EXTENT OF DAMAGE CAUSED BY PULSE BEETLE

(Callosobruchus chinensis Linn.) IN DIFFERENT MUNGBEAN

VARITIES

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CERTIFICATE

This is to certify that the thesis entitled **'EXTENT OF DAMAGE CAUSED BY PULSE BEETLE *(Callosobruchus chinensis Linn.)* IN DIFFERENT MUNGBEAN VARITIES'** 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 **Shorifa Khatun**, Registration number: **11-04354** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017
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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

An experiment was conducted in the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December, 2016 to April, 2017 to know the extent of damage caused by pulse beetle in different mungbean varities. Six varities of mungbean invented by BARI and one local variety were selected for the experiment. This experiment was laid out in a Complete Randomized Design with four replications. The treatment $T_{6,}$ T_1 and T_5 comprising T_3, T_4 and T_7 respectively performed the best results in respect of number of eggs, weight loss and germination capacity over the extent of damage.The lowest number of eggs were found in T_1 (12) and treatment T_7 showed the highest number of eggs (95).The lowest weight loss (27.89%) was recorded from T_6 , while the highest weight loss (48.80%) was recoded in T_7.The highest germination capacity was recorded from (36.50%) T_6 and the lowest germination capacity was recorded in (12.16%) T_7 .

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CHAPTER I

INTRODUCTION

Pulses, the only rich source of vegetable proteins, are common item in the daily diet of the people of Bangladesh. Eight kinds of pulses such as lentil, mungbean, blackgram, grasspea, chickpea, cowpea, fieldpea, and pigeonpea are grown in Bangladesh. Among them mungbean, *Vigna radiata* (L) Wilezek has come up an important pulse crop in Bangladesh. It plays an important role in the dietary pattern of Asian people. Mungbean seed is a nutritious component in the human diet, as well as in livestock feed. It contains 51% carbohydrate, 26% protein, 4% minerals and 3% vitamins (Yadav *et al*. 1994). 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).

Over the years, pulse production is gradually decreasing (Sarwar *et al*. 1981). Several factors are responsible for this declining trend of which varietal instability, attack pulses of insect pests and diseases are important. Insect pests attack both in field and storage. The damage in storage is more crucial than damage in the field. About 85% of the pulse growers in Bangladesh store pulses in their house. The traders mostly store the pulses at least for few months before they sell it. Unfortunately, in storage, pulses suffer enormous losses due to Bruchid attack, infestation starts either in the field on the maturing pod and is carried to the stores with the harvested crops or it originated in the storage itself (Fletcher and Ghosh, 1920).

Three species of pulse beetles, *viz*., *C. chinensis* Linn., *C. analis* Fab., and *C. maculates* Fab. have been reported from Bangladesh as the pest of stored pulses (Begum *et al*. 1984 Rahman *et al*. 1981 and Alam, 1971). Among them

Callosobruchus chinensis to cause enormous losses to almost all kind of pulses in storage condition. In Bangladesh, commonly called pulse beetle, but in America and Japan it is known as the cowpea weevil or adzuki bean beetle. The degree of damage varies with different kinds of legumes on the basis of exposure time, storage facilities and other factors associated with seeds. Under farmers storage condition as high as 98.04%, 73.20%, 53.00%, 54.37%, 64.33% grains of mungbean, blackgram, grasspea, lentil and chickpea respectively, were reported to the damaged by pulse beetle, *C. chinensis* in Bangladesh (Anon. 1984). The rate of increases or decreases with the duration of storage under normal condition i.e., the longer the duration the higher the damage (Gujar and Yadav, 1978). 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 caused 50.37 - 57.58% grain content loss in storage.

In our country, pulses continue to be in short supply; this calls for a review of agricultural policy at national level with some change in emphasis and approach, through which the production of pulses can be greatly increased. Insects destroy at least 5% of the world production of all cereal grains after they are harvested and while they are in storage, on the farms, in elevators or in warehouses. These losses consist of lowered weight and food value, insect adulteration, heating of grains, mould spoilage and low germination of seed.

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. Sometimes persistent pesticides accumulate in the higher food chain of both wildlife and human and become concentrate by biomagnification (Metcalf, 1975).

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

Although many reports have been published on the use of plant products against pulse beetle hosted on lentil, cowpea, chickpea, greengram, arhar but information on the use of plant products in mungbean are scanty. Therefore, the present study was undertaken to fulfil the following objectives:

- To assess the extent of damage in different mungbean varities
- To assess the comparatively less susceptible variety of mungbean against pulse beetle

CHAPTER II

REVIEW OF LITERATURE

Mungbean (*Vigna radiata* L. Wilczek) is an important grain legume in tropical and subtropical region of the world. In Bangladesh, dry seeds of mungbean are consumed as soup and dal, but its sprouts can also be used as a substitute of vegetables, which are rich in iron and vitamins. Mungbean and pulses play a vital role in the diet of the people of Bangladesh. Nutritionally, they are two to three times richer in protein than in other cereal grains and have remind the least expensive source of protein for people since the dawn of the civilization (Kay, 1979). In fact until today, pulses provide the only high protein component of the average diet of the vast majority of the people of Bangladesh (Rahman *et al.* 1988).

As mungbean is tropical and subtropical crop, it is grown as a summer crop and can be cultivated in a wide range of soil. However, yield of mungbean is very low as compared to many other seeds. There are many constraints responsible for the low yield of mungbean. The poor yield mainly due to the varietal aspect, climatic factors, management practices, insect-pest and diseases (Rahman *et al.* 1981).

Besides these, poor yield of mungbean is also associated with the use of low quality seeds. Seed quality may be deteriorated severely by storage pests. The post harvest damage of the seeds caused by a group bruchids is quiet extensive (Suagawara *et al.* 1996). Bruchids are seed feeding weevils that are a common pest of storage pests and can cause downgrading of seed quality. Therefore, the most relevant literatures on the control of pulse beetle utilizing botanicals, physical materials and chemical protectants have been reviewed in this chapter. In addition, the origin, distribution, economic importance of the pulse beetle were reviewed, as these would be relevant and necessary for pest control studies of the beetles.

2.1 Origin and distribution of pulse beetle

Pulse beetle or bruchids (*C. chinensis*) was first reported and described from China in 1978 (Alam 1975), though Southgate (1979) has mentioned that the species of bruchidae have their origin in Afro-Asian region. Rahman *et al.* (1942) recorded that the Bruchidae contain more than 100 injurious species recorded in India. The distribution of *C. chinensis* is worldwide and it has been reported from USA, Mauritius, Hawai, England, Germany, Puerto Rico, Rhodesia, Santa Domonigo, Formosa, Africa, China, Philippines, Japan, Java, Sri Lanka, Myanmar and India. Southgate (1979) has mentioned that the species of Bruchidae bred in every continent except Antarctica. They got the composition distribution through the agency of man. Most of the species live in tropical region of Asia, Africa and Central and South America.

2.2 Economic Importance

Chakraborty *et al.* (2004) reported that the susceptibility of 37 mung bean *(Vigna radiata*) genotypes to pulse beetle (*C. chinensis)* and the correlation between pest susceptibility and different seed parameters were studied in pre-monsoon (March-May) and monsoon (July-September) seasons. The susceptibility parameters, i.e. percentage of affected seeds, number of eggs laid, number of adults emerged and percentage of weight loss were significantly and positively correlated with seed coat width. The moisture and protein contents of seeds had no effect on the susceptibility of mungbean to pulse beetle. The coefficients of variation for seed weight and seed coat width were less than 20%; thus, both characters may be used as indirect selection criteria for resistance to *C. chinensis* in mungbean.

Islam *et al.* (1997) also reported that *C. chinensis* caused extensive damage to chickpea, mungbean, blackgram peas, piegeonpea, cowpea , lentil , lathyrus in Indian subcontinent (Rahman *et al.* 1942, Arora and Singh 1970, Raina 1970)

Islam (1994) reported that *C. chinensis, C. maculatus* and *C. analis* are the major pests of stored legume grains in Bangladesh. The major hosts mungbean , chickpea, cowpea, grasspea, lentil, gardenpea, blackgram and piegeon pea. Among these grains blackgram was found less affected. Fuji and Miyazaki (1987) investigated the resistance of beans of various *vigna* species to infestations with *C. chinensis* in the laboratory in Japan .They found that *V. mungu, V. umbellate, V. amgularis,V. radiate* and *V. trilobata* were susceptible. A race of *V. sublobata*, was also susceptible. This suggests the existence of 2 groups within *V. sublobata*, the supposed progenitor of both *V. mungo* and *V. radiata*.

Begum *et al.* (1982) stated that in Bangladesh, *C. chinensis* is one of the major pests among the *C.* spp. attacking and causing considerable damage to storage legume grains. Southgate (1979) has stated that Bruchidae have been infesting pulses grown by man since the dawn of the agriciulture. Tauthong and Wanleelag (1983) found that among the *C.* spp., the infestation by *C. chinensis* renders beans unsuitable for human consumption. Infested seeds are non viable and sometimes unusual sprouting in mungbean promotes replanting.

Southgate (1979) has observed that a single larvae of *C. maculates* removed about a quarter of the cotyledon of an average size cowpea seed but consume the whole cotyledon of smaller seed of leaving no chance of germination.

Gujar and Yadav (1978) have reported that in India the ratio of food eaten by *C. chinensis* and *C. maculatus* was 1.00; 1.45. The percentage of weight loss in seed ranged from 55.6% to 60.0% due to *C. maculates* and 30.2 to 55.7 due to *C. chinensis.* The losses in protein by *C. chinensis* and *C. maculatus* were 44.55 to 66.3% and 17.0% to 63.5% respectively. In a laboratory study, Ahmed and Ahmed (1969) obtained weight losses to the extent of 22.8%, 44.58% and 61.14% of gram mungbean and blackgram respectively caused by *C. maculates* in a generation of 4 weeks.

2.3 Oviposition

Lambrides and Imrae (2000) reported that the texture, layer present on the seed coat of some mungbean varieties and small seed size might act as oviposition deterrents. Consequently, these assays for determining resistance to bruchid infestation may not be suitable for identifying biochemical resistance of some mungbean genotype.

Buctuanon *et al.* (1997) reported that the influence of different insect and seed sample sizes and heat treatment on the infestation of *C. chinensis* on mungbean, was studied. Insect and seed sample size as well as varieties/genotype had a significant effect on obtaining large responses in the number of eggs and progenies of the weevil. Use of at least 10 adult weevils to infest test samples containing at least 40 seeds for a 5 day oviposition period was shown to produce reliable results when infesting mungbean seeds with unexed weevils.

Dharmasena *et al.* (1986) reported that twelve varieties of mungbean were studied for seed characteristics contributing to resistance to *C.* spp. Varieties with small seeds and glossy seed coats were shown to be associated with a higher degree of resistance than large seeds with a dull surface. Female bruchids find it more difficult to lay their eggs on the highly convex and shiny surfaces of small seed.

Jakhmola and Laxman- Singh (1971) reported that studies with ten varieties showed a positive correlation between seed size and oviposition and it is thought that the low incidence of damage in a small- seeded wild variety is not due to any resistance mechanism per se, but to insect preference for large seeds.

Raina (1970) observed that usually 1 to 3 eggs are laid per pulse seed but as many as 7 eggs have been observed in a single seed. She also found that the female laid an average of 78 eggs ranging from 63 to 90 over a period of 8 days at 30 C with RH 70%on mungbean. Arora and Singh (1970) have been recorded 36 eggs on a single seed of chickpea.

2.4 Larval development

Chakraborty (2003) reported that the biological effect of feeding of *C. chinensis* on seeds of 37 different mungbean genotypes was investigated in the laboratory during 2000 to 2001. The highest hatchability (90%) was recorded on genotype HUM-6, while the lowest (63.3%) was found it on A-89. The incubation period was longest (5.12 days) on A-89 and shortest (3.68 days) on A-189-1.

Moreno *et al.* (2000) reported that the duration of the different states of the cowpea weevils, *C. maculatus* (F), were egg 6.48 days larva 31.84 days, pre pupa 3.41 days, pupa 3.67 days, adult female 11.45 days, adult male 10.9 days. The female grubs shows an oviposition period, with an average duration of 10.2 days. A total fecundity of 63.42 eggs and a percentage of fertility of 46%.Theoritically the rate of increment by generation for *C. maculatus* is 32.025, the intrinsic growth rate was 0.830 and the finite rate of the growth or number of times of manipulation of insects population was 2.29 showing 6 generations per year. The study of the life cycles in 6 hosts showed that *pigeon pea* presented 32 to 40 days and the lentil showed the maximum duration 81 to 83 days. In the preferable proofs of the insect oviposition (A y B) was obtained the following order: pea, soyabean, chickpea, and lentil. In order to percentage of the emergence the order obtained was the following: chickpea, cowpea, soyabean, pigeon pea, pea and lentil.

Brewer and Horber (1984) evaluated 16 varities of 7 species of grain legumes for their resistance to *C. chinensis* in the U.S.A. They found that mungbean suffered the highest damage while lentil, broad bean, cowpea and one variety of chickpea had the least damage. Pigeon pea, adzuki bean (*V. angularis*) and most chickpeas were intermediate in infestation. Ovipositional antixenosis in the resistant chickpea variety was due to the rough and almost spiny pericarp. Antibiosis was expressed in lentil, broad bean and cowpea.

Raina (1970) reported that characters distinguishing *C. chinensis* (L.) *C. maculatus* (F.) and *C. analis* (F.) are described. The biology of the Bruchids was studied in populations reared in the laboratory on seeds of mungbean at 30 C and 70% R.H. for the species average of 78, 128 and 96 eggs per female were laid, respectively, the egg stage lasted 3, 5, 4 and 5 days and 94 to 99% of the eggs hatched. The duration of post embryonic development averaged 18.8, 20 and 23.5 days, and males and females occurred in about equal numbers. There was no significant difference in the development times for eggs laid on successive days of oviposition , but mortality was lowest amongst eggs laid early and was usually 100% amongst those laid on the last day of oviposition.

After an average incubation period of 3 to 5 days, the larvae hatch and bore into the seed feeding upon the cotyledon until fully developed Raina (1970). After boring vertically into the seed, the larva turns at right angles and pushes forward horizontally and feeding continuously on the cotyledon.

Razzak and Pundey (1965) observed that the full grown larvae are curved and the dorsal body wall is raised into a segment dome like structure. The larva undergoes 4 instars prior to pupation. The full grown larva migrates to the periphery just beneath the seed coat and cut an exit hole that appears as a window or dark spot. The larvae pupate with its mandible facing towards the window. The pre pupal and pupal position passes in this position.

2.5 Adult emergence

Palmeto Singal *et al.* (1989) studied the effect of infestation of Chickpea with 1, 2, 3, 4 or 5 male female pairs of *C. chinensis* up to F1 and F2. They found significant correlations between grain damage and final population were recorded for F1 and F2 generations.

Sharma *et al.* (1986) evaluated the biochemical losses caused by the bruchid to Kabuligram stored in different types of household container for 4 months under fluctuating laboratory conditions. Tin and plastic containers, polythene bags, and earthen pitchers were filled with 1 kg of disinfected grains and the total number of adults to emerge was determined at monthly intervals. The population of pest increased over the storage period in each type of container used, but after 4 months the population was lowest in the tin and plastic containers (43 adults) and highest in earthen pitchers (6658).

Kulkami *et al.* (1985) studied the damage caused by *C. chinensis* to different pulses stored in selected containers and found maximum weight loss of seeds in mungbean and dew bean (*V. acontifolius*) while adult emergence and percentage damage were minimum in pea.

2.6 Damage potential

Sharma *et al.* (2013) studied five insect pests i.e. *C. chinensis* (L.), *Tribolium casteneum (*H), *Trogoderma granarium* (E), *Rhizopertha dominica* (F), and *Sitophilus oryzae* (L.) infesting stored chickpea was *C. chinensis* which reached its peak during September-October and the grain damage was rated the highest during January-February (13.75%) and lowest during June-July (3.05%).

Modgil and Mehta (1996) reported that decrease in calorific value in green gram and red gram infested with *C. chinensis*.

Singh *et al.* (1995) observed the effects of various chemical characters of gram (chickpea) varieties on the growth and development of *C. chinensis* in the laboratory. They found fecundity; F1 progeny and index of susceptibility were comparatively lower on the varieties of gram with characters such as high protein, and low oil and starch contents. The varieties with high protein, and low oil and starch contents showed lower egg deposition, F1 progeny and index of susceptibility, F1 progeny index of susceptibility was observed to be positive and highly significant. The protein content of different gram varieties was found to be highly significantly and negatively correlated with fecundity. F1 progeny and index of susceptibility except inthe case of total sugars, which showed a significant negative correlation with index of susceptibility.

Osman *et al.* (1991) stated that damage caused by *C. maculatus* to 4 varieties of stored seeds of *Vigna radiata* and 5 varieties of soyabeans was assessed. In *Vigna radiata*, the number of bruchids was highest in cv. MG50-10A and lowest in 1968. The damage after 3 months was 100% and therefore the germination rate could not be assessed. In soyabeans, the percentage of damaged seeds was low for all varieties and germination rate was highest in cv.

In a laboratory study Rahman (1990) found that the initial presence of four larvae or eggs or one pair *C.* spp. Adult could completely damage 10g of the pulse grains within 2 to 4 months depending on the type of the pulses stage of maturity and species of the beetle. In storage, a maximum infestation level of 64.33% in chickpea by *C. chinensis* was recorded after 6 to 8 months of storage.

Epino and Regesus (1983) reported that the physical characteristics and chemical components of mungbean seed appeared to be correlated with varietal susceptibility to bruchid infestation. Large and heavy seeds were more preferred by the bruchids than small seeds. The resistant accessions had lower percentage of fats and starch but a higher percentage of protein than the susceptible accessions. Epino and Regeus (1983) reported that the physical characteristics and chemical components of mungbean seed appeared to be correlated with varietal susceptibility to bruchid infestation. Large and heavy seeds were more preferred by the bruchids than small seeds. The resistant accessions had lower percentage of fats and starch but a higher percentage of protein than the susceptible accessions.

Janzen *et al.* (1977) carried out a detailed set of feeding trials using *C. maculatus* and found that several non protein amino acids were lethal at concentrations of 0.1%. They also found that alkaloids were generally the most toxic compounds present in the resident legume seeds. Epino and Regesus (1983) reported that the physical characteristics and chemical components of mungbean seed appeared to be correlated with varietal susceptibility to bruchid infestation. Large and heavy seeds were more preferred by the bruchids than small seeds. The resistant accessions had lower percentage of fats and starch but a higher percentage of protein than the susceptible accessions.

Jay *et al.* (1973) reported that at the time of sample collection damage caused by *C. maculatus* was less than 1%, but after 120 days of sample storage in laboratory it rose to 44% in soyabean. Chopra and Khurab (1970) concluded in their laboratory experiments on extent of damage by *C. analis* that the beetles caused severe damage at high temperature and the pulses, therefore if stored at a temperature of 23.5 degree centigrade or less would relatively safer.

Lefevre (1950) in Belgium- Congo found that after harvest 48-70% of beans were damaged by bruchids during a period of 8 months. He also stated that 93% of beans stored in sacks, were found drilled by these insects in a period of 12 months causing enormous loss. In Nigeria Caswell (1973) estimated 50-60% of insect damage after 6 months of traditional storage.

2.7 Weight loss of grain

Rawat and Srivasatva (2011) reported that quantitative (seed damage and weight loss) and qualitative (biochemical) losses by pulse beetle in three pulses showed a maximum seed damage of 96.15% in cowpea (*V. radiata)* followed by 88.44% in green gram (*V. unguicalata)* and (74.22%) in moth bean (*Phaseolus aconitifolius)* while highest weight loss was registered in green gram (48.13%) followed by moth bean (39.7%) and cowpea (18.6%).

Anandhi *et al.* (2008) revealed that the release of five pairs of *C. chinensis* adults in 250g of pulse increased to a mean population of 648.3 after 180 days of storage. The loss in weight increased up to 17.3% during this period. The population buildup and percentage infestation were high during mid March, when the minimum and maximum temperatures were 15.5 and 30.1 degree C, respectively and the relative humidity was 40.1 to 89.2% .As high as 7.60% weight loss was recorded at 90 days after incubation. Among the containers, the plain pot and pot lined with polythene did not permit any bruchid infestation.

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 years camphor provided better protection than other materials for all the containers and storage period.

Bhaduria and Jakhmola (2006) reported that losses due to seed damage by pulse beetle was maximum in green gram (55.4%) ,followed by gram [chickpea] (11.15%) and pea (8.8%). Infested seeds of green gram, black gram and pigeon pea with only one hole failed to germinate. Infested pea, gram and cowpea seeds showed 20,40 and 52% germination, while healthy pea ,gram and cowpea seeds recorded 68,86 and 82% germination ,respectively. Infestation reduced seed germination from 30% to 72%.

Rahman *et al.* (2004) conducted experiments to study the bio-efficacies of different plant/weed derivatives that affect the development of the pulse beetles, *C. maculatus* F. (Coleoptera: Bruchidae) feed on black gram, *V. mungo*, seeds. Plant extracts, powder, ash and oil from nishinda (*Vitex nigundo* L.), eucalyptus (*Eucalyptus* *globules* Labill), bankalmi *(Ipomoea sepiaria* K.), neem (*Azadirachta indica*), safflower (*Carthamus 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.

Bhuiyah (2001) reported that the oils of neem, Royna and Castor at 6 and 8 ml/kg and leaf of Biskatali, Marigold and Castor @ 5% w/w were most effective in preventing the egg laying in lentil and chickpea and leaf powder of Biskatali, 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.

Rouf *et al*. (1996) in the laboratory of the Department of Entomolgy, Bangladesh Agricultural University (BAU), Mymensingh and found that the leaf powder of neem (*A. indica*), nishinda (*Vitex nigundo*) and biskatali *(Polygonum hydropiper*) alone and in combination of these materials at lower were less effective against the pulse

Satya Vir *et al.* (1994) carried out studies on manipulation of *C. maculatus* Fab., infestation of seed and weight loss in moth bean and cowpea seeds at four levels of infestation viz., 1, 2, 3 and 5 pairs. He reported that the infestation of seeds varied from 31.66 to 81.66 percent with a weight loss of 24.20 to 58.20 percent in moth and 35.00 to 68.90 percent with a weight loss of 18.0 to 38.5 percent in cowpea seeds after 6 months of storage.

Dohary *et al.* (1987) reported that *C. chinensis* caused 1.35, 45.82,83.12 and 99.91 percent seed damage and 0.62, 16.74, 25.56 and 43.26 percent weight loss while *C. maculatus* caused 1.57, 90.42, 97.40, and 90.03 percent seed damage and 1.15, 36.36, 48.84 and 51.91 percent weight loss after 30, 60, 90 and 120 days storage period, respectively. The germination loss also increased gradually with the increase in seed damage and storage period. *C. maculatus* caused cent percent loss in viability after 90 days and whereas *C. chinensis* after 120 days of storage.

According to Tikku *et al*. (1981), the factors responsible in preventing the multiplication of *C. chinensis* by vegetable oils could be attributed to the prevention of normal exchange of gases, hardening the outer membrane to prevent hatching, interference with water balance. Interference with the water balance of the eggs and penetration by the oil of the wax layer under the chorion and consequent contact with the embryo were found the most probable factors in completion of developmental cycle of *C. chinensis*.

Daniel *et al.* (1977) reported that 8 to 52 percent damage in green gram after 1 to 25 months of infestation by 5 pairs of 3 days old adults of *C. chinensis,* under controlled condition whereas loss in chickpea and pigeon pea ranged from 11 to 56 percent and 10 to 49 per cent after 1 to 5 months infestation period respectively.

Jotwani and Sirear (1964) studied the extent of damage and germination loss caused by *C. maculatus*. They observed 1 to 7 holes per pea seed and weight loss in bruchid development was about 12.0, 22.5, 32.0 and 35.5 percent in 1, 2, 3 and 4 holes per seed, respectively. The germination percentage loss recorded in 1, 2, 3, and 4 grubs developed in seeds were 39.9, 79.5, 94.5 and 100 percent respectively.

A loss assessment conducted by Cockbill (1953) and observed a mean net loss in weight of 13.3% in beans during five months storage and the number of damaged grains increased by 29.5%. In a similar study done in Pakistan, Razzak and Manzoor (1969) found that the first generation progenies from two gravid *C. maculatus* caused loss due to the extent of 22.8%, 48.58% and 61.14% to gram, mung and mash respectively in 4 weeks duration.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted in the Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka during summer season of the year 2017. Seven different mungbean varieties name BARI Mung-1, BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BARI Mung-6 and Local varieties were used as seed materials. In this experiment degree of damage caused by pulse beetle was assessed. Before starting the experiment pulse beetles were reared in the laboratory.

3.2 Sample collection

The life cycle from egg to adult of pulse beetle is completed in about 25--30 days. Healthy adults of virgin pulse beetle *(C. chinensis)* were collected from Entomology laboratory of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. 6 different kind of mungbean varieties were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and 1 local variety was collected from local market "*Krishi market*" Dhaka.


Plate1.1: Mungbean (*Vigna radiata*) sample collected from BARI, Joydebpur, Gazipur.

3. 3 Systematic position

Phylum: Arthropoda

Class: Insecta

Sub-Class:Pterygota

Division:Endopterygota

Order:Coleoptera

Family:Chrysomelidae

Genus:*Callosobruchus*

Species:*Callosobruchus chinensis*

3.4 Pulse beetle mass rearing

The insect was mass reared in the laboratory of SAU at ambient room temperature in 10x15 cm plastic jar containing 500g mungbean seeds. Thirty adults pulse beetle were released in a plastic jar, the mouth being covered with synthetic cloth to provide aeration. In a week, when the beetles started to ovipositon the grains, the beetles were separated from the grains by sieving. The beetles were then introduced into a fresh lot of healthy mungbean seeds in glass jars for further egg laying. The larvae hatching out of the eggs were allowed to develop on the grains in plastic jars until adult emergence. The culture jars were observed everyday and they were mildly shaken from time to time to prevent clotting on the grains, which is usually formed due to secretion of saliva by the larvae.

 

Plate 02: Rearing of Pulse Beetles

The cycle of introducing the pulse beetle adults for egglaying and rearing the larvae on the grains within the plastic jars was maintained to obtain large number of adults at a time.

3.5 Treatments of the experiment

There are 7 treatments that were applied to extent the damage of mungbean caused by pulse beetles in the storage condition. Seven pulse varities are used in this experiment as treatments.

3.6 Procedure

Hundred gram mungbean grains were taken in individual plastic pot (10cm dia. x12cm height). Five pairs of newly emerged adults (male and female) were released in each plastic pot. Each treatment was replicated four times. The pots were arranged in Complete Randomized Design (CRD) on a wooden table and stored under laboratory condition at temperature ranged from 26.2 to 33.80 degree C and 75% relative humidity. Extent of damage caused by pulse beetle in mungbean seeds were valuated considering oviposition, adult emergence, percent grain infestation, percent of weight loss from the treated seeds. The methods employed to record data on the above mentioned parameters are described separately.

(A)

(B)

Plate 03: Setup of experiment (A&B)

3.7 Oviposition

Data on the rate of oviposition were recorded after 5 days from the release of insects and continued to 9 days. Twenty five mungbean seeds were selected randomly from each jar. The selected seeds were carefully examined using magnifying glass and the number of eggs glued on the surface of mungbean seeds were counted.

Plate04: Egg of Pulse beetle (*C. chinensis)* on Mungbean

3.8 Adult Emergence

The number emerged adults were counted daily. After every count, adults were removed from each plastic jar to avoid egg laying. This observation was continued from the first day of adult emergence to last day of emergence.

Plate 05: Adult Emergence of pulse beetle (*C. chinensis)*

3.9 Damage assessment

Freshly harvested mungbean seeds of different varieties were collected from Bangladesh Agricultural Research Institute and local market.. The seeds were thoroughly cleaned, sun dried and cooled. Initial moisture content of mungbean was determined by using the digital moisture meter. 100g of each mungbean variety was stored in each plastic jar with pert¯crated plastic lid covered with fine synthetic net cloth and stored at ambient room temperature in the laboratory of SAU. To estimate seed infestation and seed weight loss, we recorded insect population, hundred gram seed weight, moisture content, number of eggs per 100 seed, no of newly emerged insect, no of bore seed per 100 seed and finally the germination capacity at every 30 days interval up to 120 days. The percent infestation, percent grain weight loss due to pulse beetle was calculated by using the following formula.

%grain damage (by number) =Number of bore seed /Total number of seed x 100

3.10 Germination test

The viability of stored mungbean seeds was assessed through germination test. The test was done to determine whether or not the pulse beetle infestation could affect grain germination. From each plastic pot, we took 400 seed randomly for germination test. The initial germination rate of mungbean seed was determined at the beginning of storage in the laboratory.

3.11 Percent infestation

Percent infestation = (Nb/Tn) x 100 according to Chowdhury *et al.* 1991

Where, Nb = Number of infested seed, Tn = Total number of seed

3.12 Percent weight loss

After the complete emergence of adults from the egg laying grains, the weight of grains for each pot was recorded separately. Then the percent weight loss was measured using the following formula:

Percent grain content loss = Weight loss per pot /Initial weight of grains per pot x 100

Where,

Weight loss per pot = (Initial weight – final weight) of grains per pot

3.13 Statistical Analysis

The experiment were analyzed using one way Completely Randomized Design (CRD) by a personal computer using MSTAT package program, and the treatment relationships were determined using Duncan's Multiple Range Test (DMRT).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results obtained from the extent of damage caused by pulse beetle in different mungbean verities. Results of the different parameters studied in the experiment have been presented and discussed under the following headings.

4.1 Number of alive and dead insects after release of adult beetle

Number of live insect was highest in Local variety (4.40) and BARI Mung-5 (4.40) after a week of storage where 4.20 in BARI Mung-3, 2.80 in BARI Mung- 2, 2.40 in BARI Mung-1, 1.80 in BARI Mung- 4, 0.40 in BARI Mung- 6. Local varities are more susceptible to the pulse beetle than other BARI mungbean varities.

Table 1. Number of dead and alive insects from five pairs of pulse beetle of different mungbean varieties

Mungbean variety	Dead insects (No.)	Alive insects (No.)
T_1	7.60 b	2.40bc
T_2	7.20 b	2.80 b
T_3	5.80 c	4.20 a
T_4	8.20 b	1.80 c
T_5	5.60 c	4.40 a
T_6	9.60 a	0.40 d
T_7	5.60 c	4.40 a
$LSD_{(0.05)}$	0.955	0.889
Level of significance	0.01	0.01
CV (%)	10.40	25.28

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

4.2 Number of insect eggs

Numbers of eggs per 100 seeds of different varieties of mungbean were counted at different period of time stored at room temperature (Table 2). Irrespective of variety, number of egg increased over time. The Local variety showed the highest eggs (95.00) at third week of storage followed by BARI Mung-4 (84.00) , BARI Mung-3 (45.20), BARI Mung-5 (42.20), BARI Mung-3 (19.4), BARI Mung-6 (15.4) and BARI Mung-1 (12.00). There was similar trend in increasing number of insect eggs in different mungbean varieties over the storing period. In comparison to second week, number of eggs increased in very high rate in different mungbean variety. This result supported the result of Dharmascna (1986). He reported varieties with small seeds and glossy seed coats were shown to be associated with a higher degree of resistance than large seeds with a dull surface. Female bruchids find it more difficult to lay their eggs on the highly convex and shiny surfaces of small seed. This result was also supported by Epino and Morallo (1983). They reported that in laboratory examinations the physical characteristics and chemical components of seeds of *Vigna radiata* were found to be correlated with varietal susceptibility. Hard, large and heavy seeds were preferred for oviposition by *C. chinensis* and heavy seeds were also more susceptible to weevil damage. Seeds of a resistant accession had a lower starch and fat content but a higher protein content than the susceptible counterpart. This result also supported by Lambrides and Lmrae, 2000. He reported that the texture, layer present on the seed coat of some mungbean verities and small seed size might act as oviposition deterrents. Consequently, these assays for determining resistance to bruchid infestation may not be suitable for identifying biochemical resistance of some mungbean genotype.

Table 2. Number of eggs per 100 g seeds of different mungbean varieties

Mungbean variety	No. of eggs per 100 g seeds at different weeks	
	2nd	3rd
T_1	3.20 e	12.00 g
T_2	3.40 e	19.40 e
T_3	19.00 c	45.20 c
T_4	30.60 b	84.00 b
T_5	19.60 c	42.20 d
T_6	5.20 d	15.40 f
T_7	34.20 a	95.00 a
$LSD_{(0.05)}$	1.696	2.497
Level of significance	0.01	0.01
CV (%)	7.96	4.31

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

The female beetle laid eggs on the surface of seven types of pulse grains.The eggs look like white dot clearly visible on the seed coat (Plate- 4) .Eggs were deposited on all tested pulse seeds .Number of eggs laid on pulse seeds varied among different pulses (Table-2).The result indicated that different pulse seeds influence the oviposition performance of *C. chinensis.* The variation on the oviposition of the beetle may be attributed to the characteristics of the seeds in respect of seed coat texture, seed size and color. Due to their more brownish color BARI Mung-1 might have been attracted mostly by *C. chinensis* .While gradually less preference to the other varities.The findings supported the results of Gupta and Seghal (1989) .They observed color preference of pulse beetle for oviposition in order of red> green> yellow >blue > white .The color preference of the beetles in respect of the seed studied were similar to the above findings.This result was also similar with the findings of Saehdeva and

Sehgal (1987) where they reported that the characteristics in respect of color and play a vital role on oviposition of pulse beetle.

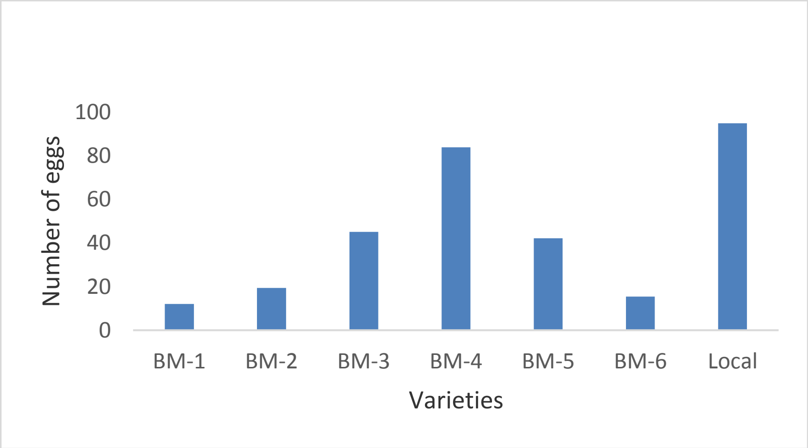

Fig 1. Oviposition preference of pulse beetle

4.3 Damage of grain caused by beetle

The rate of bored seeds of different pulse seeds by pulse beetle showed significant variation (Fig 2). Number of bored seed was highest in Local variety (24.20) where the number of bored seeds in BARI Mung-1 was (5.60) , BARI Mung-2 (5.80) , BARI Mung- 3 (7.20), BARI Mung-4 (7.80), BARI Mung- 5 (11.00), BARI Mung-6 (9.80) per 100 grains after three weeks of storage. On the otherhand, number of viable seed was maximum in BARI Mung-1 (94.40) and minimum in local variety (75.80).

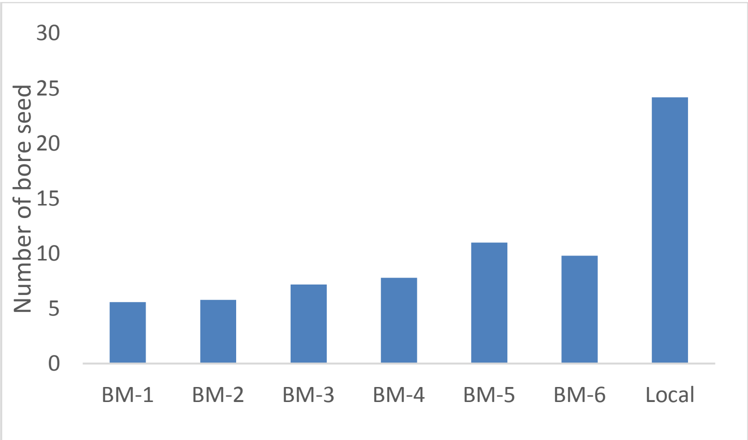

Fig 2. Number of bore seed of different mungben varities

4.4 Insect infestation

Irrespective of varieties number of pulse beetle to stored mungbean seeds increased over time (Table 3). The number of insect was the highest (60) in BARI Mung-6 after third week of storage followed by BARI Mung-5 (44), BARI Mung-4 (55), BARI Mung-3 (34), Local variety (34), BARI Mung-2 (9.4), BARI Mung- 1 (15.6) after third week of storage. In the first two week of storage, insect population increased slowly but in the third week it increased rapidly. In three week storage period, the population was increased in all the varieties of mungbean under study. Lefevre (1953) also reported that 93% of the bean seeds were seriously damaged when stored in sacks without any protection measures. In this study mungbean seeds were stored in plastic container covered by perforated plastic lid and synthetic net. After 5 pairs insect release and no protection measure showed the similar results of Lefevre (1953). The result further revealed that BARI Mung-6 more susceptible to (*C. chinensis)* than all other BARI Mung varieties. Seed of Local variety of pulse is the smallest size which may act as oviposition deterrents. On the contrary, BARI Mung-5 may possess some biochemical factors to bruchid resistance. Similarly, Begum *et al.* (1982) stated that *C. chinensis* is one of the major pests among the *C.* spp. attacking and causing considerable damage to storage grain legumes in Bangladesh. Other author Rahman (1991) also reported that initial presence of four larvae or eggs or one pair of adult *C.* spp. could completely damage l0g of the pulse grains within 2 to 4 months depending on the type of the pulses and species of the beetle. Such serious damaging potential of pulse beetle suggested taking appropriate control measures for safe storage of mungbean seeds.

Table 3. Insect population per 100g seeds of different mungbean varieties at storage period

Mungbean variety	Insect No. at different weeks				
	1^{st}	2^{nd}	3^{rd}	Total	Average
T_1	8.60 f	9.00 e	15.60 e	33.20 e	11.07 e
T_2	6.60 g	9.80 e	9.40 f	25.80 f	8.60 f
T_3	19.00 e	18.40 d	34.20 d	71.60 d	23.87 d
T_4	41.20 c	42.80 b	55.60 b	139.60 b	46.53 b
T_5	49.20 a	44.00 b	44.80 c	138.00 b	46.00 b
T_6	43.20 b	52.00 a	60.80 a	156.00 a	52.00 a
T_7	24.00 d	36.20 c	34.60 d	94.80 c	31.60 c
$LSD_{(0.05)}$	1.812	2.369	1.977	1.977	1.542
Level of significance	0.01	0.01	0.01	0.01	0.01
CV (%)	5.11	6.03	4.19	3.79	3.79

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.5 Weight loss of grain

Percent weight loss of mungbean seeds caused by *(C. chinensis)* is presented in Table 5. After three weeks of storage period, percent weight loss was found the highest in Local variety (55.69%) followed by BARI Mung-4 (46.18%), BARI mung-3 (22.44%), BARI Mung-5 (22.29%), BARI Mung-2 (17.45%) BARI Mung-1 (12.42%) and BARI Mung-6 (11.56%), BARI Mung-4 (46.18%) showed comperatively higher weight loss than other BARI mungbean variety.

Table 4. Percentage of weight loss of different mungbean varieties

Mungbean variety	Weight loss (%)				
	T_1	T_2	T_3	T_4	Average
T_1	2.27 e	9.48 f	12.42 e	91.39bc	28.89 e
T_2	7.16 d	14.58 e	17.45 d	93.12 b	33.08 d
T_3	8.28 c	17.66 c	22.44 c	93.92 b	35.58 c
T_4	12.13 b	24.86 b	46.18 b	98.61 a	45.45 b
T_5	8.28 c	16.18 d	22.29 c	92.42 b	34.79 c
T_6	2.12 e	8.78 f	11.56 e	88.72 c	27.79 f
T_7	13.54 a	26.35 a	55.69 a	99.62 a	48.80 a
$LSD_{(0.05)}$	0.480	0.788	1.306	3.002	0.796
Level of significance	0.01	0.01	0.01	0.01	0.01
CV (%)	4.83	3.61	3.75	2.47	1.69

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 = 1st week of storage ,T_2 = 2nd week of storage
T_3 = 3rd week of storage , T_4 = 4th week of storage

4.6 Germination capacity

Germination percent of different varities of mungbean at different storage period is shown in Table 6 .Initially germination percentage of BARI Mung- 6 was the highest (86%) followed by BARI Mung-1 (84%), BARI Mung-2 (81%), BARI Mung-5 (75%), BARI Mung- 3 (74%), BARI Mung-4 (66%) and local variety (61%). Germination percentage of BARI Mung-1, BARI Mung- 2 and BARI Mung- 6 were statistically similar where BARI Mung-3 and BARI Mung-4 were statistically similar but these were significantly different from the variety BARI Mung-5 and local variety. In the following week of storage, germination percentage of all the seven varieties decreased because of insect infestation and seed moisture absorbs. Germination percentage in the third week of storage was 32.64% in BARI Mung-1, 25.98% in BARI Mung-2, 24.66 % in BARI Mung-3, 16.47 % in BARI Mung-4, 22.68 % in BARI Mung-5, 36.50 % in BARI Mung-6 and 12.16 % in Local variety. Here we observed that the maximum reduction in germination of mungbean seed found in the Local variety and highest germination found in the BARI Mung-6. The highest reduction in germination capacity of Local variety might he attributed to initial poor germination coupled with insect infestation.

Table 5. Germination capacity of of different mungbean varieties at different storage period

Mungbean variety	Germination (%) at different weeks		
	1st	2nd	3rd
T_1	84.9 a	65.23 a	32.64 b
T_2	81.6 a	58.63 b	25.98 c
T_3	74.51 b	48.29 cd	24.66 cd
T_4	66.07 c	44.48 de	16.47 e
T_5	75.54 b	51.58 c	22.68 d
T_6	86.30 a	68.71 a	36.50 a
T_7	61.60 c	42.22e	12.16 f
$LSD_{(0.05)}$	4.551	4.068	2.642
Level of significance	0.01	0.01	0.01
CV(%)	4.64	5.80	8.34

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

CHAPTER V

SUMMARY

The experiment was conducted at Entomology Laboratory, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, to evaluate the degrees of damage *by C. chinensis* on seven variety of stored mungbean. Seven varieties of mungbean seeds were used in this experiment. They were BARI Mung-1, BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, BARI Mung-6 and Local variety. The seed samples were sun dried and cleaned thoroughly and preserved in the refrigerator at freezing temperature to disinfectant from hidden infestation. Initial moisture percentage and germination of the mungbean samples were taken before the start of experiment.

Pulse beetle (*C. chinensis*) were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Five pair of pulse beetle (*C. chinensis*) were collected for the experiment. Then the experiment was conducted in the Entomology department of Sher-e-Bangla Agricultural University, Sher-e- Bangla Nagar, Dhaka.

In this experiment, 5 pairs of virgin pulse beetle (*C. chinensis*) insects were released in each plastic container. Insect population was counted at 7 days interval up to 21 days. The results of insect population showed that every variety was significantly differed with each other in case of population growth. The most susceptible variety of mungbean was BARI Mung-6, followed by other varieties of mungbean.

The number of alive and dead insects were studied. Number of live insects was highest in local variety and BARI Mung -5 (4.40), followed by BARI Mung-3 (4.20), BARI Mung -2 (2.80). BARI Mung -1 (2.40), BARI Mung -4 (1.80) and BARI Mung -6 (0.40).

Number of eggs per 100g seed was the highest in case of Local variety of mungbean followed by BARI Mung -4, BARI Mung- 3, BARI Mung -5, BARI Mung -2, BARI Mung -6, and BARI Mung -1. In three week of storage period the number of eggs per 100g seeds were increased by 2.7 to 5.7 times higher than initial number. The number of eggs per 100 seeds was positively correlated with the insect population.

The number of bored seed per 100g seed was highest in case of Local variety of mungbean, followed by BARI Mung- 5, BARI Mung-6, BARI Mung-4, BARI Mung-3, BARI Mung-2 and BARI Mung-1. It indicates that the number of viable seed per 100g of mungbean seed was highest in the BARI Mung-1, followed by the BARI Mung- 2, BARI Mung-3, BARI Mung-4, BARI Mung-6 and BARI Mung- 5. The insect population and the number of bored seed per hundred gram seeds were positively correlated.

In three weeks of storage period, Local variety of mungbean showed the highest weight loss followed by BARI Mung-4, BARI Mung-3, BARI Mung-5, BARI Mung -2, BARI Mung-1 and BARI Mung-6. Though in the first and second week the trend of weight loss was rather different. The weight loss was significantly different among the mungbean varieties. The insect population and percent weight loss was positively correlated with each other.

Initially, the germination percentage of BARI Mung-6 was the highest followed by BARI Mung -1, BARI Mung -2, BARI Mung -5, BARI Mung- 3, BARI Mung- 4 and local variety. The germination percentage was gradually decreased in all the mungbean varieties. In the three weeks of storage it was suddenly changed and abruptly decreased. In the last week the germination was recorded highest in case of BARI Mung- 6 and it was 36.50% followed by BARI Mung-1 (32.64%) and BARI Mung -2 (25.98 %) BARI Mung-3, BARI Mung -5 (22.68%), BARI Mung- 4 (16.47%) and Local variety (12.16%). The cause of lower rates of germination over time was insect infestation and feeding dry matter of the grains.

CONCLUSION

Pulse beetle *C. chinensis* is one of the most destructive pests of stored pulse. Seven mungbean varieties were taken for the experiment. Irrespective of varieties, pulse weevil population increased overtime and the highest number of insect was found in Local variety of mungben in three weeks of storage. Pulse weevil population was lowest in BARI Mung-6 in same duration of storage. Amount of seed damage and weight loss was found highest in Local variety and lowest in BARI Mung-6 after three weeks of storage. That indicates that the local variety is highly susceptible for pulse beetle and comparatively less susceptible variety is BARI Mung-6. This experiment also indicates that all other variety of mungbean are better than the local variety of mungbean.

Recommendations:

1. BARI Mung-6 is less susceptible to pulse beetle compared to other mungbean variety.
2. Further investigation on mungbean including more varieties against stored grain pest is recommended.

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APPENDIX

Appendix I. Analysis of variance of the data on number of dead and live insects in five pair of different mungbean varieties

Source of variation	Degrees of freedom	Mean square	
		Dead insects	Live insects
Between	6	11.590**	11.590**
Within	28	0.543	0.471

**: Significant at 1% level of probability

Appendix II. Analysis of variance of the data on number of eggs per 100 g seeds of different mungbean varieties

Source of variation	Degrees of freedom	Mean square	
		No. of eggs per 100 g seeds at different weeks	
		2nd	3rd
Between	6	836.781**	5540.781**
Within	28	1.714	3.714

**: Significant at 1% level of probability

Appendix III. Analysis of variance of the data on insect population per 100 g of seeds of different mungbean varieties at storage period

Source of variation	Degrees of freedom	Mean square				
		Insect No. at different weeks				
		1st	2nd	3rd	Total	Average
Between	6	1486.27**	1554.32**	1836.90**	13924.58**	1547.18**
Within	28	1.957	3.343	2.329	12.743	1.416

**: Significant at 1% level of probability

Appendix IV. Analysis of variance of the data on number of viable and bore seedsof different mungbean varieties

Source of variation	Degrees of freedom	Mean square	
		Viable seeds	Bore seeds
Between	6	210.067**	210.067**
Within	28	3.900	3.900

**: Significant at 1% level of probability

Appendix V. Analysis of variance of the data on percentage of weight loss of different mungbean varieties

Source of variation	Degrees of freedom	Mean square				
		Weight loss (%)				
		T_1	T_2	T_3	T_4	Average
Between	6	96.079**	233.554**	1479.834**	75.744**	316.973**
Within	28	0.137	0.370	1.017	5.371	0.377

**: Significant at 1% level of probability

Appendix VI. Analysis of variance of the data on germination capacity of different mungbean varieties at different stage period

Source of variation	Degrees of freedom	Mean square		
		Germination (%) at different weeks		
		1st	2nd	3rd
Between	6	437.576**	526.456**	360.426**
Within	28	12.342	9.858	4.158

**: Significant at 1% level of probability