ECO-FRIENDLY MANA
GEMENT OF PULSE BEETLE, *CALLOSOBRUCHUS CHINENSIS* LINN. USING BOTANICALS AND FUMIGANTS ON STORED MUNGBEAN

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CERTIFICATE

This is to certify that thesis entitled, "**ECO-FRIENDLY MANAGEMENT OF PULSE BEETLE, *CALLOSOBRUCHUS CHINENSIS* LINN. USING BOTANICALS AND FUMIGANTS ON STORED MUNGBEAN**" 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. ZAHID KHAN**, Registration No. 05-01560 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2011
Place: Dhaka, Bangladesh

………………………………………………
Prof. Dr. Md. Serajul Islam Bhuiyan
Supervisor

Dedicated

to

My Beloved Parents

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TABLE OF CONTENTS

CHAPTER	TITLE	PAGE

	ACKNOWLEDGEMENTS		I
	LIST OF CONTENTS		II-IV
	LIST OF TABLES		V
	LIST OF FIGURES		VI
	LIST OF PLATES		VII
	ABSTRACT		VIII
CHAPTER I	**INTRODUCTION**		**1-4**
CHAPTER II	**REVIEW OF LITERATURE**		**4-27**
	2 .1.	Taxonomy of *Callosobruchus chinensis* L.	5
	2.2.	Biology of pulse beetles	6
	2.2.1.	Mating	6
	2.2.2.	Oviposition and incubation	7
	2.2.3.	Larval period	7
	2.2.4.	Pupal period	8
	2.2.5.	Adult emergence and its longevity	8
	2.2.6.	Identification of male and female bruchids	8
	2.3.	Nature and extent of damage	9-10
	2.4.	Origin and distribution of pulse beetles	10-11
	2.5.	Alternative management of pulse beetles on mungbean	11
	2.5.1.	Botanicals for the management of pulse beetle	11-22
	2.5.2.	Fumigants for the management of pulse beetle	22-26
	2.6.	Effect of botanicals on seed viability	26-27
CHAPTER III	**MATERIALS AND METHODS**		**28-38**
Experiment 1	**Effect of some botanicals for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage**		**28-35**
	3.1.1.	Design of the experiment	28
	3.1.2.	Materials used in the study	29
	3.1.3.	Viability test of the seeds	29
	3.1.4.	Treatments	29-30
	3.1.5.	Collection and preparation of botanicals	30
	3.1.6.	Application of the botanicals	31-32
	3.1.7.	Release of *Callosobruchus chinensis* L.	32

	3.1.8.	Germination test of seed	32
	3.1.9.	Data sampling	33
	3.1.10.	Data collection and calculation	34
	3.1.10a.	Data on grain infestation by number and weight	34
	3.1.10b.	Data on adult emergence	34
	3.1.10c.	Data on grain content loss	35
	3.1.10d.	Data on seed germination	35
Experiment 2		**Effect of some fumigants for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage**	**35-38**
	3.2.1.	Design of the experiment	36
	3.2.2.	Materials used in the study	36
	3.2.3.	Germination test of the seeds	36
	3.2.4.	Treatments	36-37
	3.2.5.	Collection and preparation of fumigants	37
	3.2.6.	Application of the fumigants	38
	3.2.7.	Release of *C. chinensis* Linn.	38
	3.2.8.	Data sampling, collection and recording	38
CHAPTER IV		**RESULTS AND DISCUSSION**	**39-64**
Experiment 1		**Effect of some botanicals for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage**	**39-50**
	4.1.1.	Effect of botanicals on grain infestation by number	39-41
	4.1.2.	Effect of botanicals on grain infestation by weight	41-43
	4.1.3.	Effect of botanicals on the adult emergence of *C. chinensis* during its management	44-46
	4.1.4.	Effect of botanicals on the grain content loss caused by *C. chinensis* during 120 days after insect release	46-48
	4.1.5.	Effect of botanicals on viability of seed	48-50
Experiment 2		**Effect of some fumigants for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage**	**50-64**
	4.2.1.	Effect of fumigants on grain infestation by	50-52

	number	
4.2.2.	Effect of fumigants on grain infestation by weight	52-54
4.2.3.	Effect of fumigants on the adult emergence of *C. chinensis*	54-55
4.2.4.	Effect of fumigants on the grain content loss	56-57
4.2.5.	Effect of fumigants on germination of mungbean seed	57-59
4.3.	Comparative effectiveness of botanical and fumigant based management practices	59
4.3.1.	Comparative performance of botanicals and fumigants on reduction of grain infestation	60
4.3.2.	Comparative performance of botanicals and fumigants in reducing adult emergence of *C. chinensis*	61
4.3.3.	Comparative performance of botanicals and fumigants in reducing grain content loss	62
4.3.4.	Comparative performance of botanicals and fumigants on seed germination	63-64

CHAPTER V	**SUMMARY AND CONCLUSION**	**65-72**
CHAPTER VI	**REFERENCES**	**73-83**

LIST OF TABLES

TABLE NO.	TITLE	PAGE

1.	Effect of botanicals on the mungbean grain infestation by number aganist *C. chinensis* during April to July, 2011	40
2.	Effect of botanicals on the mungbean grain infestation by weight aganist *C. chinensis* during April to July, 2011	43
3.	Effect of botanicals on adult emergence during 40 days after insect release to 120 days after insect release of *C. chinensis*	45
4.	Effect of botanicals on mungbean grain content loss during 120 days after insect release of *C. chinensis*	47
5.	Effect of botanicals on the germination of mungbean during 20 days after insect release to 120 days after insect release of *C. chinensis*	48
6.	Effect of fumigants on the mungbean grain infestation by number aganist *C. chinensis* during April to July, 2011	51
7.	Effect of fumigants on the mungbean grain infestation by weight aganist *C. chinensis* during April to July, 2011	53
8.	Effect of fumigants on adult emergence during 40 days after insect release to 120 days after insect release of *C. chinensis*	55
9.	Effect of fumigants on mungbean grain content loss during 120 days after insect release of *C. chinensis*	56
10.	Effect of fumigants on the germination of mungbean during 20 days after insect release to 120 days after insect release *C. chinensis*	58

LIST OF FIGURES

FIGURE NO.	FIGURES	PAGE
1.	Comparative effectiveness of botanicals and fumigants on	60

	the percent grain infestation reduction over control	
2.	Comparative performance of botanicals and fumigants in reducing adult emergence of *C. chinensis*	61
3.	Comparative performance of botanicals and fumigants in reducing grain content loss	62
4.	Comparative performance of botanicals and fumigants on seed germination	63

LIST OF PLATES

PLATE NO.	TITLE	PAGE
1a.	Neem leaf	31
1b.	Bishkatali leaf	31
1c.	Marigold leaf	31
1d.	Dried dholkolmi	31

2a.	Adult pulse beetle	33
2b.	Eggs laid on mungbean seed	33
2c.	Larva	33
3a.	Camphor	37
3b.	Napthalene	37
3c.	Phostoxin container with tablets	37

ECO-FRIENDLY MANAGEMENT OF PULSE BEETLE, *CALLOSOBRUCHUS CHINENSIS* LINN. USING SOME PROMISING BOTANICALS AND FUMIGANTS ON STORED MUNGBEAN

BY

MD. ZAHID KHAN

ABSTRACT

The experiment was conducted in the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from April to July, 2011 to find out the eco-friendly management of pulse beetle using some promising botanicals and fumigants on stored mungbean. The study consist two separate experiments considering botanical and fumigant. Five botanicals were used viz. dried leaf powder of neem @ 2.5 g/kg mungbean grains (T_1), bishkatali @ 2.5 g/kg mungbean grains (T_2), marigold @ 2.5 g/kg mungbean grains (T_3), dholkolmi @ 2.5 g/kg mungbean grains(T_4), chopped garlic bulb @ 1.0 g/kg mungbean grains (T_5) along with control (T_6). Three fumigants viz. camphor @ 1.0 g/kg mungbean grains (T_1), phostoxin tablet @ 200 mg/kg mungbean grains (T_2), naphthalene @ 500 mg/kg mungbean grains (T_3) along with control (T_4). The experiments were laid out in Completely Randomized Design with four replications. It was observed that the treatment T_1 reduced the highest percent of grain infestation by number and weight (43.12% & 41.72%, respectively) over control than other botanicals while T_3 showed the least performance (6.57% &2.25%, respectively). Conversely, T_5 reduced the highest percent of adult emergence (43.65%) and grain content loss (49.91%) over control while T_3 showed the least performances (11.71%). Similarly, T_5 increased the highest percent seed germination (25.65%) over control while the lowest was in T_2 (6.57%). Among three fumigants, T_1 reduced the percent of grain infestation by number and weight (49.65% &49.54%, respectively), adult emergence (77.66%) and grain content loss (95.18%) over control than other fumigants. Conversely, T_1 increased the highest percent of seed germination (26.57%) over control than other fumigants. Irrespective of botanicals and fumigants, all fumigants especially camphor showed better performance. So, it can be concluded that camphor @ 1.0 g/kg mungbean grains was suitable for managing pulse beetle on stored mungbean.

CHAPTER I

INTRODUCTION

Pulses serve as one of the main sources of protein and minerals as well as play a vital socio-economic role in the diet of common people of Bangladesh. Among pulses, mungbean, *Vigna radiata* (Linn.) Wileazek has come up an important pulse crop in Bangladesh. It contains 51% carbohydrate, 26% protein, 4% minerals, 3% vitamins (Yadav *et al.*, 1994). Its sprout is a high quality vegetable and rich in vitamin-C. Bioavailability of iron in sprouts is twelve-fold high as compared to mungbean as a dhal (soup). A four-fold increase in iron availability of mungbean can be achieved through cooking with vegetables like tomato. Mungbean plant fixes atmospheric nitrogen in symbiosis with soil bacteria to enrich soil fertility as well as it provides useful fodder (Afzal *et al.*, 2004). The traders mostly store the pulses produced in the country. The primary producers also store the pulses at least for few months before they sell it. Almost all growers store the required quantity of pulse seeds in their houses for growing next year. Unfortunately, in storage, pulses suffer enormous losses due to bruchid attack, which infestation starts either in the field on the maturing pod and is carried to the stores with the harvested crops or it originates in the storage itself (Fletcher and Ghosh, 2002). Three species of pulse beetles, viz., *Callosobruchus chinensis* Linn., *C. analis* Fab., and *C. maculatus* Fab. have been reported from Bangladesh as the pest of stored pulses (Begum *et al.*, 1984; Rahman *et al.*, 1981 and Alam, 1971). However, Alam (1971) reported that *Callosobruchus chinensis* to cause enormous losses to almost all kind of pulses in storage condition. Rahman (1971) reported 12.5% loss due to pulse beetles infestation in pulses stored in warehouses. Ali *et al.* (1999) reported that mungbean, *Vigna radiata* appeared to be the most common and suitable host for *C. chinensis* in respect of oviposition, egg deposition, adult emergence (66.11-70.29%) and grain content loss (50.37 - 57.58%) but no significant influence on egg hatching (94.33 - 98.50%). Ali and Rahman (2006) also reported that mungbean, *Vigna radiata* appeared to be the most common and suitable host for the species *C. maculatus* in respect of oviposition, larvae (58.21-76.31%), pupae (55.35-64.40%), adult emergence (33.18-46.62%) and grain content loss (37.30 - 55.30%).

Synthetic chemicals have become a common practice among the farmers and stockholders to control the storage pests of pulses. Several reports are available on the efficacy of different chemicals for controlling insect pests in stored production (Chandra *et al.*, 1989; Prakash and Rao, 1983; Stoyanova and Shikrenov, 1983; Yadav, 1983; Singh *et al*., 1989; Dilwari *et al.*, 1991). It is now widely known that the chemical method has several problems, which include health hazards to the users and grain consumers. It causes residual toxicity, environmental pollution and development of pesticide resistance against bruchids. The residues of the chemical insecticides remain in the stored grain and also in the environment (Srivastava, 1980). On the other hand, the traditional method of controlling storage pests by sun - drying is safer to human health and environment. But this method is laborious, time consuming, often expensive and requires suitable drying yard, when large volume of stored grain is involved. Moreover, it depends on favorable weather condition. Besides these, reports are also available on the efficacy of plant oils (Chander *et al.,* 1991; Su, 1991). Plant-derived materials are more readily biodegradable, less toxic to mammals, may be more selective in action, and may retard the development of resistance. It was reported that when mixed with stored-grains, leaf bark, seed powder, or oil extracts of plants reduce oviposition rate and suppress adult emergence of bruchids, and also reduced seed damage rate (Keita *et al*., 2001). Hence, search for the alternative method of pulse beetle control utilizing some non-toxic, environment friendly and human health hazard free methods are being pursued now-a-days. In the world, as many as 2400 plant species have been recorded that have potential pesticidal properties and biological activity against a wide range of pest (Grainge and Ahmed, 1988).

In Bangladesh, as many as 54 plant species have been evaluated for their bio-efficacy against different insect pests, pathogens and weeds (Karim, 1994). A number of botanicals and their derivatives have been tested in Bangladesh and other developing countries particularly against pulse beetles and have shown promising results (Yadava and Bhatnagar, 1987). Bhuiyah (2001) reported that the oils of neem, royna and castor at 6 and 8 ml/kg and leaf powder of bishkatali, marigold and castor at 5% w/w were most effective in preventing the egg laying in lentil and chickpea and leaf powder of bishkatali, marigold, castor and mango at 5% were most effective in reducing the adult emergence in lentil and chickpea, whereas the adult emergence were nil in pre and post storage release methods.

Now a day, Camphor ($C_{10}H_{16}O$), locally named as *Karpur* in Bangladesh is very new and unexploited approach in this context, which extracted from the leaves and wood of Camphor tree (*Cinamomum camphora*). Chauvin *et al.* (1994) reported that camphor has fumigation properties and has got a very low mammalian toxicity. Rahman *et al.*, (2001) reported the fumigation action of camphor against pulse beetle, *C. chinensis.* Miah (2007) reported that camphor @ 2 gm/kg seeds performed the best results in respect of percent reduction (100%) of larvae and pupae, grain infestation and grain content loss over control for both *C. chinensis C. maculatus*, while partial reduction occurred by neem oil and castor oil. In Bangladesh, very little study has so far been reported on the efficacy of camphor against pulse beetles. Another fumigant, the phostoxin is available in the market at its tablet or pellet form. The chemical name phostoxin is aluminium phosphide (Onu and Aliyu, 1995), which is used as a rodenticide, insecticide, and fumigant for stored cereal grains (Mahadi and Hamoudi, 2010). Naphthalene is a household fumigant also, which build up vapors that are toxic to both the adult and larval forms of many insects that attack textiles (Bryn, 2002) and other stored products. But a very little study has so far been reported on the efficacy of phostoxin and naphthalene against pulse beetles. However, the use of quality insecticides and their proper management is a burning issue in respect of agro-socio economic, environmental aspect and health of consumers. At present situation in Bangladesh, there is a great need of research about appropriate environment friendly and human health hazards free management practices to pulse beetles in stored pulses.

OBJECTIVES

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

1. To assess the extent of damage of stored mungbean grain by pulse beetle, *C. chinensis*;

2. To determine the efficacy of some botanicals against pulse beetle, *C. chinensis* on mungbean;

3. To determine the efficacy of some fumigants against pulse beetle, *C. chinensis* on mungbean.

CHAPTER II

REVIEW OF LITERATURE

Pulse beetles are the most serious pests of stored pulses in Bangladesh (Rahman, 1971). The species of pulse beetles so far reported to infest various pulses include *Callosobruchus chinensis* L., *C. analis* Fab. and *C. maculatus* Fab. (Begum *et al*., 1984). Results revealed that mungbean, *Vigna radiata* appeared to be the most common and suitable host for *C. chinensis* (Ali *et al*., 1999) and *C. maculatus* (Ali and Rahman, 2006) in respect of adult emergence and grain content loss. But very few works have so far been done for identifying the suitability or resistance source(s) among the available seeds of mungbean varieties and their efficacy against bruchids in Bangladesh. However, voluminous reports are available from studies conducted throughout the world including India, Pakistan, Thailand, Japan, the U.K and the U.S.A. on the susceptibility or resistance of various grain legumes to infestations by bruchids. Redden and McGuire (1983) reported various criteria for the assessment of suitability or resistance of grain legumes to bruchid infestation. These include adult emergence over a given period, percentage of weight loss and undamaged seeds.

Literatures on some of such studies relevant to the present study collected from various sources including Bangladesh were reviewed here in brief under the following sub-headings. Prior to this, the biology, identification of male and female, nature and extent of damage, hosts preference, origin and distribution of the pulse beetles pertaining to the identification were also reviewed.

2.1. Taxonomy of *Callosobruchus chinensis* L.

Alam (1971) reported that the adult of *Callosobrus chinensis* L. is 4 mm long and can be distinguished from other species by the elevated ivory like spots near middle of the body. The beetle is dark and inconspicuous in colour and its body is clothed with hairs.

Taxonomic position of *Callosobruchus chinensis* Linn. is furnished below:

Kingdom : Animalia

Phylum: Arthropoda

Subphylum: Mandibulata

Class : Insecta

Infraclass: Neoptera

Subclass: Pterygota

Sub-order : Polyphaga

Order : Coleoptera

Family : Bruchidae

Sub-family : Bruchinae

Tribe : Bruchidini

Genus: *Callosobruchus*

Species : *Callosobruchus chinensis* L.

2.2. Biology of pulse beetle

2.2.1. Mating

According to Bhuiyan and Peyara (1978), the mating takes place immediately after emergence of the adult beetles. Adults of bruchids are sexually mature at emergence and ready to mate (Raina, 1970). In laboratory condition, mating left for 2 to 3 minutes, when a male and female of *Callosobruchus chinensis* L. are introduced, the male moves first around rather sluggishly but suddenly beings to move with rapid antennal movement. This sort of behavioral change is called 'Activation' and this activation cannot be seen when a male is alone (Nakamura, 1969).

2.2.2. Oviposition and incubation

The female oviposits within 24 hours of their emergence and mating. The ovipositional period ranges from 3-8 days depending upon the season of the year.

Govindarajan *et al*. (1981) observed the ovipositional behavior of *Callosobruchus chinensis* and *C. maculatus* Fab. in relation to seed size. Laboratory observations on the effect of seed size on mungbean (*Vigna radiata*) showed that two bruchids preferred to oviposition seeds weighing more than the average of those used and the number of eggs laid on them was in proportion to seed weight. According to Bhuiyan and Peyara (1978), the mean ovipositional period is 6.83 days in winter and 4.00 days in summer. Several eggs may be laid singly on the grain. Incubation period lasts from 3-5 days in summer and 7-9 days in winter.

The freshly laid eggs are translucent, smooth and shining but become pale yellowish or grayish white with, age: The eggs are elongated and oval in shape (Alam, 1971). Raina (1970) reported that on an average 78, 128 and 96 eggs/female were laid on mungbean seeds at 30^{O}C and 70% RH by *Callosobruchus chinensis C. maculatus* Fab. and *C. analis* Fab., respectively. Eggs lasted for 3.5, 4 and 5 days, respectively and 94-99%, of the eggs hatched.

2.2.3. Larval period

According to Dennis (1990), the larva is scarabeiform having five instars developed, in about 20 days. The full-grown larva is six mm long, flesh, strongly winkled, perfectly white except brown color at mouth region. Soon after hatching, the young larvae bore into the seeds and start to consume the contents (Bhuiyan and Peyara, 1978).

2.2.4. Pupal period

Dennis. (1990) reported that the pupation takes place inside the seed in a chamber covered by a thin window of tests prepared by a mature larva. The pupae are exarate type with a mean pupal duration of 2.5 days in summer and 4.25 days in winter (Bhuiyan and Peyara, 1978).

2.2.5. Adult emergence and its longevity

The males are short lived and smaller than females. The antennae of male and female are pectinate and serrate respectively (Dennis, 1990). Bhuiyan and Peyara (1978) reported that the head of the beetle is small, hypognathous and provided with short snout. The life cycle of *Callosobruchus chinensis* L. completes in 30-32, 20-23 and 40-46 days in early summer, mid summer and winter seasons respectively (Bhuiyan and Peyara, 1978).

According to Shukla and Pandey (1977) the average longevity of the male and female are 4.3 and 5.4 days in summer and 7.4 and 9.2 days in winter respectively. The adult is 4 mm long and can be distinguished from other species by the elevated ivory like spots near middle of the body. The beetle is dark and inconspicuous in colour and its body is clothed with hairs (Alam, 1971).

2.2.6. Identification of male and female bruchids

The distinctive characters of males and females have been well documented by Shukla and Pandey (1977). Antennae of male are pectinate type with elongated and oblong apical segment and curved towards each other. Pectination in antenna become prominent from the 4^{th} to the apical segment. Antenna of female is straight but serrate type with prominent serration in 5^{th} to the apical segment. The apical segment is somewhat bluntly rounded or ovate in shape. Male and female pulse beetles can easily be distinguished from one another by general appearance. The most distinguishing characteristic is the sex specific, coloration of the post abdominal plate that's called

'Pygidium'. In some strains, females are larger in size than males. Also, females are black in coloration and males are brown.

2.3. Nature and extent of damage

Ali *et al.* (1999) reported that mungbean, *Vigna radiata* appeared to be the most common and suitable host for *C. chinensis* in respect of oviposition, egg deposition, adult emergence (66.11-70.29%) and grain content loss (50.37 - 57.58%) but no significant influence on egg hatching (94.33 - 98.50%).

In the laboratory study, Rahmnan (1991) found that the initial presence of 4 larvae or eggs or one pair of *Callosobruchus* spp. adult could completely damage 10 g of the pulse grain within 2-4 months, depending on the type of the pulses, stage of maturity and species of the beetle.

Begum *et al*. (1982) stated that in Bangladesh *Callosobruchus chinensis* L. is one of the major pests belonging to *Callosobruchus* spp. causing considerable damage to stored legume grains.

Southgate (1979) stated that pulses grown by man have been infested by bruchids since the dawn of agriculture. The larval stage causes only severe damage rendering the seeds unfit for planting and human consumption.

Gujar and Yadav (1978) recorded 55-60% logs by seed weight and 45-66% loss in protein content by the pulse beetle.

Islam (1977) found that *C. chinensis* L. is the most serious storage pest in Bangladesh and obtained 10-20% destruction of the stored legume grains every year in the small storehouse of the marginal farmers. The extent of damage of munghean seed might be up to 100% during a period of one year storage (Chowdury, 1961).

Ali and Rahman (2006) also reported that mungbean, *Vigna radiata* appeared to be the most common and suitable host for the species *C. maculatus* in respect of oviposition, larvae (58.21-76.31%), pupae (55.35-64.40%), adult emergence (33.18-46.62%) and grain content loss (37.30 - 55.30%).

Raja *et al.* (2004) conducted storage studies for 7 months to evaluate the effect of different levels of bruchid (*C. maculatus*) infestation in green gram seed revealed do there was significant decrease in seed weight (g), germination (%), vigor index (VI) and protein content (%) with increase in the level of bruchid infestation. A rhythmic decrease in qualitative and quantitative character of seeds was observed with advances in period of storage.

2.4. Origin and distribution of pulse beetle

Most of the species live in the tropical regions of Asia, Africa, Central and South America. *Callosobruchus chinensis* L. is of Asian origin, where it is still the dominant species (Dennis, 1990). He mentioned that *Callosobruchus chinensis* is thought to be African. However, both the species are now widely distributed throughout the warmer parts of the world. Other species of *Callosobruchus* recorded as pest including *C. maculatus* Fab. in parts of (Asia on *Vigna* species, *C. phaseole* (Gyllenhal) in Africa, parts of Asia and South America on *Vigna* and *Dolichos lablab*, *C. sibinnotastus* in Africa on cowpea, *C. sibnnotastus* in Fast Africa on *Vigna* s*ubterranean* and *C. theobromae* in India on field crops of pigeon pea.

Callosobruchus chinensis L. was first reported and the described from China in 1958 (Alam, 1971) though Southgate (1979) has mentioned that the species of Bruchidae have their origin in Afro-Asian region. According to Southgate (1979), the species of

Bruchidae breed in every continent except Antarctica. Through the agency of bruchids have their cosmopolitan distribution.

2.5. Alternative management of pulse beetle on mungbean

Control of storage pests by using synthetic chemicals has become a common practice among the farmers and stockholders. It is now widely known that the chemical method has several problems, which include health hazards to the users and grain consumers. It causes residual toxicity, environmental pollution and development of pesticide resistance against bruchids. On the other hand, the traditional method of controlling storage pests by sun-drying is safer to human health and environment. But this method is laborious, time consuming, often expensive and requires suitable drying yard, when large volume of storage grain, is involved. Moreover, it depends on favorable weather condition. Recently, the use of different plants and their derivatives has appeared as an effective alternative to the use of poisonous chemical insecticides or the cumbersome traditional methods for the control of various insect pests of crops and storage.

Literatures on some of such studies relevant to the present study collected from various sources including Bangladesh were reviewed here in brief.

2.5.1. Botanicals for the management of pulse beetle

Neem (*Azadirachta indica, A. juss*) is a perennial plant belongs to the family Meliaceae. It is famous for its medicinal properties. The major active constituent is azadirachtin, which is well known for its antifeedant, toxic and growth regulating effects on insects (Saxena, 1989; Schmutterer, 1990; Mordue and Blackwell, 1993). It has been an age-old practice in rural areas of Bangladesh to mix dried neem leaves with stored

stored rice to control stored-stored rice insects. A variety of preparations based on neem extracts have been tested against stored product insects. Azadirachtin-rich commercial "Margosan-O" is already produced in developing countries for controlling pests. However, neem compounds are too complex to be synthesized for practical purposes (Jacobson 1986).

The bishkatali (*Polygonum hydropiper* Linn.) belongs to the family of polygonaceae. It is a medicinal plant and also used to control insect pests as repellent, antifeedant and toxic materials.

The Marigold (*Calendula officinalis* Linn.) belongs to the family of Asteraceae or Compositae. It is an ornamental plant and also used to control insect pests as repellent, antifeedant and toxic materials.

The Dholkolmi (*Ipomoea carnea* Fistulosa) belongs to the family of *Convolvulaceae*. It is a weed and also used to control insect pests as repellent, antifeedant and toxic materials.

Singh and Maharaj (2010) evaluated the effect of castor and karanji oil at 0.25, 0.50, 0.75 and 1.0% w/w concentration/100 g of green gram against pulse beetle *C. chinensis* were studied. The study revealed encouraging results as the seeds of green gram could effectively be protected from the damage by mixing the seed at the rate of 0.25 to 1.0 ml/100 g seed. The study suggested these oils to be pest effective, safer to predators, economically viable and socially acceptable especially by the farmers of the region.

Misra (2010) carried out an experiment with black gram where seeds were treated with 3% dried leaf powders of *Vitex negundo*, *Aegle marmelos*, *Azadirachta indica*, *Datura stramonium*, *Ocimum sanctum* [*Ocimum tenuiflorum*], *Lantana camara*, *Annona squamosa*, *Citrus lemon*, and fruit powder of *Capsicum annuum*, and rhizome powder of *Acorus calamus* for control of *Callosobruchus chinensis* during storage in jars. These treatments were compared over five months with the local treatments of red soil powder, cow dung ash powder (both at 3%) and mustard oil coating. Tabulated data on the effect of the treatments on the fecundity of *Callosobruchus chinensis* on stored black gram, seed weight loss and seed quality are presented. All treatments resulted in lower *Callosobruchus chinensis* fecundity and seed weight losses than the untreated control. However, only the cowdung ash and mustard oil treatments completely inhibited oviposition. However, the *Vitex negundo*, *Aegle marmelos*, *Azadirachta indica* and *Datura stramonium* treatments reduced fecundity more than the other powder treatments and, as with the cowdung ash, mustard oil and *L. camara* treatments, completely prevented losses in seed weight and seed quality.

Subash (2010) conducted an experiment to study the efficacy of various grain protectants against pulse beetle, *Callosobruchus chinensis* (L.) infesting greengram, *Vigna radiata* (L.). Efficacy of 11 grain protectants viz., neem seed kernel powder @ 20 g/kg seed, neem oil @ 10 ml/kg, mustard and groundnut oil each @ 7.5 ml/kg, turmeric powder @ 3.5 g/kg, mustard oil powder @ 3.75 ml.75 g/kg, groundnut oil powder @ 3.75 ml.75 g/kg, 7 cm covering with each of saw dust, sandy soil, dung cake ash and wheat husk was investigated on adult mortality (%) and weight loss (%) by *Callosobruchus chinensis* on treated and untreated greengram seeds (Control) at an interval of 1, 35, 70 and 105 days after storage. Greengram seed treated with all the grain protectants except saw dust resulted in significantly high adult mortality per cent of *C. chinensis* in comparison to control when observed at 1, 35, 70 and 105 days after storage. Maximum (100%) adult mortality was observed in treatment with neem oil; however, it was at par with those treated with 7 cm covering with dung cake ash and was most effective adult mortality treatment. Treatment with wheat husk, sandy soil and turmeric powder (3.33% in each treatment) was least effective which was followed by mustard oil powder (16.67%), groundnut oil powder (10%) and mustard oil (13.33%) and groundnut oil (16.67%) when observed after 105 days of storage. On the basis of per cent weight loss, all the grain protectant treatments proved significantly more effective in comparison to untreated control after 35, 70 and 105 days of storage. After 105 days of storage, percent weight loss recorded was zero when greengram seed was either treated with neem oil or covered with 7 cm covering of sandy soil and dung cake ash. Maximum per cent weight loss (2.16%) was recorded in greengram seed covered with wheat husk (7 cm covering) followed by neem seed kernel powder (1.8%).

Saxena and Saxena (2009) conducted an experiment with five plant extracts from (*Azadirachta indica* kernels, *Allium sativum* bulbs, *Citrus sinensis* peels, *Citrus limon* peels and *Mangifera indica* leaves) each having three concentrations (1, 1.5 and 2%) were tested against pulse beetle, *C. maculatus* regarding mungbean crop. The petroleum ether extract of neem kernel was most effective as 1.5 and 2% level showed 50 and 61.11% mortality, whereas its methanol extract showed 38.88 and 55.55% mortality with respective concentrations. Two percent concentration of garlic in both solvents also showed 50% mortality. Minimum number of eggs were laid (21.67, 15.00 and 5.67 at 1%, 1.5% and 2% level respectively) with petroleum ether extract of neem kernel. Methanol extract of plant parts showed more developmental period of pests compared to the petroleum ether extract.

Puneet (2009) conducted an experiment with nine edible plant products, viz., aonla [*Phyllanthus emblica*], black pepper, bitter gourd [*Momordica charantia*], clove

[*Syzygium aromaticum*], cinnamon, fenugreek, ginger, red chilli and turmeric were evaluated for toxicity against *Callosobruchus analis* infesting green gram (*Vigna radiata*). Maximum adult mortality after 7 days exposure was recorded in clove (78.88%) followed by black pepper (75.55%) and cinnamon (68.88%). Clove powder treatment recorded the minimum adult emergence and minimum number of eggs/100 grains after a 5 month storage period.

Singal and Chauhan (2008) observed in treating pigeon pea, *Cajanus cajan* (L.), seed with neem seed kernel powder (4% w/w) and neem seed oil (1.0% v/w) individually prevented egg laying by *Callosobruchus chinensis* (L.) for up to 8 months of storage, as a negligible adult population developed after this period. Coal ash and soft stone were ineffective in this respect.

Salama (2008) observed the leaf extracts of three ornamental plants, *Myoporum pictum*, *Pittosporum tobira* and *Thevetia peruviana*, used as seed protectants, were tested for their efficiency in controlling two stored product insects, the rice weevil, *Sitophilus oryzae* (Coleoptera: Curculionidae), and the pulse beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae). *M. pictum* was the most efficient in controlling both insects as depicted by its LC< sub>50</ sub> and LC< sub>90</ sub> values when used either as leaf powder or organic solvent extracts. *T. peruviana* was the least efficient among the test plants, as it had no toxic effect on *S. oryzae* when used in powder form. *C. maculatus* was generally more sensitive to the *M. pictum* extracts than the *S. oryzae*. The chloroform extract of *M. pictum* more effective than the other extracts of this plant in controlling both insects. *P. tobira* petroleum either extract showed higher efficiency than that its chloroform extracts. Generally, extraction by n-hexane or acetone exhibited the lowest efficiency against both insects. *M. pictum* had the longest residual effect when used in powder form and as extracts especially when chloroform was used as the solvent. *T. peruviana* showed a relatively low bio-residual activity especially when tested on *S. oryzae*.

Tripathi (2006) carried out a study to observe the effect of neem leaf powder on infestation of the pulse beetle *Callosobruchus chinensis* in stored pigeon pea (*Cajanus cajan*). Seeds of pigeon pea can be effectively protected from the pulse beetle *Callosobruchus chinensis* Linn. by mixing dried neem leaf powder (NLP) in a dose of 0.50 mg to 2 mg/50 gm seed. The most effective dose of NLP as pesticide is 2 mg/50 gm of pigeon pea seeds.

Yadav and Bhargava (2005) conducted an experiment for the evaluation of seed protectants against the pulse beetle, *Callosobruchus maculatus* (Fab.) infesting stored mothbean (*Vigna aconitifolia*). Four plant extracts, i.e. neem seed extract (*Azadirachta indica*), undi extract (*Calophyllum inophyllum*), karanj extract (*Pongamia glabra* [*P. pinnata*]) and mustard oil (*Brassica juncea*), were tested against *Callosobruchus maculatus* infesting storede mothbean seeds. All plant extracts caused significant mortality in adults after three days of treatment. The neem seed extract at 1.0 ml/100 g seeds was found to be most effective, causing 49.17% mortality of adults. The mean mortality varied from 37.47 to 49.17% in different oils at the highest dose level of 1.0 ml/100 g seeds. Neem seed extract at 1.0 ml/100 g seed was the most effective in inhibiting the oviposition (21.67 eggs/female) compared with 82.67 eggs/female in untreated seeds. At 1.0 ml/100 g seeds, karanj extract caused maximum reduction in egg viability, followed by neem seed extract (64.58%), undi extract (51.72%) and mustard oil (48.52%). The longevity of both the sexes decreased with the increase in doses of plant extracts. No adverse effect of plant extracts was observed on the germination of mungbean seeds up to 90 days of treatment.

Jagjeet (2005) carried out a study with pigeon pea (cv. Manak) seeds that were treated with 11 seed protectants, i.e. neem [*Azadirachta indica*] seed kernel powder at 20 g, neem oil at 10 ml, mustard oil and groundnut oil each at 7.5 ml, turmeric powder at 3.5 g, mustard oil powder at 3.75 ml.75 g, groundnut oil powder at 3.75 ml.75 g each per one kg of seed, 4 m covering with each of sand, dung cake ash, sawdust and wheat husk and mixed them with half kg of seed by shaking it manually. Untreated seeds were taken as the control. All the seed protectants, except for sawdust and turmeric powder, recorded significantly higher adult mortality than the control after the first day of treatment. At 105 days after treatment (DAT), only dung cake ash with sand and wheat husk recorded significant adult mortality. Neem oil was effective (64.33% adult mortality) up to 35 DAT and it were followed by mustard oil powder, which recorded only 16.33% adult mortality. All the other treatments were not effective. When compared to the control, dung cake ash was the most effective treatment followed by wheat husk and sand up to 105 days of storage, and neem oil was effective up to 35 days of storage on the basis of adult mortality one day after release; turmeric powder and sawdust treatments were the least effective.

Dwivedi (2004) conducted an experiment with mixing of plant extracts to study the effect of mixing of plant extracts on their oviposition deterrent property against the pulse beetle, *Callosobruchus chinensis* (L.). Leaf extract of *Tabernaemontana divaricata* was blended with that of *Quisqualis indica*, *Chenopodium album*, *Annona squamosa*, *Anethum sowa* and *Tamarindus indica* at 1:1 ratio (v/v) and assessed for their oviposition deterrent action against the pulse beetle, *Callosobruchus chinensis*, on cowpea seeds. When mixed with *A. squamosa* and *C. album*, the mixture resulted in 97.15 and 94.70% deterrence, respectively, while with *Q. indica* it gave 75.15% reduction in oviposition over the control. The other two combinations resulted in moderate reduction in oviposition, varying from 51.83 to 57.74%.

Yadav (2004) conducted a study to investigate the effect of vegetable oils on the orientation and oviposition of pulse beetle (*C. maculatus*) on green gram during storage. Sesame, coconut, mustard, groundnut and soyabean, and non-edible oils (mahua, castor, karanja [*Pongamia pinnata*] and neem) were mixed with seeds at 10 ml/kg seed. Seeds were exposed to insects at 1, 10, 30 and 75 days after seed treatment. Vegetable oils reduced beetle incidence on seeds to 5.91-7.50 beetles, compared to the control (16 beetles). Among vegetable oils, mahua oil was the most effective. Oviposition was reduced by vegetable oil treatment. Neem oil reduced the number of oviposited eggs to 3.58 eggs, compared to untreated control (91.25 eggs).

Swaroop and Gireesh (2003) carried out an experiment with seed coating of greengram (*Vigna radiata*) with nine plants oils (1 edible; 8 non-edible and medicinal, at 2.5, 5.0 and 10.0 ml/kg seed) gave significant protection against pulse beetle, *Callosobruchus chinensis*, compared to the untreated control. The plant oils were: neem (*Azadirachta indica*); mhendi (*Lawsonia inermis*); banana (*Musa paradisiaca*); malkangni (*Celastrus paniculatus*); castor (*Ricinus communis*); karanja (*Pongamia pinnata*); babchi (*Psoralea corylifolia*); Indian mustard (*Brassica juncea*); and olive (*Olea europaea*). The oil coating, 4-6 hours after treatment, gave complete protection for all the oils evaluated at the treatment doses of 2.5, 5 and 10 ml/kg seeds, while protection at 3, 6 and 9 months after treatment was partial to complete against the pulse beetle. Neem, mehndi, malkangni, and babchi oils at 10 ml/kg seed were effective even after 6 months of treatment. These three oils were effective in controlling *C. chinensis* even after 9 months of the oil treatment. The germination test carried out with the oil treated seeds (4 to 6 hours, and, 3, 6 and 9 months, post-treatment), when the treated seeds were given 8 h exposure to sun, revealed nonsignificant differences among the treatments and untreated control. However, the germination of oil treated seeds, if not exposed to sun for 8 h, was adversely affected, especially with babchi oil.

Veer-Singh and Yadav (2003) conducted a laboratory experiment to evaluate the efficacy of six different oils, i.e. neem (*Azadirachia indica*), mehandi (*Lawsonia inermis*), castor (*Ricinus communis*), karanja (*Pongamia pinnala*), mustard (*Brassica juncea*) and olive, against *C. chinensis* in green gram. The seed coating with these oils gave significant protection against *C. chinensis* compared to the untreated control. The oil coating 6-8 h. after treatment gave complete protection at doses of 2.5, 5 and 10 ml/kg seeds, whereas partial to complete protection was observed at 90, 150 and 210 days after treatment. Neem and Mehandi oils at 10 ml/kg seed were effective even beyond 150 days after treatment and the rest of the oils were effective even after 280 days of oil treatment. Germination test carried out with the oil-treated seeds at 4 different time intervals (6 to 8 h, 90, 150 and 210 days after treatment) showed significant difference among the treatments and untreated control, but it was beyond 80% in all the treatments; germination in the untreated control ranged from 94.3 to 97.0%. However, the difference became non-significant when the treated seeds were given 8h. exposure to sun.

Dhakshinamoorthy and Selvanarayanan (2002) evaluated the effects of different natural products on the survival of *C. maculatus* infesting stored green gram (*Vigna* *radiata*). The treatments comprised leaves (as dried powder) of various plants (neem, nochi [*Vilex negundo*], pungam [*pongamia*, *pinnata*], citrus and thulasi, fly ash, kitchen ash, castor oil, red earth, malathion (as standard control) and untreated control. Treated seeds were kept in plastic containers and 20 adult beetles were introduced into each container and kept covered with muslin cloth. The results revealed that the mortality of the beetle at 7 days after treatment was highest (100%) in castor oil followed by neem leaf powder (91.66%).

Haque *et al*. (2002) conducted a comparative study to assess the efficacy of coconut, mustard (*Brassica* app.), sesame, castor, olive, safflower, soyabean, neem (*Azadirachta indica*) oils, and a mixture of the oils, against the pulse beetle (*Callosobruchus chinensis*) on mungbean under laboratory condition, considering the ovipositional behavior and adult emergence of the pulse beetle and seed viability of mungbean. No harmful effect was found on oviposition due to oil treatment. However, the percentage of adult emergence was greatly reduced and completely inhibited by the application of oils on the seeds. There was also no adverse effect on the viability of seeds due to different treatments.

Plant-derived materials are more readily biodegradable. Some are less toxic to mammals, may be more selective in action, and may retard the development of pesticide resistance to insects. Their main advantage is that they may be easily and cheaply produced by farmers and small-scale industries as crude, or partially purified extracts. In the last two decades, considerable efforts have been directed at screening plants in order to develop new botanical insecticides as alternatives to the, existing insecticides. It was reported that when mixed with stored-grains, leaf, learn, seed powder, or oil extracts of plants reduced oviposition rate and suppress adult emergence of bruchids, and also reduced seed damage rate (Keita *et al*., 2001).

Bhuiyah (2001) reported that the oils of Neem, Royna and Castor at 6 and 8 ml/kg and leaf powder of Biskatali, Marigold and Castor @ 5% were most effective in preventing the egg laying in lentil and chickpea and leaf powder of Bishkatali, Marigold; Castor and Mango @ 5% were most effective in reducing the adult emergence in lentil and chickpea, whereas the adult emergence were nil in pre and post storage release methods.

In Bangladesh, as many as 54 plant species have been evaluated for their bio-efficacy against different insect pests, pathogens and weeds (Karim, 1994).

Babu *et al*. (1989) studied the effect of pre-storage treatment of mungbean (*Vigna radiates*) variety PS- 16 with neem (*Azadirachta indica*), karanja (*Pongamia glabra*), mustard, groundnut and castor (*Ricinus communis*) oils, each at 2.5, 5.0 and 10.0 ml/kg seed, on infestation by the bruchid (*Callosobruchus chinensis)* from May 1985 to August 1987. Treatments with karanja oil (5 and 10 ml/kg) and castor oil (10 l/kg) effectively reduced oviposition by the bruchid under conditions of artificial infestation, while maintaining a high level of germination for over 18 months of storage under ambient conditions. After 24 months of storage, the yield of neem oil treated seed was significantly lower.

Babu *et al*. (1989) reported that among neem; karanja, mustard, groundnut and castor oil; the karanja (5 and 10 ml/kb) and castor (10 ml/kg) oil effectively reduced oviposition by the bruchid (*Callosobruchus chinensis*) under conditions of artificial infestation.

In the world, as many as 2400 plant species have been recorded that have potential pesticidal properties and biological activity against a wide range of pests (Grainge and Ahmed, 1988).

A number of botanicals and their derivatives have been tested in Bangladesh and other developing countries particularly against pulse beetles and have shown promising results (Yadava and Bhatnagar, 1987).

Mummigatti and Ragunathan (1977) reported that castor, mustard and ginger oils inhibited the multiplication of *Callosobruchus chinensis* on green gram at 0.3% level, coconut and groundnut oils at 0.5 % level and sunflower oil was ineffective even at 0.5% level.

In India, Pandey *et al*. (1976) prepared powder from drupes of *Thevetia nerifolia*, rhizomes of *Acorus calanrus*, leaves of *Adhatoda vasica* and *Ipomea cornea* and petroleum ether extracts from bulbs of garlic, *Allium salivum*, and onion, *A. cepa* and Neem and these were tested for their repellent properties against *Callosobruchs chinensis* infesting grain seed.

2.5.2. Fumigants for the management of pulse beetle

Camphor

Camphor is a white transparent waxy crystalline solid with a strong penetrating pungent aromatic odor. It is found in wood of the camphor laurel, *Cinnamonum camphora*, which is a large evergreen tree found in Asia (particularly in Borneo and Taiwan). It is widely used for medicinal purposes, and in religious ceremonies (Mann *et al.*, 1994). In extreme cases, even topical application of camphor may lead to hepatotoxicity (Bishop and Sanders, 2000). Lethal doses in adults are in the range 50–

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

Now a day, Camphor ($C_{10}H_{16}O$), locally named as *Karpur* in Bangladesh is very new and unexploited approach in this context, which extracted from the leaves and wood of Camphor tree (*Cinamomum camphora*). Chauvin *et al.* (1994) reported that camphor has fumigation properties and has got a very low mammalian toxicity. Abiverdi (1977) reported the insecticidal efficacy of camphor. Rahman *et al.,* (2001) reported the fumigation action of camphor against pulse beetle, *C. chinensis.*

Miah (2007) reported that camphor @ 2 g/kg seeds performed the best results in respect of percent reduction (100%) of larvae and pupae, grain infestation and grain content loss over control for both *C. chinensis C. maculatus*, while partial reduction occurred by neem oil and castor oil.

Ahmed *et al*. (2006) conducted an experiment to evaluate the effect of seed containers, indigenous materials and chemicals for the management of pulse beetles in storage. In this experiment, mungbean seeds were stored for two years in different containers with two types of chemicals (naphthalene and camphor) and two types of indigenous materials (sand and neem leaf powder). In both the years camphor provided better protection than other materials for all the containers and storage period.

Latif *et al*. (2005) conducted a study to evaluate the toxicity of camphor against different stages of rice weevil, *Sitophilus oryzae* L. (Curculionidae: Coleoptera) in parboiled polished rice grains revealed that there exists a very sharp difference among the different stages of the insect and exposure durations in respect of the toxic .action of camphor. The LD_{50} camphor against adult, egg, larva and pupa was the lowest (1.3316 mg, 1.152 mg, 6.1399 mg and 8.1093 mg respectively) at the 96 h. exposure while it was the highest (4.204 mg, 3.7954 mg, 10.6040 mg and 18.9371 mg respectively) at the 24 h. exposure.

Rahman *et al*. (2004) conducted experiments to study the bio-efficacies of different plant/weed derivatives that affect the development of the pulse beetle, *C. maculatus* Fab. (Coleoptera: Bruchidae) fed on black gram, *Vigna mungo*, seeds. Plant extracts, powder, ash and oil from nishinda (*Vitex negundo* L.), eucalyptus (*Eucalyptus globules* Labill.), bankalmi (*Ipomuea sepiaria* K.), neem (*Azadirachta indica* L.), safflower (*Carthanrus tinctorius* L.), sesame (*Sesamum indicum* L.) and babla (*Acacia arabica* L.) were evaluated for their oviposition inhibition, surface protectant, residual toxicity and direct toxicity effects on *C. maculatus*. The results showed that plant oils were effective in checking insect infestation.

Ralunan *et al*. (2001) reported the fumigation of camphor against pulse beetle *Callosobruchus chinensis.* In Bangladesh, very little study has so far been reported on the efficacy of camphor against pulse beetles.

Latif and Rahman (2000) conducted an experiment to evaluate the efficacy of camphor in protecting maize grains in storage against maize weevil, *Sitophilus zeamais* Motsch. The experiment comprised 3 treatments of camphor a 2.0 g, 4.0 g and 6.0 g per kg maize grains and an untreated control and way set in CRD. The individual treatment composition had required amount of camphor placed inside the container having 200 g maize grains which was composed each of 7 g of grains infested with eggs, larvae and pupae separately and 179 g disinfested grains and released 5 pairs of adults. After 5 months storage, all the doses kept the infestation 93.03% - 95.57% less than that of the control and offered 90.48% - 93.53% protection of loss. The dose @ 6.0g camphor per kg maize grains was the most effective although the dose 2.0g camphor per kg maize grain,, provided more than 90% protection.

Phostoxin

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

Rout and Mohanty (1967) reported that, fumigation of paddy seeds with aluminium phosphide with 4.98 (1/2 tablet), 2.49 (1/4 tablet), 1.24 (1/8 tablet) and 0.62 (1/16 tablet) mg per one kg seed at 84 to 32°C temperature did not affect the germination.

Cogburn and Tilton (1963) a dosage between 73 and 121 aluminium phosphide tablets per 1000 cubic feet was required to kill 100 percent of immature rice weevils in rough rice when temperature averaged between 11 to 14°C. Germination of seed rice was not affected by fumigation with any dosage or combination of dosage of phosphine that was used under the condition of this test.

Lallanrai *et al.* (1963) various dosage rates of 4, 3, 2 and 1 tablet per ton of phostoxin tried gave complete mortality of all stages of the insect infesting the wheat stocks in the experimental bones. Phostoxin did not impair viability of the treated wheat lots. There were strong indications that it possessed high degree of toxicity to hidden insect infestation also.

Naphthalene

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

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2.6. Effect of botanicals on seed viability

Bato and Sanchez (1972) reported that the, larvae of pulse beetle are internal feeders and feed inside the seeds, causing loss of quality, quantity and viability of seeds.

Ahmed *et al*. (2006) reported that considering the combination of containers and materials, camphor with tin container and polythene lined gunny bag had almost no infestation (< 1.00%) after 270 days of storage and the germination percentage of stored seeds of mungbean was 87.82 - 88.73% against *C. chinensis* and they suggested that mungbean seeds can be stored up to 270 days using camphor either in tin container or gunny bag lined with polythene.

Haque *et al*. (2002) also evaluated different plant oils against the pulse beetle (*Callosobruchus chinensis*) on mungbean and they found that no harmful effect was found on oviposition due to oil treatment. However, the, percentage of adult emergence was greatly reduced and completely inhibited by the application of oils on the seeds. There was also no adverse effect on the viability of seeds due to different treatments.

CHAPTER III

MATERIALS AND METHODS

The study was conducted to explore the efficiency of easily available some botanicals and fumigants for eco-friendly management of pulse beetle, *Callsobruchus chinensis* L. on stored mungbean grain in the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka during the period of April, 2011 to July, 2011. The study was conducted under following two separate experiments.

Experiment 1: Effect of some botanicals for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage

Experiment 2: Effect of some fumigants for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage

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

Experiment 1: Effect of some botanicals for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage

This experiment was conducted to evaluate the efficacy of five botanicals viz. dried leaf of neem (*Azadirachta indica*), bishkatali (*Polygonum hydropiper* L.), marigold (*Calendula officinalis*), dholkolmi (*Ipomoea carnea)* and bulb of garlic (*Allium sativum*) applied against pulse beetle, *Callosobruchus chinensis* L. infesting stored mungbean in the laboratory condition. The detail procedure of the experiment has been described below:

3.1.1. Design of the experiment

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

3.1.2. Materials used in the study

Twenty four kg of newly harvested mungbean grains were purchased and collected from the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka. Collected seeds were sun dried on the cemented floor for three consecutive days in the month of May, 2011 and kept the rice grains in 24 plastic pots maintaining one kg per pot and then these pots were kept in an ambient room temperature in the laboratory under the Department of Entomology of Sher-e-Bangla Agricultural University. The moisture content of the grains was 15-16% measured by using a digital moisture meter (Indosoaw, Model-2004, India) with the technical help and support from the Seed treatment and preservation center of BADC, Gabtoli, Dhaka.

3.1.3. Viability test of the seeds

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

3.1.4. Treatments

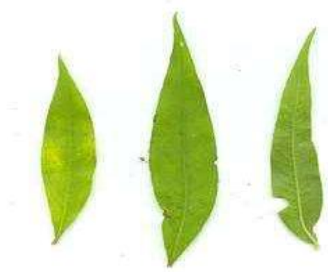
The five botanicals viz. dried leaf powders of neem, bishkatali, marigold, dholkolmi and bulb of garlic were evaluated in this experiment, where each botanical was treated as an individual treatment. Besides these botanicals, one untreated control was also considered.

The treatments and there doses selected for the experiment have been furnished below:

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

3.1.5. Collection and preparation of botanicals

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



(a) **(b)**

(c) **(d)**

Plate 1: Different botanicals (a) Neem leaf, (b) Bishkatali leaf, (c) Marigold leaf (d) Dried dholkolmi leaf

3.1.6. Application of the botanicals

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

3.1.7. Release of *Callosobruchus chinensis* Linn.

The pulse beetles are collected from the stock kept in the laboratory under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka were release in the mungbean grains kept in plastic containers assigned for each treatment. Haundred pairs of adult pulse beetle from the stock were released on the mungbean grains kept in each container. Immediately after the release of the adult pulse beetle, each container was covered with its lid. The lid was previously fine perforated for normal respiration of the pulse beetle. The plastic containers with mungbean grains for each treatment were preserved in ambient temperature of the laboratory up to four months that is 120 days after insect release (DAIR) for recording data.

3.1.8. Germination test of seed

The 100 seed sample for each treatment was taken randomly and placed those in water soaked blotting papers in Petridish, and preserved for 5 days at room temperature ranging from 27^{o}C to 34^{o}C for maximum germination of the seeds.

a. Adult pulse beetle

b. Eggs laid on mungbean seed

c. Larva

Plate 2: Different stages of *Callosobruchus chinensis* (a) Adult pulse beetle (b) Eggs laid on mungbean seed (c) Larva

3.1.9. Data sampling

The data on grain infestation by number and weight, adult emergence, grain content loss, and seed germinations were recorded. The data were collected and recorded at 20 days intervals started from 20 DAIR and continued up to 120 DAIR considering the sampling procedure. For each sample, one spoon (6 g mungbean grains) from each replicate of each of the treatment was randomly drawn at each data recording time. The sample was taken from the middle of each container (10-15 cm below from the surface) by inserting a spoon.

3.1.10. Data collection and calculation

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

3.1.10a. Data on grain infestation by number and weight

The number and weight of infested grains was counted for one spoon mungbean grains. The infested grains were identified by recognizing the bore grains caused by the pulse beetle after emergence of adult from the grains. Magnifying lens and simple microscope were used in that purpose whenever needed. The percent grain infestation and percent reduction of grain infestation over control were then calculated using the following formulae (Khosla, 1997):

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

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

Where

X_1 = Mean value of treated pot

X_2 = Mean value of untreated pot

3.1.10b. Data on adult emergence

The 10 sample infested seeds from each treatments were collected and kept in petridish separately at ambient room condition upto adult emergence. After the completion of adult emergence from the preserved seeds, the number of adult emerged were counted and recorded. The per cent reduction of adult emergence over control then calculated using the data on number of adult emergence from 10 sample seeds.

3.1.10c. Data on grain content loss

After 4 months i.e. 120 DAIR weights of the grains for each treatment was measured and recorded. Finally, the percent grain content loss was calculated from the data on initial weight (1 kg) of mungbean grains and final weight for each treatment using the following formula:

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

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

Where

X_1 = Mean value of treated pot

X_2 = Mean value of untreated pot

3.1.10d. Data on seed germination

The germination test was done to determine whether or not the pulse beetle infestation can affect seed germination. The germination rate of the mungbean seeds was determined at each data recording time from 20 to 120 DAIR. The 100 seed sample for each treatment was taken randomly and placed those in water soaked blotting papers in petridish, and preserved for 5 days at room temperature ranging from 27^{o}C to 34^{o}C for maximum germination of the seeds. After complete germination, the number of germinated seeds was counted and recorded.

Finally, the per cent seed germination and per cent increase of seed germination over control were calculated using the following formulae:

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

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

Where

X_1 = Mean value of treated pot

X_2 = Mean value of untreated pot

Experiment 2: Effect of some promising fumigants for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage

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

3.2.1. Design of the experiment

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

3.2.2. Materials used in the study

Sixteen (16) kg of newly harvested pulse beetle were purchased and collected from the Agricultural Farm of Sher-e-Bangla Agricultural University, Dhaka. The collected mungbean seeds were then used in this experiment considering the procedures as mentioned earlier in the Experiment1. The lid of the containers were not perforated due to fumigants are used as treatments.

3.2.3. Germination test of the seeds

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

3.2.4. Treatments

There were three promising fumigants viz. camphor, phostoxin tablet and naphthalene evaluated in this experiment, where each fumigant was treated as an individual treatment. Besides these fumigants, one untreated control was also considered.

The treatments and their doses selected for the experiment have been furnished below:

Treatments	Fumigants	Dose of the fumigants

T_1	Camphor	1.0 g /kg mungbean grains
T_2	Phostoxin tablet	200 mg /kg mungbean grains
T_3	Naphthalene	500 mg /kg mungbean grains
T_4	Untreated control	No fumigant was used

3.2.5. Collection and description of the fumigants

The camphor, phostoxin tablet and naphthalene were from local market of the Agargaon bazaar, and Siddik bazaar, Dhaka.

(b) Naphthalene

(a)**Camphor**

(c) Phostoxin container with tablets

Plate 3. Different fumigants (a) Camphor, (b) Napthalene, (c) Phostoxin container with tablet

3.2.6. Application of the fumigants

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

3.2.7. Release of *C. chinensis* Linn.

100 pairs of *C. chinensis* from stock culture were released on the mungbean grains for each treatment and replication considering the similar procedure as mentioned in the earlier experiment. The containers were then covered with their respective lids and preserved in ambient temperature of the laboratory up to 4 months that is 120 days after insect release (DAIR) for recording the data.

3.2.8. Data sampling, collection and recording

The data on grain infestation by number and weight, adult emergence, grain content loss, and seed germinations were recorded. The data were collected and recorded at 20 days intervals started from 20 DAIR and continued up to 120 DAIR considering the sampling procedure as mentioned earlier in the Experiment 1.

CHAPTER IV
RESULTS AND DISCUSSION

The study was conducted to find out the efficacy of some promising botanicals and fumigants for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. infesting mungbean under two separate experiments in the laboratory under the Department of Entomology at Sher-e-Bangla Agricultural University, Dhaka during the period from April, 2011 to July, 2011. The findings of the study have been interpreted and discussed under the following sub-headings:

Experiment 1. Effect of some promising botanicals for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage

The significant variations were observed among five promising botanicals viz. dried neem leaf powder, dried bishkatali leaf powder, dried marigold leaf powder, dried dholkolmi leaf powder and bulb of garlic including untreated control applied against pulse beetle, *C. chinensis* L. in respect of grain infestation by number and weight, grain content loss, adult emergence and viability of mungbean seeds.

4.1.1. Effect of botanicals on grain infestation by number

The significant variations were observed among different botanical based management practices in terms of percent grain infestation by number throughout the storing period starting from 20 to 120 days after insect release (DAIR) considering 20 days interval during the management of pulse beetle, *C. chinensis* on mungbean. In case of 20 DAIR, the highest grain infestation (45.73%) was observed in T_6, which was statistically different from all other treatments followed by T_3 (40.57%). This was also followed by T_2 (31.57%) and T_5 (31.18%) (Table 1). On the other hand, the lowest grain infestation (27.19%) was found in T_1 followed by T_4 (30.31%).

In case of 40 DAIR, the highest grain infestation (51.40%) was recorded in T_6, which was statistically different from all other treatments followed by T_3 (46.32%). This was also followed by T_2 (37.12%) and T_4 (36.98%) (Table 1). On the other hand, the lowest grain infestation (27.20%) was recorded in T_5 (36.79%). More or less similar trends of results were also recorded in case of 60, 80, 100 and 120 DAIR in terms of percent grain infestation by number.

Table 1: Effect of botanicals on the mungbean grain infestation by number aganist *C. chinensis* during April to July, 2011

Treatment	% Grain infestation by number							% grain infestation reduction over control
	20 DAIR	40 DAIR	60 DAIR	80 DAIR	100 DAIR	120 DAIR	Mean	
T_1	27.1e	27.2d	28.1d	29.5e	31.7e	33.0e	29.47e	43.12
T_2	31.5c	37.1c	38.8c	42.8c	42.6c	43.7c	39.47c	23.83
T_3	40.5b	46.3b	48.3b	50.7b	51.9b	52.5b	48.41b	6.57
T_4	30.3cd	36.9c	38.9c	40.5d	40.7d	41.9d	38.24d	26.20
T_5	31.1c	36.7c	39.7c	41.8c	41.9c	43.2c	39.10c	24.54
T_6	45.7a	51.4a	52.1a	52.5a	53.0a	55.9a	51.81a	--
$LSD_{(0.05)}$	1.32	1.22	1.02	1.11	1.35	0.94	0.91	--
CV(%)	3.32	2.16	3.14	3.24	3.11	2.54	3.26	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Dried neem leaf powder @ 2.5 g/kg mungbean grain, T_2= Dried bishkatali leaf powder @ 2.5 g/kg mungbean grain, T_3= Dried marigold leaf powder @ 2.5 g/kg mungbean grain, T_4= Dried dholkolmi leaf powder @ 2.5 g/kg mungbean grain. T_5=Bulb of garlic@1g/kg grain, T_6=Untreated control]

Considering the mean grain infestation by number, the highest grain infestation (51.81%) was recorded in T_6, which was statistically different from all other treatments followed by T_3 (48.41%). This was also followed by T_2 (39.47%). On the other hand, the lowest grain infestation (29.47%) in T_4 (38.24%) and T_5 (39.10%).

In case of grain infestation reduction over control, the highest reduction (43.12%) was recorded in T_1 followed by T_4 (26.20%) and T_5 (24.54%). On the other hand, the lowest grain infestation reduction (6.57%) was observed in T_3 followed by T_2 (23.83%).

From the above findings it was revealed that among five botanical based treatments, the T_1 comprised of dried neem leaf powder @ 2.5 g/kg grain performed as the best treatment, which reduced the highest grain infestation (43.12%) over control followed by T_4 (26.20%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. On the other hand, the lowest grain infestation reduction over control (6.57%) was achieved in T_3 comprised of dried marigold leaf powder @ 2.5 g/kg grain followed by T_2 (23.83%) comprised of dried bishkatali leaf powder @ 2.5 g/kg grain. The order of effectiveness of different botanicals aganist *C. chinensis* in terms of percent reduction of grain infestation by number is $T_1 > T_4 > T_5 > T_2 > T_3$.

More or less similar findings were also found by several researchers. Babu *et al*. (1989) reported that among neem, karanja, mustard, groundnut and castor oils, the karanja oil (5 and 10 ml/kg) and castor oil (10 l/kg) effectively reduced the oviposition by the *C. chinensis* under conditions of artificial infestation. After 24 months of storage, the infestation of neem oil treated seed was significantly lower.

Similar findings were also obtained by Veer-Singh and Yadav (2003) and Dhakshinamoorthy and Selvanarayanan (2002) and they found that neem treatment against pulse beetle was more effective.

4.1.2. Effect of botanicals on grain infestation by weight

The significant variations were observed among different botanical based management practices in terms of percent grain infestation by weight throughout the storing period starting from 20 to 120 (DAIR) considering 20 days interval during the management of pulse beetle, *C. chinensis* on mungbean. In case of 20 DAIR, the highest grain infestation was found in T_6 (42.08%), which was statistically different from all other treatments followed by T_3 (38.75%) and also followed by T_4 (36.25%) and T_2 (33.33%) (Table 2). On the other hand, the lowest grain infestation by weight in T_1 (22.25%) followed by T_5 (27.19%).

In case of 40 DAIR, the highest grain infestation (43.75%) was also recorded in T_6, which was statistically different from all other treatments followed by T_3 (42.92%) (Table 2). This was also followed by T_4 (37.92%) and T_2 (35.00%). On the other hand, the lowest grain infestation was found in T_1 (22.08%). More or less similar trend of results were also observed in case of 60, 80, 100 and 120 DAIR in terms of percent grain infestation by weight.

Considering the mean grain infestation by weight, the highest grain infestation (46.11%) was recorded in T_6, which was statistically different from all other treatments followed by T_3 (45.07%). This was also followed by T_4 (39.79%). On the other hand, the lowest grain infestation by weight was found in T_1 (26.88%) followed by T_5 (35.35%).

In case of grain infestation reduction over control, the highest reduction (41.72%) was recorded in T_1 followed by T_5 (23.35%) and T_2 (15.67%). On the other hand, the lowest grain infestation reduction (2.25%) was recorded in T_3 followed by T_4 (13.70%).

Table 2: Effect of botanicals on the mungbean grain infestation by weight aganist *C. chinensis* during April to July, 2011

Treatment	% Grain infestation by weight							% grain infestation reduction over control
	20 DAIR	40 DAIR	60 DAIR	80 DAIR	100 DAIR	120 DAIR	Mean	
T_1	21.25f	22.08f	23.33e	27.92e	32.92e	33.75d	26.88e	41.72
T_2	33.33d	35.00d	38.33c	40.83c	41.25c	44.58b	38.89c	15.67
T_3	38.75b	42.92b	45.00b	46.25b	47.75b	49.75a	45.07ab	2.255
T_4	36.25c	37.92c	38.33c	40.00c	41.67c	44.58b	39.79c	13.70
T_5	28.75e	32.08e	35.00d	37.08d	38.33d	40.83c	35.35d	23.35
T_6	42.08a	43.75a	45.83a	47.08a	47.92a	50.00a	46.11a	--

LSD $_{(0.05)}$	0.48	0.65	1.02	1.10	0.86	1.27	0.94	--
CV(%)	3.02	3.36	2.28	3.58	3.18	3.34	2.27	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Dried neem leaf powder @ 2.5 g/kg mungbean grain, T_2= Dried bishkatali leaf powder @ 2.5 g/kg mungbean grain, T_3= Dried marigold leaf powder @ 2.5 g/kg mungbean grain, T_4= Dried dholkolmi leaf powder @ 2.5 g/kg mungbean grain. T_5=Bulb of garlic@1g/kg grain, T_6=Untreated control]

From the above findings it was revealed that among five botanical based treatments, the T_1 comprised of dried neem leaf powder @ 2.5 g/kg grain also performed best result, which reduced the highest grain infestation (41.72%) over control followed by T_5 (23.35%) comprised of bulb of garlic @ 1.0 g/kg grain. On the other hand, the lowest grain infestation reduction over control (2.25%) was achieved in T_3 comprised of dried marigold leaf powder @ 2.5 g/kg grain followed by T_4 (13.70%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. The order of effectiveness of different botanicals against *C. chinensis* in terms of grain infestation reduction by weight is $T_1 > T_5 > T_2 > T_4 > T_3$.

Similar findings were also obtained by Veer-Singh and Yadav (2003) and Dhakshinamoorthy and Selvanarayanan (2002) and they found that neem treatment against pulse beetle was more effective.

4.1.3. Effect of botanicals on the adult emergence of *C. chinensis* during its management

The significant variations were observed among different botanical based management practices in terms of adult emergence throughout the storing period starting from 40 to 120 (DAIR) considering 20 days interval during the management of pulse beetle, *C. chinensis* on mungbean. In case of 40 DAIR, the highest number of adult emergence was recorded in T_6 (3.67/10 infested grains) which was statistically different from all other treatments followed by T_1 (3.33/10 infested grains) and also followed by T_2 (3.00/10 infested grains) (Table 3). On the other hand, the lowest number of adult emergence was recorded in T_5 (1.00/10 infested grains) followed by T_3 (2.00/10 infested grains).

In case of 60 DAIR, the highest number of adult emergence (6.00/10 infested grains) was recorded in T_6, which was statistically different from all other treatments followed by T_2 (5.33/10 infested grains) (Table 3). This was also followed by T_1 (5.00/10 infested grains) and T_4 (4.67/10 infested grains). On the other hand, the lowest adult emergence was recorded in T_5 (3.33/10 infested grains). More or less similar trends of results were also recorded in case of 80, 100 and 120 DAIR regarding the number of adult emergence of pulse beetle during its management.

Table 3: Effect of botanicals on adult emergence during 40 days after insect release to 120 days after insect release of *C. chinensis*

Treatment	Adult emergence (No./10 infested seeds)						% adult emergence reduced over control
	40 DAIR	60 DAIR	80 DAIR	100 DAIR	120 DAIR	Mean	
T_1	3.33b	5.00c	5.00d	5.33d	7.00c	5.13b	18.12
T_2	3.00c	5.33b	5.67c	6.00c	6.67d	5.33b	14.90
T_3	2.00d	4.00e	6.00b	6.67b	7.33b	5.20b	17.04
T_4	3.00c	4.67d	4.67e	5.33d	7.00c	4.93c	21.28
T_5	1.00d	3.33f	4.00f	4.33e	5.00e	3.53d	43.65
T_6	3.67a	6.00a	6.67a	7.33a	7.67a	6.27a	--
$LSD_{(0.05)}$	0.03	0.04	0.04	0.03	0.05	0.21	--
CV(%)	2.03	3.02	3.64	3.43	3.00	3.11	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Dried neem leaf powder @ 2.5 g/kg mungbean grain, T_2= Dried bishkatali leaf powder @ 2.5 g/kg mungbean grain, T_3= Dried marigold leaf powder @ 2.5 g/kg mungbean grain, T_4= Dried dholkolmi leaf powder @ 2.5 g/kg mungbean grain. T_5=Bulb of garlic@1g/kg grain, T_6=Untreated control]

Considering the mean adult emergence, the highest number adult emergence (6.27/10 infested grains) was recorded in T_6, which was statistically different from all other treatments followed by T_2 (5.33/10 infested grains). This was also followed by T_1 (5.13/10 infested grains). On the other hand, the lowest number of adult emergence was recorded in T_5 (3.53/10 infested grains) followed by T_4 (4.93/10 infested grains).

In case of adult emergence reduction by number over control, the highest reduction (43.65%) as recorded in T_5 followed by T_4 (21.28/%) and T_1 (18.12%). On the other hand, the lowest adult emergence reduction by number (14.90%) was recorded in T_2 followed by T_3 (17.04%).

From the above findings it was revealed that among five botanical based treatments, the T_5 comprised of bulb of garlic @ 1.0 g/kg grain performed as the best treatment, which reduced the highest adult emergence by number (43.65%) over control followed by T_4 (21.28%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. On the other hand, the lowest adult emergence reduction over control (14.90%) was achieved by T_2 comprised of dried bishkatali leaf powder @ 2.5 g/kg grain followed by T_3 (17.04%) comprised of dried marigold leaf powder @ 2.5 g/kg grain. The order of effectiveness of different botanicals against *C. chinensis* in terms of adult emergence reduction by number is $T_5 > T_4 > T_1 > T_3 > T_2$.

The results obtained from Saxena and Saxena (2009) was not similar. They found that neem kernel was more effective than garlic. Two per cent concentration of garlic solvents also showed 50% mortality in mungbean crops. Similar result was also found by Singal and Chauhan (2008).

4.1.4. Effect of botanicals on the grain content loss caused by *C. chinensis* during 120 days after insect release

Grain content losses by weight were significantly varied by different botanicals applied against pulse beetle, *C. chinensis* during its management. After 4 months (i.e. 120 DAIR), it was observed that the highest grain content loss was found in T_6 (48.33%), which was statistically different from all other treatments followed by T_3 (42.67%) and T_4 (34.00%) (Table 4). On the other hand, the lowest grain content loss by weight (24.21%) was recorded in T_5 followed by T_2 (28.55%).

Table 4: Effect of botanicals on mungbean grain content loss during 120 days after insect release of *C. chinensis*

Treatment	Grain content loss(%) by weight	% grain content loss reduction over control
T_1	32.17d	33.44
T_2	28.55e	40.93
T_3	42.67b	11.71
T_4	34.00c	29.65
T_5	24.21e	49.91
T_6	48.33a	--
LSD $_{(0.05)}$	1.03	--
CV(%)	2.00	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Dried neem leaf powder @ 2.5 g/kg mungbean grain, T_2= Dried bishkatali leaf powder @ 2.5 g/kg mungbean grain, T_3= Dried marigold leaf powder @ 2.5 g/kg mungbean grain, T_4= Dried dholkolmi leaf powder @ 2.5 g/kg mungbean grain. T_5=Bulb of garlic@1g/kg grain, T_6=Untreated control]

In case of grain content loss reduction over control, the highest reduction (49.91%) was recorded in T_5 followed by T_2 (40.93%) and T_1 (33.44%) (Table 4). On the other hand, the lowest grain content loss reduction over control (11.71%) was recorded in T_3 followed by T_4 (29.65%).

From the above findings it was revealed that among five botanical based treatments, the T_5 comprised of bulb of garlic @ 1.0 g/kg grain performed as the best treatment, which reduced the highest grain content loss (49.91%) over control followed by T_2 (40.93%) comprised of dried bishkatali leaf powder @ 2.5 g/kg grain. On the other hand, the lowest grain content loss reduction over control (11.71%) was achieved in T_3 comprised of dried marigold leaf powder @ 2.5 g/kg grain followed by T_4 (29.65%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. The order of effectiveness of different botanicals against *C. chinensis* in terms of grain infestation reduction is $T_5 > T_2 > T_1 > T_4 > T_3$.

Under the present study, garlic showed the best result and it might be due to cause of its pungent smell and also its chemical properties that cause reduced attack of pulse beetle and as a result of lowest grain content loss.

4.1.5. Effect of botanicals on viability mungbean of seed

The significant variations were observed among different botanical based management practices in terms of percent germination by number of mungbean seed throughout the storing period starting from 20 to 120 DAIR considering 20 days interval during the management of pulse beetle, *C. chinensis* on mungbean. In case of 20 DAIR, the maximum seed germination was recorded in T_5 (94.67%), which was statistically different from all other treatments followed by T_1 (92.67%) and also followed by T_4 (88.67%) (Table 1). On the other hand, the minimum percent seed germination in T_6 (84.67%) followed by T_2 (88.00%).

Table 5: Effect of botanicals on the germination of mungbean during 20 days after insect release to 120 days after insect release of *C. chinensis*

Treatment	% seed germination by number							% seed germination increase over control
	20 DAIR	40 DAIR	60 DAIR	80 DAIR	100 DAIR	120 DAIR	Mean	
T_1	92.6b	78.6d	78.0b	76.0b	76.0b	72.0c	78.8b	8.40

T_2	88.0c	78.6d	76.0d	71.3d	70.0d	68.0e	75.3d	3.51
T_3	88.0c	82.6b	78.6b	75.3c	76.0b	73.3b	79.0b	8.55
T_4	88.6c	80.0c	77.3c	75.3c	70.67d	69.3d	76.8c	5.65
T_5	94.6a	92.6a	91.3a	90.6a	90.0a	89.3a	91.4a	25.65
T_6	84.6d	77.3e	73.3e	70.0e	67.3e	64.0f	72.7e	--
LSD $_{(0.05)}$	0.68	0.74	0.82	0.64	0.66	0.58	0.67	--
CV(%)	3.12	2.66	2.10	3.38	2.11	3.00	3.01	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Dried neem leaf powder @ 2.5 g/kg mungbean grain, T_2= Dried bishkatali leaf powder @ 2.5 g/kg mungbean grain, T_3= Dried marigold leaf powder @ 2.5 g/kg mungbean grain, T_4= Dried dholkolmi leaf powder @ 2.5 g/kg mungbean grain. T_5=Bulb of garlic@1g/kg grain, T_6=Untreated control]

In case of 40 DAIR, the maximum germination by number (92.67%) was recorded in T_5 which was statistically different from all other treatments followed by T_3 (82.67%) (Table 5). This was also followed by T_4 (80.00%) and T_1 (78.67). On the other hand, the minimum seed germination was recorded in T_6 (77.33%) followed by T_1 (78.67). More or less similar trends of results were also recorded in case of 60, 80, 100 and 120 DAIR in terms of per cent germination of mungbean seed.

Considering the mean germination, the maximum germination of mungbean seed (91.45%) was observed in T_5, which was statistically different from all other treatments followed by T_3 (79.00%). This was also followed by T_1 (78.89%). On the other hand, the minimum germination was found in T_6 (72.78%) followed by T_2 (75.33%).

In case of seed germination increase over control, the highest increase (25.65%) was recorded in T_5 followed by T_3 (8.55%) and T_1 (8.40%). On the other hand, the lowest percent germination increase (3.51%) over control was recorded in T_2 followed by T_4 (5.65%).

From the above findings it was revealed that among five botanical based treatments, the T_5 comprised of bulb of garlic @ 1.0 g/kg grain performed as the best treatment, which increased the highest seed germination (25.65%) over control followed by T_3

(8.55%) comprised of dried marigold leaf powder @ 2.5 g/kg grain. On the other hand, the lowest seed germination increase over control (6.57%) was found in T_2 comprised of dried bishkatali leaf powder @ 2.5 g/kg grain followed by T_4 (5.65%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. The order of effectiveness of different botanicals against *C. chinensis* in terms of seed germination increase is $T_5 > T_3 > T_1 > T_4 > T_2$.

This result might be due to cause of garlic's repulsive and chemical characters that cause reduced infestation of grains and resulted highest germination of seeds.

Experiment 2. Effect of some promising fumigants for eco-friendly management of pulse beetle, *Callosobruchus chinensis* L. on mungbean in storage

The significant variations were observed among three promising fumigants viz. camphor, phostoxin tablet, napthlene and one untreated control applied against pulse beetle, *C. chinensis* L. in respect of grain infestation by number and weight, grain content loss, adult emergence and viability of mungbean seeds.

4.2.1. Effect of fumigants on grain infestation by number

The significant variations were observed among different fumigant based management practices in terms of percent grain infestation by number throughout the storing period starting from 20 to 120 (DAIR) considering 20 days interval during the management of pulse beetle, *C. chinensis* on mungbean. In case of 20 DAIR, the highest grain infestation by number (45.73%) was recorded in T_4 comprised of untreated control, which was statistically different from all other treatments followed by T_3 (31.57%) comprised of napthlene (Table 6). On the other hand, the lowest grain infestation by number (20.29%) was recorded in T_1. In case of 40 DAIR, the highest grain infestation by number (51.40%) was recorded in T_4 comprised of untreated control, which was statistically different from all other treatments followed by T_3 (32.04%) (Table 6). On the other hand, the lowest grain infestation (22.59%) was recorded in T_1 (36.79%) followed by T_2 (28.51%). More or less similar trends of results were also recorded in case of 60, 80, 100 and 120 DAIR in terms of percent grain infestation by number.

Considering the mean grain infestation by number, the highest grain infestation (51.81%) was recorded in T_4, which was statistically different from all other treatments followed by T_3 (34.77%). On the other hand, the lowest grain infestation (26.09%) was recorded in T_1 followed by T_2 (29.47%).

In case of grain infestation reduction over control, the highest reduction (49.65%) was recorded in T_1 followed by T_2 (43.13%). On the other hand, the lowest grain infestation reduction (32.89%) was recorded in T_3.

Table 6: Effect of fumigants on the mungbean grain infestation by number aganist *C. chinensis* during April to July, 2011

Treatments	% Grain infestation by number							% grain infestation reduction over control
	20 DAIR	40 DAIR	60 DAIR	80 DAIR	100 DAIR	120 DAIR	Mean	
T_1	20.29d	22.59d	24.63d	29.28c	29.76c	29.98c	26.09d	49.65
T_2	27.80c	28.51c	29.45c	30.17c	30.23c	30.63c	29.47c	43.13
T_3	31.57b	32.04b	33.17b	35.98b	37.12b	38.74b	34.77b	32.89
T_4	45.73a	51.40a	52.17a	52.58a	53.05a	55.93a	51.81a	--
$LSD_{(0.05)}$	1.37	1.01	1.32	2.06	1.58	1.62	1.99	--
CV(%)	2.12	2.38	3.20	3.22	3.04	3.15	3.27	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Camphor @ 1 g/kg mungbean grain, T_2=Phostoxin @ 200 mg/kg mungbean grain, T_3=Napthlene @ 500 mg/kg mungbean grain, T_4= Untreated control]

From the above findings it was revealed that among three fumigant based treatments, the T_1 comprised of camphor @ 1 g/kg mungbean grain performed as the best treatment, which reduced the highest grain infestation (49.65%) over control followed by T_2 (43.13%) comprised of phostoxin @ 200 mg/kg grain. On the other hand, the lowest grain infestation reduction over control (32.89%) was achieved in T_3

comprised of napthalene @ 500 mg/kg grain. The order of efficacy of different fumigants against *C. chinensis* in terms of grain infestation reduction by number is $T_1 > T_2 > T_3$.

Another findings obtained by Ahmed *et al*. (2006) was similar. They experimented in mungbean seeds and were stored for two years in different containers with two types of chemicals (naphthalene and camphor) and two types of indigenous materials (sand and neem leaf powder). They observed that camphor provided better protection than other materials for all the containers and storage period.

4.2.2. Effect of fumigants on grain infestation by weight

The significant variations were observed among different fumigants based management practices in terms of grain infestation by weight throughout the storing period starting from 20 to 120 DAIR considering 20 days interval during the management of pulse beetle, *C. chinensis* on mungbean. In case of 20 DAIR, the highest grain infestation was recorded in T_4 (42.08%) which was statistically different from all other treatments followed by T_3 (31.25%) (Table 7). On the other hand, the lowest grain infestation (19.17%) was recorded in T_1.

In case of 40 DAIR, the highest grain infestation by weight (43.75%) was recorded in T_4 which was statistically different from all other treatments followed by T_3 (32.92%) (Table 7). On the other hand, the lowest grain infestation was recorded in T_1 (20.00%). More or less similar trends of results were also recorded in case of 60, 80, 100 and 120 DAIR in terms of percent grain infestation by weight.

Considering the mean grain infestation by weight, the highest grain infestation (46.11%) was recorded in T_4, which was statistically different from all other treatments followed by T_3 (34.86%). On the other hand, the lowest grain infestation was recorded in T_1 (23.27%).

In case of grain infestation reduction over control, the highest reduction (49.54%) was recorded in T_1 followed by T_2 (26.80%). On the other hand, the lowest grain infestation reduction (24.40%) over control was recorded in T_3.

Table 7: Effect of fumigants on the mungbean grain infestation by weight aganist *C. chinensis* during April to July, 2011

Treatment	% Grain infestation by weight							% grain infestation reduction over control
	20 DAIR	**40 DAIR**	**60 DAIR**	**80 DAIR**	**100 DAIR**	**120 DAIR**	**Mean**	
T_1	19.1d	20.0c	22.5c	25.00c	26.2c	26.67c	23.27c	49.54
T_2	26.6c	31.6b	32.5b	36.25b	37.5b	37.92b	33.75b	26.80
T_3	31.2b	32.9b	33.3b	35.00b	38.3b	38.33b	34.86b	24.40
T_4	42.0a	43.7a	45.8a	47.08a	47.9a	50.00a	46.11a	--
$LSD_{(0.05)}$	1.15	1.68	1.88	1.49	2.01	1.81	1.65	--
CV(%)	3.22	3.62	3.29	2.55	3.23	2.86	3.85	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Camphor @ 1 g/kg mungbean grain, T_2=Phostoxin @ 200 mg/kg mungbean grain, T_3=Napthlene @ 500 mg/kg mungbean grain, T_4= Untreated control]

From the above findings it was revealed that among three fumigant based treatments, T_1 comprised of camphor @ 1 g/kg grain performed as the best treatment, which reduced the highest grain infestation (49.54%) over control followed by T_2 (26.80%) comprised of phostoxin tablet @ 200 mg/kg grain. On the other hand, the lowest grain infestation reduction (24.40%) over control was achieved by T_3 comprised of napthlene @ 500 mg/kg mungbean grain. The order of efficacy of different fumigants against *C. chinensis* in terms of grain infestation reduction by weight is $T_1 > T_2 > T_3$.

Ahmed *et al*. (2006) found similar findings in mungbean seeds taht were stored for two years in different containers with two types of chemicals (naphthalene and camphor) and two types of indigenous materials (sand and neem leaf powder). They observed that camphor provided better protection than other materials for all the containers and storage period.

4.2.3. Effect of fumigants on the adult emergence of *C. chinensis*

The significant variations were observed among different fumigant based management practices in terms of adult emergence by number throughout the storing period starting from 40 to 120 DAIR considering 20 days interval during the management of pulse beetle, *C. chinensis* on mungbean. In case of 40 DAIR, the highest number of adult emergence was recorded in T_4 (3.67/10 infested seed) which was statistically different from all other treatments followed by T_3 (0.67/10 infested seed) (Table 8). On the other hand, no adult was emerged from T_1 (0.00/10 infested seed) and T_2 (0.00/10 infested seed).

In case of 60 DAIR, the highest number of adult emergence (6.00/10 infested seed) was recorded in T_4 which was statistically different from all other treatments followed by T_3 (1.00/10 infested seed) (Table 8). On the other hand, the lowest number of adult emergence was recorded in T_1 (0.33/10 infested seed). More or less similar trends of results were also recorded in case of 60, 80, 100 and 120 DAIR in terms of adult emergence by number of pulse beetle during its management.

Considering the mean adult emergence, the highest number of adult emergence (6.27/10 infested seed) was recorded in T_4, which was statistically different from all other treatments followed by T_3 (1.73/10 infested seed). On the other hand, the lowest number of adult emergence was recorded in T_1 (1.40/10 infested seed).

In case of adult emergence reduction over control, the highest reduction (77.66%) was recorded in T_2 followed by T_1 (74.47%). On the other hand, the lowest adult emergence reduction (72.37%) was recorded in T_3.

Table 8: Effect of fumigants on adult emergence during 40 days after insect release to 120 days after insect release of *C. chinensis*

Treatment	Adult emergence (No./10 infested seeds)						% adult emergence reduction over control
	40 DAIR	60 DAIR	80 DAIR	100 DAIR	120 DAIR	Mean	
T_1	0.00c	0.33c	0.67d	2.33b	3.67b	1.40c	77.66
T_2	0.00c	0.33c	1.67b	2.33b	3.67b	1.60b	74.47
T_3	0.67b	1.00b	1.33c	2.33b	3.33c	1.73b	72.37
T_4	3.67a	6.00a	6.67a	7.33a	7.67a	6.27a	--
$LSD_{(0.05)}$	0.03	0.08	0.07	0.09	0.08	0.18	--
CV(%)	2.67	3.34	3.23	3.66	3.11	3.25	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Camphor @ 1 g/kg mungbean grain, T_2=Phostoxin @ 200 mg/kg mungbean grain, T_3=Napthlene @ 500 mg/kg mungbean grain, T_4= Untreated control]

From the above findings it was revealed that among three fumigant based treatments, the T_1 comprised of camphor @ 1 g/kg mungbean grain performed as the best treatment, which reduced the highest adult emergence by number (77.66%) over control followed by T_2 (74.47%) comprised of phostoxin @ 200 mg/kg grain. On the other hand, the lowest adult emergence reduction over control (72.37%) was achieved by T_3 comprised of napthalene @ 500 mg/kg grain. The order of efficacy of different fumigants against *C. chinensis* in terms of adult emergence reduction is $T_1 > T_2 > T_3$. Similar finding was found by Latif *et al*. (2005) in case of rice weevil, *Sitophilus oryzae* Linn. (Curculionidae: Coleoptera) in parboiled polished rice grains against camphor and they found that there exists a very sharp difference. The LD_{50} camphor against adult, egg, larva and pupa was the lowest.

4.2.4. Effect of fumigants on the grain content loss

Percent (%) grain content loss was also significantly varied among different fumigants applied against pulse beetle, *C. chinensis* during its management.

Table 9: Effect of fumigants on mungbean grain content loss during 120 days after insect release of *C. chinensis*

Treatment	Grain content loss (%)	% grain content loss reduction over control
T_1	2.33c	95.18
T_2	3.00b	93.79
T_3	3.00b	93.79
T_4	48.33a	--
LSD $_{(0.05)}$	0.06	--
CV(%)	3.12	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Camphor @ 1 g/kg mungbean grain, T_2=Phostoxin @ 200 mg/kg mungbean grain, T_3=Napthlene @ 500 mg/kg mungbean grain, T_4= Untreated control]

After the completion of the experiment (i.e. at 120 DAIR), it was observed that the highest grain content loss was achieved by T_4 (48.33%), which was statistically different from all other treatments followed by T_2 (3.00%) (Table 9). On the other hand, the lowest grain content loss (2.33%) was observed in T_1.

In case of grain content loss reduction over control, the highest reduction (95.18%) was recorded in T_1, which was more or less similar but significant with other two fumigants such as T_2 (93.79) and T_3 (93.79).

From the above findings it was revealed that among three fumigant based treatments, the T_1 comprised of camphor @ 1 g/kg grain performed as the best treatment, which reduced the highest grain content loss (95.18%) over control. On the other hand, the lowest grain content loss reduction over control (93.79%) was achieved by T_2 comprised of phostoxin tablet @ 200 mg/kg grain. The order of efficacy of different fumigants against *C. chinensis* in terms of grain content loss reduction is $T_1 > T_2, T_3$.

The better performance from camphor under the present study might be due to cause of its chemical action which is comparatively better than the others against pulse beetle in mungbean and gave ultimately the best results. Here camphor effectively reduced the pulse beetle infestation and that causes reduced grain content loss.

4.2.5. Effect of fumigants on germination of mungbean seed

The significant variations were also observed among three fumigant based management practices in terms of percent seed germination throughout the storing period starting from 20 to 120 DAIR considering 20 days interval during the management of pulse beetle, *C. chinensis* on mungbean. In case of 20 DAIR, the maximum seed germination was recorded in T_1 (94.67%) which was statistically identical with all other treatments (Table 10). On the other hand, the lowest seed germination in T_4 (84.67%).

In case of 40 DAIR, the maximum seed germination (94.00%) was observed in T_1 which was statistically different from all other treatments followed by T_2 (92.67%) (Table 10). On the other hand, the lowest seed germination was recorded in T_4 (77.33%). More or less similar trends of results were also recorded in case of 60, 80, 100 and 120 DAIR in terms of percent mungbean seed germination.

Table 10: Effect of fumigants on the germination of mungbean during 20 days after insect release to 120 days after insect release of *C. chinensis*

Treatment	% seed germination							% seed germination increase over control
	20 DAIR	40 DAIR	60 DAIR	80 DAIR	100 DAIR	120 DAIR	Mean	
T_1	94.6a	94.0a	93.3a	90.6a	90.0a	90.0a	92.1a	26.57
T_2	94.6a	92.6b	91.3b	90.6a	90.0a	89.3a	91.4b	25.65
T_3	92.6b	91.3c	91.0b	90.0a	90.0a	87.3b	90.3c	24.20
T_4	84.6c	77.3d	73.3c	70.0b	67.3b	64.0c	72.7d	--
$LSD_{(0.05)}$	0.31	0.18	0.26	0.21	0.38	0.26	0.22	--
CV(%)	3.17	3.39	3.29	2.55	3.69	3.16	3.63	--

DAIR= Days after insect release

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT.

[T_1=Camphor @ 1 g/kg mungbean grain, T_2=Phostoxin @ 200 mg/kg mungbean grain, T_3=Napthlene @ 500 mg/kg mungbean grain, T_4= Untreated control]

Considering the mean germination, the maximum seed germination (92.11%) was recorded in T_1, which was statistically different from all other treatments followed by T_2 (91.45%). On the other hand, the lowest percent germination in T_4 (72.78%)

In case of increase in percent germination of mungbean seed over control, the highest increase (26.57%) was recorded in T_1 followed by T_2 (25.65%). On the other hand, the lowest percent germination increase (24.20%) was recorded in T_3.

From the above findings it was revealed that among three fumigant based treatments, the T_1 comprised of camphor @ 1 g/kg mungbean grain performed as the best treatment, which increased the maximum seed germination (26.57%) over control followed by T_2 (25.65%) comprised of phostoxin tablet @ 200 mg/kg grain. On the other hand, the lowest grain germination increase over control (24.20%) was achieved by T_3 comprised of napthlene @ 200 mg/kg grain. The order of efficacy of different fumigants in terms of seed germination increase over control is $T_1 > T_2 > T_3$.

Generally seed viability is damaged with insect infection during storage condition. The better performance from camphor under the present study in terms of seed viability might be due to cause of its chemical action which is comparatively better than the others fumigant materials that were used against pulse beetle in mungbean and gave ultimately the best results. Similar findings were also found by Ahmed *et al*. (2006).

4.3. Comparative effectiveness of botanical and fumigant based management practices

The performances of both botanical and fumigant based management practices on the infestation level of pulse beetles on mungbean were elucidated to find out the comparative effectiveness of the treatments and the significant variations were observed as depicted in the following sub-headings and graphical figures.

4.3.1. Comparative performance of botanicals and fumigants on reduction of grain infestation

The data represented in the Figure 1 illustrated that the fumigant based treatments performed better in terms of percent grain infestation reduction over control by number as compared with botanical based treatments during the management of pulse beetle infestation on mungbean. Irrespective of all botanicals and fumigants, Camphor showed the best performance followed by dried neem leaf powder in reducing the grain infestation reduction and the dried marigold leaf powder showed the least performance.

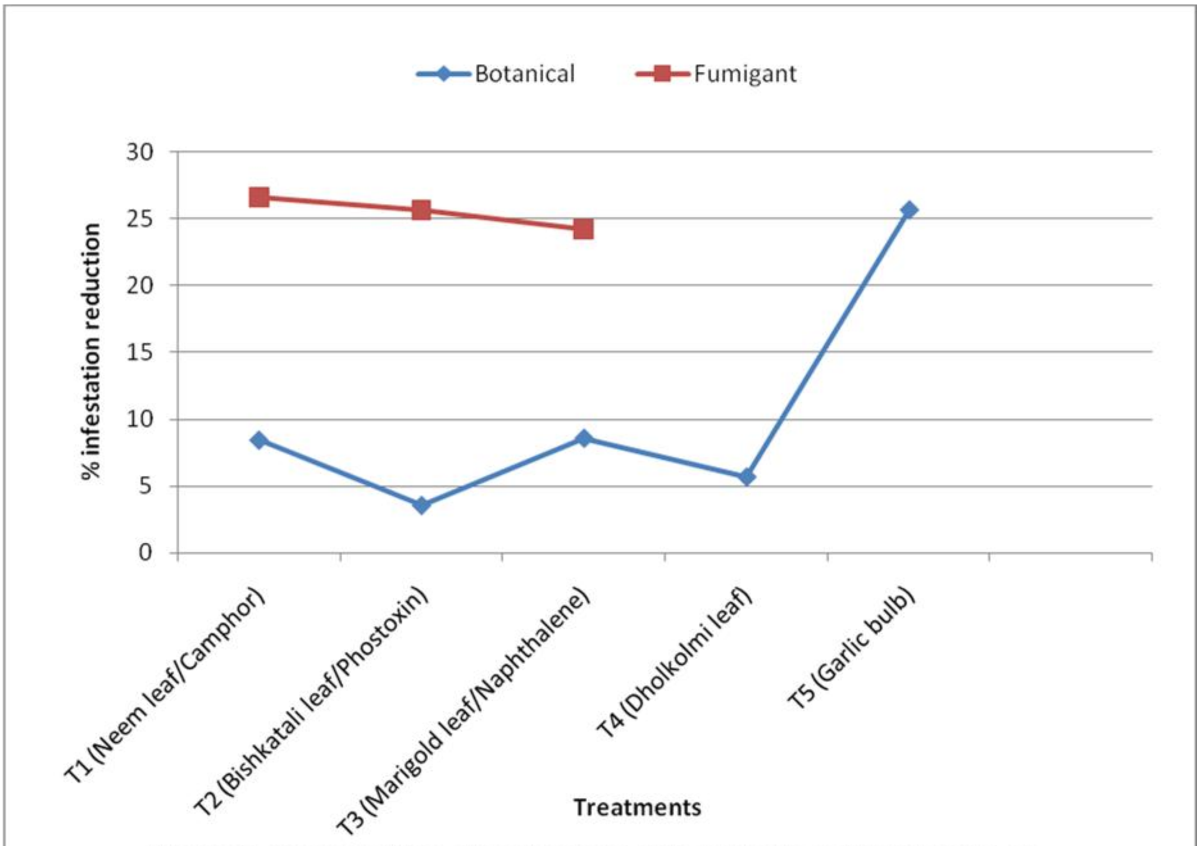


Figure 1. Comparative effectiveness of botanicals and fumigants on the percent grain infestation reduction over control

4.3.2. Comparative performance of botanicals and fumigants in reducing adult emergence of *C. chinensis*

The data represented in the Figure 2 illustrated that the fumigant based treatments performed better in terms of percent adult emergence reduced over control as compared with botanical based treatments during the management of pulse beetle infestation on mungbean. Irrespective of all botanicals and fumigants, Camphor showed the best performance followed by bulb of garlic in reducing the adult emergence reduction and the dried bishkatali leaf powder showed the least performance.

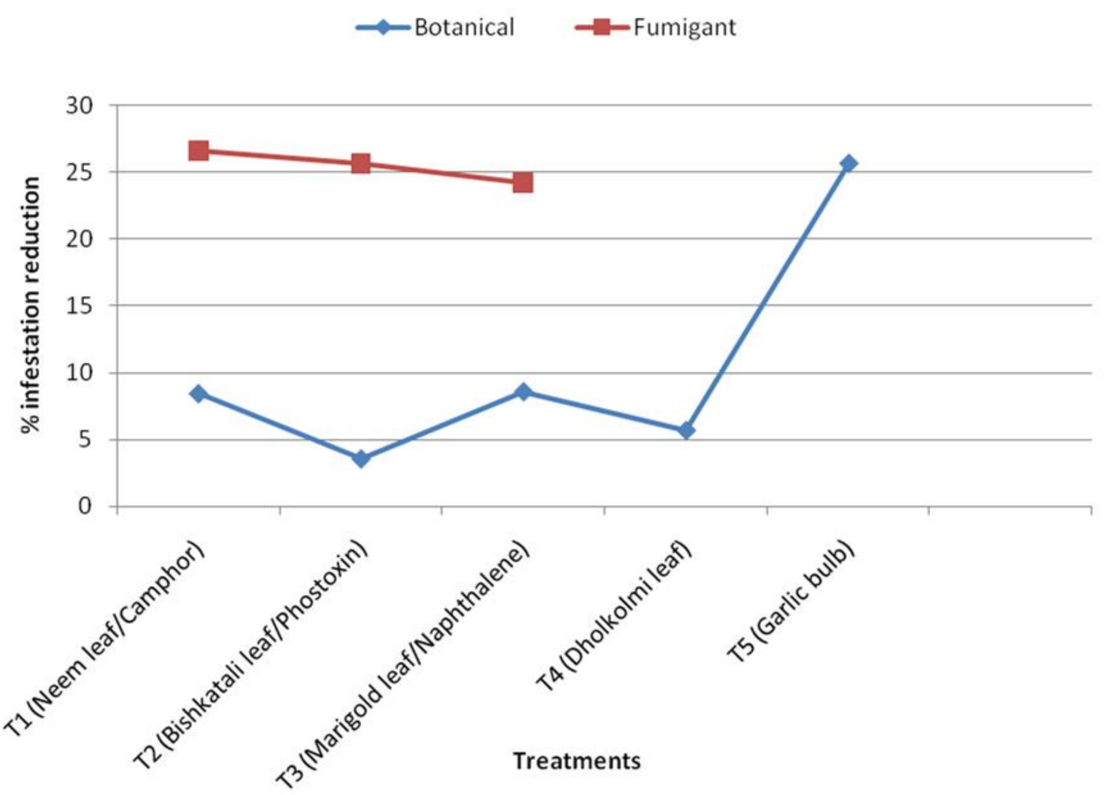


Figure 2. Comparative performance of botanicals and fumigants in reducing adult emergence of *C. chinensis*

4.3.3. Comparative performance of botanicals and fumigants in reducing grain content loss

The data represented in the Figure 3 illustrated that the fumigant based treatments performed better in terms of percent grain content loss reduction over control as compared with botanical based treatments during the management of pulse beetle infestation on mungbean. Irrespective of all botanicals and fumigants, Camphor showed the best performance followed by bulb of garlic in reducing the grain content loss reduction and the dried bishkatali leaf powder showed the least performance.

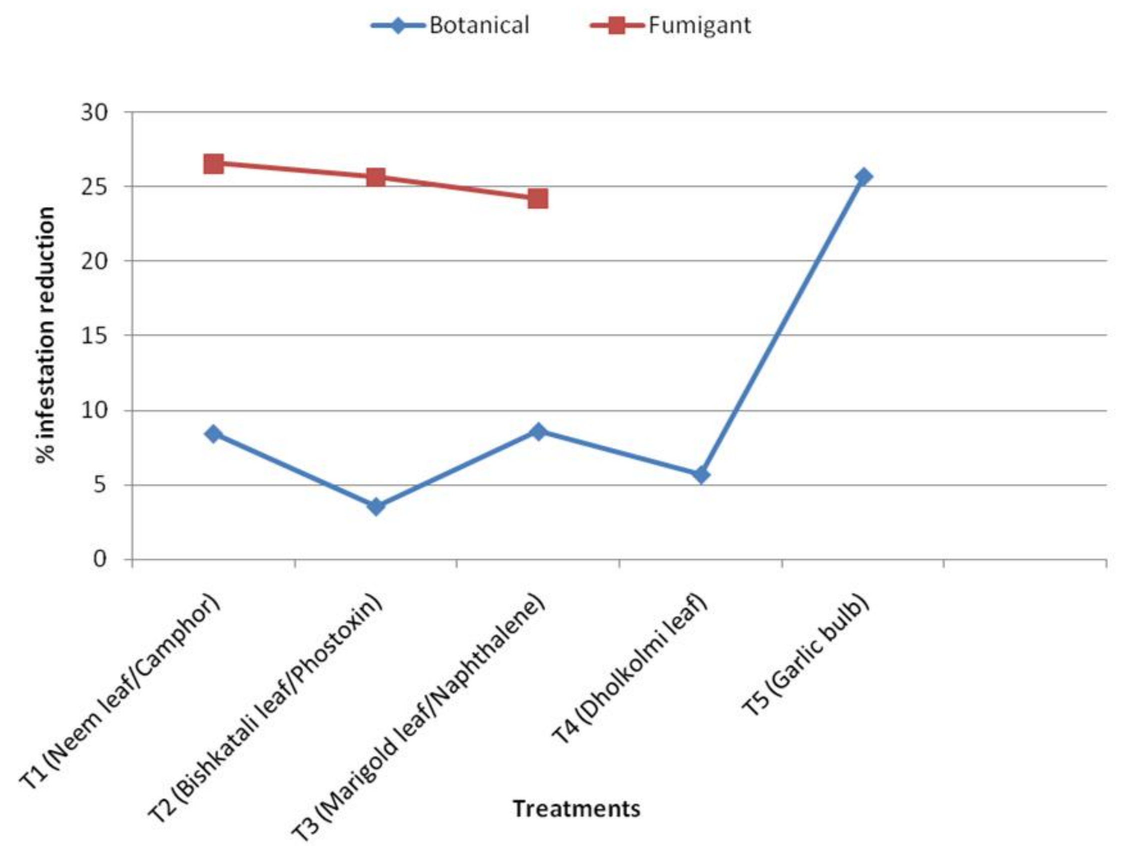


Figure 3. Comparative performance of botanicals and fumigants in reducing grain content loss

4.3.4. Comparative performance of botanicals and fumigants on seed germination

The data represented in the Figure 4 illustrated that the fumigant based treatments performed better in terms of percent seed germination increase over control as compared with botanical based treatments during the management of pulse beetle infestation on mungbean. Irrespective of all botanicals and fumigants, Camphor showed the best performance followed by bulb of garlic in increasing the seed germination reduction and the dried bishkatali leaf powder showed the least performance.

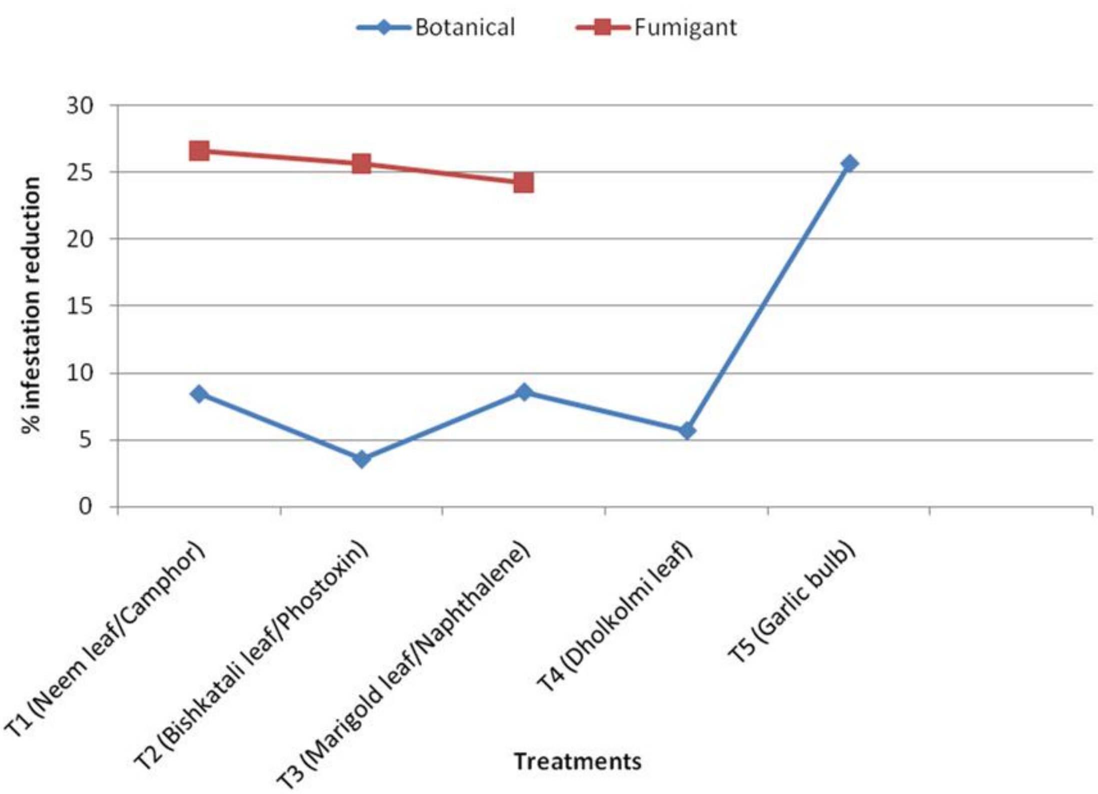


Figure 4. Comparative performance of botanicals and fumigants on seed germination

From the above comparative study it was revealed that the fumigant based treatments performed better in reducing grain infestation, adult emergence, grain content loss and increasing seed germination as compared with botanical based treatments during the management of pulse beetle infestation on mungbean. Irrespective of all botanicals and fumigants, Camphor showed the best performance for above mentioned parameters. Among the botanicals dried neem leaf powder showed the best result in reducing grain infestation, whereas bulb of garlic showed best performance in reducing adult emergence, grain content loss and increasing seed germination during the management of pulse beetle on mungbean in storage.

Plant-derived materials are more readily biodegradable, less toxic to mammals, may be more selective in action, and may retard the development of resistance. It was reported that when mixed with stored-grains, leaf bark, seed powder, or oil extracts of plants reduce oviposition rate and suppress adult emergence of bruchids, and also reduced seed damage rate (Keita *et al*., 2001).

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The study was conducted to find out the efficacy of some promising botanicals and fumigants applied against pulse beetle, *Callosobruchus chinensis* L. on mungbean grains in storage in the laboratory under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during April to July 2011. The study was conducted under two separate experiments. In first experiment, five botanicals along with one untreated control were used viz. (i) T_1 = Dried neem leaf powder @ 2.5 g/kg mungbean grain, (ii) T_2 = Dried bishkatali leaf powder @ 2.5 g/kg mungbean grain, (iii) T_3 = Dried marigold leaf powder @ 2.5 g/kg mungbean grain, (iv) T_4 = Dried dholkolmi leaf powder @ 2.5 g/kg mungbean grain, (v) T_5 = Garlic @ 1 g/kg, (vi) T_6 = Untreated control. While in second experiment, three fumigants along with untreated control treatments were used viz. (i) T_1 = Camphor @ 1 g/kg mungbean grain, (ii) T_2 = Phostoxin tablet @ 200 mg/kg mungbean grain, (iii) T_3 = Naphthalene

@ 500 mg/kg mungbean grain and (iv) T_4 = untreated control. Both the experiments were laid out in Completely Randomized Design (CRD) with 4 replications. Data were collected on grain infestation by number and weight, grain content loss, adult emergence and viability of mungbean seeds as well as the comparative studies on the efficiency of botanicals and fumigants was also done.

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

In terms of percent grain infestation by number, T_1 comprised of dried neem leaf powder @ 2.5 g/kg grain performed as the best treatment, which reduced the highest grain infestation by number (43.12%) over control followed by T_4 (26.20%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. On the other hand, the lowest grain infestation reduction over control (6.57%) was achieved in T_3 comprised of dried marigold leaf powder @ 2.5 g/kg grain followed by T_2 (23.83%) comprised of dried bishkatali leaf powder @ 2.5 g/kg grain. The order of efficacy of different botanicals in terms of grain infestation reduction is T_1 (Dried neem leaf powder) > T_4 (Dried dholkolmi leaf powder) > T_5 (Chopped garlic bulb) > T_2 (Dried bishkatali leaf powder) > T_3 (Dried marigold leaf powder).

Considering percent grain infestation by weight, more or similar trend of results were observed, where T_1 comprised of dried neem leaf powder @ 2.5 g/kg grain performed as the best treatment, which reduced the highest grain infestation (41.72%) over control followed by T_5 (23.35%) comprised of bulb of garlic @ 2.5 g/kg grain. On the other hand, the lowest grain infestation reduction over control (2.25%) was achieved in T_3 comprised of dried marigold leaf powder @ 2.5 g/kg grain followed by T_4 (13.70%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. The order of efficacy of different botanicals in terms of grain infestation reduction is T_1 (Dried neem leaf powder) > T_4 (Dried dholkolmi leaf powder) > T_5 (Chopped garlic bulb) > T_2 (Dried bishkatali leaf powder) > T_3 (Dried marigold leaf powder).

Regarding the adult emergence of *C. chinensis*, T_5 comprised of bulb of garlic @ 1.0 g/kg grain performed as the best treatment, which reduced the highest adult emergence (43.65%) over control followed by T_4 (21.28%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. On the other hand, the lowest adult emergence reduction over control (14.90%) was achieved in T_2 comprised of dried bishkatali leaf powder @ 2.5 g/kg grain followed by T_3 (17.04%) comprised of dried marigold leaf powder @ 2.5 g/kg grain. The order of efficacy of different botanicals in terms of grain infestation reduction was T_5 (Chopped garlic bulb) > T_4 (Dried dholkolmi leaf powder) > T_1 (Dried neem leaf powder) > T_3 (Dried marigold leaf powder) > T_2 (Dried bishkatali leaf powder).

In terms of grain content loss after the completion of the experiment, T_5 comprised of bulb of garlic @ 2.5 g/kg grain performed as the best treatment, which reduced the highest percentage of grain content loss (49.91%) over control followed by T_2 (40.93%) comprised of dried bishkatali leaf powder @ 2.5 g/kg grain. On the other hand, the lowest grain content loss reduction over control (11.71%) was achieved in T_3 comprised of dried marigold leaf powder @ 2.5 g/kg grain followed by T_4 (29.65%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. The order of efficacy of different botanicals in terms of grain infestation reduction was T_5 (Chopped garlic bulb) > T_2 (Dried bishkatali leaf powder) > T_1 (Dried neem leaf powder) > T_4 (Dried dholkolmi leaf powder) > T_3 (Dried marigold leaf powder).

Considering the germination of mungbean seeds, T_5 comprised of bulb of garlic @ 2.5 g/kg grain performed as the best treatment, which increase the highest grain germination (25.65%) over control followed by T_3 (8.55%) comprised of dried marigold leaf powder @ 2.5 g/kg grain. On the other hand, the lowest grain germination increase over control (6.57%) was achieved in T_2 comprised of dried bishkatali leaf powder @ 2.5 g/kg grain followed by T_4 (5.65%) comprised of dried dholkolmi leaf powder @ 2.5 g/kg grain. The order of efficacy of different botanicals in terms of of increasing percent seed germination was T_5 (Chopped garlic bulb) > T_3 (Dried marigold leaf powder) > T_1 (Dried neem leaf powder) > T_4 (Dried dholkolmi leaf powder) > T_2 (Dried bishkatali leaf powder).

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

Regarding the per cent grain infestation by number, T_1 comprised of camphor @ 1 g/kg grain performed as the best treatment, which reduced the highest grain infestation (49.65%) over control followed by T_2 (43.13%) comprised of phostoxin @ 200 mg/kg grain. On the other hand, the lowest grain infestation reduction over control (32.89%) was achieved in T_3 comprised of napthlene @ 500 mg/kg grain. The order of efficacy different fumigants in terms of grain infestation reduction was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene).

In terms of percent grain infestation by weight, T_1 comprised of camphor @ 1 g/kg grain performed as the best treatment, which reduced the highest grain infestation (49.54%) over control followed by T_2 (26.80%) comprised of phostoxin tablet @ 200 mg/kg grain. On the other hand, the lowest grain infestation reduction (24.40%) over control was achieved by T_3 comprised of napthlene @ 500 mg/kg mungbean grain. The order of efficacy different fumigants in terms grain infestation reduction is T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene).

Considering adult emergence of *C. chinensis*, T_2 comprised of camphor @ 1 g/kg mungbean grain performed as the best treatment, which reduced the highest adult emergence by number (77.66%) over control followed by T_3 (74.47%) comprised of phostoxin @ 200 mg/kg grain. On the other hand, the lowest adult emergence reduction over control (72.37%) was achieved by T_1 comprised of napthlene @ 500 mg/kg grain. The order of efficacy different fumigants in terms of percent reduction of adult emergence was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene).

In terms of grain content loss of mungbean after the completion of the experiment, T_1 comprised of camphor @ 1 g/kg grain performed as the best treatment, which reduced the highest grain content loss (95.18%) over control. On the other hand, the lowest grain content loss reduction over control (93.79%) was achieved by T_2 comprised of phostoxin tablet @ 200 mg/kg grain. The order of efficacy different fumigants in terms percent reduction of grain content loss of mungbean was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene).

Considering the viability of mungbean seeds, T_1 comprised of camphor @ 1 g/kg mungbean grain performed as the best treatment, which increased the maximum seed germination (26.57%) over control followed by T_2 (25.65%) comprised of phostoxin tablet @ 200 mg/kg grain. On the other hand, the lowest grain germination increase over control (24.20%) was achieved by T_3 comprised of napthalene @ 200 mg/kg grain. The order of efficacy different fumigants in terms percent increase of seed germination over control was T_1 (Camphor) > T_2 (Phostoxin) > T_3 (Naphthalene).

Considering the comparative study of the efficiency of both botanical and fumigant based management practices, the findings of the results have also been summarized below:

The comparative study revealed that the fumigant based treatments performed better in reducing grain infestation, adult emergence, grain content loss as well as increasing the percent seed germination as compared with botanical based treatments during the management of pulse beetle, *C. chinensis* infestation on mungbean in storage. Irrespective of all botanicals and fumigants, Camphor @ 1.0 g/kg mungbean grains showed the best performance for above mentioned parameters. Among the botanical based management practices, the dried neem leaf powder @ 2.5 g/kg mungbean grains showed the best result in reducing grain infestation, whereas bulb of garlic showed best performance in reducing adult emergence, grain content loss and increasing seed germination during the management of pulse beetle on mungbean in storage.

CONCLUSION

Based on the above findings of the study, the following conclusions have been drawn:

In case of botanical based management practices

- Dried neem leaf powder reduced the highest percent of grain infestation of *C. chinensis* by number and weight (43.12% & 41.72%, respectively) over control than dried leaf powder of dholkolmi, chopped garlic bulb, dried leaf powder of bishkatali and marigold. Whereas, the lowest grain infestation reduction over control (6.57% &2.25%, respectively) was achieved in T_3 comprised of dried marigold leaf powder.
- Chopped bulb of garlic reduced the highest percent of adult emergence (43.65%) over control than dried leaf powder of dholkolmi, neem, bishkatali and marigold, whereas the lowest percent reduction of adult emergence (14.90%) over control was found in dried bishkatali leaf powder.
- In terms of grain content loss, chopped bulb of garlic reduced the highest percentage of grain content loss (49.91%) over control than dried leaf powder of bishkatali, neem, dholkolmi marigold, whereas the lowest percent reduction of grain content loss over control (11.71%) was found in dried marigold leaf powder.

- Considering the viability of mungbean seeds, chopped garlic bulb increased the highest percent seed germination (25.65%) over control than dried leaf powder of marigold, neem, dholkolmi and bishkatali, whereas, the lowest percent increase of seed germination over control (6.57%) was found in dried bishkatali leaf powder.

In case of fumigant based management practices

- In terms of percent reduction of grain infestation by number and weight, camphor reduced the highest percent grain infestation (49.65% &49.54%, respectively) over control than phostoxin and naphthalene, whereas, the lowest percent reduction of grain infestation over control (32.89% & 24.40%, respectively) was found in napthalene.
- Considering adult emergence of *C. chinensis*, camphor reduced the highest percent of adult emergence by number (77.66%) over control than phostoxin (74.47%) and napthlene (72.37%).
- In terms of grain content loss, camphor reduced the highest grain content loss (95.18%) over control than phostoxin and naphthalene (93.79%).
- In terms of seed germination, camphor increased the highest percent of seed germination (26.57%) over control than phostoxin (25.65%) and naphthalene (24.20%)

Considering the comparative study of the efficiency of botanicals and fumigants

- Fumigant based treatments performed superior in terms of the reduction of percent grain infestation, adult emergence, grain content loss as well as increasing the percent seed germination as compared with botanical based treatments.

- Camphor showed the best performance for above mentioned parameters.
- Among the botanical based management practices, the dried neem leaf powder showed the best performance in terms of the percent reduction of grain infestation, whereas bulb of garlic showed best performance in reducing adult emergence, grain content loss and increasing the percent seed germination of mungbean in storage.

Recommendations

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

1. Dried neem leaf powder and camphor may be applied against pulse beetles infesting pulses in storage as effective control measures and human health safety point of view.
2. Further intensive laboratory studies based on both *C. chinensis* and *C. maculatus* may be done.
3. More number of botanicals, their derivatives and fumigants may be included in further elaborative research for controlling insect pests in stored products.

CHAPTER VI

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