USE OF DIFFERENT CONTAINERS, INDIGENOUS MATERIALS AND CHEMICALS FOR THE MANAGEMENT OF INSECT PESTS OF WHEAT IN STORAGE

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CERTIFICATE

This is to certify that thesis entitled, **"USE OF DIFFERENT CONTAINERS, INDIGENOUS MATERIALS AND CHEMICALS FOR THE MANAGEMENT OF INSECT PESTS OF WHEAT IN STORAGE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by ***MD. YOUSUF ALI***, Registration No. **00484** under my supervision and guidance. No part of the thesis has been submitted for any other degree.

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

Dated:
Place: Dhaka, Bangladesh

(Md. Abdul Latif)
Supervisor

DEDICATED TO

MY Beloved Parents

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The Author

USE OF DIFFERENT CONTAINERS, INDIGENOUS MATERIALS AND CHEMICALS FOR THE MANAGEMENT OF INSECT PESTS OF WHEAT IN STORAGE

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THESIS ABSTRACT

The present study on the use of containers, indigenous materials and chemicals for the management of insect pests of wheat in storage was conducted in the laboratory of the Department of Entomology, Sher-e- Bangla Agricultural University (SAU), Dhaka during April 2006 to November 2006. The experiment was laid out in Factorial RCBD having two factors with three replications. Four types of containers such as tin kouta, earthen pot, plastic container and gunny bag were considered as one factor and different indigenous materials and chemicals such as neem leaf powder, sand, camphor, naphthelene and an untreated control were considered as another factor. Three insect pests such as grain moth (*Sitotroga cerealella*), red flour beetle (*Tribolium castaneum*), and rice weevil (*Sitophilus oryzae*) were found to attack wheat grain during the study period. Among them grain moth population was initially higher but the population of red flour beetle was always higher than rice weevil. The plastic container and tin kouta showed the best performance in protecting the wheat from attack of different insect pests while, gunny bag was less effective. Among the materials, naphthalene showed the

best performance than any other materials in protecting the wheat seed from insect attack however, camphor showed similar results as naphthalene followed by neem leaf powder. The lowest population of grain moth (0.00-4.67), red flour beetle (7.00-18.33) and rice weevil (0.0-5.33) was recorded from the plastic container and tin kouta in combination with naphthelene and camphor. On the other hand, the highest population of grain moth (15.33-136), red flour beetle (32.33-95.33), and rice weevil (2.67-21.67) was recorded from gunny bag. The highest percentage of grain infestation (11.23-46.36%) was recorded from gunny bag and in combination with different materials. The lowest percent grain infestation (7.25-26.30%) was recorded from plastic container in combination with naphthelene. The percent grain infestation fluctuated with temperature and relative humidity and the percent grain infestation (7.25-26.30%) was low in June after 2 months of storage and gradually increased to a peak in September 2006. A range of 100% - 86.67% of germination of wheat seed was observed in the treatments, tin kouta + neem leaf powder, plastic container + camphor and plastic container + neem leaf powder. The lowest percentage (66.67-73.33%) of wheat seed germination was observed in the gunny bag + neem leaf powder and gunny bag sole. Plastic container and tin kouta in combination with naphthelene provided maximum (86.73%) germination of wheat seed after six months of storage.

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LIST OF ACRONYMS

Anon.	Anonymous
Atm.	Atmospheric
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
cm	Centi-meter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
et al.	And others
etc.	Etcetera
FAO	Food and Agricultural Organization
g	Gram (s)
hr	Hour(s)
Kg	Kilogram (s)
LSD	Least Significant Difference
m^2	Meter squares
mm	Millimeter
No.	Number
NS	Non significant
SAU	Sher-e- Bangla Agricultural University
var.	Variety
Wt.	Weight
t ha^{-1}	Ton per hectare
^0C	Degree Centigrade
%	Percentage

Chapter 1
Introduction

CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most widely grown food crop in the world, which ranks first in terms of area and production in the world (Anonymous,1988). Wheat has been established as a farmer's crop and is important food supplement of the common people. Nutritional values as well as diversified uses prove its importance for cultivation and expansion. With the increase of population more food grain production is needed in the country and wheat can play a vital role in food requirement in the nation perspective (BARI, 1997). In storage, insect pests became important soon after men first learned to keep grains for seed and food purposes. Saxena *et al*. (1988) stated that agricultural practices began about 10,000 years ago and that of storing food grain started about 4,500 years ago as a safeguard against poor harvests and famines. Wheat and other cereals are stored in the government and public godown both in Bangladesh and developed countries.

A considerable amount of wheat as well as other grains is lost every year in storage. It has been estimated that about 15% - 20% of the world's agricultural production is lost every year due to insect infestation. Out of this, 8% production is lost every year due to insect infestation alone in storage. In India, losses caused by insects accounted for 6.5% of stored grain (Raju 1984). About 10-25% of food products in Bangladesh were wasted due to lack of proper post harvest technologies at various levels from rural homes to national godowns (Ali, 1999). In Bangladesh, the annual grain losses cost over taka 100 crores (Alam, 1971). Caswell (1964) reported 30-50% damage of wheat grains occurred after 6 months of storage. Both biotic and abiotic factors are responsible for the loss of wheat in storage. The major biotic factors influencing wheat loss during storage are insects, moulds, birds and rats (Baloch *et al.* 1994).

There are approximately 200 species of insect and mite species attacking stored grains and stored products (Maniruzzaman, 1981). Their attacks reduced both quantity and food value of stored seed (Kabir, 1978). David *et al.* (2005) revealed that losses of grain in storage due to insects were the final components of the struggle to limit insect losses in agricultural production. Losses caused by insects include not only the direct consumption of kernels, but also include accumulations of frass, exuviae, webbing, and insect cadavers. Gentile and Trematerra (2004) reported that twenty insect pests infested stored wheat, with *Troqium pulsatorium, Ephestia elutella, Plodia interpunctella, Sitotroga cerealella, Cryptolestes ferrugineus, Oryzaephilus surinamensis, Rhyzopertha dominica, Sitophilus granarias, Sitophilus oryzae* and *Tribolium castaneum* being the most dominant pests. Among them, *Sitotroga cerealella* occurred during pre harvest and post harvest storage. On the other hand, Chaudhary and Mahla (2001) observed 10 insect species of wheat in storage, which varied depending upon the prevailing climatic conditions. He found that major pests of wheat were angoumois grain moth (*Sitotroga cerealella* Olivier), lesser grain borer (*Rhizopertha dominica* F.), rice weevil (*Sitophilus oryzae* L.), red flour beetle (*Tribolium castaneum* L.) in the storage. Anisur (2000) reported that the red flour beetle (*T. castaneum* L.) was serious pest of stored wheat and can penetrate deeply into the storage commodity.

In Bangladesh, most of the farmers are poor and marginal. They store small quantities of wheat grains in their house for their consumption and seed purpose and they can not afford expensive control measure. They store wheat in tin kouta, earthen pot or motka, iron or metal container, plastic container, gunny bag and thick polythene bag. Moreover, they use various indigenous materials such as sand, lime, neem leaf, and cheap chemicals like naphthalene, camphor etc. Therefore, they essentially need some cheap, easy to use and readily available but effective methods for safety storing of wheat.

Tin kouta, plastic containers, earthen pot, gunny bag, polythene etc. are localy available containers and farmers can easily collect them. Kabir *et al*. (2003) reported that tin, gunny bag with polythene provided effective protection against insect pests of mung bean in storage. Moreover, neem leaf powder and sand are also locally available indigenous source of materials with low or no mammalian toxicity and no adverse effect on seed germination, cooking quality and milling, have been in use for more than a century in India (Kabir *et al*., 2003; Prakash *et al*., 1987). Camphor, originally a natural component of essential oil having very low mammalian toxicity (Abivardi, 1977; Abivardi and Benz, 1984) was found highly effective against rice weevil (Latif et al. 2004; Kabir *et al*. 2003) as well as maize weevil (Latif and Rahman 2000). Moreover, naphthalene a cheap and easily available chemical was found effective against different stored grain pests (Kabir *et al*., 2003). Therefore, it is important to know single and combined effect of these containers and storage materials for easy and cheap storage of wheat but little study has been done regarding these.

Considering above, four different types of containers such as earthen pot, tin kouta, plastic containers and gunny bag were selected for this experiment. Moreover, four easily available and cheap indigenous materials and chemicals were chosen for this study. Under the above perspective, the present study has been undertaken with the following objectives:

- To observe the effectiveness of different locally available storage containers for the protection of insect pests of wheat in storage.
- To evaluate the protection efficacy of some indigenous materials and chemicals against insect pests in storage.
- To investigate the combined effectiveness of these containers and materials against the insect pests in storage and
- To determine effect of these storage containers and materials on germination of wheat seed.

Chapter 2
Review of literature

CHAPTER 2

REVIEW OF LITERATURE

Wheat (*Triticum aestivum* L.) is the most widely grown food crop in the world. Globally it ranks first in terms of area and production (Anonymous, 1988). Nutritional values as well as diversified uses of wheat prove its importance for cultivation and expansion. Insect pests cause heavy food grain losses in storage, particularly at the farm levels in tropical countries. The efficient control and removal of stored grain pests from food commodities have long been the goals of entomologists throughout the world because insect infestation is the most serious problem of stored grain and stored products. Losses due to insect infestation are the most serious problem of cereal grains, pulses, oil seeds in storage, particularly, in villages and towns of developing countries like Bangladesh. However, for the purpose of the study the most relevant information pertaining to the loss of wheat in storage, factors responsible for loss during storage, effectiveness of different storage structure and materials for the management of insect pests of wheat were reviewed under the following sub-headings:

2.1. Loss of wheat in storage

Loss is defined as a measurable decrease of the food quantity and quality. Loss should not be confused with superficial damage generally due to deterioration.

Quantitative loss is physical and can be measured in weight or volume, while qualitative loss can only be assessed. Quantitative loss, qualitative loss, nutritional loss, seed viability loss and commercial loss may gauge this reduction (Baloch *et al.* (1994).

David *et al.* (2005) revealed that losses of grain in storage due to insects were the final components of the struggle to limit insect losses in agricultural production. Losses caused by insects include not only the direct consumption of kernels, but also include accumulations of frass, exuviae, webbing, and insect cadavers. High levels of this insect detritus may result in grain that is unfit for human consumption. Insect-induced changes in the storage environment may cause warm, moist 'hotspots' that are suitable for the development of storage fungi that cause further losses. Worldwide losses in stored products, caused by insects, have been estimated to be between 5-10% percent. Heavy insect pest infestation caused about 30% damage in the tropics.

The rice weevil complex (*S. oryzae and S. zeamais*) present a very serious problem in the preservation of harvested grains during storage. In the Philippines, over 90% of the total insect damage in stored corn may be attributd to *S. spp.* (Uichanco and Capco, 1984). FAO's estimation as cited by Sing (1972) showed that insect damage and loss in stored grains in temperate and developed countries ranged from 5 to 10% of worlds production.

On the other hand, Labadan (1968) observed that at least 5% of the grains weight lost due to insect pests during the first 3 months of storage and this could increase 17%

for the next 6 months. Caswell (1964) observed 30-50 percent damage of wheat grains after 6 months of storage.

2.2. Factors regulating loss of wheat in storage

2.2.1. Biotic factors

Both biotic and abiotic are responsible for the loss of wheat in storage. Baloch *et al.* (1994) revealed that the major biotic factors influencing wheat loss during storage are insects, moulds, birds and rats. Gentile and Trematerra (2004) reported that twenty insect pests infested stored wheat, with *Troqium pulsatorium, Ephestia elutella, Plodia interpunctella, Sitotroga cerealella, Cryptolestes ferrugineus, Oryzaephilus surinamensis, Rhyzopertha dominica, Sitophilus granaries, Sitophilus oryzae* and *Tribolium castaneum* being the most dominant pests. *Sitotroga cerealella* occurred during pre harvest and post harvest storage.

Chaudhary and Mahla (2001) reported that insect pests of stored cereal food grains were varied depending upon the prevailing climatic conditions. About 10 (ten) insect species (*Trogoderma granarium, Rhyzopertha dominica, Sitophilus oryzae, Tribolium castaneum, Oruzaephilus surinamensis, Tenebrioides mauritanicus, Cryptolestes ferrugineus, Cerealella, Plodia interpunctella and Ephestia kuehniella*) and one mite (*Acarus siro*) were infested in stored wheat grains. Amonog them, *Trogoderma granarium, Sitophilus oryzae,* and *Rhyzopertha dominica* were the major insects in various climatic zones, while other insects were minor pests.

The most commonly encountered stored wheat grain pests were *Cryptolestes* spp., which occurred in large populations. Less frequent and with smaller population sizes were *Rhyzopertha dominica, Sitophilus oryzae*, but less frequently were *Oruzaephilus surinamensis, Tribolium castaneum.* The methods of control were cleaning; cooling and application of the diatomaceous earth formulation and other insecticide protectants (Hamel *et al*. 1999).

Samuels and Modgil (1999) observed that wheat was infested by rice weevil, rust red flour beetle and Angomois grain moth when it stored in jute bags, perus, metal bins and polyethylene bags for 6 (six) months. Insect infested wheat stored in different structures had a significant effect on the biological utilization of wheat protein. Insect infested grains should not be consumed as it may pose a serious health hazard in man.

Baloch *et al.* (1994) found the major insect species to infect wheat include Khapra beetle, *Trogoderma granarium* Everts; Lesser grain borer, *Rhizopertha dominica* (F); Rice Weevil, *Stitophilus oryzae* L. and Red flour beetle, *Tribolium castaneum* (Hbst). All these insects may be found extensively in most developing countries to different extremes. Other insect species are recognized storage pests that also infest stored wheat like angoumois grain moth, *Sitotroga cerealella* (Oliv.); rice moth, *Corcyra cephalonica* Straint; saw toothed grain beetle *Oryzaephilus surinamensis* (L.); long headed flour beetle *Latheticus oryzae* Wat.; flat grain beetle *Cryptolestes pusillus* (Schoen).

The major pests of wheat were anguomois grain moth (*Sitotroga cerealella* Olivier), lesser grain borer (*Rhizopertha dominica* F.), rice weevil (*Sitophilus oryzae* L.), red flour beetle (*Tribolium castaneum* L.) in the during storage. Anisur (2000) reported that the red flour beetle (*T. castaneum* L.) was serious pest of stored wheat and can penetrate deeply into the storage commodity.

On the other hand, Karim (1987) revealed that rice weevil (*Sitophilus oryzae*), granary weevil (*Sitophilus granaris*), greater rice weevil (*Sitophilus zeamais*), lesser grain borer (*Rhhizopertha dominica*), red grain beetle (*Tribolium castaneum*), khapra beetle (*Trigoderma granarium*), saw toothed grain beetle (*Okryzaephilus surinamensis*) and rice moth (*Sitotroga cerealella*) caused most damage to wheat seed in storage in Bangladesh.

Simwat and Chahal (1980) visited six farmers' wheat stores from June to October at monthly intervals in India to draw the grain samples at three depths i.e. 5, 30 and 75 cm and found the infestation of *R. dominica, S. cerelella, T. granarium and T. castaneum.* Srivastava *et al*. (1973) reported that insects viz. *S. oryzae, R. dominica, S. cerealella and T. castaneum* attack the grains of wheat and maize and responsible for severe damage.

Henderson and Christensen (1961) found the most common insects in stored seeds or grains were rice weevil (*Sitophilus oryzae*), granary weevil (*Sitophilus granaris*), lesser grain borer (*Rhhizopertha dominica*), saw toothed grain beetle (*OKryzaephilus surinamensis*), Cadelle beetle (*Tenebriodes maurtanicus*), Flour beetle (*Tribolium sp*), Dermistids (*Trogokderma sp*), Bruchids, bean and cowpea weevils

(*Callosobruchus spp*), India meal moth (*Plodia interpunctella*) and Alamond moth (*Ephestia cautella*).

Longstaff (1986) stated that rice weevil was a serious pest of wheat occurring throughout the world. Both adult and grubs cause serious damage to grains of wheat, maize and sorghum particularly, in the monsoon. These also cause damage to oat, barley, cotton seed, linseed and cocoa. It can cause losses to grain either directly through consumption of the grain or indirectly by producing 'hot spots' causing increase of moisture and thereby making grain more suitable for attack by other stored grain pests.

Red flour beetle, *Tribolium castaneum* is a serious pest and occurs widely throughout the world (Anonymous, 1973). Both grubs and adults of red flour beetle feed on a wide range of commodities and is an important pest of stored cereal (Alam, 1971; Husain, 1995). It stands out as an agricultural pest of primary importance in the tropics. It is stated that this insect most commonly occurs in situations where grain products are stored (Metcalf and Flint, 1962; Alam, 1971). Neither grub nor adult could generally damage whole or intact grains but they can feed on grains only, which had already been damaged by other pests.

Red flour beetles may be present in large numbers in infested grain, but are unable to attack sound or undamaged grain (Walter, 1990). The adults are attracted to light, but will go towards cover when disturbed. Typically, these beetles can be found not only inside infested grain products, but also in cracks and crevices where grains may have spilled. This insect commonly occurs in the grain milling houses and wire houses.

They are attracted to grain with high moisture content and can cause a grey tint to the grain they are infesting. The beetles give off a displeasing odour, and their presence encourages mold growth in grains and grain products.

The larvae and adults of *T. castaneum* feed on a wide range of durable commodities and important secondary pests of cereals, nuts species dried fruits and occasionally of pears and beans (Via, 1999; Weston and Rattlingourd, 2000). Like most other storage beetles, *T. castaneum* can penetrate deeply into the storage commodity. However, the red flour beetle can only attack the broken grains and therefore, they are known as secondary stored product pests. Beside these, red flour beetles attack and damage the powdery products of cereal grains.

2.2.2. Abiotic factors

Abiotic factors including temperature, humidity and type of storage, all affect environmental conditions in storage. High temperature causes deterioration, while low temperature is good for storage. High temperature accelerates the respiration of grain, which produces carbon dioxide, heat and water, conditions favourable for spoilage. Humidity equally impacts grain storage. Increasing humidity increases spoilage, while decreasing humidity is good for storage (Baloch *et al.* 1994).

The type of storage plays a fundamental role in storage efficiency. If a concrete or mud storage structure can absorb water or allow the water vapours to pass through, in the case of a jute bag, the bio-chemical changes and mould attack are minimal, but the risk of insect infestation increases. Sun drying or turning of food grain has many advantages as it provides an opportunity for inspection and precautionary measures to avoid spoilage. Aeration greatly minimizes mould growth, insect activity, and respiration of the seed. Further aeration provides a cooling action and equalizes the temperature throughout the mass of the grain stored (Baloch *et al.* 1994).

Climate conditions, grain conditions at storage (presence of infestation, moisture content, and foreign matter content), the period of storage, grain and pest control practices all contribute to the rate of loss caused by insects and mould growth. As these factors interact, it is difficult to isolate them or identify one factor, which has a direct influence on loss. Average statistics for loss, whether for store types, areas, or quantities of grain stored are inconclusive. An average figure for loss for a region or a country holds no significance unless a decision regarding a new system of storage, or new pest control techniques is required. Nevertheless average loss figures are always sought (Baloch *et al.* 1994).

2.3. Factors and affecting infestability

Physical environment viz. temperature, moisture, daylight and weather are the important factors responsible for insect infestation and losses caused by them in storage (Tyagi and Girish, 1977). Besides the physical environment, there are certain other factors which also influence the infestability of insect pests, such as the type of storage structures, period of storage and grain characteristics (Prakash and Rao, 1985a, 1985b).

2.3.1. Physical environment

In storage ecosystem, temperature and relative humidity fluctuated within a definite range, which allowed insects to survive and multiply. However the temperature range of 25^0C to 32^0C and relative humidity range of 70-85% were considered optimum ranges within which the insects could multiply well (Prakash, 1982).

Local climatic condition including temperature, relative humidity and moisture content influence the infestation of storage insects in wheat. Atmospheric humidity is directly related to the moisture of the grains and has been found positively correlated with insect infestation (Khare, 1972; Chatterjee, 1953; Prakash, 1982).

2.3.2. Atmospheric humidity and grain moisture content

Analysis of infested and non infested grains at different moisture levels showed that weight loss of infested grains was 1.3 to 1.5 times higher at all moisture levels. Similarly, the weight loss of infested grains due to rice weevil infestation increased gradually with the increase of moisture levels (Haque, 1995).

Qayyum (1964) reported that at higher humidity weevil had better chance of survival than at the lower humidity. He also reported a direct relationship between relative humidity and moisture content of grain which influenced the oviposition. Nishigaki (1958) reported that development and the rate of reproduction of S. oryzae increased in general as the water content of the rice increased from 12.2 to 16.7%.

2.3.3. Temperature

Temperature is an important factor governing the rate of metabolism, growth, development, reproduction, general behaviour and distribution of insects (Prakash *et al*. 1987). Boldt (1974) observed highest fecundity of *S. oryzae* at 30°C. At highest temperature of 40 ±1°C adult *S. oryzae* was not survive. While, Cook (2003) observed 100% mortality of *S. granarius* and *T. castaneum* at temperatures <more or =>35^{0}C, with 89% of *S. granarius* surviving in untreated controls at 35^{0}C, and the more heat tolerant *T. castaneum* surviving at 35 and 40^{0}C .

Storage at 40-60^{0}F is optimal for most home stored grains but is usually impractical in most homes except during winter months. Freezing or sub-zero temperatures do not damage stored grains or pulses. Storage at temperatures above 60° F causes a more rapid decline in seed viability (ability to germinate) but only a slightly faster loss in food value. All nuts (including peanuts) and ground, whole wheat flour should be refrigerated in closed containers to prevent the development of off flavors and rancidity (Ralph, 1995).

2.4. Materials for protection of wheat in storage

2.4.1. Physical materials

Siddika (2004) reported that white lime powder significantly reduced the emergence of adult rice moth in storage and the additive also reduced the loss of grain weight and percentage of infested grain during storage. Kabir *et al*. (2003) revealed that neem leaf powder and sand showed some efficacy in protecting mung bean against *Callosobruchus chinensis* L. in storage. In contrast, Choudhary (1961) observed that a layer of 2 and 3 cm sand over the grain were the most effective with regard to poor oviposition emergence, development and less damage to seed of Bengal gram (*Icer arietinum*).

Results of laboratory test conducted by Chatterjee (1984) revealed that the ashes and sand, which were widely used, acted as hygroscopic substances and reduced the moisture content of the commodities to some extent, with which they were mixed and indirectly affected insect multiplication. In Japan, Takai and Miyajima (1981) reported paddy husk ash to be an effective inert material for the control of *S. oryzae* in stored paddy.

On the other hand, Anonymous (1980) reported that most of the inorganic dust exhibited adsorptive property and more or less insecticidal activities against insect pests. Moreover, several inert dusts like silica, aluminium oxide, magnesium oxide and inorganic dusts like lime, salt, sulphur, and borax effectively protect grains in storage from insect infestation (Cotton, 1967).

2.4.2. Plant materials

Facknath and Sunita (2006) reported that Neem (*Azadirachta indica* A. Juss.) has been demonstrated to reduce insect populations in stored products through its toxic and growth-disrupting and other effects on the pests. Grain movement and percussion also help to kill pests in grain. The combination of neem and grain movement on population growth and development of four insect pests is reported in this study. Dried whole neem leaves, neem leaf powder and neem seed kernel oil were combined individually with dried beans and rice in separate experiments, and subjected to varying degrees of gentle grain tumbling. The results showed that the combined treatments were more effective in reducing populations and disturbing growth and development of *Acanthoscelides obtectus* (Say) (Bruchidae), *Sitophilus oryzae* (Linnaeus) (Curculionidae), *Oryzaephilus surinamensis* (Linnaeus) (Silvanidae) and *Cryptolestes ferrugineus* (Stephens) (Cucujidae) compared to the untreated control or the neem or tumbling treatments alone. This study demonstrated the potential of a simple, effective and cheap method of protecting stored seed or food grain in small-scale storage for resource-poor farmers who do not have access to sophisticated control methods, entoleters or other mechanical devices for grain protection.

Latif *et al.* (2004) reported that different doses of camphor kept the infestation 94.14%-95.74% less than that of the control and offered 95.39%-98.86% protection of rice grains against rice weevil, *Sitophilus oryzae* in storage after six months of storage. The dose @ 6.0 g of camphor per kg grains was the most effective (98.86% protection of loss) although the dose @ 2.0 g per kg grains provide more than 90.00% protection of loss. Similarly, Siddika (2004) reported that camphor and dried neem leaves significantly reduced the emergence of adult rice moths in storage. The additives also protected the loss of grain weight and percentage of infested grain and camphor showed the best result among them.

Kabir *et al.* (2003) reported that camphor and naphthalene showed the best performance than sand and neem leaf powder in protecting mung bean against insect pests during storage. Tin containers provided the highest protection followed by gunny bags with polythene. The highest percentage of weight loss occurred with mung bean storage in gunny bag while tin provided the better protection than other containers. The highest percentage of germination of mung bean seeds after 3, 6 and 9 month storage was observed the mung bean seeds stored in tin followed by gunny bag with polythene.

Laboratory experiment conducted by Latif and Rahman (2000) stated that different doses of camphor kept the infestation 93.03%-95.57% less than that of the control and offered 90.84%-93.53% protection of loss against maize weevil, *S. zeamais*. The dose @ 6.0 g camphor per kg maize grains was the most effective although the dose @ 2.0 g camphor per kg maize grains provided more than 90% protection.

Weaver *et al.* (1995) stated that volatile components of dried leaves of *Atemisia tridentate* (Nutt.) and *Monarda fistulosa* L. were terpenoids with camphor (9.7 mg/g) and 1, 8-cineole (40 mg/g) but abundant in *A. tridentate* and carvacrol (26.3 mg/g) largely available in *M. fistulosa*. Both the plant species were less effective against the rice weevil in wheat. The maximal control achieved against *S. cerealella* was less than 50% at 3% w/w.

A study with 8 essential oils of plant origin (Citronella, palmarosa, geranium, eucalyptus, wintergreen, patchouli, citrodora and camphor) to 3rd instars larvae of *Pericallia ricini* at concentration of 2.5 and 10% on castor leaves revealed that all oils have some antifeedant properties. *Citrodora* oils gave the best protection to leaves. Camphor oils at 10% concentration gave no mortality. It was concluded that the antifeedant action of essential oils was dose dependent (Dale and Saradamma, 1981).

2.4.3. Storage structure for protection of wheat

Local storage structure, which are commonly used in rural India and Bangladesh fail to provide complete grain protection from insects. In general, these structures are not moisture proof. The moisture content is high in stored grain which facilitates insect multiplication. The longer the storage period, higher is the insect infestation (Prakash, 1982).

Singh (2001) made a survey on the storage structures used by the farming community in North Bihar, India. He reported that they owned at least 13 different types of storage structures for storing of their agricultural products. Among all, gunny bags were maximum (25.78%), however, the farmers use different types of structures at a time.

Mandal *et al*. (1984) reported that average losses and deterioration of grains in silo/ godown storage were estimated to be 1.5% and for warehouse storage to be 2.8%. Among the existing structures used by the private sector, bamboo made "dole" was suitable for short term storage.

Mahboub and Ahmed (1996) reported that extracts of castor (*Ricinus communis*) seeds prepared using various solvents (petroleum ether, chloroform, acetone and methanol) were studied against the curculionid *Sitophilus oryzae* infesting wheat grains. On the basis of the LC_{50} and LC_{95}, a petroleum ether extract was the most potent and had the highest contact toxicity. Other extracts produced toxicities which were slightly lower. The order of decreasing toxicity was methanol, acetone and chloroform extracts, respectively. The residual effects of extracts were studied after 15, 30, 45, 60, 75 and 90 days. However, the germination rate of wheat grains treated with castor oil seed extracts was reduced.

2.4.4. Management of temperature and humidity

Proper management of temperature and humidity helps prevent stored-grain pests. Insects require a temperature higher than 60° F for normal growth and reproduction. Even if the temperature is not cold enough to kill insects directly, it may decrease feeding enough to cause starvation. Again, mass temperature of less than 60° F (50 to 55° F would be ideal) is difficult to get when wheat and early season soybeans and rice are cut. However, if the grain is to be kept through the fall and winter, the grain mass temperature can be lowered as temperatures decrease in the fall. You can run aeration fans when temperatures are in the 50° C and the humidity is below 60 percent. Cooling the grain mass reduces insect development and provides a good storage environment for the grain. Insects get their moisture from the grain, so it is easy to see the role that grain moisture can play in insect survival. The potential for insect growth and reproduction increases when grain moisture rises above 12 percent.

2.4.5. Management of light

Light is also an important physical factor, which directly influences the movement, oviposition and development of the stored grain insects. Most of the rice storage insects are found to show photonegative response. Incase of S. *oryzae* photonegative response has been observed (Pajni and Virk, 1982).

2.4.6. Resistance to pest populations

Mohapatra and Khare (1989) studied on the development of *sitotroga cerealella* on grains of 34 wheat cultivars in order to identify sources of resistance to the pest. Percentage basis adult emergence and mean body weight of adults, UP 324, UP 335, HD 2009, Pak 20, WG 377 and India 66 were found to be relatively resistant to the pest, while UP 101, UP 319, HD 2088, Raj 827, WL 371 and S 310 were considered to be susceptible.

Satasook and Williams (1990) were conducted the susceptibility of nine cultivars of Australian wheat to *Sitophilus oryzae* and *Rhyzopertha dominica* was studied at combinations of two temperatures, 25 and 30^0C, and three relative humidities, 48, 60 and 70%. Index of susceptibility experiments were conducted on seven cultivars at 30^0C and 70% RH, six of the cultivars were grown at two locations and at one of these more fertilizer was applied resulting in high protein content wheat. Although there were interactions between cultivar, temperature, and relative humidity, some of the cultivars were consistent in their effects. The cultivars Wyuna and Olympic showed a high degree of susceptibility to both insect species in almost all conditions tested. Matong was susceptible to *S. oryzae* but resistant to *R. dominica*, probably because of the effect of its chemical composition on developing larvae of *R. dominica*. Condor and Oxley were relatively resistant to both *S. oryzae* and *R. dominica*. Other varieties varied greatly in their susceptibility to both species. Low relative humidity at 48% reduced the productivity of both species. Oviposition of *R. dominica* on the high protein wheat was reduced, but this did not ultimately influence the index of susceptibility.

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Chapter 3
Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

The study relating to the effect of containers, indigenous materials and chemicals against insect pests of wheat in storage, was conducted in the laboratory of the Department of Entomology, Sher-e- Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka during April 2006 to November 2006.

The materials and methods adopted in the study are discussed in the following sub-headings:

3.1. Materials required

Wheat of variety kanchan was used as stored grain in this experiment. On the other hand, tin kouta, plastic containers, earthen pots and gunny bags were selected as storage containers for this study. Neem leaf powder and sand was selected as indigenous materials, while camphor and naphthalene were selected as chemicals for this experiment. The indigenous materials and chemicals were selected according to the previous reports advocated by various authors, which have been discussed in the review section.

3.2. Selection of commodities

Cereals constitute major staple food in Bangladesh. For crop grown, seed storage is essential in proper condition. Govt. and non Govt. institute or NGO's supply only 5-7% to 12% seed for crop grown. The rest percentages are stored by farmers. Farmers store these commodities for different lengths of time for seed purpose. During such storage, these cereals are subject to different levels of infestation by various pests depending on the storage systems and storage periods. Among all the commodities in these cases cereals are usually stored in the largest bulk. Thus considering the importance of cereals in terms of quantities stored and pest's incidence of wheat selected for the present study. For the experiment, the wheat was collected from BADC, Dhaka centre.

3.3. Selection of containers

Four different widely used containers such as tin kouta, plastic container, earthen pot and gunny bag were selected for this study because the farmers usually used these containers for storing cereals and other grains in their house. Moreover, these containers are easily available, cheap and easy to handle. The containers were purchased from the local market of Chakbazar, Dhaka.

3.4. Selection of storage materials

Four different easily available and widely used indigenous materials and chemicals such as neem leaf powder, sand, camphor and naphthalene were selected for this study. Neem leaf powder and sand are easily available for the farmers and no cost is involved for these materials. While, camphor and naphthalene are also easily available and cheap require few amount of money for them. Neem leaf was collected from SAU campus, Dhaka. The collected leaves were washed and air dried then dried in the oven at 50^0C for 24 hours. Dried leaves were than powdered in an electric grinder. Sand was also collected from SAU, campus Dhaka. The collected sand was clean and air dried then sieved to remove the inert materials. Dried sand was used in the experiment.

38 Camphor and naphthalene are fumigant like chemicals. Camphor is available in the white crystalline form with characteristics fragrance, while naphthalene is a white pellet. They were collected from Krishi Market, Mohammadpur, Dhaka.

3.5. De-infestation of wheat grains

After collection wheat grains was dried in the open sun light for two days. Hill (1990) reported that solar heat treatment of grains destroys the initial insect infestation in the grains before storage.

3.6. Treatments and experimental design

The experiment was laid out in Factorial Design having two factors with three replications. Various containers were considered as one factor and different materials and chemicals were considered as another factor. Four types of container such as tin kouta, earthen pots, plastic containers and gunny bag indicate the 4 levels one factor. On the other hand, four indigenous materials and different containers such as neem leaf powder, sand, camphor, naphthalene and an untreated control indicate the five levels of the other factor. Therefore, a total of 20 (4 × 5) treatment combinations and 60 (4 × 5 ×3) experimental units were used in this experiment. Although, completely randomized design is usually followed in the laboratory experiments however, the experiment was set in Randomized Completely Block Design (RCBD), where one replication was considered as a block. Because it was very difficult to collect data from 60 experimental units in a day and 3 days were needed for each observation. So, data collected from one replication in a day were considered as a block to avoid the error in different days.

3.7. Test procedure

Twenty containers were marked with black colour mentioning the treatment combinations (containers and storage materials), the replication and untreated control. Similarly, 60 containers were marked for the total experimental purpose. For this experiment, 2 (two) kg of healthy wheat grains were kept in each of the 60 containers. Then neem leaf powder (10 gm/kg), sand (100 gm/kg), camphor (4 gm/kg) and naphthalene (4 gm/kg) were added to the seeds or grains in the respective marked container. Neem leaf powder, sand, camphor and naphthalene were placed in 3 (three) layers in the containers. At first, 1/3 (one third) neem leaf powder, sand, camphor (granular) and naphthalene (pellet) was placed in the bottom of the respective marked container, then half of the grains (1 kg) was placed in the container. Again 1/3 (one third) neem leaf powder, sand, camphor and naphthalene were kept on upper layer of the grains. The rest of the grains (1 kg) was placed in the respective mark containers and finally 1/3 (one third) neem leaf powder, sand, camphor and naphthalene were placed on the upper surface of the grains in the containers. Nothing except grains was kept to the respective untreated control. The open ends of each of the containers were closed by its cover and gunny bag was closed tightly with rope.

3.8. Sampling procedure

After 2 (two) months of storage, 3 (three) samples were collected with a sampling probe from each container using a sampling core. The sample was collected from middle layer of the grain and thoroughly mixed. The sample thus collected was brought to the laboratory of Entomology Department, SAU, Dhaka and were subjected to the following steps. The same way 2nd, 3rd, 4th sampling was done after 4 months, 6 months and 8 months respectively of storage and data was counted.

3.9. Data collection

3.9.1. Studies on prevalence and population of insect pests

The insect pests in each sample were properly identified and their population was counted and recorded. For convenience of handling and data recording, the insects in each sample were collected by the aspirator in which drops of ethyl acetate were added for anesthesia. For grain moths, a cylindrical insect holder made of mosquito net was placed upper side of the containers and shaken frequently. So that all the moths flew up and was captured in the net. Then the moths were killed with ethyl acetate to count their number.

3.9.2. Recording of infestation

The grains of each sample were then immediately sorted into infested and healthy. The grains that contained any sign of infestation such as bores, holes, scratches, pierces, eaten up areas etc. observed under magnifying glass were considered as infested. The number and weight of infested grains and healthy seeds were recorded. The percentage of grain infestation by number and weight was calculated with the following formulae:

$$\text{\% grain infestation (by number)} = \frac{\text{No. of infested grains}}{\text{No. of total grains}} \times 100$$

$$\text{\% grain infestation (by weight)} = \frac{\text{Wt. of infested grains}}{\text{Wt. of total grains}} \times 100$$

3.10. Germination test

Ten seeds were taken randomly from sample collected from each container for germination test after two, four, six and eight months of storage respectively. Then the seeds were kept in petridish with water soaked filter paper and proper moisture was maintained regularly by adding of distilled water. Number of germinated seeds was counted after the 5th day of germination test. Germination was calculated in percent using the following formula:

$$\% \text{ germination of grains} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds tested for germination}} \times 100$$

Data analysis

All of the collected data were subjected to proper statistical analysis. The percentage data was subjected to ArcSin transformation while the data in number was subjected to square root transformation as and when needed. The data was analyzed by using MSTAT statistical package programme applicable for the Factorial Randomized Completely Block Design (RCBD). Graphical interpretations were also performed wherever needed.

Chapter 4

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

The results of the experiments are presented here sequentially to reach a conclusion regarding the efficacy of different materials like neem leaf powder, sand, camphor, and naphthalene against major insect pests of wheat in storage condition.

4.1. Effect of different containers on incidence of insect pests of wheat in storage

This study revealed that three insect pests such as grain moth (*Sitotroga cerealella*), red flour beetle (*Tribolium castaneum*), and rice weevil (*Sitophilus oryzae*) attacked wheat seriously during the study period. The population dynamics of grain moth, flour beetle, rice weevil in different containers are shown in Figure 1, 2 and 3, respectively. The highest population of grain moth was observed in gunny bag followed by earthen pot (Figure 1).

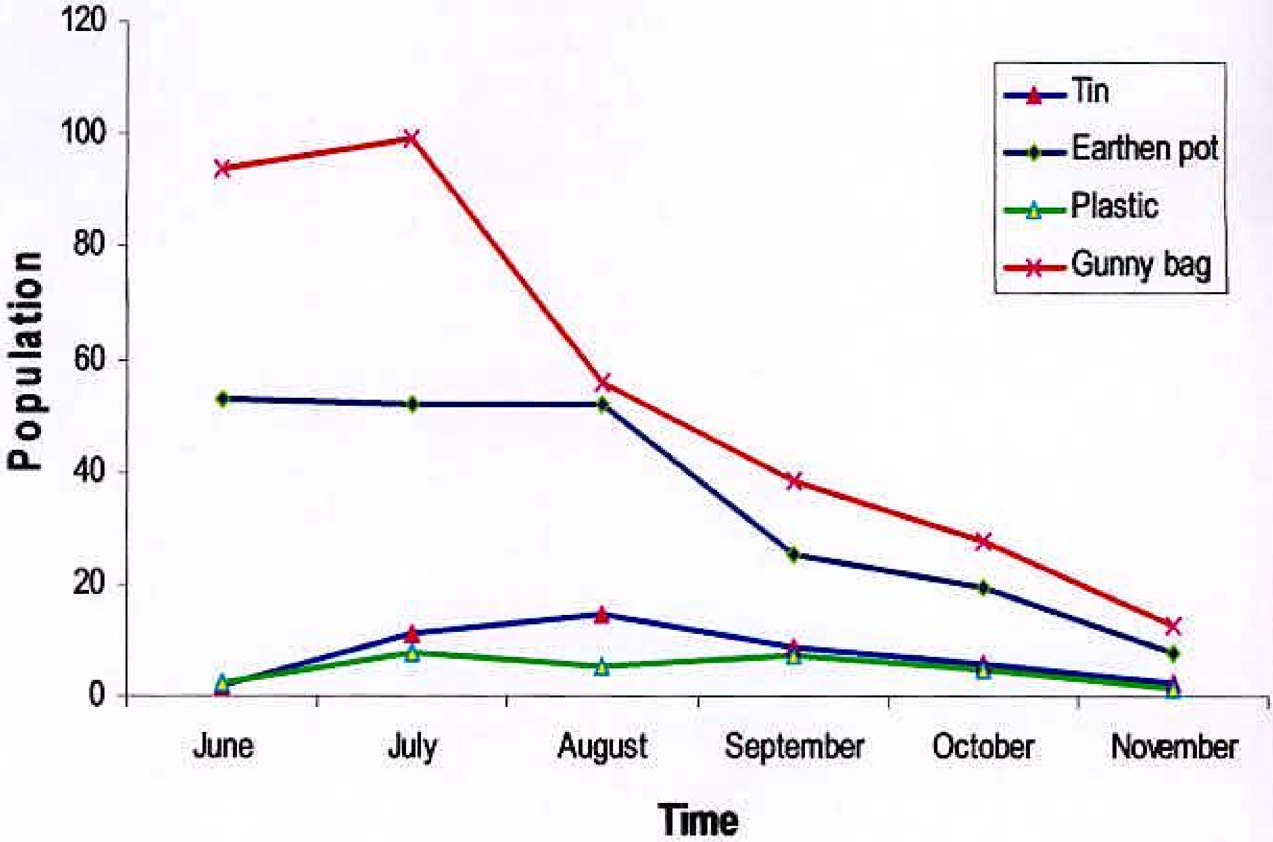

Figure 1. Population dynamics of grain moth in different containers during the period from June to November 2006.

The lowest population of grain moth was observed in plastic container and tin kouta. In all the containers. The highest population of grain moth was recorded in gunny bag followed by earthen pot. The population of grain moth gradually declined from June to November. The lowest population was observed in November (Appendix I). Similarly, in case of red flour beetle, significantly higher population was recorded from the gunny bag followed by earthen pot. The lowest population was found in the plastic container and tin kouta. Initially, the population was low during June, then gradually increased and reached to the maximum level in August and then the population again declined to the minimum level in November (Appendix-II).

Similarly, the maximum population of rice weevil was found in gunny bag followed by earthen pot. The population of the weevil was significantly lowest in plastic container and tin kouta (Figure 3). The number of rice weevil was initially low in different containers then gradually increased and reached to the highest level in October and then declined in all the containers (Appendix III).

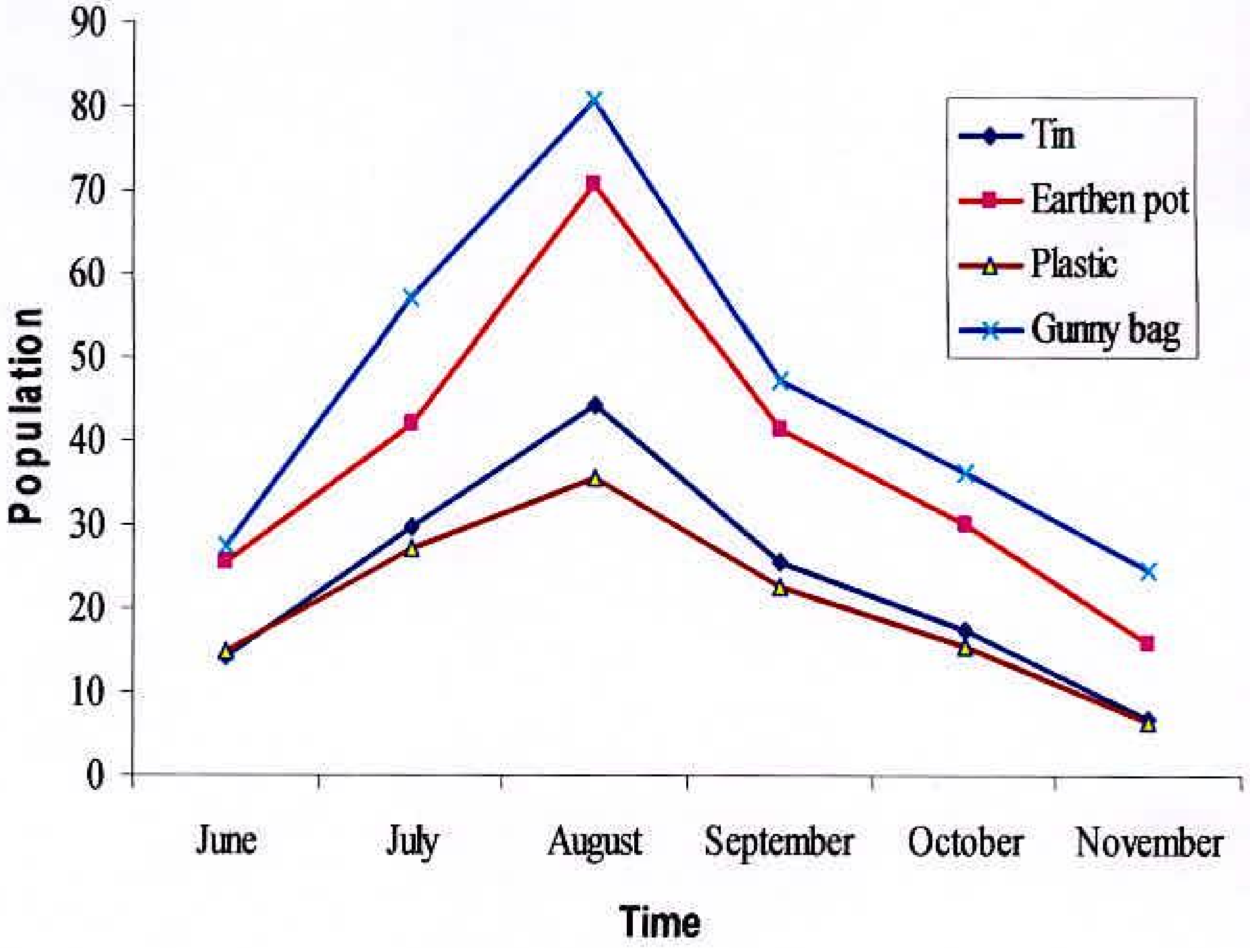

Figure 2. Population dynamics of red flour beetle in different containers during the period from June to November 2006.

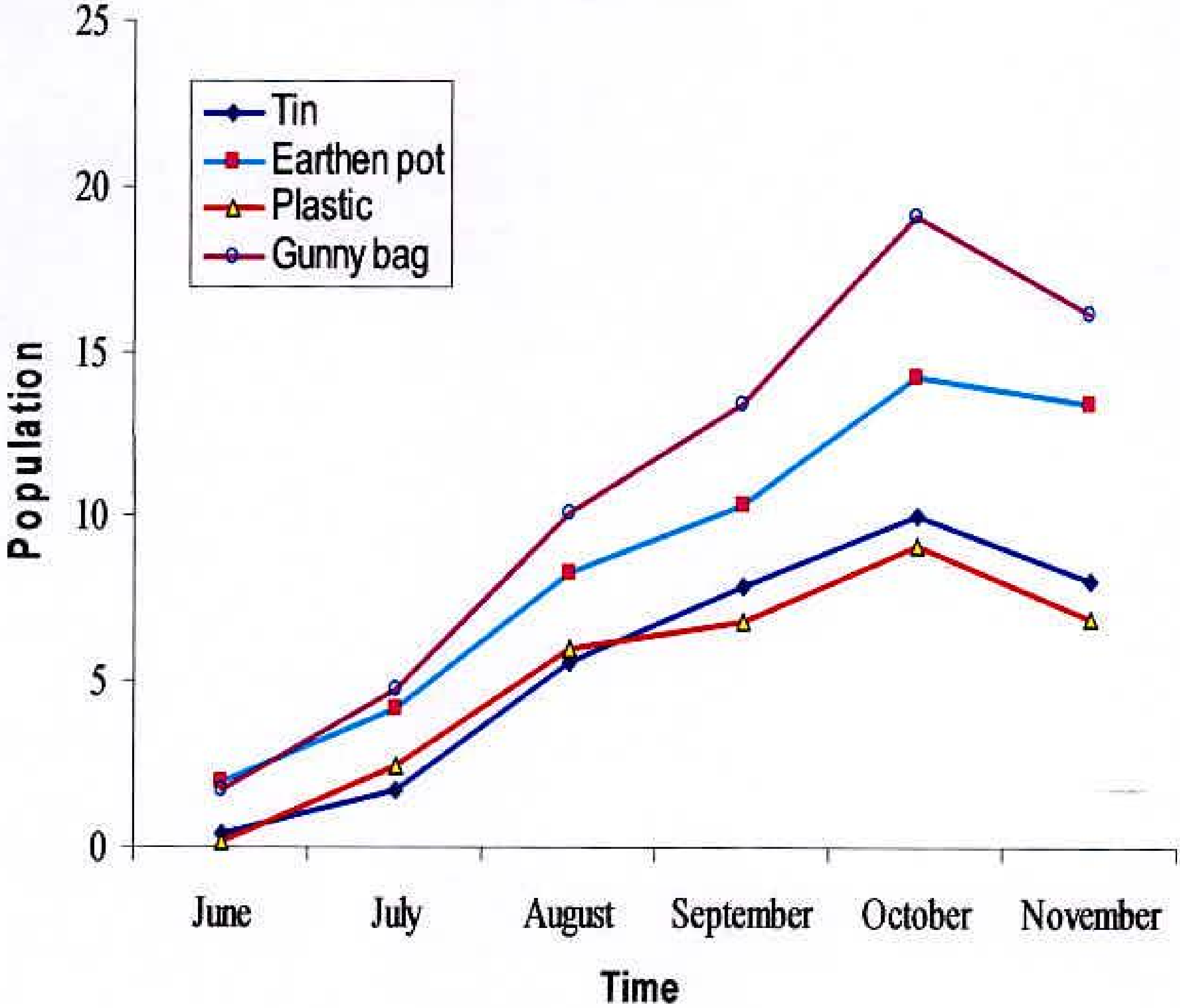

Figure 3. Population dynamics of rice weevil in different containers during the period from June to November 2006.

Figure 4 revealed the comparative abundance of grain moth, red flour beetle and rice weevil during the study. The different containers, the population of grain moth, red flour beetle and rice weevil were highest in gunny bag. Initially the population of grain moth was high but at the middle stage red flour beetle was higher than grain moth and rice weevil. The grain moth population was always significantly higher than rice weevil population during the study period. Although the weevil population increased gradually but its highest population was lower than the grain moth in October. Therefore, grain moth was the most abundant insect pests initially and grain moth was abundant throughout the study period.

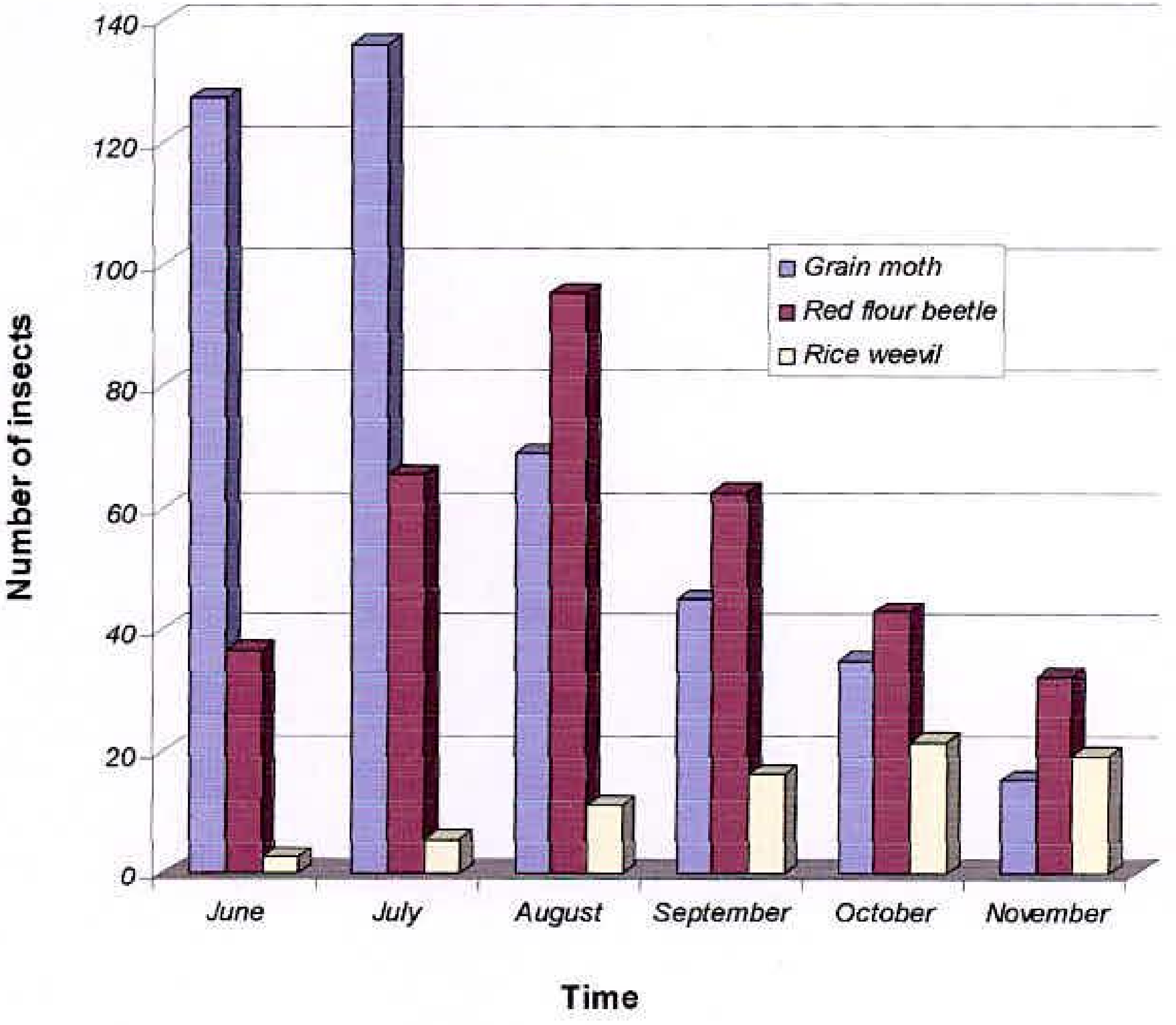

Figure 4. Comparative abundance of grain moth, red flour beetle and rice weevil in gunny bag during the period from June to November 2006.

Among the containers plastic container provided the highest protection of wheat from insect attack followed by tin kouta. Considering all the containers, the trend in the protection of wheat grain from insect population showed the following decreasing order plastic container>tin kouta>earthen pot>gunny bag. The results thus obtained in the present study supported the finding obtained by several researchers (Hamel *et al.*, 1999; Samuels and Modgil 1999; Karim 1987), who reported that wheat was attacked by rice weevil (*Sitophilus oryzae*), grain moth (*Sitotroga cerealella*) and red flour beetle (*Tribolium castaneum*). On the other hand, Gentile and Trematerra (2004) observed twenty insect pests of stored wheat and *Sitotroga cerealella* occurred during pre harvest and post harvest storage. While, Chaudhary and Mahla (2001) reported 10 insect pest of wheat in storage and these 3 species were also found major in storage. Although the number of wheat attacking species varied but it was logical because the abundance of major insects may be varied with climatic zones (Chaudhary and Mahla 2001).

The population trends of the three insect pests indicate that the population of grain moth was higher in June and gradually declined. In contrast, rice weevil population was low initial stage of the expt. and gradually increased and reached to the highest level in October. The similar trend of population of grain moth and rice weevil was reported by Alam (1971) and Prakash (1982). On the other hand, lowest population of grain moth at initial stage of the expt. indicates its lower infestation. Metcalf and Flint (1962) and Alam (1971) stated the lower level of infestation of the beetle at early stage and they also revealed that neither grub nor adult could generally damage whole or intact grains but they can feed on grains only, which had already been damaged by other pests. Moreover, Walter (1990) reported that Red flour beetles may be present in large numbers in infested grain, but are unable to attack sound or undamaged grain. Therefore, the results thus shown in above figure (Fig.4) validate the findings of the other researchers.

The highest number of insect pests in gunny bags indicates its lower efficacy for protecting the grain against insect infestation. Baloch *et al.* (1994) observed similar result and concluded that jute bag increased the risk of insect infestation. However, Kabir *et al.* (2003) reported that gunny bag with polythene reduced the insect infestation. Similar high level of infestation in gunny bags were also observed by Sing (2001) in stored wheat. The high porosity of gunny bag provides better aeration for the different insect pests, which increases the moisture content of the grain and facilitates higher infestation. However, among the four different containers tin kouta and plastic containers showed the best performance in protecting the grain. These findings supported the results obtained by Kabir *et al.* (2003). Tin kouta and plastic containers prevented aeration as well as increase of moisture percentage of the grain. Prakash (1982) reported that high moisture content facilitates insect infestation in storage.

4.2. Effect of different indigenous materials and chemicals on incidence of insect pests of wheat in storage

The effect of different indigenous materials and chemicals on abundance of the grain moth, flour beetle and rice weevil are shown in Figure 5, 6 and 7, respectively. The highest population of grain moth was observed in untreated control followed by sand and neem leaf powder (Figure 5).

Significantly the lowest population was observed in naphthalene followed by camphor (Appendix IV). Similarly, red flour beetle abundance was the highest in control followed by sand and neem leaf powder during the study period. The lowest population of red flour beetle was found in naphthalene followed by the camphor (Figure 6). No significant difference was observed between the population of red flour beetle in naphthalene and camphor but significant difference was observed with other materials (Appendix V).

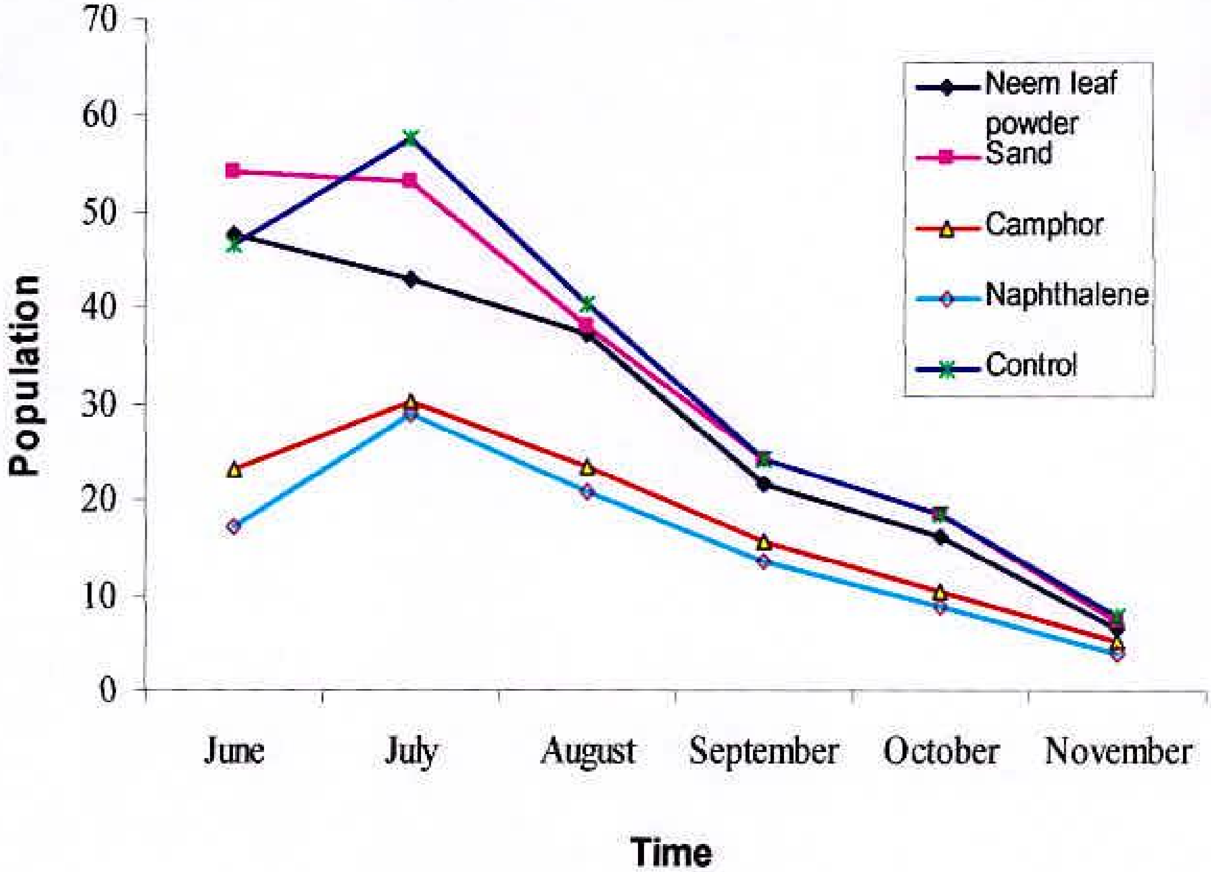

Figure 5. Effect of different indigenous materials and chemicals on grain moth abundance during June to November 2006.

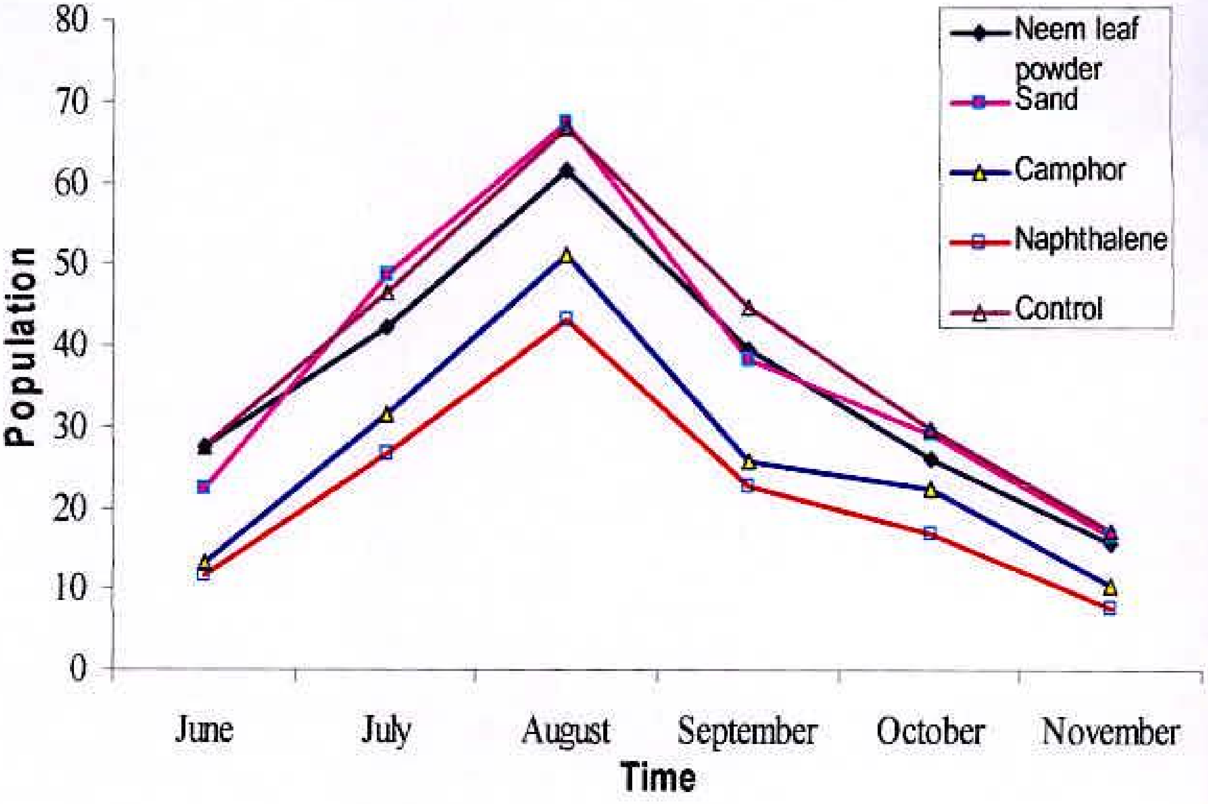

Figure 6. Effect of different indigenous materials and chemicals on red flour beetle abundance during June to November 2006.

The same way, maximum population of rice weevil was recorded from control followed by sand and neem leaf powder and no significant difference was observed among them. The population of the rice weevil was the lowest in naphthalene followed by camphor (Figure 7) and no significant difference was observed between them (Appendix VI).

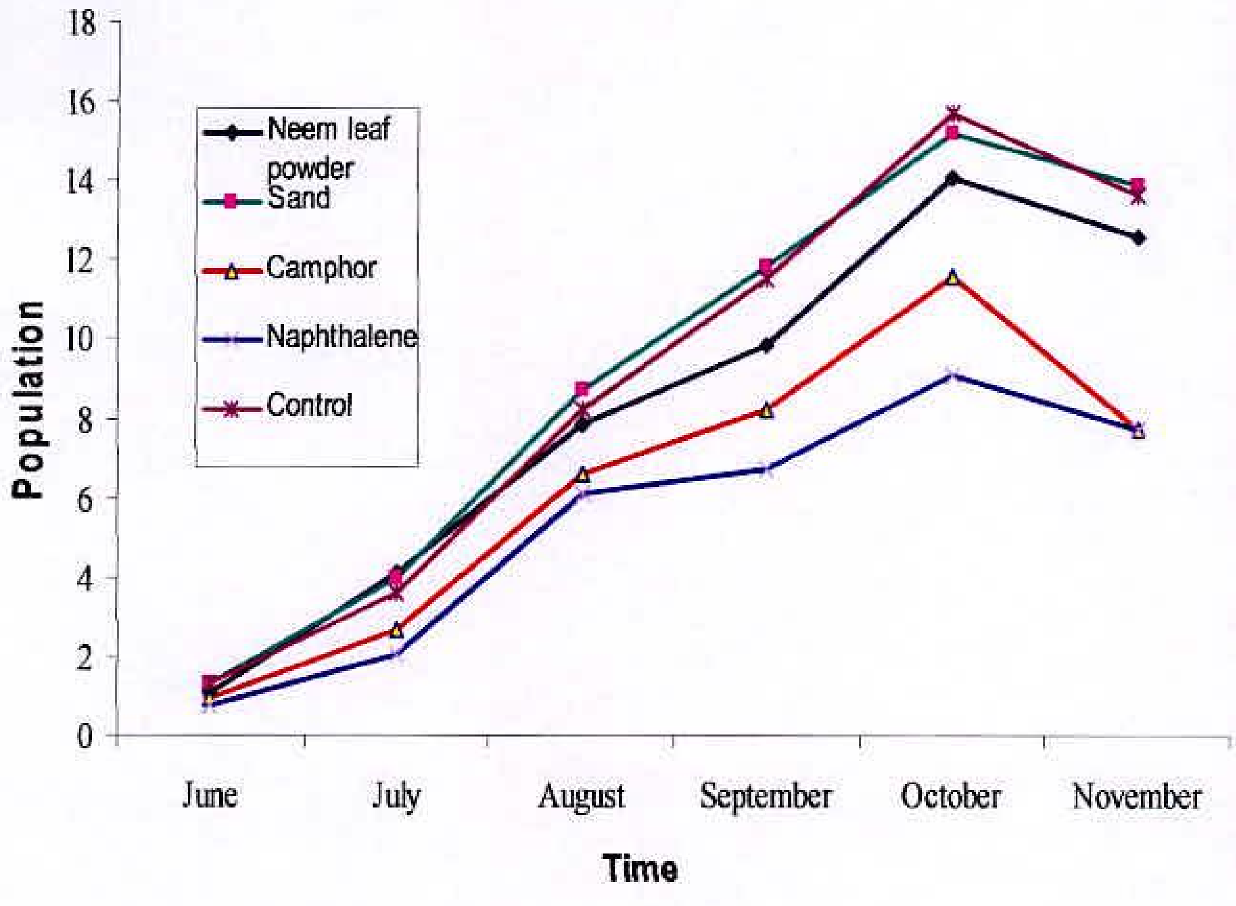

Figure 7. Effect of different indigenous materials and chemicals on rice weevil abundance during June to November 2006.

However, significant difference was found between the population of rice weevil in naphthalene and control. Therefore, the results of the present study indicate that naphthalene and camphor provided the highest efficacy in protecting wheat from the insect pests in storage. In contrast, neem leaf powder and sand were not effective in protecting wheat from the insect attack in storage. Considering all the materials, the trend in the protection of wheat grain from insect population showed the following decreasing order naphthalene> camphor> neem leaf powder> sand.

The effectiveness of naphthalene and camphor thus obtained in the present findings supported the results obtained several researchers (Latif *et al*., 2004, Siddika, 2004; Kabir *et al*. 2003). Latif *et al*. (2004) stated that camphor provided more than 90% efficacy against the rice weevil. While Siddika (2004) reported that the camphor significantly reduced the infestation of wheat pest in storage. On the other hand, Kabir *et al*. (2003) revealed that naphthalene and camphor showed the best performance in protecting mung bean against insect pests in storage. Although the neem leaf powder and sand showed some efficacy in protecting the wheat against insect pests but their effect was not satisfactory. These results were different from the finding observed by some researchers (Facknath and Sunita 2006; Choudhary, 1989; Chatterjee 1984). Facknath and Sunita (2006) reported that neem (*Azadirachta indica* A. Juss.) has been demonstrated to reduce insect populations in stored products through its toxic and growth-disrupting and other effects on the pests. The efficacy of *Azadirachta indica* leaf extracts (70, 90, and 100%) to control weevil population on hosts increased with the increase in extract concentration. The highest control rate of 80-90% was obtained with 100% leaf extract. Choudhary (1989) observed that a layer of 2 and 3 cm sand over the grain were the most effective with regard to poor oviposition emergence, development and less damage to seed of bengalgram (*Cicer arietinum*). However, the efficacy thus obtained in this study was in conformity with findings obtained by Kabir *et al.* (2003), who revealed that neem leaf powder and sand showed some efficacy in protecting mung bean against *Callosobruchus chinensis* L. in storage. Although, the result obtained in this study may be different from that of the other workers but it is logical because they used neem leaf extract against different pests and the efficacy of leaf extract and neem leaf powder may be varied against different pests.

4.3. Effect of different containers, indigenous materials and chemicals on incidence of insect pests of wheat in storage

The effect of different storage containers, indigenous materials and chemicals on incidence of grain moth is shown in Table 1. The highest number of grain moth (15.33-136.0) was recorded from gunny bag sole, which was significantly different from all other treatment combinations during the study period. The lowest number of grain moth was recorded from plastic + naphthalene (0.00-4.67), followed by plastic + camphor (0.67-5.67), tin + naphthalene (1.33-5.33) and tin + camphor (1.33-6.0) during the study period. Plastic container and tin kouta in combination with neem leaf powder and sand also showed significant effectiveness in protecting the wheat grain from grain moth infestation. Earthen pot in combination with naphthalene and camphor had significantly low level of grain moth incidence. Therefore, among the treatment combinations plastic container in combination with naphthalene and camphor showed the best performance in protecting wheat grains during the study period.

Table 1. Effect of different containers, indigenous materials and chemicals on incidence of grain moths in storage during June to November 2006

Treatment combinations	Number of grain moth					
	June	July	August	Sept.	Oct.	Nov.
Tin sole	3.00 i	17.00 h	20.33 f	12.67 e	9.00 gh	3.67 g
Tin+NLF	2.00 i	11.67 hij	15.00 g	8.33 efg	6.67 hijk	2.67 ghi
Tin+sand	2.00 i	15.33 hi	20.00 f	10.67 ef	7.67 hi	3.33 gh
Tin+camphor	1.33 i	6.00 jkl	10.00 h	6.67 fg	3.67 ijk	1.67 ghi
Tin+naphthalene	1.33 i	5.33 kl	8.00 h	5.33 fg	3.00 jk	1.00 ghi
Earthen pot sole	52.67 e	66.67 d	64.33 ab	30.67 c	24.00 c	10.00 de
Earthen pot+ NLF	62.33 d	58.33 e	63.67 bc	28.00 c	21.67 cd	8.67 ef
Earthen pot+ sand	93.33 c	59.67 e	59.00 c	28.67 c	24.67 c	6.67 f
Earthen pot+ camphor	36.67 g	40.00 f	37.67 e	20.00 d	14.33 ef	7.00 f
Earthen pot+ naphthalene	20.33 h	34.67 g	34.67 e	18.33 d	12.00 fg	7.00 f
Plastic sole	3.67 i	10.33 ijkl	8.00 h	9.00 efg	6.33 hijk	2.67 ghi
Plastic+ NLF	4.000 i	8.00 jkl	5.67 hi	8.67 efg	6.00 hijk	1.33 ghi
Plastic+ sand	2.67 i	11.00 ijk	8.33 h	10.00 ef	7.00 hij	2.33 ghi
Plastic+ camphor	0.67 i	5.67 kl	2.66 i	5.33 fg	2.67 jk	0.67 hi
Plastic+ naphthalene	0.000 i	4.67 l	2.33 i	3.67 g	2.33 k	0.00 i
Gunny bag sole	127.3 a	136.0 a	69.00 a	45.00 ab	35.00 a	15.33 ab
Gunny bag+ NLF	122.0 b	93.33 c	64.67 ab	41.00 b	30.33 b	13.00 bc
Gunny bag+ sand	118.7 b	126.3 b	64.67 ab	48.00 a	35.00 a	16.67 a
Gunny bag+ camphor	53.67 e	68.67 d	43.33 d	30.00 c	21.33 cd	11.33 cd
Gunny bag+ naphthalene	47.00 f	71.00 d	38.00 e	27.00 c	17.67 de	7.67 ef
LSD value	**4.65**	**5.29**	**4.87**	**5.05**	**3.94**	**2.49**
CV%	**5.56**	**5.62**	**6.88**	**11.49**	**12.26**	**18.31**

Data are mean of three replications. Means in the column followed by the same letter are not significantly different at 1% level by DMRT.

A further analysis of the effect of different storage containers, indigenous materials and chemicals on incidence of insect pests revealed that the highest number of red flour beetle (32.33-95.33) was observed in gunny bag sole, which was similar to that of the gunny bag + sand (22.67-93.33) but significantly different from all treatment combinations during the study period (Table 2). The lowest number of red flour (7.0-18.33) beetle was found in plastic container + naphthalene, followed by plastic container + camphor (8.0-20), tin kouta + naphthalene (6.33-31.33), and tin + camphor (7.0-39.0) during the study period. Plastic container and tin kouta in combination with neem leaf powder and sand also showed significant effectiveness in protecting the wheat grain from red flour beetle infestation during storage. Earthen pot in combination with naphthalene and camphor had significantly low level of red flour beetle incidence but their effect on wheat grain protection against red flour beetle was not satisfactory. Therefore, among the treatment combinations plastic container and tin kouta in combination with naphthalene showed the best performance in protecting wheat grains from red flour beetle infestation in storage.

Similarly, the highest number of rice weevil was recorded in gunny bag sole (2.67-21.67) and gunny bag in combination with indigenous materials and chemicals during the period from June to November 2006. The same level of rice weevil population was also recorded from earthen pot sole and earthen pot in combination neem leaf powder and sand (Table 3). The lowest number of rice weevil was observed in plastic container in combination with naphthalene (0.00-5.33) and camphor (0.00-6.33), and tin in combination with naphthalene (0.0-6.33) and camphor (0.0-6.67) respectively.

Table 2. Combined effect of different containers, indigenous materials and chemicals on incidence of red flour beetle in storage during June to November 2006

Treatment combinations	Number of red flour beetle					
	June	July	August	Sept.	Oct.	Nov.
Tin sole	22.33 c	36.00 ef	54.33 e	31.33 gh	21.33 efg	8.67 f
Tin+NLF	18.67 cd	33.33 fg	43.33 f	27.67 hij	18.00 ghi	9.00 f
Tin+sand	16.00 de	35.33 ef	53.33 e	32.33 fg	19.67 efgh	9.00 f
Tin+camphor	7.00 f	24.33 hi	39.00 fg	19.00 k	15.00 ij	5.00 g
Tin+naphthalene	6.33 f	19.67 i	31.33 hi	16.33 kl	12.67 j	3.00 g
Earthen pot sole	31.67 b	51.00 cd	77.33 c	55.67 b	36.00 bc	20.00 c
Earthen pot+ NLF	34.00 ab	41.33 e	79.33 c	47.67 cd	3033 d	17.33 d
Earthen pot+ sand	31.00 b	56.67 bc	77.33 c	49.33 c	34.67 c	19.00 cd
Earthen pot+ camphor	16.00 de	32.67 fg	66.33 d	29.67 ghi	27.67 d	13.33 e
Earthen pot+ naphthalene	14.33 e	27.67 gh	53.33 e	24.33 j	22.00 ef	9.67 f
Plastic sole	19.33 cd	32.67 fg	39.33 fg	29.00 ghi	18.33 gh	8.00 f
Plastic+ NLF	19.67 cd	31.33 fg	35.67 gh	27.00 ij	17.67 hi	8.00 f
Plastic+ sand	19.67 cd	33.00 fg	44.33 f	26.33 ij	19.67 fgh	9.00 f
Plastic+ camphor	8.00 f	20.67 i	28.67 i	15.67 kl	12.33 jk	4.00 g
Plastic+ naphthalene	7.00 f	18.33 i	28.67 i	14.33 l	9.33 k	3.00 g
Gunny bag sole	36.67 a	65.67 a	95.33 a	62.67 a	43.00 a	32.33 a
Gunny bag+ NLF	37.33 a	62.67 ab	86.67 b	54.67 b	38.33 b	27.67 b
Gunny bag+ sand	22.67 c	68.67 a	93.33 a	44.67 d	42.33 a	29.33 b
Gunny bag+ camphor	22.00 c	48.33 d	69.67 d	38.67 e	34.67 c	19.00 cd
Gunny bag+ naphthalene	18.67 cd	40.67 e	59.00 e	35.33 ef	23.00 e	14.67 e
LSD value	**3.81**	**6.69**	**6.40**	**3.48**	**3.07**	**2.33**
CV%	**8.42**	**7.74**	**5**	**4.6**	**5.6**	**7.83**

Data are mean of three replications. Means in the column followed by the same letter are not significantly different at 1% level by DMRT.

Plastic container and tin kouta in combination with neem leaf powder and sand also showed significant effectiveness in protecting the wheat grain from rice weevil infestation. Therefore, among the treatment combinations plastic container and tin kouta in combination with naphthalene and camphor showed the best performance in protecting wheat grains during the study period.

The present findings, the plastic container and tin kouta in combination with naphthalene and camphor provided the best performance in reduction of grain moth and weevil population are supported by the previous investigations in Bangladesh (Latif *et al*. 2004; Siddika, 2004; Kabir *et al*., 2003, Latif and Rahman 2000). Kabir *et al*. (2003) observed that tin kouta in combination with camphor significantly reduced the pulse beetle population and similar results were also found for naphthalene. Latif *et al*. (2004) reported that 2.0 g camphor per kg rice grain provided more than 80% protection of loss in rice against *Sitophilus oryzae*. The intermediate efficacy of *Azadirachta indica* leaf extracts against rice weevil population but it varied with concentration of the extract. Thus, the present findings validate the results of those researchers.

Table 3. Combined effect of different containers, indigenous materials and chemicals on incidence of rice weevil in storage during June to November 2006

Treatment combinations	Number of rice weevil					
	June	July	August	Sept.	Oct.	Nov.
Tin sole	1.00 ab	2.00 cde	6.67 fghi	9.33 defg	12.00 hij	10.33 cd
Tin+NLF	0.00 b	1.67 de	7.00 fghi	8.33 fgh	11.67 hij	8.67 def
Tin+sand	1.00 ab	2.33 cde	6.33 ghij	10.33 de	12.67 hi	10.33 cd
Tin+camphor	0.00 b	1.67 de	4.67 jk	7.00 hi	7.67 lm	5.67 gh
Tin+ naphthalene	0.00 b	1.00 e	3.33 k	4.67 j	6.33 lm	5.33 h
Earthen pot sole	1.67 ab	4.00 abc	9.33 cd	12.67 b	18.00 cd	16.67 b
Earthen pot+ NLF	1.67 ab	5.67 a	8.00 defg	10.00 def	15.00 fg	15.67 b
Earthen pot+ sand	2.33 a	5.67 a	9.33 cd	12.33 bc	16.00 def	16.33 b
Earthen pot+ camphor	2.33 a	3.33 bcd	7.33 efgh	8.67 efgh	13.67 gh	8.67 def
Earthen pot+ naphthalene	2.00 ab	2.33 cde	7.33 efgh	8.33 fgh	8.33 kl	9.67 cde
Plastic sole	0.00 b	2.67 cde	5.67 hij	7.67 ghi	11.00 ij	8.33 ef
Plastic+ NLF	1.00 ab	3.67 abcd	6.33 ghij	7.33 hi	10.33 jk	7.33 fg
Plastic+ sand	0.00 b	2.67 cde	7.33 efgh	8.33 fgh	11.00 ij	8.67 def
Plastic+ camphor	0.00 b	1.67 de	5.33 ij	6.33 i	7.33 lm	5.33 h
Plastic+ naphthalene	0.00 b	1.67 de	5.33 ij	4.33 j	6.00 m	5.00 h
Gunny bag sole	2.67 a	5.67 a	11.33 ab	16.33 a	21.67 a	19.33 a
Gunny bag+ NLF	1.67 ab	5.33 ab	10.00 bc	13.67 b	19.33 bc	18.67 a
Gunny bag+ sand	2.00 ab	5.33 ab	12.00 a	16.33 a	21.00 ab	20.33 a
Gunny bag+ camphor	1.33 ab	4.00 abc	9.00 cde	11.00 cd	17.67 cde	11.33 c
Gunny ba+ naphthalene	1.00 ab	3.33 bcd	8.33 cdef	9.67 def	15.67 efg	11.00 c
LSD value	**1.92**	**1.94**	**1.68**	**1.56**	**2.02**	**1.74**
CV%	**79.85**	**26.62**	**10.12**	**7.32**	**6.97**	**7.07**

Data are mean of three replications. Means in the column followed by the same letter are not significantly different at 1% level by DMRT.

Monthly observations on the percent grain infestation fluctuation with temperature and relative humidity are presented in Figure 8.

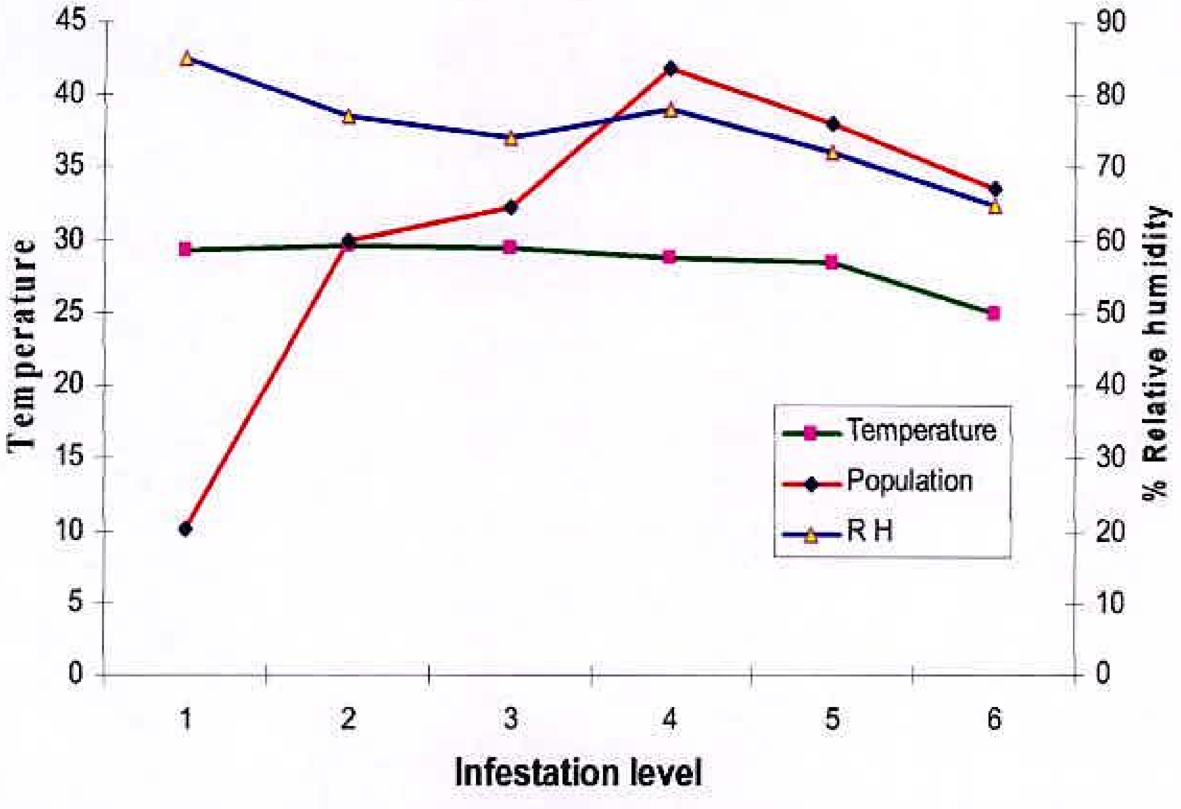

Figure 8. Monthly variation of percent wheat grain infestation in gunny bag with temperature and relative humidity.

The figure (8) showed that the infestation of grain was low in initial stage of storage and gradually increased to a peak in September 2006 and then it started to decline (Appendix VII). High temperature and relative humidity during July to September favour the insect infestation. When temperature increased the percent infestation was increased. The percent infestation also increased with humidity in stable temperature. Therefore, positive correlation prevailed between percent grain infestation with temperature and relative humidity. In storage ecosystem, temperature and relative humidity fluctuated within a definite range, which allowed insects to survive and multiply. However, the temperature range of 25°C to 32°C and relative humidity range of 70-85% were considered optimum ranges within which the insects could multiply well (Prakash, 1982). Atmospheric humidity is directly related to the moisture of the grains and has been found positively correlated with insect infestation (Khare, 1972; Chatterjee *et al.*, 1953; Prakash, 1982). Low relative humidity at 48% reduced the productivity of *Sitophilus oryzae* and *R. dominica* (Satasook and Williams, 1990). If the population decreased, the infestation decreased. Population and infestation have a correlation for damage.

4.4. Effect of different containers, indigenous materials and chemicals on wheat grain infestation in storage

The comparative effect of different containers in combinations with indigenous materials and chemicals on percent grain infestation both by number and weight is presented in Table 4 and 5 respectively. The Table 4 revealed that the highest number of grain infestation was in gunny bag sole (11.23-46.36%) during the study period followed by gunny bag in combination with sand (10.58-45.78%) and neem leaf powder (9.25-44.58%), which were significantly higher than all treatment combinations. The lowest grain infestation was observed in tin kouta in combination with naphthalene (7.25-26.30%) and camphor (7.64-27.4%) and plastic container in combination with naphthalene (7.45-26.56%) and camphor (7.45-27.67%). No significant difference was found in the percent grain infestation among these treatment combinations. Moreover, plastic container and tin kouta alone and in

Table 4. Effect of different containers, indigenous materials and chemicals on percent grain infestation by number during June to November 2006

Treatment combinations	Percent grain infestation by number					
	June	July	August	Sept.	Oct.	Nov.
Tin sole	8.81 de (2.97)	20.86 efg (4.566)	28.22 bcd (5.31)	37.53 def (6.13)	30.94 def (5.56)	25.84 de (5.08)
Tin+NLF	8.48 e (2.92)	17.37 ghi (4.17)	22.80 ef (4.77)	36.47 ef (6.04)	28.92 fg (5.38)	23.60 ef (4.86)
Tin+sand	8.44 e (2.91)	19.22 fgh (4.38)	25.10 de (5.01)	35.50 f (5.96)	30.83 def (5.55)	23.74 ef (4.87)
Tin+camphor	7.64 f (2.76)	14.00 ijk (3.74)	19.23 gh (4.38)	27.14 g (5.21)	24.24 hi (4.92)	16.85 g (4.11)
Tin+naphthalene	7.25 f (2.69)	13.60 jk (3.69)	18.00 h (4.24)	26.30 g (5.13)	23.74 i (4.87)	16.85 g (4.10)
Earthen pot sole	10.56 ab (3.25)	27.32 bcd (5.22)	31.15 b (5.58)	43.36 ab (6.59)	37.42 b (6.12)	33.49 abc (5.79)
Earthen pot+ NLF	10.56 ab (3.25)	28.62 bc (5.35)	30.33 bc (5.51)	40.15 cd (6.34)	33.52 cd (5.79)	27.87 d (5.28)
Earthen pot+ sand	10.42 b (3.23)	29.33 b (5.415)	30.91 b (5.56	42.44 bc (6.51)	36.04 bc (6.00)	33.09 bc (5.751)
Earthen pot+ camphor	9.43 cd (3.07)	21.88 ef (4.68)	24.91 de (4.99)	34.87 f (5.90)	32.11 de (5.67)	23.60 ef (4.857)
Earthen pot+ naphthalene	8.79 de (2.97)	17.47 ghi (4.18)	20.84 fgh (4.563)	34.38 f (5.86)	28.87 fg (5.37)	23.21 ef (4.82)
Plastic sole	9.55 c (3.09)	16.26 hij (4.03)	23.08 ef (4.80)	35.05 f (5.92)	30.08 ef (5.48)	22.23 f (4.71)
Plastic+ NLF	8.38 e (2.9)	11.33 k (3.36)	20.27 fgh (4.50)	35.74 f (5.98)	26.63 gh (5.16)	21.00 f (4.58)
Plastic+ sand	8.55e (2.92)	15.50 hij (3.93)	22.38 efg (4.73)	39.45 cde (6.28)	31.66 def (5.63)	22.94 ef (4.79)
Plastic+ camphor	7.45 f (2.73)	12.70 jk (3.56)	20.57 fgh (4.53)	27.64 g (5.26)	23.42 i (4.84)	17.11 g (4.14)
Plastic+ naphthalene	7.45 f (2.73)	11.94 k (3.46)	14.84 i (3.85)	26.56 g (5.15)	20.72 j (4.549)	15.72 g (3.96)
Gunny bag sole	11.23 a (3.35)	34.93 a (5.91)	37.52 a (6.125)	46.36 a (6.81)	43.25 a (6.58)	36.75 a (6.07)
Gunny bag+ NLF	9.25 cd (3.04)	35.51 a (5.96)	31.39 b (5.60)	44.58 ab (6.68)	37.10 b (6.090)	36.33 ab (6.03)
Gunny bag+ sand	10.58 ab (3.25)	31.49 ab (5.61)	38.26 a (6.19)	45.78 a (6.77)	43.06 a (6.56)	35.84 ab (5.99)
Gunny bag+ camphor	9.46 c (3.08)	23.48 def (4.84)	26.75 cd (5.17)	37.14 def (6.09)	33.67 cd (5.80)	31.44 c (5.61)
Gunny bag+ naphthalene	9.55 c (3.09)	24.10 cde (4.91)	27.36 bcd (5.23)	35.73 f (5.98)	32.84 de (5.73)	27.58 d (5.25)
LSD value	**0.10**	**0.43**	**0.34**	**0.234**	**0.244**	**0.274**
CV%	**2.69**	**8.44**	**5.91**	**3.38**	**3.91**	**4.77**

Data are mean of three replications. Value within parentheses are transformed value based square root transformation. Means in the column followed by the same letter are not significantly different at 1% level by DMRT.

combination with sand and neem leaf powder had significantly lower level of grain infestation than gunny bag and its combination with other materials. Earthen pot in combination with different materials provided significant percent wheat grain protection from insect infestation but it was not satisfactory. As the storage time progressed, the percent grain infestation increased for all the treatment combinations. Therefore, the plastic container and tin kouta in combination with naphthalene and camphor had significant effect in wheat protection against insect attack.

Similarly, the comparative effectiveness of different containers in their combinations with indigenous materials and chemicals on percent grain infestation by weight is shown in Table 5. It is clear from Table 5 that the maximum percent grain infestation by weight was observed in gunny bag sole (28.94-41.46%) during the study period followed by gunny bag in combination with sand (23.52-40.68%) and neem leaf powder (21.34-41.34%), which was significantly higher than all treatment combinations. The minimum grain infestation was observed in plastic container and tin kouta in combination with naphthalene (9.08-25.48%) and camphor (11.51-26.48%) and tin kouta in combination with naphthalene (12.10-27.71%) and camphor (12.10-29.36%). No significant difference was found in the percent grain infestation among these treatment combinations. Moreover, plastic container and tin kouta alone and in combination with sand and neem leaf powder had significantly lower level of grain infestation than gunny bag and its combination with other materials. Earthen pot in combination with different materials provided significant percent wheat grain protection from insect infestation but it was not satisfactory.

Table 5. Effect of different containers, indigenous materials and chemicals on percent grain infestation by weight during June to November 2006

Treatment combinations	Percent infestation by weight					
	June	July	August	Sept.	Oct.	Nov.
Tin sole	19.32 c (4.39)	21.87 cd (4.67)	27.54 cd (5.25)	38.02 bcd (6.17)	29.53 efg (5.43)	23.20 ef (4.82
Tin+NLF	14.47 de (3.80)	19.65 cde (4.43)	21.65 g (4.65)	34.00 de (5.83)	27.61 fgh (5.25)	20.82 g (4.56)
Tin+sand	14.72 de (3.83)	20.52 cd (4.53)	24.86 def (4.98)	36.62 cde (6.05)	29.74 efg (5.45)	23.11 ef (4.81)
Tin+camphor	12.10 f (3.48)	16.70 ef (4.09)	20.27 gh (4.50)	29.36 f (5.42)	24.36 ij (4.93)	17.40 h (4.17)
Tin+naphthalene	12.12 f (3.48)	14.10 f (3.75)	19.10 h (4.37)	27.71 fg (5.26)	21.24 k (4.61)	15.87 hi (3.98)
Earthen pot sole	24.7 ab (4.97)	36.51 a (6.04)	42.51 a (6.52)	42.83 a (6.54)	37.15 b (6.10)	32.55 bc (5.71)
Earthen pot+ NLF	23.53 b (4.85)	31.03 b (5.57)	41.43 ab (6.44)	42.27 a (6.50)	34.03 cd (5.83)	31.43 c (5.61)
Earthen pot+ sand	19.96 c (4.47)	33.36 ab (5.77)	39.03 b (6.25)	43.20 a (6.57)	35.62 bc (5.97)	32.24 bc (5.68)
Earthen pot+ camphor	14.44 de (3.80)	21.73 cd (4.66)	24.06 f (4.90)	37.42 cde (6.12)	32.07 de (5.66)	25.58 d (5.06)
Earthen pot+ naphthalene	14.14 e (3.76)	22.22 c (4.71)	24.62 ef (4.96)	33.52 e (5.79)	31.16 de (5.58)	25.29 d (5.03)
Plastic sole	15.96 de (3.99)	22.20 c (4.71)	26.86 cde (5.18)	37.28 cde (6.11)	27.14 gh (5.21)	22.96 ef (4.79)
Plastic+ NLF	15.94 de (3.99)	18.57 de (4.30)	25.15 def (5.02)	36.00 de (5.10)	25.78 hi (5.08)	21.45 fg (4.63)
Plastic+ sand	16.38 d (4.04)	20.78 cd (4.56)	25.12 def (5.01)	35.39 de (5.95)	27.43 gh (5.24)	21.43 fg (4.63)
Plastic+ camphor	11.51 f (3.39)	18.77 cde (4.33)	19.69 gh (4.44)	26.68 fg (5.16)	22.66 jk (4.76)	16.10 hi (4.01)
Plastic+ naphthalene	9.08 g (3.01)	16.85 ef (4.10)	18.62 h (4.31)	25.48 g (5.05)	20.80 k (4.56)	14.65 i (3.83)
Gunny bag sole	28.94 a (5.38)	33.51 ab (5.79)	44.18 a (6.65)	41.61 ab (6.45)	41.35 a (6.43)	35.33 a (5.94)
Gunny bag+ NLF	21.14 c (4.597)	29.34 b (5.41)	41.34 ab (6.43)	40.18 abc (6.34)	38.30 ab (6.19)	34.17 ab (5.85)
Gunny bag+ sand	23.52 b (4.489)	32.01 b (5.66)	43.68 a (6.619)	40.25 abc (6.3444)	37.50 b (6.12)	34.83 a (5.90)
Gunny bag+ camphor	15.92 de (3.99)	21.98 cd (4.69)	27.50 cd (5.24)	36.19 cde (6.02)	30.33 ef (5.51)	25.15 d (5.02)
Gunny bag+ naphthalene	15.81 de (3.98)	22.25 c (4.72)	27.92 c (5.28)	35.47 de (5.96)	28.25 fgh (5.32)	24.84 de (4.98)
LSD value	**0.2425**	**0.3501**	**0.2425**	**0.2970**	**0.2425**	**0.1852**
CV%	**5.15%**	**6.48**	**4.10**	**4.52**	**3.88**	**3.26**

Data are mean of three replications. Value within parentheses are transformed value based square root transformation. Means in the column followed by the same letter are not significantly different at 1% level by DMRT.

As the storage time progressed, the percent grain infestation increased for all the treatment combinations. Therefore, the plastic container and tin kouta in combination with naphthalene and camphor had significant effect in wheat protection against insect attack.

The findings in the present study indicated the best performance of plastic container and tin kouta in combination with naphthalene and camphor. However, neem leaf powder in combination with them also showed significant efficacy in protection of wheat from insect infestation. Latif *et al.* (2004) reported 2.0 g per kg camphor provided 95.39%-98.86% protection of rice grains against rice weevil, *Sitophilus oryzae* after six months in storage. Similarly, Siddika (2004) reported that camphor and dried neem leaves significantly reduced the emergence of adult rice moths in storage. Kabir *et al.* (2003) obtained similar results for pulse grain. They stated that tin kouta in combination with naphthalene or camphor provided best performance against pulse beetle. The efficacy of *Azadirachta indica* leaf extracts (70, 90, and 100%) to control weevil population on hosts increased with the increase in extract concentration. The highest control rate of 80-90% was obtained with 100% leaf extract. The results thus obtained in the present study were in accordance with the above findings.

4.5. Effect of different containers, indigenous materials and chemicals on germination of wheat seed

The percentages of germination of wheat seeds in different treatment combinations during June to November 2006 are shown in Table 6. The highest percentage (100%-86.67%) of germination of wheat seed was observed in the treatments tin kouta + neem leaf powder, plastic container + camphor and plastic container + neem leaf powder. The lowest percentage (66.67-73.33%) of wheat seed germination was observed in the gunny bag + neem leaf powder and gunny bag sole. Considering the containers, the highest percentage of germination was observed in tin kouta and plastic containers followed by earthen pot and gunny bags. The rate of germination steadily declined as the time of storage progressed. The similar trend of results was observed among all the treatment combinations. Although the germination percentage gradually declined in the all the treatment combinations the germination percentage was always above in the tin kouta + neem leaf powder, plastic container + camphor and plastic container + neem leaf powder. Therefore, plastic and tin container in combination with naphthalene provided maximum (86.73%) germination of wheat grain after six months of storage.

Table 6. Effect of different containers, indigenous materials and chemicals on percent germination of wheat seed during June to November 2006

Treatment combinations	Percent germination					
	June	July	August	Sept.	Oct.	Nov.
Tin sole	83.33 bc (9.13)	83.33 bc (9.13)	76.67 ab (8.75)	83.33 a (9.13)	83.33 a (2.45	86.67 a (9.31)
Tin+NLF	100.00 a (10.00)	100.00 a (10.00)	83.33 ab (9.13)	83.33 a (9.13)	86.67 a (2.45	86.67 a (9.31)
Tin+sand	83.33 bc (9.13)	83.33 bc (9.13)	80.00 ab (8.94)	80.00 a (8.94)	83.33 a (2.45	83.33 a (9.125)
Tin+camphor	93.33 ab (9.66)	93.33 ab (9.66)	76.67 ab (8.75)	83.33 a (9.13)	83.33 a (2.45	86.67 a (9.31)
Tin+naphthalene	83.33 bc (9.13)	83.33 bc (9.13)	80.00 ab (8.93)	83.33 a (9.13)	83.33 a (2.45	86.67 a (9.31)
Earthen pot sole	66.67 d (8.16)	66.67 d (8.16)	73.33 ab (8.56)	73.33 a (8.559)	73.33 a (2.45)	73.33 a (8.56)
Earthen pot+ NLF	66.67 d (8.16)	66.67 d (8.16)	76.67 ab (8.75)	73.33 a (8.56)	76.67 a (2.45	73.33 a (8.56)
Earthen pot+ sand	76.67 cd (8.75)	76.67 cd (8.752)	76.67 ab (8.75)	73.33 a (8.56)	73.33 a (2.45	73.33 a (8.56)
Earthen pot+ camphor	83.33 bc (9.13)	83.33 bc (9.13)	73.33 ab (8.56)	73.33 a (8.56)	73.33 a (2.45	76.67 a (8.75)
Earthen pot+ naphthalene	86.67 abc (9.306)	86.67 abc (9.31)	76.67 ab (8.752)	73.33 a (8.56)	73.33 a (2.45	73.33 a (8.56)
Plastic sole	86.67 abc (9.31)	86.67 abc (9.306)	83.33 ab (9.13)	80.00 a (8.944)	86.67 a (2.45	83.33 a (9.13)
Plastic+ NLF	100.00 a (10.00)	100.00 a (10.00)	86.67 a (9.31)	86.67 a (9.31)	86.67 a (2.45	86.67 a (9.31)
Plastic+ sand	93.33 ab (9.658)	93.33 ab (9.66)	76.67 ab (8.7512)	83.33 a (9.13)	80.00 a (2.45)	83.33 a (9.13)
Plastic+ camphor	100.00 a (10.00)	100.00 a (10.00)	76.67 ab (8.7512)	83.33 a (9.13)	83.33 a (2.45	83.33 a (9.13)
Plastic+ naphthalene	93.33 ab (9.658)	93.33 ab (9.66)	83.33 ab (9.13	86.67 a (9.31)	90.00 a (2.45	86.67 a (9.31)
Gunny bag sole	73.33 cd (8.56)	73.33 cd (8.56)	73.33 ab (8.559)	73.33 a (8.56)	73.33 a (2.45	73.33 a (8.56)
Gunny bag+ NLF	**66.67 d (8.16)**	**66.67 d (8.16)**	**73.33 ab (8.56)**	**73.33 a (8.56)**	**70.00 a (2.45**	**76.67 a (8.75)**
Gunny bag+ sand	76.67 cd (8.75)	76.67 cd (8.75)	70.00 b (8.37)	73.33 a (8.56)	73.33 a (2.449)	73.33 a (8.56)
Gunny bag+ camphor	76.67 cd (8.75)	76.67 cd (8.75)	73.33 ab (8.56)	76.67 a (8.75)	73.33 a (2.45	73.33 a (8.56)
Gunny bag+ naphthalene	76.67 cd (8.75)	76.67 cd (8.75)	73.33 659)	73.33 a (8.56)	70.00 a (2.45)	73.33 a (8.56)
LSD value	**0.67**	**0.67**	**0.73**	**0.68**	**0.67**	**0.71**
CV%	**6.49**	**6.49**	**7.49**	**6.95**	**7.31**	**7.20**

Data are mean of three replications. Value within parentheses are transformed value based square root transformation. Means in the column followed by the same letter are not significantly different at 1% level by DMRT.

The results, thus obtained in the study indicated that plastic container and tin kouta in combination with naphthalene and camphor had no inhibitory effect on germination of wheat grain. These results supported the findings of Kabir *et al*. (2003) who stated that tin in combination with camphor provided highest level germination (88.73%) of black gram seeds 270 days after storage.

Chapter 5
Summary and conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The present study using the of containers, indigenous materials and chemicals for the management of insect pests of wheat in storage, was undertaken in the laboratory of the Department of Entomology, Sher-e- Bangla Agricultural University (SAU), Dhaka during April 2006 to November 2006. The experiment was laid out in Factorial RCBD having two factors with three replications. Various containers such as tin kouta, earthen pots, plastic containers and gunny bag were considered as one factor and different materials and chemicals were such as neem leaf powder, sand, camphor, naphthalene and an untreated control considered as another factor.

Three insect pests such as grain moth (*Sitotroga cerealella*), red flour beetle (*Tribolium castaneum*), and rice weevil (*Sitophilus oryzae*) were found to attack wheat grain seriously during the study period. Initially the grain moth population was higher and gradually declined as storage period progressed. The red flour beetle population was initially low and reached to the highest level in August and then declined. In contrast, the rice weevil population gradually increased as the time progressed up to October and then declined. In case of comparative abundance of 3 pests red flour beetle was always higher than rice weevil.

The plastic containers and tin kouta showed the best performance in protecting the wheat from attack of different insect pests. On the other hand, gunny bag was worse in providing the protection of wheat grains from the insect pests attack.

Among the materials, naphthalene showed the best performance than other materials in protecting the wheat seed from insect attack and camphor showed similar results as naphthalene. Neem leaf powder showed intermediate performance.

The lowest population of grain moth (0.00-4.67), red flour beetle (7.00-18.33) and rice weevil (0.0-5.33) was recorded from the plastic container and tin kouta in combination with naphthalene and camphor. In contrast the highest population of grain moth (15.33-136), red flour beetle (32.33-95.33), and rice weevil (2.67-21.67) was recorded from gunny bag in combination with different materials. Gunny bag and earthen pot in combination with different materials had also the similar level of population.

The highest percentage of grain infestation (11.23-46.36%) was recorded from gunny bag and its combination with different treatments throughout study period. The similar level of grain infestation was also observed in case of earthen pot. The lowest percent grain infestation (7.25-26.30%) was recorded from plastic container in combination with naphthalene and plastic container in combination with neem leaf powder showed intermediate performance during the study period. The similar efficacy was obtained from tin kouta in combination with different storage materials.

The percent grain infestation fluctuates with fluctuations of temperature and relative humidity and the infestation of grain was low after 2 months of storage and gradually increased to a peak in September 2006 and then it started to decline. Significantly positive correlation prevailed between percent grain infestation with temperature and relative humidity.

The highest percentage (100%-86.67%) of germination of wheat seed was observed in the treatments tin kouta + neem leaf powder, plastic container + camphor and plastic container + neem leaf powder. The lowest percentage (66.67-73.33%) of wheat seed germination was observed in the gunny bag + neem leaf powder and gunny bag sole. Considering the containers, the highest percentage of germination was observed in tin kouta and plastic containers followed by earthen pot and gunny bags. The rate of germination steadily declined as the time of storage progressed. Although the germination percentage gradually declined in all the treatment combinations the germination percentage was always higher in the tin kouta + neem leaf powder, plastic+ camphor and plastic + neem leaf powder. Plastic and tin container in combination with naphthalene provided maximum (86.73%) germination of wheat grain after six months of storage.

Chapter 6
Recommendations

CHAPTER 6

RECOMMENDATIONS

- Plastic container and tin kouta in combination with naphthalene provided the best performance in protecting wheat grain against different insect pests of wheat. So, it can be recommended that plastic container and tin kouta in combination with naphthalene may be used for storage of wheat.

- Moreover, the germination percentage in these treatment combinations was more than 80% after six months of storage, which was higher than all treatments. Therefore, plastic container and tin kouta in combination with naphthalene may be used for storage of wheat seed.

- Although the neem leaf powder provided the intermediate level of infestation, however it can be used in the storage of wheat in combination with plastic containers and tin kouta considering environmental point view.

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CHAPTER 7

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Appendices

APPENDICES

Appendix I. Population dynamics of grain moth in different containers during the period from June to November 2006.

	June	July	August	September	October	November
Tin	01.93	11.07	14.67	8.73	06.00	02.47
Earthen pot	53.07	51.87	51.87	25.13	19.33	07.87
Plastic	2.20	07.93	05.40	07.33	04.86	01.40
Gunny bag	93.73	99.07	55.93	38.2	27.87	12.80

Appendix II. Population dynamics of red flour beetle in different containers during the period from June to November 2006

	June	July	August	September	October	November
Tin	14.07	19.73	44.27	25.33	17.33	06.93
Earthen pot	25.40	41.87	70.73	41.33	30.13	15.87
Plastic	14.73	27.20	35.33	22.47	15.47	06.40
Gunny bag	27.47	57.2	80.80	47.20	36.27	24.60

Appendix III. Population dynamics of rice weevil in different containers during the period from June to November 2006

	June	July	August	September	October	November
Tin	0.40	01.73	05.60	07.93	10.07	08.07
Earthen pot	02.00	04.20	08.27	10.40	14.20	13.40
Plastic	0.20	02.47	06.00	06.80	09.13	06.94
Gunny bag	01.73	04.74	10.13	13.40	19.07	16.13

Appendix IV. Effect of different indigenous materials and chemicals on grain moth abundance during June to November 2006

	June	July	August	September	October	November
Neem leaf powder	47.58	42.83	37.25	21.50	16.17	06.48
Sand	54.00	53.08	38.00	24.33	18.58	07.25
Camphor	23.25	30.08	23.42	15.50	10.50	05.17
Naphthelene	17.17	28.92	20.75	13.58	08.75	03.92
Control	46.67	57.50	40.42	24.33	18.58	07.92

Appendix V. Effect of different indigenous materials and chemicals on red flour beetle abundance during June to November 2006

	June	July	August	September	October	November
Neem leaf powder	27.42	42.17	61.25	39.25	26.08	15.50
Sand	22.33	48.42	67.08	38.17	29.08	16.58
Camphor	13.25	31.50	50.92	25.75	22.42	10.33
Naphthelene	11.58	26.58	43.08	22.58	16.75	7.58
Control	27.50	46.33	66.58	44.67	29.67	17.25

Appendix VI. Effect of different indigenous materials and chemicals on rice weevil abundance during June to November 2006

	June	July	August	September	October	November
Neem leaf powder	1.08	4.08	7.83	9.83	14.08	12.58
Sand	1.33	4	8.75	11.83	15.17	13.92
Camphor	0.92	2.67	6.58	8.25	11.58	7.75
Naphthelene	0.75	2.08	6.08	6.75	9.08	7.75
Control	1.33	3.58	8.25	11.5	15.67	13.67

Appendix VII. Monthly variation of percent wheat grain infestation in gunny bag with temperature and relative humidity.

Time	Temperature	Population	Relative humidity (%)
June	29.25	10.01	85
July	29.55	29.90	77
August	29.50	32.26	74
September	28.85	41.92	78
October	28.50	37.99	72
November	24.90	33.59	65