BIOLOGY OF DRIED FRUIT BEETLE, *CARPOPHILUS HEMIPTERUS* (L) AND ITS DAMAGE ASSESSMENT ON DIFFERENT DRIED FRUITS IN STORAGE

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CERTIFICATE

This is to certify that the thesis entitled **'Biology of dried fruit beetle, *Carpophilus hemipterus* (L) and its damage assessment on different dried fruits in storage'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Entomology** embodies the result of a piece of bona fide research work carried out by **Mst. Rezennahar Kumkum**, Registration number: **11-04566** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017

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LISTS OF ABBREVIATIONS

Full word	Abbreviation
and others	*et al.*
Co-efficient of Variation	CV
Completely Randomized Design	CRD
Gram	g
Id est	i.e.,
Journal	*j*.
Least significant difference	LSD
Videlicet	Viz.,
Days after adult released	DAAR

BIOLOGY OF DRIED FRUIT BEETLE, *CARPOPHILUS HEMIPTERUS* (L) AND ITS DAMAGE ASSESSMENT ON DIFFERENT DRIED FRUITS IN STORAGE

ABSTRACT

Two experiments were conducted to study the biology of dried fruit beetle; *Carpophilus hemipterus* (F.) and its damage assessment on different dried fruits in the laboratory of the department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 during August, 2016 to January, 2017. Experiments were laid out in a Completely Randomized Design (CRD). In the study of biology, it was revealed that the adult female laid an average of 52.75±9.26 eggs. The adult insect completed it life cycle by 16-21 days and the incubation period, larval period, pupal period and adult longevity of dried fruit beetle were 2.60 ± 1.21, 8.20 ± 1.06, 3.40 ± 1.32 and 153.60 ± 25.32 days respectively, at 23-30^0c temperatures and 68-87% humidity. Morphometric measurement of different life stages of the beetle was also recorded. In the second experiment almond, cashew nut, ground nut and dried dates were used as experimental materials. The experiment concerning damage assessment of the dried fruits such as cashew nut, almond, ground nut and dried dates by dried fruit beetle, indicated that the adult longevity, larval and pupal duration and number of adult emergence of dried fruit beetle were varied in different dried fruits. The highest percent of infestation 61.83% and 87.13% was recorded in cashew nut 30 and 60 days after adult released respectively, whereas the lowest percent of infestation 25.25% and 52.94% was recorded in dried dates 30 and 60 days after adult released respectively. But 100% infestation was occurred in all types of dried fruits due to dried fruit beetle at the 90 days after adult released. The highest weight loss 11.00% was observed in cashew nut, whereas the lowest weight loss 1.50% was observed in dried dates 30 days after adult released and more or less similar percent of weight loss also was recorded at 60 and 90 days after adult released respectively. Weight loss of different dried fruits was increased due to increase of percent of infestation at different days during the study period.

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CHAPTER I

INTRODUCTION

Insects infesting stored foods are one of the most common problem now a day in Bangladesh. The pests are now predominant because of huge amount of importation of dry fruits and nuts; as a result, damage percentage also high in markets and home in stored condition. The pests contaminate more food than they consume, and most people find the contaminated products unfit for consumption. Many insects attack dry fruits and nuts in storage condition and the pests are usually not noticed until they become abundant. Insects found in dry fruits and nuts are often referred to as beetles, moths, weevil etc. Beetles and moths have four stages in their development egg, larva, pupa and adult. All stages may be present in the food, but the eggs are so tiny they are seldom seen. The larval stage is most destructive, but the adult stage is most often seen. If infestations are prolonged, foods may be seriously damaged and may need to be discarded. Many people will discard food products that are even lightly infested by insects. These insects typically pose little health hazard, although some species (notably carpet beetles) can produce irritation or allergic reactions. Indian meal moth, flour beetles, saw-toothed grain beetles and dried fruit beetle, *Carpophilus hemipterus* are particularly common in markets and homes and are found throughout the world (Rado *et al.,* 1970). More often, insects enter homes on food already infested during storage or transportation period.

Dried fruit beetle, *C. hemipterus*, is a cosmopolitan pest of fresh and dried fruit, as well as many fresh and stored grains, spices, drugs, and seeds (Hinton, 1945). These beetles of the family Nitidulidae under the order Coleoptera are among the major pests of ripening and drying fruits. During the past decade, nitidulid beetles in the genus *Carpophilus* have become serious pests of ripening stone fruit in southern Australia (James *et al.,* 1997). Populations of *Carpophilus spp.* in stone-fruit orchards were previously suppressed by frequent applications of broad-spectrum insecticides for key pests such as the oriental fruit moth, *Cydia molesta* (Busck) and the two spotted spider mite, *Tetranychus urticae* Koch (Hely *et al*., 1982). Adults feed and larvae develop in a moist, dark environment of yeasty and often moldy pulp. These beetles also carry yeasts and mold spores in and on their bodies and inoculate ripening fruits with plant diseases (Miller *et al*., 1954 and Lussenhop *et al*., 1990). This species may also be destructive to dried fruits and cereals in storage (Essig, 1942). The majority of damage, these pests do, is through contamination. The weight of dry fruits and nuts may be reduced, but total weight may increase because of water absorption caused by the metabolic processes of insect populations. Molds may begin to grow on the gain, further reducing grain quality and value (El-Sohaimy *et al*., 2010). Heavily infested fruits and nuts spread bad smells and become less attractive and unfit for consumption.

So, it is important to study biology of the insect pest and calculate their damage percentage that are imported in our country to take proper measures of control as well as to reduce the economic loss.

OBJECTIVES OF THE STUDY

- To study the biology of insect pest of dried fruit beetle, *Carpophilus hemipterus* in dried fruits and
- To determine the extent of damage due to infestation of dry fruits and nuts by *C. hemipterus.*

CHAPTER II

REVIEW OF LITERATURE

Dried fruits and nuts may help to improve our health and to prevent some diseases when included regularly in eating habits. It's can be consumed as a snack, on top of cereal, in yogurt, salads and pasta, and can provide us with some important health benefits. Nuts not only offer nutritional benefits but may help to control body weight. This is especially important as obesity rates continue to rise across developed nations. Research suggests that dried fruit consumption is also good for people who have diabetes. A study by Louisville Metabolic and Atherosclerotic Research Center observed that consuming raisins as an alternative to processed snacks resulted in a significant 23% reduction in postprandial glucose levels. Dried fruits are well-known sources of dietary fiber, which has a direct effect on gastrointestinal function. Insect pests cause heavy seed losses in storage, particularly in tropical and sub-tropical countries (Aitken, 1975).

The efficient control and removal of stored pests from food commodities have long been the goals of entomologists throughout the worlds because insect infestation is the most serious problem of stored products. Losses due to insect infestation are the most serious problem of seeds in storage, particularly, in developing countries like Bangladesh. A search in the literature revealed that the biology of Saw-toothed grain beetle most varied with environmental conditions, seasons and types of dry fruit and nuts. Information of the biology of dried fruit beetle on different dry fruit and nuts is not available in Bangladesh perspective.

2.1 Origin and distribution of dried fruit beetle

This beetle is distributed world-wide but found in abundance in mountainous areas, where climate is rather warm and humid. *Carpophilus hemipterus* has been reported from India, Pakistan, Sri Lanka, Turkey, Poland, Brazil, Britain, Mediterranean region, East Africa, Argentina, Bulgaria, Switzerland, West Kenya, Indonesia, USA, Canada, Israel, Russia, Australia and Japan, China, Bangladesh, Hawaii, Phillipines, German, and Saudi Arabia and is found in almost any stored food of nuts, dry fruits, flour, maida, biscuits, raising, dried fruits and other grain products. It is cosmopolitan in distribution. This pest was described in 1767 from Surinam, hence named as *C. hemipterus*. The dried fruit beetle is distributed throughout the world and frequently transported in grain product.

The dried Fruit beetle is found world wide; especially any where that fruit in any form is grown or stored. The dried fruit beetle has become an extreme nuisance and serious pest particularly in plants or farms where fruit is grown, processed, stored, or consumed. These beetles may be found in leaf litter, rotten fruit, flowers, or trees. They are also commonly found foraging indoors for food.

The Dried fruit beetle eats not just dried fruit, but also all types of fresh, packaged, or rotting fruit. It also feeds on scale insects, beans, wheat, rice, honey, and spices. Wherever stored food products are found, so is the Dried fruit beetle. The beetles will attack ripe and dry fruit prior to packaging. (mailto:info@ pestnet.com).

The dried fruit beetle is cosmopolitan, widespread in warm-temperate to tropical regions. In temperate regions the beetle is found in sheltered or heated environments. (https://www.daf.qld.gov.au/flower-or-dried-fruit-beetle).

At least 12 species of *Carpophilus* beetle occur in Australia with *C. davidsoni*, *C. hemipterus* and *C. mutilates* causing the greatest economic damage in ripening stone fruit. *C. davidsoni* is native to Australia whereas the other two species are cosmopolitan. It's worth high lighting *C. davidsoni* is the common species caught in Australian stone fruit orchards and is often first on the scene preferring fruit that is in its early stages of ripening. *C. hemipterus* normally arrives on the scene once the fruit begins to rot and drops to the ground. Understanding the population dynamics in Australian almond orchards would go a long way season in both almonds and stone fruit.

2.2 Host suitability and moisture requirements of dried fruit

C. hemipterus is a well-known insect pest of stored tobacco (Cotton, 1989) and dried processed plant material. Substrates that have been reported as breeding materials or food for *C. hemipterus* include tobacco seed, dried figs, dried roots of various kinds, pressed yeast, dried dates, starch, bran, belladonna, dried fish, pyrethrum powder, dried cotton, cotton seed, dog food, almonds, furniture stuffing, and bookbinders' paste (Runner, 1919; Singh *et al*., 1977; Yokoyama and Mackey, 1987). It has also been recorded in a very large number of processed products from ground grain, pulses and beans, spices, dried fruit and vegetables and yeast.

Howe (1957) in his extensive study on the biology and literature survey of *C. hemipterus* recorded a list of hosts including bamboo, beans, biscuits, cassava, chickpea, cocoa, coffee beans, copra, coriander, cotton seed both before and after harvesting, cotton seed meal, atta, cumin, dates, dried banana, dried cabbage, dried carrot, drugs, flaxtow, flour, ginger, grain groundnut, herbs, herbaceous specimens, insecticides containing pyrethrum, juniper seed, liquor rice root, nut meg, raisins, rhubarb, rice, seeds of bauhinia, yeast, tobacco, dried fish, fish meal, meat meal, leather and stored wax of cocos and caronda were infested with this beetle. Padmavathamma and Rao (1989) recorded the stored spice of *Carum copticum* as a new host of *C. hemipterus* in Andhra Pradesh, India causing severe damage.

Various factors determine whether an insect pest can establish or increase population in postharvest conditions. Nutritional requirements are an obvious factor. Survival and development time can also be affected profoundly by the state or maturity of the host, and by the type of host, as demonstrated in studies of the Indian meal moth (Johnson *et al.*, 1995), the carob moth (Nay and Perring, 2008), and the navel orange worm (Siegel *et al.*, 2010). Moisture requirements are another important variable. The almond moth has greater moisture requirements than the Indian meal moth at similar temperatures (Burges and Haskins, 1965; Arbogast, 2007a), and also benefits more from access to water as adults (Hagstrum and Tomblin, 1975).

Storage of large amounts of a commodity can provide a heterogeneous environment (e.g. more fines, broken product, or pockets of fungal infection) that may allow the presence of a pest that cannot develop on small samples of the same commodity under laboratory conditions. This observation has been dubbed the host paradox (Arbogast *et al.*, 2005). Indian meal moth, for example, does poorly in the laboratory on dried fruits such as raisins or prunes when compared to almonds, walnuts or pistachios (Johnson *et al.*, 1995, 2002), and yet it is still of greatest concern for dried fruit processors. Another situation occurs when certain processing activities, such as partial rehydration of dried fruit during packing attracts oviposition by field pests such as the dried fruit beetle or raisin moth, resulting in returns of shipments for these pests even though they normally cannot maintain a population on these commodities at that point in the marketing chain.

2.3 Seasonal abundance of dried fruit beetle *C. hemipterus*

C. hemipterus life stages consist of the egg, larva, pupa and adult. Adults of *C. hemipterus* could usually be found in the field on or about fruits as mentioned. The natural abundance of such fruits sustained the beetle populations throughout the year. However, the developmental duration varied with temperature. In rearing cabinets at 30°C, development lasted as follows: egg 2 days, larva 5-7 days, pupa 7 days (Jones, 1985).

The adult beetles lay their eggs on damaged, often fermenting parts of the host material, where their larvae developed at the expense of the fermenting tissues. Larvae remained on the surface of the food material and did not penetrate into liquid parts, probably being unable to breathe therein. Once the larvae matured, they dropped onto the drier ground under the food and pupated there. The emerging adults, being attracted to decaying material, ovipositor at the same site in which they had developed, providing the host material was still suitable.

The use of host-derived volatiles to locate suitable hosts is important in many insects, including the Coleoptera (Metcalf, 1987). Aggregation pheromones also are produced by many Coleoptera (Jones, 1985). Host-derived volatiles and aggregation pheromones also can interact to produce synergized attraction of bark beetles (Jones, 1985). An increasing number of studies (Walgenbach *et al.*, 1987; Burkholder, 1988; Oehlschlager *et al.*, 1988) also have demon started that stored-product beetle attraction is synergistically enhanced by combining aggregation pheromones and host volatiles. However, synergized attraction of insects by combinations of host volatiles and pheromones is just beginning to be appreciated as a widespread phenomenon.

The dried fruit beetle, *C. hemipterus,* is a cosmopolitan pest of fresh and dried fruit, as well as many fresh and stored grains, spices, drugs and seeds (Hinton, 1945). Past information indicates these insects also are attracted by host odors (especially fermenting ones) or isolated volatiles (Smilanick *et al.*, 1978; Blackmer and Phelan, 1988). For example, a 1: 1: 1 combination of ethanol-acetaldehyde-ethyl acetate was a highly effective e-combination for attracting *C. hemipterus* (Smilanick *et al.*, 1978).

Fermented baits have been used successfully to reduce populations of this insect when the insects collected by the traps were not immediately killed (Warner, 1960, 1961).

However, poisoned attractive baits were not able to outcompete naturally ripe (and presumably fermenting) figs in orchards (Smilanick, 1979). This information suggests that a combination of aggregation pheromone and host volatiles is necessary to equal the attraction of natural host materials with insects present and could potentially involve synergism as well. Bartelt *et al.,* (1990a) recently reported the first example of an aggregation pheromone from nitidulids, which interacts synergistically with some host volatiles. To further examine this important interaction, host materials, host extracts, and individual host-derived volatiles were combined with the pheromone of C. *hemipterus* and tested for relative attractiveness versus individual components in wind-tunnel bioassays. Structure-activity studies of individual host components combined with the pheromone extract also were run to determine if optimal host-derived individual attractancy, synergism, and overall attractancy could be predicted by quantitative analysis of physio co-chemical parameters or use of other structural relationships.

The C. *hemipterus* were reared according to previously described methods (Dowd, 1987). Adults used in assays were 7-10 days old. The insects were conditioned for flight by 16 hr starvation (Bartelt *et al.*, 1990a).

Dried fruit beetles attack fresh, ripened fruit and dried fruit before it can be packaged and stored. Figs, dates and raisins are frequently attacked. They have also been found in apricots, bananas, peaches, nuts, bread and biscuits. Besides being unsightly, these beetles can contaminate fruit with bacterial and fungal diseases.

2.4 Dispersal

Adults may fly at twilight in warm conditions (Surtees, 1965). Adults fly and will walk rapidly, sometimes for long distances. Transfer in contaminated foodstuffs, particularly from food processing and packaging plants. Dried fruit beetles are strong fliers and can travel several kilometers in search of hosts. Summer rainfall and rotting of fruit provides the best conditions for beetle breeding. Dry summer and autumn conditions reduce the threat in the following season by providing less favorable breeding conditions.

Carpophilus beetles are a major vector of brown rot. As they crawl through damaged fruit, the spores of brown rot stick to their bodies and are spread through the tree canopy and from orchard to orchard. The disease is carried on the body of the insect and fruit can become infected with the disease simply by contact, without the beetle actually feeding on fruit. Control of *carpophilus*, where they are present, is an important part of controlling brown rot. (https://www.agric.wa.gov.au).

2.5 Systematic position

Kingdom: Animalia

Phylum: Arthropoda

Sub-phylum: Hexapoda

Class: Insecta

Order: Coleoptera

Sub-order: Polyphaga

Super-family: Cucujoidea

Family Nitidulidae

Subfamily: Carpophilinae

Genus: *Carpophilus*

Species: *hemipterus*

2.6 Synonyms and other taxonomic changes

Carpophilus hemipterus (Linnaeus, 1758).

Original Combination: *Dermestes hemipterus* (Linnaeus 1758).

2.7 Sites of infection/infestation

Dried fruit beetle can be found at the manufacturing, storage and retail levels of stored food production. Foods that may be infested include cereals, corn meal, corn starch, flour, pasta, nuts, sugar, popcorn, rice, rolled oats, bran, spices, herbs, dried fruits, dried meats, oilseeds, damaged grain and broken kernels, germ and grain dust (Surtees, 1965; Barnes, 2002 and Lyon-undated), also chocolate-based products (Bowditch and Madden, 1997).

2.8 Description of dried fruit beetle

Dried fruit beetles, also known as sap beetles, are a complex of several closely related species in the family Nitidulidae that have similar life histories and resemble each other in appearance. The dried fruit beetle, *C. hemipterus*, is the most common species, but the freeman sap beetle, *C. freemani,* and the confused sap beetle, *C. mutilatus,* are also common and can be the most abundant in some orchards. *C. marginellus*, *Haptoncus luteolus,* and *Urophorus humeralis* are sometimes present in lesser numbers. (https://www.google.com/search). The dried fruit beetle, *C. hemipterus* (L.), is a stored product pest. It is one of a family called Nitidulidae. They are also called “sap beetles” because of their attraction to plant juices. There are other sap beetles, including the corn sap beetle, the pineapple beetle and the yellow-brown sap beetle. (https://www.orkin.com/other/beetles/dried-fruit-beetle). A very small beetle, only about 1/8 of an inch long, the Dried Fruit beetle has clubbed antennae, the typical oval shape of beetles, and are brown or black in color. Most varieties have two large yellow, gold, or amber colored spots on their elytra (wing covers). The head, legs, and antennae are usually tan to brown in color. (mailto:info@pestnet.com).

The Dried fruit, *C. hemipterus* (L.), is a world-wide pest of a wide variety of fruits and grains, both before and after harvest (Hinton, 1945). In California, *C. hemipterus* and related nitidulid beetles have been persistent pests of figs, dates, and stone fruits (Lindgren and Vincent, 1953; Tate and Ogawa, 1975; Smilanick, 1979; Warner *et al.*, 1990) Impact on crop value is primarily due to the presence of beetles in products for sale (e.g., dried fruits) and to the transmission by the beetles of harmful microorganisms into the crop. Control by mass trapping has been tried in fig orchards by using fermenting fig baits and was shown to be economically feasible (Warner, 1961). A synthetic version of the fermenting fruit volatiles has been developed as bait for field use (Smilanick *et a1.*, 1978). Although synthetic compounds are in principle far easier to use than the natural baits, and large numbers of beetles were captured in the study, attractants of this type are not in general use today. Although using attractants in the management of nitidulids appears promising, having still more potent attractants would be desirable. A likely improvement for beetle attractants would be the inclusion of the pheromones of the spethecies. An aggregation pheromone has been identified and synthesized for *C. hemipterus* (Bartelt *et al.*, 1990a). In the laboratory, the pheromone was most attractive when combined with a host related coat tract ant. Our objectives in the study reported here were to determine whether the synthetic aggregation pheromone was active under field conditions and whether it was advantageous to combine host-type coat tract ants with the pheromone. The answers to these and related practical questions will determine whether the aggregation pheromone, as presently defined, can have a useful role in controlling or monitoring this pest.

Because a complex of nitiddid species *Occursin* the studies areas, we also had an opportunity to look for cross-attraction to the *C. hemipterus* pheromone. The major reported species in *California date* gardens include *C. mutilates* Erichson, *C. (Urophorus) humeralis* (F) and *Haptoncus luteolus* Erichson (Lindgren and Vincent, 1953; Warner *et al*., 1990) (Before its re-description by Dobson, 1954), *C. mutilates* was confused with *C. dimidiatus* (F). In addition to these, two other *Carpophilus* species are well known from fig orchards: *C. freeman* Dobson and *C. lugubris* Murray (Smilanick *et al.*, 1978).

A number of moth's beetle and too few extent flies are important pests of dried fruits, although some of them may be equally or even more important as pests of nuts, cereals and other stored products (Simmons and Howard, 1975; Mound, 1989; Lewis, 1995; Okunade *et al.*, 2001; Degri, 2007; Linda and Timothy, 2008).

There are several species of beetles that are problematic to growers and they have distinguishing features that make them severe pests, Dried fruit beetles are members of the certain insect family like Nitidulidae, a beetle known for its wide host range and willingness to chew on many different garden fruits and vegetables. These pests are tiny, with elongated bodies and short clubbed antennae. Adults are typically brown or black, some bearing yellow spots on their backs. The larvae of the dried fruit beetle resemble a tiny grub, with a tan head, white body and two hornlike structures coming out of its end. Adult beetles are active feeders and damage dried fruits even more than their larvae because some of them live longer in the adult stage. All of the principal species, except saw-toothed grain beetle, infest commodities by flying or crawling into storage buildings or by being carried in with dried fruits. (Okunade *et al.*, 2001).

This insect group is a major pest of the dried fruit industry, although it will attack grain and grain based products, especially if the cereal product is damaged. This insect is also a serious pest of fruits in the field and can spread yeast cells and bacteria causing damage to the fruit before harvest. (info@indiaprodotti.Com).

Adult dried fruit beetles (3-4 mm (1/8 inch)) are oval and black in color with two large conspicuous yellow-brown spots on the wing covers. Sometimes these spots run together to form one large spot.

The corn sap beetle (2-3.5 mm (1/8 to 1/4 inch)) can be distinguished from the dried fruit beetle by the absence of the yellow-brown spots on the wing covers. The eleven segmented antennae are slender except for the last few segments, which are distinctly enlarged into a club. To distinguish the dried fruit and corn sap beetles from other beetles, examine the wing covers. If the wing covers are very short and you can see the tip of the abdomen, it is in the "sap" beetle family. The slender larvae are small (1/4 inch), white, with a light brown head and hardened projections from the end of their abdomens that are species specific. (https://en.wikipedia.org/wiki/Almond).

2.9 Biology of dried fruit beetle

Carpophilus, also known as dried fruit beetles, are a worldwide pest of fruits, both pre- and post-harvest, and grains. Dried fruit beetles attack a wide variety of hosts including stone fruit, persimmons, fallen citrus, apples and figs. Adult *carpophilus* can cause feeding damage on ripening stone fruit and is a vector of the fungal disease brown rot. (https://www.agric.wa.gov.au).

Eggs are white, cylindrical, and 2 to 3 mm long. Larvae develop in the host, and are up to 0.25 inch, white to yellow, with two spine-like projections at the tail end. Larvae leave the host to pupate, typically in surrounding soil (Simmons and Nelson, 1975) and emerge as adults. The larval developmental period is potentially as short as 12 days. Adults live for more than 100 days at 25°C, and up to 60 days at 35°C (El-Kady *et al.*, 1962). Unlike the previous moth species, the dried fruit beetle flies during the day and only when the temperature is above 18°C (Simmons and Nelson, 1975).

Adult *Carpophilus* are small at around 3mm long, oblong shaped beetles with short wing covers such that the end of the abdomen is not covered and have clubbed antennae. They can be black, brown or mottled yellow. Larvae are yellowish with a brown head and forked tail and are about 5mm long when fully grown. (https://www.agric.wa.gov.au*)*. The dried fruit beetle adult is small (0.1 to 0.2 inch) and black with yellow markings on the elytra (forewings). The elytra do not completely cover the abdomen. Adults feed and live long relative to larval development time. Rotting, fermenting, or overripe fruit are the preferred oviposition site. The dried fruit beetle is an important field pest of dried figs and dates and can infest raisins during the drying process (Simmons and Nelson, 1975; Carpenter and Elmer, 1978). It also feeds on a variety of other rotting fruits (e.g., peaches and grapes), where it is usually considered of minor importance since sound fruit is not attacked.

Mating

Males and females have more than one mate. Mating occurs within 2-3 days after adult emergence. Males remain responsive to females after previous mating. Females normally mate with 2 males, and males normally mate at least 6 times (Ashworth, 1993; Papadopoulou, 2006). Mating System is polygynandrous. Mating takes place soon after adults emerge from the soil, and eggs are laid from 1 to 8 days thereafter. In warm weather, there may be a generation every 3weeks. (www.australianalmonds.com.au (Ben Brown, Almond Board of Australia).

Reproduction

The female beetle deposits eggs in cracks in food or on ground food, like flour. When the eggs hatch, the larvae feed and grow. When the larvae are ready to change to adult beetles, they make a cocoon from food particles. In warm, humid conditions, the entire life cycle, from egg to mature adult, takes about two months. There can be several generations per year. Males have a tooth on the femur of the hind leg.

Oviposition

Females lay up to about 1000 eggs. The eggs of *C. hemipterus* are white in color, 0.1 to 0.2 mm long and 0.2 mm wide (Jones, 1913). Each egg weighs approximately 8.4 μg and has a waxy shell which protects the egg from desiccation and hatch in 3 to 10 days in warm weather. The larva eats the egg shell at the time of hatching (Ashworth, 1993). The eggs become dull in color before hatching. Surface of the egg is smooth, without sculpture except at the end portion of egg from which the larva emerges (Runner, 1919). When the shell breaks at the head and the undulating movements carry the young larva gradually clear of it. The dark red eyespots and the ochre spot of mouth parts (mandibles and ciboria sclerite) are visible through the chorion at the anterior end. The chorion appears smooth, but SEM magnification (550-2000 x) reveals imprints of the polygonal follicular cells. No aeropyles or micropyles have been detected. Female dried fruit beetles can lay over 2,134 eggs at 28.1°C, however the average is 1,071 eggs in her lifetime. The pre-oviposition, oviposition, and post-oviposition periods are 3, 61, and 9 days respectively.

Egg

Dried fruit beetle does not breed in fruit on the tree. Adults lay eggs in rotting or damaged fruit on the orchard floor. Adults live for an average of three months. (https://www.agric.wa.gov.au). A female lays an average 1000 eggs, which hatch in 2-3 days. Eggs are laid on ripe and rotting fruit of all types. Eggs hatch in 1 to 5 days, and larvae feed actively as they move through their food. (http://www.australianalmonds.com.au) (Ben Brown, Almond Board of Australia). Mature larvae emerge from the fruit and pupate in the ground. The female beetle deposits its eggs on the fruit of a tree, then when they hatch will burrow into the fruit, destroying the yield. Sometimes hatching several generations per year (especially in warm, humid climates), the beetle matures from egg to adult in approximately two weeks. A female lay as many as 1000 eggs in her lifetime. (mailto:info@pestnet.com). Eggs are laid singly, on ripe or fermenting fruit, in the field or in stored-products. Eggs take 1-4 days to hatch.

Larval period

Larvae are white and 1/10 to 1/5 inch long when mature. They have tan head capsules, three pairs of true legs, and two hornlike structures on the anal end. Full grown larvae enter the soil and make earthen cells in which they pupate. (http://www.australianalmonds.com.au) (Ben Brown, Almond Board of Australia). The larval stage lasts 6-8 days and pupation 5-7 days.

Larvae when fully grown are white or yellowish, head and the rear end of the body are amber-brown, sparsely hairy, and have two prominent spines like projections at the tail end, with two smaller ones in front of them.

The adults and larvae are among the chief pests of ripening and drying figs, and maybe found in fruit dumps, rotting melons, stick-tight pomegranates, dropped peaches, plums, citrus fruits, cull figs and moist raisins. Larval development is completed in 4-14 days. Larval stages are very active and will try to hide if disturbed. Larvae are white and 0.1 to 0.2 inch long when mature. They have tan head capsules, three pairs of true legs, and two hornlike structures on the anal end. (https://www.google.com/search).

Length of larval stage

The length of the larval stage as determined at Washington, D. C, varied considerably, and was affected chiefly by the temperature. Data bearing on larval life will be found in during the spring the period from hatching to pupation ranged from about4 to 7 weeks, whereas in midsummer this period was about 2 weeks, 12 days being the shortest larval period recorded. With the approach of cooler weather in the fall, the period again lengthened until during the winter months, when the laboratory was heated only during the day, the period was about 8 to 10 weeks. The number of molts varied. A majority of the larvae observed molted three times, a few molted four times and quite a number molted but twice. Those individuals that molted four times were all reared during the fall and winter, when development was slow and the larval period quite long. Ashworth (1993) stated that the first instar is less than 1 mm long and covered with fine hairs. The larvae go through four larval instars before pupation, and the weight ranges from 2.5 to 5.0 mg.

Runner (1919) reported that the first instar is 0.55 to1.4 mm long and yellowish white in color. The second instar is about 3 mm long and yellowish white, and the last instar is 4 mm long, and body is yellowish white, set entirely with long, yellowish brown hairs. Newly hatched larvae move away from light and are extremely active (Ashworth, 1993).

These tiny larvae are able to infest packaged food by entering through small holes (Runner, 1919). The older larvae are less active but are still capable of considerable wandering and remain negatively phototropic. Larvae are scarabaei form in shape, i.e., when at rest, bodies curl into a “c” shape. The larvae stop feeding and build cell when they are fully grown, and the formation of this cell is influenced by the food substrate. Disturbance may cause old larvae to give up a partly-made cell and build new cells or even cause them to form naked pupae (Howe, 1957). They tend to penetrate deeply into loosely packed commodities. Insect activity ceases when the temperature falls below 19.5ºC (Runner, 1919) and the beetle overwinters in the larval stage (Ashworth, 1993). Development of larvae stops when the temperature falls below 17ºC or above 42ºC (Howe, 1957).

Pupal period

Pupa is uniformly white when first formed and is 3.5 mm long and 1.7 mm wide. Pupal period is 7-21 days. Tips of elytra reach the fourth segment of the abdomen. Metathoracic legs are formed under the elytra. The head is curved beneath pronotum. The ultimate portion of the abdomen is paired with lateral protuberances (Runner, 1919).

Last instar larvae usually construct cocoon-like casings from grain fragments cemented together with a sticky oral secretion in which to pupate, while sometimes no pupal cell is made. The larva attaches itself by the anal end to a solid object (Anon., 2009; Back and Cotton, 1926).

Pupation usually takes place in heavy soil in field populations, but in stored-products, pupation takes place within the infested commodity. In warm areas or within heated buildings, breeding is continuous and there are several generations per year.

Pupation occurs after a prepupal period of 3-8 days, and adults emerge 4-16 days later. Thus, the development cycle is about 12 days at warm temperatures (32.2°C) and up to 42 days at cooler temperatures (18.3°C). When temperatures are too low for breeding, the beetles hibernate as mature larvae, pupae or adults in the soil, stored commodity, or fruit left on the ground.

Adult

Adults emerge from the pupae and attack fruit in late spring and summer. If no hosts are available they overwinter in cracks in the tree, under bark or in mummified fruit. It takes about a month in summer to develop from egg to adults so there are many generations per year. (https://www.agric.wa.gov.au*)*. Adults are small brown or black beetles with or without lighter spots on the wings, depending on the species. They range in size from 0.1 to 0.2-inch-long and have clubbed antennae. The wings do not cover the last two to three abdominal segments. (https://www.google.com/search). The adult beetle is small (3 mm long). It is an oval, black insect. There are two amber-colored spots on the wing covers. The wing covers are short and leave part of the abdomen exposed. The legs or antennae are often reddish or amber colored. (https://www.orkin.com/other/beetles/dried-fruit-beetle/). Adults of dried fruit beetle are black and with two amber brown spots on each wing cover, one nears the tip and a smaller one at the outer margin of the base. Though adults can live for more than a year, dried fruit beetle males generally live 146 days while females average 103 days.

2.10 Biology and behavior of dried fruit beetle

Insect infestation of dried fruit and nuts, and detection of this infestation, is determined in part by adult behavior, including mating and aggregation, dispersal, and ovipositional preferences. In moths the female releases sex pheromone and males find females using this scent trail. The codling moth, navel orange worm, and carob moth each have distinct pheromone blends, whereas the remaining moths are attracted by the same principle component (El-Sayed, 2011).

In the dried fruit beetle and vinegar flies, males and females locate each other and food resources via a synergistic attraction to food odors and aggregation pheromones produced by males. In the dried fruit beetle the aggregation pheromone is a blend of 13- to 15-carbon molecules, released by males and attractive to both males and females (Bartelt *et al.,* 1992). Similar pheromones are produced by the related and often coexisting species, *Carpophilus freemani*and *C. mutilate* (Bartelt *et al.,* 1995).

These aggregation pheromones have little effect by themselves, but the pheromone in combination with volatile alcohols, esters, and acids produced by food sources the pheromone is far more attractive than either by itself (Dowd and Bartelt, 1991, Blumberg *et al.,* 1993).

Vinegar flies also use a combination of host volatiles and aggregation pheromone. Long-range host-associated cues are primarily acetic acid and similar compounds associated with vinegar (Becher *et al.,* 2010). At closer range mating and oviposition in *Drosophila* is influenced by aggregation pheromone and another pheromones associate with the cuticle. Generally, these are produced by males, but in some cases passed to females during mating (Wertheim *et al.*, 2002; Dahanukar and Ray, 2011).

Destructive stages of pest: Both adult and larva (grub).

2.11 Nature and extent of damage

Both adults and larvae cause damage to stored products but the damage done by larvae is more serious (Bousquet, 1990). In Australian conditions adults are short-lived and feed little if at all (Rees, 2004). Damage is caused by *C. hemipterus* usually results in loss of weight and decrease in quality. A single insect only causes a few milligrams of weight loss, whereas populations measured by millions of *C. hemipterus* individuals can bring considerable weight loss. Stored products are holed and contaminated with cocoons and frass when infested by *C. hemipterus*.

In nuts & dry fruits the holes destroy the product, and holes spoil the sack or package. Infestation of cereal grains and of seeds of beans and other plants could adversely affect germination as the germ is attacked (Howe, 1957). Malhotra (2007) reported that about 17 to 25 percent losses are caused by insects, molds, rodents etc. to different dried fruits during storage. These losses are caused by converting dried fruits into powder form.

2.12 Effect of environment on pest survival

Larval activity of the dried fruit beetle ceases when the temperature falls below 15°C (59°F) and these larvae can remain dormant for many months and may over-winter in this stage in cool climates. Howe (1957) stated that the developmental period is affected by humidity and temperature as well as type and availability of food. Lefkovitch and Currie

(1963) reported that food shortages prolong development and reduces survival of the immature stages and also reduces the weight of the resulting adults.

Larvae will eat eggs and pupae in the absence of other food sources. Ashworth (1993) concluded that the minimal temperature for development was about 18°C, but oviposition has been recorded at 15°C.

All stages are killed at 2.2°C for 16 days or -3.8°C for 7 days but eggs may survive shorter periods of exposure.

2.13 Factors regulating loss in storage

Ecology

Ecology deals with interaction of abiotic and biotic environment of dried nut and fruits in storage of *C. hemipterus* High temperatures and humidities during summer promote the buildup of large sap beetle populations. In date groves the first source of food is provided during June, when many green fruit drops. They are infested by beetles of the first generation, whereas the adults of the second generation infest dates on the tree. These beetles are secondary pests, and as such, almost never attack sound fruit. However, their presence on dates is an exception to the rule. Adults can live 6-12 months and deposit 500-1000 eggs. Adults and larvae occur in all seasons and several generations are produced annually. In Israel, *C. mutilates* Erichson and *C. hemipterus* are prevalent throughout the autumn, winter and spring, their populations declining in summer. In summer, they are replaced by *Carpophilus humeralis* (Fabricius) and *Haptoncus luteolus* (Erichson), the latter being most abundant during the summer and autumn. Most sap beetles damage to ripening fruit is apparently caused by the latter two species. (Bartelt, 1997; Blumberg, *et al*.,1985,1993; Carpenter and Elmer, 1978)

The number and abundance of species associated with dried fruits and nuts is determined principally by abiotic and host-associated factors and control measures, in part because there is usually a very low tolerance for insects associated with these high-value food items.

Factors such as host nutrition and condition, processing methods, field and storage temperatures, day-length, and other storage organisms influence the development and survival of pest populations, and their economic impact.

Biotic factors

Both biotic and abiotic factors are responsible for the loss of stored dried fruits in storage. The major biotic factors influencing seeds loss during storage are insects, molds, birds and rats. Biotic environment includes living associations of storage insects among themselves as well as with other organisms. Storage insects are usually confined in a specially limited ecosystem and interact among themselves and also with storage fungi, mites and nematodes etc. living together in this complex ecosystem

Abiotic factors

Abiotic factors including temperature, humidity and type of storage, all affect environmental conditions in storage. High temperature causes deterioration, while low temperature is good for storage. High temperature accelerates the respiration of dried fruits, which produces carbon dioxide, heat and water, conditions favorable for spoilage, while decreasing humidity is good for storage for any crop. Generally, the colder and drier surrounding of the environment is better for storage dried fruits.

The conditions with 30% relative humidity, temperature bellow 59o F (15^{o}C) and darkness are the three factors for optimal dried fruits storage. Light stimulate and support the germination process of the dried fruits and storage in darkness helps keeping the pre-germination process in the dried fruits at a low level.

Hagstrum and Milliken (1988) studied the development period of 9 species of coleoptera attacking stored products in relation to temperature, moisture & diet and stated that at most temperature, the order of relative influence of these factors on development was temperature, moisture and diet. However, moisture and diet influenced larval development more than temperature.

Zhang and Wang (1996) carried out an ecological study on a laboratory population of dried fruit beetle, *C. hemipterus* under the treatment combination of six levels of temperature (20.3^{0}C, 23.9^{0}C, 27.7^{0}C, 32.2^{0}C, 33.7^{0}C, 35.9^{0}C) and three levels of relative humidity (51.3%-55.0%, 75.5%-76.0%, 83.8%-85.0%). They reported that the optimum temperature and relative humidity were 30^{0}C-34^{0}C and 70-85 percent respectively for the growth and development of this pest and the temperature higher than 360C and relative humidity less than 51% had an adverse influence on its survival.

According to Abdelghany *et al.,* (2010), mortality of each stage generally increased with an increase of temperature and exposure time. Heat tolerance for different stages from highest to lowest was young larvae, old larvae, eggs, adult, and pupae. The mortality after 7 h at 42^{0}C for young larvae, old larvae, eggs, adults, and pupae, respectively, were 16 ±

5, 31 ± 6, 48 ± 3, 63 ± 8, and 86 ± 2% (mean ± SEM). Similar trends for stage specific mortality were seen with the lethal time for 90% mortality (LT90) at 42°C; 773, 144, 12, and 11 h for old larvae, eggs, adults, and pupa, respectively. Mortality was too low with young larvae to estimate LT90. The LT90 for young larvae at 42, 45, 50, 55, and 60°C was 25, 20, 3.9, 0.18 h, and 0.08 h, respectively.

Temperature

The effect of temperature on development has been examined using various approaches. For field pests, degree-day models tend to be used. These models assume daily fluctuation in temperature. The upper and lower developmental threshold determined in these models are ultimately parameters in a model that are of interest primarily for their ability to predict development at intermediate temperatures.

Another approach that has been used in stored product pests is to determine empirically the ability of populations to grow at various constant temperatures of interest. This latter approach implies that populations of interest experience something close to constant temperature, an assumption that is more likely to be met in stored products than in field situations. As a result, a model for the population development for the almond moth includes an implied developmental threshold of 12°C, although empirical studies find that this species does not develop from egg to adult at 15°C under favorable conditions of diet and moisture content (Bell, 1975). Temperature ranges for development are one reason that the almond moth is considered a predominantly tropical species (Cox, 1975b), and the tobacco moth a predominantly temperate species (Ashworth, 1993). The dried fruit beetle develops at higher temperatures than the other *Carpophilus* spp., *C. freeman* and *C.*

mutilates (James and Vogele, 2000). This higher temperature tolerence, along with the high temperatures encountered in production of sun-dried figs, may explain why *C. freeman* and *C. mutilates* comprise 40% of the nitidulids trapped with tri-species traps in fig orchards (C. S. Burks, unpublished data), but were rarely trapped in trapping in the substandard fig warehouse (Johnson *et al.,* 2000).

Diapause

Diapause is another factor that can influence geographical range. There is evidence that all of the moth species discussed in this chapter can be induced by environmental conditions into diapause at the end of the last larval instar (Bell, 1994). Diapause is a genetically plastic characteristic; it may assist the codling moth in adapting to local host availability (Barnes, 1991), and can vary in presence, prevalence, and intensity in the Indian meal moth (Mohandass *et al.,* 2007). Despite genetic plasticity, diapause is a factor in limiting the range of the raisin moth (Cox, 1975a and 1975b) and the codling moth (Willett *et al.,* 2009). Because diapausing larvae are often the stage most tolerant to disinfestation treatments, particularly fumigation (Bell and Glanville, 1973; Tebbets *et al.,* 1986), their occurrence in product may affect control efficacy. Factors regulating loss of grain in storage.

Humidity

Humidity is very important to the survival of dried fruit beetles while corn sap beetles, often found in rice, only require 10% moisture to mature to the adult stage (it prefers 15-33% moisture). Low humidity is unsuitable for dried fruit beetle larval development and oviposition. Larval development times increase with decreasing humidity so that the mean period from egg to adult increases from 19 days at 92% rh to 24 days at 66% rh. Humidity has little effect on the egg, prepupal or pupal stages. Usually there are four larval instars, however, as humidity decreases, the proportion with five instars increase.

Oviposition is also affected by humidity; at 75% rh 1.5 eggs/day are laid while at 58% rh the rate diminishes to 0.1 egg/day.

The corn sap beetle and dried fruit beetle can be found in a wide variety of ripe and decomposing fruit in the field and is a serious pest of dried fruit. The dried fruit beetle can also be found on stored corn, cornmeal, wheat, oats, rice, beans, nuts, peanuts, cottonseed, copra, spices, drugs, bread, sugar, and honey. The corn sap beetle is most commonly found feeding on rice, wheat bran, dried fruit, or moldy food.

Light

Pajni and Gill (1974) reported photopositive response of *C. hemipterus* in case of movements of the adults. Elvin and Schroeder (1961) also observed the photopositive responses of UV light in adult movements (50% at one or more intensities of 3660 A^0 light) of *C. hemipterus.*

2.14 Storage structure for protection of stored dried fruit beetle

Local storage structures which are commonly used in rural India and Bangladesh fail to maintain the optimum flavor of dried fruit and also fail to provide complete seeds protection from insects. In general, these structures are not moisture proof. The moisture content is high in stored spices seed which facilitates insect multiplication. The longer the storage period, higher is the insect infestation.

The type of storage plays a fundamental role in storage efficiency. Dried fruits should be kept in tightly sealed container. Climate conditions, seeds conditions at storage, dried fruits and pest control practices all contribute to the rate of loss caused by insects. As these factors interact, it is difficult to isolate them or identify one factor, which has a direct influence on loss. Average statistics for loss, whether for store types, areas, or quantities of dried fruits stored are inconclusive.

An average figure for loss for a region or a country holds no significance unless a decision regarding a new system of storage, or new pest control techniques adopted. Never the less average loss figures are always sought.

2.15 Management of dried food beetle, *Carpophilus hemipterus* (L.)

The first step against insect pests is good management during production, the second is careful harvesting and preparation for market in the field, and thirdly sorting out damaged or decaying produce can limit contamination of the remaining, healthy produce. Yet, even when the greatest care is taken, sometimes produce must be treated to control insects or decay-causing organisms (Krischik, 1995; Gerald and Frank, 2005; Sarwar, 2010, 2013; Sarwar *et al*., 2013).

C. hemipterus (L.) is a widespread nitidulid beetle, which together with a few allied species, occurs on decaying vegetation and fruit. This species may also be destructive to dried fruits and cereals in storage (Essig, 1942). In Hawaii, these beetles breed in large numbers in knocked down pineapple fields where they feed upon the rotting stems. Once their food source has been exhausted, the beetles migrate to other places looking for new food sources. Large swarms of migrating beetles arrive inhuman habitations and cause a nuisance problem. A search for natural enemies of these pests has been undertaken, and the senior author was contacted and asked to obtain parasites of souring beetles from Israel to ship to Hawaii. This paper deals with some biological observations made during the project. The development and use of non-pesticidal approaches to the control of these key pests (Vickers *et al.*, 1985; James 1990) has substantially reduced insecticide inputs in stone fruit production and led to an increase in importance of *Carpophilus* spp. *Carpophilus* beetles, particularly *C. davidsoni* Dobson, *C. hemipterus* (L.) and *C. mutilates* Erichson (James *et al.* 1994, 1995a) are attracted to and penetrate ripening fruit causing rapid breakdown (Hely *et al.* 1982), which can result in substantial fruit losses (James *et al.*, 1997).

2.16 Economic importance of *Carpophilus hemipterus* (L.)

Carpophilus spp. are worldwide pests of fruits and grains, both before and after harvest, and are a nuisance in canning factories and other food processing establishments. They infest ripening dates on the tree and on the ground. They enter the fruit, usually at the calyx end, feeding on the pulp and thereby causing damage. Pest penetration into the fruit facilitates the development of microorganisms, resulting in rot and fruit fermentation that further downgrades the fruit. Damage is thus reflected in reduced yield and quality. The pattern of their specific damage varies between years and in different regions. Infestation by sap beetles in untreated groves may be high, up to 40% in Israel and about 90% in Aswan, Egypt. (Lindgren and Vincent, 1953; Kehat,1983; Navarro, *et al*., 1993).

CHAPTER III

MATERIALS AND METHODS

The present research work contains three set of experiments. The details of the materials and methods that used to conduct three experiments are described below:

Experiment 1: Study on the biology of dried fruit beetle, *Carpophilus hemipterus* (F.) on cashew nut in the laboratory

The study was conducted in the laboratory of the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from August, 2016 to January, 2017. The biology of *C. hemipterus* was studied on cashew nut, which was collected from SAU market.

3.1.1 Test insect collection

Adults of dried fruit beetle along with the infested dried fruit and nuts were collected from the laboratory under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka.

3.1.2 Stock culture of dried fruit beetle, *C. hemipterus*

The collected insects were maintained in the laboratory of Entomology Department. Different stages of *C. hemipterus* were reared in a plastic container with cashew nut in the laboratory. For the study of adults were sort out from infested dried fruit (Plate 01) and then transferred to another plastic container and released in test tube with the help of aspirator (Plate 02) for laying eggs.

3.1.3 Collection of eggs for the study of biology:

For collection of eggs, 5 pairs of newly emerged dried fruit beetle were released in 5 test tubes separately and the top of the test tube was covered by net. After 24 to 48 hours the beetle was removed from the test tube and the eggs were gently collected from the bottom part of test tube and their number were recorded.

Plate 01. Stock culture of *C. hemipterus* in the laboratory condition

Plate 02. Aspirator for the collection of dried fruit beetle, *C. hemipterus*

Plate no. 03: Each test tube with one pair of dried fruit beetle, *C. hemipterus* kept for egg laying

3.1.4 Biology of *C. hemipterus*

Eggs were transferred on pieces of white paper in petri dishes (Plate 04) for hatching. After hatching without exuviae, only the newly hatched larvae of *C. hemipterus* were transferred in petri dishes containing cashew nut. The morphological characteristics of the larvae (Plate 05) and pupae (Plate 06) were studied and recorded during the period of larval and pupal development respectively. Different growth and development stages of *C. hemipterus* such as larval period, pupal period and adult longevity were recorded during the study (Plate 07). The incubation period was measured by time interval between egg laying and larval hatching.

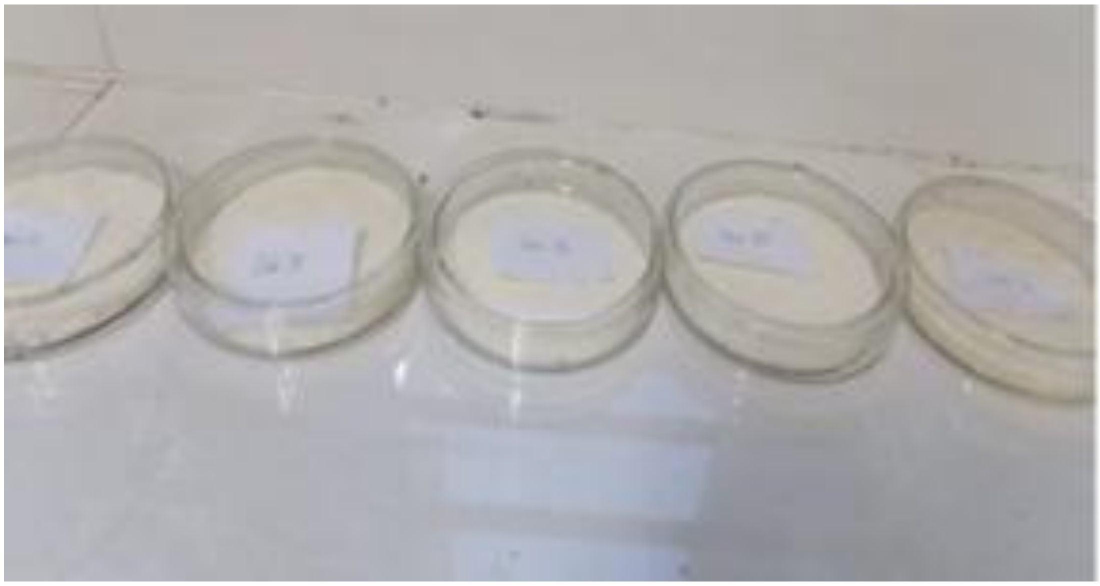

Plate no. 04: Newly hatched larvae of *C. hemipterus* were transferred in petri-dishes containing cashew nut for the study of biology in laboratory

Plate no. 05: Infested cashew nut with larvae of dried fruit beetle, *C.hemipterus* during the study of biology in laboratory

Plate no. 06: Larvae (A) and Pupa (B) of dried fruit beetle, *C. hemipterus* by microscopic view during the study of biology in laboratory

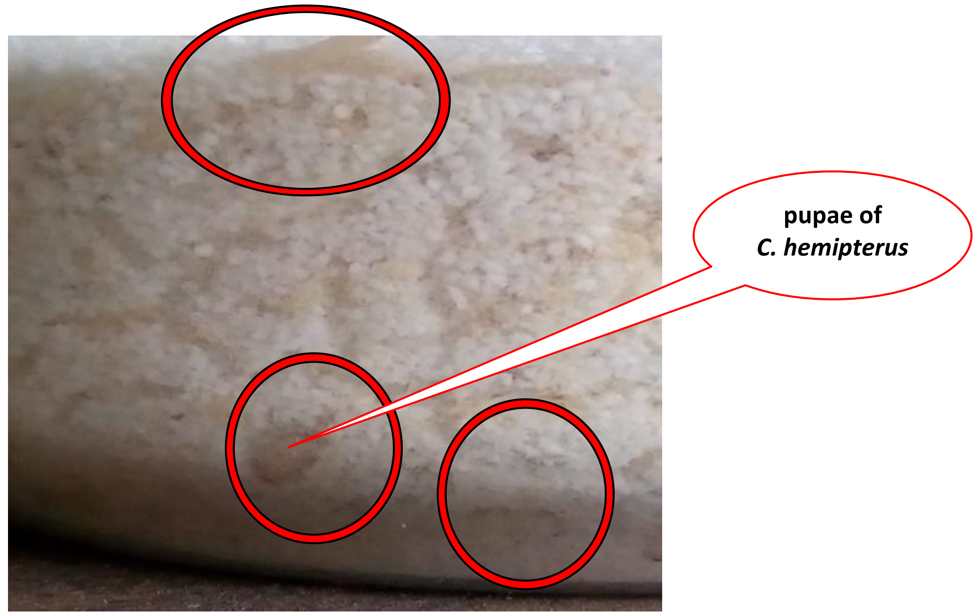

Plate no. 07: Pupa of dried fruit beetle, *C. hemipterus* in chamber on cashew nut during the study of biology in laboratory

Plate no. 08: Newly emerge adult (A) and mature adult (B) of dried fruit beetle, *C. hemipterus* during the study of biology in laboratory

3.1.5 Data recorded: Data were recorded on the following parameters

- Number of laid eggs
- Incubation period
- Larval period
- Larval mortality
- Pupal period
- Pupal mortality
- Adult emergence

3.1.6 Design of the experiment

The experiment was laid out in CRD (Completely randomized design) with 5 replications.

Experiment 2: Damage assessment in different dried fruits caused by dried fruit beetle, *C. hemipterus*

The experiment was conducted to study the extent of damages in different dried fruits inflicted by dried fruit beetle during the period from August, 2016 to March, 2017. A brief description of the experimental site, experimental design, data collection and analysis of different parameters has been explained under the following sub-headings:

3.2.1 Preparation of test materials

Dried fruit were collected from Krishi market, Dhaka in July, 2016 to carry out the study. The dried fruits were cleaned, dried and sorted out from damage unhealthy dried fruits and stored in plastic jar with airtight condition to keep free from the insects and micro-organisms.

3.2.2 Collection of dried fruit beetle

The process of collection was described similar to that in 3.1.1 – 3.1.3 of the experiment 01.

3.2.3 Experimental design and layout

The experiment was laid out in the ambient condition of laboratory and laid out in CRD (Completely randomized design) with 5 replications.

3.2.4 Data collection: The data were recorded on different parameters

- Number of dead insects at different months
- Number of adult emergence
- Status of dried fruits in 30, 60 and 90 days after adult released by weight
- Weight loss of different dried fruits

3.2.5 Experimental material

Ten (10) gm of different dried fruit Alamond (Kat badam), Cashewnut (Kaju badam), Ground nut (China badam) and Dried dates (Khegur) were used as experimental material in each plastic container 5 pairs of dried fruit beetle were released to assess the damage percentage (Plate 9).

Plate 09. Different dried fruits which used as Experimental materials to determine the damage assessment by dried fruit beetle

3.2.5.1 Almond (Kat badam)

The almond ((*Prunusa mygdalus*, *Prunusdulcis*, syn. *Prunusamygdalus*) is a species of tree native to the Middle East, the Indian subcontinent and North Africa."Almond" is also the name of the edible and widely cultivated seed of this tree. Within the genus *Prunus*, it is classified with the peach in the subgenus *Amygdalus*, distinguished from the other subgenera by corrugations on the shell (endocarp) surrounding the seed. The almond is the edible seed that grows on the tree Prunusdulcis, more commonly called the almond tree. (http://faostat3.fao.org.).

Almonds are native to the Middle East, but the United States is now the world's largest producer. The almonds we buy at the store have usually had the shell removed, revealing the edible nut inside. The fruit of the almond is a drupe, consisting of an outer hull and a hard shell with the seed, which is not a true nut, inside. Shelling almonds refers to removing the shell to reveal the seed. Almonds are sold shelled or unshelled. Blanched almonds are shelled almonds that have been treated with hot water to soften the seed coat, which is then removed to reveal the white embryo (https://www.hort.purdue.edu.).

Plate 10: Healthy Almond **(A)** and Infested Almond **(B)** by dried fruit beetle

Importance

Almonds contain lots of healthy fats, fiber, protein, magnesium and vitamin E. The health benefits of almonds include lower blood sugar levels, reduced blood pressure and lower cholesterol levels. They can also reduce hunger and promote weight loss.

Natural, unsalted almonds are a tasty and nutritious snack with plenty of health benefits. Loaded with minerals, they are also among the healthiest of tree nuts. Just a handful of nutrient-rich almonds a day helps to promote heart health and prevent weight gain and it may even help fight diseases like diabetes and Alzheimer's.

Uses

While the almond is often eaten on its own, raw or toasted, it is also a component of various dishes. Almonds are available as almond oil Almond milk, Almond flour and skins, Almond syrup, almond butter.

3.2.5.2 Cashew nut (kajubadam)

The cashew tree (*Anacardium occidentale*) is a tropical evergreen tree that produces the cashew nut and the cashew apple. It can grow as high as 14 m (46 ft), but the dwarf cashew, growing up to 6 m (20 ft), has proved more profitable, with earlier maturity and higher yields (http://www.theplantlist.org.).

The cashew nut, often simply called a cashew, is widely consumed. It is eaten on its own, used in recipes, or processed into cashew cheese or cashew butter. The shell of the cashew seed yields derivatives that can be used in many applications from lubricants to paints. The cashew apple is light reddish to yellow fruit, whose pulp can be processed into a sweet, astringent fruit drink or distilled into liquor (*w*ww.kew.org.*)*.

The species is originally native to northeastern Brazil. Major production of cashews occurs in Vietnam, Nigeria, India, and Ivory Coast.

Plate 11: Healthy Cashew nut **(A)** and Infested Cashew nut **(B)** by dried fruit beetle

Importance

Although cashews are one of the lowest-fiber nuts, they are packed with vitamins, minerals and antioxidants. These include vitamins E, K, and B6, along with minerals like copper, phosphorus, zinc, magnesium, iron, and selenium, all of which are important for maintaining good bodily function.

Cashews are one of those nuts that are so desirable and delicious, you can give them as a Christmas gift and get rave reviews.

On top of that, the nutritional aspects are astonishing. Healthy amounts of copper, magnesium, manganese, phosphorus, and vitamin K, along with lesser-known phytonutrients, such as antioxidants, tyrosinase, melanin, elastin, proantho cyanidins, and oleic acid, provide hard-to-ignore benefits for the body. Each nutrient plays its part in providing bone strength and joint flexibility, discouraging migraines, improving memory, lowering blood pressure, and protecting against UV damage, heart disease, and cancer.

Use

Animal feed, Cashew oil, Traditional medicine

3.2.5.3 Groundnut (chinabadam)

The peanut,*(Arachis hypogaea)* also known as the groundnut and the goober and taxonomically classified as *Arachishy pogaea*, is a legume crop grown mainly for its edible seeds. It is widely grown in the tropics and subtropics, being important to both small and large commercial producers. It is classified as both a grain legume and, because of its high oil content, an oil crop. World annual production of shelled peanuts was 42 million tonnes in 2014. Atypically among crop plants, peanut pods develop underground rather than aboveground. It is this characteristic that the botanist Linnaeus used to assign the specific name *hypogaea*, which means "under the earth." (peanut-institute.org.).

As a legume, the peanut belongs to the botanical family: Fabaceae; this is also known as Leguminosae, and commonly known as the *bean,* or *pea,* family. Like most other legumes, peanuts harbor symbioticnitrogen-fixing bacteria in root nodules.

This capacity to fix nitrogen means peanuts require less nitrogen-containing fertilizer and improve soil fertility, making them valuable in crop rotations (www.hort.purdue.edu.).

Peanuts are similar in taste and nutritional profile to tree nuts such as walnuts and almonds, and are often served in similar ways in Western cuisines. The botanical definition of a "nut" is a fruit whose ovary wall becomes very hard at maturity. Using this criterion, the peanut is not a true nut, but rather a legume. However, for culinary purposes and in common English language usage, peanuts are usually referred to as nuts (http://www.biofuelstp.eu).

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Plate 12: Healthy Groundnut **(A)** and Infested Groundnut **(B)** by Dried fruit beetle

Importance

The protein in peanuts is used in the manufacture of ardil, a synthetic fibre. The vegetable ghee is made from the peanut oil after hydrogenation. The kernels are also used in various foods and confectionery. They are ground and made into peanut butter.

The groundnut is particularly valued for its protein content (26%). On equal weight basis (Kg for Kg), groundnuts contain more protein than meat and about two and a half times more than eggs. Being an oil seed crop, it contains 40 to 49% oil. In addition to protein and oil, groundnuts are a good source of calcium, phosphorus, iron, zinc and boron. The groundnuts also contain vitamin E and small amounts of vitamin B complex.

Peanuts are rich in essential nutrients (right table, USDA nutrient data). In a 100 g serving, peanuts provide 570 calories and are an excellent source (defined as more than 20% of the Daily Value, DV) of several B vitamins, vitamin E, several dietary minerals, such as manganese (95% DV), magnesium (52% DV) and phosphorus (48% DV), and dietary fiber (right table). They also contain about 25 g protein per 100 g serving, a higher proportion than in many tree nuts (http://nutritiondata.self.com).

Some studies show that regular consumption of peanuts is associated with a lower risk of mortality specifically from certain diseases. However, the study designs do not allow cause and effect to be inferred. According to the US Food and Drug Administration, "Scientific evidence suggests but does not prove that eating 1.5 ounces per day of most nuts (such as peanuts) as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease." (http://lpi.oreggonstate.edu.).

Uses

Peanut oil (cooking), Peanut flour, Boiled peanuts (Snack), Peanut flour, Dry-roasted peanuts, Cuisine (List of peanut dishes), Malnutrition, Animal feed etc.

3.2.5.4 Dates

Phoenix dactylifera, commonly known as date or date palm (Plate 13), is a flowering plant species in the palm family, Arecaceae, cultivated for its edible sweet fruit. Although its place of origin is unknown because of long cultivation, it probably originated from lands around.

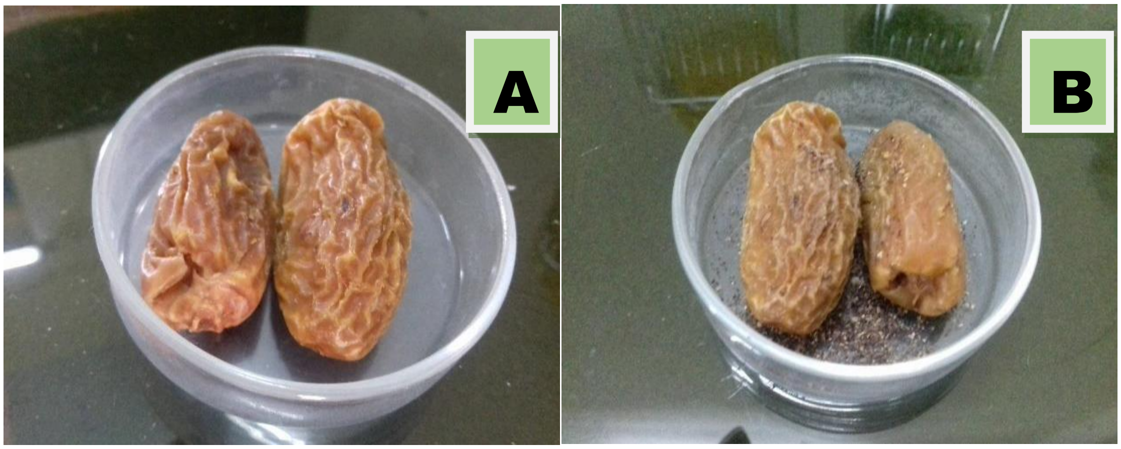

Plate 13: Healthy Dates **(A)** and Infested Dates **(B)** by dried fruit beetle

Importance

Dates are a good source of various vitamins and minerals. It is also a good source of energy, sugar and fiber. Essential minerals as calcium, iron, phosphorus, sodium, potassium, magnesium and zinc can be found in them. They also contain vitamins such as thiamin, riboflavin, niacin, folate, vitamin A and vitamin K.

Uses

In Bangladesh special occasions such as Ramadan, it is traditional to eat a date first.

3.2.6 Adult mortality and new emergence

Ten gm of insect free different tested dried fruit and nuts were taken into each plastic container separately. Then 5 pairs of newly emerged adult beetle were released carefully into each container. Insect mortality was recorded at 4 days intervals up to 30 days. The container was observed from outside to examine death of released beetle. The mortality of the adult was recorded from almond, cashew nut, ground nut and dried dates.

The adult mortality was recorded and converted into percent.

$$\text{Percent of mortality} = \frac{\text{No. of dead insects}}{\text{Total no. of insects}} \times 100$$

After 28 – 35 days, new adults started emerging from those dried fruit and nuts. The counting of emerged adult beetle was made by opening the net. After beginning, few beetles came out from the plastic container at first and the rest of them came out after shaking of container gently.

3.2.7 Extent of damage and weight loss of different spices

The final weight of dried fruits was taken to obtain weight loss. Sieving and winnowing was done to clean the dried fruits. The clean dried fruits except those having holes in each container were weighted separately. The weight losses of dried fruits were found out by subtracting the final weight from the initial weight (10 g). The weight losses were converted into percentage of weight loss of dried fruits. The percentage of weight loss was calculated as follows:

$$\text{\% Infestation (by weight)} = \frac{\text{Weight of infested dried fruits}}{\text{Total weight of dried fruits}} \times 100$$

$$\text{\% Weight loss due to infestation} = \frac{\text{Initial weight of dried fruits} - \text{Final weight of dried fruits}}{\text{Initial weight of dried fruits}} \times 100$$

3.2.8 Statistical Analysis

The observed data were statistically analyzed following Completely Randomized Design (CRD). Mean values were separated by Duncan's Multiple Range Test (DMRT) (Duncan, 1951). All statistical analysis was done through a package program namely MSTAT-C computer package.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study on biology of dried fruit beetle, *Carpophilus hemipterus* (L) and its damage assessment on different dried fruit and nuts in the laboratory. The results have been presented and discussed under the following headings and sub headings:

4.1 Biology of dried fruit beetle, *Carpophilus hemipterus* (F.) on cashew nut in laboratory

4.1.1 Mating and Oviposition

Males and females mated more than one times. Mating occurs within 2-3 days after adult emergence. The adult female beetle laid 180-260 eggs with an average of 211.00 eggs throughout up to 4 days and number of laid egg per day was 52.75±9.26 in Table 1. *C. hemipterus* laid eggs singly. The eggs of *C. hemipterus* are white in color and become dull in color before hatching. Females normally mate with 2 males, and males normally mate at least 6 times (Ashworth, 1993; Papadopoulou, 2006).

Table 01. Day specific fecundity in terms of laid eggs of dried fruit beetle, *C. hemipterus* (L) on cashew nut in laboratory condition

Insect	Number of laid eggs				Total number of egg	Number of laid eggs/day Mean ± SD
	1st day	**2nd day**	**3rd day**	**4th day**		
1st pair	35	45	57	43	180	45.00±9.09
2nd pair	40	60	65	50	215	53.75±11.09
3rd pair	40	58	58	47	205	51.25±9.43
4th pair	37	60	60	50	195	48.75±9.43
5th pair	53	72	78	72	260	65.00±11.92
Average	41	54	63.6	52.4	211	**52.75±9.26**

4.1.2 Developmental period of different life stages

Average incubation period was 2.60 ± 1.21 days on cashew nut in laboratory condition. The newly hatched larva is white with a light brown head. Total 8.20 ± 1.06 and 3.40 ± 1.32 days, were required for larval stage and pupal stage respectively. Adult longevity of dried fruit beetle, *C. hemipterus* (L) was 153.60 ± 25.32 in Table 02.

Table 02. Developmental period of different life stages of dried fruit beetle, *C. hemipterus* (L) on cashew nut in laboratory condition

Development stage	Duration (days)	Data range	Statistics
Incubation period	2.60 ± 1.21	1-5	P<0.003
Larval period	8.20 ± 1.06	4-14	P<0.005
Pupal period	3.40 ± 1.32	3-4	P<0.001
Adult longevity	153.60 ± 25.32	120-180	P<0.007

4.1.3 Newly hatched larvae

From table 3 and figure 1 it was observed that, at 1st, 2nd, 3rd and 4th day the numbers of newly hatched larvae were 28-37, 35-55, 48-60 and 30-56, respectively. The total highest number of larvae hatched in Set-V (202) and the total lowest number (141) of larvae hatched in Set-I with an average number of larvae hatched (50.50) throughout a period of up to 4 days and average number of larvae per day (42.40).

Table 03. Day specific fecundity in terms of newly hatched larvae of dried fruit beetle on cashew nut in laboratory condition

Set/Replication	Number of newly hatched larvae				Total number of larvae	Average number of larvae/day
	1st day	2nd day	3rd day	4th day		
I	28	35	48	30	141	35.25
II	30	50	54	38	172	43.00
III	35	55	50	40	180	45.50
IV	30	35	48	40	153	38.25
V	37	49	60	56	202	50.50
Average	**32.00**	**44.80**	**52.00**	**40.80**	**169.60**	**42.40**

4.1.4 Larval and pupal mortality of dried fruit beetle, *C. hemipterus* (L) at different days during the study period

Larval mortality

The highest percentage (21.43%) of larval mortality was observed from set-V, whereas the lowest percentage (12.90%) of larval mortality was observed from set-II (Figure 1a and 1b), with total average number of larval mortality 11.00 (Appendix I).

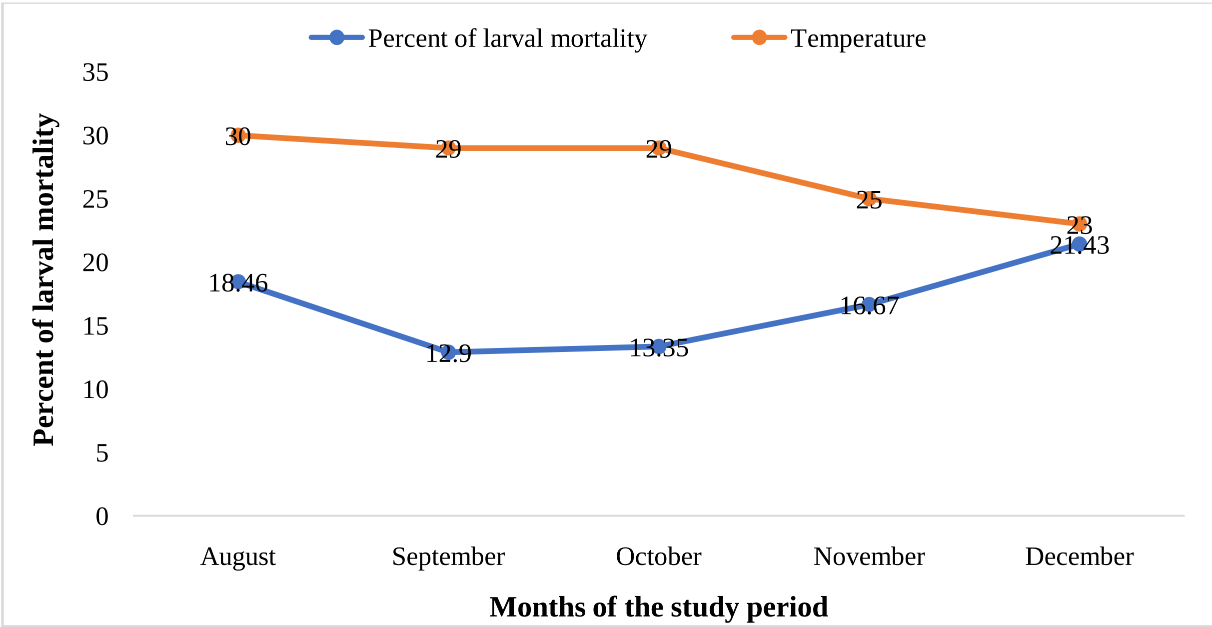

Figure 1a. Larval mortality of dried fruit beetle, *C. hemipterus* (L) on cashew nut at different temperatures during the study period

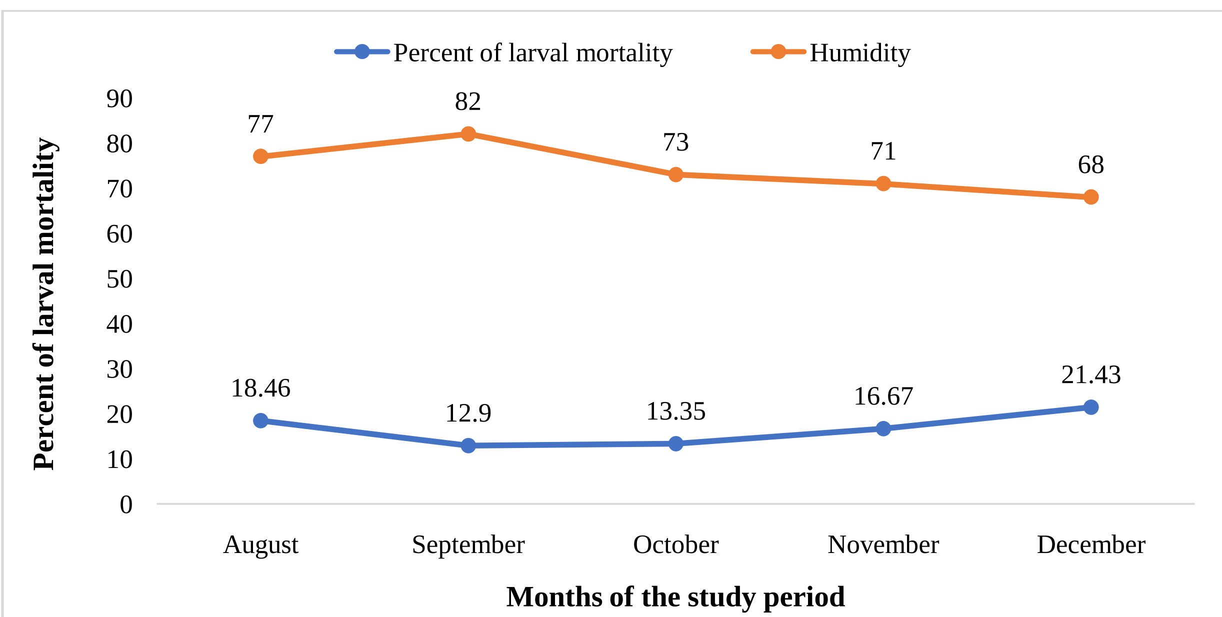

Figure 1b. Larval mortality of dried fruit beetle, *C. hemipterus* (L) on cashew nut at different humidity during the study period

Pupal mortality

The highest percentage (83.36%) of pupal mortality was observed from set-III, whereas the lowest percentage (47.17%) of pupal mortality was observed from set-I (Figure 2a and 2b), with total average number of pupal mortality 35.40 (Appendix II).

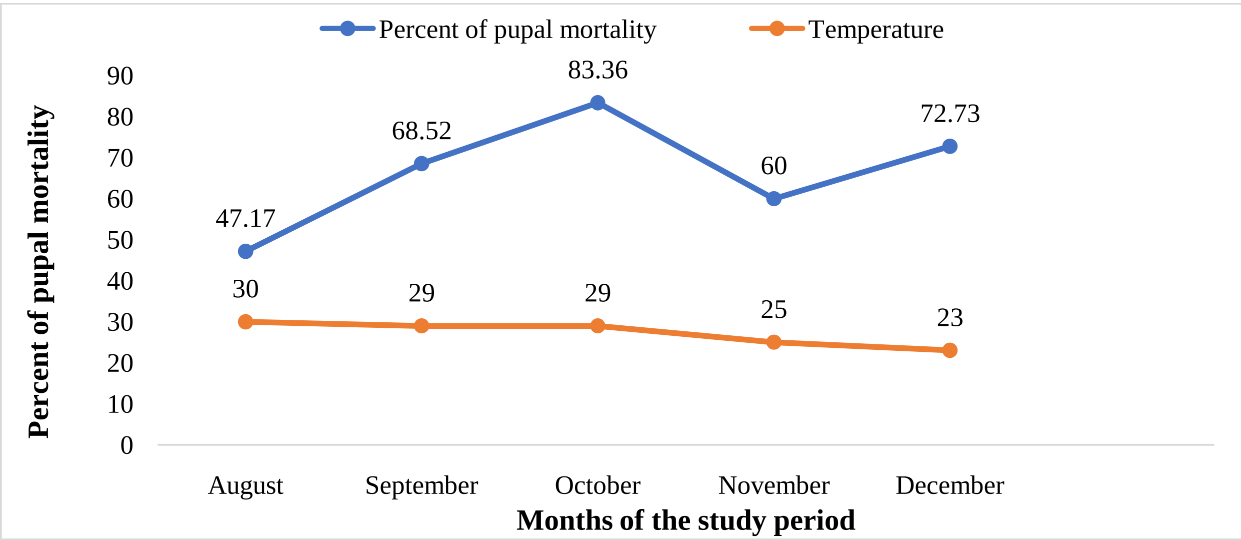

Figure 2a. Pupal mortality of dried fruit beetle, *C. hemipterus* (L) at different temperatures during the study period

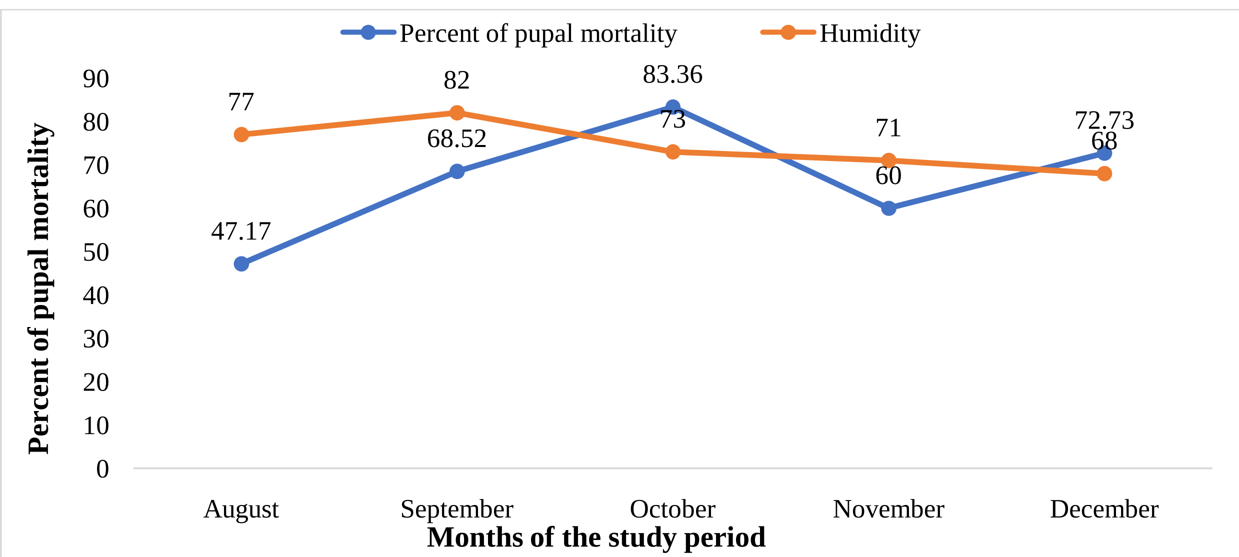

Figure 2b. Pupal mortality of dried fruit beetle, *C. hemipterus* (L) at different humidity during the study period

4.1.5 Newly formed pupae

From table 4 and figure 2 it was observed that, at 1st, 2nd, 3rd and 4th day the numbers of newly formed pupae were 23-32, 32-50, 44-54, and 27-52, respectively. The total highest number of pupae formed in Set-V (183) and the total lowest number (126) of pupae formed in Set-I with an average number of pupae formed (45.75) throughout a period of up to 4 days and average number of pupae per day (38.85).

Table 04. Day specific fecundity in terms of newly formed pupae of dried fruit beetle on cashew nut in laboratory condition

Set/ replication	Number of newly formed pupae				Total number of pupae	Average number of pupae/day
	1st day	2nd day	3rd day	4th day		
I	23	32	44	27	126	31.50
II	30	46	50	35	161	40.25
III	32	50	49	37	168	42.00
IV	26	32	44	37	139	34.75
V	32	45	54	52	183	45.75
Average	**28.60**	**41.00**	**48.20**	**37.60**	**155.40**	**38.85**

4.1.6 Newly adult emergence

From table 5 it was observed that, at 1st, 2nd, 3rd and 4th day, the numbers of newly emerged adults were 13-18, 21-37, 34-40, and 22-44, respectively. The total highest number of adults emerged in Set-V (135) and the total lowest number (96) of adults emerged in Set-I with an average number of adults emerged (33.75) throughout a period of up to 4 days on cashew nut in laboratory condition and average number of adults per day (28.65).

Table 05. Day specific fecundity in terms of newly emerged adults of dried fruit beetle on cashew nut in laboratory condition

Set/ replication	Number of newly emerged adults				Total number of adults	Average number of adults/day
	1st day	2nd day	3rd day	4th day		
I	13	25	36	22	96	24.00
II	18	31	40	32	121	30.25
III	15	37	34	33	119	29.75
IV	17	21	34	30	102	25.50
V	18	34	39	44	135	33.75
Average	**16.20**	**29.60**	**36.60**	**32.20**	**114.60**	**28.65**

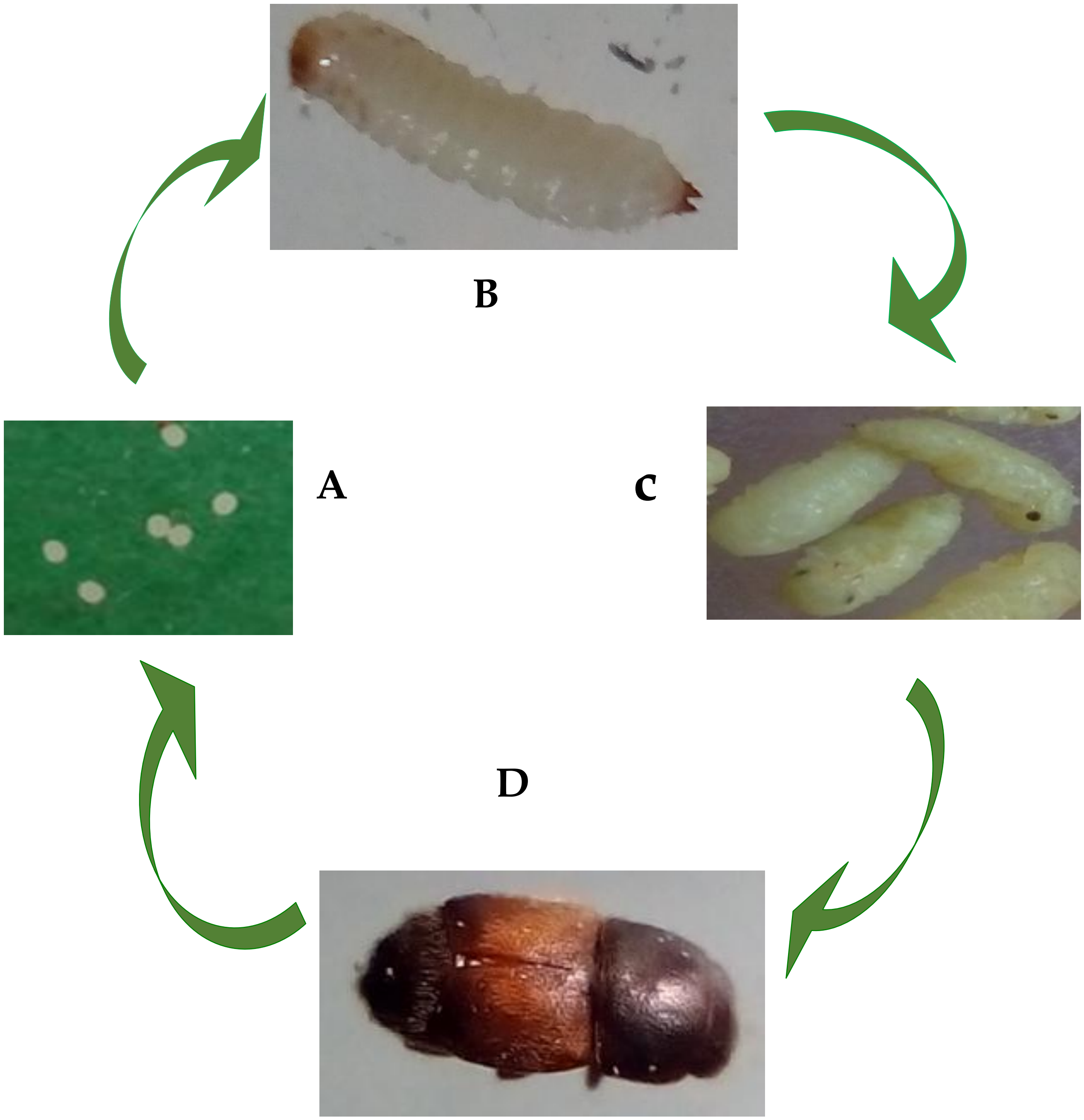

Plate 14: Life cycle of dried fruit beetle, *C. hemipterus* (L), **A.** Egg, **B.** Larva, **C.** Pupa and **D.** Adult

4.2 Damage assessment of Dried fruit beetle, *C. hemipterus* in different dried fruits

4.2.1 Adult emergence

At 30 days after adult released, the highest number of adults emerged were recorded in cashew nut (30.00) which was followed by Almond (18.00), Ground nut (19.00), respectively and statistically different from all other dried fruits. Similar trend of results also observed, at 60 days after adult released (DAAR), in the term of number of adult emerged, longevity and mortality (Table 06).

Table 06. Effect of different for dried fruits adult emerged, longevity and mortality of dried fruit beetle at different days after adult released in stored conditions

Dried Fruits	At the day after adult released (DAAR)					
	30 DAAR			60 DAAR		
	Adult emerged (No.)	Adult longevity	Adult mortality	Adult emerged (No.)	Adult longevity	Adult mortality
Almond	18.00 b	12.00 ab	11.00 a	7.00 d	14.00 a	6.00 bc
Cashew nut	30.00 a	13.00 a	9.00 bc	25.00 a	12.00 b	8.00 a
Ground nut	19.00 b	11.00 bc	10.00 ab	15.00 b	10.00 c	5.00 c
Dates	15.00 c	10.00 c	8.00 c	10.00 c	11.00 bc	7.00 ab
$LSD_{(0.01)}$	**2.993**	**1.847**	**1.460**	**1.847**	**1.728**	**1.131**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
CV(%)	**7.90**	**8.70**	**8.32**	**7.02**	**7.96**	**9.42**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 5 replications

4.2.2 Status of different dried fruits in 30,60 and 90 days after adult released by weight basis

4.2.2.1 Study of 30 days after adult released of *C. hemipterus*

Status of different dry fruit and nuts in terms of healthy infested and % infestation showed statistically by significant variation (Table 07 to Table 08) under the present trial for the damage assessment of different stored dried fruit and nuts by dried fruit beetle, *C. hemipterus*.

Table 07. Effect of different dried fruits on percent infestation and total weight of dried fruits caused by dried fruit beetle in stored condition at 30 days after adult released

Dried Fruits	Total weight of dried fruits		Infestation (%)
	Healthy (g)	Infested (g)	
Almond	7.10 b	2.19 c	23.60 c
Cashew nut	3.40 d	5.50 a	61.83 a
Ground nut	6.16 c	3.53 b	36.43 b
Dates	8.35 a	1.50 d	15.25 d
$LSD_{(0.01)}$	**0.492**	**0.405**	**2.786**
Significance level	**0.01**	**0.01**	**0.01**
CV (%)	**4.26**	**6.87**	**4.40**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 5 replications

In 30 days after adults released on weight basis, the highest weight of healthy fruit (8.35 g) was recorded in Dates, which were closely followed by almond (7.10 g). The lowest was observed in Cashew nut (3.40 g). The highest weight of infested dried fruit was observed in

Cashew nut (5.50 g). The lowest weight of infested dried fruit was recorded in Dates (1.50 g). Considering % infestation, the highest infestation was recorded from cashew nut (61.83%). while the lowest percent of infestation was recorded in dates (15.25 %) in Table 07.

4.2.2.2 At 60 days after adult released of dried fruit beetle, *C. hemipterus*

In 60 days after adult released on weight basis, the highest weight of healthy fruit were dates (4.00g) respectively, which was closely followed by almond (2.30g) and ground nut (2.10g) statistically different from other dried fruits. The lowest was observed in cashew nut (1.05g).

Table 08. Effect of different dried fruits on percent infestation and total weight of dried fruits caused by dried fruit beetle in stored condition at 60 days after adult released

Dried Fruits	**Total weight of dried fruits**		**Infestation (%)**
	Healthy (g)	**Infested (g)**	
Almond	2.30 b	6.25 b	73.16 b
Cashew nut	1.05 c	7.10 a	87.13 a
Ground nut	2.10 b	5.40 c	71.98 b
Dates	4.00 a	4.50 d	52.94 c
$LSD_{(0.01)}$	**0.330**	**0.383**	**2.915**
Significance level	**0.01**	**0.01**	**0.01**
CV (%)	**7.56**	**3.59**	**2.21**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 5 replications

In case of infested dried fruits, the highest weight of infested dried fruit was observed in cashew nut (7.10g) which was followed by almond (6.25g). Whereas almond was statistically identical by groundnut (5.40g). The lowest weight of infested dried fruit was recorded in dates (4.50). Consideration of % infestation, the highest infestation was recorded from cashew nut (87.13%) which was statistically different from other dried fruits and followed by almond (73.16%) and ground nut (71.98%) while low percent of infestation was recorded in date (52.94%) in Table 08.

4.2.2.3 Study of 90 days after adult released of dried fruit beetle, *C. hemipterus*

At 90 days after adult released, in case of healthy dried fruit, there were no healthy dried fruit were recorded from almond, cashew nut, ground nut, dates. But In case of percent of infestation, 100% infestation was occurred in all types of dried fruit in Table 09.

Table 09. Effect of different dried fruits on percent infestation and total weight of dried fruits caused by dried fruit beetle in stored condition at 90 days after adult released

Dried Fruits	Total weight of dried fruits		Infestation (%)
	Healthy (g)	Infested (g)	
Almond	0.00	2.11 b	100
Cashew nut	0.00	1.00 c	100
Ground nut	0.00	2.00 b	100
Dates	0.00	2.70 a	100
$LSD_{(0.01)}$	**--**	**0.194**	**--**
Significance level	**--**	**0.01**	**--**
CV (%)	**--**	**5.45**	**--**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 5 replications

4.2.3 Weight loss of different dried fruits due to *C. hemipterus*

The highest weight loss (11.00%) was observed in cashew nut and the lowest weight loss (1.50%) was observed in dates, caused by dried fruit beetle, *C. hemipterus* at 30 days after adult released (Table 10).

From Table10, at 60 days after adult release the highest weight loss (29.33%) was recorded in ground nut and the lowest weight loss (8.78%) was recorded in almond.

Table 10. Weight loss of different dried fruits caused by dried fruit beetle on at 30, 60 and 90 days after adult released in stored conditions

Dried Fruits	**Percentage of weight loss at**		
	30 DAAR	**60 DAAR**	**90 DAAR**
Almond	7.10 ab	8.78 b	75.31 b
Cashew nut	11.00 a	9.16 b	87.74 a
Ground nut	3.10 b	29.33 a	73.21 b
Dates	1.50 b	15.92 b	68.20 c
$LSD_{(0.01)}$	**6.60**	**8.29**	**3.59**
Level of Significance	**0.01**	**0.01**	**0.01**
CV(%)	**12.99**	**8.39**	**2.56**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.01 level of probability and numeric data represents the mean value of 5 replications

At 90 days after adult release the highest weight loss (87.74%) was observed in Cashew nut, whereas the lowest weight loss (68.20%) in dates, respectively. The insect generations developed on the dried fruit and the loss increased with the number of generations consistently.

4.2.4 Correlation between percent of infestation and weight loss of almond by *C. hemipterus*

Correlation study was done to establish the relationship between percent of infestation and weight loss of almond. From the figure 03, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 34.956x - 38.2 gave a good fit to the data and the co-efficient of determination R^2 = 0.9806 fitted regression line had a significant regression co-efficient. It may be concluded from the figure that percent of infestation was strongly as well as positively correlated with weight loss of dried fruit. Weight loss of almond was increased due to increase of percent of infestation.

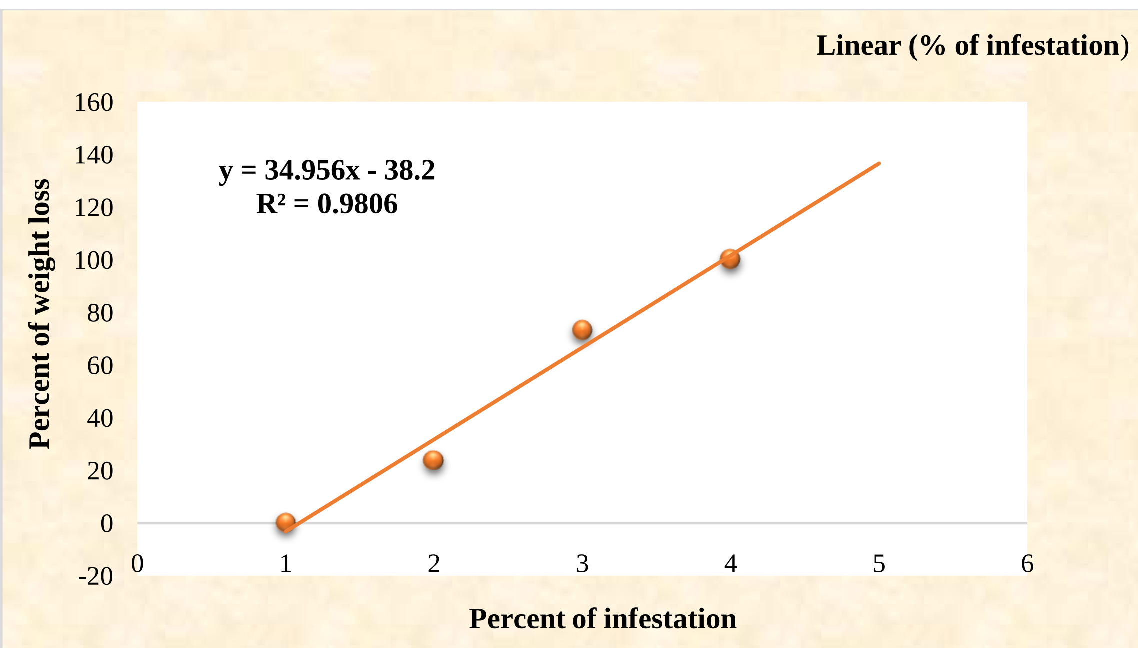

Figure 03: Relationship between percent of infestation and weight loss of almond by *C. hemipterus* at 30, 60 and 90 days after adult released

4.2.5 Correlation between percent of infestation and weight loss of cashew nut by *C. hemipterus*

Correlation study was done to establish the relationship between percent of infestation and weight loss of cashew nut. From the figure 04, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 32.53x - 19.085 gave a good fit to the data and the co-efficient of determination R^2 = 0.8939 fitted regression line had a significant regression co-efficient. It may be concluded from the figure that percent of infestation was strongly as well as positively correlated with weight loss of dried fruit. Weight loss of cashew nut was increased due to increase of percent of infestation.

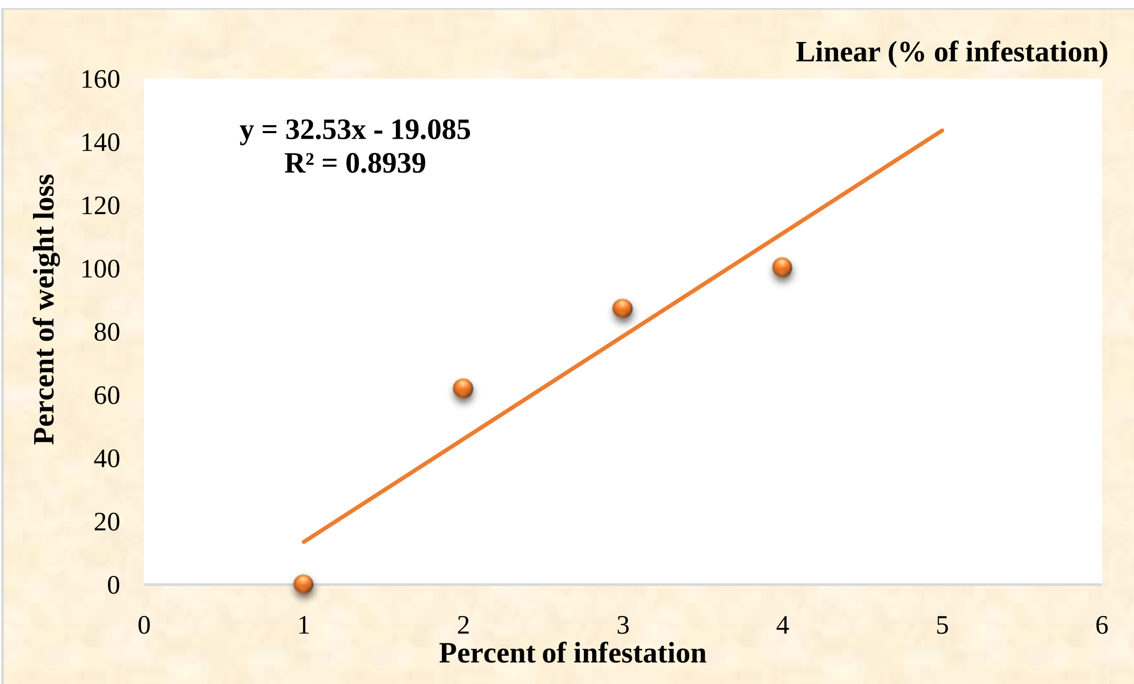

Figure 04: Relationship between percent of infestation and weight loss of cashew nut by *C. hemipterus* at 30, 60 and 90 days after adult released

4.2.6 Correlation between percent of infestation and weight loss of ground nut by *C. hemipterus*

Correlation study was done to establish the relationship between percent of infestation and weight loss of ground nut. From the figure 05, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 33.555x - 31.785 gave a good fit to the data and the co-efficient of determination R^2 = 0.9965 fitted regression line had a significant regression co-efficient. It may be concluded from the figure that percent of infestation was strongly as well as positively correlated with weight loss of dried fruit. Weight loss of ground nut was increased due to increase of percent of infestation.

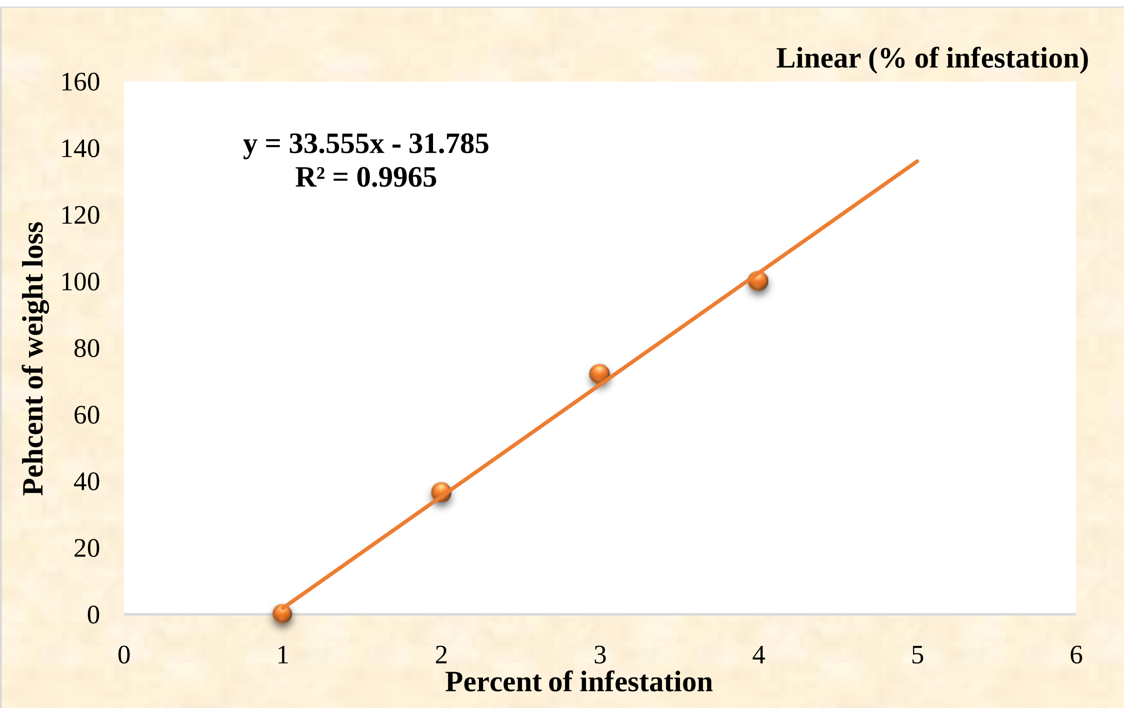

Figure 05: Relationship between percent of infestation and weight loss of ground nut by *C. hemipterus* at 30, 60 and 90 days after adult released

4.2.7 Correlation between percent of infestation and weight loss of dates by *C. hemipterus*

Correlation study was done to establish the relationship between percent of infestation and weight loss of dates. From the figure 06, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 33.769x - 42.375 gave a good fit to the data and the co-efficient of determination R^2 = 0.9561 fitted regression line had a significant regression co-efficient. It may be concluded from the figure that percent of infestation was strongly as well as positively correlated with weight loss of dried fruit. Weight loss of ground nut was increased due to increase of percent of infestation.

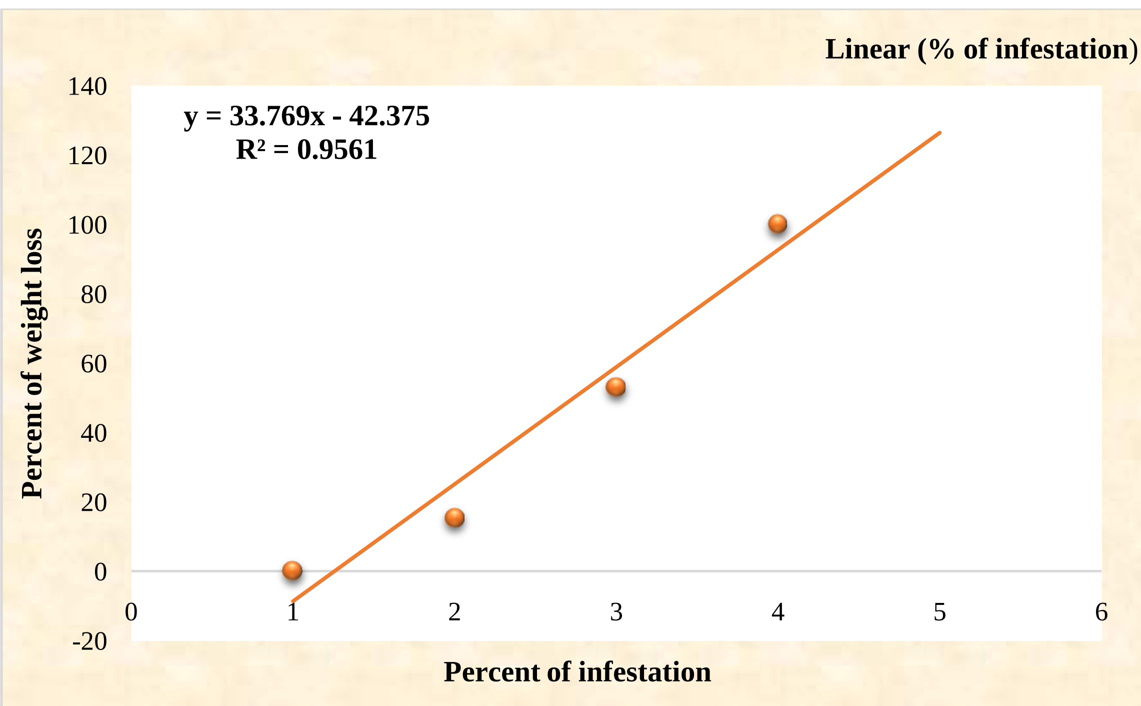

Figure 06: Relationship between percent of infestation and weight loss of dates by *C. hemipterus* at 30, 60 and 90 days after adult released

CHAPTER V

SUMMARY AND CONCLUSION

Two experiments were conducted in the laboratory of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from January to June, 2017 to damage assessment and study on the biology of Dried fruit beetle, *Carpophilus hemipterus* in different dried fruit and nuts Cashew nut, almond, ground nut, and dates were used as experimental materials.

Experiment1: Study on the biology of dried fruit beetle, *C. hemipterus* in the laboratory

Mating occurs within 2-3 days after adult emergence. The adult female beetle laid 180-260 eggs with an average of 52.75±9.26 eggs throughout up to 4 days. An average incubation period was 2.60 ± 1.21 days respectively on cashew nut in laboratory condition. Total 8.20 ± 1.06 and 3.40 ± 1.32 days were required for larval stage and pupal stage respectively. Adult longevity of dried fruit beetle, *C. hemipterus* was 153.60 ± 25.32 at 23-30^{0}c temperatures and 68-87% humidity.

At 1st, 2nd, 3rd and 4th day the number of newly hatched larvae ranges were 28-37, 35-55, 48-60 and 30-56, respectively, with an average number of larvae hatched (42.40) throughout up to 4 days.

There is a special characteristic of pupa of dried fruit beetle that 5th instar larvae create chambers for pupation. In chambers they spend their pupal life that is inactive stage of their life cycle.

At 1st, 2nd, 3rd and 4th day, the number of newly formed pupae ranges were 23-32, 32-50, 44-54, and 27-52, respectively, with an average number of pupae emerged (38.85) throughout up to 4 days.

At 1st, 2nd, 3rd and 4th day the number of newly emerged adult's ranges was 13-18, 21-37, 34-40, and 22-44, respectively. The highest average number of adults emerged in Set-V (135) and the lowest average number (96) of adults emerged in Set-I with an average number of adults emerged (28.65) throughout up to 4 days on cashew nut in laboratory condition.

Experiment 2: The extent of damage of dried fruits due to infestation by dried fruit beetle, *C. hemipterus*

At 30 days after adult released, the highest number of adults was recorded in cashew nut (30.00) which was followed by almond, ground nut, (18 and 19) respectively and statistically different from all other dried fruits. At 60 days after adult released in cashew nut adult emergence was almost four times higher than 30 days. Whereas adult emergence was lower in dates (10) at 60 days after adults released.

At the 30 days after adult released, on weight basis, the highest weight of healthy dried fruits (8.35 g) were recorded in dates, which were closely followed by almond (7.10g).

The lowest was observed in cashew nut (3.40 g). The highest weight of infested dried fruit was observed in cashew nut (5.50 g). The lowest weight of infested dried fruit was recorded in dates (1.50 g). Consideration of % infestation, the highest infestation was recorded from cashew nuts (61.83%), while low percent of infestation was recorded in dates (15.25 %).

At 60 days after adult released, on weight basis, the highest weight of healthy dried fruits were dates (4.00g) respectively, which was closely followed by almond (2.30g) and groundnut (2.10g) statistically different from other dried fruits. The lowest was observed in cashew nut (1.05g). In case of infested dried fruits, the highest weight of infested dried fruit was observed in cashew nut (7.10g) which was followed by almond (6.25g). Whereas, almond was statistically identical by groundnut (5.40g). The lowest weight of infested dried fruit was recorded in dates (4.50). Consideration of % infestation, the highest infestation was recorded from cashew nut (87.13%) which was statistically different from other dried fruits and followed by almond (73.16%) and ground nut (71.98%), while low percent of infestation was recorded in dates (52.94%).

At 90 days after adult released, in case of healthy dried fruit, there were no healthy dried fruit were recorded from almond, cashew nut, ground nut, dates. But In case of percent of infestation, 100% infestation was occurred in all types of dried fruit.

In case of weight loss, at 30 days after adult released the highest weight loss (11.00%) was observed in cashew nut and the lowest weight loss (1.50 %) was observed in dates caused by dried fruit beetle, *C. hemipterus*. From 60 days the highest weight loss (29.33%) was recorded in ground nut and the lowest weight loss (8.78%) was recorded in almond. At 90 days, the highest weight loss (87.74%) was observed in cashew nut, whereas the lowest weight loss (68.20%) in dates, respectively. The insect generations developed on the dried fruits and the loss increased with the number of generations consistently.

CONCLUSION

The dried fruit beetle, *Carpophilus hemipterus* is one of the most serious pests of different dried fruit and nuts at post harvest level. The beetle develops through egg, five larval instars, pupa, pre-pupa and adult stages. The total duration for larval stage development were 8.20 ± 1.06 days and for pupal stage, it was 3.40 ± 1.32 days. Adult longevity of dried fruit beetle was 153.60 ± 25.32 days.

Considering the adult mortality, adult emerged of dried fruit beetle, weight of healthy and infested dried fruit and nuts and percent infestation, the study revealed that the highest damage occurred in cashew nut and lowest damage occurred in dates respectively by dried fruit beetle, *C. hemipterus.* Information on the biology and host infestation pattern of *C. hemipterus* may help to explain how various stored commodities are affected by this dried fruits and nuts; and may angst to develop appropriate pest management strategies for this insect pest.

CHAPTER VI

RECOMMENDATION

Considering the situation of the present experiment, further study in the following areas may be conducted:

➢ Influence or impact of different environmental factors may be studied the biology of the pest in different seasons of the year

➢ Studies on the efficiency of different control measures of stored dried fruits and nuts pests.

CHAPTER VII

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Appendixes

Appendix I. Day specific mortality of larvae of dried fruit beetle on cashew nut in laboratory condition

Sample	Mortality of larvae			Total mortality of larvae	Percent of larval mortality
	1st day	2nd day	3rd day		
I	5	3	4	12	18.46
II	0	4	4	8	12.90
III	3	5	1	9	13.35
IV	4	3	4	11	16.67
V	5	4	6	15	21.43
Average	**3.40**	**3.80**	**3.80**	**11.00**	**16.56**

Appendix II. Day specific mortality of pupae of dried fruit beetle on cashew nut in laboratory condition

Sample	Mortality of larvae			Total mortality of larvae	Percent of larval mortality
	1st day	2nd day	3rd day		
I	10	7	8	25	47.17
II	12	15	10	37	68.52
III	17	13	15	45	83.36
IV	9	11	10	30	60.00
V	14	11	15	40	72.73
Average	**12.40**	**11.40**	**11.60**	**35.40**	**66.36**

Appendix III. Average temperature and humidity at the different month during the study period

Month	Average Temperature	Average Humidity
August	30	77
September	29	82
October	29	73
November	25	71
December	23	68