Agricultural and Biological Sciences Journal
Vol. 3, No. 3, 2017, pp. 12-27
http://www.aiscience.org/journal/absj
ISSN: 2381-7178 (Print); ISSN: 2381-7186 (Online)

Economic Impacts of Using Botanicals Against Rice Weevils Infestation During Storage

Mohammad Amir Hossain Mollah[1], Razia Khatun[2], Abdul Jabber Hawlader[3], Mohammad Razzab Ali[4], Shamim Ahmed[2], Mohammad Showkat Mahmud[5], Md Amirul Hasan[2, *]

[1]Development Technical Consultants Pvt. Ltd. Dhaka, Bangladesh
[2]Training Planning and Technology Testing Division, Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh
[3]Departments of Zoology, Jahangirnagar University, Savar, Dhaka, Bangladesh
[4]Department of Entomology, Sher-e-Bangla Agrcultural University, Dhaka, Bangladesh
[5]Animal Health Research Division, Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh

Abstract

The research work was designed to investigate the management of the most damaging rice pest, the angoumois grain moth, *Sitotrogacerealella* (Olivier) by following some commonly practiced techniques. During the present study, the efficacy of different types of containers viz. plastic pots, tin pots, earthen pots and polyester bags, different types of botanicals viz. neem leaf powder, mango leaf powder, mahogany leaf powder and chopped garlic was tested. Plastic container was found the most suitable to protect the rice grain infestation in storage against rice moth in laboratory condition than tin pot, earthen pot and polyester bag., While Plastic container tested along with botanicals, had reduced 69.51% rice grain infestation, 63.96% adult emergence, 46.49% grain content loss and increased 43.13% seed germination over polyester bag followed by tin pot, which reduced 55.05% grain infestation, 46.59% adult emergence, 24.87% grain content loss and increased 40.43% seed germination. The earthen pot reduced 37.88% grain infestation, 41.57% adult emergence, 8.87% grain content loss and increased 31.48% seed germination over the polyester bag. The dried neem leaf powder was observed the most effective to protect the rice grain infestation in storage against rice moth in laboratory condition than mango leaf, mahogany leaf and garlic bulb. Dried neem leaf had reduced 74.31% rice grain infestation, 71.96% adult emergence, 67.46% grain content loss and increased 41.00% seed germination over control followed by garlic bulb, which reduced 68.51%% grain infestation, 68.38% adult emergence, 58.77% grain content loss and increased 35.47% seed germination. The mahogany leaf reduced 66.03% grain infestation, 65.04% adult emergence, 53.72% grain content loss and increased 35.03% seed germination. The mango leaf also reduced 50.28% grain infestation, 54.33% adult emergence, 42.19% grain content loss and increased 23.00% seed germination. The inclusion level of neem leaf @ 2.5 gm/kg rice grains based management practice was indicate the most economically viable rice moth in storage that gave the highest (11.3) benefit-cost ratio (BCR) followed by dried mahogany leaf (9.76), garlic bulb (8.31) and mango leaf (6.72).

Keywords

Rice Weevils, Botanicals, Storage, Economic Impact, Bangladesh

Received: April 3, 2017 / Accepted: August 8, 2017 / Published online: October 23, 2017

* Corresponding author
E-mail address: amirul.blri@gmail.com (Md A. Hasan)

1. Introduction

About 90% of the population of Bangladesh depends on rice for their major food intake (Anon., 1981). Bangladesh is the fourth largest rice producing country in the world (IRRI, 2008). In 2016/2017 financial year the estimated rice consumption in Bangladesh is near about 35 million metric tons (The Statistics Portal 2017). The farmers store more than 65% of the total rice produces till the next season for their food, feed and seed purposes reported that about 5-8% of rice stored for seed. During the storage condition rice is being damaged by a number of agents, such as insects, rodents, fungi, mites, birds and moisture (Prakash and Rao, 1983; Calverley, 1994; Quasem and Siddiquee, 2009; Abedin *et. al.*2012). 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 (*Sitotrogacerealella*), rice weevil (*Sitophilusoryzae* Linn.) and beetles (*Tribolium castaneum*) predominate in parboiled rice. Among all the insects, *Sitotrogacerealella* is often placed at the top of the list of major insect pests of stored rice. On the other hand, rice moth and beetles predominate in raw rice and weevils predominate in milled (BRRI, 1984). The rice moth, *Sitotrogacerealella* (Oliv.) known as the angoumois grain moth or paddy moth is one of the most dominant species in the stored paddy (Prakash *et al.,* 1984). It is cosmopolitan throughout the tropical and subtropical parts of the world. While stores in bag it appeared to be the major and number one pest (Douglus, 1941). Cogburn (1975) experimental assessed weight losses during rice storage and concluded that one gravid female of *Sitotrogacerealella* in 50 gm of stored rice could destroy the grain completely for three subsequent generations. Food grain losses due to insect infestation during storage are a serious problem, particularly in the developing countries [1, 2]. High levels of the insect detritus may result in grain that is unfit for human consumption and loss of the food commodities, both, in terms of quality and quantity. Bangladesh produces a total of 33.542 million tons of rice from an area of 26.018 million acres (BBS, 2011). Rice 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 parboiled milled rice in earthen pot (called motka) (BRRI, 1984).

Chemical control, however as an alternative method has got great value. Several reports are available on the efficacy of different chemicals (Chandra *et al.*, 1989; Prakash and 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 (Chander *et al.,* 1991; Su, 1991). But the oils are not always available, not good in efficacy, have pungent smell and cannot de-infest the seeds. 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.

National sales of the classes of insecticide used on rice, including granular carbofuran, synthetic pyrethroids, and malathion exceeded 13,000 tons of formulated product in 2003(Livelihoods and environment (Riches)" Archived 2007). The insecticides not only represent an environmental threat, but are a significant expenditure to poor rice farmers. In Bangladesh, most of the farmers are poor and marginal. They store small quantities of seed for edible rice and cannot offer expensive control measures. Therefore, they essentially need some cheap, easy to use, readily available but effective methods for safe storing of rice. Plant products being liberally available as indigenous source of insecticides and insect repellents have been in use for more than one century in India. 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 (Prakashand Mathur, 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*(Azardirachtaindica*) products like leaves, seed, bark from which oil cake and extracts are prepared have been reported to possess fungicidal, nematicidal, insecticidal, insect repellent and anti feedent properties (Ketkar, 1976). Neem *(Azardirachtaindica*) 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). Yadav *et al.* (2007) reported that among 10 grain protectant plant oils, neem oil performed as the most effective against growth and development of *S. cerealella*followed by castor and mahua oils. The works conducted by Dwivedi and Anand (1999) reported that 100% inhibition of egg hatching of rice meal moth, *Corcyra* *cephalonica*was exhibited by the leaf extract of *Withaniasomnifera.*

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 insecticide based management to pest in rice. A reliable research is essential for identifying the current status of the technological knowledge so that administrators and policy makers can formulate proper strategy for ensuring sustainable crop production in the country. Considering these facts the study was undertaken with the following objectives.

2. Objectives

a) Assessment of the extent of damage of stored rice grains by rice moth, *Sitotrogacerealella;*

b) Evaluation of the suitability of commonly used containers for storing rice grains; and

c) Determination of the efficacy of some promising botanicals against rice moth

3. Materials and Methods

The hybrid rice variety 'Hira' was used in the present study to test against rice moth in the laboratory. About 170 kg of newly harvested rice grains were purchased from the local seed market. Collected seeds were directly sun dried and kept in ambient room temperature for further use. To assess the level of infestation on rice grains, the newly laid eggs of rice moth, *Sitotrogacerealella* were also collected. The present study was conducted in 2-factor completely randomized design (CRD), where container was used as factor one and botanical as factor two.

Treatments

The combinations of the botanical treatments along with containers used for storing rice grains are shown (Table 1):

Table 1. The botanical treatments used with containers for storing rice grains.

Container	Botanicals	Dose (gm/kg rice grains)	Container	Botanicals	Dose (gm/kg rice grains)
	Dried neem leaf	2.5		Dried neem leaf	2.5
	Dried mango leaf	2.5		Dried mango leaf	2.5
Plastic container	Dried mahogoni leaf	2.5	Earthen pot	Dried mahogoni leaf	2.5
	Bulb of garlic	1		Bulb of garlic	1
	Untreated control	Not used		Untreated control	Not used
	Dried neem leaf	2.5		Dried neem leaf	2.5
	Dried mango leaf	2.5		Dried mango leaf	2.5
Tin pot	Dried mahogoni leaf	2.5	Polyester bag	Dried mahogoni leaf	2.5
	Bulb of garlic	1		Bulb of garlic	1
	Untreated control	Not used		Untreated control	Not used

Viability Test of the Seeds

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

Collection of Containers and Preparation

Four different types of containers viz. Plastic pots, Tin pots, Earthen pots and Polyester bags were used. The collected containers were washed; cleaned; sun dried, and kept in the cool place in the laboratory.

Collection of Botanicals and Preparation

The leaves of neem (*Azadirachtaindica*), mango (*Mangiferaindica*), and mehogani (*Swieteniamahogoni*) were collected then directly sun dried and finally the dried leaves grinding separately. Each type of powdered leaf was then taken into a separate plastic pot and stored in cool dry place for future use in the experiments. The bulbs of garlic (*Allium sativum* Linn) were also collected and the scale leaves of garlic were removed from the bulbs, then bulbs were chopped into small pieces for further use.

Application of the Botanicals

About 20 kg of the selected rice grains were taken and distributed in 20 plastic pots each having one kg of the grains. The pots were then arranged into groups 1 to 5, each group having 4 replications. About 2.5 gm of dried neem leaf powder were thoroughly mixed with the grains of each pot of the group 1. The grains of each pot of group 2 were mixed with 2.5 gm of mango leaf powder. Simultaneously, 2.5 gm of mahagoni leaf powder were mixed with the grains of each of group 3 pots. In case of the grains of group 4 pots, 1.0 gm of chopped garlic bulb were mixed thoroughly with the grains of each pot. The pots of group 5 were kept as untreated control, having no plant products were mixed with the grains of this group. Similar procedures were followed for the experiments with Tin pots, Earthen pots and Polyester bags cases. Initial weight of 100 grains taken from each type of containers was recorded for further use in the calculation of the percent grain content loss.

Release of the Rice Moth Eggs

About 500 newly laid eggs (10 mg) of rice moth were released on the rice grains packed in each container. Immediately after the release of the rice moth eggs, each container was air tightened with its lid. The earthen pots were covered and air tightened with the help of their lids along with mud. The air tight containers with rice grains were preserved in ambient temperature of the laboratory up to 6 months that is 180 days after egg release (DAER) for recording data.

Data Sampling

The data on grain infestation by number, number of adult emergence, 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 gm of 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 circular plastic pot (7 cm ht x 5 cm dia) with its mouth closed by a lid and then filling the containers with rice grains by opening its mouth. From each of the 100 gm samples, 100 grains were used to record the data for each time and each parameter.

Data Collection and Calculation

The data on the grain infestation by number, number of adult emergence, grain content loss, and seed germinations were recorded by using the following formulae:

Percent Grain Infestation

The number of infested grains was counted for each sample of 100 grains. The infested grains were identified by recognizing the bored grains caused by the rice moth after emerging adult from the grains. Magnifying lens and simple microscope were also used whenever needed. The percent grain infestation was then calculated from by using the following formula-1:

$$(1)\ \text{Percent grain infestation} = \frac{\text{Number of infested grains}}{\text{Number of total grains observed}} \times 100$$

Adult Emergence

The number of adult emergence after the completion of the life cycle of the rice moth was recorded for each sample of 100 grains. For each treatment, the 100 grains were preserved on the petridish in the ambient temperature of the laboratory up to adult emergence from the infested grains. After complete emergence, the number of adults were counted for each treatment and recorded.

Percent Grain Content Loss

The weight (gm) of the 100 grains for each treatment was preserved for the adult emergence, were measured and recorded. The grain content loss was calculated from the data on initial weight (gm) of 100 healthy grains before setting the experiment and the weight of 100 grains after complete emergence of the adult rice moth at each recording time from 30 DAER to 180 DAER. Finally, the percent grain content loss was calculated by using the following formula-2:

$$(2)\ \text{Percent grain content loss} = \frac{\text{Initial weight of grains recording time} - \text{Weight of grains at data}}{\text{Initial weight of the grains}} \times 100$$

Viability of the Seeds

The viability of stored rice grains were assessed through grain germination test. That was done to determine whether or not the rice moth infestation can affect grain germination. The germination rate of the grains was determined at each data recording time from 30 to 180 DAER. The samples each of 100 grains were taken randomly from sampled grains for each of the treatments and placed those in water soaked blotting papers in Petridish, and preserved for 5 days at room temperature ranging from 27°C to 34°C for maximum germination of the seeds. After complete germination, the number of germinated seeds was counted out of the tested seeds and the percent seed germination was calculated using the following formula-3:

$$(3)\ \text{Percent seed germination} = \frac{\text{Number of germinated seeds}}{\text{Number of total seeds tested for germination}} \times 100$$

Percent Reduction or Increase over Control (or Polyester Bag)

Data from each treated and untreated control grains were recorded and the percent reduction or increase over control or polyester bag in terms grain infestation, adult emergence, grain content loss and seed germination were calculated using the following formula-4:

(4) Percent reduction or increase over control

$$= \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of the treated grains

X_2 = the mean value of the untreated control (or polyester bag) grains

The effect of containers on different aspects of infestation of the rice grains during the testing of botanicals and fumigants were also calculated.

Economic Analysis of the Management Practices Comprising Botanical Based Treatments

Economic analysis in terms of Benefit Cost Ratio (BCR) was analyzed on the basis of total expenditure of the respective management practices along with the total return from that particular treatment using different botanicals 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.

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-5 described by Elias and Karim (1984).

(5) Benefit Cost Ratio (BCR)

$$= \frac{\text{Adjusted net return}}{\text{Total management cost}} \times 100$$

Data Analysis

The data on above mentioned parameters were analyzed on 2-factor CRD with help of Computer based program MSTAT-C software. The means were separated to determine the level of significance following Least Significance Difference (LSD) and Duncan's Multiple Range Test (DMRT) wherever necessary at 1% level of probability.

4. Results and Discussion

a) Effect of Containers and Botanicals on the Infestation of Rice grain by Rice moth Sitotrogacerealella (Oliver)

Effect of Containers on the Infestation of Rice grain Induced by Rice moth, S. cerealella

More or less similar but increasing trends of percent grain infestation by number were observed at different exposure time after egg release from 60 to 180 DAER except 30 DAER among different containers used in the present study. Significant variations among different containers were observed on the grain infestation by number throughout the storing period from 30 days after egg release (DAER) to 180 DAER (Table 2). Among different containers, plastic container performed as most suitable container to reduce the rice moth infestation and the level of grain infestation was ranged from 0.60 to 7.46% at 60 to 180 DAER, respectively. This trend was followed by tin pot (1.60 to 11.0%) and earthen pot (1.60 to 15.20%), whereas polyester bag performed as least suitable container and showed highest infestation that was ranged from 3.06 to 24.47% at 60 to 180 DAER, respectively. In case of 30 DAER, statistically similar grain infestations by number were observed among different containers and it might be the reasons for the initial stage of the rice moth infestation. Based on the average grain infestation, plastic container performed as most suitable container to reduce the rice moth infestation and level of infestation was 3.22% followed by tin pot (5.64%) and earthen pot (7.36%), whereas polyester bag performed as least suitable and showed highest infestation (11.13%).

Considering the performance of different containers showing reduction of grain infestation, plastic container showed highest reduction (69.51%) followed by tin pot (55.05%) and earthen pot (37.88%) over polyester bag.

Table 2. Effect of Containers on the Infestation of Hybrid Rice grains (Hira) by Rice moth *S. cerealella*in Storage during Testing of Botanicals.

Containers	Percent grain infestation by number							% reduction over bag
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Plastic container	0.06a	0.60b	2.13c	3.33d	5.73d	7.46d	3.22d	69.51
Tin pot	0.26a	1.60b	4.20b	6.13c	10.67c	11.00c	5.64c	55.05
Earthen pot	0.33a	1.60b	4.86b	8.73b	13.47b	15.20b	7.36b	37.88
Polyester bag	0.46a	3.06a	6.60a	12.07a	20.20a	24.47a	11.13a	-
$LSD_{(0.01)}$	0.59	1.07	0.99	1.31	1.7	1.59	0.57	-
CV(%)	151.12	28.14	10.05	7.82	6.19	4.95	3.77	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

Effect of Botanicals on the Infestation of Rice grain Induced by Rice moth, S. cerealella

More or less similar but increasing trends of percent grain infestation by number were observed at different exposure time after egg release from 60 to 180 DAER except 30 DAER among different botanicals used in the study. Significant variations among different botanicals were observed on the rice grain infestation by number used against rice moth throughout the storing period from 30 days after egg release (DAER) to 180 DAER (Table 3). Among different botanicals, dried neem leaf performed as most effective botanical to reduce the rice moth infestation, which showed the minimum infestation at different data recording time and the level of grain infestation was ranged from 0.91 to 7.75% at 60 DAER to 180 DAER, respectively. This trend was followed by garlic bulb (0.91 to 9.50%). This was also followed by dried mahogany leaf (1.41 to 10.25%) and dried mango leaf (1.66 to 15.00%), whereas maximum infestation was recorded in untreated control grains and the level of infestation was ranged from 3.66 to 30.17% at 60 DAER to 180 DAER, respectively. In case of 30 DAER, statistically similar grain infestations by number were observed among different botanical treated grains and it might be the reasons for the initial stage of the infestation. Based on the average grain infestation, dried neem leaf performed as the most effective botanical to reduce the rice moth infestation and level of infestation was 3.45%, which was statistically different from all other botanicals and followed by garlic bulb (4.05%) followed by dried mahogany leaf (4.54%) and dried mango leaf (6.78%), whereas maximum infestation was recorded in untreated control grains (15.36%).

Considering the performance of different botanicals in reducing the grain infestation over control, the dried neem leaf showed the highest reduction (74.31%) over control followed by garlic bulb (68.51%) and dried mahogany leaf (66.03%), whereas the lowest reduction of grain infestation was recorded in dried mango leaf (50.28%) over control.

Table 3. Effect of Botanicals on the Infestation of Hybrid Rice gains (Hira) by Rice moth *S. cerealella.*

Botanicals	Percent grain infestation by number							% reduction over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Dried neem leaf	0.083a	0.91b	2.08c	3.41c	6.50c	7.75d	3.45d	74.31
Dried mango leaf	0.25a	1.66b	3.75b	7.33b	12.75b	15.00b	6.78b	50.28
Dried mahogany leaf	0.33a	1.41b	2.75c	4.58c	7.91c	10.25c	4.54c	66.03
Bulb of garlic	0.16a	0.91b	2.91bc	4.00c	6.83c	9.50c	4.05c	68.51
Control	0.58a	3.66a	10.75a	18.50a	28.58a	30.17a	15.36a	-
$LSD_{(0.01)}$	0.59	1.07	0.99	1.31	1.71	1.59	0.57	-
CV(%)	151.12	28.14	10.05	7.82	6.19	4.95	3.77	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

Combined Effect of Botanicals and Containers on the Infestation of Rice gain infested by Rice moth, S. cerealella

Infestations of rice grain were varied significantly among different botanicals along with different containers stored in throughout the storing period (Table 4). More or less similar but increasing trends of percent grain infestation by number were observed at different exposure time after egg release from 30 DAER to 180 DAER. The lowest grain infestation was observed in dried neem leaf treated grains stored in plastic containers (0.00 to 3.33%) followed by tin pot (0.33 to 5.00%), earthen pot (0.00 to 9.00%) and polyester bag (0.00 to 13.67%). The grain infestation was nearly followed by garlic bulb treated grains stored in plastic container (0.00 to 5.66%), followed by tin pot (0.00 to 7.00%), earthen pot (0.00 to 9.66%) and polyester bag (0.00 to 15.67%). The highest grain infestation was observed in untreated control grains stored in polyester bag (1.66 to 49.33%) followed earthen pot (0.66 to 31.00%), tin pot (0.00 to 24.67%) and plastic pot (0.00 to 15.67%). The grain infestation was nearly followed by dried mahogany leaf and dried mango leaf treated grains stored in any containers (Table 3). Considering the performance of different botanicals in reducing the grain infestation over control stored in different containers, the dried neem leaf showed the highest reduction ranged from 72.29 to 78.73% over control stored in polyester bag, earthen pot, tin pot and plastic container, respectively followed by garlic bulb (63.88 to 71.62%) and dried mahogany leaf (62.84 to 70.29%), whereas the lowest reduction of grain infestation over control was recorded in dried mango leaf treated grains (48.39 to 55.41%) stored in any containers (Table 4).

Table 4. Interaction Effect of Container and Botanical on the Infestation of Hybrid Rice grain (Hira) by Rice moth *S. cerealella*in Storage.

Container	Botanicals	Percent grain infestation by number							% reduction over control
		30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Plastic container	Dried neem leaf	0.00b	0.33f	1.00k	1.33j	2.33k	3.33m	1.39 m	78.75
	Dried mango leaf	0.33b	0.66ef	2.00ijk	2.66hij	5.00i	7.66ij	3.05kl	51.11
	Dried mahogany leaf	0.00b	0.33f	1.33k	1.66ij	3.00jk	5.00l	1.88 m	68.10
	Bulb of garlic	0.00b	0.33f	1.66jk	1.33j	2.66k	5.66kl	1.94m	63.88
	Control	0.00b	1.33def	4.66e	9.66e	15.67e	15.67e	7.83ef	-
Tin pot	Dried neem leaf	0.33b	0.66ef	2.00ijk	3.00hi	4.66ij	5.00l	2.61l	79.73
	Dried mango leaf	0.33b	1.66de	3.33fgh	5.66g	11.00f	11.00g	5.50h	55.41
	Dried mahogany leaf	0.66b	1.00def	2.66hij	3.00hi	5.66hi	7.33j	3.39jk	70.29
	Bulb of garlic	0.00b	1.33def	2.66hij	3.00hi	5.33hi	7.00jk	3.22jk	71.62
	Control	0.00b	3.33b	10.33c	16.00c	26.67c	24.67c	13.50c	-
Earthen pot	Dried neem leaf	0.00b	0.66ef	2.00ijk	4.00h	7.00gh	9.00hi	3.77j	70.97
	Dried mango leaf	0.33b	1.33def	4.00efg	8.66ef	14.67e	16.00e	7.50f	48.39
	Dried mahogany leaf	0.33b	1.33def	3.00ghi	6.00g	7.66g	10.33gh	4.78i	66.67
	Bulb of garlic	0.33b	0.66ef	3.00ghi	5.66g	7.00gh	9.66gh	4.38i	68.84
	Control	0.66b	4.00b	12.33b	19.33b	31.00b	31.00b	16.37b	-
Polyester bag	Dried neem leaf	0.00b	2.00cd	3.33fgh	5.33g	12.00f	13.67f	6.05h	72.29
	Dried mango leaf	0.00b	3.00bc	5.66d	12.33d	20.33d	25.33c	11.07d	48.652
	Dried mahogany leaf	0.33b	3.00bc	4.00efg	7.66f	15.33e	18.33d	8.11e	62.84
	Bulb of garlic	0.33b	1.33def	4.33ef	6.00g	12.33f	15.67e	6.66g	68.23
	Control	1.66a	6.00a	15.67a	29.00a	41.00a	49.33a	23.73a	-
$LSD_{(0.01)}$		0.95	1.07	0.99	1.31	1.71	1.59	0.57	-
CV(%)		151.12	28.14	10.05	7.82	6.19	4.95	3.77	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

From the above findings it was revealed that among containers, the most suitable container was plastic container in reducing the grain infestation by number against rice moth followed by tin pot and earthen pot, whereas polyester bag performed as least suitable container. In case of efficiency of botanicals, dried neem leaf performed as most effective in reducing the grain infestation by number against rice moth followed by garlic bulb, dried mahogany leaf and mango leaf. Over 130 plants and plant products have been shown to have insecticide l activity against stored product pests (Bandara KANP and Seneviratne DKH,1993) Caswell GH.1981. Currently many farmers in parts of Africa and Asia are using botanicals to protect their legumes from attack by bruchids, with varying degrees of success (Chellapa K and Chelliah S,1976). Neem has been shown to contain compounds like azadirachtin, meliantriol and salanin (IRRI, 2008) which are said to be repellent, antifeedant and have growth disrupting effects (Shaaya E, Kostjukovshi *et al.* 1997). Present findings were also supported by Yadav *et al.* (2007) statement that among 10 grain protectant plant oils, neem oil performed as the most effective against growth and development of *S. cerealella* followed by castor and mahua oils. In this connection many parts of the world, locally available plants are currently in wide use to protect stored products against damage caused by insect infestation (Khater, F. A.2012). Indian farmers used neem leaves and seed for the control of stored grain pests (Ahmed, S. and Koppel, B. 1985). The works conducted by Dwivedi and Anand (1999) also supported this study that among 6 plant species, the leaf extract of *Withaniasomnifera* exhibit 100% inhibition of egg hatching of rice meal moth, *Corcyracephalonica.*

b) Effect of Containers and Botanicals on the Adult Emergence during Storage of Rice moth

Effect of Containers on the Emergence of Adult Rice moth S. cerealella

Significant variations among different containers were observed on the adult emergence during the management of rice moth in the storage throughout the storing period from 30 to 180 days after egg release (DAER) on the rice grain (Table 5). More or less similar but increasing trends of adult emergence of rice moth by number were observed at different exposure time after egg release from 30 to 180 DAER. Among different containers, plastic container performed as the least suitable container for rice moth infestation and lowest number of adults was emerged and that was ranged from 0.00 to 9.13 adults per 100 rice grains at 30 to 180 DAER, respectively. This trend was followed by tin pot (0.00

to 13.53 adults per 100 grains) and earthen pot (0.00 to 14.80 adults per 100 grains), whereas polyester bag performed as the most suitable container for rice moth infestation and the highest number of adults rice moth was emerged that was ranged from 0.00 to 25.33 adults per 100 grains at 30 to 180 DAER, respectively. Considering the average adult emergence, plastic container performed as least suitable container for rice moth infestation and the lowest number of adults was emerged (3.74 adult per 100 rice grains) followed by tin pot (5.87 adults per 100 grains) and earthen pot (6.68 adults per 100 grains), whereas polyester bag performed as the most suitable container and showed highest number of adult emergence (10.09 adult per 100 grains).

Considering the performance of different containers in reducing the adult emergence, plastic container reduced the highest percentage of adult emergence (63.96%) over polyester bag followed by tin pot (46.59%) and the lowest reduction of adult emergence was recorded in earthen pot (41.57%).

Table 5. Effect of Containers on the Emergence of Adult Rice moth *S. cerealella*in Hybrid Rice grain (Hira) during Testing of Botanicals in Storage.

Containers	**Number of adult emergence per 100 seeds**							**% reduction over Bag**
	30 DAER	**60 DAER**	**90 DAER**	**120 DAER**	**150 DAER**	**180 DAER**	**Average**	
Plastic container	0.00	0.40b	2.33c	4.00c	6.60d	9.13c	3.74d	63.96
Tin pot	0.00	1.06b	3.33c	7.40b	9.93c	13.53b	5.87c	46.59
Earthen pot	0.00	1.00b	4.80b	7.86b	11.67b	14.80b	6.68b	41.57
Polyester bag	0.00	2.20a	6.40a	10.53a	16.13a	25.33a	10.09a	-
LSD $_{(0.01)}$		1.10	1.40	1.27	1.45	1.45	0.70	-
CV(%)		42.86	15.00	7.75	5.94	4.19	4.81	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

Effect of Botanicals on the Emergence of Adult Rice moth S. cerealella

Significant variations among different botanicals were observed on the adult emergence during the management of rice moth in the storage throughout the storing period from 30 to 180 days after egg release (DAER) on the hybrid rice grain (Table 6). More or less similar but increasing trends of adult emergence of rice moth by number were observed at different time exposure. Among different botanicals, dried neem leaf performed as the most effective botanical in reducing adult emergence of rice moth and the lowest number of adults was emerged that was ranged from 0.00 to 9.16 adults per 100 grains at 30 to 180 DAER, respectively. This trend was followed by garlic bulb (0.00 to 10.33 adults per 100 grains). This was also followed by dried mahogany leaf (0.00 to 11.42 adults per 100 grains) and dried mango leaf (0.00 to 14.92 adults per 100 grains), whereas the highest number of adults was emerged from untreated control rice grains and that was ranged from 0.00 to 32.67 adults per 100 rice grains at 30 to 180 DAER, respectively. Based on the average adult emergence, dried neem leaf performed as the most effective botanical in reducing the adult emergence of rice moth and the lowest number of adults was emerged (3.37 adults per 100 grains), which was statistically different from all other botanicals and followed by garlic bulb (3.95 adults per 100 grains). This was also followed by dried mahogany leaf (4.52 adults per 100 grains) and dried mango leaf (6.72 adults per 100 grains), whereas the highest number of adults was emerged from untreated control grains (14.40 adults per 100 rice grains).

Considering the performance of different botanicals in reducing the adult emergence of rice moth over control, the dried neem leaf showed the highest reduction (71.96%) over control followed by garlic bulb (68.38%) and dried mahogany leaf (65.04%), whereas the lowest reduction of adult emergence over control was recorded in dried mango leaf treated rice grains (54.33%).

Table 6. Effect of Botanicals on the Emergence of Adult Rice moth *S. cerealella* infesting Hybrid Rice grain (Hira) in Storage.

Botanicals	**Number of adult emergence per 100 seeds**							**% reduction over control**
	30 DAER	**60 DAER**	**90 DAER**	**120 DAER**	**150 DAER**	**180 DAER**	**Average**	
Dried neem leaf	0.00a	0.41b	2.08c	3.33d	5.25d	9.16d	3.37d	71.96
Dried mango leaf	0.00a	1.25b	5.00b	7.66b	11.58b	14.92b	6.72b	54.33
Dried mahogany leaf	0.00a	1.00b	3.08c	4.75c	6.91c	11.42c	4.52c	65.04
Bulb of garlic	0.00a	0.58b	2.41c	4.41cd	6.00cd	10.33cd	3.95cd	68.38
Control	0.00a	2.58a	8.50a	17.08a	25.67a	32.67a	14.40a	-
LSD$_{(0.01)}$		1.10	1.40	1.27	1.45	1.45	0.70	-
CV(%)		42.86	15.00	7.75	5.94	4.19	4.81	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

Combined Effect of Botanicals and Containers on the Adult Emergence

Adult emergence of rice moth was varied significantly among different botanical treated rice grains stored in different containers throughout the storing period (Table 7). More or less similar but increasing trends of adult emergence by number were observed at different exposure time after egg release from 30 DAER to 180 DAER. The minimum number of adults was emerged from dried neem leaf treated grains stored in plastic containers (0.00 to 4.33 adults per 100 rice grains) followed by tin pot (0.00 to 8.33 adults per 100 grains), earthen pot (0.00 to 8.66 adults per 100 grains) and polyester bag (0.00 to 15.33 adults per 100 grains) at 30 to 180 DAER, respectively. These trends of adult emergence were nearly followed by garlic bulb treated grains stored in plastic container (0.00 to 4.33 adults per 100 grains), followed by tin pot (0.00 to 9.00 adults per 100 grains), earthen pot (0.00 to 9.33 adults per 100 grains) and polyester bag (0.00 to 18.67 adults per 100 grains). On the other hand, the maximum adult emergence was observed in untreated control grains stored in polyester bag (0.00 to 48.33 adults per 100 grains) followed earthen pot (0.00 to 31.00 adults per 100 grains), tin pot (0.00 to 27.00 adults per 100 grains) and plastic pot (0.00 to 24.33 adults per 100 grains). These trends of adult emergence were nearly followed by dried mahogany leaf and dried mango leaf treated grains stored in any containers (Table 7).

Considering the performance of different botanicals in reducing the adult emergence of rice moth over control stored in different containers, the dried neem leaf showed the highest reduction ranged from 68.28 to 82.20% over control stored in polyester bag, earthen pot, tin pot and plastic container, respectively followed by garlic bulb (61.37 to 82.20%) and dried mahogany leaf (57.93 to 80.85%), whereas the lowest reduction of grain content loss over control was recorded in dried mango leaf treated grains (50.34 to 67.12%) stored in polyester bag, earthen pot, tin pot and plastic container, respectively as results depicted in Table 7.

Table 7. Interaction Effect of Container and Botanical on the Adult Emergence of Rice Moth *S. cerealella* infesting Hybrid Rice Grain (Hira) n Storage.

Container	Botanicals	Number of adult emergence per 100 seeds							% reduction over control
		30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Plastic container	Dried neem leaf	0.00	0.00e	1.00j	1.66j	2.33n	4.33k	1.55l	82.20
	Dried mango leaf	0.00	0.33de	3.00fghi	3.66hi	5.33jkl	8.00j	3.38jk	67.12
	Dried mahogany leaf	0.00	0.33de	1.66ij	2.33ij	4.00lm	4.66k	2.17l	80.85
	Bulb of garlic	0.00	0.33de	1.33j	2.33ij	3.33mn	4.33k	1.94l	82.20
	Control	0.00	1.00de	4.66de	10.00e	18.00d	24.33d	9.66d	-
Tin pot	Dried neem leaf	0.00	0.33de	1.66ij	3.66hi	5.66jk	8.33j	3.28jk	69.15
	Dried mango leaf	0.00	1.33cd	4.33def	7.66f	10.33f	13.00h	6.11gh	51.85
	Dried mahogany leaf	0.00	0.66de	2.33ghij	5.00gh	5.66jk	10.33i	4.00ij	61.74
	Bulb of garlic	0.00	0.33de	2.00hij	4.66gh	5.00jkl	9.00ij	3.50jk	66.67
	Control	0.00	2.66b	6.33c	16.00c	23.00c	27.00c	12.50c	-
Earthen Pot	Dried neem leaf	0.00	0.33de	2.33ghij	3.00ij	4.33klm	8.66j	3.11k	72.07
	Dried mango leaf	0.00	1.00de	5.66cd	7.33f	13.67e	14.67g	7.05ef	52.68
	Dried mahogany leaf	0.00	0.66de	3.66efg	5.66g	7.33hi	10.33i	4.61i	66.68
	Bulb of garlic	0.00	0.33de	3.00fghi	5.00gh	6.33ij	9.33ij	4.00ij	69.90
	Control	0.00	2.66b	9.33b	18.33b	26.67b	31.00b	14.63b	-
Polyester bag	Dried neem leaf	0.00	1.00de	3.33efgh	5.00gh	8.66gh	15.33g	5.55h	68.28
	Dried mango leaf	0.00	2.33bc	7.00c	12.00d	17.00d	24.00d	10.36d	50.34
	Dried mahogany leaf	0.00	2.33bc	4.66de	6.00g	10.67f	20.33e	7.33e	57.93
	Bulb of garlic	0.00	1.33cd	3.33efgh	5.66g	9.33fg	18.67f	6.39fg	61.37
	Control	0.00	4.00a	13.67a	24.00a	35.00a	48.33a	20.80a	-
LSD $_{(0.01)}$			1.10	1.40	1.27	1.45	1.45	0.70	-
CV (%)			42.86	15.00	7.75	5.94	4.19	4.81	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

From the above findings it was revealed that among containers, the most suitable container was plastic container in reducing the percent adult emergence against rice moth followed by tin pot and earthen pot, whereas polyester bag performed as least suitable container. In case of efficiency of botanicals, dried neem leaf performed as most effective in reducing the percent adult emergence of rice moth followed by garlic bulb, dried mahogany leaf and mango leaf. Yadav *et al.* (2007), Dwivedi and Anand (1999), and Rajendran and Sriranjini (2008) also reported more or similar results.

c) Effect of Containers and Botanicals on the Grain Content Loss during Storage of Rice moth

Effect of Containers on the Grain Content Loss Caused by Rice moth

Significant variations among different containers were observed on the grain content loss caused by rice moth in storage throughout the storing period on the hybrid rice (Table 8). More or less similar but increasing trends of grain content loss by weight were observed at different exposure time after egg release from 30 to 180 DAER. Among different containers, plastic container performed as the least suitable container for rice moth infestation and lowest grain content loss was recorded that was ranged from 2.81 to 13.58% at 30 to 180 DAER, respectively. This trend was followed by tin pot (5.84 to 19.27%) and earthen pot (5.55 to 23.13%), whereas polyester bag performed as the most suitable container for rice moth infestation and the highest grain content loss was recorded that was ranged from 5.55 to 25.38% at 30 to 180 DAER, respectively. Considering the mean grain content loss, more or less similar trends of results were observed for different containers as depicted in Table 8.

Considering the performance of different containers in reducing the grain content loss, plastic container reduced the highest percentage of grain content loss (46.49%) over polyester bag followed by tin pot (24.87%) and the lowest reduction (8.87%) was recorded in earthen pot (Table 8).

Table 8. Effect of Containers on the Grain Content Loss of Hybrid Rice (Hira) by Rice moth *S. cerealella* during Testing of Botanicals in Storage.

Containers	Percent grain content loss by weight							% reduction over Bag
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Plastic container	2.81b	5.65b	6.96c	9.80c	12.23d	13.58d	8.50d	46.49
Tin pot	5.84a	6.25b	9.15b	11.09b	15.95c	19.27c	11.25c	24.07
Earthen pot	5.55a	7.05a	10.27b	11.67b	17.82b	23.13b	12.58 b	8.87
Polyester bag	5.55a	7.23a	12.07a	16.08a	22.86a	25.38a	14.85a	-
$LSD_{(0.01)}$	1.14	0.69	1.24	0.59	0.99	1.03	0.33	-
CV(%)	10.42	4.77	5.86	2.20	2.59	2.30	1.27	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

Effect of Botanicals on the Grain Content Loss Caused by Rice moth

Grain content loss varied significantly among different botanical treated rice grains during the management of rice moth in storage throughout the storing period (Table 9). More or less similar but increasing trends of grain content loss by weight were observed at different time exposure from 30 to 180 DAER. Among different botanicals, dried neem leaf performed as the most effective botanical in reducing grain content loss caused by rice moth and the lowest percentage of grain content loss was recorded that was ranged from 2.51 to 10.86% at 30 to 180 DAER, respectively. This trend was followed by garlic bulb treated grains (5.10 to 15.09%). This was also followed by dried mahogany leaf treated grains (5.20 to 11.94%) and dried mango leaf treated grains (5.91 to 21.16%), whereas the highest percentage of grain content loss was recorded from untreated control rice grains and that was ranged from 5.97 to 36.60% at 30 to 180 DAER, respectively. Considering the mean grain content loss, the dried neem leaf was also performed as the most effective botanical in reducing the grain content loss caused by rice moth followed by garlic bulb, dried mahogany leaf and dried mango leaf as depicted in Table 9. These findings were supportive to worldwide reports, when mixed with stored grains, leaf, bark, seed powder, or oil extracts of plants reduce oviposition rate and suppress adult emergence of stored product insects, and also reduce seed damage rates (Talukder, F. A. and Howse, P. E. 1995, Tapondjou, L. A. *et. al.* 2002). Varous neem plant parts, namely, leaves, crushed seeds, powdered fruits, oil, and so forth, have been used to protect stored grain from infestation (F. A. Talukder *et. al.,* 2004, Sahayaraj, K. *et. al., 2008*) having effective grain protection against stored grain insect pests like Sitophilus oryzae, Tribolium cataneum, Rhyzopertha dominica, and Callosobruchus chinensis by adhered to grain forms uniform coating around the grains against storage pests for a period of 180–330 days (Ahmed, S. M. 1994).

Considering the performance of different botanicals in reducing the grain content loss over control, the dried neem leaf showed the highest reduction (67.46%) over control followed by garlic bulb (58.77%) and dried mahogany leaf (53.72%), whereas the lowest reduction of grain content loss over control was recorded in dried mango leaf treated rice grains (42.19%) as depicted in Table 9.

Table 9. Effect of Botanicals on the Grain Content Loss of Hybrid Rice (Hira) by Rice moth *S. cerealella* in Storage.

Botanicals	Percent grain content loss by weight							% reduction over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Dried neem leaf	2.51b	4.03c	6.23d	7.51d	10.86d	11.91e	7.19e	67.46
Dried mango leaf	5.91a	7.26b	8.46c	9.79b	16.83b	21.16b	11.57b	42.19
Dried mahogany leaf	5.10a	6.81b	8.07c	8.98c	13.78c	15.09d	9.62d	58.77
Bulb of garlic	5.20a	6.62b	10.05b	10.25b	13.80c	16.94c	10.48c	53.72
Control	5.97a	8.01a	15.25a	24.26a	30.80a	36.60a	20.13a	-
$LSD_{(0.01)}$	1.14	0.69	1.24	0.59	0.99	1.03	0.33	-
CV(%)	10.42	4.77	5.86	2.20	2.59	2.30	1.27	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

Combined Effect of Botanicals and Containers on the Grain Content Loss

Grain content loss caused by rice moth was varied significantly among different botanical treated rice grains stored in different containers throughout the storing period (Table 10). More or less similar but increasing trends of grain content loss by weight were observed at different exposure time after egg release from 30 DAER to 180 DAER. The lowest percentage of grain content loss was occurred in dried neem leaf treated grains stored in plastic container that was ranged from 1.55 to 6.98% followed by tin pot (2.58 to 10.40%), earthen pot (2.84 to 14.57%) and polyester bag (3.10 to 15.70%) at 30 to 180 DAER, respectively. These trends of grain content loss were nearly followed by garlic bulb treated grains stored in plastic container (2.84 to 12.00%), tin pot (6.46 to 15.83%), polyester bag (5.94 to 18.93%) and earthen pot (5.55 to 21.00%). On the other hand, the highest grain content loss was observed in untreated control grains stored in polyester bag (6.46 to 46.37%) followed earthen pot (6.97 to 39.23%), tin pot (6.97 to 33.17%) and plastic pot (3.49 to 27.63%). These trends of grain content loss were nearly followed by dried mahogany leaf and dried mango leaf treated grains stored in any containers as depicted in Table 10. Considering the performance of different botanicals in reducing the grain content loss caused by rice moth over control stored in different containers, the dried neem leaf showed the highest reduction ranged from 66.14 to 74.74% over control stored in polyester bag, tin pot, earthen pot and plastic container, respectively followed by dried mahogany leaf (59.46 to 69.13%) and garlic bulb (59.46 to 56.57%), whereas the lowest reduction of grain content loss over control was recorded in dried mango leaf treated grains (41.56 to 53.93%) stored in polyester bag, tin pot, earthen pot and plastic container, respectively as the results depicted in Table 10.

Table 10. Interaction Effect of Container and Botanical on the Grain Content Loss of Hybrid Rice (Hira) by Rice moth *S. cerealella* in Storage.

Container	Botanicals	Percent grain content loss by weight							% reduction over control
		30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Plastic container	Dried neem leaf	1.55d	1.93h	3.48i	4.90n	5.55m	6.98m	4.07r	74.74
	Dried mango leaf	3.62c	6.72de	6.97gh	7.75kl	11.73j	12.73j	8.26no	53.93
	Dried mahogany leaf	2.58cd	6.72de	6.98gh	8.40j	9.17l	8.53l	7.06p	69.13
	Bulb of garlic	2.84c	6.07e	7.62fgh	9.17hi	11.07jk	12.00j	8.14o	56.57
	Control	3.49c	6.85cde	9.76d	18.80d	23.60d	27.63d	15.00d	-
Tin pot	Dried neem leaf	2.58cd	4.26g	6.59h	6.85m	9.30l	10.40k	6.67q	68.65
	Dried mango leaf	6.59ab	6.98cd	8.79def	9.56hi	14.30hi	22.53e	11.43i	32.08
	Dried mahogany leaf	6.59ab	6.59de	8.01efg	6.98m	10.67k	14.43i	8.89m	56.49
	Bulb of garlic	6.46ab	6.46de	9.30de	9.79h	13.50i	15.83h	10.20k	52.28
	Control	6.97a	6.98cd	13.10c	22.27c	32.00b	33.17c	19.07c	-
Earthen pot	Dried neem leaf	2.84c	4.78fg	7.88fgh	7.36lm	13.77i	14.57i	8.54n	62.86
	Dried mango leaf	6.72ab	7.62bc	9.30de	9.17i	19.17f	22.27e	12.37g	43.23
	Dried mahogany leaf	5.68ab	6.85cde	8.66def	8.14jk	15.70g	18.60g	10.57j	52.59
	Bulb of garlic	5.55b	7.10bcd	9.66d	7.75kl	10.67k	21.00f	10.30jk	46.47
	Control	6.97a	8.91a	15.87b	25.90b	29.80c	39.23b	21.13b	-
Polyester bag	Dried neem leaf	3.10c	5.17f	6.98gh	10.93g	14.83gh	15.70h	9.47l	66.14
	Dried mango leaf	6.72ab	7.75b	8.78def	12.70f	22.13e	27.10d	14.20e	41.56
	Dried mahogany leaf	5.55b	7.10bcd	8.66def	12.40f	19.57f	18.80g	11.97h	59.46
	Bulb of garlic	5.94ab	6.85de	13.63c	14.30e	19.97f	18.93g	13.27f	59.18
	Control	6.46ab	9.30a	22.27a	30.07a	37.80a	46.37a	25.33a	-
$LSD_{(0.01)}$		1.14	0.69	1.24	0.59	0.99	1.03	0.33	-
CV(%)		10.42	4.77	5.86	2.20	2.59	2.30	1.27	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

From the above findings it was revealed that among containers, the most suitable container was plastic container in reducing the percent grain content loss of rice caused by rice moth followed by tin pot and earthen pot, whereas polyester bag performed as least suitable container. In case of efficiency of botanicals, dried neem leaf performed as most effective in reducing the percent grain content loss caused by rice moth followed by garlic bulb, dried mahogany leaf and mango leaf. Yadav *et al.* (2007), Dwivedi and Anand (1999), and Rajendran and Sriranjini (2008) also reported more or similar results.

d) Effect of Containers and Botanicals on the Viability of Stored Seeds during Storage of Rice moth Effect of Containers on the Viability of Stored Rice Seed

The rice seed germination was varied significantly among different containers used in storing rice grains against rice moth throughout the storing period (Table 11). More or less similar but decreasing trends of percent seed germination were observed at different data recording time after egg release from 30 to 180 DAER. Among different containers, plastic container performed as the least suitable container for rice moth infestation but the most effective for preserving the viability of the seeds for which the highest seed germination was achieved that was ranged from 95.20 to 67.87% at 30 to 180 DAER, respectively. This trend was followed by tin pot (93.27 to 64.80%) and earthen pot (90.93 to 56.33%), whereas polyester bag performed as the least suitable for preserving the viability of the seeds and the lowest seed germination was recorded that was ranged from 90.93 to 38.60% at 30 to 180 DAER, respectively. In case of mean seed germination, more or less similar trends of results were observed for different containers (Table 11).

Considering the seed germination performance of different containers plastic container increased the highest percentage of seed germination (43.13%) followed by tin pot (40.43%), whereas the lowest increase (31.48%) was recorded in earthen pot over polyester bag (Table 11).

Table 11. Effect of Containers on the Seed Germination during Testing of Botanicals against Rice moth *S. cerealella* Infesting Hybrid Rice grain in Storage.

Containers	Percent seed germination							% increase over bag
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Plastic container	95.20a	93.20a	88.13a	80.60a	76.53a	67.87a	83.56 a	43.13
Tin pot	93.27a	90.13b	85.73b	78.87b	72.20b	64.80b	80.80b	40.43
Earthen pot	90.93b	88.33bc	83.13c	76.40c	69.07c	56.33c	77.32c	31.48
Polyester bag	90.93b	87.33c	80.53d	71.73d	58.07d	38.60d	71.17d	-
$LSD_{(0.01)}$	2.06	1.87	1.40	1.48	1.78	2.08	0.67	-
CV(%)	1.01	0.94	0.75	0.87	1.17	1.65	0.39	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

As depicted in Table 11, more or less similar but decreasing trends of seed germination were observed for different containers used against rice moth infestation at different days after egg release (DAER) from 30 to 180 DAER. At the initial stage of infestation that is at 30 DAER, the seed germination was maximum (90.93 to 95.20%) for any containers. But with the increase of the exposure time the seed germinations were decreased gradually, which was minimum at 180 DAER that was ranged from 38.60 to 67.87%, where the lowest seed germination was recorded in polyester bag followed by earthen pot (56.33%). This was also followed by tin pot (64.80%) and plastic container.

Effect of Botanicals on the Viability of Stored Rice Seed

The rice seed germination was also varied significantly for different botanicals used against rice moth in storage throughout the storing period (Table 12). More or less similar but decreasing trends of percent seed germination were observed at different exposure time after egg release from 30 to 180 DAER. Among different botanicals, dried neem leaf performed as the most effective botanical for controlling rice moth as well as most effective for preserving the viability of the seeds for which the highest seed germination was achieved that was ranged from 94.42 to 68.08% at 30 to 180 DAER, respectively. This trend was followed by garlic bulb (93.08 to 62.25%) that was also followed by dried mahogany leaf (92.67 to 61.83%) and dried mango leaf treated grains (91.83 to 52.17%), whereas the untreated control grains showed the lowest seed germination that was ranged from 90.92 to 40.17% at 30 to 180 DAER, respectively. In case of the mean seed germination, more or less similar trends of the results were also observed treated with different botanicals as depicted in Table 12.

Considering the performance of different botanicals in increasing the percent seed germination over control, dried neem leaf increased the highest percentage of seed germination (41.00%) followed by garlic bulb (35.47%) and dried mahogany leaf (35.03%), whereas the lowest seed germination (23.00%) were increased for dried mango leaf treated grains (Table 12).

Table 12. Effect of Botanicals on the Seed Germination during the Management of Rice moth *S. cerealella* Infesting Hybrid Rice (Hira) in Storage.

Botanicals	Percent seed germination							% increase over control
	30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Dried neem leaf	94.42a	92.92a	89.50a	85.33a	79.08a	68.08a	84.86a	41.00
Dried mango leaf	91.83bc	90.83b	85.75c	78.50c	66.17d	52.17c	77.50c	23.00
Dried mahogany leaf	92.67abc	91.67ab	87.17b	82.00b	75.00b	61.83b	81.70b	35.03
Bulb of garlic	93.08ab	91.33ab	87.08bc	80.75b	73.08c	62.25b	81.22b	35.47
Control	90.92c	82.00c	72.42d	57.92d	51.50e	40.17d	65.78d	-
$LSD_{(0.01)}$	2.06	1.87	1.40	1.48	1.78	2.08	0.67	-
CV(%)	1.01	0.94	0.75	0.87	1.17	1.65	0.39	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

As depicted in Table 12, more or less similar but decreasing trends of seed germination were observed using different botanicals against rice moth at different days after egg release (DAER) from 30 to 180 DAER. At the initial stage of infestation that is 30 DAER, the seed germination was maximum (91.83 to 94.42%) for any of the botanicals because of the minimum infestation. But with the increase of the data recording time, the seed germinations were decreased gradually, which was minimum at 180 DAER that was ranged from 40.17 to 68.08%, where the lowest seed germination was recorded in untreated control grains followed by dried mango leaf treated grains (52.17%). This was also closely followed by dried mahogany leaf (61.83%), garlic bulb (62.25%) and dried neem leaf treated seeds (68.08%).

Combined Effect of Botanicals and Containers on the Viability of Stored Rice Seed

The seed germination was significantly varied for different botanical treated rice grains stored in different containers throughout the storing period (Table 13). More or less similar but decreasing trends of seed germination were observed at different DAER from 30 to 180 DAER. The highest seed germination was observed in dried neem leaf treated grains stored in plastic container that was ranged from 97.00 to 80.67% followed by tin pot (95.67 to 77.00%), earthen pot (93.00 to 67.67%) and polyester bag (92.00 to 47.00%) at 30 to 180 DAER, respectively. These trends of seed germination were nearly followed by garlic bulb treated grains stored in tin pot (94.33 to 74.00%), plastic container (95.00 to 72.00%), earthen pot (91.33 to 61.00%) and polyester bag (91.67 to 42.00%). On the other hand, the lowest seed germination was observed in untreated control grains stored in polyester bag (89.67 to 22.00%) followed earthen pot (90.00 to 40.33%), tin pot (90.33 to 43.33%) and plastic pot (93.67 to 55.00%). These trends of seed germinations were nearly followed by dried mahogany leaf and dried mango leaf treated grains stored in polyester bag, earthen pot, tin pot and plastic container, respectively (Table 13).

Considering the performance of different botanicals in increasing the seed germination over control stored in different containers more or less similar but reverse trends were observed, where the dried neem leaf showed the highest performance in increasing the seed germination that was ranged from 31.82 to 53.19% over control stored in polyester bag, tin pot, earthen pot and plastic container, respectively followed by garlic bulb (23.61 to 47.62%) and dried mahogany leaf (22.89 to 47.20%), whereas the lowest reduction of seed germination over control was recorded in dried mango leaf treated grains (22.17 to 45.45%) as the results depicted in Table 13. In case of mean seed germination, more or similar trends of results were also observed for different botanical treated grains stored in different containers.

Table 13. Interaction Effect of Container and Botanical on the Seed Germination during the Management of Rice moth *S. cerealella* Infesting Hybrid Rice (Hira) in Storage.

Container	Botanical	Percent seed germination							% increase over control
		30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Plastic container	Dried neem leaf	97.00a	96.67a	92.67a	89.33a	87.67a	80.67a	90.67a	31.82
	Dried mango leaf	95.33b	94.33b	89.00cde	80.00ef	71.00g	72.33cd	81.63e	23.96
	Dried mahogany leaf	95.00bc	95.00ab	91.00b	85.67b	83.33b	71.33d	86.87b	22.89
	Bulb of garlic	95.00bc	95.00ab	90.33bc	82.33c	79.00cd	72.00cd	85.57c	23.61
	Control	93.67cde	85.00h	77.67n	65.67i	61.67j	55.00g	73.07k	-
Tin pot	Dried neem leaf	95.67b	93.67bc	89.67bcd	88.00a	80.67c	77.00b	87.40b	43.73
	Dried mango leaf	92.33efg	92.33cd	87.33fgh	79.33efg	68.67h	55.67g	79.23g	22.17
	Dried mahogany leaf	93.67cde	91.67de	88.00efg	86.00b	78.00de	74.00c	85.20c	41.45
	Bulb of garlic	94.33bcd	90.00ef	89.00cde	80.67de	78.00de	74.00c	84.30d	41.45
	Control	90.33hij	83.00i	74.67o	60.33j	55.67k	43.33j	67.87l	-

Container	Botanical	Percent seed germination							% increase over control
		30 DAER	60 DAER	90 DAER	120 DAER	150 DAER	180 DAER	Average	
Earthen pot	Dried neem leaf	93.00def	91.33de	88.67def	85.00b	78.00de	67.67e	83.90d	40.40
	Dried mango leaf	90.00ij	89.00fg	84.67jk	79.33efg	65.00i	52.33h	76.67i	22.93
	Dried mahogany leaf	90.33hij	90.33def	85.67ij	80.33ef	77.00e	60.33f	80.63f	33.15
	Bulb of garlic	91.33ghi	90.67def	86.33hi	82.00cd	74.33f	61.00f	80.90f	33.89
	Control	90.00ij	80.33j	70.33p	55.33k	51.00l	40.33k	64.50m	-
Polyester bag	Dried neem leaf	92.00fg	90.00ef	87.00ghi	79.00fg	70.00gh	47.00i	77.47h	53.19
	Dried mango leaf	89.67j	87.67g	82.00m	75.33h	60.00j	40.33k	72.47k	45.45
	Dried mahogany leaf	91.67fgh	89.67efg	84.00kl	76.00h	61.67j	41.67jk	74.10j	47.20
	Bulb of garlic	91.67fgh	89.67efg	82.67lm	78.00g	61.00j	42.00jk	74.13j	47.62
	Control	89.67j	79.67j	67.00q	50.33l	37.67m	22.00l	57.67n	-
$LSD_{(0.01)}$		1.280	1.870	1.397	1.481	1.780	2.075	0.666	-
CV(%)		1.01	0.94	0.75	0.87	1.17	1.65	0.39	-

DAER = Days after egg release, LSD = Least Significance Difference, CV= Coefficient of Variation
In column, means followed by same letters are not significantly different at 1% level of significance by LSD.

As depicted in Table 13, more or less similar but decreasing trends of seed germination caused by rice moth infestation were observed at different days after egg release (DAER) from 30 to 180 DAER. At the initial stage of infestation that is at 30 DAER, the seed germination was maximum (91.83 to 94.42%) for any of the botanicals because of the minimum infestation stored in any containers. But with the increase of the data recording time, the seed germinations were decreased gradually, which was minimum at 180 DAER, where the lowest seed germination was observed for grains stored in polyester bag that was ranged from 22.00 to 47.00% for untreated control, treated with dried mango leaf (40.33%), dried mahogany leaf (41.67%), garlic bulb (42.00%) and dried neem leaf (47.00%), respectively. This trend seed germination was closely followed by the grains stored in earthen pot that was ranged from 40.33 to 67.67% for untreated control, grains treated with dried mango leaf, dried mahogany leaf, garlic bulb and dried neem leaf, respectively.

From the above findings it was revealed that among containers, the most suitable container was plastic container in preserving the viability of stored seeds by increasing their percent seed germination, from it may be concluded that rice moth could not affect the viability of seeds. This was followed by tin pot and earthen pot, whereas polyester bag performed as least suitable container. Among the containers, polyester bag could not prevent the damage caused by rice moth, resulting minimum percent seed germination was observed. In case of efficiency of botanicals, dried neem leaf performed as most effective in increasing the percent seed germination of rice grains followed by garlic bulb, dried mahogany leaf and dried mango leaf. From this findings it was also revealed that the respiratory gaseous effect of neem leaf prevent the most of the grains from the caused by rice moth and preserved the viability of the seeds and showed the maximum percent seed germination.

e) Economic Analysis of the Botanical based Management Practices

Economic analysis of botanical based management practices applied against rice moth infesting rice grains in storage is represented in Table 14. The untreated control treatment did not incur any pest management cost. The labor costs were involved in dried neem leaf, dried mango leaf and dried mahogany leaf based treatment for collecting, dried and grinding the respective leaves, and in case of garlic bulb the cost of garlic was involved. Thus the highest benefit cost ratio (BCR) 11.3 was calculated in dried neem leaf @ 2.5 gm/kg rice grains. This was followed (9.76) by dried mahogany leaf @ 2.5 gm/kg rice grains and 8.31 in using chopped bulb of garlic @ 1.0 gm/kg rice grains. On the other hand, the minimum BCR (6.72) was calculated in dried mango leaf @ 2.5 gm/kg rice grains (Table 14).

Table 14. Economic Analysis of Botanicals based Management Practices Applied against Rice moth on Rice grains in Storage.

Treatment	*Cost of management (Tk)	**Grain saved (kg/pot)	Grain saved (ton)	Gross return (Tk)	Net return (Tk)	Adjusted net return(Tk)	BCR
Dried neem leaf @ 25g/kg grains	360.00	0.88	880.90	15856.20	15496.20	4084.2	11.3
Dried mango leaf @ 25g/kg grains	360.00	0.79	788.40	14191.20	13831.20	2419.2	6.72
Dried mahogany leaf @ 25g/kg grains	360.00	0.85	849.10	15283.80	14923.80	3511.8	9.76
Bulb of garlic @ 5g/kg grains	440.00	0.83	830.60	14950.80	14510.80	3098.8	8.31
Control	0.00	0.63	634.00	11412.00	11412.00	-	-

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

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 rice gains in storage, which gave the highest BCR (11.3). As well as considering the eco-friend point of view, neem based management was also acceptable for the consumers.

5. Conclusion

Prevention of food losses during postharvest storage is of paramount economic importance. Integrated pest management is now a widely accepted strategy in pest control including postharvest infestation control The results of the study have confirmed that the plastic containers along with neem leaf @ 2.5 gm/kg rice grains based management practice was the most suitable and economic viable for controlling of rice moth in rice grain storage condition. The use of botanicals should be encouraged in small farm storage, as these are low cost and easily available when compared with the losses incurred in untreated grains. Additionally, more grains would be available for use as food and for sale by the farmer throughout the year, as grain infestation would be reduced. Thus, the present investigations indicate that botanical derivatives might be useful as insect control agents for commercial use minimizing the severe damage caused by insect pests, proved to be highly effective against stored product insects. Application of plant products to grain seeds for storage is to be an inexpensive and effective technique, and easy adaptability will give additional advantages leading to acceptances agricultural sectors of developing countries but also have less environmental impact in term of insecticidal hazard

References

[1] Anonymous, 1981. BRRI Annual Report for 1981. BRRI, Joydebpur, Gazipur, Bangladesh.

[2] Ahmed, S. and B. Koppel. 1985. “Plant extracts for pest control: village level processing and use by limited resource farmers,” in Proceedings of the American Association for the Advancement of Science Annual Meeting, Los Angeles, Calif, USA.

[3] Ahmed, S. M. 1994 “Neem (Azadirachta Indica A. Juss) a safer insecticide potentials and prospects,” Pest Management, View at Google Scholar, pp. 1–3.

[4] BRRI (Bangladesh Rice Research Institute). 1984. Annual Report. Bangladesh Rice Research Institute, Joydebpur, Gazipur, pp.135-139.

[5] BBS,1990. Statistical Yearbook of Bangladesh. Ministry of Planning, Govt. of the People’s Republic of Bangladesh, Dhaka.

[6] Bandara, KANP and DKH. Seneviratne. 1993. Effect of wild ginger Zingiber perfurium Roscoe on cowpea seed bruchid, Callosobruchus maculatus (F.) in stored cowpea. Trop Agric., 149:89-100.5.

[7] Butterworth, JH. and ED. Morgan. 1968. Isolation of a substance that suppresses feeding in locusts. J Chem Soc Chem Commun, 2:23-24.6.

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

[9] Chandra, S., B. P. Khare and V. K. Sharma. 1989. Efficacy of different chemicals on rice-weevil, *Sitophilusoryzae* Linn. *Indian J. Agril. Res.* 14(1): 19-25.

[10] Cogburn, R. R. 1975. Stored rice insect research, *The Rice J.* 7:78.

[11] Caswell, GH. 1981. Damage to stored cowpea in the Northern part of Nigeria, Samaru Journal of Agricultural Research. 1:11-19. 7

[12] Chellapa, K. and S, Chelliah. 1976. Preliminary trials with oil emulsions for the control of insect pests. Madras Agric J.63:10–11.

[13] Calverley, D. J. B. 1994. Programme for the prevention of food losses: A study of eleven projects in Asia concerned with rice. Final report, FAO.

[14] Dilwari, V. K., D. G. Dhaluiwal and M. S. Maha. 1991. Toxicity of allylisothiocyanate to rice weevil, *Sitophylusoryzae* Linn. *J. Ins. Sci.* 4(1): 101-102.

[15] Douglas, W. A. 1941. Field infestation of insects that injure rice in storage. *Circ. USDP*, No. 602, 8p.

[16] Dwivedi, S. C. and Anand, K. 1999. Ovicidal activity of six plant leaf extracts on the eggs of *Corcyra cephalonica*Stainton (Lepidoptera :Pyralidae). *Uttar Pradesh Journal of Zoology.* 9(3): 175-178.

[17] Dubey, N. K., B. Srivastava and A. Kumar. 2008. “Current status of plant products as botanical pesticides in storage pest management,” Journal of Biopesticide, vol. 1(2), pp. 182–186.

[18] Talukder F. A., M. S. Islam, M. S. Hossain, M. A. Rahman, and M. N. Alam. 2004. “Toxicity effects of botanicals and synthetic insecticides on Tribolium castaneum (Herbst) and Rhyzopertha dominica (F.),” Bangladesh Journal of Environment Science, vol. 10(2), pp. 365–371.

[19] Fry, BN., and Pruthi. 1938. Effects of azadirachtin/Neemazal on different stages and adult life table parameters of Trichogrammacacoeciae (Hymenoptera: Trichogrammatidae. Journal of Economic. pp 105-107.

[20] "IRRI, 2008– International Rice Research Institute" Archived 21 May at the Wayback Machine.

[21] Jilani and SU. 1983 Effects of dried neem leaves of with grains repel the insect pests at different stages and adult life table parameters of rice moth. Journalof Economic. pp 56-60.

[22] Khater, F. A. 2012. “Prospects of botanical biopesticides in insect pest management,” Journal of Applied Pharmaceutical Science, vol. 2(9), pp. 244–259.

[23] Ketkar, C. M. 1976. Utilization of neem (*Azadirachtaindica* A. Juss) and itsby products. KVIC, Bombay, 234p.

[24] Krishnamurthi, B. and S. D. Rao, 1950. Some important insect pests of stored grains and their control, *Entomol. Series Bull*., No. 14, Agric. College & Research Institute, Mysore, Bangalore.

[25] *"Livelihoods and environment (Riches)"*. Archived from *the original* on 28 September 2007.

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

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

[28] Prakas, A., I. C. Pasalu and Jagadiswari Rao. 1984. The pest status of insects infesting rice stored in Orissa (India). *Tropical Stored Prod. Inf.* 47(1): 15-20.

[29] Prakash, A, J. Rao, I. C. Pasalu and K. C. Mathur. 1987. Rice Storage and insect pest management. B. R. Publishing Corporation. Delhi, pp.15-60.

[30] Prakash, A. and I. P. Kauraw. 1982. A package of practices for pest management in rice storage. Farmers and Parliament. 17(11): 15-16.

[31] Pruthi and Singh. 1950 Effects of azadirachtin/Neemazal on different stages and adult life table parameters of Trichogrammacacoeciae (Hymenoptera: Trichogrammatidae. Journal of Economic pp 179-183.

[32] Quasem, M. A. and Siddiquee, M. A. 2009. "Reduction of Post-harvest losses in Rice", Paper presented at CIRDAP Workshop, on Nov. 23, CIRDAP, Dhaka.

[33] Rajendran, S. and V. Sriranjini. 2008. Plant products as fumigants for stored-product insect control. *Journal of Stored Products Research*. 44(2): 126-135.

[34] Shrivastava, J. L. 1980. Pesticide resistance in food grain and pest resistance to pesticide. *Bull. Grain Tech.* 18(1): 65-78.

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

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

[37] Shaaya E and M. Kostjukovshi. 1997. Plant oils as fumigants and contact insecticides for the control of stored products insects. J Stored Prod Res, 33(1):7 -15.

[38] Sahayaraj, K. 2008. "Common plants oils in agriculture and storage pests management," Green Farming, vol. 1(2), pp. 48–49, View at Google Scholar

[39] Talukder, F. A., M. S. Islam, M. S. Hossain, M. A. Rahman, and M. N. Alam, 2004. "Toxicity effects of botanicals and synthetic insecticides on Tribolium castaneum (Herbst) and Rhyzopertha dominica (F.)," Bangladesh Journal of Environment Science, vol. 10(2), pp. 365–371.

[40] Talukder F. A. and P. E. Howse, 1995. "Laboratory evaluation of toxic and repellent properiies of the pitharaj tree, Aphanamixis polstachya Wall & Parker, against Sitophilus oryzae (L.)," International Journal of Pest Management, vol. 40, pp. 274–279.

[41] Tapondjou, L. A., C. Adler, H. Bouda, and D. A. Fontem, 2002. "Efficacy of powder and essential oil from Chenopodium ambrosioides leaves as post-harvest grain protectants against six-stored product beetles," Journal of Stored Products Research, vol. 38(4), pp. 395–402.

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

[43] Yadav, U. S., S. S. Prasad, M. Ram, and K. Neeraj. 2007. Effect of certain grain protectant oils on growth and development of angoumois grain moth, *Sitotrogacerealella* Olivier. *Research on Crops*.; 8(2): 442-445.