

EVALUATION OF TRADITIONAL METHODS FOR
THE MANAGEMENT OF THE PULSE BEETLE
CALLOSOBRUCHUS CHINENSIS LINN.
(COLEOPTERA: BRUCHIDAE)

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BY
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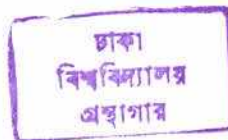
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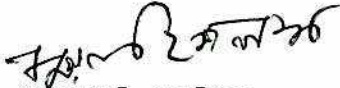
Dedicated to
my
heavenly parents

382445



D E C L A R A T I O N

I do hereby declare that the work embodied/presented in this thesis is the original result of my own investigation except where reference has been made to published literature. I have composed this thesis and this has not been submitted to any form to any other university for any other degree.



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C E R T I F I C A T E

This is to certify that the thesis entitled "Evaluation of traditional methods for the management of the pulse beetle, *Callosobruchus chinensis* Linn. (Coleoptera: Bruchidae)" is the record of bonafide research carried out at the Grain Insect Laboratory of the Division of Entomology, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur and at the Department of Zoology, University of Dhaka by Nazrul Islam, under my supervision. I further testify that all the data presented in this dissertation are based on his own observations and no portion thereof has been used in any other thesis for a diploma or degree. The assistance and help rendered during the course of investigation and the source of literature have duly been acknowledged.

University of Dhaka
November, 1999


S.M.H. KABIR
Supervisor

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CHAPTER 1

INTRODUCTION

Pulses in Bangladesh, constitute an important source of protein in the diet of great majority of people. Per hectare yield of pulses in Bangladesh, however, is very low as compared to many other countries of the world (Pulse Res. Centre, 1997). Bangladesh produces a total of about 0.523 million tons of pulses of different types from an area of about 0.696 million hectares (BBS, 1997). Compared to nutritional requirements, the quantity of pulses available is considerably low. Moreover, a significant portion of pulses kept in stores becomes unsuitable for consumption due to the attack of stored-product insect pests (Alam, 1971).

In storage, pulses are damaged by a few species of pulse beetles : *Callosobruchus chinensis* (L.), *C. maculatus* (F.), and *C. analis* (F.). Among these, *C. chinensis* is the most serious pest in Bangladesh. However, all kinds of pulses are not equally damaged by these insects. The results of a survey conducted in India indicated a maximum of 98.04%, 72.97%, 64.33%, 46.48%, 29.08% and 4.0% infestation in mungbean (*Vigna radiata* (L.) Wilczek), grasspea (*Lathyrus sativus* L.), chickpea (*Cicer arietinum* L.), lentil (*Lens culanaris* Medic), blackgram (*Vigna mungo* (L.) Hepper) and pea (*Pisum sativum* L.), respectively, caused by the pulse beetles (*C. maculatus* and *C. chinensis*) after 6-8 months of storage (Mookherjee, Jotwani, Yadav and Sircar, 1970). Although the accurate estimate is not available, pulses show a substantial loss due to pulse beetle in Bangladesh. In the reports of other tropical and sub-tropical countries, the losses due to pulse beetles were shown to be to the tune of about 60 per cent in

Nigeria (Casewell, 1973) and 20 per cent in Brazil (De Teledo, 1946).

The initial infestation of the pulse beetle occurs in the field and then carried into the stores. The larva of a pulse beetle is an internal feeder. In the field female lays eggs either outside or within the pods. After hatching, the grubs bore directly into the pods or seeds. The penetrating hole may heal up as the seeds mature, and their subsequent development takes place very rapidly when the pulses are brought to the storage. The grubs feed inside the grain, causing loss of quality, quantity and viability of seeds (Bato and Sanchez, 1972).

Most of the farmers in Bangladesh store pulses for a period of 3 to 6 months for consumption. About 10 to 20% rich farmers store their produces for nearly a year. Most farmers store pulses in traditional manner using earthen motka , dole, gunnybag, or plastic sacks. These containers cannot protect the grains from infestation because the insects can easily penetrate the containers specially the dole and gunnybags. Efforts to improve storage practices are not keeping pace with the production efforts. The climatic and socio-economic problems involved in storage vary specially in rural areas. Improved storage structures can substantially reduce the infestation. But these cannot be built due to high installation cost.

Among the available technologies, the use of chemical insecticides against the stored grain pests particularly for the commercial purpose is still the most common practice in Bangladesh. The pulse beetle is mostly controlled by using fumigants or contact insecticides (Malathion). Fumigation has some limitations particularly in rural areas due to its high technical method of

application and also its availability at the time of requirement. As a prophylactic measure premium grade malathion has been used as a contact insecticide in storage since 1954. But studies have shown that many strains of stored product insects (moth species) have developed resistance to malathion (Champ and Dyte, 1976). Apart from this, it is less effective and requires high dose against moth pests (Yadav, 1979). Moreover, the use of synthetic chemicals has several problems, such as environmental pollution because of slow rate of degradation, development of resistance by the target pest, high cost, and sometimes its non-availability. The use of toxic chemicals against the pest is hazardous to small farmers because of their traditional storage practices and financial constraints. The naturally occurring materials (plant oils, minerals, ashes etc.) are inexpensive and easily available in Bangladesh. Farmers can use these for the protection of the grain from insect attack if found effective. There are reports that the naturally occurring plant materials may contain biologically active substances which are toxic to insects. Some of the plant oil have been reported to act as physical barrier against insect pests of stored grains (Luca, 1982).

Several workers including Mummigatti and Ragunathan (1977) and Das (1987) have reported the effect of neem (*Azadirachta indica* A. Juss) oil against *C. chinensis* in chickpea and different vegetable oils against *C. chinensis* in greengram. Though different oils {neem (*A. indica*), mustard (*Brassica* spp.), coconut (*Cocos nucifera*), soybean (*Glycine max*), rapeseed and castor (*Racinus communis*)} were found to protect various seeds from insect infestation but no detail work on their effects on oviposition, larval development, adult emergence, and other biological aspects have thoroughly been done.

Different ashes are reported to be effective against *Sitophilus oryzae* (L.) infesting wheat (Khare, 1972; Khare and Agarwal, 1972), *C. chinensis* on pulses (Krishnamurti and Rao, 1950) and *Tribolium castaneum* (Herbst) on rice (Majumder, Narasiman and Subramanyan, 1959) in storage. It has experimentally been shown that the naphthalene ($C_{10}H_8$) has some fumigating effects on *C. chinensis* infesting chickpea (Islam and Karim, 1995; Rahman, 1990). A very few reports on the physical control methods particularly, disinfestation of pulse grains against stored product insect are available (Claflin, Evans, Fane and Hill, 1984; Mookherjee and Chawla, 1984). The residue and contamination problems of the treated grains resulting from the use of insecticides are of great importance. Thus in the present study, an integrated approach was undertaken to assess the efficacies of plant oils, ashes, fumigants, and some physical factors against the pulse beetle, *Callosobruchus chinensis* (L.) in storage.

The research work had the following objectives:

1. to study the extent of damage and assessment of losses caused by *C. chinensis* to chickpea, grasspea and mungbean stored in traditional containers;
2. to test the toxicity, if any, of mustard, coconut, soybean and neem oils and insecticide decis (Deltamethrin) against *C. chinensis*;
3. to evaluate the effectiveness of mustard, coconut, soybean and neem oils and decis in protecting chickpea, grasspea and mungbean against *C. chinensis* under storage conditions;

4. to test the efficacies of different ashes viz. eucalyptus wood ash, coal ash, paddy husk ash, cowdung ash, and charcoal ash as protectant of stored chickpea, grasspea and mungbean against *C. chinensis*;
5. to assess the efficacy of naphthalene ball as a deterrent of *C. chinensis* in stored chickpea, grasspea and mungbean; and
6. to test the effect of sunning, heat and cold treatments in protecting stored chickpea, grasspea and mungbean against *C. chinensis*.

The study was initiated in May, 1995 and conducted through the summer of 1998 in the Grain Insect Laboratory of the Division of Entomology, Bangladesh Agricultural Research Institute (BARI), Joydebpur.

CHAPTER 2

REVIEW OF LITERATURE

Callosobruchus chinensis (L.) (Coleoptera: Bruchidae) is commonly known as cowpea weevil, southern cowpea weevil, bean weevil, pulse beetle or adjuki bean weevil. This insect is believed to be of Asiatic origin (Hamilton, 1894) but is now widely distributed throughout the tropics. The insect is an economic pest of many edible legumes in all parts of the world causing extensive damage to legume crops in America (Garman, 1917), Africa (Parkins and Bills, 1955), Asia (Srivastava and Lal, 1967), Europe (Zacher, 1929) and Australia (Mayne, 1948).

2.1. Bioecology of *Callosobruchus chinensis*

The bionomics of the insect have been studied by many investigators (Bato and Sanchez, 1972; Raina, 1970; Arora and Tarlok, 1970; Khare and Johari, 1983; Giga and Smith, 1983; Begum, Rahman and Seal, 1982; and Southgate, 1978). Srivastava and Bhatia (1958) studied the development of *C. chinensis* with several host species and found that in swordbean (*Canavalia gladiata*), hyacinth bean (*Dolichos lablab*), cluster bean (*Cyamopsis tetragonoloba*), kidney bean (*Phaseolus vulgaris*) and soybean (*Glycine max*) the insect could not develop. Among cowpea (*Vigna unguiculata*), chickpea (*Cicer arietinum*), garden pea (*Pisum sativum*) and broadbean (*Vicia faba*), *C. chinensis* completes its life

cycle faster in cowpea and chickpea, and relatively slower in gardenpea and broadbean.

Jakhmola and Laxman (1971) found oviposition and the size of adults of *C. chinensis* positively correlated with the size of the greengram (*Vigna radiata*) seeds in a free choice test. They also observed that less damage due to pulse beetle in wild variety of greengram (*Vigna radiata*) was not due to resistance *per se* but due to smaller seed size. Singh, Odak and Singh (1977) worked on the ovipositional preference of *Callosobruchus* spp. on different pulses including greengram and observed that the suitability of host seed for development depended on larval mortality.

Rajak and Pandey (1965) studied the biology of pulse beetle and reported that a female beetle lays 50-103 eggs in her life time. An egg when freshly laid appears translucent, smooth and becomes pale-yellowish with age. Eggs are about 0.57 mm in length. Incubation period ranges from 3-18 days. Larval and pupal period are completed inside the seed. The average larval period is 29 days with 4 larval instars at 30°C temperature and 75% RH. The mean duration for 1st, 2nd, 3rd and 4th larval instars are 2.4, 3.5, 6.4 and 16.7 days respectively. The beetle hibernates as grub during winter months from November to February in India. Pupal period varies from 6-21 days. Male is smaller

in size with pectinate type of antennae, and short lived than female, the later has serrate type of antennae. Six generations were recorded from July to May. Duration of life cycle varies from season to season with minimum 27 days and maximum of 114 days (Rajak and Pandey, 1965).

2.2. Damage potential of *C. chinensis* in storage condition

According to Rajak and Pandey (1965) among several species of bruchid beetles whose economic importance is now widely recognized, *C. chinensis* may be regarded as the most widely distributed species in India. It causes enormous loss to stored pulses. After 3 months of storage the weight of pulses was reduced by 25, 17, 16, 15 and 14% respectively in case of mung, lobia (*Vigna unguiculata*), kabuligram (*Cicer arietinum*), gram and lentil, respectively.

Singh, Sharma and Thapar (1982) reported that mung varieties had higher insect infestation and weight loss than mash (*Vigna mungo* L.) varieties and per cent loss in weight increased with the increase in storage period. Further studies (Singh et al. 1982) showed that for an increase of one month of storage period there was an increase of 1.10% of attacked grains and 0.104 per cent loss in weight in "gram", 1.01% damaged grains and 0.605% loss in weight in "mash" and 2.01% damaged grains and 0.76% loss in weight in "mung". Furthermore an increase of one

per cent of damaged grains caused an increase of 0.13, 0.54 and 0.36% loss in weight in gram, mash and mung, respectively and the calculated annual loss in weight in the respective pulses was 1.98 , 9.72 and 7.96%. Lefevre (1950) found that 48 to 70% beans(*Phaseolus vulgaris*) were damaged by bruchids during storage period of 8 months in Belgian - Congo. He also stated that 93% of beans , stored in sacks, were found drilled by this insect in a period of 12 months causing enormous loss. In Rhodesia, Cockbill (1953) recorded a net loss of 13.3% of beans during five months' storage. Similarly Razzaq and Manzoor (1969) found loss of 22.8, 48.58 and 61.14% of 'gram', 'mung', and 'mash', respectively in 4 weeks duration due to *C. maculatus*.

In Nigeria, Casewell (1973) estimated 50 to 60% of insect damage after 6 months of traditional storage (motka, dol, tin etc.). In India, Mookherjee et al. (1970) observed that leguminous seeds were comparatively more damaged by pulse beetle than cucurbitaceous, solanaceous and other vegetable seeds as well as oil seeds where the maximum damage was 3%. Singal, Singh and Jaglan (1989) studied the effect of initial infestation of chickpea with 1, 2, 3, 4 or 5 male-female pairs of *C. chinensis* up to F₁ and F₂ generations and found 97% and 92% variability in grain weight loss to the number of pairs of beetles released initially.

In India, Sharma, Kapoor and Thapar (1986) evaluated the biochemical losses caused by the bruchid (*C. chinensis*) to kabuli gram stored in different types of household containers for 4 months under fluctuating laboratory conditions. They obtained lowest population in tin containers (43 adults) and highest in earthen pitchers (6658 adults). The crude protein and free fatty acid contents of the infested gram increased over the storage period irrespective of the type of container used.

The feeding loss in weight of seed progressed in three stages corresponding with early, mid and late stages of development. The relative humidity significantly affected the feeding besides sex and types of species. The ratio of food eaten by *C. maculatus* and *C. chinensis* was 1.45: 1.00 and the corresponding ratio of emerged adult weight was 1.60: 1.00. The per cent weight loss of seed ranged from 55.62 to 60.00 for *C. maculatus* and 30.2 to 55.7 for *C. chinensis*.

2.3. Use of oil as protectant of stored grains

Palm (*Elaeis guineensis* Jac.) and groundnut (*Arachis hypogea* L.) oils were found effective for the control of bruchids oviposition possessing ovicidal properties (Cotton, 1963). Likewise, neem oil had been tested and used in stored seeds in India. Ketkar (1976) found that 2 per cent neem oil mixed with bengalgram (*Cicer arietinum*)

protected seeds from being damaged by *Callosobruchus* spp. for three months.

From a study in Nigeria, Singh, Luse, Lueschner and Nangju (1978) reported that groundnut oil @ 5 ml/kg completely protected cowpea seeds in storage from *C. maculatus* for up to 180 days. The treatment had no adverse effects on cooking time or taste of the cooked beans or on germination even after 6 months of storage. This method was advocated for use in rural areas because of its advantages of availability, low cost, ease of application and lack of toxic residue. After 150 days, the untreated control contained 32,300 adults of *C. maculatus* per 5 kg seed, as compared with 0.0 adults in treated seed and the level of insect-damaged seeds was 100% compared with 0% in treated seed.

Mummigatti and Ragunathan (1977) found that 0.3% oil of castor, mustard and ginger (*Sesamum*) inhibited the multiplication of *C. chinensis* in greengram; similar result was also observed with 0.5% coconut and groundnut oils. In contrast sunflower (*Helianthus annus* L.) oil was found ineffective even at higher dosage.

In a study, Schoonhoven (1978) used palm kernel, cotton seed, maize, soybean and coconut oils against bruchid attacking beans. He reported that when beans were

tumble-mixed with the palm oil at the rate of 1 ml, 5 ml and 10 ml/kg and infested with *Zabrotes subfasciatus* (Boheman) it completely prevented F_1 emergence. Maize and soybean oils were also found effective only at higher dosage (>5ml/kg).

The effectiveness of palm oil against *C. chinensis*, *Acanthoscelides obtectus* (Say) and *Z. subfasciatus* was reported by Taylor and Evans (1980) who applied this oil on pigeonpea (*Cajanus cajan*), hairy coat beans (*Phaseolus vulgaris*) or red kidney @ 5 ml/kg and @ 10 ml/kg.

Cruz and Gardona (1981) found that purified soybean and corn oil with and without additives and raw corn oil without additives were very effective in controlling weevil at the rates of 10 and 15 ml/kg of cowpea seeds. Similarly, Ali, Singh and Misra (1983) reported that the use of neem, rape, coconut, mustard, mahua (*Madhuca indica* G.) and palm oil @ 1.0 ml/100gm to be more effective against all stages of *C. chinensis* reared on greengram.

Sujatha and Punnaiah (1985) worked on the effect of coated stored seeds of greengram with vegetable oils on the development of pulse beetle. They reported that oils of sesame, cotton seed, palm and neem at a concentration of 0.25 per cent and groundnut or coconut at 0.5 per cent can effectively control *C. chinensis*. Frank and Renwick (1983)

used peanut, sunflower, coconut and mineral oil and found complete control of *C. maculatus* on cowpea for over 75 days at a dose of 5ml/kg of seed.

In a study conducted by Qi and Burkholder (1981) used cotton seed, soybean, maize and peanut oil to suppress *Sitophilus granarius* (L) in wheat grain. They reported that insect progeny production decreased significantly at 5 ml/kg dosage. At 10 ml/kg level, complete control was achieved that lasted for at least 60 days. These oils had repellent action on adult weevils. There was no effect of the oil treatment on water absorption by the wheat seeds although the rate of seed germination was somewhat reduced.

Khaire, Kachare and Patil (1987) tested vegetable oils in the laboratory at 5 to 10 ml/kg seeds against adults of *C. chinensis* infesting pigeonpeas and found oils of neem and karanja (*Pongamia glabra*) at higher concentrations (10ml) to be most toxic.

When leaf or kernel powder of neem was used to protect grain over a 60 days storage period in aerated condition, insect mortality was 90% after treatment with the kernel powder compared with 69.8% after treatment with the leaf powder. Babu, Reddy and Hussaini (1989) studied the effect of pre-storage treatment of mung bean var. PS-16 with neem, karanja, mustard, groundnut and castor oils, each at 2.5,

5.0 and 10 ml/kg seed. They found that karanja oil (5 and 10 ml/kg) and castor oil (10 ml/kg) effectively reduced oviposition of the bruchid (*C. chinensis*) while maintaining a high level of germination for over 18 months of storage.

In Indonesia, Soedomo and Sunaryono (1988) compared the extracts of *Azadirachta indica*, *Pachyrhizus erosus*, *Leucaena leucophala*, and *Lantana camera* with maize oil and sevin (carbaryl) for the control of *C. maculatus* on *Vigna sinensis* seeds. Maize oil was as effective as carbaryl. Extracts of *P. erosus* also had potential for the protection of stored seeds.

Srivastava, Gupta and Agarwal (1988) tested the essential oils of *Mentha arvensis*, *Eucalyptus globulus*, *Cymbopogon winterianus* and *C. martinii* against *C. chinensis* on seeds of red gram (*Cajanus cajan*). At a concentration of 0.1% *C. martinii* was the most effective in preventing oviposition. At 0.2%, *M. arvensis* was effective and gave complete control of oviposition. Similar results were obtained for adult emergence. They concluded that the essential oils of *M. arvensis* and *C. martinii* at 0.2% and of *E. globulus* and *C. winterianus* at 0.4% could be used for the control of *C. chinensis* on *C. cajan*.

In Africa, Mueke and Apuuli (1987) used vegetable oils and ash for the control of *C. maculatus* in seeds of cowpea and observed castor oil as an outstanding protectant. Vegetable oils caused mortality to adult beetles and the eggs that were on the seeds failed to hatch.

In Bangladesh, Das (1987) investigated the effectiveness of various concentrations (4, 6, 8 and 10 ml/kg seeds) of neem oil on adult mortality and oviposition of *C. chinensis* in laboratory at 32.5°C and 83-85% R.H. and found 8 ml of oil/kg seed to be the most economic concentration to control *C. chinensis* infestation on chickpea seeds. Das (1989) also observed that neem oil @ 10 ml/kg of seed prevented adults from laying eggs when they came in contact with the seeds immediately after treatment.

In Iraq, Mahdi and Hamoudi (1984) evaluated the potentiality of protecting stored cowpeas against *C. maculatus* using castor, sunflower and cooking oils @ 2, 6, 9 or 12 ml/kg of seeds. Reproduction rates for weevils kept on seeds treated with castor, olive and cooking oils were 61.2, 1.27 and 0% respectively, as compared to 79.3% of untreated seeds and damage rates after treatment with the 3 oils were 78.6, 4.5 and 0% respectively as compared to 61.3% of untreated. No adverse effects on seed germination were observed, even a month after treatment.

Yadav (1985) applied neem seed oil @ 20-50 mg/10 g seeds of greengram inoculated with groups of adults of both sexes of 3 species of *Callosobruchus*. Oviposition was observed after 1 week and adult emergence after 1 month. Treatment of 50mg/10g completely prevented oviposition of *C. maculatus*, *C. chinensis* and *C. analis*. Treatments at 30, 20, and 10mg/10g suppressed adult emergence of all 3 species mainly due to toxic action against the eggs. Peel oils of eight different citrus fruits when applied to the surface of cowpea seeds prevented the production of progeny of *C. maculatus* (Su, Speirs and Mahany, 1972).

Su (1976) worked on the toxicity of chemical component of lemon oil on cowpea weevil and found that the lemon oil had toxic effect. Taylor and Vickery (1974) also used citrus oil @ 0.25 and 1 per cent w/w on black eyed peas and found that it reduced oviposition and emergence of F_1 generation of *C. maculatus*.

The survival and progeny production of *S. oryzae* and *Sitotroga cerealella* (Oliv) reduced significantly when maize grains were treated @ 1, 5 or 8 ml vegetable oil/kg grain (Oca, Garcia and Schoonhoven, 1980). Complete control for more than 120 days was obtained at 5 and 8 ml/kg when maize was already infested. Garlic (*Allium sativum*) oil also offered some effectiveness against the adult and larvae of *Trogoderma granarium* (Everts) reared on semolia

(Thomas and Pal, 1974). Singh et al. (1978) reported complete protection of stored cowpea from *C. maculatus* for up to 180 days by groundnut oil applied @ 5 ml/kg of seeds. Groundnut oil prevented emergence of adult rather than affecting oviposition or mortality of the adult weevils. At 0.5 per cent level, mustard, castor, neem and honge oils were also effective in preventing the infestation of cowpea seeds.

In a study, Pereira (1983) investigated the effectiveness of different oils (i.e.; neem kernel, karite, groundnut, palm kernel, and palm oil) as protectants of cowpea and bambara groundnuts against *C. maculatus*. He found that except neem oil, all had ovicidal effect while neem oil had larvacidal action. Khaire, Kachare and Moti (1992) tested the efficacy of ten vegetable oils @ 0.5, 0.75 and 1% (W/W) as grain protectants of pigeonpea against *C. chinensis* and found that the adult emergence was completely prevented by karanj oil at 0.75 and 1% and neem oil at all levels up to 100 days. No emergence of adults occurred up to 66 days with castor oil at 0.75 and 1% levels. Minimum grain loss was noted with castor, mustard and groundnut oils at 1% level up to 100 days after treatment. There was no adverse effect of the various oils on seed germination.

Varma and Pandey (1978) reported that the fecundity of *C. maculatus* was inhibited when stored seed of greengram was treated with the oils of coconut, mustard, groundnut, sesame and sunflower @ 1.3 parts/100 parts (w/w). Oviposition was completely inhibited when coconut and mustard oil were used and very few eggs were found in greengram seeds treated with groundnut, sesame and sunflower oils. The development of adult population of the pulse beetle was prevented at least for 6 months and the germination or viability of the treated seeds was not affected. Coconut oil was the best protective, followed by mustard, groundnut and sesame oils.

In the Philippines, Begum and Quiniones (1990) observed that coconut, soybean, mustard and peanut oils at higher dosage (3ml/kg) protected mungbean seeds from the attack of *C. chinensis*. Higher doses of oil significantly affected oviposition. Oil at 3ml/kg had long residual effect since all treated seeds even after 4 months of storage reduced oviposition and killed the eggs at their early stage. Agarwal, Deshpande and Tipnis (1973) reported that the oil of *Acorus calamus* have insecticidal activity on *T. castaneum*, *C. chinensis*, *Rhizopertha dominica* (Fab), *T. granarium* and *Corcyra cephalonica* (St.). Bhatanagar and Pal (1974) studied the insecticidal activity of garlic oil and found some mortality against *T. granarium* adult and larvae.

Deshpande, Adhikary and Tipnis (1974) tested *Progostemon heyneanus* (Patchouli) oil against *S. oryzae*, *S. panicum*, *T. castaneum* and *C. chinensis* and found that the oil was most effective against *C. chinensis* and least effective against *T. castaneum*. They also worked on *Nigella sativa* (Black cumin) and found that oleic and linoleic acids were effective against *C. chinensis* and least effective against *T. castaneum*. Oil of groundnut, castor, coconut, almond (*Amygdalus communis* L.), cucurbit, mustard, sesame and shark liver were tested by Punj, Prosad and Adarsh (1970) and found that all oils retarded the growth of both species (*T. castaneum* and *T. granarium*) at levels of 5-30% by weight and increased the mortality.

2.4. Chemical properties and mode of action of tested oils

Mustard (*Brassica* Spp.) is a cruciferous plant which contains glucoside sinigrin and the enzyme myrosin. The oil components are allyl isothiocyanate (0.7 - 1.3%).

Coconut (*Cocos nucifera*) kernel contains 35-50% fat. The main fatty acids are lauric (45%), myristic (18%), palmitic (9.5%), oleic (8.2%), caprylic (7.8%), capric (7.6%), stearic (5%) and linoleic (1-2.6%). Coconut oil contains 84% trisaturated glycerides (Jasper, 1978).

Soybean (*Glycine max*) is a leguminous crop believed to have originated in China. Its seed oil contains 21-40% protein and glucoside genistin, diadzin and 4-saponins. Fatty acids composition is palmitic acid 7-14%, stearic 2-6%, oleic acid 23-24%, linoleic acid 52-60%, linolenic acid 3% and higher saturated acids 2%. Stanislaw, Elzbieta and Marta (1995) reported that the neem oil is now produced commercially, and it exhibits enormous potential as insecticide. The active ingredient azadirachtin, extracted principally from the seeds, has growth-regulating and antifeedant properties against numerous pests. Green leaves and neem seed powder added to food stuffs repel stored product pests.

The mode of action of different oils is partially attributed to influence the normal respiration, resulting in suffocation. Their action is more complex as insects deprive of oxygen survived longer than those treated with oils. Oils are used against a variety of insects especially to kill dormant eggs. According to Singh (1975) the thin layer of the oil blocks oxygen supply to the embryo. Hill and Schoonhoven (1981) found that triglyceride fraction of African palm oil has adverse effect on the survival of adult beetle. This fraction may also reduce the oviposition rate. From among different free fatty acids tested, they found that oleic acid has some insecticidal effectiveness.

2.5. Use of plant materials as protectant and their insecticidal activity against stored grain pests

In India, Pandey, Singh and Tewari (1976) reported that extracts of *T. cornea*, neem and garlic provided effective protection for at least 135 days against *C. chinensis*. Similarly, Pandey and Varma (1977) in their study used custard apple (*Annona squamosa* L.) seed powder as a protectant of mungbean against pulse beetle (*C. maculatus*) at the rate of 0.5, 1.0 and 2 parts per 100 parts of mungbean by weight and found that treated seeds were effectively protected against *C. maculatus* for up to 100 days. The protection appeared to be of repellent nature, since the treated seeds caused no mortality of adult beetles.

Qadri and Brahmanand (1977) tested the toxicity of custard apple in combination with neem against *C. chinensis*, *R. dominica* and *Musca domestica* Fab. and found the synergistic action of neem extract in combination with custard apple against the above mentioned insects.

In Pakistan, extracts from various parts of the neem plant (i.e.; leaves, flowers, fruit exocarp and endocarp and seeds) were tested against *T. castaneum* adults by Jilani and Malik (1973) and observed a considerable level of repellent action by seeds and endocarp of neem.

In India, Mukherjee and Ramachandran(1989) found that neem extract incorporated into wheat flour reduced the growth, development and fecundity of *T. castaneum*. Application on the top of eggs or larvae @ 1, 2 and 5ml/kg did not have any adverse effect. Application to 6 hours old pupae reduced the emergence of adults.

Various components of neem plant were tested by Kossou (1989) for their insecticidal effects on the *Sitophilus zeamais* Mots. in stored maize. Seed kernel, leaf, flower and bark from the tree were used in powder and extract (80% ethanol) form at the rate of 2.5g and 2ml, respectively, per 50g of grain infested with 20 insects. Pirimiphos-methyl and ethanol were applied at 2.5g and 2ml, respectively, for comparison. Ethanolic extracts revealed higher toxicity to *S. zeamais* than the powdered neem.

In India, Khan (1986) studied the residual activity of rhizome powder of *A. calamus* (applied at 0.2%) against *C. chinensis* attacking stored grains of *C. arietinum* in the laboratory at 25°C. When the bruchids were introduced with ranges of 0-30 days after treatment the progeny did not develop and the percentage of infestation ranged from 0 - 0.04.

Saxena and Yadav (1983) observed that when pairs of newly emerged adults of the tenebrionid, *T. castaneum*, were fed with wheat flour diets containing 1, 2 and 4% concentration of an extract of the flowers of *Delonix regia*, the number of eggs laid by the females averaged 30, 25 and 15 as compared to 95 of untreated flour. Egg hatching was reduced by 59.18, 76.47 and 82.35% respectively, the pre-oviposition period increased and the oviposition period was reduced.

Yadava and Bhatnagar (1987) evaluated the efficacy of 6 plant products at 3 doses against the bruchid, *C. chinensis* on stored seeds of cowpea. The tested plant products were leaf powders of neem, dhatura (*Datura alba*) and oak (*Calotropis procea*), garlic powder and shell and seed powder of soapnut (*Sapindus trifoliatus*). All the plant products significantly reduced seed damage compared to untreated samples till 5 months of storage.

In Egypt, El-ghar and El-sheikh (1987) studied the effectiveness of some plant extracts such as *Clerodendrum enerve*, *Nerium oleander*, *Ipomea palmata* and *Atriplex lentiformis* against the bruchid (*C. chinensis*) on cowpea seeds in the laboratory. Contact toxicity was higher for *N. oleander* and *I. palmata* extracts at 5% w/v, but all extracts had some ovipositional deterrence at one or more

of the concentrations applied. They found a reduction in the fecundity of adults emerging from eggs laid on the treated seeds, leading to a smaller F_1 generation. At 0.5% w/v, the *I. palmata* extract provided 97% protection against *C. chinensis*, followed by extracts of *N. oleander* (94%), *C. enerme* (93%).

Jaipal, Singh and Malik (1984) of India studied the residual effect of various leaf extracts of neem on *R. dominica* in stored wheat. Alcohol extracts were found to be more toxic than acetone, benzene, chloroform, ethyl acetate, hexane and petroleum ether extracts. Extracts equivalent to 1 or 2g of leaf were bioassayed and found that all the adults died within 4 days of release and a further 10 pairs released on the 5th day also died within 4 days of release.

The plants, *Hyptis spicigera* and *Cassia nigricans* traditionally used by farmers of Canada to control insect pests of stored cowpeas were tested against oviposition and hatching of *A. obtectus* in beans by Lambert, Gale, Arnason and Philogene (1985). Oviposition and hatching of *A. obtectus* were reduced when extracts of the plants were applied even at lower rates.

In a laboratory study in USA by Su (1984) on the toxicity of acetone extract of the unripe fruit of *Piper*

nigrum (black pepper and green peppercorn) and hexane of the dry fruit of West African pepper (*P. guineese*) to the stored product insects *C. maculatus*, *S. oryzae*, *Lasioderma serricorne* (Fab.) and *Tribolium confusum* (Duv.) showed that black pepper gave the highest contact toxicity to *C. maculatus* and *S. oryzae*. Black pepper gave the best protection of black eyed peas (*Vigna unguiculata*) against *C. maculatus* infestation. Rajasekaran and Kumaraswami (1985) evaluated the effectiveness of extracts of karanja for the control of *S. oryzae* and *C. chinensis* on sorghum or greengram. Coating sorghum grain with karanja extract @ 0.4% v/v or with neem extract @ 1.0% w/w gave complete protection from *S. oryzae*. Coating greengram grain with both of the extracts @ 0.8% w/w provided satisfactory protection from the attack of *C. chinensis*.

2.6. Use of ash as protectant of stored grains

In India, Krishnamurti and Rao (1950) used wood ash, paddy husk ash and coal ash and found those effective against the adult of pulse beetle, *C. chinensis*. Takei and Miyajami (1941) reported that wood ash was less effective than coal or paddy husk ash, both of which are extremely effective in controlling *S. oryzae* in paddy.

In Uganda, Darling (1947) found that eucalyptus wood ash was effective against stored maize for at least 3

months. Khare (1972), Khare and Agrawal (1972) tested 1.5% cow dung ash mixed with wheat which gave 80% mortality of *S. oryzae* after 3 weeks of storage. Ash mixed with cowpea seeds afforded satisfactory control against the bruchid. Ash levels of 20 and 30% led to 8.96 and 6.18% damage, respectively, as compared with 52.59% for no treatment (Mueke and Apuuali, 1987).

Majumder et al. (1959) observed that activated charcoal and clay provided good control of *T. castaneum* in storage.

2.7. Effect of naphthalene against stored pests

Naphthalene is almost non-toxic and it is being used mostly as a fumigant in houses and as an animal repellent (George, 1980). Shepard (1951) stated that naphthalene is a safe, readily available, cheap and requires only a small quantity to saturate the air. Naphthalene flakes and balls are also used for the control of insect pests damaging insect specimens in museums and entomological laboratories. Toxicity of naphthalene flakes to eggs and larvae of the webbing cloth moth, *Tineola bisselliella* (Hum) under prolonged confinement in a tight container was also reported by Herrick and Griswold (1933) and George (1980).

Lehman (1930) reported that naphthalene applied @ 1.1g/Kg killed 50% of confused flour beetle, *T. confusum*. Islam and Karim (1995) studied the lethal effects of naphthalene balls on different development stages of the pulse beetle (*C. chinensis*) in pulse grains stored in different containers. They reported that 4 naphthalene balls/kg of chickpea exposed for 10-15 days protected the grains for 8 months against the attack of the pulse beetle. Islam et al. (1991) conducted a trial to protect maize cobs from the attack of corn weevil, *S. zeamais* in closed tin containers with different dosage of naphthalene balls and found that all three doses i.e. 2,4,6 naphthalene balls/10 cobs had protected the maize cobs from weevil infestations significantly up to 8 months of storage compared with the untreated control treatment.

Rahman (1990) reported that 200mg of naphthalene per kg grain with exposure during full storage period and 600mg/kg grain with one month exposure period protected the pulse grains effectively against *C. chinensis* and offered 88% and 100% grain protection.

2.8. Effect of physical factors against stored grain pests

Effect of heat-treatment (60°C) in killing all the stages of *C. chinensis* was reported by Claflin et al. (1984). Temperatures above 40°C were also found to be

lethal to all the stages of *C. maculatus* (Mookherjee and Chawla, 1984). Begum, Mannan and Begum (1991) found that sunning can inhibit the rate of pulse beetle multiplication and thus reduced infestation and weight loss of stored chickpea.

Hayes, Chigon, Nitta and Wang (1984) reported a complete kill of eggs and larvae of *D. dorsalis* in pawpaw fruits due to a hot water dip for 20 minutes at 48.7°C. Besides hot water treatment and cold-treatment (5°C) were also reported as effective physical means of control against stored product pests (Stoyanova, 1984; Smith, 1984).

2.9. Efficacy of insecticides for the control of stored grain pests

Almost all major categories of insecticides (i.e.; organophosphate, organocarbamate, synthetic pyrethroid) are reported to be used for the protection of stored grains against insect pests. Bitran, Campos and Oliveira (1980) found deltamethrin effective against *S. oryzae* and *A. fasciculatus*. Bengston (1982) reported that deltamethrin is a highly persistent synthetic pyrethroid capable of retaining 65 per cent of its initial activity after a year on wheat (having 12 per cent moisture content) at 25°C. Considering either the cost or maximum residue limit,

different insecticides (i.e.; chlorpyrifos-methyl, pirimiphos-methyl, fenitrothion, bioresmethrin including deltamethrin) were recommended for 9 months' protection against most species excluding multi-resistant *R. dominica*.

Chahal and Ramzan (1982) evaluated four synthetic pyrethroids (viz.; cypermethrin, permethrin, deltamethrin and fenvalerate) each at 0.0125, 0.025 and 0.05 per cent concentrations and four organophosphates (viz.; baythion, pirimiphos-methyl, fenitrothion and malathion) each at 0.025, 0.05 and 0.10 per cent concentrations against the third instar larvae of *T. granarium*. After one day of spray, deltamethrin at 0.05 per cent caused 100 per cent kill while at 0.0125 and 0.025 per cent caused 26.5 and 66.5 per cent mortality, respectively. Larval mortality varied from 0 to 16.3 per cent in other treatments. In subsequent observations which were recorded at 2, 3, 5 and 7 days after spraying, there was a progressive increase in per cent kill and after 7 days, except malathion and cypermethrin, the remaining treatments caused 100 per cent mortality of the larvae. Thus deltamethrin was ranked best followed by permethrin and fenvalerate.

The toxicity of photostable pyrethroids as permethrin (ambush), deltamethrin (decis), cypermethrin (ripcord), fenvalerate (sumicidin) and fenpropathrin to a number of

insects including *S. granarius* along with a comparison with that of bioresmethrin, organophosphates and carbamates was reported by Malinowski and Kroczyński (1983). Among all, deltamethrin and cypermethrin were found more effective than bioresmethrin, malathion and lindane against *S. granarius*. In a separate study, Webley and Kilminster (1991) compared the wettable powder formulation of fenitrothion, pirimiphos-methyl, permethrin and deltamethrin for persistence and toxicity on woven polypropylene fabric against *S. oryzae* and *T. castaneum*. Permethrin @ 41 and 83 mg/m² was found to be very effective for 12 weeks while deltamethrin @ 6.2 and 12.5 mg/m² was almost equally effective but after 4 weeks the deposits were slower acting against *S. oryzae*. Fenitrothion and pirimiphos-methyl were effective only up to 2 weeks at 250 mg/m² and up to 4 weeks at 500 mg/m². Williams, Semple and Amos (1983) compared the effectiveness of permethrin, deltamethrin and fenvalerate applied @ 10 and 500 mg/m² on blocks of concrete, galvanized iron and wood with that of fenitrothion @ 1000 mg/m². Organophosphorus resistant strains of *R. dominica*, *S. oryzae* and *T. castaneum* were tested. Deltamethrin was found to be the most effective amongst all insecticides up to 32 weeks.

Casewell and Akibu (1980) investigated the action of pirimiphos-methyl against the bruchids. They found spray

applications of 0.25-1.0 per cent pirimiphos-methyl to stored cowpeas (*Vigna unguiculata*) in 19 granaries in Nigeria were effective against bruchids.

In a study, Bang (1963) tested 1-16 ppm dust of fenthion and trichlorophon and 4 ppm sprays of fenthion, trichlorophon and malathion against *C. chinensis* on seeds of small red bean (*P. angularis*) and reported no economic reduction of infestation after 30 days. On the other hand, Nisa and Ahmad (1970) studied the efficacy of dusts of methyl parathion, dimethoate, malathion, lindane and carbaryl against *C. analis* on chickpea and found lindane to be effective for a few months.

Weaving (1970) evaluated the toxicity of pyrethrins and pyrethrins synergised with piperonyl butoxide under laboratory conditions against adults of *A. obtectus*, *Z. subfasciatus* and *C. chinensis*. Dusts using talc were admixed with wheat and pea. Wheat showed better kill than pea due to more adhesive properties. Susceptibility was observed among 3 species of insects with LD₅₀ 's between 6.6 and 8.0 ppm of pyrethrins. *C. chinensis* was reported to show greatest response to the synergist. The author concluded that a powder with 1.5 synergist ratio, applied to give 2 ppm of pyrethrins, would be expected to give excellent control of pulse beetles.

Yadav (1973) made a comprehensive study on the efficacy of seed protectant dusts of malathion, DDT, lindane, carbaryl and DDVP on seeds of chickpea, pea, lentil, greengram, pigeonpea, grasspea and blackgram against *C. maculatus* and *C. chinensis*. Significant differences in the efficacy of insecticides and their dosage on different seeds against both the species were observed. However, based on gross efficacy, the author made a general comparison among all these dusts. Against *C. maculatus*, malathion and DDT were superior to lindane and carbaryl on most of the seeds and lindane and carbaryl proved to be superior to malathion on lentil. Against *C. chinensis*, malathion was superior to DDT on most of the seeds and lindane proved to be inferior to carbaryl on seeds of grasspea but reverse was on greengram where carbaryl was least effective. Thus the author concluded that malathion was the most promising seed protectant which could be used @ 40 ppm for most of the seeds to give protection up to 9-12 months against both species. Similar observation was also made by Srivastava and Dadhich (1973) who evaluated malathion as grain protectant in the laboratory on chickpea against *C. maculatus* and *C. chinensis*.

Yadav and Pant (1975) studied the relative toxicity of malathion, carbaryl, lindane and DDVP against *C. maculatus*

and *C. chinensis* reared on greengram, blackgram, pea, chickpea, lentil, grasspea and pigeonpea. The efficacy of spray (emulsion), dust and solution (seed treatment) was also compared. They reported that the susceptibility of bruchids to insecticide was greatly influenced by types of host (pulse) on which the insects were reared. The order of toxicity for dust treatment was DDVP > lindane > malathion > DDT > carbaryl against both the species. Similarly, the order of toxicity of solution treatment against *C. maculatus* was lindane > malathion > DDVP > DDT > carbaryl and only DDVP and malathion interchanged their positions against *C. chinensis*. In general, *C. maculatus* was less susceptible than *C. chinensis* and the dust was superior to solution. In a separate study, Pawar and Yadav (1976) observed that emulsion of baythion was 22.9 and 1.89 times more toxic than malathion against *C. maculatus* and *C. chinensis* respectively. Both the species displayed nearly equal susceptibility to baythion but contrary to this malathion was less toxic to *C. maculatus*. In general, *C. chinensis* was more susceptible than *C. maculatus* to malathion irrespective of diluents used.

Dhari, Dass and Dass (1977) reported that for long and safe storage of chickpea more than 24 ppm dose of malathion or methoxychlor should be used. Contact toxicity of malathion, DDVP, methoxychlor, thanite, pyrethins and pyrethins synergist with PBO came down to a practically

insignificant level of biological effectiveness after 41, 17, 44, 31, 27 and 27 days, respectively.

Govindrajan, Vadivelu and Balasubramaniam (1978) applied activated clay at 1 per cent level, fenvalerate (sumicidin) at 1:1000, baythion at 1:500, fenvalerate (sumicidin) at 1:500 and neem seed kernel powder at 3 per cent level on greengram and found that activated clay at 1 per cent was the best in providing protection against *C. chinensis* with a minimum infestation of 5.74 per cent. Other treatments viz.; fenvalerate 1:1000; baythion 1:500 and fenvalerate 1:500 had 6.64, 6.80 and 7.50 per cent infestation, respectively after 12 months of storage. Neem seed kernel failed to give any protection beyond one month of storage.

The toxicity of DDT, tetrachlorvinphos, malathion and lindane on chickpea against *C. chinensis* was investigated by Singh, Odak and Singh (1979) and observed that DDT @ 100 and 200 ppm and tetrachlorovinphos @ 20 ppm remained effective for 21 weeks with 100 per cent mortality of *C. chinensis* while malathion at 15 ppm and lindane at 100 ppm gave satisfactory control only for 12 weeks and were ineffective at lower dosage.

Yadav (1980) assessed the efficacy of five insecticidal dusts (i.e.; malathion, DDT, lindane, carbaryl and DDVP) against developing stages of *C. maculatus* and *C. chinensis* on seeds of pigeonpea, greengram and lentil. He found that only malathion and DDVP possessed ovicidal action.

Yadav, Pawar, Khanna and Singh (1980) also tested the toxicity of baythion, bromophos, fenitrothion, iodofenphos, malathion, pirimiphos-methyl and etrimfos against seven stored product beetle including *C. maculatus* and *C. chinensis* and found that etrimfos was most toxic against all pests while baythion was only toxic against *C. chinensis* and *C. maculatus*. In Bangladesh, Sultana, Ahmed and Ahmed (1980) evaluated the effectiveness of dichlorvos, fenitrothion (sumithion) and malathion and reported that none of the insecticides sprayed at 1000mg toxicant/m² on gunny bags were found to give adequate protection of black gram against infestation by *C. chinensis* beyond 2 months of storage.

Taylor and Evans (1980) evaluated dust of pirimiphos-methyl @ 2.5, 5 or 10 mg/kg and permethrin @ 2.5 or 5.0 mg/kg against *C. chinensis* reared and tested on pigeonpea and *A. obtectus* reared and tested on white haricot beans for their efficacy against adults as well as developmental

stages. They found application of pirimiphos-methyl and permethrin to pigeonpea and haricot beans at concentrations between 2.5 and 10 mg/kg brought about rapid control of adult of both species. All treatments except 2.5 mg/kg of pirimiphos-methyl on pigeonpea stored for four weeks gave complete protection of pulses and prevented breeding of newly introduced adults up to 24 weeks after insecticide treatment. However, the application of either insecticides to pulses already infested did not significantly reduce the total number of matured adults produced of either species. It had been suggested that for the effective control of *C. chinensis* and *A. obtectus* pirimiphos-methyl or permethrin could be used @ 5mg per kg seed.

Lekha, Pandey, Srivastava and Singh (1984) tested 6 insecticides by applying topically to adults of *C. chinensis* and found malathion to be 4.7087, carbaryl 3.6391, tichlorfon 3.5083, baythion 3.4811 and fenitrothion 2.8642 times more toxic than lindane. Toxicity of deltamethrin, cypermethrin and permethrin were determined against 13 stored product insects including *C. maculatus* and *C. chinensis*. The LC_{50} values were 0.585, 0.588 and 6.550 ppm against *C. maculatus* and 0.950, 0.144 and 15.740 ppm against *C. chinensis*, respectively (Yadav, 1984).

Adu and Muthu (1985) tested seven fumigants against different developmental stages of *C. chinensis* and found that the pupal stage was the most resistant to ethyl formate, methyl formate, methyl bromide and acrylonitrile at CT products of 1136, 955, 96 and 44 mg/l. Phosphine followed by methyl iodide which was the most toxic to the insect stages while methyl formate and ethyl formate were the least potent.

Yadav (1979) studied the fate of malathion residues on seven pulse seeds and found that the seeds of pulses which were otherwise prone to pulse beetle infestation could be protected with 40 ppm malathion dust. The pick up of dust was dissimilar on different surface of pulse seeds and varied from 19.97 to 33.34 ppm. The quantity of residues on different seeds was significantly different and even after 3 months and at 50 - 60% relative humidity grasspea seeds retained nearly initial residue of 30.40 ppm but on lentil seed residue was only 6.5 ppm.

Regupathy (1973) reported that the application of wettable powder of the antifeedants fentin acetate and fentin chloride at 0.01 to 0.4% to seeds of cowpea in laboratory tests in India gave poor protection from the attack of *C. chinensis*.

CHAPTER 3

MATERIALS AND METHODS

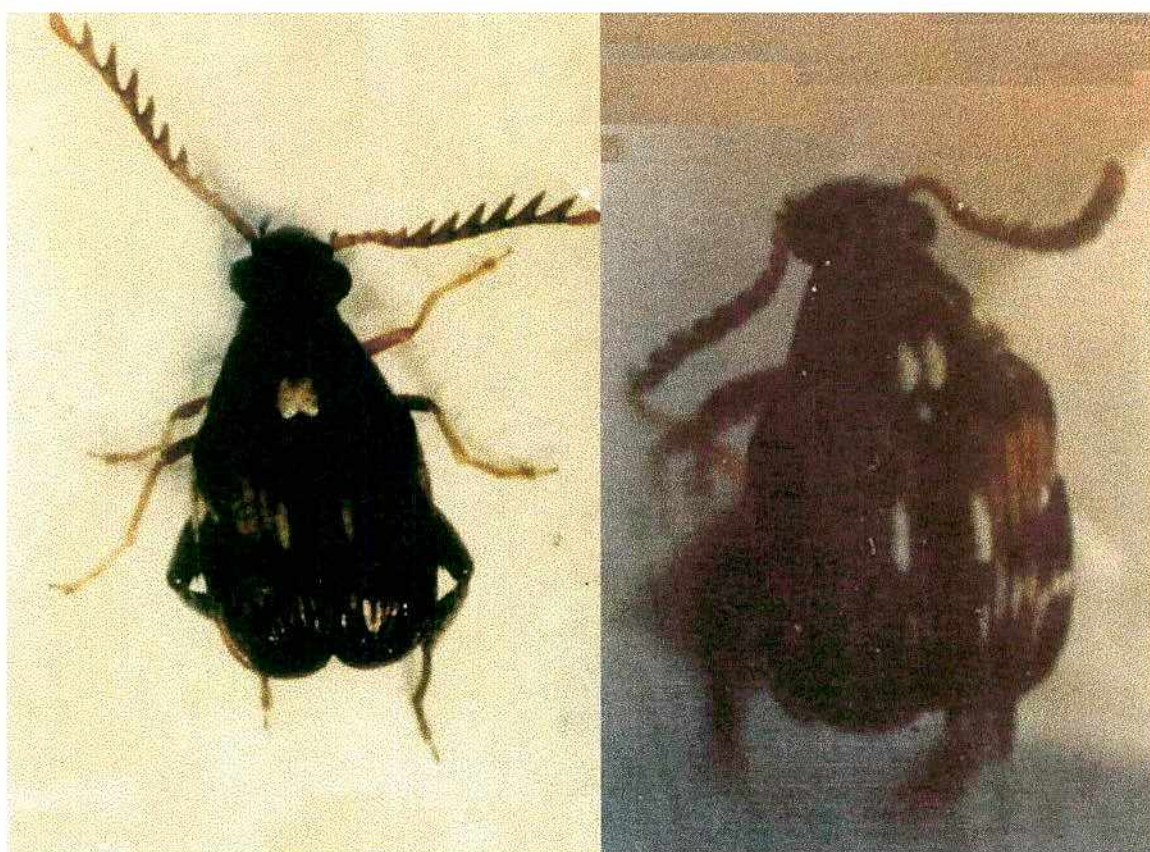
All experiments of the present work were conducted in the laboratory of Entomology Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur during 1995-98. Methods of conducting the experiments are described under different sub-heads:

3.1. Mass rearing

Callosobruchus chinensis (L.) (Fig. 1 & 2) was mass-reared under the laboratory conditions at ambient room temperature. Five hundred gram pulse grains were kept in 15 x 10cm glass jars. Two hundred adults of *C. chinensis* were released in each jar. Each jar was covered with cheese cloth for aeration. After a week, when oviposition occurred, the pulse grains were sieved to separate the beetles. The insects, in turn, were then transferred to a fresh medium. One day old adult beetles that emerged out from the mass culture were used in various experiments. The jars containing the culture medium were shaken from time to time to prevent creation of an adverse environment.

3.2. Effect of containers for the protection of pulse grains from the attack of pulse beetle

Freshly harvested chickpea, grasspea and mungbean were bought from local markets. The pulse grains were well dried, cleaned and stored in three types of traditional



Male x 24.88

Female x 28

Fig.1. Adults of *Callosobruchus chinensis*



Eggs of *C. chinensis* on lentil



Larva x 27

Pupa x 35

Fig. 2. Developmental stages of *C. chinensis*

containers (i.e.; tin, gunnybag and earthen motka) commonly used by the growers (Fig.3). Ten kilogram pulse grains were taken in each container and kept in the laboratory under ambient temperature (24-32°C) and relative humidity (65-90%). The experiment was setup using complete randomized design with four replications and no control measures were adopted. After 90, 180 and 270 days of storage, data on per cent infestation, per cent weight loss, per cent germination and per cent moisture content were recorded.

3.2.1. Estimation of per cent infestation

To estimate the per cent infestation, samples were drawn from each container at an interval of 90 days and continued up to 270 days. At each sampling 200g pulse seeds were taken from 3 different places of each container (top, middle and bottom). From each sample 1000 grains were counted and separated randomly. Out of 1000 grains bored grains (Fig.4) were sorted out and the per cent infestation was computed by using the following formula:

$$\text{Per cent infestation} = \frac{Nb}{Tn} \times 100 \quad \text{where,}$$

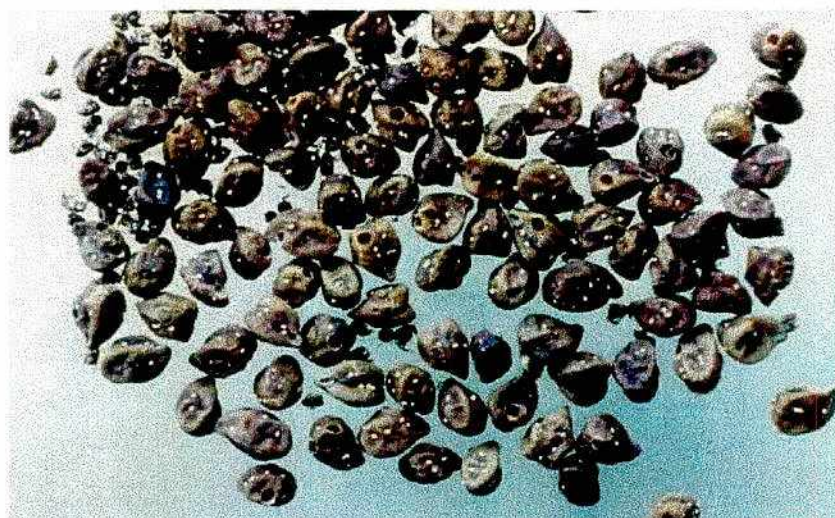
Nb = Number of bored grains, Tn = Total number of grains

3.2.2. Estimation of per cent weight loss

For estimation of weight loss one thousand (1000) grains were taken from each container. Bored and unbored grains were



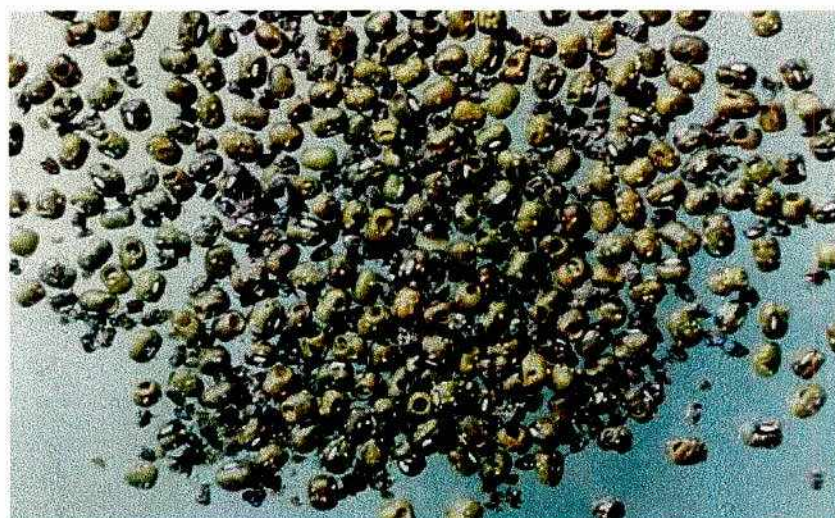
Fig. 3. Traditional containers used in Bangladesh



CHICKPEA



GRASSPEA



MUNGBEAN

Fig. 4. Infested pulse grains by *C. chinensis*

separated, counted and weighed. Weight loss was estimated using the formula adopted by Lal (1988).

$$\text{Per cent weight loss} = \frac{(UNd) - (DNu)}{U (Nd + Nu)} \times 100$$

where,

U= Weight of unbored grains, Nu= Number of unbored grains,

D= Weight of bored grains, Nd= Number of bored grains

3.2.3. Determination of viability

Viability test was done by taking 100 pulse seeds at random from each container and replicated four times. The seeds were placed in Petri dishes having blotting paper at the bottom soaked with water. The seeds were incubated at room temperature and from germinated seeds percentage of germination was calculated. Viability test was done at 90, 180 and 270 days after storage.

3.2.4. Estimation of moisture content

For estimating the initial moisture content, 10g pulse seeds were taken at random from a well-dried seed lot and replicated four times. Sample grains were placed in aluminum foil and dried in an electric oven at 40°C until constant weight was reached. Then the sample was cooled in a dessicator and weighed.

The per cent moisture content was estimated by using the following formula:

$$\text{Moisture content (\%)} = \frac{100 (M_1 - M_2)}{M_1 - M}$$

Where,

- M_1 = mass in gram of the aluminum foil with material before drying;
 M_2 = mass in gram of the aluminum foil with the material after drying;
 M = mass in gram of the aluminum foil.

3.3. Testing the direct toxicity of oils and insecticide against pulse beetle

Mustard (*Brassica spp.*), coconut (*Cocos nucifera*), soybean (*Glycine max*) and neem (*Azadirachta indica*) oil and decis, an insecticide of deltamethrin group were tested to document their toxicity against the pulse beetle. Adult beetles (1-2 days old) from the stock culture were used. Newly emerged adults of both sexes were randomly selected for the test. To test direct toxicity of different oils and commercial formulation of decis, 0.5ml of each oil was poured to plastic Petri dish (5cm diameter) using microapplicator. Then the Petri dish was tilted carefully to allow uniform spray of oils and insecticidal solution followed by drying for 15 minutes under electric fan. Petri dish treated with water was used as control. Each treatment was replicated four times in a complete randomized design and twenty adult of both sexes were released in each Petri dish. After treatment, Petri dishes were kept in the

laboratory at room temperature ($27 \pm 1.5^\circ\text{C}$) and at 65-75% relative humidity. After 24 hours, the mortality was counted by adjudging moribund insects also as dead. Percentage of mortality was calculated and corrected for control mortality (Abbott, 1925). Mortality data were subjected to probit analysis (Finney, 1971) to calculate LC_{50} and LC_{90} values with confidence intervals and slopes.

3.4. Efficacy of different oils and insecticide in protecting pulse grain against pulse beetle

To evaluate the effectiveness of mustard, coconut, soybean, neem oil and decis in protecting chickpea, grasspea and mungbean against *C. chinensis* under storage condition, the following dosage of oils and insecticide were assigned in this experiment:

Treatments	Dosage
T ₁ Mustard oil	4 ml/kg of seed
T ₂ "	7 ml/kg "
T ₃ "	10 ml/kg "
T ₄ Coconut oil	4 ml/kg "
T ₅ "	7 ml/kg "
T ₆ "	10 ml/kg "
T ₇ Soybean oil	4 ml/kg "
T ₈ "	7 ml/kg "
T ₉ "	10 ml/kg "
T ₁₀ Neem oil	4 ml/kg "
T ₁₁ "	7 ml/kg "
T ₁₂ "	10 ml/kg "
T ₁₃ Decis (Deltamethrin)	2 ppm
T ₁₄ "	3 ppm
T ₁₅ "	4 ppm
T ₁₆ Control	untreated

Decis (Deltamethrin): (S)- α - cyano-3-phenoxybenzyl (IR)- cis-3-(2, 2-dibromovinyl) -2, 2-dimethyl- cyclopropanecarboxylate (99.5% purity and 135 mg/kg LD₅₀ acute oral).

Pulse seeds bought from local markets were dried and cleaned. The seeds were disinfested at 5°C for six days before setting up the experiment. One kilogram of pulse grains was used in each plastic container and the oils and insecticide were thoroughly mixed with the grains.

Ten pairs of 1-2 day old adults of *C. chinensis* were released in each container and kept in the laboratory under ambient temperature (24-32°C) and relative humidity (65-90%). The treatments were assigned in completely randomized design with four replications (Fig.5). After 90, 180 and 270 days of storage the data on oviposition, per cent hatchability, per cent adult emergence, per cent infestation, per cent weight loss, per cent germination and per cent moisture content were recorded.

3.4.1. Oviposition

One hundred seeds were sampled from each treatment. The seeds were examined and the number of eggs laid by the insects was counted. The counting was done at 90, 180 and 270 days after storage.



Fig. 5. Showing the experimental set up

3.4.2. Egg hatchability

One hundred grains from each treatment with eggs were separated and stored in small plastic pots having perforations at the top for aeration. After 90, 180 and 270 days the observations were done and the per cent hatchability was determined by counting the larvae which entered the grains by making holes.

3.4.3. Adult emergence

A sample of one hundred grains from each treatment containing grubs inside were separated and stored in small plastic pots having perforation at the top for aeration. The progeny emergence was determined after counting the number of adults that emerged from the grains. Adult emergence data were recorded at 90, 180 and 270 days and the emerged adults were separated from the pots.

3.4.4. Estimation of per cent infestation

The methodology used to estimate the per cent infestation was similar as described in 3.2.1.

3.4.5. Estimation of per cent weight loss

The methodology used to estimate the per cent weight loss was similar as described in 3.2.2.

3.4.6. Determination of viability

The methodology for determination of viability was similar as described in 3.2.3.

3.4.7. Estimation of moisture content

The methodology used to estimate the per cent moisture content was similar as described in 3.2.4.

3.5. Efficacy of different ashes in protecting pulse grains against pulse beetle

To evaluate the effectiveness of different ashes in protecting chickpea, grasspea and mungbean against the pulse beetle, the following dosage of ashes were assigned in this experiment:

Treatments	Dosage
T ₁ Eucalyptus wood ash	2% w/w
T ₂ "	4% w/w
T ₃ "	6% w/w
T ₄ Coal ash	2% w/w
T ₅ "	4% w/w
T ₆ "	6% w/w
T ₇ Paddy husk ash	2% w/w
T ₈ "	4% w/w
T ₉ "	6% w/w
T ₁₀ Cowdung ash	2% w/w
T ₁₁ "	4% w/w
T ₁₂ "	6% w/w
T ₁₃ Charcoal ash	2% w/w
T ₁₄ "	4% w/w
T ₁₅ "	6% w/w
T ₁₆ Control	Untreated

The experiment was set up using completely randomized design (CRD) and replicated 4 times. One kilogram of pulse seeds was used for each replication and stored in a plastic container. Different ashes were mixed with seeds by hand shaking. Ten pairs of 1-2 days old adult of *C. chinensis* were released in each container. The data on the oviposition, per cent hatchability, per cent adult emergence, per cent infestation, per cent weight loss, per cent germination and per cent moisture content were taken at 3 months' intervals and continued up to 9 months. The methodology of collecting data on different aspects was similar as described in sections 3.4.1 to 3.4.7.

3.6. Effect of naphthalene ($C_{10}H_8$) as protectant of stored pulse grains against pulse beetle

Chemical nature of naphthalene: Naphthalene is a colourless crystalline aromatic hydrocarbon ($C_{10}H_8$) with the familiar odor of moth balls, melting point $80.1^{\circ}C$ and boiling point $218^{\circ}C$. It is almost insoluble in water but soluble in nearly all organic solvents. Naphthalene, the simplest of the fused or condensed ring hydrocarbon compounds is composed of two benzene rings sharing two adjacent carbon atoms. It is an important hydrocarbon raw material that gives rise to a host of other products used in the manufacture of dyestuffs and synthetic resins.

Naphthalene is highly volatile and has a characteristic odour, as carbon balls or moth balls; it is commonly used as moth repellent. Evaluation of the efficacy of naphthalene as protectant of stored chickpea, grasspea and mungbean against pulse beetle was done assigning the following treatments:

Treatment	Dosage	Exposure (days)
T ₁ Naphthalene ball	2 balls/kg	07
T ₂ "	2 balls/	15
T ₃ "	2 balls/	21
T ₄ "	3 balls/	07
T ₅ "	3 balls/	15
T ₆ "	3 balls/	21
T ₇ "	4 balls/	07
T ₈ "	4 balls/	15
T ₉ "	4 balls/	21
T ₁₀ No use of naphthalene (control)		

The experiment was set up using CRD and replicated 4 times. One kilogram chickpea, grasspea and mungbean seeds were used for each treatment. Naphthalene balls (2 gm) of assigned treatments were exposed for 7, 15 and 21 days. After 7, 15 and 21 days of exposure the naphthalene balls were removed from the pots and ten pairs of one day old *C. chinensis* were introduced into the pots including untreated control. After 90, 180 and 270 days of storage data on the oviposition, per cent hatchability, per cent adult emergence, per cent infestation, per cent weight loss, per cent germination and per cent moisture content were recorded. The methodology of collecting data on different

aspects was the same as described in sections 3.4.1 to 3.4.7.

3.7. Effect of sunning, heat and cold treatment as protectant of pulse grains against pulse beetle

In evaluating the effect of sunning, heat and cold treatment in protecting stored chickpea, grasspea and mungbean against pulse beetle, the following treatments were made:

Treatments		Mode of treatments	
T ₁	Sunning	30 days	interval
T ₂	"	45 days	"
T ₃	"	60 days	"
T ₄	Heat treatment	5 minutes	in boiling water
T ₅	"	7.5	"
T ₆	"	10	"
T ₇	Cold treatment	2 days	in cold chamber
T ₈	"	4	"
T ₉	"	6	"
T ₁₀	Control	Untreated	

The experiment was set up using CRD with 4 replications. One kilogram seeds of each kind were used for each replication.

For sunning, one kilogram seeds of each pulse type was stored in plastic pots and ten pairs of one day old *C. chinensis* were introduced into each pot. Sunning was done every 30, 45, and 60 days interval for 4 hours.

For heat treatment, one kilogram seeds of each pulse type was kept in polyethylene bags and 10 pairs of

approximately one day old *C. chinensis* were introduced into the bag and sealed. After four days the bags were dipped in boiling water (100°C) for 5, 7.5 and 10 minutes.

For cold treatment, one kilogram seeds of each pulse type was stored in polyethylene bags and ten pairs of approximately one day old *C. chinensis* were introduced into the bag and sealed. After four days the bags were kept in cold chamber at a regulated temperature of 5°C for 2, 4, and 6 days.

After 90, 180 and 270 days of storage the data on oviposition, per cent hatchability, per cent adult emergence, per cent infestation, per cent weight loss, per cent germination and per cent moisture content were recorded. The methodology of collecting data on different aspects was the same as described earlier.

The data were analyzed and analysis of variance was determined and then the means were compared by the Duncan's Multiple Range Test (Duncan, 1955).

CHAPTER 4

RESULTS

4.1. Effect of containers

4.1.1. **Intensity of infestation:** The intensity of pulse beetle infestation in chickpea, grasspea and mungbean stored in tin, motka and gunnybag over nine months period is presented in table 1 (Figures 6, 7 and 8). The percentage of infestation between pulses within container and between containers of same pulse varied significantly for 90, 180 and 270 days after storage (DAS). But the variation between pulses was insignificant at 180 and 270 DAS.

Among the containers used in this experiment tin provided the highest protection than others for all kind of pulses. The results also indicated that gunnybag was worse in providing the protection of grains from the attack of pulse beetle. At 90 DAS, pulse beetle infestation were 5.80-10.10%, 6.40-15.00 and 9.35-21.10% in seeds stored in tin, motka and gunnybag respectively. Although seeds stored in tin had almost 2 times lower infestation than gunnybag at 90 DAS but as the time progressed the importance of containers in protecting the grains became less worthy. At 270 DAS, the percentages of infestation were 44.60-70.93,

Table 1. Per cent infestation in chickpea, grasspea and mungbean caused by *Callosobruchus chinensis* stored in different containers for nine months

Containers	Pulse type	% infestation after (days)		
		90	180	270
Tin	Chickpea	7.70B ab (2.58)	36.30B b (36.95)	62.78B b (52.60)
	Grasspea	5.80B b (2.50)	23.10B c (28.59)	44.60B c (41.88)
	Mungbean	10.10Ba (2.93)	48.03B a (43.84)	70.93B a (57.38)
Motka	Chickpea	8.85B ab (2.76)	41.25A b (39.93)	65.25B b (53.96)
	Grasspea	6.40B b (2.61)	28.60A c (32.30)	45.63B c (42.46)
	Mungbean	15.00Ba (3.86)	53.75A a (47.14)	73.30B a (58.88)
Gunnybag	Chickpea	19.58Aab (4.41)	43.98A b (41.51)	70.35A b (57.02)
	Grasspea	9.35A b (3.12)	35.03A c (36.25)	57.35A c (49.41)
	Mungbean	21.10Aa (4.58)	51.80A a (46.02)	78.78A a (62.55)
CV%		36.28	13.27	12.83

- All figures are average of four replications
- Means in a column having the different capital letters are significantly different among the containers at the 1% level of DMRT.
- Means in a column having the different small letters are significantly different among the crops at the 5% level of DMRT.
- Figures in the parentheses are square root and arc sine transformed values.

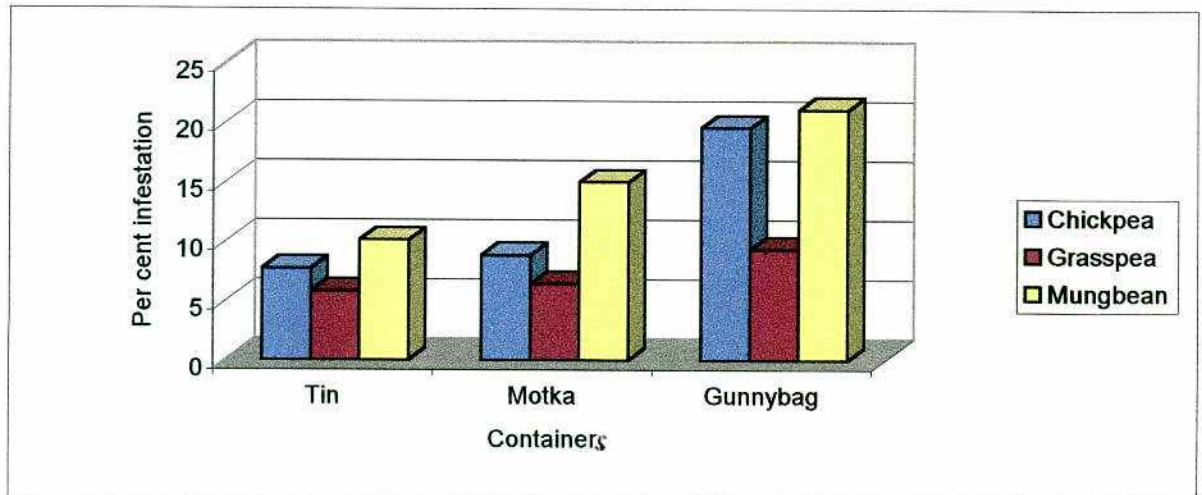


Fig. 6. Per cent infestation after 90 days in different containers

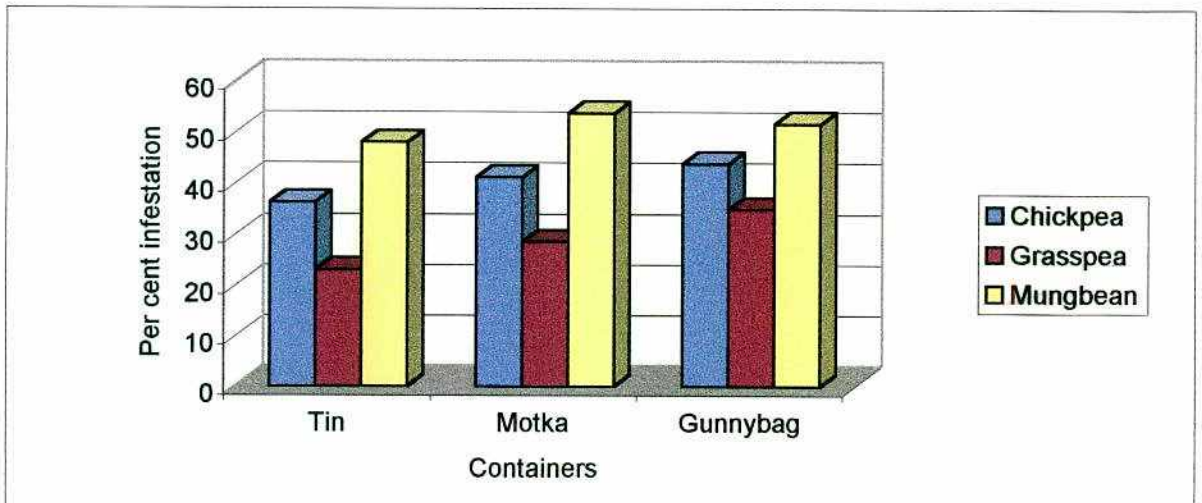


Fig. 7. Per cent infestation after 180 days in different containers

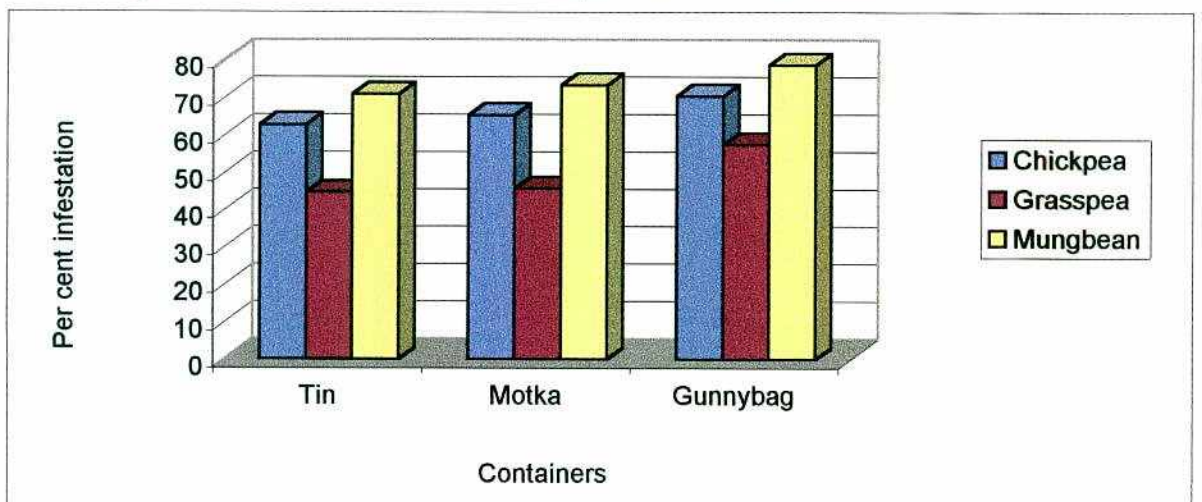


Fig. 8. Per cent infestation after 270 days in different containers

45.63-73.30 and 57.35-78.78 in seeds stored in tin, motka and gunnybag respectively. Of three pulses grasspea always had lower infestation than others. Mungbean was more susceptible to the attack of pulse beetle than chickpea. At 90 DAS, pulse beetle infestation varied from 5.80 - 9.35, 7.70-19.58 and 10.10-21.10% for grasspea, chickpea and mungbean respectively. Similar to containers, the physiological ability of pulse grains in resisting pulse beetle infestation was eminent at early stage of storages but again as the time progressed the difference of pulses became insignificant. At 270 DAS, pulse beetle infestation ranged from 44.60-57.35%, 62.78-70.35% and 70.93-78.78% for grasspea, chickpea and mungbean respectively. Comparison of the results of infestation occurring at 90, 180 and 270 DAS indicated that within three months of storage, the pulse beetle infestation rose to 5.80-21.10% which further aggravated to 23.10-53.75% at six months of storage. At nine months of storage, the level of infestation intensified to 44.60-78.78%. The results clearly led to assume that none of the containers used could provide sufficient protection for chickpea, grasspea and mungbean particularly for longer period.

4.1.2. Weight loss: The percentage of weight loss of chickpea, grasspea and mungbean due to the attack of pulse beetle varied significantly for all containers and storage period (Table 2 and figures 9, 10 and 11). The variation

Table 2. Per cent weight loss of chickpea, grasspea and mungbean caused by *C. chinensis* stored in different containers for nine months

Containers	Pulse type	% weight loss after (days)		
		90	180	270
Tin	Chickpea	2.39B ab (1.61)	11.09Cb (3.36)	30.46Bb (33.41)
	Grasspea	2.11B b (1.61)	6.94C c (2.71)	21.50Bc (27.60)
	Mungbean	3.18B a (1.81)	15.24Ca (3.90)	34.81Ba (36.14)
Motka	Chickpea	2.91ABab (1.74)	13.00Bb (3.60)	32.18ABb (34.51)
	Grasspea	2.05ABb (1.59)	8.57B c (3.10)	22.09ABc (28.00)
	Mungbean	4.78ABa (2.29)	17.39Ba (4.17)	36.81ABa (37.33)
Gunnybag	Chickpea	5.40A ab (2.42)	14.09Ab (3.75)	33.53Ab (35.36)
	Grasspea	2.39A b (1.70)	11.66A c (3.41)	27.43Ac (31.41)
	Mungbean	6.02A a (2.54)	18.01Aa (4.24)	38.18Aa (38.14)
CV%		39.69	13.30	12.80

- All figures are average of four replications.
- Means in a column having the different capital letters are significantly different among the containers at the 1% level of DMRT.
- Means in a column having the different small letters are significantly different among the crops at the 5% level of DMRT.
- Figures in the parentheses are square root and arc sine transformed values.

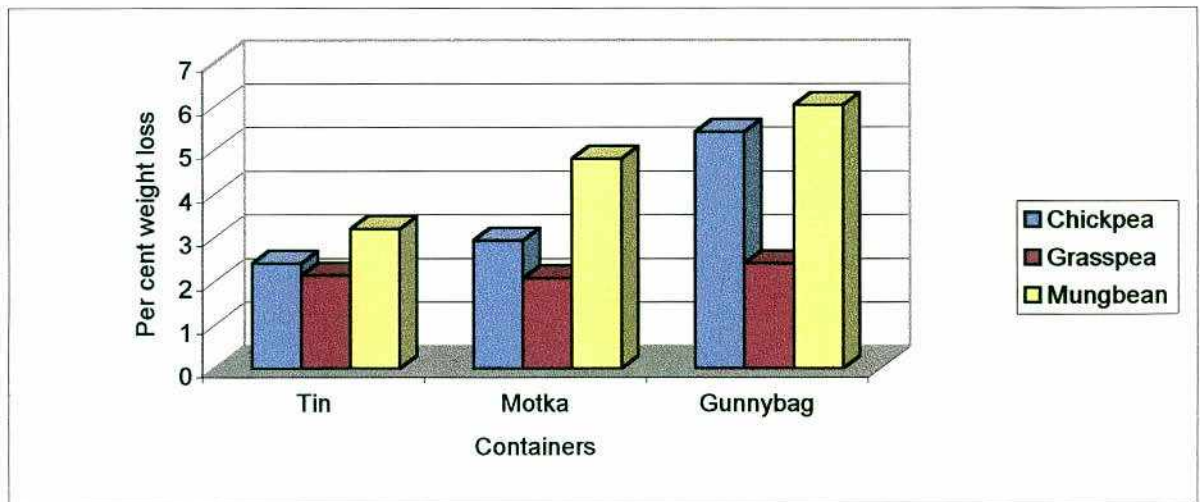


Fig. 9. Per cent weight loss after 90 days in different containers

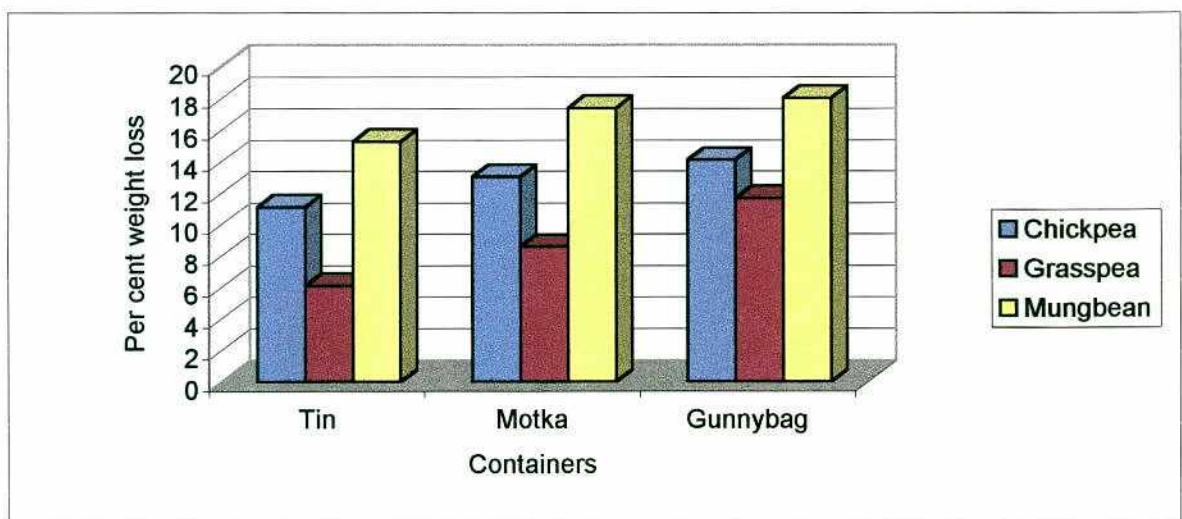


Fig. 10. Per cent weight loss after 180 days in different containers

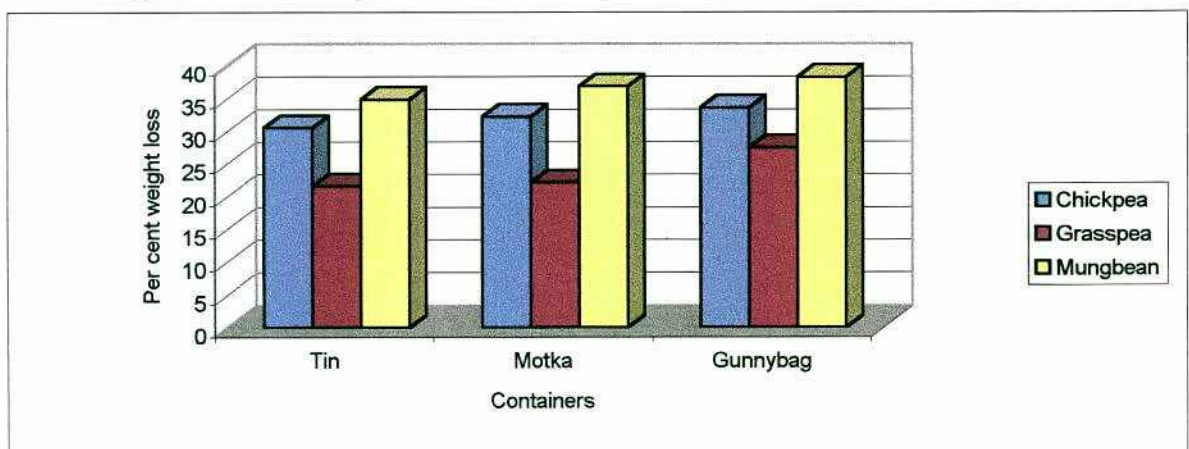


Fig. 11. Per cent weight loss after 270 days in different containers

between the containers for all pulses was also statistically significant. The highest per cent of weight loss occurred for the grains stored in gunnybag while tin provided the better protection than motka. At 90 DAS, the percentages of weight loss were 2.11-3.18, 2.05-4.78 and 2.39-6.02 for seeds stored in tin, motka and gunnybag respectively. Per cent weight loss went up to 6.94 - 15.24, 8.57- 17.39 and 11.66-18.01 at 180 DAS which further rose to 21.50-34.81%, 22.09-36.81% and 27.43-38.18% at 270 DAS respectively for seeds stored in tin, motka and gunnybag. Among the tested pulses, mungbean always suffered from the higher weight loss than the others. Grasspea was more tolerant than chickpea. These results reflect the similarity with per cent infestation (Table 1). At 90 DAS, the percentages of weight loss were 2.05-2.39, 2.39-5.40 and 3.18-6.02 for grasspea, chickpea and mungbean respectively. As the storage time progressed (at 180 DAS) per cent weight loss increased to 6.94-11.66, 11.09-14.09 and 15.24-18.01 for grasspea, chickpea and mungbean respectively. At 270 DAS, these values further intensified to 21.50-27.43%, 30.46-33.53% and 34.81-38.18%. Similar to the results of per cent infestation, per cent weight loss data also lead to assume that up to three months of storage tin, motka and gunnybag could provide acceptable level of protection against pulse beetle but they are not suitable at all for long time storage.

4.1.3. Germination: The percentages of germination of chickpea, grasspea and mungbean after storing for nine months' period in tin, motka and gunnybag are shown in table 3. Statistically, the percentages of germination between pulses within containers varied significantly for 90 DAS. However, the highest percentage of germination was observed with mungbean and chickpea stored in tin and motka respectively at 90 DAS. Grasspea stored in tin revealed the lowest percentage of germination. The rate of germination declined steadily as the time of storage progressed. At 180 DAS, the percentage of germination ranged from 62.75-78.50 which further declined to a range of 32.75-60.00 at 270 DAS. Of the three containers, seeds stored in gunnybag always manifested significantly lower percentage of germination than seeds stored in tin and motka except for 90 DAS. The germination percentages observed from the seeds stored in tin and Motka varied insignificantly (Table 3). At 90 DAS, seeds stored in tin, motka and gunnynag respectively revealed 88.75-94.00%, 89.75-94.00% and 90.00-91.50% germination. These levels of germination declined further at 180 DAS and went down to 53.50-59.00%, 55.75-60.00% and 32.75-35.00% at 270 DAS. Similar to per cent infestation (Table 1) and weight loss (Table 2), the results of germination further confirmed the poor performance of gunnybag as a storage container than tin and motka. For longer storage, however, none of the tested

Table 3. Per cent germination of chickpea, grasspea and mungbean stored in different containers for nine months

Containers	Pulse type	Initial germination (%)	% germination after (days)		
			90	180	270
Tin	Chickpea	94.50	93.50ab (9.67)	72.50b (58.36)	59.00a (50.18)
	Grasspea	93.50	88.75d (9.42)	75.50ab (60.35)	53.50ab (47.01)
	Mungbean	96.25	94.00a (9.70)	76.25ab (60.84)	57.50ab (49.31)
Motka	Chickpea		94.00a (9.70)	75.50ab (60.35)	60.00a (50.76)
	Grasspea		89.75cd (9.47)	77.75ab (61.86)	55.75ab (48.30)
	Mungbean		92.50a-c (9.62)	78.50a (62.40)	56.50ab (48.73)
Gunnybag	Chickpea		91.50a-d (9.57)	64.75c (53.59)	32.75c (34.90)
	Grasspea		90.00cd (9.49)	64.00c (53.12)	34.75c (36.12)
	Mungbean		91.00b-d (9.54)	62.75c (52.43)	35.00c (36.27)
CV %			2.02	5.42	8.36

- All figures are average of four replications.
- Means in a column having the different letters are significantly different at the 5% level of DMRT.
- Figures in the parentheses are square root and arc sine transformed values.

containers was effective in maintaining the quality of seeds.

4.1.4. Moisture content: The moisture content in chickpea, grasspea and mungbean stored in tin, motka and gunnybag was measured at the beginning of the experiment and at 90, 180 and 270 DAS. The results are presented in table 4. The initial moisture levels were 9.8, 10.1 and 9.9 per cent in chickpea, grasspea and mungbean respectively. Statistically, the moisture level between the pulses varied significantly only at 180 and 270 DAS. Seeds stored in gunnybag always retained higher moisture content than tin and motka with some exception. At 90 DAS, the moisture contents were 11.00-11.75%, 11.50-12.25% and 11.50-12.25% in seeds stored in tin, motka and gunnybag respectively. At 180 DAS, the moisture level slightly increased in seeds stored in tin and motka than at 90 DAS but significant increase was noticed in seeds stored in gunnybag. The moisture contents further increased to 16.75-17.75%, 17.00-18.50% and 18.75-19.75% in seeds stored in tin, motka and gunnybag respectively at 270 DAS. The retention of higher moisture content in seeds stored in gunnybag was possibly the main reason of building up of pulse beetle population which ultimately caused higher intensity of infestation (Table 1), weight loss (Table 2) and reduced germination (Table 3).

Table 4. Per cent moisture level in chickpea, grasspea and mungbean stored in different containers for nine months

Containers	Pulse type	Initial moisture level (%)	% moisture level after (days)		
			90	180	270
Tin	Chickpea	9.8	11.50 (3.39)	13.25c (3.64)	17.00de (4.12)
	Grasspea	10.1	11.00 (3.19)	13.25c (3.64)	17.75cd (4.21)
	Mungbean	9.9	11.75 (3.43)	13.50c (3.67)	16.75e (4.09)
Motka	Chickpea		12.00 (3.46)	13.25c (3.64)	17.75cd (4.21)
	Grasspea		12.25 (3.50)	13.25c (3.64)	17.00de (4.12)
	Mungbean		11.50 (3.39)	14.50bc (3.81)	18.50bc (4.30)
Gunnybag	Chickpea		12.25 (3.50)	15.75ab (3.97)	18.75b (4.33)
	Grasspea		11.50 (3.39)	16.00a (4.00)	19.25ab (4.39)
	Mungbean		11.75 (3.43)	15.50ab (3.93)	19.75a (4.44)
CV %			6.67	5.85	3.61

- All figures are average of four replications
- Means in a column having the different letters are significantly different at the 5% level of DMRT
- Figures in the parentheses are square root transformed values

4.2. Toxicity of oils and insecticide against pulse beetle

The toxicity of different oils along with an insecticide (Decis) was tested under laboratory condition against pulse beetle and determined using log-probit analysis. The results are expressed in lethal concentrations values and presented in table 5. Among the tested materials, decis was more toxic to pulse beetle considering both LC_{50} ($0.00697\mu\text{l/insect}$) and LC_{90} ($0.02132\mu\text{l/insect}$) values. Decis also revealed the lowest slope value (2.08 ± 0.32), which indicated that the estimation of the LC values of decis against pulse beetle was more precise than others. The toxicity of others was in the following order: neem oil > mustard oil > coconut oil > soybean oil. The highest slope value (3.14 ± 0.33) was obtained for soybean oil which indicated the heterogenous mortality of pulse beetle while exposed to soybean oil. These resulted the lowest toxicity of soybean oil. LC_{50} value of soybean oil was 14 times higher than decis. Both LC_{50} and LC_{90} values revealed that decis was 2.87 times more toxic than coconut oil.

4.3. Efficacy of different oils and insecticide

4.3.1. Rate of oviposition: The rate of oviposition of pulse beetle on different oils and decis treated seeds of chickpea, grasspea and mungbean was monitored at 90, 180 and 270 DAS and the results are presented in table 6. It was evident from the table that decis treated seeds had no

Table 5. Toxicity of mustard, coconut, soybean, neem oil and decis (Deltamethrin) against *C. chinensis*

Treatments	LC ₅₀ (μ l/insect)	95% confidence interval	LC ₅₀ (μ l/insect)	95% confidence interval	Slope $\pm$ SE
Mustard oil	0.00966	0.00709-0.01272	0.02955	0.02228-0.04124	2.62 $\pm$ 0.31
Coconut oil	0.02001	0.00725-0.01300	0.03019	0.02275-0.04220	2.89 $\pm$ 0.32
Soybean oil	0.0987	0.01555-0.02578	0.06119	0.04555-0.08959	3.14 $\pm$ 0.33
Neem oil	0.00922	0.00674-0.1216	0.02819	0.02128-0.03919	2.47 $\pm$ 0.31
Decis	0.00697	0.00491-0.00943	0.02132	0.01586-0.02972	2.08 $\pm$ 0.32

eggs at all in all sampling dates. In other words, decis provided the complete protection of the stored seeds even for longer time. In contrast, 61.50-112.50, 63.00-119.25 and 58.50-107.75 egg/100 grains were recorded from the untreated seeds of chickpea, grasspea and mungbean respectively. For all of the tested oils, three dosage were tested of which the highest dosage (10 ml/kg) of mustard and two dosage (7 & 10 ml) of neem was almost as effective as decis except coconut and soybean. In the remaining doses, significantly lowest number of eggs was always observed in 7 ml/kg than 4 ml/kg. Neem oil had the lowest number of eggs in all sampling dated for all pulses. Toxicity test (Table 5) also projected similar observation. Results of 90, 180 and 270 DAS revealed that the increasing number of eggs was always recorded from the longer storage period. Irrespective of treatments, doses and pulses, 90 DAS had lower number of eggs than 180 DAS which further increased at 270 DAS.

4.3.2. Hatchability: The per cent hatchability of eggs laid by pulse beetle on different oils and decis treated seeds of chickpea, grasspea and mungbean are shown in table 7. Likewise the rate of oviposition, all doses of decis and the highest dosage (10 ml/kg) of mustard and two dosage (7 & 10 ml) of neem oil yielded zero per cent hatchability in all sampling occasions. On the other hand, the per cent

Table 6. Efficacy of different oils and insecticide on the oviposition of *C. chinensis* on chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose ml/kg	No. of eggs/100 grains after								
		90 days			180 days			270 days		
		Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Mustard oil	4	31.75b (1.50)	28.75c (1.45)	35.50b (1.55)	41.00b (1.61)	39.25c (1.57)	49.00b (1.67)	55.75c (1.74)	53.00c (1.72)	57.00c (1.75)
	7	16.25d (1.20)	18.75d (1.25)	15.00d (1.17)	30.00c (1.47)	34.50d (1.54)	31.50d (1.50)	38.25d (1.57)	39.50d (1.59)	41.00d (1.61)
	10	0.00e (0.00)	0.00f (0.00)	0.00e (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)
Coconut oil	4	35.50b (1.55)	37.50b (1.57)	41.00b (1.61)	46.25b (1.66)	47.00b (1.67)	54.00b (1.73)	62.25b (1.79)	61.50b (1.78)	63.00b (1.78)
	7	22.75c (1.35)	21.75d (1.33)	24.50c (1.38)	36.75c (1.56)	38.25c (1.58)	42.25c (1.62)	48.50c (1.68)	50.25c (1.70)	47.50d (1.67)
	10	14.50d (1.16)	16.25d (1.21)	12.75d (1.10)	23.50d (1.37)	22.25e (1.34)	22.75e (1.35)	31.25d (1.49)	37.50d (1.57)	38.50d (1.58)
Soybean oil	4	36.50b (1.56)	40.00b (1.60)	43.50b (1.63)	49.75b (1.69)	48.75b (1.68)	57.50b (1.75)	69.25b (1.84)	64.75b (1.81)	67.50b (1.82)
	7	24.00c (1.38)	26.75c (1.42)	27.25c (1.43)	42.75b (1.63)	41.50c (1.61)	51.25b (1.70)	51.25c (1.70)	54.50c (1.73)	52.25c (1.71)
	10	16.25d (1.21)	17.50d (1.24)	14.25d (1.15)	25.50d (1.40)	26.75e (1.42)	22.75e (1.35)	35.75d (1.55)	39.25d (1.59)	38.25d (1.58)
Neem oil	4	12.25d (1.08)	11.50e (1.06)	13.75d (1.13)	21.00d (1.32)	19.25e (1.28)	22.50e (1.35)	34.75d (1.54)	31.00e (1.49)	29.25e (1.46)
	7	0.00e (0.00)	0.00f (0.00)	0.00e (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)
	10	0.00e (0.00)	0.00f (0.00)	0.00e (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)
Decis	2ppm	0.00e (0.00)	0.00f (0.00)	0.00e (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)
	3ppm	0.00e (0.00)	0.00f (0.00)	0.00e (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)
	4ppm	0.00e (0.00)	0.00f (0.00)	0.00e (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)	0.00e (0.00)	0.00f (0.00)	0.00f (0.00)
Control		61.50a (1.78)	63.00a (1.79)	58.50a (1.76)	84.50a (1.92)	88.75a (1.94)	96.75a (1.98)	112.50a (2.05)	119.25a (2.07)	107.75a (2.03)
CV %		24.92	24.11	24.48	14.12	14.36	12.13	10.21	8.1	8.15

- All figures are means of four replications,
- Means in a column having same letters are not significantly different at the 5% level of DMRT,
- Figures in the parenthesis are log transformation values.

Table 7. Efficacy of different oils and insecticide on the per cent hatchability of *C. chinensis* on chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose ml/kg	% egg hatch after								
		90 days			180 days			270 days		
		Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Mustard oil	4	25.47a (5.04)	26.77b (5.17)	21.55c (4.64)	33.93b (35.61)	31.51a (34.14)	31.06b (33.83)	39.24b (38.76)	41.57a (41.11)	37.68c (37.82)
	7	21.49b (4.67)	20.23c (4.49)	20.04c (4.47)	22.71c (28.45)	24.23b (29.47)	23.36c (28.86)	32.29c (34.57)	33.18b (35.12)	35.50c (36.57)
	10	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)
Coconut oil	4	22.04b (4.69)	19.96c (4.46)	23.92c (4.89)	32.05b (34.45)	31.63a (34.20)	36.22b (34.57)	41.44a (40.05)	42.65a (40.74)	39.26c (38.76)
	7	18.15c (4.26)	19.24c (4.38)	20.76c (4.55)	25.73c (30.46)	26.84b (31.18)	27.76c (31.76)	35.88c (36.75)	38.65b (38.41)	36.56c (37.17)
	10	13.50d (3.67)	13.31d (3.64)	12.22d (3.49)	16.50e (23.97)	21.18b (27.05)	19.23d (25.99)	30.20c (25.33)	31.56b (27.45)	22.37d (28.18)
Soybean oil	4	25.47a (5.04)	22.89b (4.78)	26.85b (5.18)	32.91b (35.00)	32.05a (34.45)	333.46b (35.30)	39.66b (39.00)	42.91a (40.92)	44.51b (41.84)
	7	25.06a (5.00)	24.36b (4.93)	24.92c (4.99)	26.14c (30.72)	28.93b (32.52)	30.93b (33.77)	39.10b (38.70)	40.98a (39.76)	38.53c (38.35)
	10	14.51d (3.80)	15.06d (3.88)	17.32d (4.16)	20.16d (26.64)	18.72c (25.62)	21.66c (27.69)	26.72d (31.11)	28.89c (32.46)	29.39d (32.77)
Neem oil	4	13.48d (3.67)	14.17d (3.76)	13.41d (3.66)	19.96d (26.49)	16.34c (23.81)	20.80c (27.13)	23.56d (29.00)	25.71c (30.46)	26.01d (30.66)
	7	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)
	10	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)
Decis	2ppm	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)
	3ppm	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)
	4ppm	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)
Control		26.11a (5.10)	23.40a (4.83)	27.90a (5.28)	39.92a (39.17)	32.90a (35.00)	35.43a (36.51)	41.97a (40.34)	43.15a (41.03)	47.71a (43.68)
CV %		34.72	33.66	36.71	21.99	25.95	20.42	29.06	25.78	30.02

- All figures are means of four replications,
- Means in a column having same letters are not significantly different at the 5% level of DMRT,
- Figures in the parenthesis are square root and arc sin transformed values

hatchability of eggs laid on untreated seeds of chickpea, grasspea and mungbean respectively ranged from 26.11-41.97%, 23.40-43.15% and 27.90-47.71%. Similar to the results of the rate of oviposition, neem treated seeds always yielded the lowest per cent hatchability than other oils. Although coconut and soybean oils could not reduce the per cent hatchability as did other oils but the results of this treatment significantly varied from untreated control (Table 7). For all treatments and pulses, the per cent hatchability increased with the increase of storage period. The per cent hatchability between pulses varied in an irregular fashion which indicated that the pulse seeds did not have any influence in reducing or increasing the per cent hatchability.

4.3.3. Adult emergence: The percentages of adults emerged from oils and decis treated seeds of chickpea, grasspea and mungbean over nine months of storage period are presented in table 8. All doses of decis and the highest dosage (10 ml/kg) of mustard and two dosage (7 & 10 ml) of neem oil prevented pulse beetle for laying eggs (Table 6) which ultimately resulted no adult emergence in these treatments. From the untreated seeds of chickpea, grasspea and mungbean on the other hand, 29.73-49.00%, 30.87-47.21% and 31.48-45.51% adults emerged respectively. Of the tested oils, the lowest per cent of adults emerged from mustard treated

Table 8. Efficacy of different oils and insecticide on the per cent adult emergence of *C. chinensis* on chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose ml/kg	% adult emergence after								
		90 days			180 days			270 days		
		Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Mustard oil	4	27.92ab (5.28)	29.61a (5.44)	26.50b (5.14)	32.52b (34.76)	34.17b (35.73)	31.42b (34.08)	34.37c (35.05)	37.32b (37.64)	36.55bc (37.17)
	7	18.28b (4.27)	20.95c (4.57)	19.35c (4.39)	24.45bc (29.60)	27.30bc (31.50)	24.11c (29.40)	28.92d (32.52)	31.21bc (33.96)	27.86d (31.82)
	10	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00e (0.29)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)	0.00f (0.29)
Coconut oil	4	28.10a (15.30)	29.92a (5.46)	27.42b (5.23)	33.13b (36.93)	34.88b (36.15)	39.63a (34.82)	42.18b (40.46)	46.49a (42.94)	41.23b (39.93)
	7	20.59b (4.53)	22.37c (4.72)	21.22c (4.60)	25.02b (30.85)	29.27bc (33.02)	27.64c (31.69)	31.42c (34.08)	34.80b (36.15)	30.96c (33.37)
	10	18.26b (4.27)	17.12c (4.13)	18.53c (4.30)	22.24c (28.11)	23.24c (28.79)	20.27d (26.71)	25.29d (30.13)	27.11c (31.37)	26.46d (30.92)
Soybean oil	4	28.75a (5.36)	30.13a (5.48)	28.25b (5.31)	34.71b (36.06)	35.26b (36.45)	32.93b (35.00)	44.95b (42.07)	46.99a (43.22)	43.12b (41.03)
	7	27.52ab (5.24)	26.40b (5.13)	26.83b (5.17)	31.37b (34.02)	32.49b (34.70)	30.70b (33.65)	34.73c (36.09)	35.88b (36.75)	31.83c (34.33)
	10	16.12b (4.01)	18.17c (4.26)	19.52c (4.41)	21.83c (27.90)	22.61c (28.38)	23.84c (29.20)	27.97d (31.88)	29.11c (32.65)	26.20d (30.79)
Neem oil	4	13.21c (3.63)	11.39d (3.37)	15.12d (3.88)	17.40d (24.65)	19.62d (26.28)	18.35d (25.33)	21.90e (27.28)	20.96d (27.20)	23.41e (8.93)
	7	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00e (0.29)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)	0.00f (0.29)
	10	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00e (0.29)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)	0.00f (0.29)
Decis	2ppm	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00e (0.29)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)	0.00f (0.29)
	3ppm	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00e (0.29)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)	0.00f (0.29)
	4ppm	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00e (0.29)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)	0.00f (0.29)
Control		29.73a (5.45)	30.87a (5.55)	31.48a (5.61)	36.29a (36.99)	37.44a (37.70)	39.19a (38.70)	49.00a (44.43)	47.21a (34.39)	45.51a (42.42)
CV %		39.52	27.59	34.01	22.32	25.40	13.72	7.44	7.12	10.12

- All figures are means of four replications,
- Means in a column having same letters are not significantly different at the 5% level of DMRT,
- Figures in the parenthesis are square root and arc sin transformed values

seeds in earlier period of storage (90 and 180 DAS) but in the later stage (270 DAS) the performance of neem was better than mustard. Statistically, the effect of the lowest dosage of all oils in terms of per cent adults emerged was identical to that of untreated control (Table 8). Similar to the rate of oviposition and per cent hatchability, the percentages of adult emergence increased with the increase of storage period. Irrespective of treatments and dosage, the variation between pulses could not ascertain since the percentages of adult emergence from pulses varied irregularly.

4.3.4. Intensity of infestation: The effect of different oils and decis for the protection of pulse grains of chickpea, grasspea and mungbean varied significantly in all sampling occasions (Table 9 and figures 12, 13 and 14). All dosage of decis and the highest dosage of mustard and two dosage of neem oil provided complete protection of seeds. These results were expected since no eggs, per cent hatchability and adult emergence were obtained from the above treatments. In untreated control the percentages of infestation varied from 14.85-46.97, 15.34-45.03 and 16.26-48.47 for chickpea, grasspea and mungbean respectively. Among the tested oils, neem exhibited better results than others irrespective of doses providing the lowest percentages of infestation. Similar to 10 ml/kg of mustard,

Table 9. Efficacy of different oils and insecticide on the per cent infestation of chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose ml/kg	% infestation after								
		90 days			180 days			270 days		
		Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Mustard oil	4	6.28bc	6.65c	7.65c	14.93bc	13.68c	16.23c	18.85d	19.08bc	20.88b
		(2.76)	(2.50)	(2.53)	(3.86)	(3.69)	(4.02)	(25.70)	(25.84)	(27.20)
		3.35c	3.03d	3.63d	7.15d	7.63cd	8.68e	11.60e	13.78bc	14.73c
	7	(1.83)	(1.74)	(1.90)	(2.67)	(2.93)	(2.77)	(19.91)	(21.72)	(22.55)
		0.00d	0.00e	0.00e	0.00f	0.00e	0.00f	0.00g	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)
Coconut oil	4	7.68b	8.50c	9.28b	17.80b	19.28b	20.03b	23.30bc	23.38b	24.11b
		(2.91)	(2.77)	(3.04)	(4.21)	(4.39)	(4.47)	(29.40)	(28.86)	(28.86)
		4.10c	3.85d	4.70d	9.65d	10.25cd	12.95d	17.33d	19.98bc	17.68c
	7	(2.02)	(1.96)	(2.16)	(3.10)	(3.20)	(3.59)	(24.58)	(46.49)	(24.80)
		2.65c	3.19d	2.78d	3.92e	4.55d	4.47e	6.40f	7.26d	7.66d
		(1.62)	(1.78)	(1.66)	(1.97)	(2.13)	(2.11)	(15.79)	(17.66)	(14.89)
Soybean oil	4	10.63b	12.55b	13.62a	19.33b	20.08b	21.88b	27.40b	28.85b	29.90b
		(3.26)	(3.54)	(3.69)	(4.39)	(4.48)	(4.67)	(32.20)	(31.82)	(33.15)
		6.75bc	7.40c	6.13c	10.25d	12.10c	14.80c	22.92bc	21.43b	20.78b
	7	(2.59)	(2.72)	(2.47)	(3.20)	(3.47)	(3.84)	(28.59)	(87.56)	(27.06)
		3.03c	2.48d	2.55d	5.20e	4.63d	5.57e	9.70e	11.81d	10.50d
		(1.74)	(1.57)	(1.59)	(2.28)	(2.15)	(2.36)	(18.15)	(20.09)	(18.91)
Neem oil	4	2.00c	2.25d	2.95d	4.10e	4.11d	5.68e	7.90f	9.58d	9.00d
		(1.71)	(1.41)	(1.50)	(2.02)	(2.02)	(2.38)	(16.32)	(17.95)	(17.46)
		0.00d	0.00e	0.00e	0.00f	0.00e	0.00f	0.00g	0.00e	0.00e
	7	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)
		0.00d	0.00e	0.00e	0.00f	0.00e	0.00f	0.00g	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)
Decis	2ppm	0.00d	0.00e	0.00e	0.00f	0.00e	0.00f	0.00g	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)
		0.00d	0.00e	0.00e	0.00f	0.00e	0.00f	0.00g	0.00e	0.00e
	3ppm	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)
		0.00d	0.00e	0.00e	0.00f	0.00e	0.00f	0.00g	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)
Control	4ppm	0.00d	0.00e	0.00e	0.00f	0.00e	0.00f	0.00g	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)
		14.85a	15.34a	16.26a	30.40a	28.38a	30.47a	46.97a	45.03a	48.47a
		(4.03)	(3.91)	(3.85)	(5.51)	(5.32)	(5.51)	(43.22)	(42.13)	(44.08)
		CV%	10.58	9.66	10.00	9.14	6.87	8.64	11.28	11.11
										12.32

- All figures are means of four replications,
- Means in a column having same letters are not significantly different at the 5% level of DMRT,
- Figures in the parenthesis are square root and arc sin transformed values

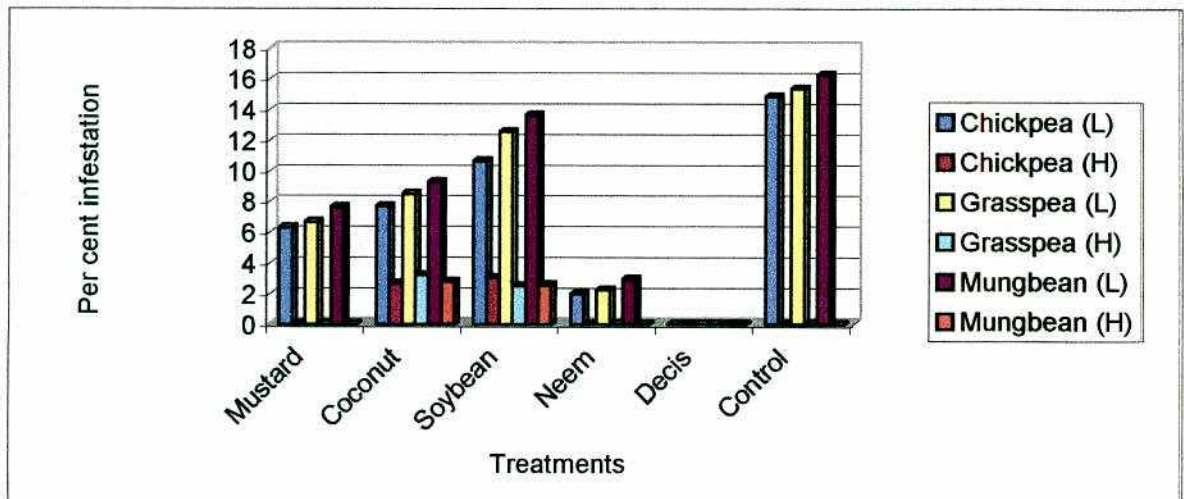


Fig. 12. Per cent infestation after 90 days at lowest and highest dosage of oils and insecticide

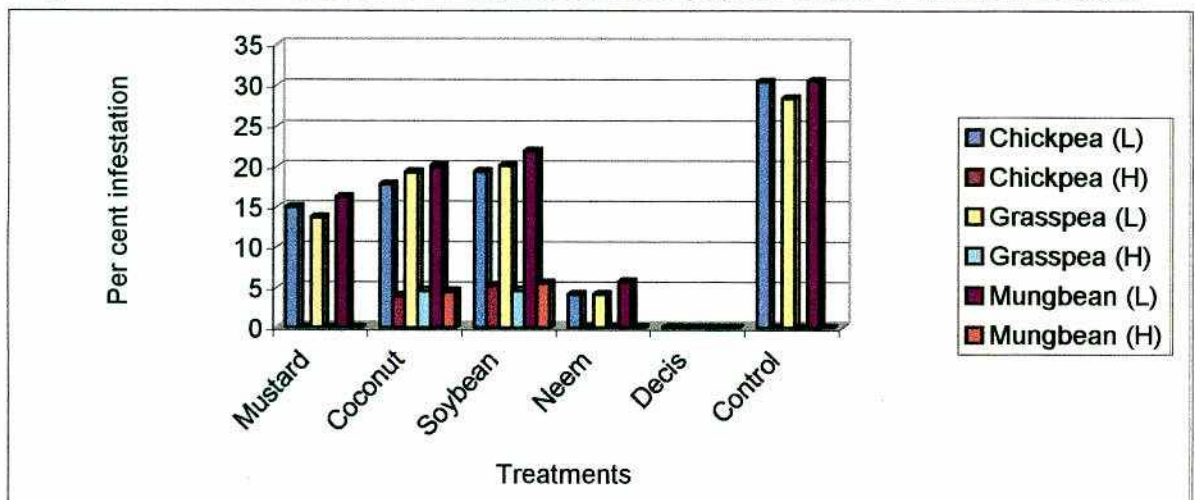


Fig. 13. Per cent infestation after 180 days at lowest and highest dosage of oils and insecticide

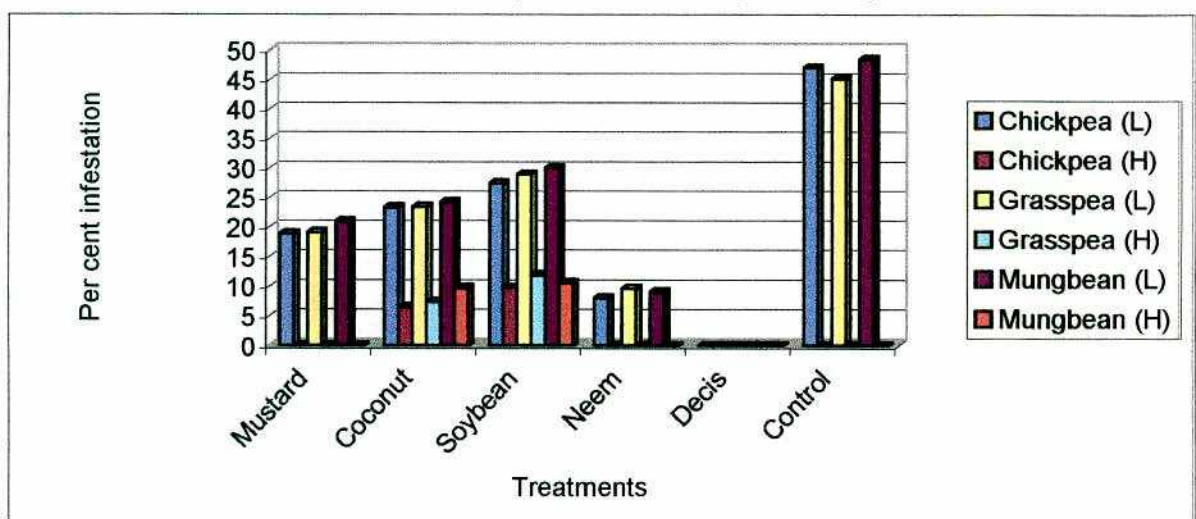


Fig. 14. Per cent infestation after 270 days at lowest and highest dosage of oils and insecticide

7 ml/kg of neem oil was also as effective as decis in protecting pulse grains. Statistically, the percentages of infestation obtained from different oils of similar doses did not vary significantly with some exception at 90, 180 and 270 DAS. For all treatments, the percentages of infestation increased with the increase of storage period. At 90 DAS, 2.00-16.26% infestation was found which increased to 4.10-30.47% at 180 DAS. The damage of seeds further intensified and reached to 6.40-48.47% at 270 DAS. Comparison of the results of treated and untreated control treatment revealed that in almost all sampling occasions (at 90, 180 and 270 DAS) the chickpea exhibited lower infestation than grasspea and mungbean.

4.3.5. Weight loss: Statistically, per cent weight loss of treated seeds varied significantly with those of untreated seeds in all sampling occasions (Table 10 and figures 15, 16 and 17). All doses of decis and the highest doses of mustard and neem oils showed no weight losses. The weight loss of untreated seed of chickpea, grasspea and mungbean ranged from 8.48-24.21%, 8.35-23.11% and 9.93-24.42%, respectively at 9 months periods. Irrespective of doses and storage periods neem oil provided the lowest weight losses. Comparison between mustard, coconut and soybean oils revealed that mustard oil was more effective than the others. The percentages of weight loss was found to

Table 10. Efficacy of different oils and insecticide on the per cent weight loss of chickpea, grasspea and mungbean after storage for nine months

Treat-ments	Dose ml/kg	% weight loss after								
		90 days			180 days			270 days		
		Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Mustard oil	4	3.88bc (2.05)	3.97c (1.99)	4.21c (1.96)	6.65b (2.77)	7.71c (2.57)	8.95c (2.99)	9.25bc (3.04)	9.77bc (3.12)	10.32bc (3.21)
	7	1.51d (1.31)	1.58d (1.36)	1.63d (1.27)	4.14c (2.03)	4.37d (2.09)	3.88d (1.96)	5.88d (2.42)	6.57c (2.56)	7.14d (2.67)
	10	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.71)	0.00e (0.71)	0.00f (0.71)	0.00d (0.71)	0.00f (0.71)
Coconut oil	4	3.11bc (2.05)	4.21c (1.76)	4.77c (2.18)	8.93b (2.98)	9.63b (3.10)	10.91b (3.30)	12.44b (3.52)	11.56b (3.40)	12.65b (3.55)
	7	1.58d (1.72)	2.52d (1.25)	2.67cd (1.63)	4.42c (2.10)	5.54c (2.35)	6.98c (2.64)	9.31bc (3.05)	9.51b (3.24)	9.08bc (3.01)
	10	0.88e (0.93)	1.02d (1.00)	1.01d (1.00)	2.21d (1.48)	2.11e (1.45)	2.26d (1.50)	3.16e (1.78)	3.19c (2.14)	4.62e (1.77)
Soybean oil	4	5.46b (2.33)	6.62b (2.61)	6.86b (2.57)	10.17b (3.03)	11.08b (3.32)	11.41b (3.18)	14.10b (3.75)	13.27b (3.64)	14.75b (3.84)
	7	3.87bc (1.96)	4.54c (2.13)	3.58c (1.89)	5.65c (2.37)	6.81c (2.60)	7.65c (2.76)	11.90b (3.44)	11.91b (3.45)	10.25bc (3.20)
	10	1.41d (1.18)	1.39d (1.17)	1.51d (1.22)	2.45d (1.56)	2.35e (1.53)	3.30d (1.81)	5.17d (2.27)	6.41c (2.53)	5.16d (2.27)
Neem oil	4	1.85d (1.36)	1.45d (1.20)	1.56d (1.18)	2.55d (1.59)	2.40e (1.54)	3.65d (1.91)	3.75e (1.93)	4.92c (2.24)	5.03d (2.21)
	7	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.71)	0.00e (0.71)	0.00f (0.71)	0.00d (0.71)	0.00f (0.71)
	10	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.71)	0.00e (0.71)	0.00f (0.71)	0.00d (0.71)	0.00f (0.71)
Decis	2ppm	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.71)	0.00e (0.71)	0.00f (0.71)	0.00d (0.71)	0.00f (0.71)
	3ppm	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.71)	0.00e (0.71)	0.00f (0.71)	0.00d (0.71)	0.00f (0.71)
	4ppm	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00f (0.71)	0.00e (0.71)	0.00f (0.71)	0.00d (0.71)	0.00f (0.71)
Control		8.48a (3.15)	8.35a (2.91)	9.93a (2.88)	15.42a (3.92)	14.27a (3.77)	16.89a (4.10)	24.21a (4.92)	23.11a (4.80)	24.42a (4.94)
CV%		7.14	7.66	5.57	7.89	6.76	8.63	9.34	7.63	9.59

- All figures are means of four replications,
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

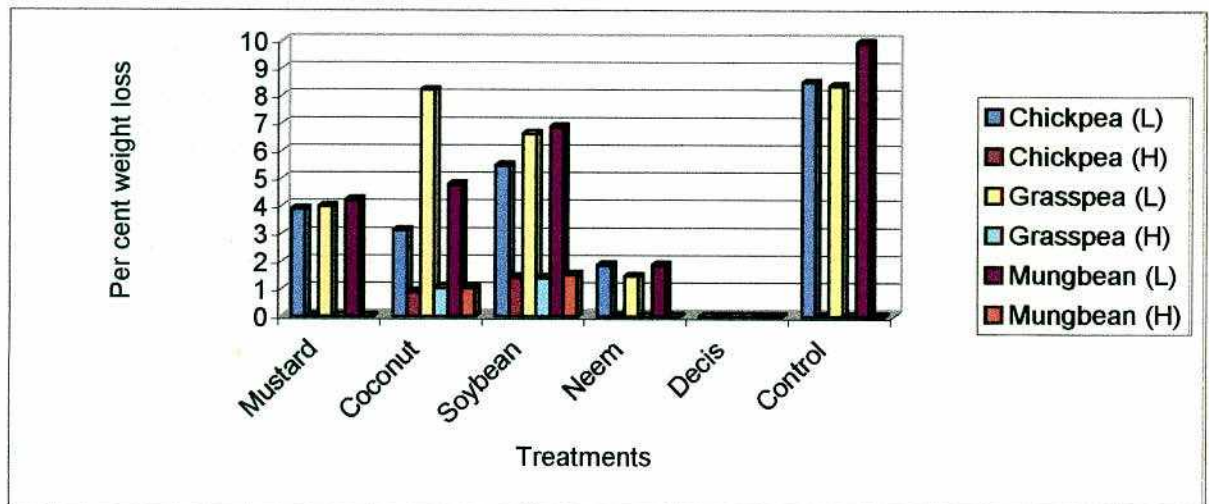


Fig. 15. Per cent weight loss after 90 days at lowest and highest dosage of oils and insecticide

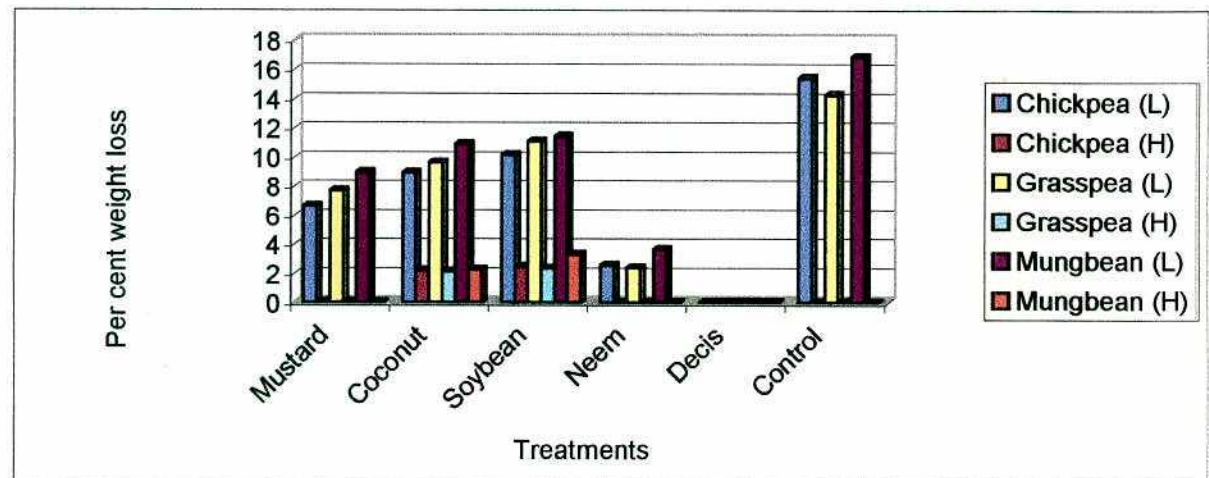


Fig. 16. Per cent weight loss after 180 days at lowest and highest dosage of oils and insecticide

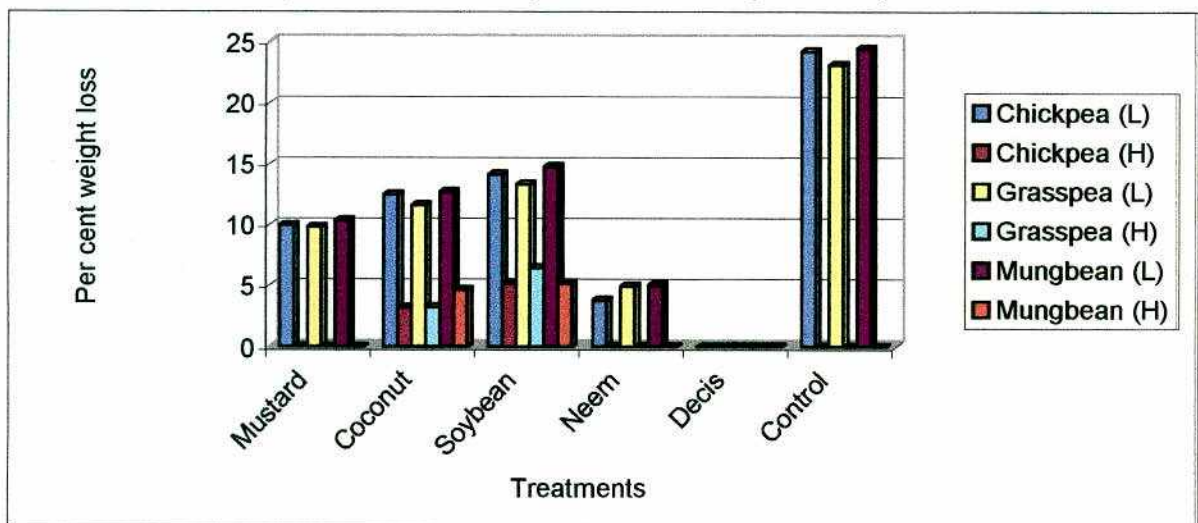


Fig. 17. Per cent weight loss after 270 days at lowest and highest dosage of oils and insecticide

increase with the increase of storage periods for all treatments and pulses. At 90 DAS, incurred loss was 0.88-8.48%, 1.02-8.35% and 1.01-9.93% for chickpea, grasspea and mungbean respectively. These losses increased to 2.21-15.42%, 2.11-14.27% and 2.26-16.89%, respectively for chickpea, grasspea and mungbean at 180 DAS. At 270 DAS the per cent weight loss was further intensified to 3.16-24.21%, 3.19-23.11% and 4.62-24.42% for chickpea, grasspea and mungbean respectively.

4.3.6. Germination: The results of the germination of chickpea, grasspea and mungbean seeds treated with decis and different oils and stored for nine months period are presented in table 11. At 90 DAS, the highest per cent germination (99.00%) of coconut oil treated seed was recorded in mungbean while the lowest (80.25%) was also recorded in mungbean in untreated seed. At 180 days the highest per cent (93.00%) germination was recorded from decis treated seeds and the lowest (60.25%) was also recorded from untreated seeds. At 270 DAS, the effect of decis and all of the tested oils was statistically identical except the lowest doses of coconut and soybean oil. The observed percentages of germination were 80.50-89.00, 83.00-89.50, 66.50-87.25, 48.75-89.50 and 80.75-89.50 for decis, neem, soybean, coconut and mustard treated seeds respectively. On the other hand, untreated seeds scored 40.00-48.00% germination at 270 DAS.

Table 11. Efficacy of different oils and insecticide on the per cent germination of chickpea, grasspea and mungbean stored for nine months

Treatments	Dose ml/kg	% germination after								
		90 days			180 days			270 days		
		Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mungbean
Mustard oil	4	92.00c	91.25b	93.00b	86.75b	84.50a-c	81.50de	85.50c	80.75c	80.75cd
		(9.59)	(9.60)	(9.64)	(9.31)	(9.19)	(9.02)	(67.62)	(63.44)	(63.94)
	7	92.50c	93.00b	97.50ab	84.00b	87.75c	88.50a	85.75c	83.50c	84.75cd
		(9.62)	(9.64)	(9.87)	(9.16)	(9.36)	(9.40)	(67.78)	(66.03)	(66.97)
	10	92.00c	92.25b	97.25ab	88.75a	87.50a-c	89.00ab	87.75ab	84.00c	89.50d
		(9.59)	(9.60)	(9.86)	(9.42)	(9.35)	(9.43)	(69.47)	(66.42)	(71.09)
Coconut oil	4	92.00c	94.00c	99.00a	81.25b	79.75d	76.50f	60.00d	48.75ab	62.25ab
		(9.59)	(9.70)	(9.92)	(9.01)	(8.93)	(8.74)	(50.77)	(44.25)	(52.24)
	7	92.73c	94.00c	93.25b	88.25a	85.75b-d	84.00ab	81.25ab	79.75c	76.75c
		(9.63)	(9.69)	(9.65)	(9.39)	(9.26)	(9.16)	(64.30)	(63.22)	(61.14)
	10	92.00c	93.25b	95.00ab	88.00a	85.00b-d	85.50b-d	87.75ab	87.50c	89.50d
		(9.59)	(9.65)	(9.74)	(9.38)	(9.21)	(9.24)	(69.47)	(69.30)	(71.09)
Soybean oil	4	86.75b	87.25ab	85.00c	80.00b	77.75a-d	76.50f	68.50c	70.00b	66.50ab
		(9.31)	(9.34)	(9.21)	(8.94)	(8.81)	(8.74)	(55.86)	(56.79)	(54.63)
	7	90.75c	92.25b	91.00b	83.00b	83.75ab	87.25a-c	75.75ab	76.50c	79.75c
		(9.52)	(9.61)	(9.53)	(9.11)	(9.15)	(9.34)	(60.47)	(61.00)	(63.22)
	10	93.00c	93.25b	97.25ab	88.25a	87.00a-c	89.00a-c	86.75ab	85.75c	87.25d
		(9.64)	(9.65)	(9.86)	(9.39)	(9.32)	(9.43)	(68.61)	(67.78)	(69.04)
Neem oil	4	92.75c	91.00b	96.00ab	89.50a	89.00a	88.00a-c	89.25ab	86.75c	89.50d
		(9.63)	(9.54)	(9.79)	(9.46)	(9.43)	(9.38)	(70.81)	(67.61)	(71.09)
	7	91.25c	90.00b	96.50ab	88.00a	83.00cd	89.75e	83.00b	82.25c	86.00d
		(9.55)	(9.49)	(9.82)	(9.38)	(9.11)	(9.47)	(65.65)	(65.05)	(68.03)
	10	93.75c	90.00b	93.25b	88.25a	86.50a-d	89.25e	86.75ab	83.50c	88.25d
		(9.68)	(9.52)	(9.65)	(9.39)	(9.30)	(9.44)	(68.71)	(66.03)	(66.91)
Decis	2ppm	91.75c	92.00b	96.25ab	89.00a	85.50b-d	90.50de	80.50b	81.25c	85.75cd
		(9.58)	(9.59)	(9.81)	(9.43)	(9.24)	(9.51)	(63.44)	(64.30)	(67.78)
	3ppm	91.25c	91.25b	97.50ab	87.25ab	87.75ab	93.00a-c	84.00ab	82.50c	89.00d
		(9.55)	(9.55)	(9.87)	(9.34)	(9.37)	(9.64)	(66.42)	(65.27)	(70.63)
	4ppm	91.25c	90.25b	96.25ab	85.50b	85.25b-d	92.75bc	82.25ab	82.00c	88.25d
		(9.55)	(9.50)	(9.81)	(9.24)	(9.23)	(9.63)	(65.05)	(64.90)	(69.91)
Control		82.50a	84.00a	80.25d	66.00c	63.75e	60.25g	48.00e	40.00a	45.75a
		(9.08)	(9.16)	(8.95)	(8.12)	(7.98)	(7.76)	(43.85)	(39.23)	(42.53)
CV%		1.29	1.4	1.24	2.00	1.8	1.82	2.35	3.4	2.9

- All figures are means of four replications,
- Means in a column having same letters are not significantly different at the 5% level of DMRT,
- Figures in the parenthesis are square root and arc sin transformed values

4.3.7. Moisture content: The initial moisture content in chickpea, grasspea and mungbean were 9.8%, 10.1% and 9.9% respectively. At 90 DAS, per cent moisture levels between treated and untreated seeds were statistically identical except mungbean. In the other sampling occasions (180 and 270 DAS), moisture levels between treated seeds did not vary significantly but they significantly varied from untreated seeds (Table 12). Untreated seeds always had higher moisture content than treated seeds for all pulses and sampling occasions. Slight increase or no increase of moisture level than initial was recorded for all pulses at 90, 180 and 270 DAS. But in the case of untreated seeds, increase of moisture level was quite evident. At 90 DAS, the recorded moisture levels in chickpea, grasspea and mungbean were 12.50%, 12.75% and 13.25% respectively which increased to 13.75%, 15.00% and 13.25% at 180 DAS. The moisture levels further increased to 17.00%, 16.75% and 15.50% at 270 DAS. Recording of higher moisture content in the untreated seeds might be one of the factors for obtaining higher percentage of infestation.

4.4. Efficacy of different ashes

4.4.1. Rate of oviposition: The rate of oviposition of pulse beetle on chickpea, grasspea and mungbean treated with different ashes and stored for nine months period are shown in table 13. It was evident from the table that

Table 12. Efficacy of different oils and insecticide on the per cent moisture level in chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose ml/kg	% moisture level after									
		90 days			180 days			270 days			
		Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	
Mustard oil	4	11.75 (3.43)	11.75 (3.43)	12.00ab (3.46)	12.00b (3.46)	12.75b (3.43)	12.75b (3.43)	13.50b (3.39)	12.00b (3.46)	12.75b (3.43)	
		12.00 (3.46)	11.75 (3.43)	11.75b (3.43)	12.75b (3.43)	12.50b (3.39)	12.25b (3.36)	12.75b (3.43)	12.50b (3.39)	12.50b (3.39)	
	7	12.25 (3.50)	11.75 (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	12.75b (3.43)	12.75b (3.43)	12.50b (3.39)	
		10	12.00 (3.46)	12.00 (3.46)	12.25ab (3.50)	12.00b (3.46)	11.75b (3.43)	11.75b (3.43)	12.75b (3.43)	12.75b (3.43)	12.75b (3.43)
	Coconut oil	4	11.25 (3.36)	12.00 (3.46)	11.75b (3.43)	11.75b (3.43)	12.00b (3.46)	11.50b (3.39)	13.00b (3.43)	12.75b (3.39)	12.75b (3.43)
		7	12.00 (3.46)	12.00 (3.46)	12.25ab (3.50)	12.00b (3.46)	11.75b (3.43)	11.75b (3.43)	12.75b (3.43)	12.75b (3.43)	12.75b (3.43)
Soybean oil	4	11.25 (3.36)	11.75 (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	11.50b (3.39)	11.25b (3.36)	12.00b (3.46)	11.75b (3.43)	
		10	11.25 (3.36)	11.75 (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	11.50b (3.39)	11.25b (3.36)	12.00b (3.46)	11.75b (3.43)
	7	11.75 (3.43)	11.50 (3.39)	11.75b (3.43)	12.75b (3.43)	12.75b (3.43)	12.50b (3.39)	13.50b (3.39)	12.75b (3.43)	13.25b (3.50)	
		10	12.00 (3.46)	11.50 (3.39)	11.50b (3.39)	12.75b (3.43)	12.25b (3.50)	12.75b (3.43)	13.50b (3.39)	12.50b (3.39)	12.50b (3.39)
	Neem oil	4	11.25 (3.36)	11.75 (3.43)	12.00ab (3.46)	11.25b (3.36)	12.50b (3.36)	12.50b (3.36)	12.75b (3.43)	12.25b (3.50)	12.00b (3.46)
		7	11.50 (3.39)	11.50 (3.39)	11.50b (3.39)	12.00b (3.46)	12.00b (3.46)	11.50b (3.39)	11.50b (3.39)	11.50b (3.39)	11.75b (3.43)
Decis	2ppm	12.00 (3.46)	11.50 (3.43)	11.75b (3.36)	11.75b (3.46)	12.50b (3.43)	11.50b (3.39)	11.50b (3.43)	11.25b (3.43)	11.50b (3.43)	
		12.25 (3.50)	11.75 (3.43)	11.75b (3.43)	11.25b (3.36)	11.50b (3.39)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	
	3ppm	11.50 (3.39)	11.75 (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	16.75b (4.09)	11.50b (3.39)	
		12.00 (3.46)	11.50 (3.43)	11.50b (3.36)	12.00b (3.46)	12.00b (3.43)	11.50b (3.39)	11.50b (3.43)	11.50b (3.43)	11.75b (3.43)	
	4ppm	12.25 (3.50)	11.75 (3.43)	11.75b (3.43)	11.25b (3.36)	11.50b (3.39)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	11.75b (3.43)	
		Control	12.50 (3.53)	12.75 (3.57)	13.25a (3.64)	13.75a (3.71)	15.00a (3.87)	13.25a (3.64)	17.00a (4.12)	16.75a (4.09)	15.50a (3.93)
CV %		6.84	7.48	7.21	7.17	7.30	6.91	6.91	7.02	7.01	

- All figures are means of four replications,
- Means in a column having same letters are not significantly different at the 5% level of DMRT,
- Figures in the parenthesis are square root transformed values

significantly highest number of eggs were recorded from untreated seeds of chickpea, grasspea and mungbean. At 90 DAS the recorded number of eggs per 100 grains were 54.50, 59.25 and 64.25 from chickpea, grasspea and mungbean respectively. These number increased to 63.50, 69.25 and 71.50 at 180 DAS and further increased to 83.25, 89.50 and 79.25 at 270 DAS. Among three dosage of all of the tested ashes the highest dosage (6% w/w) always resulted lower number of eggs than others. Irrespective of dosage and sampling occasions, eucalyptus wood ash provided better protection followed by paddy husk ash, cowdung ash, coal ash and charcoal ash respectively. Between pulses, the number of recorded eggs per 100 seeds varied in an irregular way for all treatments and sampling occasions.

4.4.2. Hatchability: The per cent hatchability of the eggs laid by pulse beetle on ashes treated seeds of chickpea, grasspea and mungbean varied significantly between treatments in all sampling occasions (Table 14). Significantly highest per cent of hatchability was recorded from untreated seeds of all pulses in all sampling occasions. At 90 DAS, the per cent hatchabilities were 19.86, 21.86 and 23.14 from the eggs laid on untreated seeds of chickpea, grasspea and mungbean respectively. These values slightly increased to 31.08%, 30.31% and 29.12% at 180 DAS for chickpea, grasspea and mungbean

Table 13. Efficacy of different ashes on the oviposition of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treatments	Dose (%w/w)	No. of eggs/100 grains after								
		90 days			180 days			270 days		
		Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean
Eucalyptus wood ash	2	13.00d (1.11)	14.50c (1.16)	14.00d (1.14)	21.50c (1.33)	19.00c (1.27)	18.00c (1.25)	31.75c (1.50)	34.50bc (1.53)	27.25bc (1.43)
	4	10.50d (1.02)	11.50d (1.06)	11.00e (1.04)	13.50d (1.13)	17.25c (1.23)	16.25cd (1.21)	22.50cd (1.35)	23.00d (1.36)	22.50c (1.35)
	6	4.50e (0.65)	6.75e (0.82)	5.50f (0.74)	7.00e (0.84)	8.75f (0.94)	7.50d (0.87)	9.25e (0.96)	10.50e (1.02)	9.75e (0.98)
Coal ash	2	17.50c (1.24)	18.00bc (1.25)	17.50c (1.24)	25.25b (1.40)	30.75b (1.48)	31.00b (1.49)	37.50b (1.57)	38.25bc (1.58)	35.75b (1.55)
	4	15.50c (1.19)	14.50c (1.16)	13.00d (1.11)	22.50c (1.35)	26.00bc (1.41)	20.50c (1.31)	28.50c (1.45)	31.00c (1.49)	36.50c (1.42)
	6	11.75d (1.07)	10.00d (1.00)	8.50f (0.92)	12.00d (1.07)	11.00e (1.04)	9.50d (0.97)	14.00e (1.14)	13.50e (1.13)	14.00d (1.14)
Paddy husk ash	2	15.00c (1.17)	16.00c (1.20)	15.50c (1.19)	22.00c (1.34)	19.50c (1.29)	20.50c (1.31)	32.50c (1.51)	36.25bc (1.55)	28.50bc (1.45)
	4	11.00d (1.04)	13.00c (1.11)	11.50e (1.06)	14.25d (1.15)	18.25c (1.26)	17.25c (1.23)	23.00cd (1.36)	24.50d (1.38)	24.25c (1.38)
	6	5.00e (0.69)	7.25e (0.86)	6.00f (0.77)	7.50e (0.87)	9.25f (0.96)	8.75d (0.94)	10.00e (1.00)	11.25e (1.05)	10.25e (1.01)
Cowdung ash	2	17.00c (1.23)	16.75c (1.22)	17.00c (1.23)	24.00b (1.34)	28.25b (1.45)	29.00b (1.46)	35.50b (1.55)	36.75bc (1.56)	33.25b (1.52)
	4	12.00d (1.07)	14.00c (1.14)	11.75e (1.07)	21.50c (1.33)	20.50c (1.31)	19.50c (1.29)	27.50c (1.43)	27.25c (1.43)	25.25c (1.40)
	6	9.50e (0.97)	7.50e (0.87)	8.00f (0.90)	10.50e (1.02)	9.50f (0.97)	9.25d (0.96)	12.25e (1.08)	11.50e (1.06)	13.25d (1.12)
Charcoal ash	2	26.25b (1.41)	24.00b (1.38)	23.50b (1.37)	31.75b (1.49)	31.50b (1.49)	32.50b (1.51)	38.25b (1.58)	41.50b (1.61)	37.75b (1.57)
	4	22.50b (1.35)	20.00bc (1.30)	21.25b (1.32)	25.50b (1.40)	29.25b (1.46)	27.25bc (1.43)	30.50c (1.48)	37.50bc (1.57)	29.25bc (1.46)
	6	14.75c (1.16)	12.75d (1.10)	11.75e (1.07)	15.25d (1.18)	14.50d (1.16)	13.50cd (1.13)	17.00d (1.23)	15.25e (1.18)	16.25d (1.21)
Control		54.50a (1.73)	59.25a (1.77)	64.25a (1.80)	63.50a (1.80)	69.25a (1.84)	71.50a (1.85)	83.25a (1.92)	89.50a (1.95)	79.25a (1.89)
CV %		12.74	11.75	12.13	20.98	31.8	28.54	32.04	24.91	23.41

- All figures are means of four replications,
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are log transformation values

Table 14. Efficacy of different ashes on the per cent hatchability of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treatments	Dose (kg/w)	% egg hatch after								
		90 days			180 days			270 days		
		Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mungbean
Eucalyptus wood ash	2	4.37c (2.14)	3.32cd (1.82)	5.45bc (2.33)	19.75bc (4.44)	17.33c (4.16)	20.18c (4.49)	34.82c (36.15)	38.11c (38.12)	35.54c (36.57)
	4	3.00d (1.73)	3.49cd (1.83)	3.20cd (1.79)	16.10c (4.01)	15.40b (3.92)	15.91d (3.39)	33.44c (35.30)	34.21c (35.79)	31.19c (33.89)
	6	1.03e (1.01)	2.28e (1.51)	2.25d (1.50)	13.14c (3.62)	14.50d (3.81)	13.40e (3.66)	30.70d (24.88)	31.50c (22.38)	33.65c (23.26)
	2	6.41b (2.53)	7.46b (2.73)	6.44b (2.54)	20.45b (4.52)	21.18b (4.60)	21.00c (4.58)	49.51b (44.71)	53.49b (47.01)	47.70b (43.68)
	4	4.94c (2.22)	3.44cd (1.85)	3.43cd (1.85)	19.90bc (4.46)	20.70b (4.55)	19.11cd (4.37)	46.29b (42.88)	47.26bc (43.39)	43.44b (41.21)
	6	3.24d (1.80)	2.31e (1.52)	2.12d (1.46)	15.45c (3.93)	17.10c (4.14)	18.12cd (4.264)	32.33c (34.63)	29.90d (33.15)	31.23c (33.96)
Paddy husk ash	2	5.25bc (2.29)	4.92c (2.22)	4.07c (2.01)	21.80b (4.67)	19.25bc (4.39)	18.50cd (4.30)	36.62c (37.23)	41.24bc (39.93)	36.45c (37.11)
	4	3.10d (1.76)	4.66c (2.16)	3.30cd (1.82)	15.41c (3.92)	16.47c (4.06)	18.46cd (4.30)	35.88c (36.75)	35.55c (36.57)	33.20c (35.18)
	6	1.28e (1.13)	2.67e (1.63)	1.95e (1.39)	14.15c (3.76)	13.29d (3.64)	17.00d (4.12)	28.00d (25.10)	31.87c (23.42)	35.19c (23.66)
	2	4.58c (2.09)	4.92c (2.22)	3.40cd (1.84)	20.29b (4.50)	19.14bc (4.37)	21.21c (4.60)	47.29b (43.39)	49.90b (44.94)	44.41b (41.78)
	4	3.49d (1.87)	2.63e (1.62)	2.70d (1.64)	18.41bc (4.29)	17.26cc (4.15)	19.81cd (4.45)	42.39bc (40.57)	43.51bc (41.27)	39.33c (38.42)
	6	1.17e (1.08)	1.20f (1.09)	1.79e (1.34)	13.22c (3.64)	14.39d (3.79)	15.24d (3.90)	29.34d (31.50)	35.66c (31.05)	36.29c (32.08)
Charcoal ash	2	7.45b (2.73)	6.50b (2.55)	6.29b (2.51)	23.26b (4.82)	23.19b (4.82)	24.80b (4.98)	50.15b (45.05)	55.60b (48.22)	49.92b (44.94)
	4	4.85c (2.20)	3.11cd (1.76)	4.45c (2.10)	22.41b (4.73)	21.26b (4.61)	21.60c (4.65)	49.29b (44.54)	50.19b (56.06)	46.54b (42.99)
	6	3.77d (1.94)	3.29cd (1.81)	2.49d (1.58)	18.32bc (4.28)	19.31bc (4.39)	20.11c (4.48)	34.30c (35.85)	31.41c (34.08)	33.30c (35.24)
	2	19.86a (4.46)	21.86a (4.68)	23.14a (4.81)	31.08a (5.57)	30.31a (5.50)	29.12a (5.39)	63.01a (52.53)	61.66a (51.71)	65.10a (53.79)
	4	19.86a (4.46)	21.86a (4.68)	23.14a (4.81)	31.08a (5.57)	30.31a (5.50)	29.12a (5.39)	63.01a (52.53)	61.66a (51.71)	65.10a (53.79)
	6	19.86a (4.46)	21.86a (4.68)	23.14a (4.81)	31.08a (5.57)	30.31a (5.50)	29.12a (5.39)	63.01a (52.53)	61.66a (51.71)	65.10a (53.79)
CV %		10.86	9.01	9.38	10.19	14.96	17.78	15.99	13.19	11.49

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

respectively. Further increase of per cent hatchability was noticed at 270 DAS. Similar increment of hatchability from 90 DAS to 180 DAS and 270 DAS was also recorded in the case of treated seeds of chickpea, grasspea and mungbean. Similar to the rate of oviposition, the highest dosage of all ashes yielded relatively lower percentages of hatchabilities than others for all pulses in all sampling occasions. Irrespective of dosage, eucalyptus wood ash always showed lower per cent hatchability followed by cowdung ash. Likewise the rate of oviposition, the per cent hatchability of eggs laid on different seeds varied in an irregular way for all treatments in all sampling occasions.

4.4.3. Adult emergence: The percentages of adult emerged from the ash treated seeds of chickpea, grasspea and mungbean stored for nine months period are presented in table 15. It was evident from the table that untreated seeds manifested significantly highest percentage of adult emergence which ranged from 23.85- 27.99, 39.10-45.40 and 58.42-61.36 for 90 DAS, 180 DAS and 270 DAS respectively. Although the tested dosage of different ashes were not so effective in reducing per cent adult emergence of pulse beetle but they showed significantly lower per cent of adult emergence than untreated control. Irrespective of pulses and sampling occasions, the highest dosage of all ashes gave lower percentage of adult emergence. In many

Table 15. Efficacy of different ashes on the per cent adult emergence of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treatments	Dose (%w/w)	% adult emergence after								
		90 days			180 days			270 days		
		Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Eucalyptus wood ash	2	13.54d (3.68)	14.40d (3.79)	13.78c (3.71)	18.29c (25.33)	19.19d (25.99)	19.10c (25.92)	24.11c (29.40)	25.51d (30.33)	14.92d (29.93)
	4	10.20e (3.19)	14.43e (3.38)	9.26d (3.04)	14.22d (22.14)	16.62d (24.04)	15.50d (23.19)	22.50d (28.32)	21.20d (27.42)	22.00d (27.97)
	6	4.13f (2.03)	5.29f (2.30)	5.21e (2.28)	8.81e (17.26)	9.21f (17.66)	8.10e (16.54)	13.29e (21.30)	14.40e (22.30)	14.14e (22.06)
Coal ash	2	22.40c (4.73)	20.54bc (4.58)	21.13ab (4.57)	27.30bc (31.50)	28.75bc (32.39)	28.70bc (32.39)	33.34bc (35.24)	37.80bc (37.94)	38.55b (38.35)
	4	18.10c (4.25)	19.90c (4.46)	19.80ab (4.44)	26.60bc (31.05)	25.41c (30.26)	22.30c (28.18)	32.49bc (34.70)	34.11bc (35.73)	35.27bc (36.39)
	6	9.50e (3.08)	9.11f (3.01)	8.45d (2.90)	15.29d (22.95)	14.14e (22.06)	14.21d (22.14)	20.00d (26.56)	24.12d (29.40)	24.98d (29.93)
Paddy husk ash	2	17.11cd (4.14)	16.60c (4.07)	16.49c (4.06)	22.20bc (28.11)	21.54c (27.63)	23.00c (28.66)	29.80c (33.09)	31.30c (34.02)	30.21c (33.34)
	4	14.45d (3.80)	13.31d (3.65)	13.36c (3.65)	18.45c (25.40)	19.90d (26.49)	18.40c (25.40)	27.11c (31.37)	26.88d (31.18)	27.77c (31.76)
	6	7.30f (2.70)	6.91f (2.63)	7.71e (2.77)	12.29d (20.44)	11.28e (19.55)	11.24d (19.55)	18.62d (25.55)	18.45e (25.40)	19.35d (26.66)
Cow dung ash	2	19.14c (4.37)	18.41c (4.29)	19.00ab (4.35)	24.40bc (29.60)	23.77c (29.13)	25.50bc (30.33)	31.66bc (34.20)	35.14bc (36.27)	34.24bc (35.79)
	4	15.60d (3.95)	15.50d (3.93)	15.67c (3.96)	23.30bc (28.86)	21.00c (27.35)	20.44c (26.85)	30.00bc (30.21)	30.64c (33.58)	31.88c (34.33)
	6	8.24e (2.87)	8.23f (2.86)	7.99e (2.83)	14.19d (22.06)	13.47e (21.47)	13.59d (21.56)	19.76d (26.28)	21.11d (27.35)	20.29d (26.71)
Charcoal ash	2	25.29b (5.02)	24.11b (4.91)	24.40a (4.93)	31.41b (34.08)	31.96b (34.39)	32.20b (34.57)	37.70b (37.88)	41.55b (40.11)	42.45b (40.63)
	4	21.43c (4.63)	23.91bc (4.89)	22.00ab (4.69)	30.61b (33.58)	29.19b (32.65)	26.11bc (30.72)	36.46b (37.11)	38.29bc (38.17)	39.91b (39.17)
	6	11.59e (3.40)	12.21e (3.49)	10.44d (3.23)	18.70c (25.62)	16.60d (24.04)	19.29c (25.99)	22.45d (28.25)	27.50d (31.63)	26.49d (30.92)
Control	-	27.99a (5.29)	26.63a (5.25)	23.85a (4.88)	39.10a (38.70)	43.65a (41.32)	45.40a (42.36)	61.36a (51.53)	59.85a (50.65)	58.42a (49.84)
CV %		8.68	9.29	12.61	14.54	10.24	14.06	9.26	7.93	12.8

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

cases although the efficacy of ashes was statistically identical but eucalyptus wood ash produced relatively lower per cent of adult emergence and charcoal ash was the higher irrespective of dosage for all pulses in all sampling occasions. Difference between pulses in terms of adult emergence was difficult to ascertain in all dosage and in all sampling occasions.

4.4.4. Intensity of infestation: All dosage of different ashes provided significantly lower percentages of infestation than untreated control (Table 16 and figures 18, 19 and 20). At 90 DAS, 16.74%, 18.47% and 18.80% infestation of untreated chickpea, grasspea and mungbean respectively were recorded. These percentages increased to 31.36, 29.61 and 32.95 at 180 DAS. Further substantial increase of per cent infestation (51.35-55.85) was noticed as the time of storage progressed (270 DAS). The highest dosage of all of the tested ashes offered relatively lower percentages of infestation for all pulses in all sampling occasions. Per cent infestation in these dosage ranged from 0.49-2.49, 10.01-19.72 and 30.53-39.56 for 90, 180 and 270 DAS respectively. Irrespective of dosage, eucalyptus ash always had lower infestation (bored grain) followed by paddy husk ash, cowdung ash, coal ash and charcoal ash for all pulses in all sampling occasions. Similar to the results of oviposition, hatchability and adult emergence,

Table 16. Efficacy of different ashes on the per cent infestation of chickpea, grasspea and mungbean stored for nine months

Treatments	Dose (%w/w)	% infestation after								
		90 days			180 days			270 days		
		Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean
Eucalyptus wood ash	2	2.28d (1.50)	2.24d (1.49)	2.13c (1.45)	16.32d (4.04)	14.08e (3.75)	18.22c (4.27)	37.79b (37.88)	35.92b (36.81)	40.45b (39.47)
	4	1.41e (1.18)	1.49e (1.22)	1.65d (1.28)	15.51d (3.94)	14.59e (3.82)	16.32d (4.03)	30.79c (33.71)	37.82b (37.94)	39.82b (39.11)
	6	0.49f (0.07)	0.62f (0.78)	0.52e (0.72)	12.05e (3.47)	10.01f (3.16)	11.91e (3.45)	30.53c (33.52)	32.41c (34.70)	35.35c (36.45)
	2	3.86c (1.96)	3.71c (1.92)	3.18b (1.78)	19.14c (4.37)	19.72b (4.40)	20.98b (4.58)	35.16b (36.33)	35.29b (36.39)	44.69b (41.90)
	4	2.74d (1.65)	2.80cd (1.67)	2.31c (1.51)	18.92c (4.35)	19.66b (4.43)	20.77b (4.55)	34.16b (35.73)	32.71c (34.88)	40.12b (39.29)
	6	1.11e (1.05)	1.16e (1.07)	1.05d (1.02)	15.88d (3.98)	16.38d (4.04)	16.80d (4.09)	31.13c (33.89)	30.96c (33.77)	39.27bc (38.76)
Paddy husk ash	2	3.06c (1.75)	2.98cd (1.73)	2.65bc (1.63)	18.46c (4.29)	17.72c (4.21)	19.49c (4.41)	33.29b (35.18)	39.80bc (39.11)	41.72b (40.22)
	4	2.32d (1.52)	2.02d (1.42)	1.92d (1.38)	15.16d (3.89)	15.88d (3.98)	17.64d (4.20)	31.51c (34.14)	34.85b (36.15)	38.92bc (38.53)
	6	0.85f (0.92)	0.77f (0.87)	0.78e (0.88)	13.09e (3.61)	12.09e (3.47)	16.88d (4.10)	30.56c (32.90)	33.46c (35.55)	37.27c (37.58)
	2	3.40c (1.84)	3.36c (1.83)	2.98bc (1.73)	19.63c (4.43)	18.86c (4.34)	19.88c (4.45)	37.64b (37.82)	41.86b (40.28)	42.18b (40.46)
	4	2.39d (1.55)	2.46d (1.57)	2.04c (1.43)	17.64c (4.20)	17.31c (4.16)	18.67c (4.32)	34.12b (35.73)	39.64b (39.00)	39.29bc (38.76)
	6	0.98f (0.98)	1.01e (1.00)	0.92e (0.95)	14.12e (3.76)	15.42d (3.92)	16.36d (4.04)	30.63c (33.58)	34.42b (35.91)	37.66c (37.82)
Charcoal ash	2	5.46b (2.33)	4.97b (2.22)	5.29a (2.30)	22.21b (4.71)	21.50b (4.64)	23.56b (4.85)	37.41b (37.70)	42.50b (40.69)	43.65b (41.32)
	4	3.42c (1.84)	3.21c (1.79)	3.62b (1.90)	21.92b (4.68)	20.12b (4.48)	22.29b (4.47)	35.21b (36.39)	39.12bc (38.70)	40.54b (39.52)
	6	2.20d (1.48)	2.40d (1.55)	2.49bc (1.54)	17.41c (4.17)	17.42c (4.17)	19.72c (4.44)	33.91b (35.61)	37.42b (37.70)	39.56bc (38.94)
	-	16.74a (4.09)	18.47a (4.29)	18.80a (4.33)	31.36a (5.60)	29.61a (5.44)	32.95a (5.74)	52.29a (46.26)	55.85a (48.33)	51.35a (45.75)
	-	16.74a (4.09)	18.47a (4.29)	18.80a (4.33)	31.36a (5.60)	29.61a (5.44)	32.95a (5.74)	52.29a (46.26)	55.85a (48.33)	51.35a (45.75)
	-	16.74a (4.09)	18.47a (4.29)	18.80a (4.33)	31.36a (5.60)	29.61a (5.44)	32.95a (5.74)	52.29a (46.26)	55.85a (48.33)	51.35a (45.75)
CV %		11.15	19.23	12.39	6.73	8.33	9.23	7.90	7.78	6.65

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

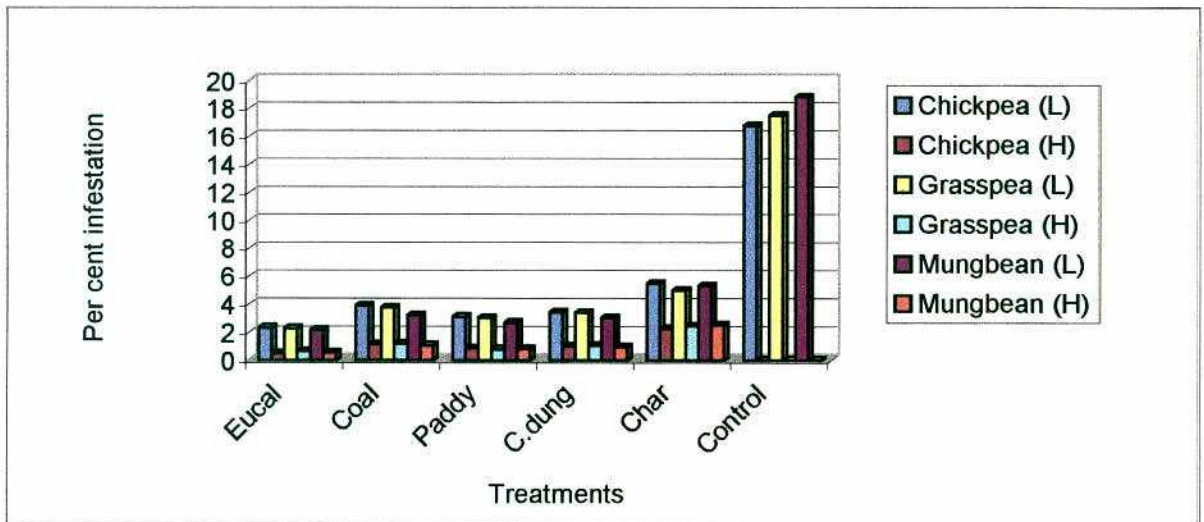


Fig. 18. Per cent infestation after 90 days at lowest and highest dosage of ashes

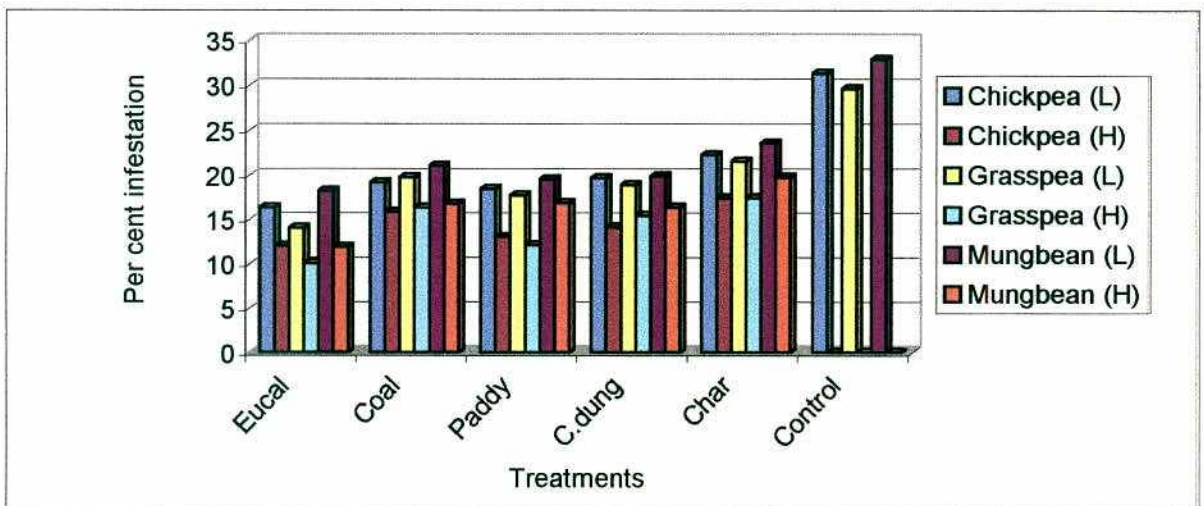


Fig. 19. Per cent infestation after 180 days at lowest and highest dosage of ashes

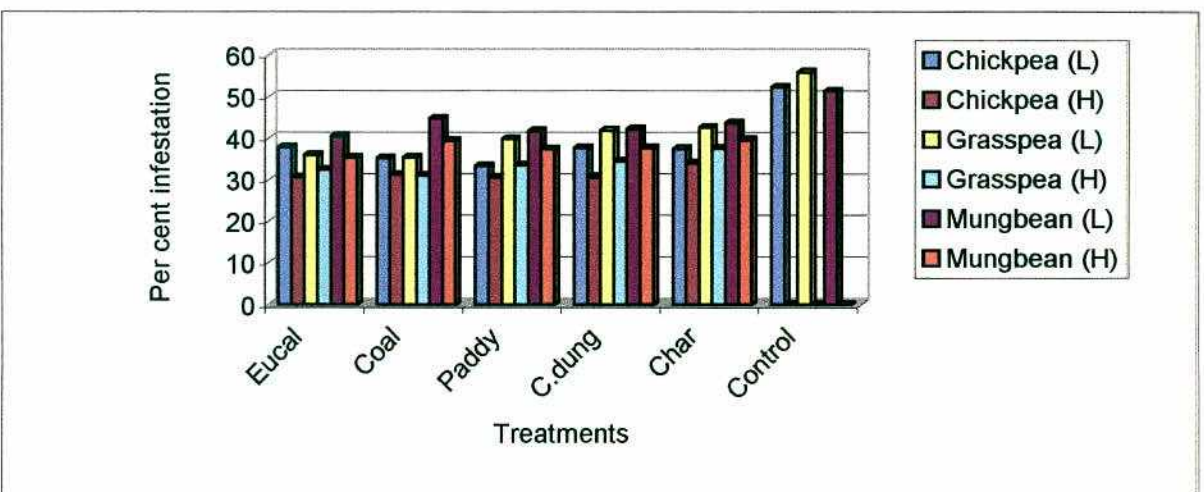


Fig. 20. Per cent infestation after 270 days at lowest and highest dosage of ashes

difference between pulses in resisting the attack of pulse beetle could not be ascertained in all sampling occasions.

4.4.5. Weight loss: It was evident from table 17 (Figures 21, 22 and 23) that 8.87-28.44%, 9.88-26.52% and 10.43-29.97% weight losses of chickpea, grasspea and mungbean respectively occurred when those were stored for nine months without treatment. Although ashes were not so effective, these also revealed significant effect in protecting pulses over untreated control. The highest dosage of all treated ashes yielded significantly lower percentages of weight loss than others for all pulses in all sampling occasions. Per cent weight loss in these dosage ranged from 0.16-1.46, 6.30-10.11 and 15.51-21.93 for 90, 180 and 270 DAS respectively. The performance of different ashes in protecting pulses was in the order of eucalyptus wood ash > paddy husk ash > cowdung ash > coal ash > charcoal ash irrespective of dosage and sampling occasions. Per cent weight loss in those ashes ranged from 0.16-21.16, 0.24-22.76, 0.56-22.99, 0.92-24.47 and 1.35-22.27 respectively. Irrespective of treatments and type of pulses, per cent weight loss increased with the increase of storage period. At 90 DAS, the weight loss was 0.16-10.43% which increased to 6.30-18.13% at 180 DAS. This loss further increased to 15.51-29.97% at 270 DAS. The rate of weight loss over the storage period was higher in the case

Table 17. Efficacy of different ashes on the per cent weight loss of chickpea, grasspea and mungbean after storage for nine months

Treatments	Dose (%w/w)	% weight loss after								
		90 days			180 days			270 days		
		Chickpea	Grasspea	Mung- bean	Chickpea	Grasspea	Mung- bean	Chickpea	Grasspea	Mung- bean
Eucalyptus wood ash	2	0.76d (0.87)	0.73c (0.85)	0.70cd (0.83)	8.11c (2.85)	7.74e (2.78)	10.74bc (3.27)	18.61b (4.31)	18.31bc (4.28)	21.16bc (4.60)
	4	0.43e (0.65)	0.46d (0.67)	0.55cd (0.74)	7.17d (2.68)	7.41e (2.72)	9.41cd (3.04)	16.42c (4.05)	17.62c (4.19)	20.26bc (4.50)
	6	0.16f (0.40)	0.21e (0.45)	0.17d (0.41)	7.31d (2.70)	6.30e (2.51)	7.30d (2.70)	15.51c (3.93)	17.47c (4.17)	19.41c (4.41)
Coal ash	2	1.55c (1.24)	1.63b (1.27)	1.71b (1.30)	10.35bc (3.21)	10.99bc (3.32)	11.99bc (3.46)	18.62b (4.32)	18.21bc (4.26)	24.47b (4.95)
	4	1.40c (1.18)	1.39bc (1.17)	1.36bc (1.16)	9.52c (3.09)	10.59bc (3.25)	10.59bc (3.32)	18.85b (4.34)	17.78cc (4.22)	23.33b (4.83)
	6	0.92d (0.95)	0.98c (0.98)	1.07c (1.03)	8.42c (2.90)	9.29bc (3.04)	8.29d (2.88)	16.86c (4.10)	16.88d (4.11)	21.93bc (4.68)
Paddy husk ash	2	0.85d (0.92)	0.89c (0.94)	0.83c (0.91)	9.47c (8.59)	9.92bc (3.15)	10.92bc (3.30)	17.92bc (4.23)	20.69b (4.55)	22.76b (4.77)
	4	0.71d (0.84)	0.51d (0.71)	0.64cd (0.80)	8.59c (2.93)	8.59d (2.93)	8.59d (2.93)	16.96c (4.11)	18.91bc (4.35)	20.39bc (4.52)
	6	0.28f (0.52)	0.29e (0.53)	0.24d (0.49)	8.68c (2.95)	7.58e (2.75)	8.58d (2.93)	16.79c (4.09)	17.78c (4.22)	19.02c (4.36)
Cow dung ash	2	1.15cd (1.07)	1.21bc (1.10)	1.16bc (1.07)	10.99bc (3.32)	9.28bc (3.05)	10.28bc (3.21)	18.33b (4.28)	20.82b (4.56)	22.99b (4.79)
	4	0.98d (0.98)	0.89c (0.94)	0.92c (0.95)	9.11c (3.02)	8.10d (2.85)	9.10c (3.02)	17.19bc (4.15)	19.24bc (4.38)	21.85bc (4.67)
	6	0.56e (0.74)	0.59d (0.76)	0.61cd (0.78)	8.96c (2.99)	8.85d (2.97)	9.85c (3.14)	16.16c (4.02)	16.21d (4.03)	20.56bc (4.53)
Charcoal ash	2	1.92b (1.38)	1.86b (1.36)	1.99b (1.41)	12.86b (3.59)	11.47b (3.39)	12.47b (3.53)	18.11b (4.26)	21.68b (4.66)	22.27b (4.72)
	4	1.86b (1.36)	1.56b (1.25)	1.78b (1.33)	11.93bc (3.45)	11.11b (3.33)	12.91b (3.59)	19.17b (4.37)	20.27b (4.50)	19.85c (4.46)
	6	1.40c (1.18)	1.35bc (1.16)	1.46bc (1.21)	9.87c (3.14)	9.88bc (3.14)	10.11bc (3.18)	17.10bc (4.14)	20.31b (4.50)	20.54bc (4.53)
control	-	8.87a (2.97)	9.88a (3.14)	10.43a (3.22)	16.24a (4.02)	15.66a (3.96)	18.13a (4.26)	28.44a (5.33)	26.52a (5.14)	29.97a (5.47)
CV %		7.25	10.43	8.25	9.28	10.43	7.49	7.90	11.46	11.51

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

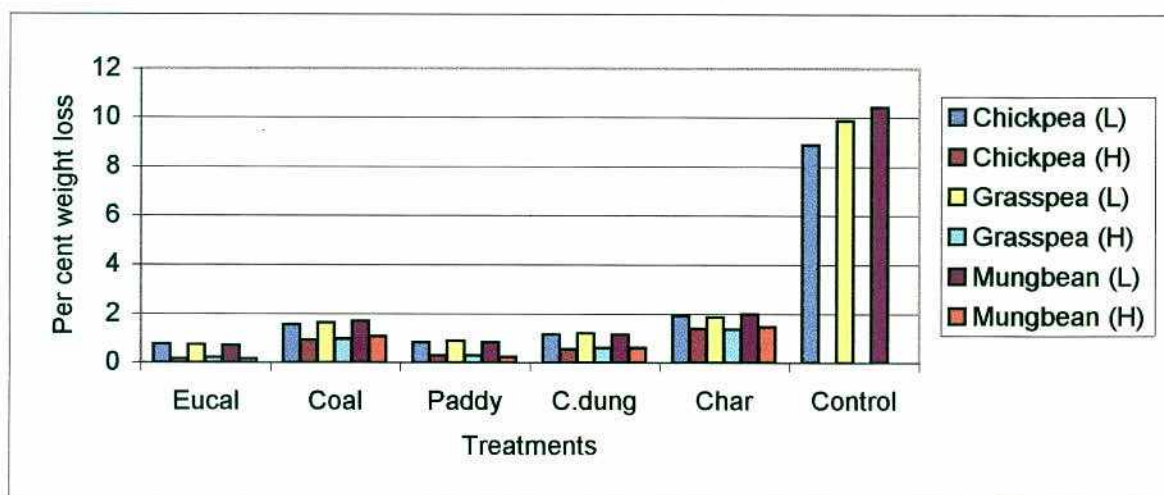


Fig. 21. Per cent weight loss after 90 days at lowest and highest dosage of ashes

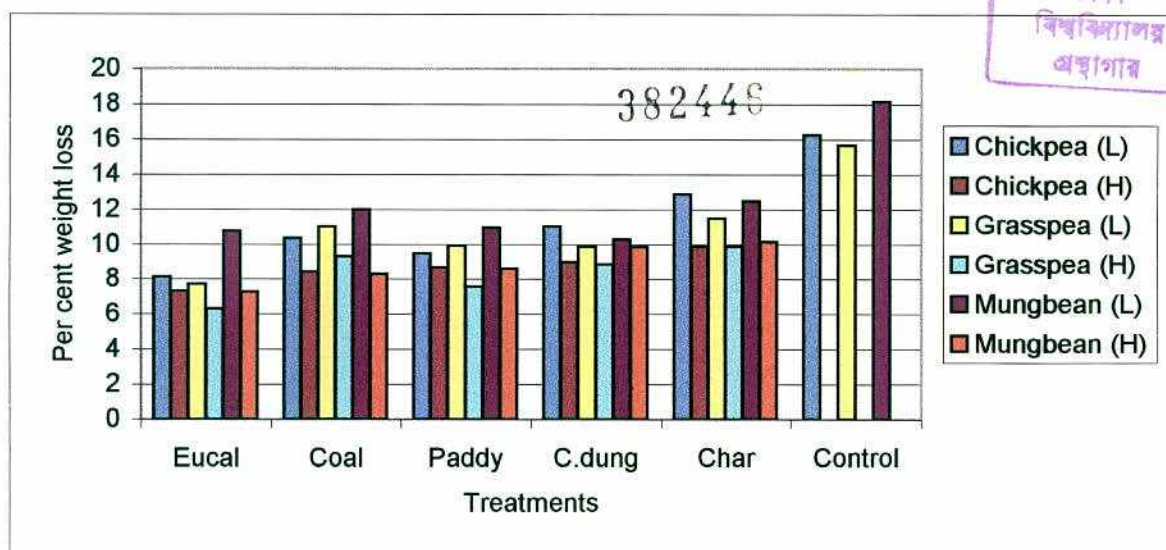


Fig. 22. Per cent weight loss after 180 days at lowest and highest dosage of ashes

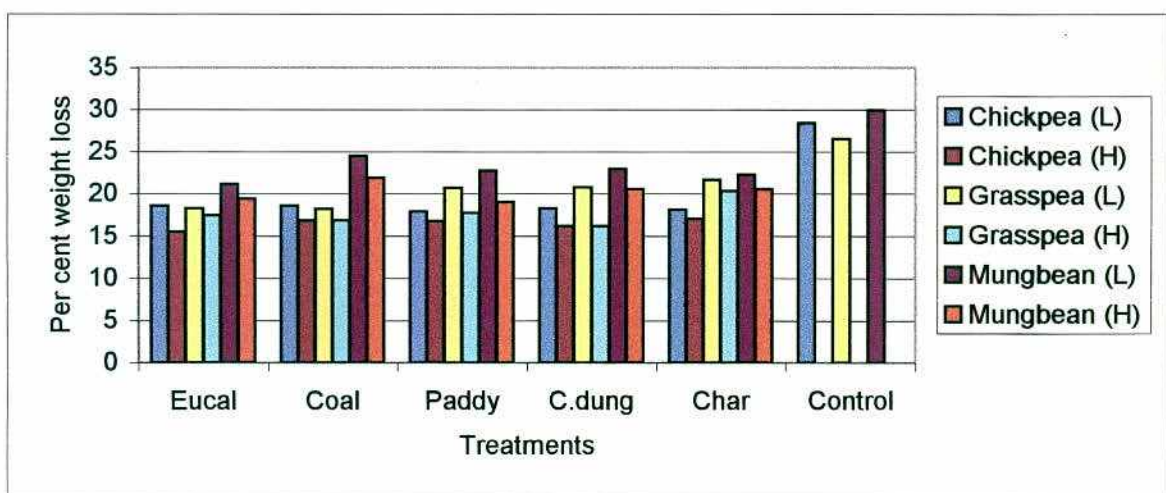


Fig. 23. Per cent weight loss after 270 days at lowest and highest dosage of ashes

of untreated seeds than treated (Table 17). Similar to the results of per cent infestation, difference between pulses was difficult to ascertain.

4.4.6. Germination: The germination percentages of chickpea, grasspea and mungbean treated with different ashes varied significantly between treated and untreated seeds at 180 and 270 DAS (Table 18). At 90 DAS, the highest percentage of germination was recorded from eucalyptus wood ash treated seeds of chickpea (95.00%), grasspea (93.25%) and mungbean (95.75%). No significant difference was observed between treated and untreated seeds of grasspea and mungbean at 90 DAS. In all sampling occasions, the untreated seeds manifested relatively lower percentage of germination for all pulses. In this treatment, the percentages of germination were 89.50, 88.00 and 89.75 for chickpea, grasspea and mungbean respectively at 90 DAS. The germination level declined to 69.25-71.25% at 180 DAS and 58.25-66.75% at 270 DAS. Similar declining trend in germination level over storage period was also noticed in the ash treated seeds. Irrespective of treatments and dosage, mungbean always had higher germination rate at 90 DAS.

4.4.7. Moisture content: The initial moisture contents of chickpea, grasspea and mungbean were 9.8%, 10.1% and 9.9%

Table 18. Efficacy of different ashes on the per cent germination of chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose (t/w/w)	% germination after								
		90 days			180 days			270 days		
		Chickpea	Grass-pea	Mung-bean	Chickpea	Grasspea	Mungbean	Chick-pea	Grass-pea	Mung-bean
Eucalyptus wood ash	2	95.00a	92.00	95.50	81.50e (64.51)	82.50cd (65.26)	81.50e (64.52)	64.25d (53.29)	70.00bc (56.77)	66.00e-g (54.33)
	4	92.50a-d	93.25	95.75	86.00a-c (68.02)	82.50cd (65.26)	86.25c-e (68.28)	69.00c (56.18)	69.75bc (56.61)	72.00c (58.03)
	6	93.00a-d	92.50	94.25	88.75a (70.43)	87.00ab (68.86)	88.00b-d (69.76)	81.25ab (64.32)	83.00a (65.70)	82.25a (65.07)
Coal ash	2	92.75a-d	90.75	92.75	82.75c-e (65.45)	84.75b-d (67.34)	81.25e (64.35)	61.50e (51.94)	70.50bc (56.9)	63.00gh (52.51)
	4	90.25b-d	92.75	91.75	82.00de (64.88)	84.00b-d (66.46)	82.00e (64.87)	73.50b (60.76)	63.75c (52.95)	70.50cd (57.08)
	6	93.00a-d	89.50	92.25	87.25ab (69.21)	87.00ab (68.89)	90.00a-c (71.67)	64.50d (53.43)	66.25c (54.45)	82.25a (64.89)
Paddy husk ash	2	91.50a-b	90.50	94.25	80.75e (63.96)	82.75cd (65.44)	82.00e (64.89)	65.25d (53.90)	71.75bc (57.89)	65.00e-h (53.73)
	4	93.50a-c	91.00	92.75	85.50a-d (67.66)	84.25b-d (66.68)	83.00e (65.63)	73.25b (58.87)	77.50b (61.69)	67.50de (55.24)
	6	92.00a-d	90.25	92.25	87.75ab (69.55)	89.25a (70.92)	90.25a-c (72.14)	84.00a (66.40)	84.00a (66.41)	81.00ab (64.14)
Cow dung ash	2	93.75a-c	88.25	91.75	84.25b-e (66.63)	81.75d (64.70)	81.50e (64.51)	62.00e (53.86)	69.50bc (56.03)	62.25h (52.07)
	4	94.00a-c	89.50	91.00	87.75ab (69.56)	83.75b-d (66.21)	85.50de (67.62)	62.50e (52.24)	61.25d (51.47)	79.00b (62.72)
	6	90.00b-d	91.25	93.75	87.50ab (69.29)	86.50a-c (68.43)	93.25a (75.00)	66.50d (53.63)	64.25c (53.25)	80.75ab (65.96)
Charcoal ash	2	88.50d	89.75	92.50	82.00de (64.88)	82.25cd (65.07)	82.50e (65.28)	65.25d (53.86)	64.75c (53.56)	66.50ef (54.63)
	4	94.25ab	93.00	92.50	86.75ab (68.64)	85.25b-d (67.41)	87.75b-d (69.52)	61.50e (51.54)	63.25d (52.65)	66.25ab (54.45)
	6	91.75a-d	91.50	91.50	87.25ab (69.08)	84.75b-d (67.07)	90.50ab (72.22)	65.50d (53.03)	61.50d (51.54)	65.75a (54.15)
Control	-	89.50cd	88.00	89.75	69.25f (56.33)	71.25e (57.56)	69.50f (56.51)	58.25e (49.74)	66.75c (54.78)	64.00e-h (53.11)
CV %		2.97	3.39	4.49	2.79	3.02	3.52	4.07	2.72	2.24

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are arc sin transformed values

respectively before the onset of this experiment. The per cent moisture levels of ash treated seeds of chickpea, grasspea and mungbean after 90, 180 and 270 days of storage are shown in table 19. The effect of ashes on increase or decrease of moisture control than initial was statistically identical in all sampling occasions. At 90 DAS, moisture level between treated and untreated seeds was statistically identical but it varied significantly at 180 and 270 DAS. At 90 DAS, 11.75-12.50%, 12.00-12.50% and 11.50-12.50% moisture contents were recorded for chickpea, grasspea and mungbean respectively. No significant increase of moisture content was recorded in ash treated seeds at 180 and 270 DAS than 90 DAS. In untreated seeds the moisture content increased as the time progressed. At 90 DAS, the moisture content increased from 12.00% to 19.25% at 270 DAS. This was probably due to higher percentage of infestation by pulse beetle.

4.5. Effect of naphthalene ball

4.5.1. Rate of oviposition: The rate of oviposition of pulse beetle on the naphthalene treated seeds of chickpea, grasspea and mungbean stored for nine months period are shown in table 20. The treatments of 4 balls/kg seed exposed for 7, 15 and 21 days and 3 balls/kg seed for 15 and 21 days completely prevented pulse beetle from laying any eggs in all pulses for all sampling occasions. The treatment of 2 balls/kg seeds also yielded significantly

Table 19. Efficacy of different ashes on the per cent moisture level in chickpea, grasspea and mungbean stored for nine months

Treatments	Dose (%w/w)	% moisture level after								
		90 days			180 days			270 days		
		Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean
Eucalyptus wood ash	2	11.75 (3.43)	12.00 (3.46)	12.00 (3.46)	11.75b (3.43)	12.00b (3.46)	12.50b (3.54)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)
	4	11.75 (3.43)	12.25 (3.50)	12.25 (3.50)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)
	6	12.25 (3.50)	12.25 (3.50)	12.50 (3.54)	11.75b (3.43)	11.75b (3.43)	12.25b (3.50)	12.25b (3.50)	12.00b (3.46)	12.00b (3.46)
Coal ash	2	12.25 (3.50)	12.25 (3.50)	12.25 (3.50)	12.50ab (3.54)	12.25b (3.50)	12.50b (3.54)	12.25b (3.50)	12.50b (3.54)	12.00b (3.46)
	4	12.00 (3.46)	12.25 (3.50)	12.00 (3.46)	11.75b (3.43)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	11.75b (3.43)	12.00b (3.46)
	6	12.00 (3.46)	12.25 (3.50)	12.25 (3.50)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.00b (3.46)	12.25b (3.50)
Paddy husk ash	2	12.00 (3.46)	12.25 (3.50)	12.25 (3.50)	12.00b (3.46)	12.25b (3.50)	12.25b (3.50)	12.25b (3.50)	11.75b (3.43)	12.00b (3.46)
	4	12.25 (3.50)	12.50 (3.54)	11.75 (3.43)	12.00b (3.46)	11.75b (3.43)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.25b (3.50)
	6	12.50 (3.54)	12.25 (3.50)	12.25 (3.50)	12.25b (3.50)	12.25b (3.50)	12.25b (3.50)	12.00b (3.46)	12.25b (3.50)	12.00b (3.46)
Cow dung ash	2	12.00 (3.46)	12.25 (3.50)	12.25 (3.50)	12.25b (3.50)	11.75b (3.43)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	11.75b (3.43)
	4	12.25 (3.50)	12.00 (3.46)	11.75 (3.43)	12.25b (3.50)	12.25b (3.50)	12.50b (3.54)	12.50b (3.54)	12.00b (3.46)	12.25b (3.50)
	6	11.75 (3.43)	12.25 (3.50)	12.25 (3.50)	12.00b (3.46)	12.00b (3.46)	11.75b (3.43)	11.75b (3.43)	12.00b (3.46)	12.25b (3.50)
Charcoal ash	2	12.00 (3.46)	12.25 (3.50)	12.00 (3.46)	12.25b (3.50)	12.00b (3.46)	12.00b (3.46)	12.25b (3.54)	12.00b (3.46)	12.00b (3.46)
	4	12.00 (3.46)	12.00 (3.46)	12.25 (3.50)	12.50ab (3.54)	12.00b (3.46)	12.25b (3.50)	12.00b (3.46)	12.25b (3.50)	12.25b (3.50)
	6	12.25 (3.50)	12.25 (3.50)	11.50 (3.39)	12.00b (3.46)	12.25b (3.50)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.25b (3.50)
Control	-	12.00 (3.46)	12.25 (3.50)	12.00 (3.46)	13.50a (3.67)	14.00a (3.74)	14.00a (3.74)	18.75a (4.33)	19.25a (4.39)	19.25a (4.39)
CV %		3.32	3.21	3.43	3.14	3.18	3.31	3.29	3.37	3.33

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

Table 20. Effect of naphthalene ball on the oviposition of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose (No. of ball/kg)	Exposure period (days)	No. of eggs/100 grains after									
			90 days			180 days			270 days			
			Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	
Naphtha-lene ball	2	7	35.00b (1.54)	28.50b (1.45)	34.00b (1.51)	67.25b (1.83)	47.25b (1.67)	52.25b (1.71)	83.25b (1.91)	61.00b (1.78)	71.55b (1.84)	
		15	22.00c (1.33)	19.25c (1.26)	19.50c (1.28)	61.25b (1.78)	47.00b (1.67)	49.25b (1.68)	60.50c (1.78)	56.50b (1.75)	58.75c (1.75)	
		21	13.50d (1.08)	11.25d (1.05)	10.25d (1.01)	36.00c (1.55)	35.75d (1.55)	37.75c (1.57)	45.25d (1.65)	37.50d (1.56)	39.50d (1.51)	
	3	7	20.00c (1.26)	14.00d (1.13)	18.50c (1.24)	40.00c (1.60)	42.25c (1.62)	39.25c (1.59)	48.50d (1.68)	46.75c (1.66)	44.50d (1.64)	
		15	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	
		21	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	
"	4	7	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	
		15	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	
		21	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00d (0.00)	0.00e (0.00)	0.00e (0.00)	0.00e (0.00)	
	Control			50.25a (1.70)	47.75a (1.67)	53.25a (1.72)	98.25a (1.99)	96.50a (1.98)	95.75a (1.98)	114.25a (2.05)	112.50a (2.05)	122.50a (2.08)
	CV %			31.47	39.92	30.08	25.26	29.93	32.22	18.86	32.60	32.22

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are log transform value

lower number of eggs than untreated seeds for all pulses in all sampling occasions. For untreated seeds, the number of eggs laid by pulse beetle/100 seeds ranged from 50.25-114.25, 47.75-112.50 and 53.25-122.50 on chickpea, grasspea and mungbean respectively. It was evident from table 20 that, the rate of oviposition of pulse beetle increased with the increase of storage period and decrease of exposure period. The treatment of 2 balls/kg seed and exposed for 21 days always had lower number of eggs than 7 and 15 days which ranged from 10.2-13.50, 35.75-37.75 and 37.50-45.25 respectively at 90, 180 and 270 DAS.

4.5.2. Hatchability: The per cent hatchability of the eggs laid by pulse beetle on naphthalene treated seeds of chickpea, grasspea and mungbean stored for nine months period is shown in table 21. Statistically, per cent hatchability between treatments varied significantly for all pulses in all sampling occasions. Likewise the rate of oviposition, the treatment of 4 balls/kg seed exposed for 7, 15 and 21 days and 3 balls/kg seed exposed for 15 and 21 days exhibited zero hatchability. The highest per cent hatchability was recorded from untreated seeds which ranged from 31.81-43.25, 29.25-44.41 and 27.46-41.22 respectively for chickpea, grasspea and mungbean. Although the performance of the treatment of 2 balls/kg seed exposed for 7, 15 and 21 days was not as good as 3 or 4 balls/kg

Table 21. Effect of naphthalene ball on the per cent hatchability of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose (No. of ball /kg)	Exposure period (days)	% egg hatch after								
			90 days			180 days			270 days		
			Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Naphtha-lene ball	2	7	24.89b	23.92b	23.45b	28.47b	27.30b	30.13b	35.94b	39.36b	36.60b
			(4.98)	(4.89)	(4.82)	(32.20)	(31.50)	(33.27)	(36.81)	(38.82)	(37.23)
		15	22.78b	20.29c	22.41b	30.03b	25.73b	26.80c	31.29c	34.76c	23.61c
			(4.77)	(4.50)	(4.73)	(33.21)	(30.46)	(31.18)	(33.96)	(36.09)	(29.06)
		21	16.82d	14.72d	15.31c	17.25d	15.12d	16.42e	25.29d	27.00d	23.00c
			(4.10)	(3.83)	(3.91)	(24.50)	(22.87)	(23.89)	(30.13)	(31.31)	(28.66)
"	3	7	19.21c	17.92c	18.92c	21.23c	20.24c	22.30d	27.92d	28.42d	24.97c
			(4.38)	(4.13)	(4.34)	(27.42)	(26.71)	(28.18)	(31.88)	(32.20)	(29.93)
		15	0.00e	0.00e	0.00d	0.00e	0.00e	0.00f	0.00e	0.00e	0.00d
			(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
		21	0.00e	0.00e	0.00d	0.00e	0.00e	0.00f	0.00e	0.00e	0.00d
			(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
"	4	7	0.00e	0.00e	0.00d	0.00e	0.00e	0.00f	0.00e	0.00e	0.00d
			(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
		15	0.00e	0.00e	0.00d	0.00e	0.00e	0.00f	0.00e	0.00e	0.00d
			(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
		21	0.00e	0.00e	0.00d	0.00e	0.00e	0.00f	0.00e	0.00e	0.00d
			(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
Control			31.81a	29.25a	27.46a	36.11a	34.41a	38.71a	43.25a	44.41a	41.22a
			(5.64)	(5.40)	(5.24)	(36.93)	(35.91)	(38.47)	(41.09)	(41.78)	(39.93)
CV %			11.73	8.60	9.37	10.58	6.02	10.58	6.70	9.31	8.94

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

treatments, but it also significantly reduced the per cent hatchability than untreated control. Per cent hatchability in this treatment ranged from 14.72-24.89, 15.12-30.13 and 23.00-39.36 respectively at 90, 180 and 270 DAS. Similar to the rate of oviposition, the per cent hatchability also increased with the increase of storage period and decrease of exposure period of naphthalene balls. For untreated seeds, per cent hatchability was 27.46-31.81 at 90 DAS while these increased to 34.41-38.71 and 41.22-44.41 respectively at 180 and 270 DAS. Exposure period of 21 days for 2 balls/kg seed manifested 14.72-16.82%, 15.12-17.25% and 23.00-27.00% hatchability respectively at 90, 180 and 270 DAS while these were 23.45-24.89%, 27.30-30.13% and 35.94-39.36% in 7 days exposure period.

4.5.3. Adult emergence: Per cent adult emergence between the treatments varied significantly for all pulses in all sampling occasions (Table 22). Similar to the rate of oviposition and per cent hatchability, the treatment of 4 balls/kg seed exposed for 7, 15 and 21 days and 3 balls/kg seed exposed for 15 and 21 days manifested zero adults emergence. In contrast, per cent adult emergence from untreated seeds of chickpea, grasspea and mungbean ranged from 29.67-60.01, 26.23-54.10 and 27.69-56.61 respectively. The treatment of 2 balls/kg seed also had significantly lower adult emergence than untreated control. Per cent adult emergence in this treatment ranged from 14.00-18.29,

Table 22. Effect of naphthalene ball on the per cent adult emergence of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose (No. of ball /kg)	Exposure period (days)	% adult emergence after								
			90 days			180 days			270 days		
			Chick-pea	Grass-pea	Mung-bean	Chickpea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Naphtha-lene ball	2	7	18.29b (4.27)	16.01b (4.00)	17.02b (4.12)	31.63b (34.19)	28.92b (32.51)	30.39b (33.42)	42.76b (40.81)	40.66b (39.59)	42.02b (40.38)
		15	16.81c (4.09)	15.73b (3.90)	15.88c (3.98)	29.84b (33.09)	22.43c (28.25)	25.04c (30.00)	40.30b (39.23)	37.11bc (37.52)	41.70b (40.20)
		21	15.00d (3.86)	14.00c (3.74)	15.01c (3.86)	21.00c (27.28)	18.52d (25.48)	19.08d (25.84)	29.33c (32.77)	35.88c (36.77)	38.12c (38.12)
	3	7	15.36d (3.92)	14.50c (3.71)	16.44b (4.05)	23.46c (28.93)	21.10c (27.35)	20.56d (26.92)	31.89c (34.33)	38.24bc (38.17)	41.50b (40.11)
		15	0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)	0.00d (0.29)
		21	0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)	0.00d (0.29)
"	4	7	0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)	0.00d (0.29)
		15	0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)	0.00d (0.29)
		21	0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)	0.00d (0.29)
	Control		29.67a (5.45)	26.23a (5.12)	27.69a (5.25)	53.09a (47.23)	46.21a (42.80)	46.98a (43.24)	60.01a (50.77)	54.10a (47.35)	56.61a (48.79)
CV %			8.58	6.43	7.93	9.51	10.67	10.62	4.82	8.71	7.93

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

18.52-31.63 and 29.33-42.76 respectively at 90, 180 and 270 DAS. Like the rate of oviposition and per cent hatchability, per cent adult emergence also increased with the increase of storage period and exposure period of naphthalene balls.

For untreated seeds, per cent adult emergence was 26.23-29.67 at 90 DAS while these increased to 46.21-53.09 and 54.10-60.01 respectively at 180 and 270 DAS. Exposure period of 21 days for 2 balls/kg seed revealed 14.00-15.01%, 18.52-21.00% and 29.33-38.12% adult emergence respectively at 90, 180 and 270 DAS while these were 16.01-18.29%, 28.92-31.63% and 40.66-42.76% in 7 days exposure period.

4.5.4. Intensity of infestation: The percentages of infestation of chickpea, grasspea and mungbean treated with naphthalene balls and stored for nine months period are shown in table 23 (Figure 24, 25 and 26). The treatments of 4 balls/kg seed and exposed for 7, 15 and 21 days and 3 balls/kg seed and exposed for 15 and 21 days provided the complete protection of the tested pulses while untreated seeds revealed 17.11-48.60%, 19.58-47.15% and 16.31-50.78% infestation respectively for chickpea, grasspea and mungbean. Although the performance of the treatment of 2 balls/kg seed was not as good as 3 and 4 balls/kg seed but

Table 23. Effect of naphthalene ball on the per cent infestation of chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose (No. of ball/ kg)	Exposure period (days)	% infestation after								
			90 days			180 days			270 days		
			Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grass-pea	Mung-bean
Naphthalene ball	2	7	8.83b (2.97)	6.42b (2.53)	7.81b (2.79)	18.76b (4.33)	14.69b (3.83)	15.60b (3.94)	28.05b (31.95)	25.78b (30.46)	26.95b (31.24)
		15	5.84c (2.41)	4.97c (2.22)	5.90c (2.42)	17.58b (4.19)	12.73c (3.56)	13.53c (3.67)	19.73c (26.35)	20.03c (26.56)	20.28c (26.71)
		21	2.47d (1.57)	2.87d (1.67)	2.80d (1.67)	6.56c (2.56)	8.11d (2.84)	8.14d (2.85)	12.33d (20.53)	10.99e (19.28)	11.23d (19.55)
	3	7	3.20d (1.78)	2.92d (1.70)	3.11d (1.76)	7.80c (2.79)	8.30d (2.88)	8.85d (2.97)	14.96d (22.71)	13.88d (21.81)	12.56d (20.79)
		15	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)
		21	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)
"	4	7	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)
		15	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)
		21	0.00e (0.71)	0.00e (0.71)	0.00e (0.71)	0.00d (0.71)	0.00e (0.71)	0.00e (0.71)	0.00e (0.29)	0.00f (0.29)	0.00e (0.29)
	Control	7	17.11a (4.13)	19.58a (4.42)	16.31a (4.03)	31.65a (5.62)	29.95a (5.47)	28.83a (5.36)	48.60a (44.20)	47.15a (43.34)	50.78a (45.40)
		15									
		21									
CV %			11.53	11.24	9.35	6.88	9.41	7.65	5.83	8.80	6.83

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

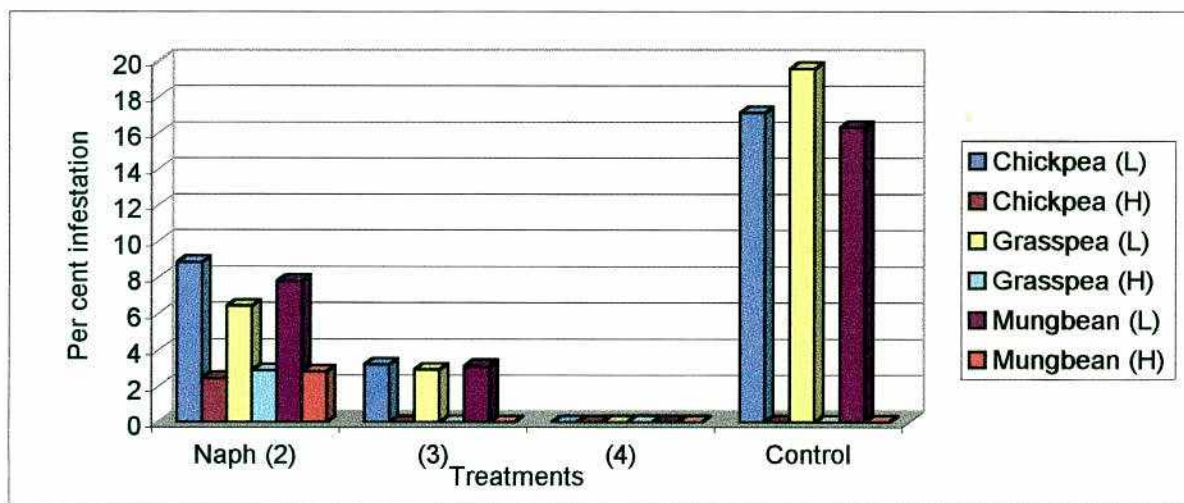


Fig. 24. Per cent infestation after 90 days at lowest and highest dosage of naphthalene ball

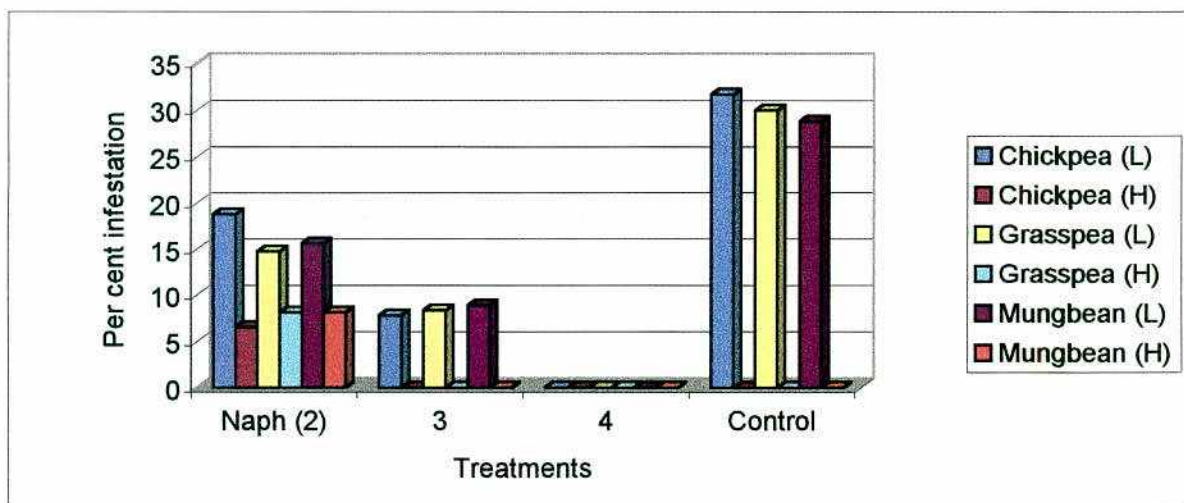


Fig. 25. Per cent infestation after 180 days at lowest and highest dosage of naphthalene ball

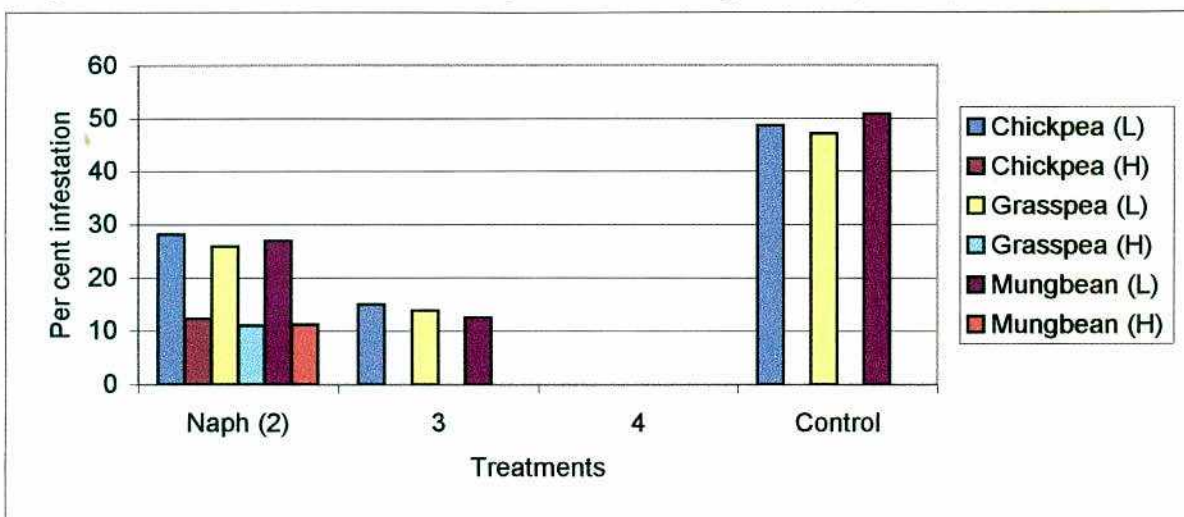


Fig. 26. Per cent infestation after 270 days at lowest and highest dosage of naphthalene ball

it gave significantly lower percentages of infestation compared to untreated control for all pulses in all sampling occasions. Per cent infestation in this treatment ranged from 2.47-8.83, 6.56-18.76 and 10.99-28.05 respectively at 90, 180 and 270 DAS. Similar to the rate of oviposition, per cent hatchability and adult emergence, the intensity of per cent infestation increased with the increase of storage period and decrease of exposure period of naphthalene balls.

For untreated control the per cent infestation ranged from 16.31-19.58 at 90 DAS while these increased to 28.83-31.65 and 47.15-50.78 respectively at 180 and 270 DAS. Exposure period of 21 days for 2 balls/kg seed gave 2.47-2.87%, 6.56-8.14% and 10.99-12.33% infestation, respectively at 90, 180 and 270 DAS while these were 6.42-8.83%, 14.69-18.76% and 25.78-28.05% in 7 days exposure period.

4.5.5. Weight loss: Statistically, the percentages of weight loss of chickpea, grasspea and mungbean between treatments varied significantly (Table 24 and figure 27, 28 and 29) in all sampling occasions. No weight loss was incurred in the treatments of 4 balls/kg seed exposed for 7, 15 and 21 days and 3 balls/kg seed exposed for 15 and 21 days. For untreated seeds, the weight loss was found to

Table 24. Effect of naphthalene ball on the per cent weight loss of chickpea, grasspea and mungbean after storage for nine months

Treat-ments	Dose (No. of ball/ kg)	Exposure period (days)	% weight loss after								
			90 days			180 days			270 days		
			Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean
Naphtha- lene ball	2	7	4.26b	3.08b	4.22b	9.21b	8.91b	8.41b	14.91b	13.85b	14.28b
			(2.06)	(1.75)	(2.05)	(3.03)	(2.98)	(2.90)	(3.86)	(3.72)	(3.77)
		15	3.72c	3.69b	2.65c	8.54b	6.23c	7.26b	9.11c	10.64c	11.44c
			(1.92)	(1.92)	(1.62)	(2.92)	(2.49)	(2.67)	(3.01)	(3.26)	(3.38)
		21	1.80d	1.50c	1.32d	3.81c	4.61d	4.72c	6.81d	5.71d	6.74d
			(1.34)	(1.22)	(1.14)	(1.95)	(2.14)	(2.17)	(2.60)	(2.38)	(2.59)
"	3	7	1.92d	1.56c	1.87d	3.68c	2.26d	4.31c	7.12d	7.88d	6.82d
			(1.38)	(1.24)	(1.36)	(1.91)	(2.06)	(2.07)	(2.66)	(2.80)	(2.61)
		15	0.00e	0.00d		0.00d	0.00e	0.00d	0.00e	0.00e	0.00e
			(0.71)	(0.71)	0.00e	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
		21	0.00e	0.00d	(0.71)	0.00d	0.00e	0.00d	0.00e	0.00e	0.00e
			(0.71)	(0.71)	0.00e	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
"	4	7	0.00e	0.00d		0.00d	0.00e	0.00d	0.00e	0.00e	0.00e
			(0.71)	(0.71)	0.00e	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
		15	0.00e	0.00d	(0.71)	0.00d	0.00e	0.00d	0.00e	0.00e	0.00e
			(0.71)	(0.71)	0.00e	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
		21	0.00e	0.00d	(0.71)	0.00d	0.00e	0.00d	0.00e	0.00e	0.00e
			(0.71)	(0.71)	0.00e	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
Control			8.79a	10.51a		16.26a	14.28a	14.52a	25.20a	23.92a	26.46a
			(2.96)	(3.24)	9.49a	(4.03)	(3.77)	(3.81)	(5.01)	(4.89)	(5.14)
CV %			7.33	6.63	7.40	7.29	6.51	6.55	4.91	6.40	8.25

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

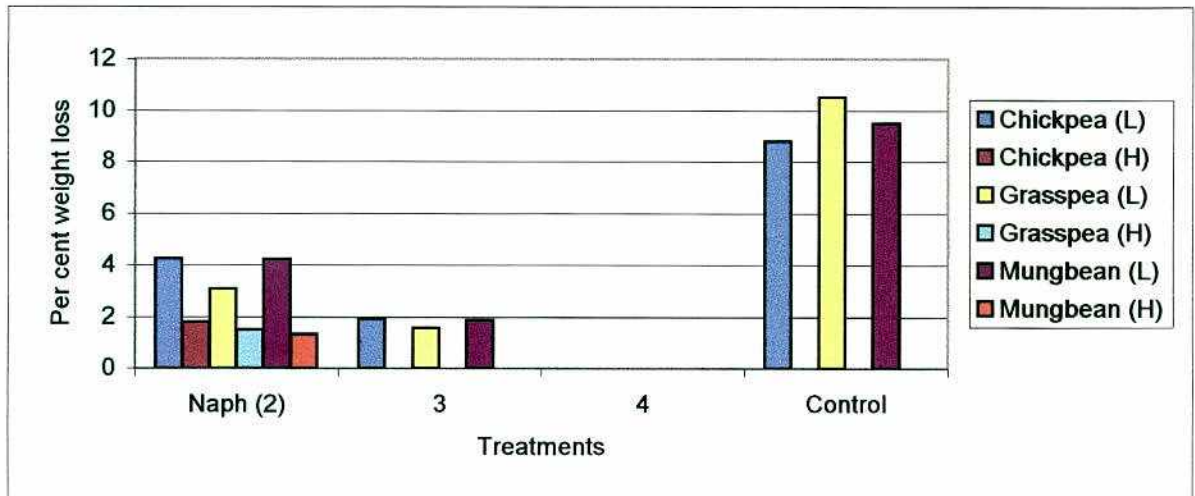


Fig. 27. Per cent weight loss after 90 days at lowest and highest dosage of naphthalene ball

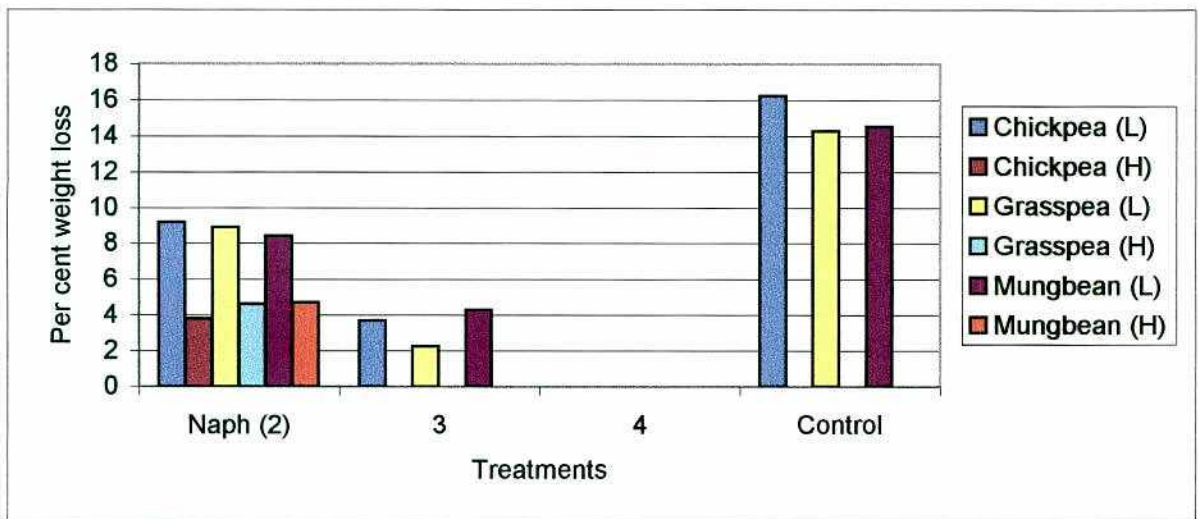


Fig. 28. Per cent weight loss after 180 days at lowest and highest dosage of naphthalene ball

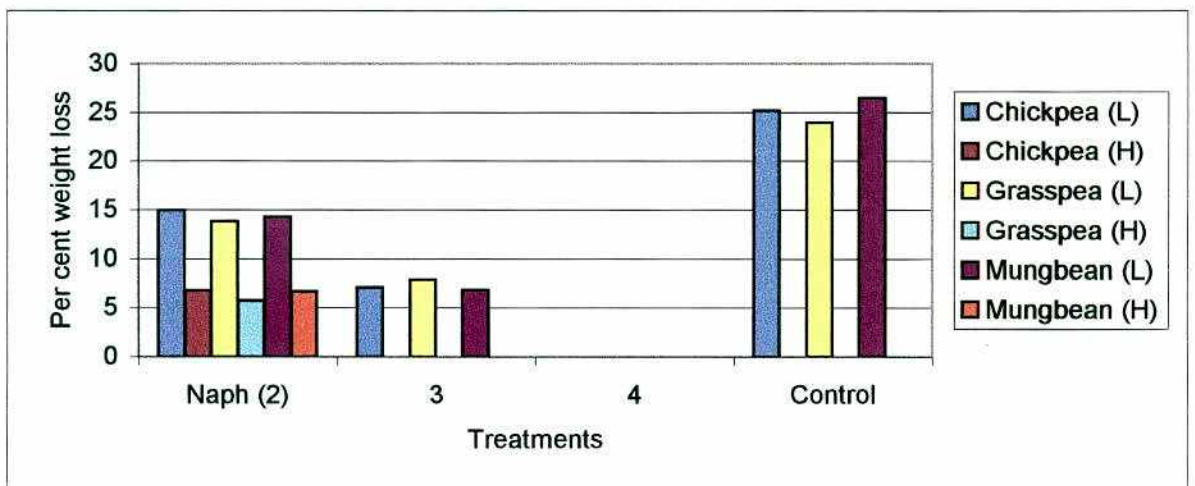


Fig. 29. Per cent weight loss after 270 days at lowest and highest dosage of naphthalene ball

range from 8.79-25.20%, 10.51-23.92% and 9.49-26.46% respectively for chickpea, grasspea and mungbean. The per cent weight loss of 3 balls/kg seed exposed for 7 days was statistically identical to that of 2 balls/kg seed exposed for 21 days for all pulses in all sampling occasions. In the later treatment, the per cent weight loss ranged from 1.32 - 1.80, 3.81-4.72 and 5.71-6.81 respectively at 90, 180 and 270 DAS. These losses were 3.08-4.26%, 8.41-9.21% and 13.85-14.91% for the treatment of 2 balls/kg seed exposed for 7 days. Comparison of the results of 90, 180 and 270 DAS indicated that the per cent weight loss increased with the increase of storage period. These results were similar to those of rate of oviposition, hatchability, adult emergence and per cent infestation. For untreated seeds, the per cent weight loss ranged from 8.79-10.51, 14.28-16.26 and 23.92-26.46 respectively at 90, 180 and 270 DAS.

4.5.6. Germination: The percentages of germination of chickpea, grasspea and mungbean treated with naphthalene after storage of 90, 180 and 270 days are shown in table 25. The initial germination percentages were 94.50, 93.50 and 96.25, respectively for chickpea, grasspea and mungbean. Untreated seeds always had significantly lower percentages of germination than treated seeds with some exception. At 90 DAS, the germination of naphthalene balls

Table 25. Effect of naphthalene ball on the per cent germination of chickpea, grasspea and mungbean stored for nine months

Treat- ments	Dose (No. of ball /kg)	Expo- sure period (days)	% germination after										
			90 days			180 days			270 days				
			Chickpea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean	Chick- pea	Grass- pea	Mung- bean		
Naphtha- lene ball	2	7	93.00ab (9.65)	93.50ab (9.67)	93.00a (9.65)	88.50b (9.41)	82.00c (9.38)	81.50b (9.49)	73.25c (9.13)	71.75d (9.31)	74.00c (9.22)		
			92.25ab (9.61)	92.00bc (9.59)	93.50a (9.67)	81.00b (9.54)	83.50c (9.51)	80.25b (9.44)	78.25c (9.34)	79.25d (9.13)	78.25c (9.18)		
		15	94.00a (9.70)	93.25ab (9.66)	93.50a (9.67)	88.00b (9.59)	87.25c (9.60)	87.00a (9.59)	83.75b (9.48)	86.50a (9.30)	86.50ab (9.30)		
			21										
		"	3	7	93.25ab (9.66)	92.00b (9.59)	90.75a (9.68)	91.00ab (9.64)	90.25a (9.61)	91.50a (9.57)	87.50b (9.36)	82.75c (9.10)	84.50ab (9.19)
					94.00a (9.69)	95.00a (9.75)	92.25a (9.61)	89.75ab (9.47)	89.25ab (9.45)	89.50a (9.46)	89.25a (9.45)	86.75a (9.10)	88.50a (9.14)
15	91.75ab (9.58)			92.75a-c (9.63)	92.00a (9.59)	91.50ab (9.57)	90.25ab (9.50)	90.25a (9.50)	86.50b (9.30)	83.75ab (9.15)	82.25b (9.07)		
	21												
"	4			7	92.00ab (9.59)	94.50ab (9.72)	92.75a (9.63)	92.75a (9.63)	90.00ab (9.48)	88.50a (9.41)	86.00b (9.27)	84.75ab (9.21)	82.75b (9.10)
					93.25ab (9.66)	91.75bc (9.58)	92.25a (9.61)	92.00ab (9.59)	91.25a (9.55)	90.00a (9.49)	87.50a (9.25)	82.00c (9.06)	82.50b (9.09)
		15	91.50ab (9.57)	92.00bc (9.59)	93.00a (9.65)	91.50ab (9.57)	88.75ab (9.42)	91.25a (9.55)	88.75a (9.42)	82.75c (9.10)	85.00ab (9.22)		
			21										
		Control		82.50b (9.51)	84.25c (9.50)	82.25b (9.50)	65.25c (8.08)	67.25d (8.20)	65.50c (8.10)	52.75d (7.60)	53.00e (7.55)	58.75d (7.66)	
CV %			1.02	0.97	1.18	1.23	1.30	1.24	1.36	1.41	1.36		

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

treated chickpea, grasspea and mungbean ranged from 91.50-94.00%, 91.75-95.00% and 90.75-93.50% respectively while for untreated seeds, the percentages of germination were 82.50, 84.25 and 82.25. As the time of storage progressed, the difference between treated and untreated seeds became much wider. At 180 DAS, germination percentages of treated seeds were 81.00-92.75, 82.00-91.25 and 80.25-91.50 respectively for chickpea, grasspea and mungbean. For untreated seeds, these were 65.25%, 67.25% and 65.50% for chickpea, grasspea and mungbean respectively. Further decline in germination percentage was observed at 270 DAS. For treated seeds the range was from 71.75-89.25%, while for untreated seeds it was from 52.75-58.75%.

4.5.7. Moisture content: Per cent moisture level between naphthalene treated and untreated seeds of chickpea, grasspea and mungbean at 90, 180 and 270 DAS varied significantly (Table 26). The initial moisture contents were 9.8, 10.1 and 9.9% respectively for chickpea, grasspea and mungbean. For naphthalene balls treated seeds, no remarkable increase of moisture content was noticed over storage period. At 90 DAS, the recorded moisture level ranged from 12.00-12.50% while these were 11.75-13.00% and 11.75-12.50%, respectively at 180 & 270 DAS. For untreated seeds, slight increase of moisture content was recorded over the storage period. At 90 DAS, the recorded moisture

Table 26. Effect of naphthalene ball on the per cent moisture level in chickpea, grasspea and mungbean stored for nine months

Treat-ments	Dose (No. of ball /kg)	Exposure period (days)	% moisture level after									
			90 days			180 days			270 days			
			Chick-pea	Grass-pea	Mung-bean	Chick-pea	Grasspea	Mung-bean	Chick-pea	Grass-pea	Mung-bean	
Naphtha-lene ball	2	7	12.25ab (3.50)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.75ab (3.57)	12.00b (3.46)	12.25b (3.50)	12.25b (3.50)	12.00b (3.46)	
		15	12.25ab (3.50)	12.00b (3.46)	12.25b (3.50)	12.50b (3.53)	12.25b (3.50)	12.25b (3.50)	12.00b (3.46)	12.50b (3.54)	12.00b (3.46)	
		21	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	11.75b (3.43)	12.25b (3.50)	12.00b (3.46)	11.75b (3.43)	12.25b (3.50)	12.25b (3.50)	
	3	7	12.50ab (3.53)	12.00b (3.46)	12.00b (3.46)	12.75b (3.57)	12.75ab (3.57)	12.50b (3.54)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	
		15	12.00b (3.46)	12.75b (3.57)	12.00b (3.46)	12.75b (3.57)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	12.50b (3.54)	12.00b (3.46)	
		21	12.25ab (3.50)	12.50b (3.53)	12.50b (3.54)	12.75b (3.57)	13.00ab (3.36)	12.00b (3.46)	12.25b (3.50)	12.00b (3.46)	12.00b (4.15)	
"	4	7	12.25ab (3.50)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.25b (3.50)	12.25b (3.50)	12.00b (3.46)	12.25b (3.50)	12.00b (3.46)	
		15	12.00b (3.46)	12.50b (3.54)	12.50b (3.54)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.50b (3.54)	12.00b (3.46)	12.00b (3.46)	
		21	12.00b (3.46)	12.25b (3.50)	12.25b (3.50)	12.75b (3.57)	12.50b (3.54)	12.25b (3.50)	12.00b (3.46)	12.00b (3.46)	11.75b (3.43)	
	Control			13.50a (3.67)	13.25a (3.64)	13.75a (3.71)	14.50a (3.81)	14.00a (3.74)	15.25a (3.90)	18.00a (4.24)	19.50a (4.42)	19.25a (4.39)
	CV %			3.44	3.52	3.05	3.52	3.50	3.04	3.22	3.05	3.25

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

level was from 13.25-13.75% while these were 14.00-15.25% and 18.00-19.50% respectively at 180 and 270 DAS.

4.6. Effect of different physical factors

4.6.1. Rate of oviposition: The rates of oviposition of pulse beetle on sundried, heat and cold treated seeds of chickpea, grasspea and mungbean stored for nine months period are shown in table 27. Statistically, the number of eggs obtained from treated and untreated seeds varied significantly for all pulses in all sampling occasions. The treatment of cooling (5°C) for 2, 4 and 6 days and heating for 10 minutes at 100°C completely prevented pulse beetle from laying eggs on all of the tested pulses. For untreated seeds of chickpea, grasspea and mungbean, 64.75-115.25, 70.50-112.75 and 69.50-110.25 eggs per 100 grains were recorded respectively. The number of eggs obtained from sunning (30, 45 and 60 days) and heat treatment (5 and 7.5 minutes) was significantly lower than untreated control. Among the interval of sunning, 30 days always had lower number of eggs than 45 and 60 days. At 30 days interval, 27.50-56.25, 34.25-62.25 and 29.00-59.75 eggs per 100 grains were recorded respectively from chickpea, grasspea and mungbean. These number were 53.00-80.50, 59.50-83.50 and 55.50-84.75 for 60 days interval. Among the duration of treatment, 7.5 minutes always manifested lower rate of oviposition than 5 minutes. For both treated and untreated seeds of chickpea, grasspea and mungbean, the rate of

Table 27. Effect of different physical factors on the oviposition of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treatments	Time interval	No. eggs/100 grains after								
		90 days			180 days			270 days		
		Chickpea	Grasspea	Mung-bean	Chickpea	Grasspea	Mung-bean	Chickpea	Grasspea	Mung-bean
Sunning (days)	30	27.50e	34.25d	29.00d	44.00d	46.00d	41.75d	56.25c	62.25d	59.75d
		(1.44)	(1.52)	(1.43)	(1.66)	(1.66)	(1.62)	(1.75)	(1.79)	(1.77)
	45	36.25d	40.50c	39.00c	49.25c	53.50c	57.25bc	61.75c	64.00d	62.00d
		(1.54)	(1.60)	(1.59)	(1.69)	(1.72)	(1.57)	(1.79)	(1.80)	(1.79)
	60	53.00b	59.50b	55.50b	66.00b	71.00b	69.75b	80.50b	83.50b	84.75b
		(1.72)	(1.77)	(1.74)	(1.81)	(1.85)	(1.84)	(1.92)	(1.92)	(1.92)
Heat treatments at 100°C (minutes)	5	45.00c	39.75c	49.25bc	59.25bc	58.50c	61.50bc	78.50b	69.50c	74.75c
		(1.65)	(1.59)	(1.69)	(1.77)	(1.76)	(1.78)	(1.89)	(1.84)	(1.87)
	7.5	36.75d	35.25d	33.25c	50.75c	54.25c	52.50c	59.75c	55.75e	60.00d
		(1.56)	(1.54)	(1.52)	(1.70)	(1.73)	(1.72)	(1.77)	(1.74)	(1.77)
	10	0.00f	0.00e	0.00e	0.00e	0.00e	0.00e	0.00d	0.00f	0.00e
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Cold treatments at 5°C (days)	2	0.00f	0.00e	0.00e	0.00e	0.00e	0.00e	0.00d	0.00f	0.00e
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	4	0.00f	0.00e	0.00e	0.00e	0.00e	0.00e	0.00d	0.00f	0.00e
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
	6	0.00f	0.00e	0.00e	0.00e	0.00e	0.00e	0.00d	0.00f	0.00e
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Control		64.75a	70.50a	69.50a	94.50a	97.00a	101.50a	115.25a	112.75a	110.25a
		(1.81)	(1.84)	(1.97)	(1.97)	(1.99)	(2.00)	(2.06)	(2.04)	(2.04)
CV %		42.11	50.44	37.23	29.87	25.54	35.06	24.3	19.48	25.27

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are log transformed values

oviposition increased with the increase of storage period. From untreated seeds, 64.75-70.50, 94.50-101.50 and 110.25-115.25 eggs per 100 grains were recorded respectively at 90, 180 and 270 DAS.

4.6.2. Hatchability: Per cent hatchability of the eggs laid by pulse beetle on sun dried, heat and cold treated seeds of chickpea, grasspea and mungbean stored for nine months period are shown in table 28. Statistically, per cent hatchability between treated and untreated seeds varied significantly for all pulses in all sampling occasions. Likewise the rate of oviposition, no hatching occurred from the cold and heat treated (10 minutes) seeds. For untreated seeds, per cent hatchability ranged from 30.96-42.42, 28.49-43.33 and 27.60-45.69 respectively for chickpea, grasspea and mungbean. Sunning at an interval of 30, 45 and 60 days and heat treatment for 5 and 7.5 minutes had slightly lower per cent hatchability than untreated control for all pulses in all sampling occasions. Sunning showed 19.96-30.65%, 29.82-41.70% and 36.56- 7.84% hatchability respectively at 90, 180 and 270 DAS while heat treatment (5 and 7.5 minute) provided 12.41-19.77%, 16.84-24.55% and 22.82-27.59% hatchability in similar occasions. Comparisons of the results of 90, 180 and 270 DAS indicated that the per cent hatchability increased with the increase of storage period. For untreated seeds, 27.60-30.96%, 35.62-

Table 28. Effect of different physical factors on the per cent hatchability of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treatments	Time interval	% egg hatch after								
		90 days			180 days			270 days		
		Chick-pea	Grass-pea	Mung-bean	Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mung-bean
Sunning (days)	30	20.53c (4.53)	19.96b (4.46)	21.08bc (4.59)	31.44bc (34.08)	29.82b (33.09)	33.71b (34.27)	38.39b (38.23)	36.56b (37.17)	39.42b (38.88)
		26.72b (5.16)	27.38a (5.23)	24.27b (4.92)	35.19b (36.33)	36.76a (37.29)	33.02b (35.06)	44.69ab (41.99)	41.01ab (39.82)	43.45ab (41.21)
	45	29.50a (5.43)	28.82a (5.36)	30.65a (5.53)	38.36a (38.23)	35.96a (36.81)	41.70a (40.22)	47.84a (43.74)	46.32a (42.88)	44.42a (41.78)
	60									
Heat treatments at 100°C (minutes)	5	19.77c (4.44)	17.98b (4.24)	16.75c (4.09)	22.11c (28.04)	24.55bc (27.67)	21.35c (27.49)	25.17c (30.07)	27.37c (31.50)	27.59c (31.63)
		14.54d (3.81)	12.41c (3.52)	15.00c (3.87)	16.84d (24.20)	17.76c (24.88)	17.67d (24.80)	22.82d (28.52)	24.86c (29.73)	25.42c (30.26)
	7.5	0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)
	10									
Cold treatments at 5°C (days)	2	0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)
		0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)
	4	0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)
		0.00e (0.71)	0.00d (0.71)	0.00d (0.71)	0.00e (0.29)	0.00d (0.29)	0.00e (0.29)	0.00e (0.29)	0.00d (0.29)	0.00d (0.29)
	6									
Control		30.96a (5.56)	28.49 (5.33)	27.60a (5.25)	37.26a (37.58)	35.62a (36.63)	36.56a (37.17)	42.42ab (41.78)	43.33a (41.15)	45.69a (42.48)
CV %		8.33	12.65	8.62	5.50	6.84	6.65	5.14	5.23	4.49

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

37.26% and 42.42-45.69% hatchability were observed respectively at 90, 180 and 270 DAS..

4.6.3. Adult emergence: The percentages of adult emerged from treated untreated seeds of chickpea, grasspea and mungbean stored for nine months period are presented in table 29. Statistically, per cent adult emergence between treatments varied significantly for all pulses in all sampling occasions. No adult was found to have emerged from cold (2,4 and 6 days) and heat (10 minutes) treatments since these treatments completely prevented pulse beetle from laying eggs. The highest percentages of adults were found to emerge from untreated seeds, which ranged from 31.60-46.94, 30.15-47.84 and 29.84-48.95 respectively for chickpea, grasspea and mungbean. Sunning (30, 45 and 60 days) and heating (5 and 7.5 minutes) also resulted significantly lower percentages of adult emergence than untreated. The percentages of adult emergence from sunning ranged from 15.00-18.18, 18.78-24.35 and 25.96-35.22 respectively at 90, 180 and 270 DAS. Heating (5 and 7.5 minutes) manifested 15.56-24.73%, 16.93-28.25% and 29.74-42.51% adult emergence respectively at 90, 180 and 270 DAS. Like other studied parameters, per cent adult emergence also increased with the increase of storage period. From untreated seeds, 29.84-31.60%, 35.00-36.04% and 46.94-48.95% adults emerged respectively at 90, 180 and 270 DAS.

Table 29. Effect of different physical factors on the per cent adult emergence of *C. chinensis* in chickpea, grasspea and mungbean stored for nine months

Treatments	Time interval	% adult emergence after								
		90 days			180 days			270 days		
		Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mung-bean	Chickpea	Grasspea	Mung-bean
Sunning (days)	30	15.00c	15.83d	16.22c	19.05d	18.78d	18.95c	25.96e	32.19c	27.81d
		(3.86)	(3.98)	(4.02)	(25.84)	(25.62)	(25.77)	(30.59)	(34.51)	(31.42)
	45	16.92c	17.40c	17.22c	22.04c	20.13c	19.22c	30.78d	34.73c	31.05c
		(4.11)	(4.17)	(4.14)	(27.97)	(26.56)	(25.99)	(33.65)	(36.09)	(33.83)
	60	16.93c	17.56c	18.18c	24.35c	22.31c	19.75c	33.84c	35.22c	31.68c
		(4.11)	(4.19)	(4.26)	(29.53)	(28.18)	(26.35)	(35.55)	(36.39)	(34.33)
Heat treatments at 100°C (minutes)	5	19.35b	20.37b	24.73b	28.25b	26.26b	27.01b	36.92b	42.51b	35.70b
		(4.39)	(4.51)	(4.95)	(32.08)	(30.79)	(31.31)	(37.41)	(40.69)	(36.69)
	7.5	15.56c	17.33c	17.07c	16.93d	18.92d	18.28c	29.74d	31.46c	34.08b
		(3.34)	(4.16)	(4.13)	(24.27)	(25.77)	(25.25)	(33.02)	(34.08)	(35.67)
	10	0.00d	0.00e	0.00d	0.00e	0.00e	0.00d	0.00f	0.00d	0.00e
		(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
Cold treatments at 5°C (days)	2	0.00d	0.00e	0.00d	0.00e	0.00e	0.00d	0.00f	0.00d	0.00e
		(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
	4	0.00d	0.00e	0.00d	0.00e	0.00e	0.00d	0.00f	0.00d	0.00e
		(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
	6	0.00d	0.00e	0.00d	0.00e	0.00e	0.00d	0.00f	0.00d	0.00e
		(0.71)	(0.71)	(0.71)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)	(0.29)
Control		31.60a	30.15a	29.84a	36.04a	35.02a	35.00a	46.94a	47.84a	48.95a
		(5.62)	(5.49)	(5.46)	(37.11)	(36.27)	(36.27)	(43.22)	(43.74)	(44.37)
CV %		5.55	5.64	7.12	6.53	5.48	5.99	4.88	5.21	7.33

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

4.6.4. Intensity of infestation: As shown in table 30 (Figures 30, 31 and 32), the percentages of bored grains between treated and untreated seeds of chickpea, grasspea and mungbean varied significantly in all sampling occasions. Since no eggs were found from cold (2, 4 and 6 days) and heat (10 minutes) treated seeds, no bored grains were found in these treatments. But for untreated seeds, 18.08-48.10%, 19.88-46.48% and 19.70-49.40% infestation were recorded respectively from chickpea, grasspea and mungbean. Although sunning (30, 45 and 60 days) and heating (5 and 7.5 minutes) did not perform equally as cold treatment but provided better protection than untreated control for all of the tested pulses in all sampling occasions. Sunning resulted 6.18-14.88%, 13.48-29.70% and 21.82-40.85% infestation, respectively at 90, 180 and 270 DAS. Heating (5 and 7.5 minutes) on the other hand gave 4.43-7.95%, 7.10-13.53% and 12.48-19.15% infestation respectively at 90, 180 and 270 DAS. Like other studied parameters, per cent infestation also increased with the increase of storage period. For untreated seeds, 18.08-19.88%, 33.63-34.55% and 46.48-49.40% infestations were recorded respectively at 90, 180 and 270 DAS.

4.6.5. Weight loss: In table 31 (Figures 33, 34 and 35) the percentages of weight loss of treated and untreated seeds of chickpea, grasspea and mungbean due to the attack of pulse beetle over nine months of storage period have been

Table 30. Effect of different physical factors on the per cent infestation of chickpea, grasspea and mungbean stored for nine months

Treatments	Time inter-val	% infestation after								
		90 days			180 days			270 days		
		Chickpea	Grasspea	Mung-bean	Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mung-bean
Sunning (days)	30	7.63d (2.76)	6.18d (2.48)	6.44d (2.53)	14.75d (22.55)	16.20c (23.73)	13.48d (21.47)	23.65d (29.06)	21.82c (27.83)	24.80cd (29.87)
	45	9.35c (3.05)	10.53c (3.24)	9.58c (3.09)	18.85c (25.70)	19.58bc (26.21)	17.83c (24.95)	28.40c (32.20)	26.05bc (30.66)	27.41c (31.56)
	60	13.88b (3.72)	14.65b (3.82)	14.88b (3.85)	24.70b (29.80)	25.40b (30.26)	29.70b (33.02)	39.80b (39.11)	40.85b (39.70)	38.35b (38.23)
Heat treatments at 100°C (minutes)	5	7.73d (2.78)	6.50d (2.54)	7.95cd (2.81)	10.20e (18.63)	13.53c (21.56)	12.52d (20.70)	18.57de (25.48)	17.28d (24.50)	19.15d (25.92)
	7.5	5.50e (2.34)	4.43d (2.10)	6.35d (2.51)	7.10f (15.45)	8.38d (16.74)	8.15e (16.54)	13.43e (21.47)	12.48e (20.62)	14.23e (22.22)
	10	0.00f (0.71)	0.00e (0.71)	0.00e (0.71)	0.00g (0.09)	0.00e (0.09)	0.00f (0.09)	0.00f (0.09)	0.00f (0.09)	0.00f (0.09)
Cold treatments at 5°C (days)	2	0.00f (0.71)	0.00e (0.71)	0.00e (0.71)	0.00g (0.09)	0.00e (0.09)	0.00f (0.09)	0.00f (0.09)	0.00f (0.09)	0.00f (0.09)
	4	0.00f (0.71)	0.00e (0.71)	0.00e (0.71)	0.00g (0.09)	0.00e (0.09)	0.00f (0.09)	0.00f (0.09)	0.00f (0.09)	0.00f (0.09)
	6	0.00f (0.71)	0.00e (0.71)	0.00e (0.71)	0.00g (0.09)	0.00e (0.09)	0.00f (0.09)	0.00f (0.09)	0.00f (0.09)	0.00f (0.09)
Control		18.08a (4.25)	19.88a (4.45)	19.70a (4.43)	33.63a (35.43)	34.45a (35.91)	34.55a (35.97)	48.10a (43.91)	46.48a (42.94)	49.40a (44.66)
CV %		11.53	11.24	9.35	6.88	9.41	7.65	5.83	8.80	6.83

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root and arc sin transformed values

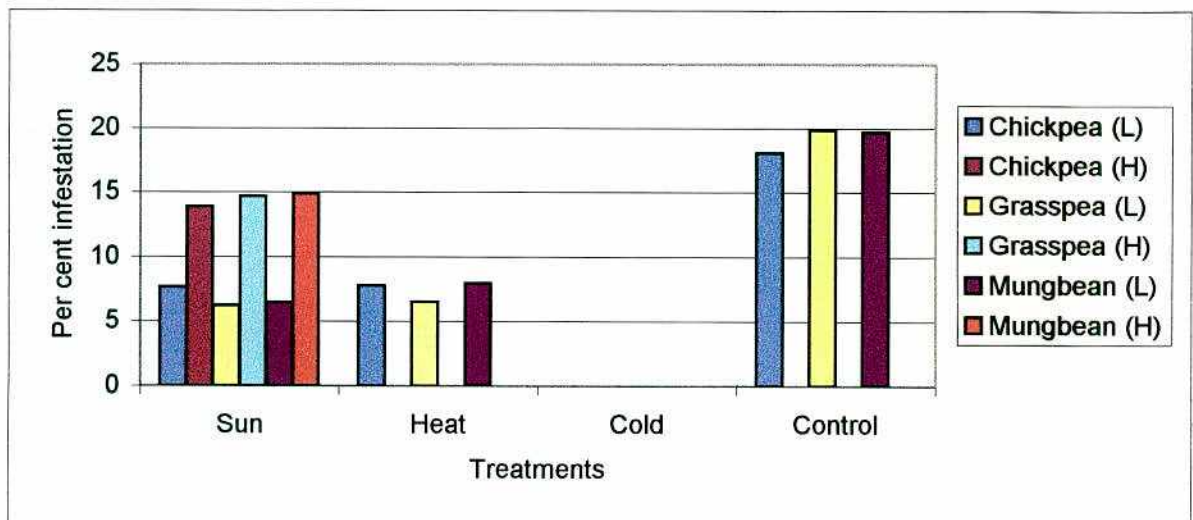


Fig. 30. Per cent infestation after 90 days at lowest and highest dosage of physical factors

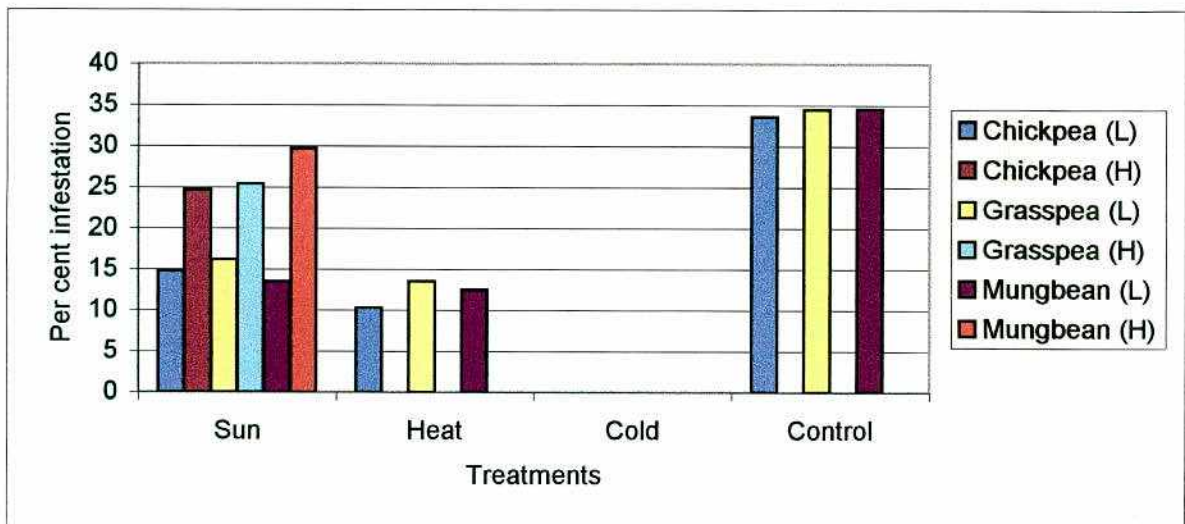


Fig. 31. Per cent infestation after 180 days at lowest and highest dosage of physical factors

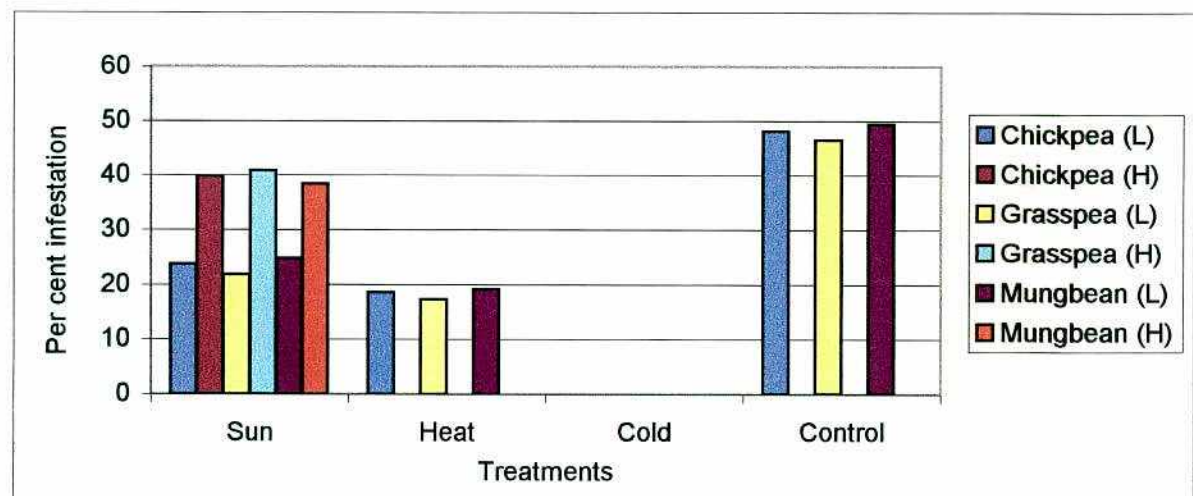


Fig. 32. Per cent infestation after 270 days at lowest and highest dosage of physical factors

presented. Statistically, per cent weight loss between treatments varied significantly. No weight loss was recorded from the treatments of cooling (2, 4 and 6 days) and heating (10 minutes) while 10.20-25.73%, 11.92-24.56% and 11.56-26.94% weight losses were recorded respectively from untreated seeds of chickpea, grasspea and mungbean. Sunning (30, 45 and 60 days) and heating (5 and 7.5 minutes) also recorded significant weight loss of all of the tested pulses in all sampling occasions than the untreated ones. Sunning resulted 3.58-8.47%, 7.79-15.55% and 11.77-20.68% weight loss respectively at 90, 180 and 270 DAS. On the other hand, heating (5 and 7.5 minutes) manifested 2.63-4.76%, 4.08-6.63% and 6.17-10.64% weight loss respectively at 90, 180 and 270 DAS. As seen in the case of other studied characters, per cent weight loss also increased with the increase of storage period. For untreated seeds, 10.20-11.92%, 17.21-18.08% and 24.56-26.94% weight losses were found respectively at 90, 180 and 270 DAS.

4.6.6. Germination: The percentages of germination of treated and untreated seeds of chickpea, grasspea and mungbean recorded at 90, 180 and 270 DAS are shown in table 32. The pretreatment germination of chickpea, grasspea and mungbean were 94.50%, 93.50% and 96.25% respectively. Statistically, the percentages of germination between treatments varied significantly. In all sampling occasions,

Table 31. Effect of different physical factors on the per cent weight loss of chickpea, grasspea and mungbean after storage for nine months

Treatments	Time inter-val	% weight loss after								
		90 days			180 days			270 days		
		Chickpea	Grasspea	Mung-bean	Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mung-bean
Sunning (days)	30	4.55c	3.58d	3.86d	7.79c	8.13c	7.94d	12.95c	11.77b	13.94c
		(2.13)	(1.89)	(1.96)	(2.79)	(2.85)	(2.81)	(3.59)	(3.43)	(3.73)
	45	5.84bc	5.99c	4.48c	9.14bc	10.39bc	10.92c	14.57c	13.15b	14.44c
		(2.41)	(2.44)	(2.11)	(3.02)	(3.22)	(3.30)	(3.81)	(3.62)	(3.80)
	60	7.15b	8.37b	8.47b	12.87b	13.07b	15.55b	19.72b	20.36ab	20.68b
		(2.67)	(2.89)	(2.91)	(3.58)	(3.61)	(3.93)	(4.44)	(4.51)	(4.54)
Heat treatments at 100°C (minutes)	5	4.60c	3.56d	4.76c	5.59c	6.54d	6.63d	9.45d	9.88c	10.64cd
		(2.14)	(1.88)	(2.18)	(2.36)	(2.55)	(2.57)	(3.07)	(3.14)	(3.26)
	7.5	3.14d	2.63e	3.58d	4.89d	4.08e	5.17d	7.16d	6.17d	7.30d
		(1.77)	(1.62)	(1.89)	(2.21)	(2.01)	(2.27)	(2.67)	(2.48)	(2.70)
	10	0.00e	0.00f	0.00e	0.00e	0.00f	0.00e	0.00e	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
Cold treatments at 5°C (days)	2	0.00e	0.00f	0.00e	0.00e	0.00f	0.00e	0.00e	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
	4	0.00e	0.00f	0.00e	0.00e	0.00f	0.00e	0.00e	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
	6	0.00e	0.00f	0.00e	0.00e	0.00f	0.00e	0.00e	0.00e	0.00e
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
Control		10.20a	11.92a	11.56a	17.54a	17.21a	18.08a	25.73a	24.56a	26.94a
		(3.19)	(3.45)	(3.40)	(4.18)	(4.14)	(4.25)	(5.07)	(4.95)	(5.19)
CV %		7.33	6.63	7.40	7.29	6.51	6.55	4.91	6.40	8.25

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

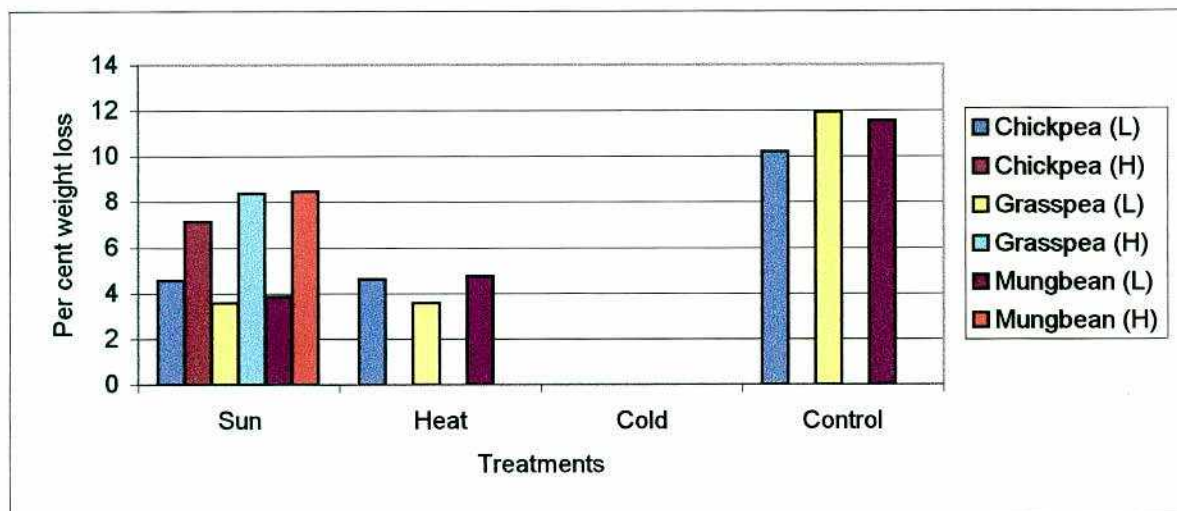


Fig. 33. Per cent weight loss after 90 days at lowest and highest dosage of physical factors

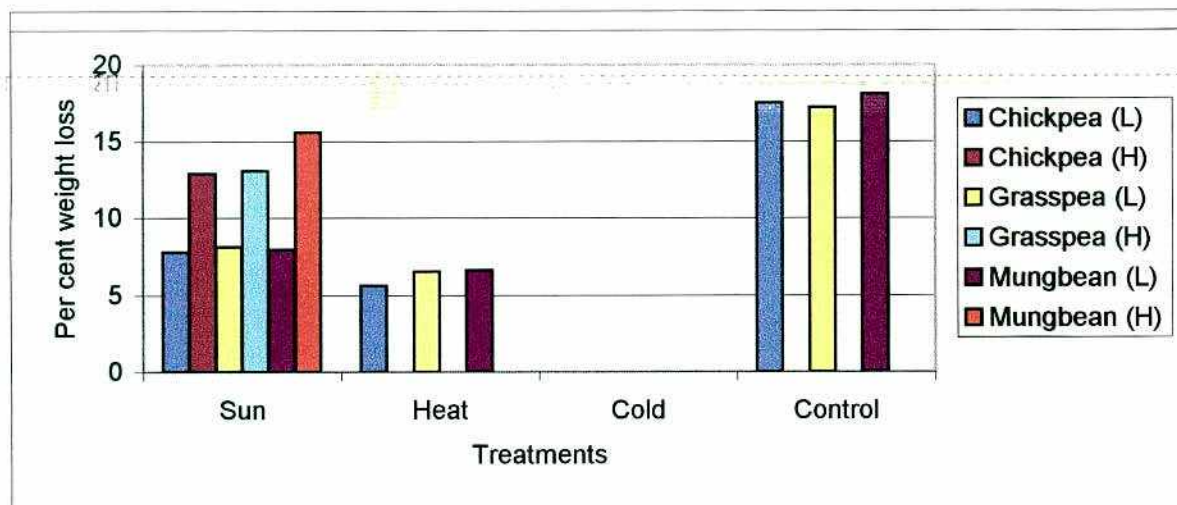


Fig. 34. Per cent weight loss after 180 days at lowest and highest dosage of physical factors

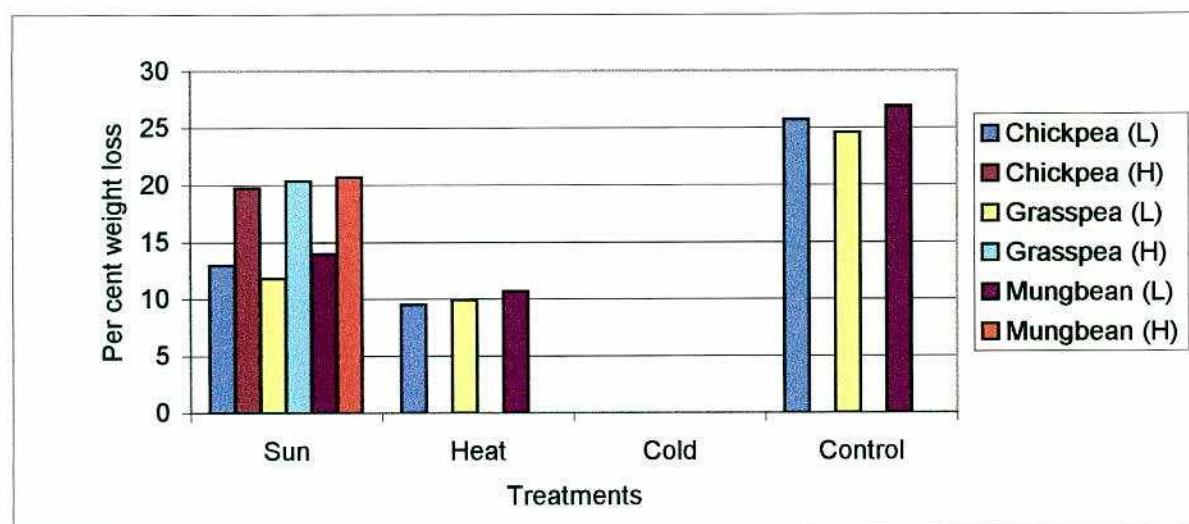


Fig. 35. Per cent weight loss after 270 days at lowest and highest dosage of physical factors

heating for 10 minutes resulted significantly lowest percentages of germination than others, although no infestation of pulse beetle was recorded from this treatment. The estimated percentages of germination in this treatment were 51.25-59.00, 53.75-56.75 and 33.00-37.25 respectively at 90, 180 and 270 DAS. In the remaining treatments, the recorded germination ranged from 89.50-94.50%, 60.25-92.75% and 55.50-86.00% respectively at 90, 180 and 270 DAS.

4.6.7. Moisture content: The initial moisture contents were 9.8%, 10.1%, and 9.9% respectively for chickpea, grasspea and mungbean. In table 33 the per cent moisture level of treated and untreated seeds of chickpea, grasspea and mungbean stored for nine months period have been shown. Statistically, moisture level between treatments varied significantly for all pulses in all sampling occasions except for chickpea at 90 DAS. Untreated control always revealed highest percentages of moisture content which was likely to be an important factor of obtaining higher infestation and weight loss. Per cent moisture content in untreated seeds ranged from 13.25-14.00, 15.00-15.50 and 18.75-19.25 respectively at 90, 180 and 270 DAS. For treated seeds, no significant increase in moisture content was observed over the storage period except heating for 10 minutes where per cent moisture content ranged from 12.25-12.75, 14.25-16.25 and 18.75-19.25 respectively at 90, 180 and 270 DAS.

Table 32. Effect of different physical factors on the per cent germination of chickpea, grasspea and mungbean stored for nine months

Treatments	Time inter-val	% germination after								
		90 days			180 days			270 days		
		Chick-pea	Grasspea	Mung-bean	Chick-pea	Grasspea	Mung-bean	Chickpea	Grasspea	Mung-bean
Sunning (days)	30	93.00a (9.65)	93.00ab (9.65)	89.50c (9.46)	90.75a (9.53)	91.25a (9.55)	90.75ab (9.52)	77.75c (9.26)	75.75b (9.21)	76.75c (9.26)
	45	93.00a (9.64)	93.25ab (9.66)	93.75ab (9.68)	80.00a (9.49)	81.25a (9.55)	82.50b (9.46)	71.25c (9.23)	69.75c (9.10)	68.75d (9.10)
	60	92.50a (9.62)	93.50ab (9.67)	93.00a-c (9.65)	60.25b (9.50)	61.00b (9.50)	69.50c (9.46)	55.50d (9.25)	58.75d (9.04)	56.25d (9.13)
	5	93.25a (9.66)	93.25ab (9.66)	91.25a-c (9.58)	89.75a (9.48)	89.00a (9.43)	87.75ab (9.37)	80.00b (9.94)	79.75b (8.93)	78.75c (8.87)
	7.5	92.75a (9.63)	93.25ab (9.65)	93.25a-c (9.65)	89.75a (9.47)	88.50c (9.41)	88.00ab (9.38)	84.75ab (9.21)	80.25ab (8.96)	80.00ab (8.95)
	10	53.25b (8.38)	59.00c (8.54)	51.25d (8.39)	56.75c (7.53)	55.25c (7.43)	53.75d (7.33)	37.25e (6.10)	34.00e (5.83)	33.00f (5.74)
Cold treatments at 5°C (days)	2	93.00a (9.65)	92.25ab (9.61)	94.50a (9.72)	92.75a (9.63)	91.25a (9.55)	90.75ab (9.52)	86.00a (9.27)	82.50ab (9.09)	83.50a (9.14)
	4	93.25a (9.66)	95.25a (9.76)	92.00a-c (9.59)	89.50a (9.46)	90.00a (9.48)	91.25a (9.55)	84.00ab (9.17)	82.00ab (9.06)	83.00a (9.11)
	6	91.50a (9.57)	92.75ab (9.63)	93.00a-c (9.65)	90.50a (9.51)	87.75a (9.37)	88.50ab (9.41)	82.50ab (9.09)	85.00a (9.22)	82.50ab (9.09)
	Control	82.50a (9.51)	83.25b (9.50)	81.25bc (9.50)	65.25b (8.08)	67.25b (8.20)	65.50c (8.10)	51.75d (7.60)	52.00d (7.55)	53.75e (7.66)
	CV %	1.38	1.26	1.37	1.47	1.62	1.18	1.86	1.46	1.62

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

Table 33. Effect of different physical factors on the per cent moisture level in chickpea, grasspea and mungbean stored for nine months

Treat-ments	Time inter-val	% moisture level after								
		90 days			180 days			270 days		
		Chickpea	Grasspea	Mung-bean	Chickpea	Grasspea	Mungbean	Chickpea	Grasspea	Mung-bean
Sunning (days)	30	12.00 (3.46)	12.25c (3.50)	12.50b (3.54)	12.00b (3.46)	12.25b (3.50)	11.75b (3.43)	12.00b (3.46)	12.00c (3.46)	12.00b (3.46)
	45	12.75 (3.57)	12.25c (3.50)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.00b (3.46)	12.00c (3.46)	12.75b (3.57)
	60	12.00 (3.46)	12.75bc (3.57)	12.50b (3.54)	12.75b (3.57)	12.25b (3.50)	12.00b (3.46)	12.00b (3.46)	12.25c (3.50)	12.00b (3.46)
Heat treat-ments at 100°C (minute)	5	12.25 (3.50)	12.75bc (3.57)	12.25b (3.50)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.00c (3.46)	12.00b (3.46)
	7.5	12.00 (3.46)	12.25c (3.50)	12.00b (3.46)	12.00b (3.46)	12.50b (3.54)	12.25b (3.50)	12.00b (3.46)	12.00c (3.46)	11.75b (3.43)
	10	12.75 (3.57)	12.25c (3.50)	12.25b (3.50)	15.25a (3.90)	14.25a (3.90)	16.25a (3.90)	17.50a (4.18)	17.25b (4.15)	18.00a (4.24)
Cold treat-ments at 5°C (days)	2	12.25 (3.50)	12.25c (3.50)	12.50b (3.54)	12.00b (3.46)	12.25b (3.50)	12.00b (3.46)	12.00b (3.46)	12.00c (3.46)	11.50b (3.39)
	4	12.00 (3.46)	12.75bc (3.57)	12.25b (3.50)	12.25b (3.50)	12.00b (3.46)	12.00b (3.46)	12.25b (3.50)	12.00c (3.46)	12.50b (3.53)
	6	12.00 (3.46)	12.50bc (3.54)	12.00b (3.46)	12.00b (3.46)	12.00b (3.46)	12.50b (3.54)	12.00b (3.46)	12.00c (3.46)	12.25b (3.50)
Control		13.25 (3.64)	13.75a (3.71)	14.00a (3.74)	15.00a (3.87)	15.50a (3.94)	15.25a (3.90)	18.75a (4.33)	19.25a (4.39)	19.25a (4.39)
CV %		3.49	3.18	2.93	3.26	2.86	2.96	3.16	3.13	3.25

- All figures are means of four replications
- Means in a column having same letters are not significantly different at the 5% level of DMRT
- Figures in the parenthesis are square root transformed values

CHAPTER 5

DISCUSSION

Pulse production in Bangladesh is far below the national requirement. This shortage is further intensified because of post harvest losses due to the attack of pulse beetle in storage. It has been estimated that more than 90% of stored pulses could be damaged by the pulse beetle within 6-8 months of storage (Mookherjee et al. 1970), if left unprotected. Traditionally, pulse growers in Bangladesh store pulses in locally available containers like gunny bag, earthen motka, tin, drum, bamboo-made dole etc. These containers cannot provide satisfactory protection of stored pulses because of their structural limitations unless they are taken out and sun dried several times during the storage period.

Use of chemical insecticides for the protection of stored pulses is generally practiced by commercial traders and those who store pulses to be used as seed. Because of risk factors (health hazard, environmental pollution, development of resistance etc.) of using chemical insecticides, storing pulses in suitable containers treated with hazard free low-cost non-chemical materials could be considered as the best approach. In the present

considered as the best approach. In the present investigation, efforts have been made to evaluate such an approach.

In the present study, 3 containers (Tin, motka and gunnybag) were evaluated. Among the tested containers tin provided the highest protection for all kind of pulses and DAS (Days after storing) against pulse beetle considering both intensity of infestation and weight loss. Similar observation was also made by Gonesh (1989), Sharma et al.(1986) and Chaudhury, Bhuiyah, Miaruddin, Karim and Amiruzzaman (1991).

Obtaining better protection from tin container than motka and gunnybag was likely because pulse beetle had higher opportunities of penetration against gunny bag and seeds stored in motka adsorbed higher moisture than tin.

Results of 90, 180 and 270 DAS revealed that within 3 months of storage the pulse beetle infestation and weight loss rose to 5.80 - 21.10% and 2.05-6.02% respectively. These further increased to 23.10-53.75% and 6.94-18.01% at 180 DAS. At 270 DAS, these values intensified to 44.60-78.78% and 21.50-38.18%. Significant increase of infestation and weight loss over the storage period might be due to proportional increase of moisture content than

period was also found to affect germination and quality of seeds. In contrast, Casewell (1973) estimated 50-60% insect damage after 6 months of traditional storage.

With a view to selecting environmentally friendly oil(s) that could be exploited as protectant against pulse beetle, direct toxicity of mustard, coconut, soybean and neem oils along with decis was determined under laboratory condition. Results revealed that except soybean oil all other oils were toxic to pulse beetle. Decis was 2.87 times more toxic to pulse beetle than neem considering both LC_{50} and LC_{90} values. Lack of available literature on direct toxicity of oils limits the present results to be discussed and compared. However, many investigators tested vegetable and neem oils as protectant of stored pulses (Ketkar, 1976; Schoonhoven, 1978; Cruz and Gardona, 1981; Sujatha and Punnaiah, 1985; Khaire et al. 1987).

Obtaining some toxic effects of neem and some vegetable oils indicates that these oils can be used along with metallic container for complete protection of stored pulses from the attack of pulse beetle.

Following the determination of the direct toxicity of different oils, their efficacy as protectant of stored pulses was also evaluated using 3 dosage (4, 7 and 10 ml/kg)

of each oil. In this investigation data on different parameters like rate of oviposition, hatchability, adult emergence, intensity of infestation, weight loss of grain, germination and moisture content were taken and thus the present discussion were made on those results.

Of the three dosage of oils, 10 ml of mustard and 7 & 10 ml/kg of neem provided satisfactory protection of stored pulses up to 270 DAS as decis (Tables 9 and 10). In these treatments, the pulse beetle failed to survive and lay eggs, thereby, there was no oviposition, hatching of eggs, and adult emergence (Tables 6, 7 & 8). In other treatments, significantly lower number of eggs were found compared to untreated control. Among these treatments, the higher dosage (7 and 10 ml/kg) of mustard, coconut and soybean oils displayed some ovicidal action (Table 7). Similar ovicidal action was also reported by Cotton (1963) and Pereira (1983), who worked with neem, plam and groundnut oils.

Data of table 8 indicated that all of the tested oils particularly in higher dosage revealed larvicidal action which resulted in reduced percentages of adult emergence. Inhibition of egg laying and adult emergence from oil-treated seeds were also reported by many workers (e.g.; Qi

and Burkholder, 1981; Babu et al. 1989; Das, 1987; Yadav, 1985; Taylor and Vickery, 1974; Varma and Pandey, 1978)

Ali et al. (1983) used neem, rape, coconut, mustard, mahua and palm oil @ 1 ml/100 gram and reported that those were effective against all stages of pulse beetle reared on greengram. On the other hand, Frank and Renwick (1983) used peanut, sunflower, coconut and mineral oil @ 5 ml/kg of seed and found complete control of *C. maculatus* on cowpea for over 75 DAS. Oil-treated seeds even with lower dosage provided significantly lower infestation and weight loss than the untreated seeds. At 90 DAS, 2.00-16.26% infestation were found which increased to 4.10-30.47% at 180 DAS and further intensified to 6.40-48.47% at 270 DAS. Weight loss was 0.88-8.35%, 1.02-8.35% and 1.01-9.93% for chickpea, grasspea and mungbean respectively at 90 DAS which further increased to 2.21-15.42%, 2.11-14.27% and 2.26-16.89% at 180 DAS and at 270 DAS which increased to 3.16-24.21%, 3.19-23.11% and 4.62-24.42% for chickpea, grasspea and mungbean respectively. These results reflected the observations of direct toxicity test and led to assume that oil could be used as protectant of stored pulses.

Similar to the present results, use of neem oil was found effective as protectant of stored pulses against pulse beetle by many workers world wide (Ketkar, 1976; Ali

et al. 1983; Das, 1987; Yadav, 1985; Khaire et al. 1992). The use of mustard (Mummigatti and Ragunathan, 1977; Singh et al. 1978; Varma and Pandey, 1978; Begum and Quiniones, 1990) and coconut oils (Mummigati and Ragunathan, 1977; Schoonhoven, 1978; Frank and Renwick, 1983; Varma and Pandey, 1978; Begum and Quiniones, 1990) was also found to be effective against pulse beetle. Besides neem, mustard and coconut oils, many other oils (Palm, groundnut, castor, sesame, maize, soybean, corn, peanut, sunflower, karanja, lemon, honge, oils of acorus, garlic, oil of *Progestemon heyneanus*) are reported to be effective against stored grain pests (Cotton, 1963; Singh et al. 1978; Mummigatti and Ragunathan, 1977; Schoonhoven, 1978; Taylor and Evans, 1980; Cruz and Gardona, 1981; Su, 1976; Pereira, 1983; Agarwal et al. 1973; Deshpande et al. 1974).

In case of containers, grasspea revealed higher tolerance followed by chickpea and mungbean. In contrast when pulses were stored after treating with oils, chickpea exhibited higher tolerance against pulse beetle followed by grasspea and mungbean. These results could not be compared and discussed in details due to the non-availability of pertinent literature. However, exhibiting higher tolerance of oils treated chickpea seeds than grasspea and mungbean could be explained in such a way that the rougher the surface the higher the adherence of oils thereby producing

higher tolerance. Rahman (1985) conducted a study with chickpea and lentil mixed with deltamethrin dust and reported that chickpea seed surface adhered more amount of dust than lentil and thus displayed higher toxicity or tolerance. Similarly, Weaving (1970) evaluated the toxicity of pyrethrins and pyrethrins synergised with piperonyl butoxide and reported that wheat adhered more dust than pea, thereby resulting higher tolerance.

Like oils, the efficacy of different ashes as protectant of stored pulses from the attack of pulse beetle was also evaluated under laboratory condition. Three dosage (2, 4, and 6% W/W) of all ashes (Eucalyptus wood, coal, paddy husk, cowdung and charcoal) were evaluated. Among the tested ashes eucalyptus wood ash provided better protection than others. The performance of other ashes was in the order of cowdung ash > paddy husk ash > coal ash > charcoal ash. Although ashes were not as effective as oils for the protection of stored pulses (Chickpea, grasspea and mungbean) but the recorded percentages of infestation and weight loss led to assume that the ashes could offer an acceptable level of protection up to 90 days only.

Pulse beetle laid significantly higher number of eggs on untreated seeds than ash treated seeds (Table 13). Number of eggs laid on untreated seeds varied from 54.50 -

89.50 per 100 grains while these were 4.50 - 41.50 for ash treated seeds. Similar to oils all of the tested ashes displayed some ovicidal and larvicidal action. Compared to 19.86-65.10% egg hatch and 23.85-61.36% adult emergence obtained from untreated seeds, 1.03-55.60% egg hatch and 4.13-42.45% adult emergence were observed from ash treated seeds.

The percentages of infestation from ash treated pulses ranged from 0.49-5.46, 10.01-23.56 and 30.53-44.69 respectively at 90, 180 and 270 DAS while weight loss ranged from 0.16-1.99, 6.30-12.86 and 15.51-24.47 respectively at 90, 180 and 270 DAS.

The present results could not suitably be compared due to the non-availability of relevant literature. However, Krishnamurti and Rao (1950) used wood ash, paddy husk ash and coal ash and found them effective against pulse beetle. Khare (1972), Khare and Agarwal (1972) tested 1.5% cowdung ash mixed with wheat which gave 80% mortality of *S. oryzae* after 3 weeks of storage while Majumder et al. (1959) reported that activated charcoal and clay provided an acceptable level of protection of storage cereals against *T. castaneum*. Mueke and Apuule (1987) reported that ash mixed with cowpea seeds afforded satisfactory control against the bruchid and they also found that ash levels of

20 and 30% led to 8.96 and 6.18% damage respectively, as compared with 52.59% for no treatment. In another study, Darling (1947) found that eucalyptus wood ash was effective against stored maize at least for 3 months. Wood ash was less effective than coal or paddy husk ash, both of which were extremely effective in controlling *S. oryzae* in paddy (Takei and Miyajami, 1941).

Besides oils and ashes, the efficacy of naphthalene was also evaluated as protectant of store pulses against pulse beetle. Three dosage (2, 3 and 4 balls/kg of seed) of naphthalene with three different exposure period (7, 15 and 21 days) were tested in the present study. The treatment of 3 and 4 balls per kg seed offered complete protection of chickpea, grasspea and mungbean up to 270 DAS considering both intensity of infestation and weight loss (Tables 23 and 24). Although the treatment of 2 balls/kg seeds was not as effective as 3 and 4 balls/kg but this treatment significantly reduced the oviposition, hatchability and adult emergence of pulse beetle compared to untreated control (Tables 20, 21 & 22). The treatment of 2 balls/kg seed gave 2.47-12.33%, 4.97-20.28% and 6.42-28.05% infestation respectively for 21, 15 and 7 days exposure period. The weight loss in this treatment ranged from 1.32-6.81%, 2.65-11.44% and 3.08-14.91% respectively for 21, 15 and 7 days exposure periods. These results were comparable

with those reported by Islam and Karim (1995). They found that 4 naphthalene balls/kg of chickpea seeds exposed for 10-15 days provided the complete protection for 8 months against pulse beetle. In another study, Islam et al. (1991) used naphthalene ball against corn weevil, *S. zeamais* and reported that 2, 4 and 6 balls/10 maize cobs protected up to 8 months of storage.

Naphthalene is almost non toxic and is being used mostly for fumigation of house to repel irritating insects. Toxicity of naphthalene was first reported by Lehman (1930) against confused flour beetle and then Herrick and Griswold (1933) and George (1980) against webbing cloth moths. Since then very little research had been done with naphthalene. The results of the present study, however, clearly demonstrated that naphthalene could be used as a good alternative for the management of stored pulses against pulse beetle.

In addition to oils, ashes and naphthalene, the effect of some physical factors (sunning, heat and cold treatments) in protecting stored chickpea, grasspea and mungbean from the attack of pulse beetle was evaluated and documented under laboratory condition. Cooling of seeds for 2, 4 and 6 days at 5°C and heating for 10 minutes in boiling water offered complete protection up to 270 DAS.

Cooling did not decline quality of seeds as the germination of the tested seeds were more than 90%, 85% and 80% respectively at 90, 180 and 270 DAS. On the other hand, though heating for 10 minutes provided complete protection against pulse beetle but this treatment hampered the germination of stored pulses. The recorded percentages of germination in this treatment were less than 60, 57 and 40 respectively at 90, 180 and 270 DAS.. Although heating for 5 and 7.5 minutes in boiling water did not perform as good as 10 minutes in terms of oviposition, hatchability, adult emergence, infestation and weight loss, but these treatments (5 and 7.5 minutes) did not reduce the germination of stored pulses. Compared to untreated control, heating for 5 and 7.5 minutes provided significant obstruction for egg laying, egg hatching and adult emergence (Tables 27, 28 & 29). In these treatments, 4.43-7.95%, 7.10-13.53% and 12.48-19.15% infested seeds and 2.63-4.76%, 4.08-6.63% and 6.17-10.64% weight loss were recorded, respectively at 90, 180 and 270 DAS compared to 18.08-19.70%, 33.63-34.55% and 46.48-49.40% infested seeds and 10.20-11.92%, 17.21-18.08% and 24.56-26.94% weight loss of untreated seeds.

Sunning at an interval of 30, 45 and 60 days was found to be ineffective since 27.50-59.50, 41.75-71.00 and 56.25-84.75 eggs/100 seeds; 19.96-30.65%, 29.82-41.70% and 36.75-

47.84% egg hatch; 15.00-18.18%, 18.78-24.35% and 25.96-35.22% adult emergence; 6.18-14.88%, 13.48-29.70% and 21.42-40.85% infested and 3.58-8.47%, 7.79-15.55% and 11.77-20.68% weight loss of stored pulses were recorded, respectively at 90, 180 and 270 DAS. Lack of available literature limit the present results to be discussed and elaborated. However, Begum et al.(1991) found that sunning could inhibit the rate of pulse beetle multiplication and thus reduced infestation and weight loss of stored chickpea while Claflin et al.(1984) reported that heating at 60°C could kill all stages of *C. chinensis*. Mookherjee and Chawla (1984) found 40°C as lethal to *C. maculatus*. Stoyanova (1984) and Smith (1984) found cold treatment (5°C) to be effective against stored product pests. It was assumed from the present discussion that physical factor like cooling could alternatively be used for the protection of stored pulses.

For conducting experiments with containers, oils, ashes, naphthalene and physical factors, three different pulses (Chickpea, grasspea and mungbean) were always used. The difference of the tested pulses in resisting pulse beetle infestation was noticeable at early stage of storage but as the time progressed the difference between pulses become insignificant. This was observed only from the

experiments conducted with containers and oils. In other cases the difference between pulses could not be ascertained.

In view of developing a complementary approach for the management of pulse beetle attacking pulses (Chickpea, grasspea and mungbean), several control components (containers, oils, ashes, naphthalene and physical factors) were chosen, assessed, evaluated and documented their effectiveness in the present investigation. From the foregoing discussion it appeared that containers like tin, motka and gunnybag could only provide acceptable level of protection against pulse beetle up to three months of storage but for longer storage they were not at all suitable. This meant, pulse seeds must be protected from the attack of pulse beetle either using insecticides or other protectants. Since insecticide usage is discouraged then the use of environmentally safer protectant would be obligatory. Of several protectants (oil, ash, naphthalene and physical factors) any one of them could be used depending on the need, choice and availability to the users. For poor or small scale farmers ashes could be the better option as ashes are easily available, low or no-cost for preparation and easy to apply. Since the effective dosage of ashes is 4-6% w/w, the storage of large quantity pulse seeds using ashes could be difficult. In this case,

in other words, for large farmers or traders, the use of naphthalene would be advantageous. Although the cost of naphthalene application has not been assessed in the present study, it is assumed that naphthalene application would be much cheaper than the application of insecticides and oils. The use of oils as seed protectant is estimated to be expensive than others. In economical and practical point of view, oils can only be used for small quantity and valuable seeds. Application of physical factors (cooling and heating) for the protection of stored pulses depends on the availability of physical facilities of cooling or heating. Rich farmers and commercial traders can successfully exploit this component for the protection of stored pulses. The present finding, indeed, widened the scope of options for storing and protecting chickpea, grasspea and mungbean seeds from the attack of pulse beetle.

CHAPTER 6

SUMMARY AND CONCLUSION

The present study was undertaken to evaluate and search the best option of storing pulses in locally available hazard free low-cost non chemical materials that can protect the stored pulses from the attack of pulse beetle, *Callosobruchus chinensis*.

Three containers namely, tin, motka and gunnybag were evaluated for storing pulses (i.e; chickpea, grasspea and mungbean) up to 9 months. Among the tested containers tin provided maximum protection against pulse beetle for all kinds of pulses than motka and gunnybag. For longer storage (>3 months), none of the containers was found effective as the intensity of pulse beetle infestation rose to 23.10 - 53.75% at 180 DAS and 44.60 - 78.78% at 270 DAS from 5.80 - 21.10% of 90 DAS.

The toxicity of mustard, coconut, soybean and neem oils along with decis was determined under laboratory conditions with a view to selecting effective protectant of pulses against pulse beetle. The oils were found to be toxic to pulse beetle except soybean. Among oils neem was

more toxic followed by mustard and coconut. Considering both LC_{50} & LC_{90} values, neem was 1.32 times less toxic than decis.

The efficacy of different oils as protectant of stored pulses was also determined using 3 dosage (4, 7 and 10ml/kg) of each oil. Of these three dosage, 10ml/kg of mustard and 7 and 10ml/kg of neem oil provided complete protection of the pulses against pulse beetle up to 270 DAS as decis. In these treatments, the pulse beetle failed to survive and lay eggs. Although, coconut and soybean oil were not effective as neem and mustard, at higher dosage they displayed some ovicidal action. Oil treated seeds even with lower dosage provided significantly lower intensity of infestation and weight loss than the untreated seeds. While storing different pulses in tin, motka and gunnybag, grasspea revealed higher tolerance than chickpea and mungbean, but when these pulses were stored after treating with oils, chickpea exhibited higher tolerance than grasspea and mungbean.

Similar to oils, three dosage (2, 4 and 6 % w/w) of different ashes (eucalyptus wood ash, coal ash, paddy husk ash, cowdung ash and charcoal ash) were evaluated as protectant of stored pulses against pulse beetle. Among the tested ashes, eucalyptus wood ash provided better

protection in terms of intensity of infestation and weight loss than others. The performance of other ashes was in the order of paddy husk ash > cowdung ash > coal ash > charcoal ash. Although ashes were not as effective as oils in protecting stored pulses, they provided an acceptable level of protection at higher dose (6% w/w). Even at lower dosage (2 & 4% w/w) pulse beetle laid significantly less eggs than untreated seeds. In addition to adult repellency all types of ashes also displayed some ovicidal and larvicidal action. Besides oils and ashes, three dosage of naphthalene (2, 3 and 4 balls/kg) with three different exposure periods (7, 15 and 21 days) were tested against the pulse beetle. The treatment of 3 and 4 balls per kg seed provided complete protection of chickpea, grasspea and mungbean up to 270 DAS considering both intensity of infestation and weight loss. Although the treatment of 2 balls/kg seed was not as effective as 3 and 4 balls/kg but this treatment significantly reduced oviposition, hatchability and adult emergence of pulse beetle compared to control. The treatment of 2 balls/kg seeds gave 2.47-13.33%, 4.92-20.28% and 4.92-26.95% infestation and 1.32-6.47%, 2.65-11.44% and 3.08-14.91% weight loss respectively for 21, 15 and 7 days exposure period compared to 16.31-50.78% infestation and 8.79-26.46% weight loss for untreated control.

The effect of several physical factors like sunning, heating and cooling in protecting stored pulses was also documented under laboratory condition. Cooling of chickpea, grasspea and mungbean seeds for 2, 4 and 6 days at 5°C and heating for 10 minutes in boiling water provided complete protection of stored pulses up to 270 DAS. Although heating of seeds for 10 minutes offered complete protection against pulse beetle, germination of seeds hampered in this treatment. The recorded per cent germination were 60, 57 and 40 respectively at 90, 180 and 270 DAS. On the other hand, cooling did not reduce the quality of seeds as the germination of tested seeds were more than 90, 85 and 80%, respectively at 90, 180 and 270 DAS.

Heating of seeds for 5 and 7.5 minutes were not as effective as that of 10 minutes but these treatments did not affect the germination of stored pulses. Sunning at an interval of 30, 45 and 60 days of storage were not found effective for the protection of stored pulses against pulse beetle. Sunning provided 6.18-14.88, 13.48-29.70 and 21.82-40.85% infestation and 3.58-8.47, 7.79-15.55 and 11.77-20.68% weight loss, respectively at 90, 180 and 270 DAS compared to 18.08-19.88, 33.63-34.55 and 48.10-49.40% infestation and 10.20-11.92, 17.21-18.08 and 24.56-26.94% weight loss recorded from untreated control respectively at 90, 180 and 270 DAS.

In view of evaluating a complementary approach for the management of pulse beetle, several control components like containers, oils, ashes, naphthalene and some physical factors were chosen, assessed and documented their effectiveness. Hence, from the present study, the following conclusions were suggested:

- 1) The locally available containers like tin, motka and gunnybag can only protect the stored pulses up to 3 months from the attack of pulse beetle.
- 2) For longer storage, pulse seeds must be protected from the attack of pulse beetle either using insecticides or other protectants.
- 3) Oil, ash, naphthalene and physical factors can be used depending on the need, choice and availability to the users.
- 4) Naphthalene may be used for protecting storage pulses as they are easily available, cheaper and easy to apply.
- 5) Ashes could be used only for short time storage.
- 6) The use of oils as grain protectants was found to be expensive than others, so oils can be used for valuable seeds; and
- 7) If facilities are available, cooling method can also be exploited for the protection of storage pulses from the attack of pulse beetle.

CHAPTER 7

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