf powder) > T_5 (bulb of garlic) > T_4 (dried mahogany leaf powder) > T_2 (dried bishkatali leaf powder) > T_3 (dried marigold leaf powder) > T_6 (untreated control).

Considering the effect of botanicals on seed germination, T_1 (28.74%) comprising dried neem leaf powder @ 2.5 g/kg paddy performed best results in increasing percent seed germination over control followed by T_5 (24.16) comprising chopped bulb of garlic @ 1.0 g/kg paddy, T_4 (23.07%) comprising dried mahogany leaf powder @ 2.5 g/kg paddy, whereas T_3 (15.60%) comprising dried marigold leaf powder @ 2.5 g/kg paddy showed the least performance among five botanicals followed by T_2 (17.67%) comprising dried bishkatali leaf powder @ 2.5 g/kg paddy. As a result, the order of trend efficiency of five botanicals and untreated control in increasing percent seed germination of rice during the management of rice moth, *S. cerealella* was T_1 (dried neem leaf powder) > T_5 (bulb of garlic) > T_4 (dried mahogany leaf powder) > T_2 (dried bishkatali leaf powder) > T_3 (dried marigold leaf powder) > T_6 (untreated control).

In case of the economic returns of botanical based management practices, the highest benefit cost ratio (BCR) 11.65 was achieved by T_1 comprising dried neem leaf @ 2.5 g/kg paddy followed by T_4 (8.00) comprising dried mahogany leaf powder @ 2.5 g/kg paddy and T_5 (7.18) comprising chopped bulb of garlic @ 1.0 g/kg paddy and T_2 (5.81) comprising dried bishkatali leaf powder @ 2.5g/kg grains. On the other hand, the lowest BCR (4.35) was achieved in T_3 comprising dried marigold leaf powder @ 2.5 g/kg paddy. As well as considering the environmental safety and human health hazards free point of view, neem based management practices against insect pests of stored products was also acceptable for the consumers.

Considering the efficacy of fumigant based management practices applied against *C. chinensis*, the findings of the results have been summarized below:

In case of grain infestation reduction by number, among three promising fumigants, T_1 comprising camphor @ 1.0 g/kg paddy showed the best performance in reducing the highest percent of grain infestation by number (100%) and T_2 (100%) comprising phostoxin tablet @ 200 mg/kg paddy, whereas T_3 comprising Naphthalene @ 500 mg/kg paddy showed the least performance (68.89%) in reducing the grain infestation by number. As a result, the order of trend efficiency of three fumigants and untreated control in reducing percent grain infestation by number during the management of rice moth, *S. cerealella* was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene) > T_4 (Untreated control).

In case of grain infestation reduction by weight, among three promising fumigants, T_1 comprising camphor @ 1.0 g/kg paddy showed the best performance in reducing the highest percent of grain infestation by number (100%) and T_2 (100%) comprising phostoxin tablet @ 200 mg/kg paddy, whereas T_3 comprising Naphthalene @ 500 mg/kg paddy showed the least performance (58.62%) in reducing the grain infestation by weight. As a result, the order of trend efficiency of three fumigants and untreated control in reducing percent grain infestation by weight during the management of rice moth, *S. cerealella* was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene) > T_4 (Untreated control).

In case percent seed germination, among three promising fumigants, T_1 (35.81%) comprising camphor @ 1.0 g/kg paddy performed the best in increasing percent seed germination and T_2 (35.05%) comprising phostoxin tablet @ 200 mg/kg paddy, where T_3 (30.79%) comprising naphthalene @ 500 mg/kg paddy showed the least performance. As a result, the order of trend efficiency of three fumigants uncluding untreated control in increasing percent seed germination of rice during the management of rice moth, *S. cerealella* was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene) > T_4 (Untreated control).

In case of the economic returns of fumigant based management practices, T_1 comprising camphor @ 1.0 g/kg paddy considered as the most economically viable tool for the management of rice moth on paddy in storage, which gave the highest (14.08) benefit cost ratio (BCR) followed by T_2 comprising phostoxin @ 200 mg/kg grains, which provided the second highest BCR (5.25), The lowest BCR (3.65) was obtained from T_3 comprising Naphthalene @ 500mg/kg. In addition considering the environmental safety and human health hazards free point of view the camphor, derived from *Cinnamonum camphora* plant applied against insect pests of stored products may be acceptable to the consumers.

CONCLUSION

Based on the above findings of the study, the following conclusions may be drawn:

In case of botanical based management practices

- Among five promising botanicals, dried neem leaf powder @ 2.5 gm/kg paddy reduced the highest grain infestation by number (72.77%) and weight (62.07%), respectively) than chopped bulb of garlic, dried leaf powder of mahogany, bishkatali and marigold, where dried marigold leaf powder @ 2.5 g/kg paddy showed the least performance (48.40% & 37.73%).
- Dried neem leaf powder @ 2.5 g/kg paddy increased the highest percent of seed germination over control (28.74%) than chopped bulb of garlic (24.16%), dried leaf powder of mahogany, bishkatali and marigold, where dried marigold leaf powder @ 2.5 g/kg paddy increased in the lowest percent of seed germination (15.60%) over control.
- Dried neem leaf @ 2.5 g/kg paddy considered as the most economic tool and provided the highest (11.65) benefit cost ratio (BCR) than mahogany leaf (8.00), chopped bulb of garlic (7.18), bishkatali (5.81) and marigold leaf powder (4.35).

In case of fumigant based management practices

- Among three promising fumigants, both camphor @ 1.0 gm/kg paddy and phostoxin tablet @ 200 mg/kg paddy reduced the highest percent of grain infestation (100% & 100%) over control by number and weight, whereas naphthalene @ 500 mg/kg paddy reduced the lowest percent of grain infestation by number (68.89%) and weight (58.62%) over control.

- Conversely, camphor @ 1.0 g/kg paddy increased the highest percent of seed germination T_1 (35.81%) followed by phostoxin tablet (35.05%), whereas naphthalene increased the lowest percent of seed germination (30.79%) over control.
- In case of the economic returns of fumigant based management practices, T_1 comprising camphor @ 1.0 g/kg paddy considered as the most economically viable tool for the management of rice moth on paddy in storage, which gave the highest (14.08) benefit cost ratio (BCR) followed by T_2 comprising phostoxin @ 200 mg/kg grains, which provided the second highest BCR (5.25), The lowest BCR (3.65) was obtained T_3 comprising Naphthalene 500 mg/kg paddy. The environmental safety and human health hazards free point of view, camphor, derived from *Cinnamonum camphora* plant applied against insect pests of stored products may be acceptable to the consumers.
- Camphor @ 1.0 g/kg paddy considered as the most economically viable tool for the management of rice moth, *S. cerealella* on paddy in storage, and provided the highest (14.08) benefit cost ratio (BCR) than phostoxin (5.25), than naphthalene (3.65).
- Considering the environmental safety point and human health hazards free measures, camphor is also acceptable for the consumers, because camphor is derived from *Cinnamonum camphora* plant applied against insect pests of stored products.

RECOMMENDATIONS

Considering the findings of the study the following recommendations may be drawn:

1. Dried neem leaf powder and camphor should be applied against rice moth infesting paddy in storage for its effective suppression and ensure human health hazards free control measures.
2. Further intensive laboratory based studies on other stored grain insect pests should be done.
3. More number of botanicals, their derivatives and fumigants should be explored for future elaborative research for controlling insect pests in stored products.

CHAPTER VI

REFERENCES

Abivardi, C. 1977. Effect of camphor on embryonic and post-embryonic development *Callosobruchus chinensis* (L.). *J. Econ. Ent.* **6**(3): 818-820.

Abivardi,C. (1976). Additional studies on insecticidal activities of camphor to stored product insects. *Zeitschrift fur Pflanzenkrankheiten und pflanzenschutz.* **83**(7-8): 119 - 121.

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

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

Amoore, J. E. and Hautala, E. (1983). Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. *J. Appl. Toxicology.* **3** (6): 272–290.

Anon. (1981). Insect anti-feedant action of some essential oils. *Pesticides*., **15**(7): 15 - 18.

Anonymous, (1978). Stored product pests. USDA agriculture Hand Book. 554:598-751.

Ansari, K.K., Prakash, S. and Pandey, P.N. (2000). Effect of some plant products on egg laying of rice-moth, *Corcyra cephalonica* (Stainton). *Flora Fauna Jhansi*. **6**(1): 33-34.

Ansari, K.K., Prakash, S. and Pandey,P.N. (2004). Effect of some indigenous plant products on the emergence and longevity of adults of rice-moth, *Corcyra cephalonica* (Stainton). *Flora Fauna Jhansi.*1**0**(1): 35-36.

Arivudainambi, N.M. and Singh,.R.P. (2005). Fumigant toxicity of neem (*Azadirachta indica*) seed oil volatiles against grain moth, *Sitotroga cerealella*. *J. Ecoxicol. Environ. Monitoring.* **15**(1): 91-98.

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

Banarjee, G.M. and Nigam, S.K. (1985). Role of indigenous plant materials in pest control. *Pesticides,* **19**: 33 - 38.

BBS (Bangladesh Bureau of Statistics). (2010). Statistical Yearbook of Bangladesh (26th ed.). p. 149-156.

Bhargava, M.C. and Meena, B.L. (2001). Effect of some spice oils on the eggs of *Corcyra cephalonica* Stainton. *Insect Environ*.**,** **7**(1): 43-44

Bhuiah, M.I.M. and Quinones, A.C. (1990). Use of leaves lagundi, *Vitex negundo* L. as corn seed protectant against the corn weevil *Sitophilous zeamais* Motsch. *Bangladesh J. Zool*., **18**(1): 127 - 129.

Bhuiah, M.I.M. and Quinones, A.C. (1990). Use of leaves lagundi, *Vitex negundo* L. as corn seed protectant against the corn weevil *Sitophilous zeamais* Motsch. *Bangladesh J. Zool*. **18**(1): 127 **-** 129.

Bishop, W. P. and Sanders, K. D. (2000). Camphor hepatotoxicity. *South Med. J.,* **93** (6): 596–598.

Bokder,H.P. (1964). Varied growth of stored grain moth *Sitotroga cerealella* Oliv. As preliminary index for using it as test organism in estimating the quality of rice. *Indian j. Agril. Sci*., **35** (3): 206.

Borah, B. and Mohan, B. (1981). Efficacy of aluminium phosphide and malathion formulations against S. cerealella and S. oryzae infesting stored paddy seeds. *J. Res. Assam Agric. Univ*., **2**(1): 74-79.

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

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

Bryn, H. Daisy, Gary, A., Strobel, U. C., David, E., Joe, S., David, K. W. and Justin, B. R. (2002). Naphthalene, an insect repellent, is produced by Muscodor vitigenus, a novel endophytic fungus. *Microbiology*., **148**: 3737-3741.

Chander, H. and Ahmed, S.M. (1983). Potential of some new plant products as grain protectants against insect infestation. *Bull. Grain Technol*., **21**: 179 - 188.

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

Chandra, S., Khare, B.P. and Sharma, V.K. (1978). Efficacy of some selected fumigants on rice-weevil, *Sitophilus oryzae* Linn. *Indian J. Agril. Res.,* **12**(2): 79 - 84.

Cogburn, R.R., Bollich, C.N. and Meola, S. (1983). Factors that affect the relative resistance of rough rice to Angoumois grain moth and lesser grain borer, *Environ. Entomol.*, **12**:336-342.

Cotton, R.T. (1963). Pests of Stored grains and grain products. *Burgess Publ. Co. Minnesota.,* 4th Edition., pp. 35 - 40.

Crombie, A. C. 1943. The development of angoumois grain moth *Sitotroga cerealell* Oliv. *Nature*, **152** (3852):246.

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

Das, G.P. (1986). Pesticidal efficacy of some indigenous plant oils against the pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). *Bangladesh J. Zool.*, **14**(1)**:** 15 - 18.

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

Dhotmal, N.J. and R.B. Dumbre. 1982. Laboratory studies on the bionomicsof Angoumois grain moth, *Sitotroga cerealella* (Oliv) on different rice vareeties (Lepidoptera: Geliechiidae). *Bull. Grain Tech*., **20** (1): 220-222.

Dilwari,V. K., Dhaluiwal, D.G. and Mahal, M.S. (1990). Taxicity of allylisothiocyanate to rice moth. *Sitotrotoga cerealella* Linn. *J. Ins. Sci*., **4**(1):101-102.

Dwivedi, S,C. and Kumar, A. (1999). Ovicidal activity of six plant leaf extracts on the eggs of *Corcyra cephalonica* Stainton (Lepidoptera : Pyralidae). *Uttar Pradesh J. Zool.,* **19**(3): 175-178.

Farid, A., Amin, K.F., Khan, A., Khattak, S.U., Ahmad, M. and Shakoori, A.R. (2002). Selection of acaricides with least toxic effect on *Sitotroga cerealella* culture efficacy. *Proced. Pakistan Congress Zool*., **22**: 133-138.

Flethcher,T. and C. C Ghosh. (1919). Stored grain pest. Proc III entomol. Meetg. Held at Pusa(1919).Pp. 712-761.

Hansen, L.S., Skovgard, H. and Hell, K. (2004). Life table study of *Sitotroga cerealella* (Lepidoptera: *Gelichiidae*), a strain from West Africa. *J. Economic Entomol*. **97**(4): 1484-1490.

Haritha, V., Vijayalakshmi, K. and Murthy, M.M.K. (2000). Biology of rice moth, *Corcyra cephalonica* Staint. on groundnut pods and kernels under controlled condition. *J. Appl. Zool. Res*. **11**(2/3): 135-136

Hiremath, I.G., Ahn, Y.G. and Kim, S.I. (1997). Insecticidal activity of Indian plant extracts against *Nilaparvata lugens* (Homoptera: Delphacidae). *Appl. Entomol. Zool.,* **32**(1): 159 – 166.

Hussain, M. (1995). Controlling rice borers under Bangladesh conditions. *Pestology*., **8**(8): 28 - 30.

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

Islam, B.N. (1984). Pesticidal action of neem and certain other indigenous plants and weeds of Bangladesh. In Proc. 2nd Int. Neem Conf. *Ranischhlolzhausen.,* pp. 263 -

Jilani, G. and Su, M.C.F. (1983). Laboratory studies on several plant materials, as insect repellents for protection of cereal grains. *J. Econ. Entomol.,* **76**: 154 - 157.

Jilani, G. (1986). Use of botanicals for protection of stored food grains against insect pests : A review. *Work Done at Grain Storage Research Laboratory*. PARC, Karachi, Pakistan. pp. 30 - 35.

Jilani, G. and Saxena, R.C. (1987). Derivatives of neem, turmeric and sweetflag as grain protectant against stored grain insect pests. International Rice Res. Inst. Los Nanos, Manila (Philippines). p.1.

Kalasagond, P.R. (1998). Management of beetle pests in stored wheat by non-insecticidal approaches. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.

Karim, A.N.M.R. (1986). The hispa episode. Modern rice cultivation workshop, BRRI, Joydebpur. pp. 125 -160.

Kashyap, N.P., Bhagat, R.M., Sharma, D.C. and Suri, S.M. (1992). Efficacy of some useful plant leaves for the control of potato tuber moth, *Phthorimaea operculella* Zell. in stores. *J. Entomol Res.*, **16**: 223 - 227.

Ketkar, C.M. (1976). Utilization of neem *(Azadirachta indica* A. Juss) and its byproducts. VIC, Bombay, India. p. 234.

Ketkar, C.M. (1989). Modified neem cake manurial project, utilization of neem (*Azadirachta indica* A. Juss) and its by products. Khadi and Village Industries Commission, Bombay, India.

Khalequzzaman, M. and Osman Goni, S.H.M. (2009). Toxic Potentials of Some Plant Powders on Survival and Development of *Callosobuchus maculatus* (F.) and *Callosobuchus chinensis* L. *J. Life Earth Sci.,* **(3,4)**: 1-6.

Khan and Wasim. (2001). Repellency of red pumpkin beetle against some plant extracts. *J. Biol. Sci.,* **1**(4): 198 - 200.

Khosla, R.K. 1997. Techniques for assessment of loses due to pest and diseases of rice. *Indian J. Agric. Sci.* 47(4): 171-174.

Mahanti, V. (2002). Ecology and management of stored grain pests of maize. *Ph. D. Thesis*, Acharya N. G., Ranga Agricultural University, Hyderabad.

Mann, J.C., Hobbs, J.B., Banthorpe, D.V. and Harborne, J.B. (1994). Natural products: their chemistry and biological significance. Harlow, Essex, England: Longman Scientific & Technical. pp. 309–311

Martin, D., Valdez, J., Boren, J. and Mayersohn, M. (2004). Dermal absorption of camphor, menthol, and methyl salicylate in humans. *J. Clin. Pharmacol.*, **44** (10): 1151–1157.

Naphthalene, an insect repellent, is produced by *Muscodor vitigenus*, a novel endophytic fungus" http://www.sciencedaily.com.

Nawrot, J. (1985). Principles for control of grain weevil, *Sitophilous granaries* L. (Coleoptera: Curculionidae) using natural plants compounds affecting the behaviour of the beetles. *J. Appl. Entomol.*, **24**(2): 173 - 197.

Niber, B.T., Helenius, J., Nairs, A.L. and Tierto Niber, B. (1992). Toxicity of plant extracts to three storage beetles (Coleoptera). *J. Appl. Entomol.*, **113**(2): 202 - 208.

Pathak, K.A., Jha, A.N., and Singh, J.P. (2001). Residual toxicity of insecticidal dusts as seed treatment of maize and paddy against adults of *Sitophilus oryzae* L. and *Sitotroga cerealella* Olivier. *Shashpa*. **8**(2): 199-206

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

Prakash, A and Mathur, I.C. (1981). Plant products in insect pests management of stored grains. *Bull. Grain Technol.*, **19**(3): 213 - 219.

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

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

Prakash, A., Rao, J., Pasalu, I.C. and Mathur, K.C. (1987). Rice Storage and insect pest management. *B. R. Publishing Corporation, Delhi*., p. 15 - 60.

Rahman, L.M. (1998). Laboratory evaluation of urmoi, neem and turmeric for controlling the rice weevil. M.S. Thesis, Dept. of Entomology, BAU, Mymensingh. p. 115.

Rahman, M.L., Hossain, M. and Ahmad, M. (1999). Repellent effect of urmoi, neem and turmeric extracts against rice weevil and granary weevil. *Bangladesh J. Entomol.,* **9**(1-2): 9 - 16.

Rahman, S.M.M., Siddika, A., Kundu, R. and Akter. T. (2006). Efficacy of some additives for suppression of Angoumois grain moth infestation in stored rice grain. *Int. J. Sustainable Agril.Tech.,* **2**(3): 27-31

Rai, L., Sarid, J.N. and Pingalc, S.V. (1963). Fumigation of food grains in India with hydrogen phosphide, Series I, Tests in concrete bins. *Bull. Grain Technol.,* **1**(1-2): 3 - 15.

Rajendran, S. and Sriranjini, V. (2008). Plant products as fumigants for stored-product insect control. *J. Stored Prod. Res*., **44**(2): 126-135

Rama Rao, C.V. and Sarangi, P.K. (1998). Control of *Sitophilus oryzae* (L.) through certain plant products. *Indian J. Plant Protec.,* **26**: 183 - 184.

Rani, P.U. and Jamil, K. (1989). Effect of water hyacinth leaf extract on mortality, growth and metamorphosis of certain pests of stored products. *Sci. Appl.,* **10**(3): 327 - 332.

Ryoo, M.I. and Cho, H.W. (1992). Feeding and ovipositional preferences and demography of rice weevil (Coleoptera: Curculionidae) reared on mixtures of brown, polished and rough rice. *Environ. Entomol.*, **21**(3): 549 - 555.

Sahayaraj, K. and Paulraj, M.G. (1998). Screening the relative toxicity of some plant extracts to *Spodoptera litura* Fab. of groundnut. *Fresenius. Environ.,* **7**(9-10): 557 - 560.

Sanguanpong, U., Kongkathip, N. and Sombatsiri, K. (2001). Reproductive inhibition of rice weevil, *Sitophilus oryzae* (L.) induced by vapor of formulated neem-oil based pellets. 20th ASEAN/2nd APEC Seminar on Postharvest “Quality Management and Market Access”, Lotus Pang Suankaew Hotel, Chiangmai, Thailand.

Sarac, A. and Tunc, I. (1995). Toxicity of essential oil vapours to stored- product insects. *Zeitschrift fiir Pflanzenkrankleiten und Pflan-Zenschhutz.,* **102**(1): 69 - 74.

Sharaby, A. (1989). Some Myrtaceae leaves of protectants of rice against the infestation of *S. oryzae* L. and *S. granaries* L. *Polskie Pesmo Entomologiczene*., **59**(2): 337 - 382.

Sharma, R.K. (1995). Suppression of insect reproductive potential by neem in stored maize. *Annals Plant Prot., Sci.,* **3**: 113 - 114.

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

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

Singh, K. (1987). Seasonal variations in the population of insect pests of stored products in West Bengal. *Indian J. Ecol.,* **4**(2): 66 - 77.

Singh, V., Dayal, D. and Bhandari, R.S. (2002). Pesticidal activity of essential oil of Vitex negundo leaves against *Sitotroga cereallela*. *Shashpa*, **9**(1): 71-75

Sivasrinivas. (2001). Evaluation of indigenous products and boric acid against stored grain pests. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.

Stoyanova, S. and Shikerenov D. (1983). Use of phosphene preparation for the de-infestation of wheat and flour. *Rasticina Zaschita,* **31**(2): 30 - 33.

Sunil kumar. (2003). Survey of indigenous technologies and evaluation of botanicals against major storage pests. M. Sc. (Agri.) Thesis, University of Agricultural

Talukder, F.A. and Howse, P.E. (1994). Laboratory evaluation of toxic and repellent properties of the pithraj tree, *Aphanamixis polystachya* Wall and Parker against *Sitophilus oryzae* L. *Int. J. Pest Management*., **41**(3): 274 - 279.

Talukder, F.A. and Howse, P.E. (1995). Efficasy of pithraj, *Aphanamixis polystachya* seed extracts against stored product pests. Proc. 6th Int. Working Conf. Stored Product Protect, Canberra, Australia.

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

Valsamma, G. and Patel, J.R. (1992). Mint, *Mentha spicata* – A promising botanicals protectant for greengram against pulse beetle *Callosobruchus analis* F. *Indian J. Plant Protec.,* **20**: 66 - 69.

Weaver, D.K., Phillips, T.W., Dunkel, F.V., Weaver, T., Grubbe, R.T. and Nance, E.L. (1995). Effect of camphor on embryonic and post-embryonic development *citikbobruchus chinensis* (L.). *J. Chemical Ecol.,* **21**(2): 127 - 142.

Xie, Y.S., Fields, P.G. and Isman, M.B. (1995). Repellency and toxicity of azadirachtin and neem concentrates to 3 stored product beetles. *J. Econ. Entomol.*, **88**: 1024 - 1031.

Xu Hanhong and Zhao Shanhuan. (1994). Studies on insecticidal activity of cassia oil and its toxic constituent analysis. *J. South China Agril. Univ.*, **15**(1): 27 - 33.

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

Yadav, U.S., Prasad, S.S., Upadhyay, K.D., and Ram, M. (2004). Growth and development of angoumois grain moth, *Sitotroga cerealella* Olivier on different rice varieties. *Proc. National Aca. Sci.India Sec. Biol. Sci*., **74**(3/4): 283-290

Yadav, U.S., Prasad,S.S., Ram, M. and Kumar, N. (2007). Effect of certain grain protectant oils on growth and development of angoumois grain moth, *Sitotroga cerealella* Olivier. *Res. Crops*. **8**(2): 442-445.

Yadav,U.S., Prasad, S.S., Upadhyay, K.D. and Ram, M. (2003). Growth and development of angoumois grain moth, *Sitotroga cerealella* Olivier on different rice varieties. *Procgs National Aca. Sci. India Sec. Biol. Sci. publ.*, **73**(3/4): 283-290.

Yadu, Y.K., Saxena, R.C., Dubey, V.K. and Rana, D.K. (2000). Evaluation of certain plant products against *S. cereallea* (Oliv.) in stored maize and paddy. *Indian J. Agril. Res*., **34**(4): 261-263.

Yevoor. (2003). Biology and management of rice weevil, *Sitophilus oryzae* (Linn.) in maize grains. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.