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# Economic Impacts of Rice Grains Storage Using Fumigants Against Rice Weevils

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## 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 fumigants viz. Organic treatment Untreated control was tested. The Camphor was the most effective fumigant to protect the rice grain infestation in storage against rice moth in laboratory condition than phostoxin, naphthalene and organic treatment. Camphor had reduced 73.77% rice grain infestation, 92.30% adult emergence, 75.75% grain content loss and increased 56.34% seed germination over control followed by phostoxin, which reduced grain infestation, 70.65% adult emergence, 74.66% grain content loss and increased 55.77% seed germination. The Naphthalene reduced 61.34% grain infestation, 71.71% adult emergence, 64.95% grain content loss and increased 55.58% seed germination. The organic treatment reduced 48.94% grain infestation, 67.65% adult emergence, 40.15% grain content loss and increased 53.77% seed germination. Considering the fumigants, the camphor @ 1.0 gm/kg rice grains was performed as the most economically viable treatment that gave the highest BCR (12.6) applied against rice moth in storage rice grains followed by organic treatment (11.30), phostoxin (6.0) and naphthalene (5.97).

## Keywords

Rice Weevils, Fumigants, Storage, Economic Impact, Bangladesh

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## 1. Introduction

About 90% of the population of Bangladesh depends on rice for their major food intake [1]. 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 was stored for seed [17]. During the storage condition of ambient temperature, rice is being damaged by a number of agents, such as insects, rodents, fungi, mites, birds and moisture [16]. Among them, storage insects are the major agents causing considerable losses every year. Nearly seventeen species of insects have been found to infest stored

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rice [17] of which rice moth (*Sitotrogacerealella*), rice weevil (*Sitophilusoryzae* Linn.) and beetles (*Triboliumcastaneum*) 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 [4]. 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 [18]. 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 [10]. 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 [8].

Bangladesh produces a total of 33.542 million tons of rice from an area of 26.018 million acres [3]. 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 parbolied milled rice in earthen pot (called motka) [4].

Chemical control, however as an alternative method has got great value. Several reports are available on the efficacy of different chemicals [7, 9, 16, 23, 24, 25]. 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 [18 & 22]. 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 [6]. 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.

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. Fumigants may be the alternative method of chemical for controlling rice moth. The fumigation toxicity of different plant oils and their derivatives were also tested by several workers against stored grain insect pests. Reported that the fumigant toxicity of essential oils of plants (mainly belonging to Apiaceae, Lamiaceae, Lauraceae and Myrtaceae) and their components (cyanohydrins, monoterpenoids, sulphur compounds, thiocyanates and others) largely reduced the infestation of beetle pests such as *Triboliumcastaneum*, *Rhyzoperthadominica*, *Sitophilusoryzae* and *Sitophiluszeamais*. Camphor is the new invention for insect pest management extracted from the wood of plant, *Cinnamonumcamphora* has fumigation action and widely used in medicinal purposes [15] and available at grocery stores. 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 [14]. The fumigation action of camphor against pulse beetle, *Callosobruchuschinensis* [20], rice weevil, *Sitophilusoryzae* [12] and maize weevil, *Sitophiluszeamais* [11], inhibited the about 100% growth and development in the laboratory conditions in Bangladesh, but little or no attention has been paid towards moths such as *Sitotrogacerealella*. [2] reported that the insecticidal efficacy of camphor. [5] reported that the camphor has fumigation properties and has got a very low mammalian toxicity. Phostoxin (aluminium phosphide) is available in the market at its tablet or pellet form [26], which is used as a rodenticide, insecticide and fumigant for stored cereal grains [13]. 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.

Therefore, a reliable research on technological knowledge on pre and post-harvest agricultural pests and their economic impacts in Bangladesh 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. Emphasis has also been given to suggest most suitable and effective technologies and future policy guideline of the sector to build a new Bangladesh with self-sufficiency in agricultural production. This study was conducted to assessment of the extent of damage of stored rice grains by rice moth, *Sitotrogacerealella,* evaluation of the suitability of commonly used containers for storing rice grains and testing the efficacy of fumigants available in the market against rice moth.

## 2. Materials and Methods

The hybrid rice variety 'Hira' were collected from Savar Bazar, then sun dried, cleaned and kept in ambient room temperature [19]. To assess the level of infestation on rice grains, the newly laid eggs of rice moth, *Sitotrogacerealella* were also collected. The present study was also conducted in

2-factor completely randomized design (CRD), where container was used as factor one which comprised with 4 levels viz. Plastic container, tin pot, earthen pot and Polyester bag. On the other hand, fumigant was used as factor two which comprised with 5 levels viz. Camphor, Phostoxin tablet, Naphthlene, Organic treatment, and untreated control. The experiment was also replicated with four times for each parameter.

## 2.1. Treatments Application

### 2.1.1. Organic Treatment

**Table 1.** The combinations of the Fumigants treatments along with containers used for storing rice grains.

| Containers | Fumigants | Dose of the fumigants |
|---|---|---|
| Plastic container | Camphor | 1 gm/kg rice grains % w/w |
| | Phostoxin | 200 mg/kg rice grains |
| | Naphthlene | 500 mg/kg rice grains % w/w |
| | Organic treatment | De-oxygenation from container |
| | Untreated control | No fumigants were used |
| Tin pot | Camphor | 1 gm/kg rice grains % w/w |
| | Phostoxin | 200 mg/kg rice grains |
| | Naphthlene | 500 mg/kg rice grains % w/w |
| | Organic treatment | De-oxygenation from container |
| | Untreated control | No fumigants were used |
| Earthen pot | Camphor | 1 gm/kg rice grains % w/w |
| | Phostoxin | 200 mg/kg rice grains |
| | Naphthlene | 500 mg/kg rice grains % w/w |
| | Organic treatment | De-oxygenation from container |
| | Untreated control | No fumigants were used |
| Polyester bag | Camphor | 1 gm/kg rice grains % w/w |
| | Phostoxin | 200 mg/kg rice grains |
| | Naphthlene | 500 mg/kg rice grains % w/w |
| | Organic treatment | De-oxygenation from container |
| | Untreated control | No fumigants were used |

The organic treatment is the thought to remove the oxygen (de-oxygenation) from the air tight container with a view to create unfavorable environment for the survival of any living beings. This is a simple technology commonly used by the rural farmers to protect their grains especially for paddy against their insect pests in storage with a negligible involvement of money. Considering the view, candle light was used in the present study. When the respective container was filled with rice grains and rice moth eggs as described earlier, a small size candle (5 cm height and 1.5 cm dia) was put on and erectly placed on the grains including an earthen plate attached beneath the candle. After placing the candle light, the container was covered with respective lid. After a certain period of time, the candle light would be put off due to the complete removal of oxygen inside the container that is the de-oxygenation would be occurred.

### 2.1.2. 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 rice grains, and stored in respective container and preserved for infestation from which necessary data were recorded.

## 2.2. Moisture Content and Viability Test of the Seeds

The moisture content and germination test of the sun dried and cleaned rice seeds were determined following the procedures as mentioned and described earlier in the experiment 1.

## 2.3. Collection of Containers and Preparation

The containers used the present study were also purchased and collected from the Savar Bazar and prepared for use considering the earlier procedure.

## 2.4. Collection of Fumigants and Preparation

The fumigants viz. Camphor, Phostoxin tablet, Naphthalene and for organic treatment, the candle were collected from the local market of Savar Bazar.

## 2.5. Application of the Fumigants

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 1.0 gm of Camphor were thoroughly mixed with the grains of each of the pots of group 1. The grains of each pot of group 2 were mixed with 200 mg of Phostoxin tablet. Similarly, 500 mg of Naphthalene were mixed with the grains of each of group 3 pots. In case of the grains of group 4 pots, de-oxygenation from air tight container was done using the candle light as 'Organic treatment', where a small size candle (5 cm height and 1.5 cm dia.) was put on and erectly placed on the grains including an earthen plate attached beneath the candle. After placing the candle light, the container was covered with respective lid. After a certain period of time, the candle light was put off due to the complete removal of oxygen inside the container that is the de-oxygenation was occurred. The pots of group 5 were kept as untreated control, i.e. no fumigants were mixed with the grains of this group. Similar procedures were followed for the experiments with Tin pots, Earthen pots and Polyester bags. 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.

### 2.6. Release of the Rice Moth (*S. cerealella*) Eggs

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 and the respective air tight containers with lids were preserved in ambient temperature of the laboratory up to 6 months that is 180 days after egg release (DAER) for recording the data.

### 2.7. Data Sampling, Collection and Calculation

The data sampling, collection on respective parameters and their calculations were done considering the similar methods and procedures as mentioned earlier experiment 1.

### 2.8. Economic Analysis of the Management Practices Comprising Fumigant Based Treatments

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 fumigants against rice moth as described in the experiment 1. Finally, BCR was calculated for each management treatment using fumigants to justify the economic basis of the management practices.

### 2.9. Data Analysis

The data on above mentioned parameters were analyzed on 2-factor CRD with help of Computer based program MSTAT-C software considering the similar procedures mentioned in the earlier experiment. The means were also 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.

## 3. Results and Discussion

### 3.1. Effect of Containers and Fumigants on the Grain Infestation of Rice Against Rice Moth in Storage

#### 3.1.1. Effect of Containers on Grain Infestation of Rice Against Rice Moth

Significant variations among different containers were observed on the grain infestation by number used against rice moth in the storage throughout the storing period from 30 days after egg release (DAER) of rice moth to 180 DAER on the grain of hybrid rice in the containers (Table 2). More or less similar but increasing trends of percent grain infestation by number were observed at different days after egg release from 60 DAER to 180 DAER. 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 0.00 to 7.26% at 60 DAER to 180 DAER, respectively. This trend was followed by tin pot (0.00 to 12.47%) and earthen pot (0.00 to 15.60%), whereas polyester bag performed as least suitable container and showed highest infestation that was ranged from 0.00 to 33.20% at 60 DAER to 180 DAER, respectively. In case of 30 DAER, no grain infestations (0.00%) were observed among different containers and it might be the reasons for the initial stage of the infestation of rice moth.

Considering the mean grain infestation, plastic container performed as most suitable container to reduce the rice moth infestation and level of infestation was 3.56% followed by tin pot (6.06%) and earthen pot (7.94%), whereas polyester bag also performed as least suitable container and showed highest infestation (16.45%). Considering the performance of different containers showing reduction of grain infestation, plastic container showed highest reduction (78.13%) over polyester bag followed by tin pot (62.44%) and earthen pot (53.01%).

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

| Containers | Percent grain infestation by number | | | | | | | % reduction over control |
|---|---|---|---|---|---|---|---|---|
| | 30 DAER | 60 DAER | 90 DAER | 120 DAER | 150 DAER | 180 DAER | Average | |
| Plastic container | 0.00 | 0.40b | 1.73c | 3.40d | 5.00d | 7.26d | 3.56c | 78.13 |
| Tin pot | 0.00 | 0.86b | 3.26b | 5.66c | 8.06c | 12.47c | 6.06b | 62.44 |
| Earthen pot | 0.00 | 1.133b | 4.46b | 9.06b | 9.46b | 15.60b | 7.94b | 53.01 |
| Polyester bag | 0.00 | 2.46a | 10.27a | 14.27a | 22.07a | 33.20a | 16.45a | - |
| $LSD_{(0.01)}$ | - | 0.81 | 1.27 | 1.07 | 1.27 | 1.59 | 1.96 | - |
| CV(%) | - | 30.01 | 11.70 | 5.96 | 5.18 | 4.20 | 3.30 | - |

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.

#### 3.1.2. Effect of Fumigants on Grain Infestation of Rice Against Rice Moth

Significant variations among different fumigants were observed on the grain infestation by number used against rice moth in the storage throughout the storing period from 30 to 180 DAER on the grain of hybrid rice (Table 3). More or less similar but increasing trends of percent grain infestation by number were observed at 30 to 180 DAER. Among different fumigants, Camphor performed as most effective fumigant 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 0.00 to 9.16% at 30 to 180 DAER, respectively. This trend was followed by phostoxin (0.00 to 10.25%). This was also followed by Naphthalene (0.00 to 13.50%) and Organic treatment (0.00 to 17.83%), whereas maximum infestation was recorded in untreated control grains and the level of infestation was ranged from 0.00 to 34.92% at 30 to 180 DAER, respectively. In case of 30 DAER, no grain infestations were observed among different fumigant treated grains and it might be the reasons for the initial stage of infestation caused by rice moth. Considering the mean grain infestation, more or less similar trends of results were observed irrespective of any fumigants (Table 3). Considering the performance of different fumigants in reducing the grain infestation over control, the Camphor showed the highest reduction (73.77%) over control followed by Phostoxin (70.65%) and Naphthalene (61.34%), whereas the lowest reduction of grain infestation over control was recorded in organic treatment (48.94%).

**Table 3.** Effect of Fumigants on the Infestation of Hybrid Rice grain (Hira) by Rice moth *S. cerealella*in Storage.

| | **Percent grain infestation by number** | | | | | | | **% reduction over control** |
|---|---|---|---|---|---|---|---|---|
| | **30 DAER** | **60 DAER** | **90 DAER** | **120 DAER** | **150 DAER** | **180 DAER** | **Average** | |
| Camphor | 0.00 | 0.08c | 0.83c | 1.83d | 5.16d | 9.16d | 3.41d | 73.77 |
| Phostoxin | 0.00 | 0.08c | 0.91c | 2.00d | 5.75d | 10.25d | 3.80cd | 70.65 |
| Naphthalene | 0.00 | 0.41c | 1.50c | 4.66c | 8.08c | 13.50c | 5.63c | 61.34 |
| Organic | 0.00 | 1.58b | 6.50b | 9.91b | 11.58b | 17.83b | 9.48b | 48.94 |
| Control | 0.00 | 3.91a | 14.9a | 22.08a | 25.17a | 34.92a | 20.20a | - |
| $LSD_{(0.01)}$ | - | 0.81 | 1.27 | 1.07 | 1.27 | 1.59 | 1.96 | - |
| CV(%) | - | 30.01 | 11.70 | 5.96 | 5.18 | 4.20 | 3.30 | - |

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.

## 3.2. Combined Effect of Fumigants and Containers on the Grain Infestation

Grain infestations of rice were varied significantly among different fumigants stored in different containers throughout the storing period (Table 4). More or less similar but increasing trends of percent grain infestation by number were observed at different days after egg release from 30 to 180 DAER. The lowest grain infestation was observed in Camphor treated grains stored in plastic containers (0.00%) followed by tin pot (0.00 to 4.66%), earthen pot (0.00 to 6.66%) and polyester bag (0.00 to 25.33%). The grain infestation was nearly followed by Phostoxin treated grains stored in plastic container (0.00 to 0.33%) followed by tin pot (0.00 to 5.00%), earthen pot (0.00 to 7.33%) and polyester bag (0.00 to 28.33%). The highest grain infestation was observed in untreated control grains stored in polyester bag (0.00 to 42.33%) followed earthen pot (0.00 to 35.00%), tin pot (0.00 to 33.67%) and plastic pot (0.00 to 28.67%). The grain infestation was nearly followed by organic treatment and Naphthalene grains stored in any containers (Table 4).

Considering the performance of different botanicals in reducing the grain infestation over control stored in different containers, the Camphor showed the highest reduction ranged from 40.16 to 100.00% over control stored in polyester bag (40.16%), earthen pot (80.97%), tin pot (86.16%) and plastic container (100.00%), respectively followed by Phostoxin (33.07 to 98.85%) and Naphthalene (29.91 to 93.02%), whereas the lowest reduction of grain infestation over control was recorded in organic treatment (4.72 to 69.32%) stored in any containers (Table 4).

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 fumigants, Camphor performed as the most effective in reducing the grain infestation by number against rice moth followed by phostoxin, Naphthalene and organic treatment. [20] reported that the camphor kept the infestation reduction from 78.46-89.14% of rice grains against rice moth, *S. cerealella*in storage. [21] reported in another study that the fumigation action of camphor against pulse beetle, *C. chinensis*; [12] also reported the toxicity efficacy of camphor against different stages of rice weevil, *Sitophilusoryzae*and maize weevil, *Sitophiluszeamais* Motsch [17]. They reported 100% inhibition of the growth and development of pulse beetle, rice weevil and maize in lab conditions in Bangladesh.

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

| Containers | Fumigants | 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 | Camphor | 0.00 | 0.00f | 0.00j | 0.00m | 0.00l | 0.00n | 0.00l | 100.00 |
| | Phostoxin | 0.00 | 0.00f | 0.00j | 0.00m | 0.00l | 0.33n | 0.06l | 98.85 |
| | Naphthalene | 0.00 | 0.00f | 0.66hij | 0.33m | 1.00kl | 2.00m | 0.80kl | 93.02 |
| | Organic | 0.00 | 0.00f | 1.66fghi | 1.66jkl | 3.00ij | 5.33kl | 2.33ijk | 81.41 |
| | Control | 0.00 | 2.00d | 6.33e | 15.00d | 21.00c | 28.67d | 14.60d | - |
| Tin pot | Camphor | 0.00 | 0.00f | 0.33ij | 0.66lm | 2.00jk | 4.66l | 1.53jkl | 86.16 |
| | Phostoxin | 0.00 | 0.00f | 0.33ij | 1.00klm | 2.33ij | 5.00l | 1.73jkl | 85.15 |
| | Naphthalene | 0.00 | 0.33ef | 0.66hij | 2.66ij | 4.66h | 8.66i | 3.40ij | 74.28 |
| | Organic | 0.00 | 0.33ef | 1.00ghij | 3.66hi | 6.66g | 10.33h | 4.40hi | 69.32 |
| | Control | 0.00 | 3.66c | 14.00d | 20.33c | 24.67b | 33.67c | 19.27c | - |
| Earthen pot | Camphor | 0.00 | 0.00f | 1.00ghij | 2.00jk | 3.33ij | 6.66jk | 2.60ijk | 80.97 |
| | Phostoxin | 0.00 | 0.00f | 1.00ghij | 2.00jk | 3.66hi | 7.33ij | 2.80ijk | 79.06 |
| | Naphthalene | 0.00 | 0.33ef | 1.66fghi | 7.66 f | 7.00g | 13.67g | 6.06gh | 60.94 |
| | Organic | 0.00 | 1.00e | 2.00fgh | 9.00e | 7.66g | 15.33f | 7.00g | 56.20 |
| | Control | 0.00 | 4.33bc | 16.67c | 24.67b | 25.67b | 35.00c | 21.27b | - |
| Polyester bag | Camphor | 0.00 | 0.33ef | 2.00fgh | 4.66gh | 15.33f | 25.33e | 9.53f | 40.16 |
| | Phostoxin | 0.00 | 0.33ef | 2.33fg | 5.00g | 17.00e | 28.33d | 10.60ef | 33.07 |
| | Naphthalene | 0.00 | 1.00e | 3.00f | 8.00ef | 19.67d | 29.67d | 12.27e | 29.91 |
| | Organic | 0.00 | 5.00ab | 21.33b | 25.33b | 29.00a | 40.33b | 24.20a | 4.72 |
| | Control | 0.00 | 5.66a | 22.67a | 28.33a | 29.33a | 42.33a | 25.67a | - |
| $LSD_{(0.01)}$ | | - | 0.21 | 1.27 | 1.07 | 1.27 | 1.59 | 1.96 | - |
| CV(%) | | - | 30.01 | 11.70 | 5.96 | 5.18 | 4.20 | 3.30 | - |

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.

### 3.3. Effect of Containers and Fumigants on the Adult Emergence During the Management of Rice Moth in Storage

Significant variations among different containers were observed on the adult emergence by number during the management of rice moth infesting rice grains treated with different fumigants in storage throughout the storing period from 30 to 180 days after egg release (DAER) on the rice grain (Table 4 to Table 6).

#### 3.3.1. Suitability of Containers on the Emergence of Adult Rice Moth *S. cerealella*

More or less similar but increasing trends of adult emergence of rice moth by number were observed at different days after egg release (Table 5). 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 0.07 to 7.67 adults per 100 rice grains at 30 to 180 DAER, respectively. This trend was followed by tin pot (0.07 to 1.47 adults per 100 grains) and earthen pot (0.20 to 2.73 adults per 100 grains), whereas polyester bag performed as the most suitable container for rice moth infestation and the highest number of adult rice moths was emerged that was ranged from 0.53 to 7.67 adults per 100 grains at 30 to 180 DAER, respectively. In case of mean adult emergence, more or less similar trends of the results were observed, where plastic container performed as least suitable container for rice moth infestation and the lowest number of adults was emerged (0.57 adult per 100 grains) followed by tin pot (1.20 adults per 100 grains) and earthen pot (2.59 adults per 100 grains), whereas polyester bag performed as the most suitable container and showed highest number of adult emergence (3.55 adults per 100 grains). Considering the performance of different containers in reducing the adult emergence, plastic container reduced the highest percentage of adult emergence (83.94%) over polyester bag followed by tin pot (66.20%) and the lowest reduction of adult emergence was recorded in earthen pot (27.04%) as results depicted in Table 5.

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

| Containers | 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 | 0.07 a | 0.27 b | 0.20 b | 0.20 b | 1.20 c | 1.47 c | 0.57 d | 83.94 |
| Tin pot | 0.20 a | 0.53 b | 0.80 b | 1.20 b | 1.73 c | 2.73 c | 1.20 c | 66.20 |
| Earthen pot | 0.53 a | 0.53 b | 2.67 a | 3.13 a | 3.60 b | 5.07 b | 2.59 b | 27.04 |
| Polyester bag | 0.53 a | 1.27 a | 2.07 a | 4.20 a | 5.60 a | 7.67 a | 3.55 a | - |
| $LSD_{(0.01)}$ | 0.6362 | 0.6983 | 0.9024 | 1.141 | 1.274 | 1.274 | 0.5586 | - |
| CV(%) | - | 37.77 | 14.80 | 12.68 | 5.96 | 4.18 | 3.69 | - |

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.

### 3.3.2. Effect of Fumigants on the Emergence of Adult Rice Moth *S. cerealella*

Significant variations among different fumigants were observed on the adult emergence during the management of rice moth in the storage throughout the storing period from 30 to 180 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 DAER. Among different fumigants, Camphor performed as the most effective fumigant in reducing adult emergence and the lowest number of adult rice moth was emerged that was ranged from 0.00 to 1.17 adults per 100 grains at 30 to 180 DAER, respectively. This trend was followed by Phostoxin (0.08 to 1.08 adults per 100 grains). This was also followed by Naphthalene (0.08 to 4.17 adults per 100 grains) and organic treatment (0.08 to 6.33 adults per 100 grains), whereas the highest number of adults was emerged from untreated control rice grains and that was ranged from 1.42 to 16.40 adults per 100 rice grains at 30 to 180 DAER, respectively. In case of mean adult emergence, more or less similar trends results regarding adult emergence, where Camphor performed as the most effective fumigant in reducing the adult emergence of rice moth and the lowest number of adults was emerged (0.68 adults per 100 grains) followed by Phostoxin (0.55 adults per 100 grains). This was also followed by Naphthalene (2.02 adults per 100 grains) and organic treatment (2.31 adults per 100 grains), whereas the highest number of adults was emerged from untreated control grains (7.14 adults per 100 grains). Considering the performance of different fumigants in reducing the adult emergence over control, the Phostoxin showed the highest reduction (92.30%) followed by Camphor (90.48%) and Naphthalene (71.71%), whereas the lowest reduction of adult emergence over control was recorded in organic treatment (67.65%) as the results depicted in Table 6.

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

| Fumigants | Number of adult emergence per 100 seeds | | | | | | | % reduction over control |
|---|---|---|---|---|---|---|---|---|
| | 30 DAER | 60 DAER | 90 DAER | 120 DAER | 150 DAER | 180 DAER | Average | |
| Camphor | 0.00b | 0.17b | 0.42b | 0.67d | 0.92c | 1.17d | 0.55c | 92.30 |
| Phostoxin | 0.08b | 0.25b | 0.92b | 0.83c | 0.92c | 1.08d | 0.68c | 90.48 |
| Naphthalene | 0.08b | 0.33b | 1.75b | 1.83c | 3.00b | 4.17c | 2.02b | 71.71 |
| Organic | 0.08b | 0.33b | 1.83b | 3.00b | 4.25b | 6.33b | 2.31b | 67.65 |
| Control | 1.42a | 2.17a | 4.25a | 7.58a | 11.0a | 16.4a | 7.14a | - |
| $LSD_{(0.01)}$ | 0.6362 | 0.1826 | 0.9024 | 1.141 | 1.274 | 1.274 | 0.5586 | - |
| CV(%) | 30.13 | 37.77 | 14.80 | 12.68 | 5.96 | 4.18 | 3.69 | - |

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.

### 3.4. Combined Effect of Fumigants and Containers on the Adult Emergence of Rice Moth

Adult emergence of rice moth was varied significantly among different fumigant treated rice grains stored in different containers throughout the storing period from 30 to 180 DAER. More or less similar but increasing trends of adult emergence by number were observed at different DAER (Table 6). The minimum number of adults was emerged from Camphor treated grains stored in plastic containers (0.00%) followed by tin pot (0.00 to 4.66 adults per 100 grains), earthen pot (0.00 to 6.66 adults per 100 grains) and polyester bag (0.00 to 25.33 adults per 100 grains) at 30 to 180 DAER, respectively. These trends of adult emergence were nearly followed by Phostoxin treated grains stored in plastic container (0.00 to 0.33 adults per 100 grains) followed by tin pot (0.00 to 5.00 adults per 100 grains), earthen pot (0.00 to 7.33 adults per 100 grains) and polyester bag (0.00 to 28.33 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 42.33 adults per 100 grains) followed earthen pot (0.00 to 35.00 adults per 100 grains), tin pot (0.00 to 33.67 adults per 100 grains) and plastic pot (0.00 to 28.67 adults per 100 grains). These trends of adult emergence were nearly followed by organic treatment and Naphthalene treated grains stored in any containers as depicted in Table 7. In case of mean adult emergence more or less similar treads of results were also observed.

Considering the performance of different fumigants in reducing the adult emergence over control stored in different containers, the Camphor showed the highest reduction ranged from 40.16 to 100.00% over control stored in polyester bag, earthen pot, tin pot and plastic container, respectively followed by Phostoxin (33.07 to 98.84%) and Naphthalene (29.90 to 93.02%), whereas the lowest reduction of grain content loss over control was recorded in organic treatment (4.72 to 81.20%) stored in polyester bag, earthen pot, tin pot and plastic container, respectively (Table 7).

**Table 7.** Interaction Effect of Container and Fumigant on the Adult Emergence of Rice moth *S. cerealella*Infesting Hybrid Rice grain (Hira) in Storage.

| Container | Fumigants | 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 | Camphor | 0.00 | 0.00f | 0.00j | 0.00m | 0.00l | 0.00n | 0.00l | 100.00 |
| | Phostoxin | 0.00 | 0.00f | 0.00j | 0.00m | 0.00l | 0.33n | 0.06l | 98.84 |
| | Naphthalene | 0.00 | 0.00f | 0.66hij | 0.33m | 1.00kl | 2.00m | 0.80kl | 93.02 |
| | Organic | 0.00 | 0.00f | 1.66fghi | 1.66jkl | 3.00ij | 5.33kl | 2.33ijk | 81.40 |
| | Control | 0.00 | 2.00d | 6.33e | 15.00d | 21.00c | 28.67d | 14.60d | - |
| Tin pot | Camphor | 0.00 | 0.00f | 0.33ij | 0.66lm | 2.00jk | 4.66l | 1.53jkl | 86.16 |
| | Phostoxin | 0.00 | 0.00f | 0.33ij | 1.00klm | 2.33ij | 5.00l | 1.73 jkl | 85.15 |
| | Naphthalene | 0.00 | 0.33ef | 0.66hij | 2.66ij | 4.66h | 8.66i | 3.40ij | 74.28 |
| | Organic | 0.00 | 0.33ef | 1.00ghij | 3.66hi | 6.66g | 10.33h | 4.40hi | 69.32 |
| | Control | 0.00 | 3.66c | 14.00d | 20.33c | 24.67b | 33.67c | 19.27c | - |
| Earthen pot | Camphor | 0.00 | 0.00f | 1.00ghij | 2.00jk | 3.33ij | 6.66jk | 2.60ijk | 80.97 |
| | Phostoxin | 0.00 | 0.00f | 1.00ghij | 2.00jk | 3.66hi | 7.33ij | 2.80ijk | 79.05 |
| | Naphthalene | 0.00 | 0.33ef | 1.66fghi | 7.66f | 7.00g | 13.67g | 6.06gh | 60.94 |
| | Organic | 0.00 | 1.00e | 2.00fgh | 9.00e | 7.66g | 15.33f | 7.00g | 56.20 |
| | Control | 0.00 | 4.33bc | 16.67c | 24.67b | 25.67b | 35.00c | 21.27b | - |
| Polyester bag | Camphor | 0.00 | 0.33ef | 2.00fgh | 4.66gh | 15.33f | 25.33e | 9.53f | 40.16 |
| | Phostoxin | 0.00 | 0.33ef | 2.33fg | 5.00g | 17.00e | 28.33d | 10.60ef | 33.07 |
| | Naphthalene | 0.00 | 1.00e | 3.00f | 8.00ef | 19.67d | 29.67d | 12.27e | 29.90 |
| | Organic | 0.00 | 5.00ab | 21.33b | 25.33b | 29.00a | 40.33b | 24.20a | 4.72 |
| | Control | 0.00 | 5.66a | 22.67a | 28.33a | 29.33a | 42.33a | 25.67a | - |
| $LSD_{(0.01)}$ | | - | 0.81 | 1.27 | 1.07 | 1.27 | 1.59 | 1.96 | - |
| CV(%) | | - | 37.77 | 14.80 | 12.68 | 5.96 | 4.18 | 3.69 | - |

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 adult emergence of rice moth followed by tin pot and earthen pot, whereas polyester bag performed as least suitable container. In case of efficiency of fumigants, Camphor performed as the most effective in reducing the adult emergence of rice moth followed by phostoxin, Naphthalene and organic treatment. The fumigation gases of camphor inhibited the growth and development of rice moth as supported by [11, 12, 21]. who reported the fumigation action of camphor against pulse beetle, rice weevil and maize weevil, respectively, where 100% growth and development insects was inhibited in the laboratory conditions in Bangladesh. [2] reported that the insecticidal efficacy of camphor. [5] reported that the camphor has fumigation properties and has got a very low mammalian toxicity.

### 3.5. Effect of Containers and Fumigants Grain Content Loss of Rice during the Management of Rice Moth in Storage

Significant variations among different containers were observed on the grain content loss during the management of rice moth infesting rice grains treated with different fumigants in storage throughout the storing period (Table 7 to Table 9).

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 DAER 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 1.24 to 10.38% at 30 to 180 DAER, respectively. This trend of grain content loss was followed by tin pot (1.44 to 15.43%) and earthen pot (1.78 to 19.38%), 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 1.88 to 26.38% at 30 to 180 DAER, respectively. Considering the mean grain content loss, more or less similar trends of results were observed for different containers.

Considering the performance of different containers in reducing the grain content loss, plastic container reduced the highest (60.65%) grain content loss over polyester bag followed by tin pot (41.51%). On the other hand, the lowest reduction (26.54%) of grain content loss over polyester bag 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 Fumigantsin Storage.

| Containers | Percent grain content loss by weight | | | | | | | % reduction over control |
|---|---|---|---|---|---|---|---|---|
| | 30 DAER | 60 DAER | 90 DAER | 120 DAER | 150 DAER | 180 DAER | Average | |
| Plastic container | 1.24a | 2.61c | 3.76c | 7.18d | 9.00d | 10.38d | 5.69d | 60.65 |
| Tin pot | 1.44a | 2.60c | 8.08b | 10.86c | 12.22c | 15.43c | 8.44c | 41.51 |
| Earthen pot | 1.78a | 3.96b | 8.95b | 12.72b | 16.56b | 19.38b | 10.56b | 26.54 |
| Polyester bag | 1.88a | 7.50a | 14.26a | 21.04a | 27.21a | 26.38a | 16.37a | - |
| $LSD_{(0.01)}$ | 1.09 | 0.70 | 0.95 | 0.89 | 0.94 | 0.86 | 0.39 | - |
| CV(%) | 31.01 | 7.60 | 4.93 | 3.13 | 2.61 | 2.17 | 1.71 | - |

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.

### 3.5.1. Effect of Fumigants on the Grain Content Loss Caused by Rice Moth

Grain content loss varied significantly among different fumigant 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 DAER. Among different fumigants, Camphor performed as the most effective fumigant in reducing grain content loss caused by rice moth for which the lowest percentage of grain content loss was recorded that was ranged from 0.90 to 8.89% at 30 to 180 DAER, respectively. This trend for grain content loss was followed by Phostoxin treated grains (1.06 to 9.29%). This was also followed by Naphthalene treated grains (1.12 to 12.85%) and organic treatment (1.84 to 21.77%), whereas the highest percentage of grain content loss was recorded from untreated control rice grains that was ranged from 3.00 to 36.66% at 30 to 180 DAER, respectively. In case of mean grain content loss, the more or less similar trends of results were also observed (Table 8).

Considering the performance of different fumigants in reducing the grain content loss over control, the Camphor showed the highest reduction (75.75%) over control followed by Phostoxin (74.66%) and Naphthalene (64.95%), whereas the lowest reduction of grain content loss over control was recorded in organic treatment (40.15%) as depicted in Table 9.

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

| Fumigants | Percent grain content loss by weight | | | | | | | % reduction over control |
|---|---|---|---|---|---|---|---|---|
| | 30 DAER | 60 DAER | 90 DAER | 120 DAER | 150 DAER | 180 DAER | Average | |
| Camphor | 0.90b | 2.32d | 4.87d | 7.71d | 9.22d | 8.89d | 5.65d | 75.75 |
| Phostoxin | 1.06b | 2.39cd | 5.00d | 7.84d | 9.60d | 9.29d | 5.85d | 74.66 |
| Naphthalene | 1.12b | 3.06c | 6.25c | 11.76c | 12.25c | 12.85c | 7.89c | 64.95 |
| Organic | 1.84b | 4.18b | 9.84b | 13.38b | 19.57b | 21.77b | 11.76b | 40.62 |
| Control | 3.00a | 8.88a | 17.85a | 24.07a | 30.61a | 36.66a | 20.15a | - |
| $LSD_{(0.01)}$ | 1.09 | 0.70 | 0.95 | 0.89 | 0.94 | 0.86 | - | - |
| CV(%) | 31.01 | 7.60 | 4.93 | 3.13 | 2.61 | 2.17 | 1.71 | - |

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.

### 3.5.2. Combined Effect of Fumigants and Containers on the Grain Content Loss

Grain content loss caused by rice moth was varied significantly among different fumigant 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 DAER. The lowest percentage of grain content loss was recorded in Camphor treated grains stored in plastic container that was ranged from 0.65 to 2.58% followed by tin pot (0.90 to 7.23%), earthen pot (1.03 to 11.20%) and polyester bag (1.03 to 14.57%) at 30 to 180 DAER, respectively. These trends of grain content loss were nearly followed by Phostoxin treated grains stored in plastic container (0.77 to 2.58%), tin pot (1.16 to 7.88%), earthen pot (1.16 to 11.47%) and polyester bag (1.16 to 15.23%). On the other hand, the highest grain content loss was observed in untreated control grains stored in polyester bag (3.61 to 43.77%) followed earthen pot (3.10 to 37.80%), tin pot (2.84 to 33.97%) and plastic pot (2.45 to 31.10%). These trends of grain content loss were nearly followed by organic treatment and Naphthalene treated grains stored in any containers as depicted in Table 10. In case of mean grain content loss, more or less similar trend of results was also observed. Considering the performance of different fumigants in reducing the grain content loss over control stored in different containers, the Camphor showed the highest reduction ranged from 66.71 to 91.70% over control stored in polyester bag, tin pot, earthen pot and plastic container, respectively followed by Phostoxin (65.20 to 91.70%) and Naphthalene (57.57 to 80.06%), whereas the lowest reduction of grain content loss over control was recorded in organic treatment (9.13 to 69.67%) stored in polyester bag, tin pot, earthen pot and plastic container, respectively (Table 10).

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

| Container | Fumigants | Percent grain content loss by weight | | | | | | | % reduction over control |
|---|---|---|---|---|---|---|---|---|---|
| | | 30 DAER | 60 DAER | 90 DAER | 120 DAER | 150 DAER | 180 DAER | Average | |
| Plastic container | Camphor | 0.65fg | 0.78j | 1.16l | 2.33j | 2.19 m | 2.58p | 1.61n | 91.70 |
| | Phostoxin | 0.77fg | 0.90ij | 1.03l | 2.32j | 2.71m | 2.58p | 1.72n | 91.70 |
| | Naphthalene | 0.51g | 1.68hi | 1.80l | 5.30i | 5.94l | 6.20o | 3.57m | 80.06 |
| | Organic | 1.80de | 2.84f | 3.62k | 7.75h | 9.04jk | 9.43m | 5.75k | 69.67 |
| | Control | 2.45bcd | 6.85d | 11.20d | 18.20d | 25.13d | 31.10e | 15.80e | - |
| Tin pot | Camphor | 0.90fg | 1.42hij | 4.52jk | 5.81i | 6.33l | 7.23n | 4.37l | 78.71 |
| | Phostoxin | 1.16efg | 1.16ij | 4.91ij | 6.20i | 6.46l | 7.88n | 4.63l | 76.80 |
| | Naphthalene | 1.16efg | 1.16hij | 5.68hi | 8.65h | 8.65k | 12.60k | 6.33j | 62.90 |
| | Organic | 1.160efg | 1.16ij | 6.85fg | 10.70g | 10.53i | 15.47h | 7.66i | 54.46 |
| | Control | 2.84bc | 8.14c | 18.47c | 22.93c | 29.13c | 33.97d | 19.20d | - |
| Earthen pot | Camphor | 1.03efg | 1.94gh | 5.68hi | 8.14h | 9.43jk | 11.20l | 6.24j | 70.37 |
| | Phostoxin | 1.16efg | 1.94gh | 5.94gh | 8.14h | 9.79ij | 11.47l | 6.41j | 69.65 |
| | Naphthalene | 1.42ef | 2.58fg | 6.85fg | 10.80g | 12.00h | 14.03j | 7.967i | 62.88 |
| | Organic | 2.20cd | 2.71f | 7.23ef | 12.00f | 21.13f | 22.40f | 11.27g | 40.74 |
| | Control | 3.10ab | 10.67a | 19.07c | 24.53b | 30.47b | 37.80c | 20.90c | - |
| Polyester bag | Camphor | 1.03efg | 5.17e | 8.14e | 14.57e | 18.93g | 14.57 ij | 10.40h | 66.71 |
| | Phostoxin | 1.16efg | 5.55e | 8.14e | 14.70e | 19.43g | 15.23hi | 10.67h | 65.20 |
| | Naphthalene | 1.42ef | 6.85d | 10.67d | 22.27c | 22.40e | 18.57g | 13.70f | 57.57 |
| | Organic | 2.20cd | 10.03ab | 21.67b | 23.07c | 37.57a | 39.77 b | 22.37b | 9.13 |
| | Control | 3.61a | 9.89b | 22.67a | 30.60a | 37.70a | 43.77a | 24.70a | - |
| $LSD_{(0.01)}$ | | 0.68 | 0.70 | 0.95 | 0.89 | 0.94 | 0.86 | 0.39 | - |
| CV(%) | | 31.01 | 7.60 | 4.93 | 3.13 | 2.61 | 2.17 | 1.71 | - |

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 also revealed that plastic container was the most effective container than others, and camphor was the most effective fumigant than others in terms of reducing the grain content loss, where fumigation gases of camphor inhibited the growth and development of rice moth as supported by Rahman*et al*. (2001), Latif*et al.* (2005), Latif and Rahman (2000), resulting the minimum grain content losses were observed.

## 3.6. Effect of Containers and Fumigants on the Viability of Stored Seeds During the Management of Rice Moth in Storage

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

| Containers | Percent seed germination | | | | | | | % reduction over control |
|---|---|---|---|---|---|---|---|---|
| | 30 DAER | 60 DAER | 90 DAER | 120 DAER | 150 DAER | 180 DAER | Average | |
| Plastic container | 96.47a | 93.80a | 87.73a | 82.87a | 72.40a | 69.93a | 83.86a | 57.49 |
| Tin pot | 92.87b | 91.27b | 80.73b | 78.47b | 67.53b | 55.40b | 77.71b | 46.34 |
| Earthen pot | 92.20b | 87.80c | 75.47c | 70.47c | 60.47c | 49.13c | 72.59c | 39.49 |
| Polyester bag | 91.47b | 85.13d | 65.47d | 57.93d | 43.13d | 29.73d | 62.14d | - |
| $LSD_{(0.01)}$ | 1.45 | 1.39 | 1.56 | 1.67 | 1.67 | 1.83 | 0.80 | - |
| CV(%) | 0.71 | 0.71 | 0.85 | 0.96 | 1.06 | 1.32 | 0.46 | - |

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.

Significant variations among different containers were observed on the viability of stored rice seeds during the management of rice moth infesting rice grains treated with different fumigants in storage throughout the storing period (Table 11 to Table 12).

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 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 and that was ranged from 96.47 to 69.93% at 30 to 180 DAER, respectively. This trend was followed by tin pot (92.87 to 55.40%) and earthen pot (92.20 to 49.13%), 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 91.47 to 29.73% 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 performance of different containers in increasing the seed germination over polyester bag, the highest seed germination (57.49%) was increased in plastic container followed by tin pot (46.34%), whereas the lowest increase (39.49%) was recorded in earthen pot (Table 11).

### 3.6.1. Effect of Fumigants on the Viability of Stored Rice Seeds

The rice seed germination was also varied significantly for different fumigants used against rice moth in storage throughout the storing period (Table 11). More or less similar but decreasing trends of percent seed germination were observed at different DAER. Among different fumigants, Camphor performed as the most effective fumigant 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 95.42 to 80.08% at 30 to 180 DAER, respectively. This trend was followed by Phostoxin (94.83 to 87.02%) that was also followed by Naphthalene (93.67 to 80.67%) and organic treatment (91.75 to 77.50%), whereas the untreated control grains showed the lowest seed germination that was ranged from 90.58 to 35.83% 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 fumigants as depicted in Table 12.

Considering the performance of different fumigants in increasing the percent seed germination over control, Camphor increased the highest seed germination (56.34%) followed by Phostoxin (55.77%) and Naphthalene (55.58%), whereas the lowest seed germination (53.77%) was increased for organic treatment (Table 12).

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

| Fumigants | Percent seed germination | | | | | | | % reduction over control |
|---|---|---|---|---|---|---|---|---|
| | 30 DAER | 60 DAER | 90 DAER | 120 DAER | 150 DAER | 180 DAER | Average | |
| Camphor | 95.42a | 93.25a | 90.25a | 86.83a | 82.17a | 82.08a | 88.33a | 56.34 |
| Phostoxin | 94.83ab | 93.08a | 89.42a | 86.50a | 82.17a | 81.02a | 87.83a | 55.77 |
| Naphthalene | 93.67b | 90.58b | 85.42b | 82.08b | 77.83b | 80.67b | 85.05b | 55.58 |
| Organic | 91.75c | 88.58c | 80.58c | 75.50c | 65.17c | 77.50c | 79.84c | 53.77 |
| Control | 90.58c | 82.00d | 72.33d | 61.25d | 48.33d | 35.83d | 65.02d | - |
| $LSD_{(0.01)}$ | 1.45 | 1.40 | 1.56 | 1.67 | 1.67 | 1.83 | 1.11 | - |
| CV(%) | 0.71 | 0.71 | 0.85 | 0.96 | 1.06 | 1.32 | 0.46 | - |

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 fumigants 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 (90.58 to 95.42%) for any of the fumigants because of the minimum infestation. But with the increase of the days after rice moth egg release, the seed germinations were decreased gradually, which was reached in minimum at 180 DAER that was ranged from 35.83 to 82.08%, where the lowest seed germination was recorded in untreated control grains followed by organic treatment (77.50%). This was also closely followed by Naphthalene (80.67%), Phostoxin (85.05%) and Camphor treated seeds (82.08%).

### 3.6.2. Combined Effect of Fumigants and Containers on the Viability of Stored Rice Seed

The seed germination was significantly varied for different fumigant treated rice grains stored in different containers throughout the storing period (Table 12). 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 Camphor treated grains stored in plastic container that was ranged from 98.33 to 91.00% followed by tin pot (95.00 to 80.33%), earthen pot (95.00 to 68.33%) and polyester bag (93.33 to 60.670%) at 30 to 180 DAER, respectively. These trends of seed germination were nearly followed by Phostoxin treated grains stored in plastic container (98.00 to 91.33%), tin pot (95.67 to 80.00%), earthen pot (93.33 to 68.33%) and polyester bag (92.33 to 60.00%). On the other hand, the lowest seed germination was observed in untreated control grains stored in polyester bag (89.33 to 22.33%) followed earthen pot (90.00 to 31.00%), tin pot (90.33 to 41.00%) and plastic pot (92.67 to 49.00%). These trends of seed germinations were nearly followed by organic treatment and Naphthalene treated grains stored in polyester bag, earthen pot, tin pot and plastic container, respectively (Table 12). In case of mean seed germination, more or similar results were also observed.

Results 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 during the management of rice moth using fumigants on rice seeds stored in different containers. At the initial stage of infestation that is at 30 DAER, the seed germination was maximum (89.33 to 98.33%) for any of the fumigants because of the minimum infestation caused by rice moth stored in any containers. But with the increase of the days after rice moth egg release, the seed germinations were decreased gradually, which reached in minimum at 180 DAER, where the lowest seed germination was observed for grains stored in polyester bag that was ranged from 22.33 to 60.67% for untreated control, treated with organic treatment (25.33%), naphthalene (55.33%), Phostoxin (60.00%) and Camphor (60.67%), respectively. This trend of seed germination was closely followed by the grains stored in earthen pot that was ranged from 31.00 to 68.33% for untreated control, grains treated with organic treatment (53.00%), naphthalene (65.00%), Phostoxin (68.33%) and Camphor (68.33%), respectively. This trend of seed germination was also followed by tin pot and plastic containers for untreated control, grains treated with organic treatment, naphthalene, Phostoxin and Camphor, respectively.

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

| Container | Fumigants | Percent seed germination | | | | | | | % increase over control |
|---|---|---|---|---|---|---|---|---|---|
| | | 30 DAER | 60 DAER | 90 DAER | 120 DAER | 150 DAER | 180 DAER | Average | |
| Plastic container | Camphor | 98.33a | 97.67a | 97.67a | 94.00a | 92.00a | 91.00a | 95.07a | 46.154 |
| | Phostoxin | 98.00a | 97.67a | 97.00a | 93.67a | 92.33a | 91.33a | 94.97a | 46.348 |
| | Naphthalene | 97.33ab | 95.33b | 91.33c | 90.00b | 90.00b | 87.67b | 91.90b | 44.109 |
| | Organic | 96.00bc | 93.67cd | 90.00c | 87.00c | 82.33d | 80.67c | 88.27d | 39.259 |
| | Control | 92.67d | 84.67g | 77.67j | 69.67h | 60.33i | 49.00k | 72.30l | - |
| Tin pot | Camphor | 95.00c | 94.33bc | 93.67b | 90.67b | 88.67b | 80.33c | 90.43c | 48.961 |
| | Phostoxin | 95.67c | 94.33bc | 93.33b | 90.67b | 88.67b | 80.00c | 90.43c | 48.750 |
| | Naphthalene | 92.67d | 93.00cd | 88.00d | 88.00c | 84.33c | 74.67d | 86.73e | 45.092 |
| | Organic | 90.67e | 92.67d | 87.33de | 82.00e | 74.33f | 71.00e | 83.00g | 42.254 |
| | Control | 90.33e | 82.00h | 76.33j | 61.00i | 51.67j | 41.00l | 67.03m | - |
| Earthen pot | Camphor | 95.00c | 90.67e | 86.33e | 85.33d | 77.67e | 68.33f | 83.87f | 54.632 |
| | Phostoxin | 93.33d | 90.33e | 84.33f | 84.33d | 77.33e | 68.33f | 82.97g | 54.632 |
| | Naphthalene | 92.33d | 88.33f | 81.67gh | 80.33f | 73.00f | 65.00g | 80.10h | 52.308 |
| | Organic | 90.33e | 88.00f | 79.67i | 77.67g | 69.67g | 53.00j | 76.37j | 41.509 |
| | Control | 90.00e | 81.67h | 70.33k | 59.67i | 49.67k | 31.00m | 63.67n | - |
| Polyester bag | Camphor | 93.33d | 90.33e | 83.33f | 77.33g | 70.33g | 60.67h | 79.20i | 63.194 |
| | Phostoxin | 92.33d | 90.00e | 83.00fg | 77.33g | 70.33g | 60.00h | 78.80i | 62.783 |
| | Naphthalene | 92.33d | 85.67g | 80.67hi | 70.00h | 64.00h | 55.33i | 74.63k | 59.642 |
| | Organic | 90.00e | 80.00i | 65.33l | 55.33j | 34.33l | 25.33n | 58.37o | 11.844 |
| | Control | 89.33e | 79.67i | 65.00l | 54.67 j | 31.67m | 22.33o | 57.07p | - |
| $LSD_{(0.01)}$ | | 1.45 | 1.40 | 1.56 | 1.67 | 1.67 | 1.83 | 0.81 | - |
| CV(%) | | 0.71 | 0.71 | 0.85 | 0.96 | 1.06 | 1.32 | 0.46 | - |

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 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 fumigants, camphor performed as most effective in increasing the percent seed germination of rice grains followed by phostoxin, naphthalene and organic treatment. From this findings it was also revealed that the respiratory gaseous effect of camphor 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.

### 3.7. Economic Analysis of the Fumigant Based Management Practices

Economic analysis of fumigant 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 camphor, phostoxin, naphthalene and organic treatment for applying the treatments and the costs were also involved for the procurement of the items. Thus the maximum benefit cost ratio (BCR) 12.60 was calculated in Camphor @ 1.0 gm/kg rice grains. This was followed (11.30) by organic treatment. On the other hand, the minimum BCR (5.97) was calculated in naphthalene @ 0.5 gm/kg rice grains followed by Phostoxin @ 0.2 gm /kg rice grains (Table 14).

From the economic analysis it revealed that the camphor @ 1 gm/kg rice grains considered as the most economically viable tool for the management of rice moth on rice gains in storage, which gave the maximum BCR (11.3). Though organic treatment gave the second highest BCR (11.30), but it was unable to protect the higher amount of grains than the phostoxin and naphthalene. The reasons behind this higher BCR were achieved due to the involvement of the low cost of candle light treatment in case of large volume of grains in storing in single container.

**Table 14.** Economic Analysis of Fumigant 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 |
|---|---|---|---|---|---|---|---|
| Camphor @ 1g/kg grains | 370 | 0.91 | 910.00 | 16380.00 | 16010.00 | 4670.00 | 12.60 |
| Phostoxin @ 0.02g/kg grains | 720 | 0.91 | 910.00 | 16380.00 | 15660.00 | 4320.00 | 6.00 |
| Naphthalene @ 0.05g/kg grains | 620 | 0.87 | 870.00 | 15660.00 | 15040.00 | 3700.00 | 5.97 |
| Organic treatment | 220 | 0.78 | 780.00 | 14040.00 | 13820.00 | 2480.00 | 11.30 |
| Control | 0 | 0.63 | 630.00 | 11340.00 | 11340.00 | - | - |

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

## 4. Conclusion

The Camphor was the most effective fumigant to protect the rice grain infestation in storage against rice moth in laboratory condition than phostoxin, naphthalene and organic treatment. Camphor had reduced 73.77% rice grain infestation, 92.30% adult emergence, 75.75% grain content loss and increased 56.34% seed germination over control followed by phostoxin, which reduced grain infestation, 70.65% adult emergence, 74.66% grain content loss and increased 55.77% seed germination. The Naphthalene reduced 61.34% grain infestation, 71.71% adult emergence, 64.95% grain content loss and increased 55.58% seed germination. The organic treatment reduced 48.94% grain infestation, 67.65% adult emergence, 40.15% grain content loss and increased 53.77% seed germination. Considering the fumigants, the camphor @ 1.0 gm/kg rice grains was performed as the most economically viable treatment that gave the highest BCR (12.6) applied against rice moth in storage rice grains followed by organic treatment (11.30), phostoxin (6.0) and naphthalene (5.97). Extensive works are needed to deliver the suggestions to farmers about using camphor as fumigant to protect the rice grains against rice moth infestation in storage condition in Bangladesh. Also, For economic point view, camphor as fumigant should be considered for getting maximum benefit for the management of rice moth in storage for storing rice grains.

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