SURVEY, DAMAGE ASSESSMENT AND BIOLOGY STUDY OF SAW-TOOTHED GRAIN BEETLE, *ORYZAEPHILUS SURINAMENSIS*

FARHANA TAZBIAN

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

DECEMBER, 2016

SURVEY, DAMAGE ASSESSMENT AND BIOLOGY STUDY OF SAW-TOOTHED GRAIN BEETLE, *ORYZAEPHILUS SURINAMENSIS*

BY

FARHANA TAZBIAN
REG. NO.: 15-06943

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JULY-DECEMBER, 2016

APPROVED BY:

……..	……
(Prof. Dr. Mohammed Ali)	**(Prof. Dr. Tahmina Akter)**
Supervisor	Co-Supervisor
Department of Entomology	Department of Entomology
SAU, Dhaka -1207	SAU, Dhaka-1207

……..
Dr. Mst. Nur Mahal Akter Banu
Chairman
Department of Entomology
&
Examination Committee

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **'Survey, Damage Assessment and Biology Study of Saw-toothed Grain Beetle, *Oryzaephilus surinamensis*'** 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 *bonafide* research work carried out by **Farhana Tazbian**, Registration number: **15-06943** 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: December, 2016
Dhaka, Bangladesh

Prof. Dr. Mohammed Ali
Supervisor

Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka-1207

Dedicated to
My
Beloved Parents

ACKNOWLEDGEMENTS

The author first wants to articulate her enormous wisdom of kindness to the Almighty Allah for His never ending blessing, protection, regulation, perception and assent to successfully complete of research and prepare thesis.

The author likes to express her deepest sense of gratitude to her respected Supervisor **Prof. Dr. Mohammed Ali,** Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period for his gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.

The author expresses the deepest sense of gratitude, sincere appreciation and heartfelt indebtedness to her respected Co-Supervisor **Prof. Dr. Tahmina Akter** Department of Entomology, SAU, Dhaka for her scholastic guidance, innovative suggestion, constant supervision and inspiration, valuable advice and helpful criticism in carrying out the research work and preparation of this manuscript.

The author expres the sincere respect to the **Dr. Mst. Nur Mohal Akhter Banu,** Chairman, Examination Committee, Department of Entomology, SAU, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.

The author also expresses heartfelt thanks to all the teachers of the Department of Entomology, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author expresses her sincere appreciation to her brother, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The author

Date: December, 2016

LISTS OF ABBREVIATIONS

Abbreviation	Full word
et al.	and others
CV	Co-efficient of Variation
CRD	Completely Randomized Design
g	Gram
i.e.,	Id est
J.	Journal
LSD	Least significant difference
viz.	Videlicet

SURVEY, DAMAGE ASSESSMENT AND BIOLOGY STUDY OF SAW-TOOTHED GRAIN BEETLE, *ORYZAEPHILUS SURINAMENSIS*

ABSTRACT

Biology and damage assessment of saw-toothed grain beetle, *Oryzaephilus surinamensis* were studied on the different dried fruit and nuts in the laboratory during August 2016 to December 2016.Cashew nut, almond, ground nut, nut meg and dates were used as experimental materials. Experiments were laid out in a completely randomized design (CRD) with five replications. Four major markets of Dhaka city were selected for survey and samples were collected from those markets to detect the infestation of saw-toothed grain beetle. The highest percent of infestation on saw-toothed grain beetle was found at Kawran bazar (7.5%) in cashew nut. In the biological study the adult female beetle laid 103-118 eggs. The ovipositional, incubation, larval, pupal periods and the adult longevity were 10.20±1.93, 8.60± 1.97, 18.20 ± 1.93, 7.80 ± 1.50 and 90.00 ± 1.21 days, respectively. Morphometric measurement of different life stages of the beetle were also recorded. Infestation was the highest (19.18%) in cashew nut at 1^{st} generation of the beetle and it raised up to (75.29%) in cashew nut also at 2^{nd} generation. Whereas the lowest infestation was recorded in dates (8.44%) and (20.23%) at 1^{st} and 2^{nd} generations respectively. The highest weight loss was found in almond (4.90%) and (6.81%) in ground nut respectively and the lowest were recorded in dates at 1^{st} and 2^{nd} generations respectively.

TABLE OF CONTENTS

CHAPTER	TABLE	PAGE
	AKNOWLEDGEMENTS	**i**
	LIST OF ABBREVIATIONS	**ii**
	ABSTRACT	**iii**
	TABLE OF CONTENTS	**iv-viii**
	LIST OF TABLES	**ix- x**
	LIST OF FIGURS	**xi**
	LIST OF PLATES	**xii- xiii**
	LIST OF APPENDICES	**xiv**
I	**INTRODUCTION**	**1-3**
II	**REVIEW OF LITERATURE**	**4-18**
	2.1 Origin and distribution of saw-toothed grain beetle, *Oryzaephilus surinamensis*	5
	2.2 Host of saw-toothed grain beetle, *Oryzaephilus surinamensis*	6
	2.3 Transmission	6
	2.4 Systematic Position	7
	2.5 Taxonomy	7
	2.6 Sites of infestation	8
	2.7 Stages of development	8
	2.8 Biology of saw-toothed grain beetle	8
	2.9 Nature and extent of damage	13
	2.10 Effects of environment on pest survival	14
	2.11 Factors regulating loss in storage	14
	2.12 Storage structure for protection	17-18

CHAPTER	TABLE	PAGE
III	**MATERIALS AND METHODS**	**19-37**
	Experiment 1: Survey and identification of insect pests in dried fruits and nuts from different local markets of the Dhaka city	19
	3.1 Study area	19
	3.2 Sample collection	21
	3..3 Rearing and data collection	21
	Experiment 2: Study on the biology of saw-toothed grain beetle, *Oryzaephilus surinamensis* in the laboratory	21
	3.2.1 Test insect collection	21
	3.2.2 Stock culture of saw-toothed grain beetle	21
	3.2.3 Collection of eggs for the study of biology	23
	3.2.4 Biology of saw-toothed grain beetle	23
	3.2.5 Design of the experiment	24
	3.2.6 Data recorded	24
	Experiment 3: The extent of damage of dried fruits and nuts due to infestation by saw-toothed grain beetle, *Oryzaephilus surinamensis*	27
	3.3.1 Preparation of test materials	28
	3.3.2 Collection of saw-toothed grain beetle	28
	3.3.3 Experimental design and layout	28

CHAPTER	TABLE	PAGE
	3.3.4 Experimental material	28
	3.4.1 Cashew nut	30
	3.3.4.2 Almond	31
	3.3.4.3 Groundnut	33
	3.3.4.4 Meg nut	34
	3.3.4.5 Dates	35
	3.3.5 Adult mortality and new emergence	36
	3.3.6 Extent of damage and weight loss of different dried fruit and nuts	36
	3.3.7 Statistical analysis	37
IV	**RESULTS AND DISCUSSION**	**38-61**
	4.1. Survey and identification of insect pests in dried fruits and nuts from different local markets of the Dhaka city	38
	4.1.1 Species of insect pests	38
	4.1.2 Incidence of insect populations in different dried fruits and nuts	39
	4.1.3 Percent of infestation on different dried fruits and nuts due to saw-toothed grain beetle in different markets in the Dhaka city	41

CHAPTER	TABLE	PAGE
	4.2.Biology of saw-toothed grain beetle, *Oryzaephilus surinamensis* on cashew nut in laboratory	44
	4.2.1 Mating and oviposition	44
	4.2.2 Developmental period of different life stages	45
	4.2.3 Morphometric measurement of different life stages	46
	4.2.4.1 Newly hatched larvae	47
	4.2.4.2 Chamber formed by larvae of saw-toothed grain beetle before pupation	48
	4.2.5 Newly formed pupae of saw-toothed grain beetle	49
	4.2.6 Larval and pupal mortality of saw-toothed grain beetle, at different replication during the study period	50
	4.2.7 Emergence of adult	52
	4.3. Damage assessment of saw-toothed grain beetle in different Dried fruit and nuts	54
	4.3.1 Adult emergence	54
	4.3.2 Status of different dried fruits and nuts in 1st and 2nd generations by weight	55
	4.3.3 Weight loss of different dried fruit and nuts	59

CHAPTER	TABLE	PAGE
	4.3.4 Correlation between percent of infestation and weight loss of cashew nut, almond, ground nut,Nutmeg and dates at 1st generation by *O. surinamensis*	60
	4.3.5 Correlation between percent of infestation and weight loss of cashew nut, almond, ground nut, nutmeg and dates at 2nd generation by *O. surinamensis*	61
V	**SUMMARY ,CONCLUSION AND RECOMMENDATIONS**	**62-68**
	SUMMARY	62-67
	CONCLUSION	68
	RECOMMENDATIONS	68
VI	**REFERENCES**	**69-75**
VII	**APPENDICES**	**76-77**

LIST OF TABLES

SL.NO.	TABLE	PAGE
1	List of insects found in different dried fruits and nuts collected from local markets in the Dhaka city during the survey	39
2	Incidence of populations and development stages of insect saw-toothed grain beetle in different dried fruit and nuts in different local markets of the Dhaka city	40
3	Percent of infestations in different dried fruits and nuts due to saw-toothed grain beetle in Mohammadpur Town hall market	41
4	Percent of infestation in different dried fruits and nuts due to saw-toothed grain beetle in Mohammadpur Krishi Market	43
5	Percent of infestation in different dried fruits and nuts due to saw-toothed grain beetle in Kawran Bazar	43
6	Percent of infestation in different dried fruits and nuts due to saw-toothed grain beetle in Chawk Bazar	44
7	Day specific fecundity in terms of laid eggs of saw-toothed grain beetle *O. surinamensis* on cashew nut in laboratory condition	45
8	Developmental period of different life stages of saw-toothed grain beetle *O. surinamensis* on cashew nut in laboratory condition	46
9	Morphometric measurement of different life stages of saw-toothed grain beetle in the laboratory	47
10	Day specific fecundity in terms of newly hatched larvae of saw-toothed grain beetle on cashew nut in laboratory condition	48
11	Day specific fecundity in terms of newly formed pupae of saw-toothed grain beetle on cashew nut in laboratory condition	49
12	Day specific fecundity in terms of newly emerged adults of saw-toothed grain beetle on cashew nut in laboratory condition	52
13	Effect of different dried fruit and nuts for adult emerged of saw-toothed grain beetle at 1^{st} and 2^{nd} generation in stored conditions	54

SL.NO.	TABLES	PAGE
14	Effect on different dried fruits and nuts on percent infestation and total weight caused by saw-toothed grain beetle in stored condition at 1st generation	56
15	Effect on different dried fruit and nuts on percent infestation and total weight caused by saw-toothed grain beetle in stored condition at 2nd generation	57
16	Weight loss of different dried fruit and nuts caused by saw-toothed grain beetle at 1st and 2nd generations in stored conditions	59

LIST OF FIGURES

SL. NO.	FIGURE	PAGE
1	Map showing the places of sample collection	20
2	Percent of infestation caused by saw-toothed grain beetle in different dried fruits and nuts in different local markets of Dhaka city	42
3	Larval mortality of saw-toothed grain beetle, at different replication during the study period	50
4	Pupal mortality of saw-toothed grain beetle, at different replication during the study period	51
5	Relationship between percent of infestation and weight loss of cashew nut, almond, ground, nutmeg nut and dates at 1st generations by *O. surinamensis*	60
6	Relationship between percent of infestation and weight loss of cashew nut, almond, groundnut, nutmeg and dates at 2nd generation by *O. surinamensis*	61

LIST OF PLATES

SL. NO.	PLATE	PAGE
1	Stock culture of *Oryzaephilus surinamensis* in cashew nut in a petridish	22
2	Aspirator for the collection of saw-toothed grain beetle, *O. surinamensis*	22
3	Each test tube with one pair of saw-toothed grain beetle, *Oryzaephilus surinamensis* to keep for egg laying	23
4	Egg and a newly emerged larvae of saw-toothed grain beetle under the microscope	25
5	Infested cashew nut with larvae (A) of *O. surinamensis* during the study of biology in the laboratory and the microscopic view of larva (B)	25
6	Pupa of saw-toothed grain beetle in chamber on cashew nut (A) and the microscopic view of pupa (B) during the study of biology in the laboratory	26
7	Newly emerged adult (A) and mature adult (B) of saw-toothed grain beetle under the microscope	26
8	Different life stages (A) and different larval instars (B) of saw-toothed grain beetle under the microscope	27
9	Experimental set up with different dried fruits and nuts to determine the damage assessment by *O. surinamensis*	29-30

10	Healthy cashew nut (A) and infested cashew nut by saw-toothed grain beetle (B**)**	31
11	Healthy almond (A) and infested almond(B) by saw-toothed grain beetle	32
12	Healthy groundnut (A) and infested groundnut (B) by saw-toothed grain beetle	33
13	Healthy nutmeg (A) and infested nutmeg by saw-toothed grain beetle (B)	34
14	Healthy dates (A) and infested dates (B) by saw-toothed grain beetle	35
15	Chamber formed by 5^{th} instar larvae of saw-toothed grain beetle on cashew nut	48
16	Infested cashew nut with larvae and pupae of *O. surinamensis* after the 1^{st} generation	49
17	Life cycle of saw-toothed grain beetle A. Egg, B. Larva, C. Pupa and D. Adult (microscopic view)	53
18	Infested different dried fruits and nuts by saw-toothed grain beetle at the 2^{nd} generation	58

SL.NO.	Appendix	Page
I	Analysis of variance of the data on adult emerged of saw-toothed grain beetle at 1st and 2nd generations in stored conditions as influenced by different dried fruit and nuts	76
II	Analysis of variance of the data on percent infestation and total weight of dried fruit and nuts and caused by saw-toothed grain beetle in stored condition at 1st generation	76
III	Analysis of variance of the data on percent infestation and total weight of dried fruit and nuts caused by saw-toothed grain beetle in stored condition at 2nd generation	76
IV	Analysis of variance of the data on weight loss of different dried fruit and nuts caused by saw-toothed grain beetle at 1st and 2nd generations in stored conditions	77
V	Day specific mortality of larvae of saw-toothed grain beetle on cashew nut in laboratory condition	77
VI	Day specific mortality of pupae of saw-toothed grain beetle on cashew nut in laboratory condition	77

CHAPTER I

INTRODUCTION

Insect infestation in stored food products is very common not only in Bangladesh also throughout the world.The pests are now common because of huge amount of importation of dry fruit and nuts; as a result damage percentage also high in markets and home in store condition. The pests contaminate more food than they consume, and most people find the contaminated products unfit for consumption. They often accumulate in pots, pans or dishes or on window sills. Fortunately, they don't bite or sting people or pets nor do they feed on or damage the house structure or contents.

A variety of different insects attack dry fruits and nuts in storage condition and the pests are usually not noticed until they become abundant. Insects found in dry fruit and nuts are often referred to as beetle, moth and 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 that 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 and saw-toothed grain beetles are particularly common in markets and homes and are found throughout the world. More often, insects enter homes on food already infested during storage or transportation period.

The majority of damage causes through contamination. The weight of dry fruit 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 fruit and nuts spread bad smells and become less attractive for consumption.

Saw-toothed grain beetle, *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) is a serious pest of storage dried fruits.The body of the beetle is flat and slender in shape, and brown in color. The size and shape of the mandibles allow the beetles to easily break through well-sealed packaged foods. The larvae and adult both cause damage. The larvae of this pest penetrate into the dry fruit and feed endosperms, thus reducing the percentage of grains as well as deteriorate nutritional value and germination capacity (Hashem *et al*., 2012; El-Sohaimy *et al*., 2010 and Howe, 1956). The adult tends to be very active, but rarely flies. There can be as many as seven generations each year, but saw-toothed grain beetles often stop breeding in the winter, unless buildings are heated and moisture is sufficient (Jacob, 1989; Komson, 1967 and Pricket, 1990).

Once the saw-toothed grain beetle infests a food product it becomes unsalable and inedible. The saw-toothed grain beetle chews through unopened boxes, plastic wrapping, tinfoil, and paper packages. Saw-toothed grain beetle populations burgeon inside stored food, surrounding food, and food debris that have been left in crevices, corners, and cracks in pantries and cupboards. All the life stages of the saw-toothed grain beetle, including eggs, larva, and pupa, and adult, can often were found. The majority of damage these pests do is through contamination. The dry weight of grain 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). They actually spoil more food than they eat. Heavily infested seeds spread bad smells and become less attractive for consumption.

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

Objectives of the study

- To survey the insect pests in dry fruit and nuts from selected local markets in Dhaka city
- To study on the biology of saw-toothed grain beetle, *Oryzaephilus surinamensis* on storage condition of dried fruit and nuts.
- To determine the extent of damage of dried fruits due to infestation by saw-toothed grain beetle, *O. surinamensis*

CHAPTER II

REVIEW OF LITERATURE

Benefits of nuts and dried fruits may help to improve our health and to prevent some diseases when included regularly in eating habits. Because of their interesting nutritional profile, some studies have evaluated the impact that nuts have on health and have observed an inverse association between the frequency of nut consumption and cardiovascular disease, diabetes and body weight. In addition, traditional dried fruits also provide essential nutrients, such as fiber and potassium, and a wide range of phyto-chemicals that have been related to health promotion and antioxidant capacity. Both nuts and dried fruits 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. While nuts have a high energy content, several studies found that frequent nut consumption was not associated with a higher body mass index. Some research has shown that nuts may have high satiety properties. In fact, long-term nut consumption is associated with lower weight gain and overweight. 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 saw-toothed grain beetle on different dry fruit and nuts is not available in Bangladesh perspective.

2.1: Origin and Distribution of Saw-toothed grain beetle, *Oryzaephilus surinamensis*

This beetle is distributed world-wide but found in abundance in mountainous areas, where climate is rather warm and humid. *O. surinamensis* 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, biscuits,dried fruits and other grain products. It is cosmopolitan in distribution. This pest was described in 1767 from Surinam, hence named as *O. surinamensis*. The saw-toothed grain beetle is distributed throughout the world and frequently transported in grain product. The biology of *O. surinamensis* suggests a tropical or as it is most similar to an African species (*O. parallelus*) and a Middle Eastern species (*O. abeilli*) (Halstead 1980).

2.2: Host of Saw-toothed grain beetle *O. surinamensis*

Saw-toothed grain beetle can be found at the manufacturing, storage and retail levels of stored food production. In milled rice this pest was found to infest after storage of 3-4 months as a minor pest (Prakash *et al*, 1982d). But in coastal India it is found to be a regular and major pest in underground and bulk containers in some of the storage seasons. Howe (1957) in his extensive study on the biology and literature survey of *O. surinamensis* recorded a list of hosts including groundnut, coconut, sunflower, barley, 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, flax tow, flour, ginger, herbs, herbaceous specimens, insecticides containing pyrethrum, juniper seed, liquorices 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.

2.3: Transmission

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.

Establishment Potential

O. surinamensis is established in Australia.

2.4: Systematic Position

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Silvanidae

Genus: *Oryzaephilus*

Species: *Oryzaephilus surinamensis*

2.5: Taxonomy

Name and Synonyms

Oryzaephilus surinamensis (Linnaeus, 1758)

Synonyms:

Oryzaephilus bicornis Erichson, 1846

Oryzaephilus cursor Fabricius, 1792

Oryzaephilus frumentarius Fabricius, 1775

Oryzaephilus sexdentatus Fabricius 1792

Oryzaephilus sexdentatus Herbst, 1783

Common name:

Getreide-Plattkaefer , Getreide-Schmalkaefer (Germany)

Chipushitmschunenthachaze (Israel)

Silvanosurinamense (Italy)

Nokogiri-kokunusuto (Japan)

Rijstkever (Netherlands

2.6: Sites of Infection/Infestation

Saw-toothed grain 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, Lyon-undated), also chocolate-based products (Bowditch and Madden 1997).

2.7: Stages of Development

O. surinamensis life stages consist of the egg, larva, pupa and adult.

2.8: Biology of Saw toothed grain beetle

Detail on life cycle

Eggs are laid loosely in flour or other food product, or are lodged in crevices in whole grain. The female lays approximately 400 eggs either loosely in flour or other milled grain products or tucked in a crevice of a grain kernel (Mason 2003). Egg laying begins about 5 days after emergence and reaches a maximum during the 2^{nd} or 3^{rd} week and then declines rapidly after about 10 weeks (Mason 2003). Eggs hatch in 3-8 days (Anon. 2009, Mason 2003) and the larvae begin to feed within a few hours of hatching (Mason 2003). Larvae are typically free-living, mobile and not concealed, usually passing through four instars (range 2 - 5) during their development. They are unable to develop on undamaged wheat (Surtees 1965 and Mason, 2003). Under favorable conditions, larvae complete their development in 12-15days.Pupae develop in about 4-7 days and total development time from egg to adult varies from 21 to 51 days, depending on temperature (Calvin

1990). Infestations will develop between 17ºC and 37ºC, 10-90% RH (Anon., 2009) and are very cold tolerant. Optimum temperature for development is between 30 - 35ºC (Halstead, 1980). Adults normally live 6 to 10 months, or even up to 3 years but quickly die on dust-free fruits (Surtees 1965 and Calvin, 1990).

Adult: The adult *O. surinamensis* is a very active, slender, flattish, brown beetle, about one-tenth of an inch (2 to 3 mm) long and has six tooth like projections along each side of the margin of the body in front of the wings (hence the name 'Saw-toothed'). It is a general feeder and in raisins stored this insect can become very abundant. It has well developed wings, but rarely if ever flies. Males, but not females have the posterior margin of the hind trochanter and the upper margin of the hind femur medially with a spine-like projection (Bousquet, 1990; Mason, 2003 and Olsen, 1977). Wings are well developed in both sexes (Mason,2003).The adult is nearly omnivorous. It is cosmopolitan and gregarious; living in nearly all stored human dried fruits & nuts. Its flattened body is well adapted for crawling into cracks and crevices. The elytra are longitudinally grooved. Additionally, there are three longitudinal ridges along the top surface of the thorax (Mason, 2003).

Egg: A female is reported to lay 50-300 eggs in 3-60 days after emergence. The eggs are dropped loosely among the food grains or tucked in crevices in the grains. Eggs are small, 0.1-0.2 mm in size; slender and white in colour. Eggs hatch within 3 to 5 days. The egg is white, shiny, and elongate-oval in form, becoming ochre-yellow as they age, symmetrically oblong with the anterior and posterior ends of almost identical shape, regularly rounded, or with the anterior end slightly narrower. Freshly laid eggs are glossy,

smooth, non-opalescent, with both ends pellucid. During embryo development, eggs lose their gloss. An oblong depression is usually formed on the ventral side. The young embryo when fully developed nearly fills the eggshell, which becomes wrinkled and undulates with the movements of the embryo. When ready to break from the shell, the embryo sets in motion a series of undulations from carded forward, the head and prothorax seeming to swell up at the end of each undulation, stretching the shell of the egg to the bursting point.

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.

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 50-300eggs. The eggs of *O. surinamensis* 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 cibarial 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.

The pre-oviposition, oviposition, and post-oviposition periods are 3, 61, and 9 days respectively.

Larva period: First hatched larvae and its movements are slow and uncertain. It soon gains strength and becomes active, however and begins to attack the available food. Its body acquires a pale yellowish color, with darker bands on the dorsal surface of the thoracic and abdominal segments. The head capsule is a pale yellowish brown. When first hatched the larva is about 0.80 to 0.90 mm. in length, and the width of the head capsule is 0.24 mm. When fully grown the larva attains a length of from 2.5 to 2.8 mm., and the width of the head capsule is from 0.46 mm. to 0.54 mm thrives on practically all foodstuffs of store products as corn, nuts, wheat, barley, and rice, both ground and unground and in all their varied forms, such as flour, meal, and breakfast food, dried foods, nut meats, copra, etc. It is free-living and active, and does not always confine its feeding to one spot, but nibbles here and there as fancy dictates. It is apparently unable to feed on wholegrain unless the grain is quite soft.

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).

Pupa: 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). 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). The pupae have many projections about 0.1 mm long arising from the lateral aspect of the pronotal and abdominal tergites. At the eclosion of the pupa, the projections lie close to the body but become erect soon after. A slightly viscous secretion is apparent within 20 hours of eclosion, remaining throughout the pupal stage if untouched, and may protect the vulnerable pupae against predation (Klein and Burkholder,1983).

2.9: Nature and extent of damage

Both adults and larvae cause damage to stored productsbut 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 *O. surinamensis* 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 *O. surinamensis* individuals can bring considerable weight loss. Stored products are holed and contaminated with cocoons and frass when infested by *O. surinamensis.* 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, moulds, rodents etc. to different spices during storage. These losses are caused by converting fruits into powder form.

2.10: Effect of Environment on Pest Survival

Larval activity of the Saw-toothed grain 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.

2.11: Factors regulating loss in storage

Ecology

Ecology deals with interaction of abiotic and biotic environment of dried nut and fruits in storage of *O. surinamensis*

Biotic environment

Biotic environment includes living associations of storage insects among themselves as well as with other organisms. Both biotic and abiotic factors are responsible for the loss of stored seeds in storage. Baloch *et al.* (1994) revealed that the major biotic factors influencing seeds loss during storage are insects, moulds, birds and rats. 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 or physical environment

This environment includes factors like atmospheric humidity, moisture content of the grain, temperature, light; season and food etc. are revised as follows. High temperature causes deterioration, while low temperature is good for storage. High temperature accelerates the respiration of fruits, which produces carbon dioxide, heat and water, conditions favorable for spoilage, while decreasing humidity is good for storage any fruits. Generally the colder and drier the surrounding environment is better for storage fruits. The conditions to aim for are 30% relative humidity or as low as possible and temperature bellow 59^{o} F (15^{o}C). Darkness is a third rule of optimal fruit storage. Light stimulate and support the germination process in the fruits and storage in darkness helps keeping the pre-germination process in the fruit at a low level.

Atmospheric humidity and moisture: Both these factors are closely related. It has been reported in case of *O. surinamensis* that its larval development, pupation and

transformation into normal sized adults could take place even in a medium containing practically no free water (Schwardt,1938).

Thomas and Shepard (1940) reported a rapid development of this beetle at higher humidity. *O. surinamensis,* however, failed to develop below 10 percent moisture content at 31°C to 34°C in nuts (Howe, 1956). Rate of population growth increased rapidly at humidity range between 42-56 per cent, but remained constant at 74% R.H. This beetle generally showed a pronounced avoidance of high humidity and a lesser avoidance of low ones (Arbogast and Carthon, 1972). No development was recorded at 46% R.H. at a constant temperature of 30°C (Arbogast, 1976). Studies conducted at CRRI, Cuttack concluded that this beetle was unable to develop in sound nuts even at high atmospheric humidity, but developed after infestation of major pests in long term storage (Prakash *et al.,* 1987).

Temperature

This is one of the most important factors governing the rate of metabolism, growth, development, reproduction, general behaviour and distribution of storage insects. No development of *O. surinamensis* took place at 15° C and at 40°C, but at 20°C and 25°C the life cycle was completed in 69.06 and 30.31 days respectively (Thomas and Shepard, 1940). In rural storage structures, which are not usually, air tight, insects are continuously subjected to variations of temperature, because temperature fluctuates with outer environment. The optimum temperature varied from 26°C to 37°C for total development (Back and Cotton, 1926) of *O. surinamensis.* But at 60-76% R.H. the optimum temperature was 35°C. The optimum temperature varied from 30°C to 35°C for larval

development (Nigam *et al.*, 1969). At 78 to 82% R.H. the optimum temperature varied from 33°C to 35°C for larval and pupal development (Prakash and Rao, 1989). At 17.5°C, eggs of large and intermediates trains of this beetle were hatched, but the larvae and pupae died with70% R.H. (Jacob and Fleming, 1990). Fatal high temperature is of great significance, wherein grains are being sterilized to kill latent stages of insects. Total mortality of all stages of *O. surinamensis* is observed in bags at 60°C-69°C. However, its adults died at 50°C in 3 minutes exposure in laboratory test.

Light

Pajni and Gill (1974) report edphotopositive response of *O. surinamensis* 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 A0 light) of *O. surinamensis*.

2.12: Storage structure for protection

Local storage structures which are commonly used in rural India and Bangladesh fail to maintain the optimum health and also fail to provide complete protection from insects. In general, these structures are not moisture proof. The moisture content is high in stored nuts 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. Nuts and dates should be kept in tightly sealed container. Climate conditions, seeds conditions at storage, seeds 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 seeds stored are inconclusive. An average figure for loss for a region or a country holds no significance unless a decision regarding a new system of storage, or new pest control techniques is required. Nevertheless average loss figures are always sought.

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 presented below:

Experiment 1: Survey and identification of insect pests in dried fruit and nuts from different markets of Dhaka city

The dried fruit and nuts samples (cashew nut, almond, groundnut, nutmeg and dried date) were collected from different markets of Dhaka City and carried to the Laboratory of Entomology Department, Sher-e-Bangla Agricultural University, Dhaka for identification and documentation of insect pest specially saw-toothed grain beetle in dried fruit and nuts during August 2016 to December 2016.

3.1 Study area

The study area included in some selected imported dried fruit and nuts from whole sellers shop of major four markets of Dhaka City. The area of Dhaka city is about 270 sq km, located at 23.42° North latitude and 90.22° East longitude with a nelevation of 4 meter from the sea level. In this study, dried fruit and nuts samples were collected from four markets of Mohammadpur town hall market, Mohammadpur Krishi Market, Kawran Bazar and Chawk bazar.

3.2 Sample collection

A total of 200 samples were collected for this study. Ten samples of each dried fruit and nuts (cashew nut, almond, groundnut, nutmeg and dried date) were collected individually from each market. Each sample contains 100gm of dried fruit and nuts.

3.3 Rearing and data collection

Collecting samples of dried fruit and nuts from local market were kept in individual petridish for 15 days in the laboratory. After emerging insect pest of dried fruit and nuts, different insects were identified and recorded.

Experiment 2: Study on the biology of saw-toothed grain beetle, *Oryzaephilus surinamensis* in the laboratory

The study was conducted in the laboratory during the period from August 2016 to June 2017.The biology of *Oryzaephilus surinamensis* was studied on Cashew nut, which was collected from local market of Dhaka.

3.2.1 Test insect collection

Adults saw-toothed grain beetle were collected along with the infested dry fruit and nuts from the laboratory.

3.2.2 Stock culture of saw-toothed grain beetle, *Oryzaephilus surinamensis*

The collected insects were maintained in the laboratory of Different stages of *O. surinamensis*

Plate 01: Stock culture of *Oryzaephilus surinamensis* in cashew nut in a petridish

Plate 02: Aspirator for the collection of saw-toothed grain beetle,*O. surinamensis*

were reared in a petridish with Cashew nut (Plate 1) in the laboratory. Adult were sorted out from infested Cashew nut and then transferred to another plastic container and released in test tube with the help of aspirator (Plate 2) for the study of biology of *O. surinamensis.*

3.2.3 Collection of eggs for the study of biology:

For collection of eggs, 10 pairs of newly emerged Saw-toothed grain beetle were released in 10 test tubes separately and the top of the test tube was covered by net (Plate 3). After 24 hours the beetles were removed from the test tube and replaced another test tube, then the eggs (Plate 4) were gently collected from the bottom part of test tube and data were recorded.

Plate 3: Test tubes with one pair of Saw-toothed grain beetle, *Oryzaephilus surinamensis* in each tube kept for egg laying

3.2.4 Biology of Saw-toothed grain beetle

Eggs were transferred on pieces of white paper in petridishes for hatching. After hatching without exuviae, only the newly hatched larvae of *O. surinamensis* were transferred in petridishes containing cashew nut. The morphological characteristics of the larvae (Plate 5) and pupae (Plate 6) were studied and recorded during the period of larval and pupal development, respectively. Different growth and development stages of *O. surinamensis* such as larval period, pupal period and adult (Plate 07) longevity were recorded during the study. The incubation period was measured by time interval between egg laying and larval hatching.

3.2.5 Design of the experiment

Three experiments were laid out in CRD (Completely randomized design) with 5 replications.

3.2.6 Data recorded: Data were recorded in the following parameters to study the biology:

- No. of laid eggs
- Incubation period
- Larval period
- Larval mortality
- Pupal period
- Pupal mortality
- Adult emergence

Plate 04: Egg and a newly emerge larvae of saw-toothed grain beetle under microscope

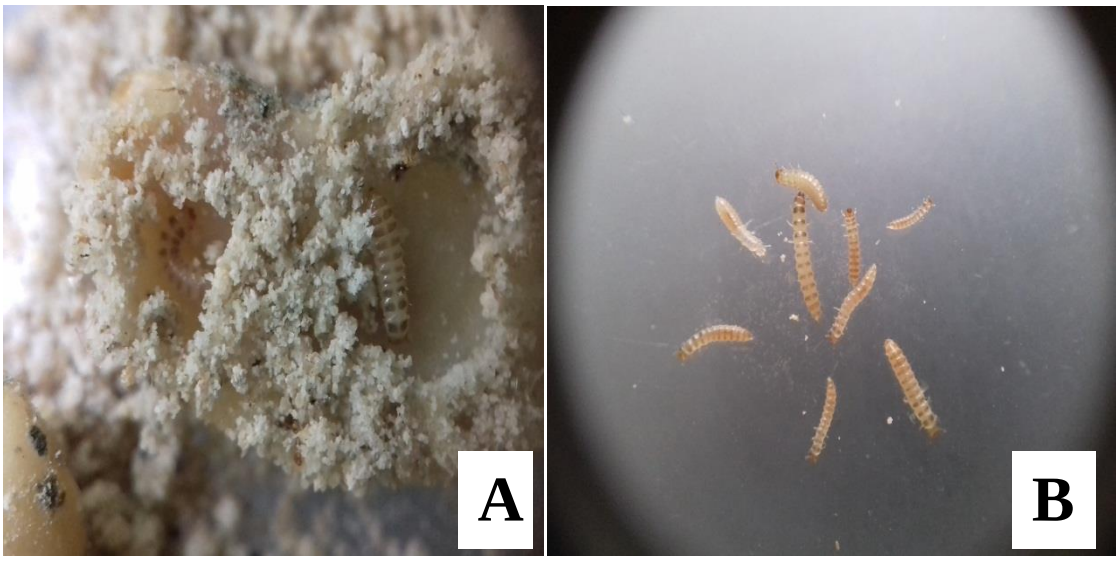

Plate 05: Infested cashew nut with larvae **(A)** of *O. surinamensis* during the study of biology in laboratory and microscopic view of larva **(B)**

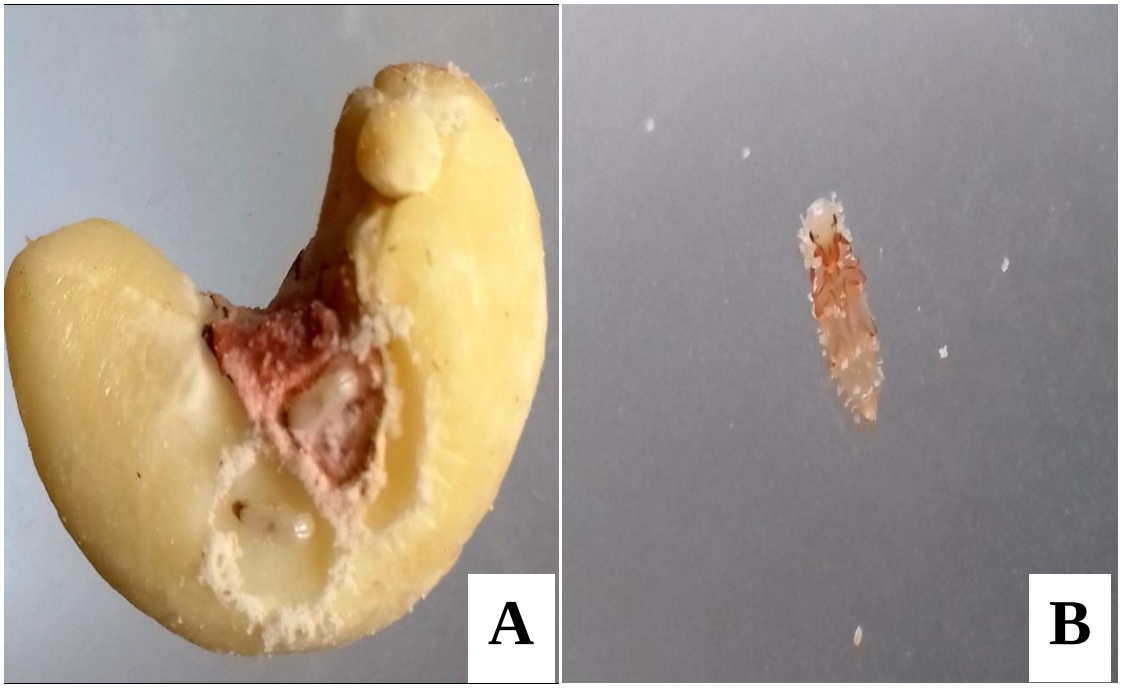

Plate 06: Pupa of saw-toothed grain beetle in the side chamber of cashew nut **(A)** and microscopic view of pupa **(B)** during the study of biology in laboratory

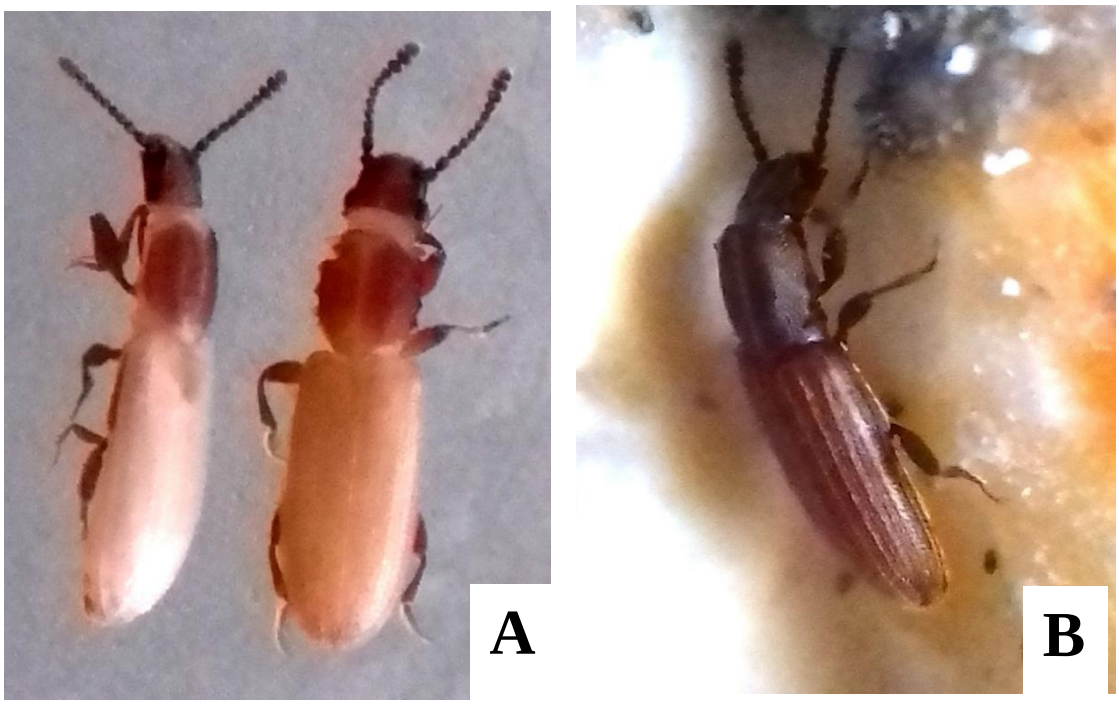

Plate 07: Newly emerged adult **(A)** and matured adult **(B)** of saw toothed grain beetle under microscope

Plate 08: Different life stages **(A)** and different larval instar **(B)** of saw toothed grain beetle under microscope

Experiment 3: The extent of damage of dried fruits and nuts due to infestation by saw-toothed grain beetle, *Oryzaephilus surinamensis*

The experiment was conducted to study the extent of damages in different dry fruit and nuts infested by saw-toothed grain beetle during the period from April 2016 to March 2017. A brief description of the experimental site, experimental design, data collection and analysis of different parameters under the following headings has been explained below:

3.3.1 Preparation of test materials

Dry fruit and nuts were collected from the local market of Dhaka city in August 2016 to carry out the study. The dry fruits were cleaned, dried and sort out from the damaged unhealthy fruits and stored in large size poly bag in airtight condition to keep free from the insects and microorganisms.

3.3.2 Collection of Saw-toothed grain beetle

The process of collection was described of the previous experiment no. 3.2

3.3.3 Experimental design and layout

The experiment was laid out in the ambient condition of laboratory considering in CDR with 5 (five) replications.

3.3.4 Experimental material

10g of different dry fruit and nuts as cashew nut, almond, groundnut, nutmeg and dates were kept as experimental material in each petridish with 5 pairs of saw-toothed grain beetle for assessment the damage percentage (Plate 9)

Plate 9a: Experimental set up with different dried fruit and nuts to determine the damage assessment by *O. surinamensis*

Plate 9b: Experimental set up with different dried fruit and nuts to determine the damage assessment by *O. surinamensis*

3.3.4.1 Cashew nut

The cashew nut *(Anacardium occidentale*) often simply called a cashew fruit is widely used in recipes, or processed into cashew cheese or cashew butter or fermented into vinegar, as well as an alcoholic drink. It is also used to make preserves, chutneys, and jams in some countries. In many countries, cashew apple is used to flavor drinks, both alcoholic and non-alcoholic.

Plate 10: Healthy Cashew nut **(A)** and Infested Cashew nut by Saw toothed grain beetle **(B)**

Importance

Raw cashew nuts provide high percent of Calories, protein, dietary fiber and carbohydrates (Cashews are rich sources) of dietary minerals, including copper, manganese, phosphorus, magnesium, thiamin, vitamin B_6 , vitamin K, Iron, potassium, zinc and selenium are present in significant content.

Use: Animal feed**,** Cashew oil, Traditional medicine

3.3.4.2 Almond

The almond (*Prunusa mygdalus*) is a species 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 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.

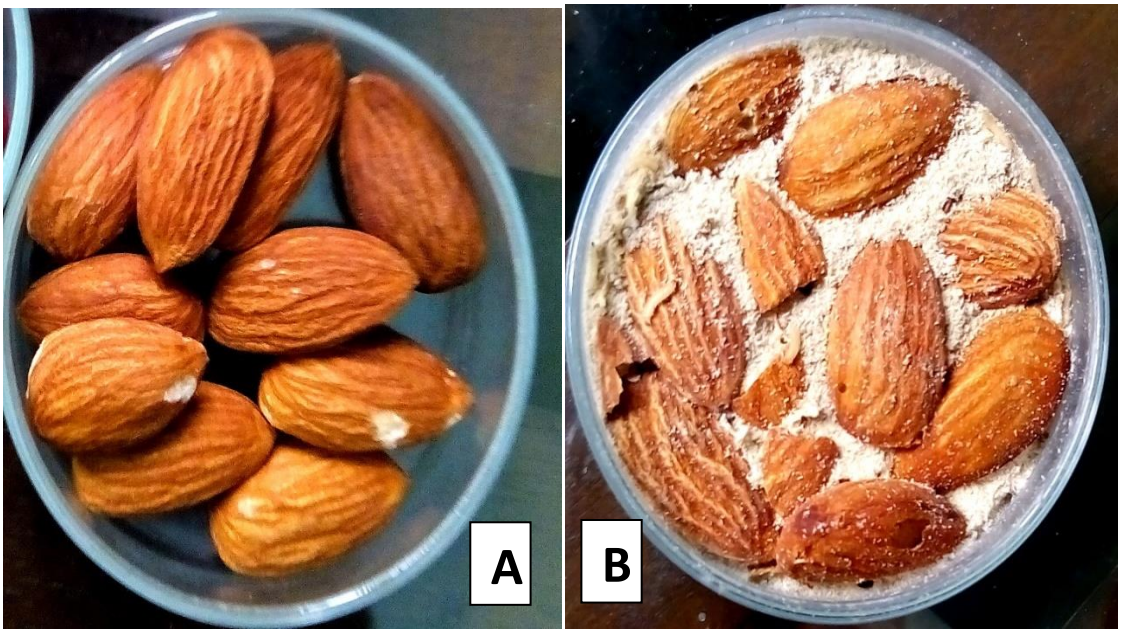

Plate 11: Healthy Almond **(A)** and Infested Almond **(B)** by Saw toothed grain beetle

Importance:

The almond is a nutritionally rich source of vitamins ,riboflavin and niacin, vitamin E, and the essential minerals calcium, iron, magnesium, manganese, phosphorus, and zinc. The same serving size also a good source of the B vitamins thiamine, and folate; choline; and the essential mineral potassium.

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.

3.3.4.3 Groundnut

The groundnut *Arachis hypogaea,* 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. It is this characteristic that the botanist Linnaeus used to assign the specific name *hypogaea*, which means "under the earth".Like most other legumes, peanuts harbor symbiotic nitrogen-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.

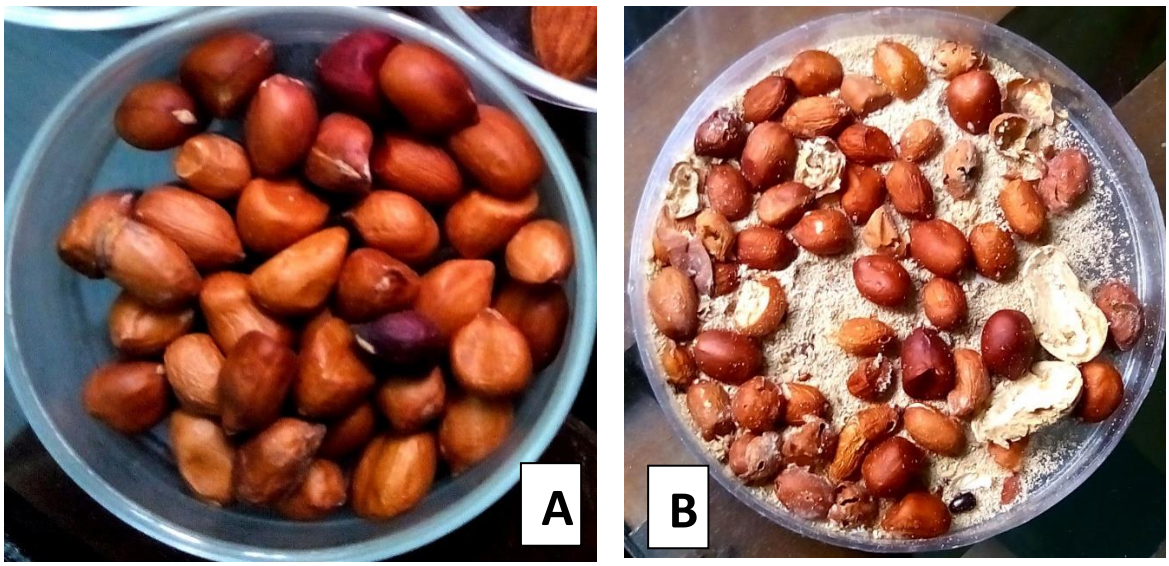

Plate 12: Healthy Groundnut **(A)** & Infested Groundnut (**B**) by Saw-toothed grain beetle

Nutritional value

Peanuts are rich in essential nutrients, rich in calories and are an excellent source of several B vitamins, vitamin E, several dietary minerals, such as manganese,

magnesium, phosphorus and dietary fiber .Some studies show that regular consumption of peanuts is associated with a lower risk of mortality specifically from certain diseases. Most nuts as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease.

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

3.3.4.4 Nutmeg

Nutmeg refers to *Myristica fragrans* is a dark-leaved, ever green tree cultivated for two dried fruit and nuts derived from its fruit, nutmeg and mace. It is also a commercial source of an essential oil and nutmeg butter. Other members of the genus, such as *M. argentea* (Papuan nutmeg) and *M. malabarica* (Bombay nutmeg), are of limited commercial value.

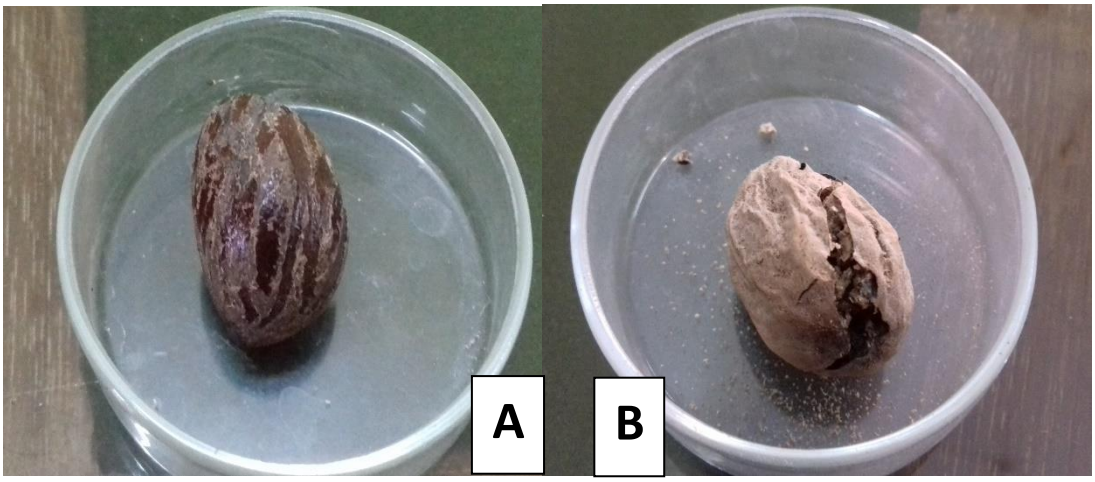

Plate 13: Healthy Nutmeg **(A)** and Infested Meg nut **(B)** by Saw-toothed grain beetle

Use: Nutmeg is used for flavouring many dishes, many spicy soups etc.

3.3.4.5 Dates

Phoenix dactylifera, commonly known as date or date palm, 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.

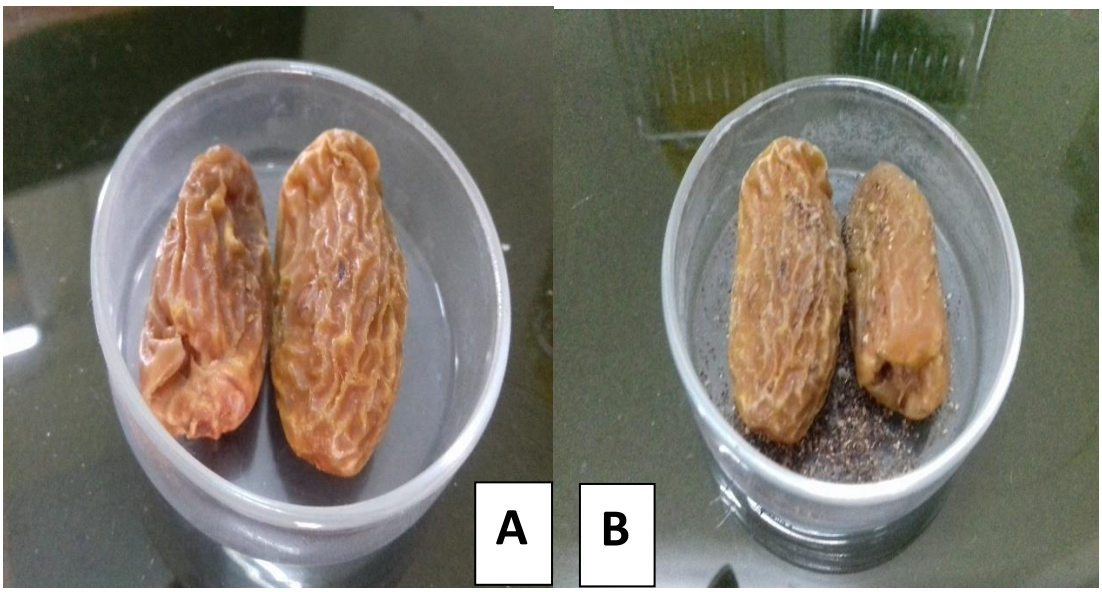

Plate 14: Healthy Dates **(A)** and Infested Dates **(B)** by Saw-toothed grain beetle

Nutritional value

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.

3.3.5 Adult Mortality and New Emergence

10 g of insect free different nuts and fruits were taken into each plastic petridish 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 90 days. The petridish were observed from outside to examine death of released beetle. The mortality of the adult was recorded against Cashew nut, Almond, Groundnut, Nutmeg and Date. The adult mortality was recorded and converted into per cent.

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

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

3.3.6 Extent of damage and weight loss of different nuts and dried fruit

The final weight of nuts and fruits was taken to obtain weight loss. Sieving and winnowing was done to clean the nuts & fruits. The clean seeds except those having scars in each container were weighted separately. The weight losses of dried fruit and nuts 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 nuts and fruits respectively. The percentage of weight loss was calculated as follows:

$$\% \text{ Infestation (by weight)} = \frac{\text{Weight of infested nuts \& fruit}}{\text{Total weight of nuts \& fruit}} \times 100$$

$$\% \text{ Weight loss due to infestation} = \frac{\text{(Initial weight– Final weight) of nuts \& fruit}}{\text{Initial weight of nuts \& fruit}} \times 100$$

3.3.7 Statistical Analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

The experiment "Survey, Damage assessment and study on the biology of Saw-toothed grain beetle *O. surinamensis"* on different dried fruit and nuts was conducted in the laboratory and survey report collected from local markets. The results have been presented and discussed with possible interpretations under the following headings and sub headings:

4.1 Survey and identification of insect pests in dried fruit and nuts from different local markets of Dhaka city

200 samples of different dried fruit and nuts (cashew nut, almond, groundnut, nutmeg and dried dates) were collected individually from four local markets (Mohammadpur Town Hall Market, Mohammadpur Krishi Market, Kawran Bazar and Chawk Bazar) of Dhaka city to detect insect pest including saw-toothed Grain beetle, *O. surinamensis*. The results obtained from this study are presented and described in the following:

4.1.1 Species of insect pests

Dried fruit and nuts compete with numerous insect pests under favorable condition. Under the present survey study 4 common species (Saw-toothed grain beetle, *Oryzaephilus surinamensis;* Dried fruit beetle, *Carpophilus hemipterus;* Red flour beetle, *Tribolium castaneum;* Cigarette beetle, *Lasioderma serricorne*) of insects were found belongs to 4 families under the order coleopteran were found infested in the dried fruit and nuts. The common name, scientific name, order, family, destructive stages of insects as storage pests are presented in Table 1

Table1.List of insects found in different dry fruit and nuts collected from local markets in Dhaka city during the survey

Sl. No.	Name of the insect pest	Scientific Name	Family	Order	Destractive stage
1	Saw-toothed grain beetle	*Oryzaephilus surinamensis*	Silvanidae	Coleoptera	Larvae and adult
2	Dried fruit beetle	*Carpophilus hemipterus*	Nitidulidae	Coleoptera	Larvae and adult
3	Red flour beetle	*Tribolium castaneum*	Tenebrionidae	Coleoptera	Larvae and adult
4	Cigarette beetle	*Lasioderma serricorne*	Anobiidae	Coleoptera	Larvae and adult

4.1.2 Incidence of insect populations in different dried fruit and nuts

The highest number of saw-toothed grain beetle found in cashew nut at Mohammadpur town hall market (3.6±1.26) and the lowest number of saw-toothed grain beetle found at Mohammadpur town hall market in dates (1.2±1.13)(Table 2)

Incase of almond, the number of saw-toothed grain beetle found at Mohammadpur town hall market was (2.6±1.17), Chawk bazar (2.2±1.39), Mohammadpur Krishi Market (2.5±1.39) and Kawran Bazar (2.8±1.03), respectively. The order of saw-toothed grain beetle found in terms of number of the different local markets were Mohammadpur town hall market > Chawk bazar > Mohammadpur Krishi Market > Kawran Bazar.

Table 2. Incidence of populations and development stage of insect Saw-toothed grain beetle in different dried fruit and nuts in different local markets of Dhaka city

Location	Different fruits and nuts	Development stage of insect	No. of insect (Mean ±SD)
Mohammadpur town hall market	Cashew nut	Adult	3.6±1.26
	Almond	Adult & larvae	2.6±1.17
	Groundnut	Adult & larvae	1.3±0.82
	Nutmeg	Adult	1.9±0.99
	Dates	Adult	1.2±1.13
Mohammadpur Krishi Market	Cashew nut	Adult	3.4±1.50
	Almond	Adult & larvae	2.2±1.39
	Groundnut	Adult	2.0±1.15
	Nutmeg	Adult	1.6±1.07
	Dates	Adult	0.7±0.67
Kawran Bazar	Cashew nut	Adult	3.2±1.50
	Almond	Adult & larvae	2.5±1.39
	Groundnut	Adult	1.9±1.15
	Nutmeg	Adult	1.5±1.07
	Dates	Adult	0.6±0.67
Chawk bazar	Cashew nut	Adult	3.6±1.26
	Almond	Adult & larvae	2.8±1.03
	Groundnut	Adult	1.9±0.99
	Nutmeg	Adult	1.0±0.81
	Dates		0.9±0.05

Incase of ground nut, the number of saw-toothed grain beetle were found in Mohammad pur Krishi Market (2.0±1.15), Kawran Bazar (1.9±1.15), Chawk bazaar (1.9±0.99) and Mohammad pur town hall market (1.3±0.82) respectively.The order of saw-toothed grain

beetle found in terms of number of the different local markets were Mohammadpur Krishi Market > Kawran Bazar > Chawk bazar > Mohammadpur town hall market. Incase of Nutmeg, the number of saw-toothed grain beetle found in Mohammad pur town hall market (1.9±0.99), Mohammad pur Krishi Market (1.6±1.07), Kawran Bazar (1.5±1.07) and Chawk bazaar (1.0±0.81) respectively. The order of saw-toothed grain beetle found in terms of number of the different local markets were Mohammadpur town hall market >Mohammadpur Krishi Market > Kawran Bazar > Chawk bazar.

4.1.3 Percent of infestation on different dried fruit and nuts due to saw-toothed grain beetle in different markets of Dhaka city

The highest percentage of infestation (5.50% was recorded in Mohammadpur town hall market (Table 3) in case of cashew nut, whereas percent of infestation was observed in almond, groundnut, nutmeg and dates (3.80, 3.20, 1.90 and 1.20%), respectively in storage condition (Figure 2)

Table 3. Percent of infestation in different dried fruit and nuts due to saw-toothed grain beetle in Mohammadpur Town hall market

Treatment(s)	Total weight (gm)	Healthy (gm)	Infested (gm)	Infestation (%)
Cashew nut	100	93.40	5.50	5.50
Almond	100	95.70	3.80	3.80
Groundnut	100	96.50	3.20	3.20
Nutmeg	100	97.05	1.90	1.90
Dates	100	98.50	1.20	1.20

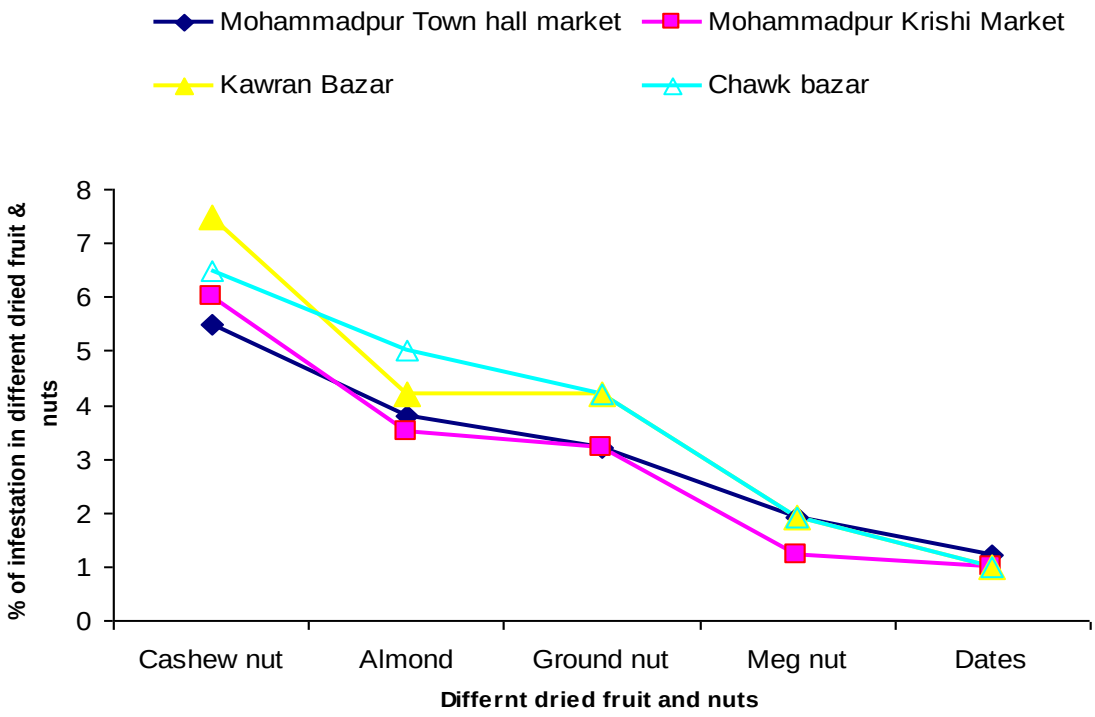

Figure 2: Percent of infestation in different dried fruit and nuts due to Saw-toothed grain beetle in different local markets of Dhaka city

From table 4, it was observed that the highest percent of infestation incase of cashew nut in Mohammadpur Krishi Market was (6.0%), whereas percent of infestation were observed in almond, groundnut, nutmeg and dates 3.5, 3.2, 1.2 and 1.0%, respectively in storage condition (Figure 2).

Table 4. Percent of infestation in different dried fruit and nuts due to saw-toothed grain beetle in Mohammadpur Krishi Market

Treatment(s)	Total weight (g)	Healthy (g)	Infested (g)	Infestation (%)
Cashew nut	100	92.40	6.00	6.0
Almond	100	94.50	3.50	3.5
Groundnut	100	96.80	3.20	3.2
Nutmeg	100	97.00	1.20	1.2
Date	100	99.00	1.00	1.0

In Kawran Bazar, the highest percent of infestation in cashew nut (7.5%) was observed (Figure 2), whereas, percent of infestation in others nuts and fruit (almond, groundnut, nutmeg and dates) were recorded 4.2, 4.2, 1.9 and1.0% respectively in storage condition (Table 5).

Table 5. Percent of infestation in different dried fruit and nuts due to saw-toothed grain beetle in Kawran Bazar

Treatment(s)	Total weight (g)	Healthy (g)	Infested (g)	Infestation (%)
Cashew nut	100	90.50	7.50	7.5
Almond	100	95.40	4.20	4.2
Groundnut	100	95.00	4.20	4.2
Nutmeg	100	98.00	1.90	1.9
Date	100	99.00	1.00	1.0

From table 6, it was observed that the highest percent of infestation in Chawk bazar in cashew nut was (6.5%), whereas the percent of infestation was observed in almond, groundnut, Nutmeg and dates were 5.0, 4.2, 1.9 and 1.0% respectively in storage condition (Figure 2).

Table 6. Percent of infestation in different dried fruit and nuts due to saw-toothed grain beetle in Chawk Bazar

Treatment(s)	Total weight (g)	Healthy (g)	Infested (g)	Infestation (%)
Cashew nut	100	92.80	6.50	6.5
Almond	100	94.50	5.00	5.0
Groundnut	100	95.00	4.20	4.2
Nutmeg	100	97.05	1.85	1.9
Date	100	98.80	1.00	1.0

4.2 Biology of Saw-toothed grain beetle, *Oryzaephilus surinamensis* on Cashew nut in laboratory

4.2.1 Mating and Oviposition

Males and females have more than one mate. Mating occurs within 2-3 days after adult emergence. The adult female beetle laid 103-118 eggs with an average of 110.00 eggs throughout up to 4 days and number of laid egg per day was 27.50±3.34 in Table 7. *O. surinamensis* laid eggs singly. The eggs of *O. surinamensis* 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 7. Day specific fecundity in terms of laid eggs of saw-toothed grain beetle *O. surinamensis* on cashew nut in laboratory condition

Insect	Number of laid eggs				Total number of eggs	Number of laid eggs/day (Mean ±SD)
	1st day	2nd day	3rd day	4th day		
1st pair	22	25	30	32	109	27.25±4.57
2nd pair	20	25	28	30	103	25.75±4.34
3rd pair	24	28	30	35	117	29.25±4.57
4th pair	28	25	28	37	118	29.50±5.19
5th pair	30	25	24	26	105	26.25±2.62
6th pair	23	27	30	32	112	28.00±3.92
7th pair	24	26	30	28	108	27.00±2.58
8th pair	28	25	32	32	117	29.25±3.40
9th pair	25	24	28	30	107	26.75±2.75
10th pair	20	22	28	34	104	26.00±6.32
Average	24.40	25.20	28.80	31.60	110.00	27.50±3.34

4.2.2 Developmental period of different life stages

An average oviposition and incubation period were 10.20±1.93 and 8.60± 1.97 days respectively on cashew nut in laboratory condition. The newly hatched larva is yellowish white with a light brown head. Total 18.20 ± 1.93 and 7.80 ± 1.50 days were required for larval stage and pupal stage respectively. Adult longevity of Saw-toothed grain beetle, *O. surinamensis* was 90.00 ± 21.21 (Table 8).

Table 8. Developmental period of different life stages of saw-toothed grain beetle *O. surinamensis* on cashew nut in laboratory condition

Development stage	Duration (days)	Data Range	Statistics
Oviposition period	10.20 ± 1.93	5-15	P<0.002
Incubation period	8.60 ± 1.97	3-15	P<0.012
Larval period	18.20 ± 1.93	15-25	P<0.001
Pupal period	7.80 ± 1.50	4-12	P<0.004
Adult longevity	90.00 ± 21.21	30-150	P<0.003

4.2.3. Morphometric measurement of different life stages

The length of egg was 0.2±0.00 and width 0.3±0.00; 1st ,2nd ,3rd ,4th and 5th instar larval length were (0.85±0.09, 1.5±0.00, 3.5±0.03, 4.0±0.02 and 3.2±0.00 respectively) and larval width were (0.25±0.00, 0.3±0.00, 0.45±0.01, 0.46±0.04 and 0.55±0.00 respectively); pupal length (3.5±0.01) and width (1.5±0.03); Adult length was (2.5±0.08) and width (1.4±0.05). 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 (Table 9).

Table 9. Morphometric measurement of different life stages of saw-toothed grain beetle in the laboratory

Life Stage	Size (mm)	
	Length (mm)	Width (mm)
Egg	0.2±0.00	0.3±0.00
Larval Instars		
1st	0.85±0.09	0.25±0.00
2nd	1.5±0.00	0.3±0.00
3rd	3.5±0.03	0.45±0.01
4th	4±0.02	0.46±0.04
5th	3.2±0.00	0.55±0.00
Pupa	3.5±0.01	1.5±0.03
Adult	2.5±0.08	1.4±0.05

4.2.4.1 Newly hatched larvae

At 1st, 2nd, 3rd and 4th day the number of newly hatched larvae were 15-27, 15-24, 16-27 and 18-28 respectively. The highest average number of larvae hatched in Set-I (25.25±2.75) and the lowest average number of larvae (16.00±1.41) hatched in Set-I with an average number of larvae hatched (20.90±0.66) throughout up to 4 days (Table 10).

Table 10. Day specific fecundity in terms of newly hatched larvae of saw-toothed grain beetle on cashew nut in laboratory condition

Set or Replication	Number of newly hatched larvae				Total number of larvae	Number of larvae (Mean ±SD)
	1st day	2nd day	3rd day	4th day		
I	15	15	16	18	64	16.00±1.41
II	20	20	21	22	83	20.75±.96
III	18	19	21	21	79	19.75±1.5
IV	24	22	27	28	101	25.25±2.75
V	27	24	22	18	91	22.75±3.77
Average	20.80	20.00	21.40	21.40	83.60	20.90±0.66

4.2.4.2 Chamber formed by larvae of saw-toothed grain beetle before pupation

There is a special characteristic of pupa of saw-toothed grain beetle that 5th instar larvae create chambers for pupation (plate15 and plate16). In chambers they spend their pupal life that is inactive stage of their life cycle. Its duration from 4-12 days.

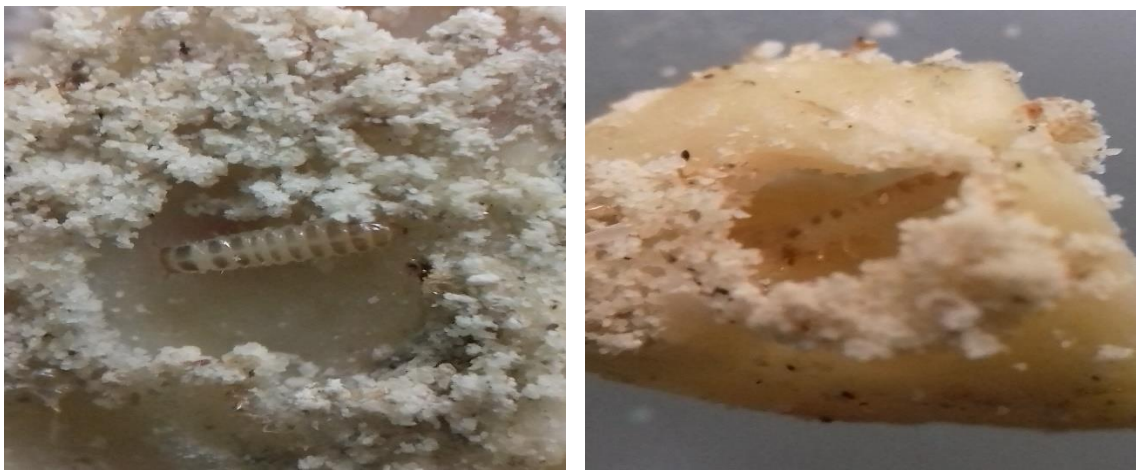

Plate 15: Chamber formed by 5th instar larvae of saw-toothed grain beetle on cashew nuts

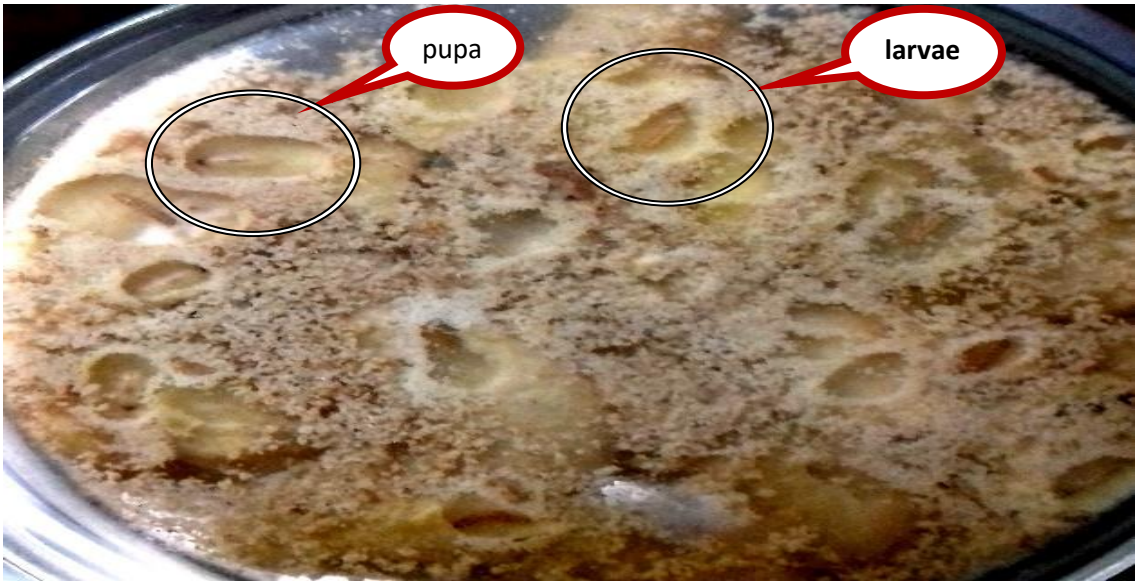

Plate 16: Infested cashew nut with larvae and pupae of *O. surinamensis* after the 1st generation

4.2.5 Newly formed pupae of saw toothed grain beetle

At 1st, 2nd, 3rd and 4th day the number of newly formed pupae were 12-20, 11-18, 13-20 and 14-22 respectively. The highest average number of pupae formed in Set-IV (19.50±1.91) and the lowest average number (12.50±1.29) of pupae formed in set-I with an average number of pupae formed (16.10±0.66) throughout up to 4 days (Table 11)

Table11.Day specific fecundity in terms of newly formed pupae of saw-toothed grain beetle on cashew nut in laboratory condition

Set or Replication	Number of newly formed pupae				Total number of pupa	Number of pupa (Mean ±SD)
	1st day	2nd day	3rd day	4th day		
I	12	11	13	14	50	12.50±1.29
II	15	16	17	18	66	16.50±1.29
III	15	14	15	16	60	15.00±0.81
IV	18	18	20	22	78	19.50±1.91
V	20	18	15	15	68	17.00±2.44
Average	16.00	15.40	16.00	17.00	64.40	16.10±0.66

4.2.6 Larval and pupal mortality of Saw-toothed grain beetle, at different sets during the study period

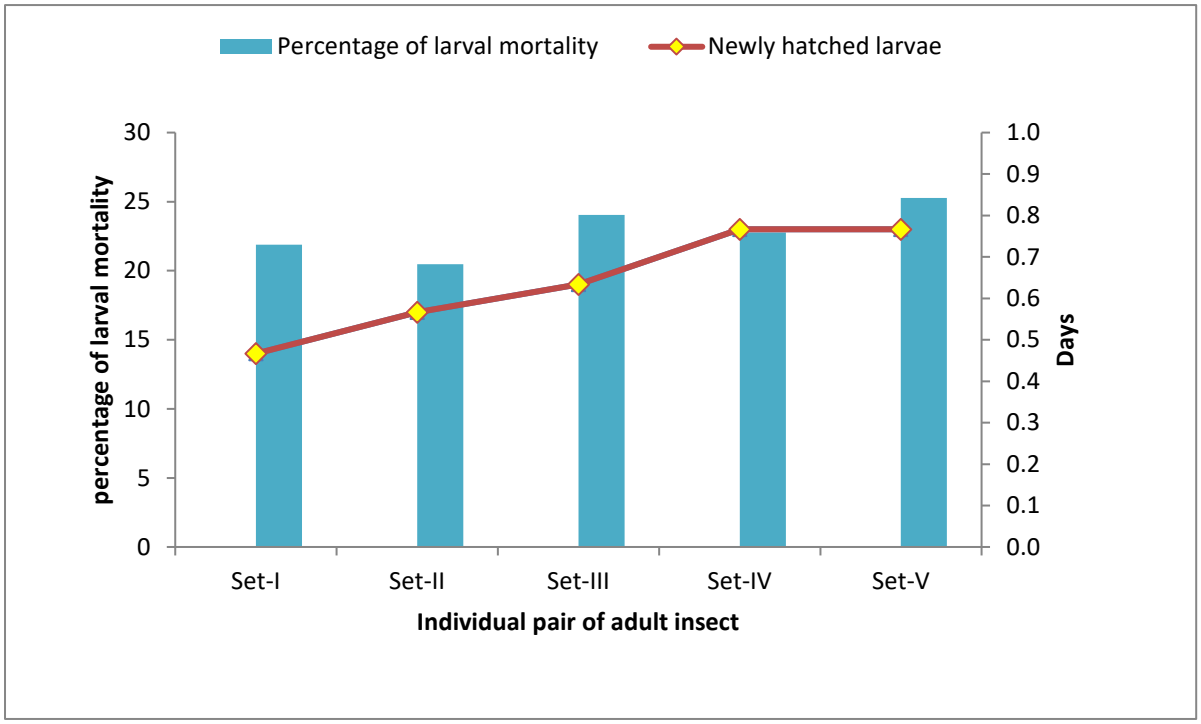

Fig. 3: Larval mortality of saw-toothed grain beetle ,at different sets during the study period

Larval mortality

The newly hatched larvae were more or less same in set-IV and set-V. Whereas the highest percentage of larval mortality was observed from set- V, and the lowest percentage of larval mortality was observed from set-II (Figure 3), with total number of larval mortality 19.2 (Appendix V).

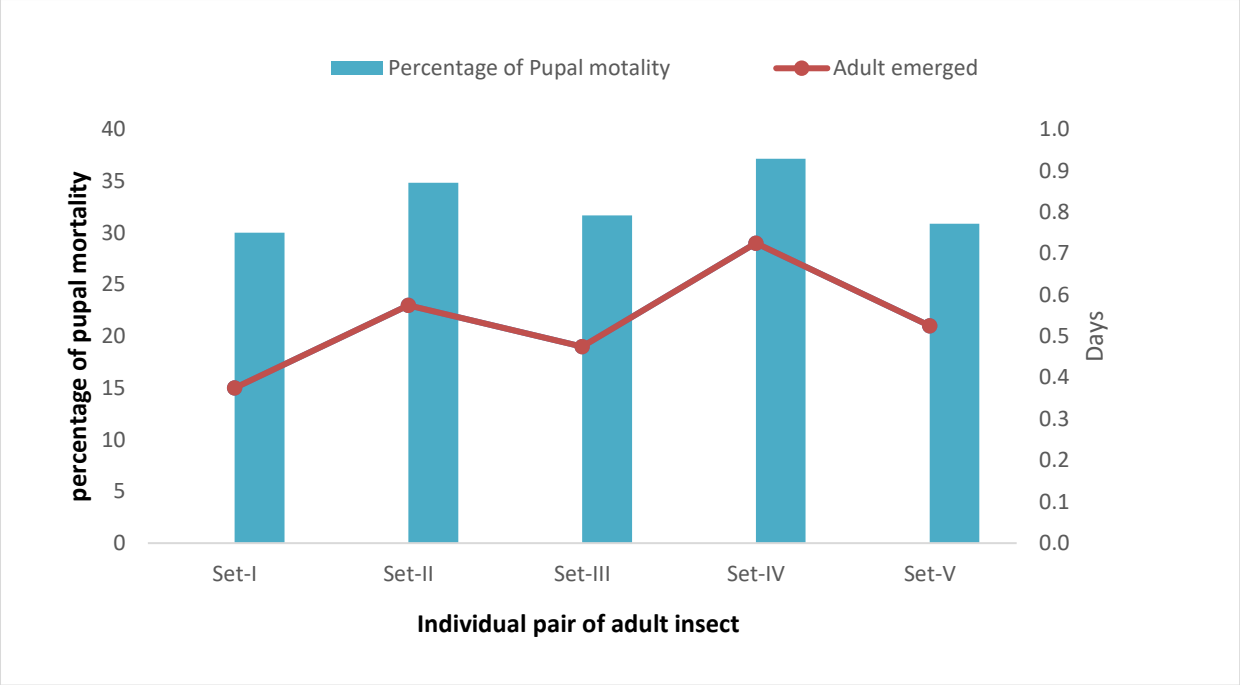

Fig. 4: Pupal mortality of Saw toothed grain beetle, at different sets during the study period

Pupal mortality

The highest percentage of pupal mortality was observed from set-IV, whereas the second highest was in Set-II and the lowest percentage of pupal mortality was observed from set-I (Figure 4), with total number of pupal mortality 21.4 (Appendix VI).

4.2.7 Newly adult emergence

At 1st, 2nd, 3rd and 4th day the number of newly emerged adults were 8-12, 7-13, 10-12 and 8-12 respectively. The highest average number of adults emerged in Set-IV (12.25±0.50) and the lowest average number (8.75±1.5) of adults emerged in Set-I with an average number of adults emerged (10.75±0.25) throughout up to 4 days on cashew nut in laboratory condition (Table 12)

Table 12. Day specific fecundity in terms of newly emerged adults of saw-toothed grain beetle on cashew nut in laboratory condition

Set or Replication	Number of newly emerged adults				Total number of adult	Number of adult (Mean ±SD)
	1st day	2nd day	3rd day	4th day		
I	8	7	10	10	35	8.75±1.5
II	10	11	12	10	43	10.75±0.96
III	12	10	11	8	41	10.25±1.70
IV	12	13	12	12	49	12.25±0.50
V	12	13	10	12	47	11.75±1.25
Average	10.80	10.80	11.00	10.40	43.00	10.75±0.25

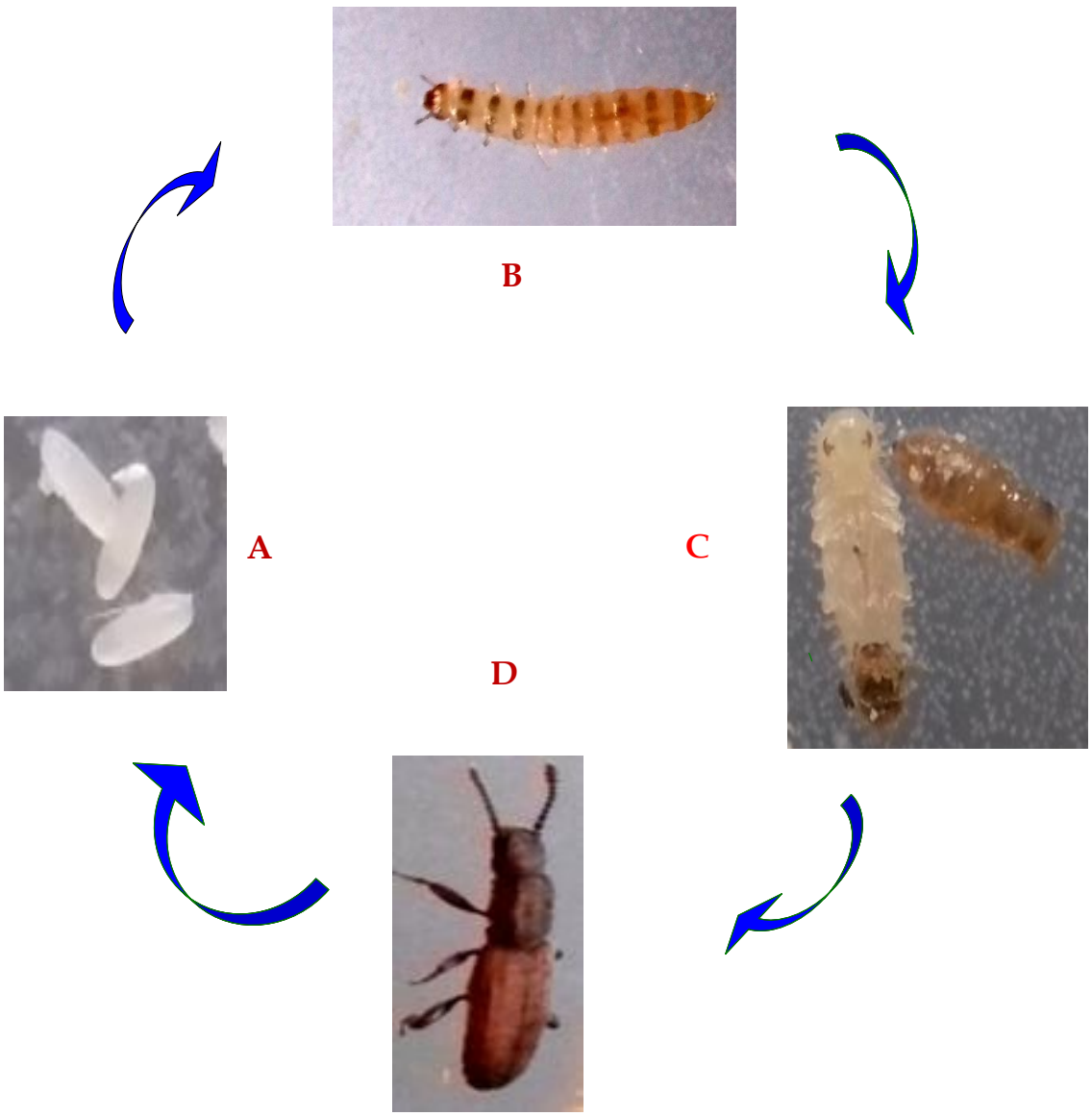

Plate 17: Life cycle of Saw-toothed grain beetle A. Egg, B. Larva, C. Pupa and D. Adult (microscopic view)

4.3. Damage assessment of Saw-toothed grain beetle in different Dried fruit and nuts

4.3.1 Adult emergence

In case of 1st generation the highest number of adults were recorded in Cashew nut (39.20) which was followed by almond, groundnut, nutmeg (32.40,30.00,28.40 and 15.20 respectively and statistically different from all other nuts. At 2nd generation in cashew nut adult emergence was almost four times higher than 1st generation. Whereas adult emergence was lower in dates (60) at 2nd generation.

Table 13. Effect of different dried fruit and nuts for adult emerged of saw toothed grain beetle at 1st and 2nd generation in stored conditions

Treatment(s)	Adult emerged at	
	1st generation	2nd generation
Cashew nut	39.20 a	150.8 a
Almond	32.40 b	129.8 b
Groundnut	30.00 bc	120.0 c
Nutmeg	28.40 c	110.4 d
Dates	15.20 d	60.00 e
$LSD_{(0.01)}$	2.704	8.158
Level of Significance	0.01	0.01
CV(%)	7.06	5.41

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

4.3.2 Status of different Dried fruit and nuts in 1st and 2nd generation by weight

At the 1st generation of saw-toothed grain beetle, *O. surinamensis* : Status of different dry fruit and nuts in terms of healthy, infested and % infestation showed statistically by significant variation (Table 14 to Table 15) under the present trial for the damage assessment of different stored dried fruit and nuts by saw toothed grain beetle.

In 1st generation on weight basis, the highest weight of healthy fruit and nuts (9.00 g) were recorded in dates, which were closely followed by nutmeg (8.50g). The lowest was observed in cashew nut (7.80 g) which was statistically identical with almond (7.86g) nuts. The highest weight of infested nut was observed in cashew nut (1.85 g) which was statistically identical by almond (1.65 g) and groundnut (1.70 g). The lowest weight of infested nut was recorded in dates (0.83 g) which was closely followed by dried nutmeg (0.93 g). Consideration of % infestation, the highest infestation was recorded from cashew nut (19.18%) which were statistically similar to almond (17.37 %) and groundnut (17.16 %), while low percent of infestation was recorded in dates (8.44 %). (Table 14).

Table 14. Effect of different Dried fruit and nuts on percent infestation and total weight caused by saw-toothed grain beetle in stored condition at 1st generation

Treatment(s)	Total weight		Infestation (%)
	Healthy (g)	Infested (g)	
Cashew nut	7.80 c	1.85 a	19.18 a
Almond	7.86 c	1.65 a	17.37 a
Groundnut	8.22 bc	1.70 a	17.16 a
Nutmeg	8.50 b	1.34 b	13.63 b
Dates	9.00 a	0.83 c	8.44 c
$LSD_{(0.01)}$	0.413	0.217	2.385
Significance level	0.01	0.01	0.01
CV (%)	3.78	11.18	11.93

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 the 2nd generation of saw-toothed grain beetle, *O. surinamensis* : In 2nd generation on weight basis, the highest weight of healthy fruit were dates (6.90 g) and nutmeg (4.80g) respectively, which were closely followed by groundnut (3.80g) and almond (3.50g) statistically different from other nut and fruits. The lowest was observed in cashew nut (1.80 g). In case of infested fruits, the highest weight of infested fruit was observed in cashew nut (5.50) which was followed by almond (4.04). Whereas almond is statistically identical by groundnut (3.86). The lowest weight of infested fruit was recorded in dates (1.75) which was closely followed by nutmeg (3.20). Consideration of % infestation, the highest infestation was recorded from cashew nut (75.29%) which was

statistically different from other nuts and followed by almond (53.59%) while low percent of infestation was recorded in date (20.23%) (Table 15).

Table 15. Effect of different Dried fruit and nuts on percent infestation and total weight caused by saw-toothed grain beetle in stored condition at 2nd generation

Treatment(s)	Total weight		Infestation (%)
	Healthy (g)	Infested (g)	
Cashew nut	1.80 e	5.50 a	75.29 a
Almond	3.50 d	4.04 b	53.59 b
Groundnut	3.80 c	3.86 b	50.38 c
Nutmeg	4.80 b	3.20 c	40.00 d
Dates	6.90 a	1.75 d	20.23 e
$LSD_{(0.01)}$	0.209	0.277	1.962
Significance level	0.01	0.01	0.01
CV (%)	4.03	5.74	3.07

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






Plate 18: Infested different dried fruit and nuts by saw toothed grain beetle at the 2nd generation

4.3.3 Weight loss of different dried fruit and nuts

At 1^{s} generation the highest weight loss (4.90%) was observed in almond and the lowest weight loss (0.80 %) was observed in groundnut which is statistically similar with nutmeg and dates caused by saw-toothed grain beetle.

At 2nd generation the highest weight loss (6.81%) was recorded in ground nut which is statistically similar with cashew nut and the lowest weight loss (3.89 %) was recorded in dates which is statistically identical with almond (4.07 %).

Table 16. Weight loss of different dried fruits and nuts caused by saw-toothed grain beetle at 1st and 2nd generation in stored condition

Treatment(s)	Percentage of weight loss at	
	1st generation	2nd generation
Cashew nut	3.50 ab	6.41 a
Almond	4.90 a	4.07 c
Groundnut	0.80 b	6.81 a
Nutmeg	1.60 b	5.88 b
Dates	1.72 b	3.89 c
$LSD_{(0.01)}$	2.855	0.49
Level of Significance	0.05	0.01
CV(%)	16.43	7.12

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

4.3.4 Correlation between percent of infestation and weight loss of Cashew nut, Almond, Nutmeg, Groundnut and dates at 1st generations by *O. surinamensis*

Correlation study was done to establish the relationship between percent of infestation and weight loss of dried fruit and nuts. From the Figure 5, it was revealed that negative correlation was observed between the parameters. It was evident that the equation y = 0.1729x - 0.1164 gave a good fit to the data and the co-efficient of determination (R2 =0.1959) 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 negatively correlated with weight loss of cashew nut, almond, groundnut, nutmeg and dates. Weight loss was increased due to increase of percent of infestation.

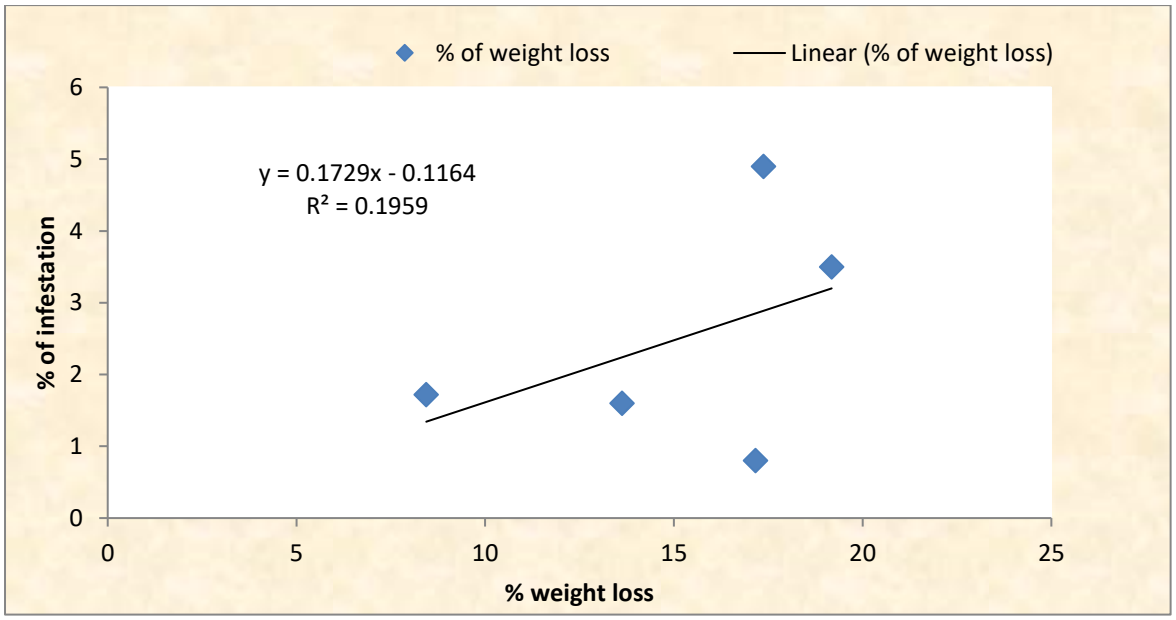

Figure 5. Relationship between percent of infestation and weight loss of Cashew nut, Almond, groundnut, nutmeg and dates at 1st generations by *O. surinamensis*

4.3.5 Correlation between percent of infestation and weight loss of Cashew nut, Almond, Ground nut, Nutmeg and dates at 2nd generations by *O. surinamensis*

Correlation study was done to establish the relationship between percent of infestation and weight loss of dried fruit and nuts. From the Figure 6, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = 0.0381x + 3.5876 gave a good fit to the data and the co-efficient of determination (R2 =0.3219) 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 cashew nut, almond, ground nut, nutmeg and dates. Weight loss was increased due to increase of percent of infestation

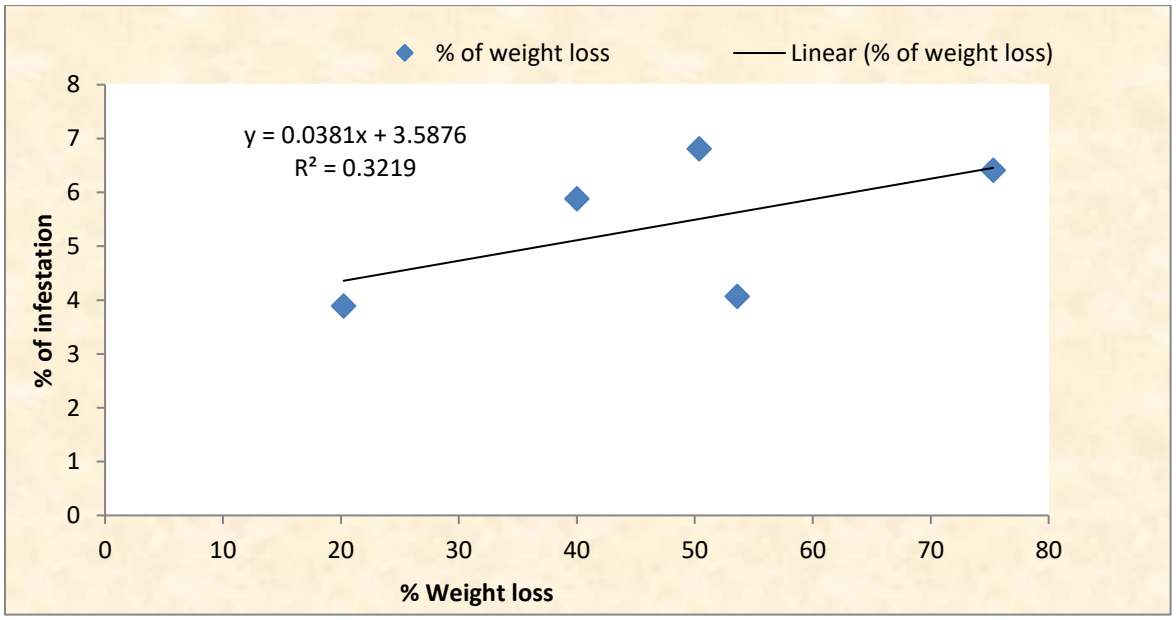

Figure 6. Relationship between percent of infestation and weight loss of Cashew nut, Almond, groundnut, Nutmeg and dates at 2nd generations by *O. surinamensis*

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 August to December, 2016 to damage assessment and study on the biology of Saw-toothed grain beetle, *Oryzaephilus surinamensis* in different dried fruit and nuts Cashew nut, almond, ground nut, Nutmeg and dates were used as experimental materials.

Experiment-1: Survey and identification of insect pests in dried fruit and nuts from different markets of Dhaka city

There were 200 samples of different dried fruit and nuts (Cashew nut, Almond, Ground nut, Nutmeg and dried Dates) were collected individually from four markets (Mohammadpur town hall market, Mohammadpur Krishi Market, Kawran Bazar and Chawk bazar) of Dhaka city to detect insect pest including Saw-toothed Grain beetle, *O. surinamensis.*

Dried fruit and nuts compete with numerous insect pests under favorable condition. Under the present survey study 4 common species (Saw-toothed grain beetle, *Oryzaephilus surinamensis;* Dried fruit beetle, *Carpophilus hemipterus;* Red flour beetle, *Tribolium castaneum;* Cigarette beetle, *Lasioderm aserricorne*) of insects were found belongs to 4 families under the order coleopteran were found infested in the dried fruit and nuts**.**

The highest number of saw-toothed grain beetle found in cashew nut at Mohammadpur town hall market (3.6±1.26), Chawk bazar (3.6±1.26), Mohammadpur Krishi Market (3.4±1.50)

and Kawran Bazar (3.2±1.50) respectively. Whereas lowest number of saw-toothed grain beetle found at Mohammadpur town hall market in dates (1.2±1.13), Chawk bazaar (0.9±0.05), Mohammadpur Krishi Market (0.7±0.67) and Kawran Bazar (0.6±0.67) respectively.

Incase of almond, the number of saw-toothed grain beetle found at Mohammadpur town hall market was (2.6±1.17), Chawk bazar (2.2±1.39), Mohammadpur Krishi Market (2.5±1.39) and Kawran Bazar (2.8±1.03) respectively. As a result, the order of saw-toothed grain beetle found in terms of number of the different local markets were Mohammadpur town hall market >Chawk bazar >Mohammadpur Krishi Market >Kawran Bazar.

Incase of ground nut, the number of saw-toothed grain beetle were found in Mohammad pur Krishi Market (2.0±1.15), Kawran Bazar (1.9±1.15), Chawk Bazaar (1.9±0.99) and Mohammad pur town hall market (1.3±0.82) respectively.As a result, the order of saw-toothed grain beetle found in terms of number within the studied local markets were Mohammadpur Krishi Market >Kawran Bazar >Chawk Bazar >Mohammadpur town hall market. Incase of nutmeg, the number of saw-toothed grain beetle found in Mohammad pur town hall market (1.9±0.99), Mohammad pur Krishi Market (1.6±1.07),Kawran Bazar (1.5±1.07) and Chawk Bazaar (1.0±0.81) respectively. As a result, the order of saw-toothed grain beetle found in terms of number within the studied markets were Mohammadpur town hall market >Mohammadpur Krishi Market >Kawran Bazar >Chawk Bazar.

The highest percent of infestation (5.50% was recorded in Mohammadpur Town hall market in case of cashew nut, whereas percent of infestation was observed in almond, ground nut, Nutmeg and dates (3.80, 3.20, 1.90 and 1.20%) respectively in storage condition.

The highest percent of infestation incase of cashew nut in Mohammadpur Krishi Market was (6.0%), whereas percent of infestation were observed in almond, ground nut, nutmeg and dates 3.5, 3.2, 1.2 and 1.0%, respectively in storage condition.

In Kawran Bazar, the highest percent of infestation in cashew nut (7.5%) was observed whereas, percent of infestation in others nuts and fruit (almond, ground nut, Nutmeg and dates) were recorded 4.2, 4.2, 1.9 and1.0% respectively in storage condition.

The highest percent of infestation in Chawk Bazar in cashew nut was (6.5%), whereas percent of infestation was observed in almond, ground nut, nutmeg and dates were 5.0, 4.2, 1.9 and 1.0% ,respectively in storage condition.

Experiment-2: Study on the biology of saw-toothed grain beetle, *Oryzaephilus surinamensis* in the laboratory

Mating occurs within 2-3 days after adult emergence. The adult female beetle laid 103-118 eggs with an average of 110 eggs throughout up to 4 days. An average oviposition and incubation period were 10.20±1.93 and 8.60± 1.97 days, respectively on cashew nut in laboratory condition. Total 18.20 ± 1.93 and 7.80 ± 1.50 days were required for larval stage and pupal stage respectively. Adult longevity of saw-toothed grain beetle, *O. surinamensis* was 90.00 ± 1.21.

The length of egg were 0.2±0.00 mm and width 0.3±0.00 mm; The length of 1st,2nd ,3rd ,4th and 5th instar larvae length were (0.85±0.09, 1.5±0.00, 3.5±0.03, 4.0±0.02 and 3.2±0.00 mm respectively) and larval width were (0.25±0.00, 0.3±0.00, 0.45±0.01, 0.46±0.04 and 0.55±0.00 mm respectively); The Pupal length (3.5±0.01) and width (1.5±0.03); Adult length was (2.5±0.08) and width (1.4±0.05).

At 1st, 2nd, 3rd and 4th day the number of newly hatched larvae were 15-27, 15-24, 16-27 and 18-28,respectively, with an average number of larvae larvae hatched (20.90±0.66) throughout up to 4 days.

There is a special characteristic of pupa of saw-toothed grain beetle that 5th instar larvae create chambers for pupation. In chambers they spend their pupal life that is inactive stage of their life cycle. Its duration from 4-12 days.

At 1st, 2nd, 3rd and 4th day the number of newly formed pupae were 12-20, 11-18, 13-20 and 14-22 respectively, with an average number of pupae emerged (16.10±0.66) throughout up to 4 days.

At 1st, 2nd, 3rd and 4th day the number of newly emerged adults were 8-12, 7-13, 10-12 and 8-12 respectively. The highest average number of adults emerged in Set-IV (12.25±0.50) and the lowest average number (8.75±1.5) of adults emerged in Set-I with an average number of adults emerged (10.75±0.25) throughout up to 4 days on cashew nut in laboratory condition.

Experiment 3: The extent of damage of dried fruits due to infestation by saw-toothed grain beetle, *Oryzaephilus surinamensis*

In case of 1st generation the highest number of adults was recorded in Cashew nut (39.20) which was followed by Almond, Ground nut, Nutmeg (32.40, 30.00, 28.40 and 15.20 respectively and statistically different from all other nuts. At 2nd generation in cashew nut adult emergence was almost four times higher than 1st generation. Whereas adult emergence was lower in dates (60) at 2nd generation.

At the 1st generation on weight basis, the highest weight of healthy fruit and nuts (9.00 g) were recorded in Dates, which were closely followed by Nutmeg (8.50g). The lowest was observed in Cashew nut(7.80 g) which was statistically identical with almond (7.86g) nuts. The highest weight of infested nut was observed in Cashew nut (1.85 g) which was statistically identical by almond (1.65 g) and Ground nut (1.70 g). The lowest weight of infested nut was recorded in Dates (0.83 g) which was closely followed by dried nutmeg (0.93 g). Consideration of % infestation, the highest infestation was recorded from cashew nuts (19.18%) which were statistically similar to almond (17.37 %) and ground nut (17.16 %), while low percent of infestation was recorded in dates (8.44 %).

At the 2nd generation on weight basis, the highest weight of healthy fruit were dates (6.90 g) and Nutmeg (4.80g) respectively, which were closely followed by ground nut (3.80g) and almond (3.50g) statistically different from other nut and fruits. The lowest was observed in cashew nut (1.80 g). In case of infested fruits, the highest weight of infested fruit was observed in cashew nut (5.50g) which was followed by almond (4.04g). Whereas, almond is statistically identical by ground nut (3.86g).The lowest weight of infested fruit was recorded

in dates (1.75g), which was closely followed by Nutmeg (3.20g). Consideration of % infestation, the highest infestation was recorded from cashew nut (75.29%) which was statistically different from other nuts and followed by almond (53.59%) while low percent of infestation was recorded in date (20.23%).

At 1^{s}generation the highest weight loss (4.90%) was observed in almond and the lowest weight loss (0.80 %) was observed in ground nut which is statistically similar with Nutmeg and dates caused by saw-toothed grain beetle. From 2nd generation, the highest weight loss (6.81%) was recorded in ground nut which is statistically similar with cashew nut and the lowest weight loss (3.89%) was recorded in dates which are statistically identical with almond (4.07 %).

CONCLUSION

The saw-toothed grain beetle, *Oryzaephilus surinamensis* is one of the most serious pests of stored different dried fruit and nuts at post harvest level. The beetle develops through egg, five larval instars, pre-pupa ,pupa and adult stages. The duration of larval and pupal stage were 18.20 ± 1.93 and 7.80 ± 1.50 ,respectively. Adult longevity of saw-toothed grain beetle, *O. surinamensis* was 90.00 ± 1.21 days. Considering the adult mortality, adult emergence of saw-toothed grain beetle, weight of healthy and infested spices and percent infestation, the present study showed that the highest damage occurs in cashew nut and lowest damage occurs in nutmeg and dates respectively by saw-toothed grain beetle. Information on the biology and host use pattern of *O. surinamensis* may help to explain how various stored commodities are affected by this nut and fruits; and may lead to develop appropriate pest management strategies for this insect pest.

Recommendation:

Considering the situation of the present experiment, further studies in the following areas may be suggested:

- Such study needs to be conducted in different season for identify environmental influences
- Using different control measures with different concentration may be used for further study.

CHAPTER VI

REFERENCES

Aitken, A.D. (1975). A strain of small *O. surinamensis* (L.) (Coleoptera:Silvanidae)

Anon, (2009). Saw toothed grain beetle *Oryzaephilus urinamensis* (L.) Canadian Grain Commission.

Ashworth, J.R. (1993). The biology of. *Oryzaephilus surinamensis. J. Stored Products Research.* **29:** 291-303.

Ayyar, T.V.R. (1934). Handbook of economic entomology for South India. P. 383.

Back, E. A. and Cotton, R. T. (1926). Biology of the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.).*Journal of Stored Product Research,***33**: 435·452.

Barnes, J.K. (2002). Saw-toothed grain beetle. Arthropod Museum Notes No.7. University of Arkansas Division of Agriculture Department of Entomology.

Beckel, H., Lorini, I. and Lazzari, S. (2007). Rearing method of *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) on various wheat grain granulometry. *RevistaBrasileira de Entomologia*, **51**(4): 501-505.

Beckett, S. J. and Evans, D. E. (1994). The demography of *Oryzaephilus surinamensis*(L.) (Coleoptera: Silvanidae) on Kibbled wheat. *Journal of Stored Products Research,* **30:** 121–137.

Bousquet, Y. (1990). Research on Beetles associated with stored products

Bousquet, Y. (1990). Beetles associated with stored products in Canada: An identification guide. Agriculture and Agri-Food Canada.

Böving, A.G. and Craighead, F.C. (1931). An illustrated synopsis of the principal larval forms of the order Coleoptera. *Entomologica am*. **11**: 1-351.

Bowditch, T.G. and Madden, J.L. (1997). Infestation of chocolate-based products: Insects responsible and origins of contamination. *Australian Journal of Entomology*, **36**: 263-267.

Calvin, D. (1990). Saw toothed and Merchant Grain Beetle. Department of Entomology Entomological Notes, Penn State College of Agricultural Sciences.

Chittenden, F. H. (1896). Some Insects Injurious to Stored Grain. U. S. Dept. Agr. Farmers' Bui. **45**, 24 P.

Collins, P. J., Mulder, J.C. and Wilson, D. (1989). Variation in life history parameters of *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae). *Journal of Stored Products Research*, **25**(4): 193-199.

Cranshaw, W.S. and Peairs, F.B. (2008) "Stored Product Pests" Purdue Cielsielska Z. (1966). Research on the ecology of *Oryzaephilus surinamensis*(L.) (Coloptera: Cucujidae). Ekol. Pol. (A) **14**:439–489.

Curtis, C.E. and Clark, J.D. (1974). Comparative biologies of *Oryzaephilus surinamensis*and *Oryzaephilus mercator* (Coleoptera: Cucujidae) on dried fruits and nuts. Technical Bulletin, No. 1488, *Agricultural Research Service*, United States Department of Agriculture, pp.1-42.

Cutler, J.R. (1971). A Key for Distinguishing the Larvae of *Ahasversus advena* (Waltl), *Cathartusqua drcollis* (Geur.). *Oryzaephilus surinamensis* (L.) and *Oryzaephilus mercator* (Fauv.) (Coleoptera: Silvanidae). Short Communication. *Journal of Stored Product Research*, **7**: 125-127.

El-Sohaimy, S.A. and Hafez, E.E. (2010). Biochemical and nutritional characterizations of Dates palm fruits (*Phoenix dactylifera* L.) *J. of Appl. Sci. and Res.***6**(8): 1060-1067.

Fleming, D.A. (1988). The influence of wheat kernel damage upon the development and productivity of *Oryzaephilus surinamensis* (L.) (Coleoptera:Silvanidae). *Journal of Stored Products Research*, **24**(4): 233-236.

Fletcher, T.B. and Ghosh, C.C. (1919). Stored grain pest. Proc III *Entomol Meeting held at Pusa.* p. 712 – 761.

from the Far East. *Journal of StoredProducts Research* **2**: 45–55.

Gentile, R. and Trematerra, Y.P. (2004). Dominant pests in grains in pre harvest and post harvest storage condition. *J. Insect Sci*. **13**(1): 33-38.

Hagstrum, D.W. and Milliken, G.A. (1988). Quantitative analysis of temperature, moisture and diet factors affecting insect development. *Ann. Entomol. Soc. Am.*,**81**: 539-546.

Halstead, D.G.H. (1980). A revision of the genus *Oryzaephilus* Ganglbauer, including descriptions of related genera (Coleoptera: Silvanidae). *Zoological Journal of the Linnean Society*, **69**(4): 271-374.

Hashem, M.Y., Ahmed, S.S., El-Mohandes, M.A. and Gharib, M.A. (2012). Susceptibility of different life stages of saw-toothed grain beetle *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae) to modified atmospheres enriched with carbon dioxide. Journal of Stored Product Research, **48**: 46-51.

Heather, N.W. and Wilson, D. (1983). Resistance to fenitrothion in *Oryzaephilus surinamensis*(L.) (Coleoptera: Silvanidae) in Queensland. *J. Aust. Entomol. Soc.***22**: p. 210.

Highland, H.A. (1991). Protecting packages against insects. In: Gorham, J.R.

Hill, D.S. (1990). Pest of stored products and their control. p. 81.

Howe, R.W., (1956) The biology of the two common storage species of *Oryzaephilus* (Coleoptera: Cucujidae) *Annals of Applied Biology*, **44**:341-355.

Hurlock, E.T. (1967). Some observations on the amount of damage caused by *Oryzaephilus surinamensis* (L.) (Coleoptera:Silvaidae) to wheat. *Journal of Stored Products Research,* **3:** 75-78

Jacob, T.A. Observations of the biology of *Oryzaephilus surinamensis*(L.) Halstead with comparative notes on the common species of *Oryzaephilus* (Coleopteran:Silvanidae). *J. of Stored Product Research*.(1981); **17**:17-23.

Jacob, T.A. and Fleming, D.A. (1989) The difference in the development period and mortality of some field strains of *Oryzaephilus surinamensis* (L.) at constant temperatures (Coleoptera: Silvanidae). *Journal of Stored Product Research*, **25**: 73-76.

Jones, C.R. (1913). The Saw-toothed Grain Beetle, in the Philippine island. The *Philippine J. Sci*. **8:** 1-51.

Kingsolver, J.M. (1987). Adult beetles (Coleoptera). In: *Insect and Mite Pests in Food:An illustrated key*. (Ed. J.R. Gorham). *USDA Handbook No. 655,* United States Department of Agriculture: Washington DC, USA. Vol 1, pp 75-94.

Klein, J.A. and Burkholder,W.E. (1983). Sawtooth projections and associated secretion of *Oryzaephilus surinamensis* (Coleoptera:Cucujidae) pupae: Structure and function. *Annals of the Entomological Society of America,* **76**: 69-74.

Komson, A. (1967).A comparitive study of the saw toothed grain beetle, *Oryzaephilus surinamensis* (L.) and the merchant grain beetle, *Oryzaephilus mercator* (Fauv.), (Coleoptera: Cucujidae). M.Sc., (Sci.), thesis, McGill University, Montreal, Que. 123p

Kucerová, Z. and Stejskal, V. (2002). Comparative egg morphology of Silvanid and laemophloeid beetles (Coleoptera) occurring in stored products. *Journal of Stored Product Research,* **38**:219-227.

Kumar, S.C.M., Jacob, T.K., Jayashree, E. and Devasahayam, S. (2014). Insect Pests of Stored Spices & Their Management. p.17.

LeCato, G.L. and Flaherty, B.R.(1974).Description of eggs of selected species of stored-product insects (Coleoptera and Lepidoptera). *Journal of the Kansas Entomological Society*, **47**(3): 308-317.

Lyon, W.F. (undated) Saw toothed and Merchant Grain Beetles HYG-2086-97. Ohio State University Extension Fact Sheet.

Mason, L.J. (2003). Grain Insect Fact Sheet E-228-W: Saw-toothed Grain Beetle, *Oryzaephilus surinamensis* (L.). Purdue University, Department of Entomology.

Neethirajan, S., Karunakaran, C., Jayas, D.S. and White, N.D.G. (2007). Detection techniques for stored-product insects in grain. *Food Control*, **18**:157-162

Olsen, A.R. (1977). Differentiating saw-toothed grain beetle, *Oryzaephilus surinamensis*(L.) and the merchant grain beetle, *Oryzaephilus mercator*, by morphology of male genitalia. *Journal of the Association of Official Analytical Chemists*, **60**(5): 1223-1226.

Pferris, E. (1853). Histoire Des Insectes Du Pin Maritime. *Ann. Soc. Ent. France* (3) **1**: 555-644.

Phillips, T.W., Berberet, R.C. and Cuperus, G.W. (2000). Postharvest integrated pest management,.*InF. J.* Francis (ed.), The Wiley encyclopedia of food science technology, 2nd Edition. John Wiley and Sons, New York. pp. 2690-2701

Rajendran, S. (2005). Detection of insect infestation in stored foods. *Advances in Food and Nutrition Research*, **49**: 163-232.

Rees, D. (2004). Insects of Stored Products. CSIRO Publishing, Collingwood. Australia.

Rees, D. Pest trends in the Australian grain bulk handling system. *Proceedings of the Australian Postharvest Technical Conference* (1998), **pp** 39-42.

Saleh, A., AL-Dosari, AL-Suhaibani AM. and Ali AG. (2002). Susceptibility of some dry date palm varieties to infestation by *Oryzaephilus surinamensis* (L.) in relation chemical composition. *Assiut J. Agric. Sci*., **2**: 1-9.

Slow, J.M. (1958).A morphological comparison of the adults of *Oryzaephilus surinamensis*(L.) and *O. mercator* (Fauvel). *Bulletin of Entomological Research*, **49**: 27-34.

Stanley, J. and Evans, S.J. (1955).Studies from the Autotrephon. IV. Rearing mass cultures of *Oryzaephilus*. *Ecology*, **36**(3): 536-537.

Surtees, G. (1965).Laboratory studies on dispersion behaviour of adult beetles in grain.X. Reaction of saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.) to isolated pockets of damp and mouldy wheat. *Journal of Applied Ecology*, **2**(1): 71-80.

Thomas, M.C. and Woodruff, R.E. (1983). First records of a stored products pest, *Oryzaephilus acuminatus* Halstead, from the western hemisphere. Entomology Circular No. 257. Florida Department of Agriculture & Consumer Services, Division of Plant Industry.

Thomas, M.C. and Woodruff, R.E. (2007). A stored products pest, *O. surinamensis* (Insecta: Coleoptera: Silvanidae). EENY-188. University of Florida IFAS Extension.

Thomas, M.C. (1988).Generic key of the known larvae of the Cuujidae, Passandridae, and Silvanidae of America north of Mexico (Coleoptera). *Insecta Mundi*, **2**(2): 81-89.

Trematerra, P., Sciarreta, A. and Tamasi, E. (2000). Behavioral responses of *Oryzaephilus surinamensis*, *Tribolium castaneum*and *Tribolium confusum* to naturally and artificially damaged durum wheat kernels. *Entomologia Experimentalis et Applicata*, **94**(2):195-200.

Walker, K. (2008). Saw-toothed grain beetle *Oryzaephilus surinamensis* (Linnaeus, 1767). PaDIL Pests and Diseases Image Library.

Wheeler, M.M. (1993). Discriminating between adult mandibles of *Oryzaephilus surinamensis* and *Oryzaephilu smercator* using setal brush length. *Journal of AOAC International*, **76**(4): 941-943.

CHAPTER VII
LIST OF APPEDICES

Appendix I. Analysis of variance of the data on adult emerged of saw-toothed grain beetle at 1st and 2nd generation in stored conditions as influenced by different dry fruit and nuts

Source of variation	Degrees of freedom	Mean square	
		Adult emerged at	
		1st generation	2nd generation
Between	4	384.240**	5710.800**
Within	20	4.200	38.240

**: Significant at 0.01 level of significance

Appendix II. Analysis of variance of the data on percent infestation and total weight of dry fruit and nuts and caused by saw-toothed grain beetle in stored condition at 1st generation

Source of variation	Degrees of freedom	Mean square		
		Total weight of seeds		Infestation (%)
		Healthy (g)	Infested (g)	
Between	4	1.221**	0.823**	90.581
Within	20	0.098	0.027	3.268

**: Significant at 0.01 level of significance

Appendix III. Analysis of variance of the data on percent infestation and total weight of dry fruit and nuts caused by saw-toothed grain beetle in stored condition at 2nd generation

Source of variation	Degrees of freedom	Mean square		
		Total weight of seeds		Infestation (%)
		Healthy (g)	Infested (g)	
Between	4	11.240**	9.286**	1825.794**
Within	20	0.025	0.044	2.211

**: Significant at 0.01 level of significance

Appendix IV. Analysis of variance of the data on weight loss of different dry fruit and nuts caused by saw-toothed grain beetle at 1st and 2nd generation in stored conditions

Source of variation	Degrees of freedom	Mean square	
		Percentage of weight loss at	
		1st generation	2nd generation
Between	4	13.835*	9.451**
Within	20	4.683	2.18

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Day specific mortality of larvae of saw-toothed grain 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	4th day		
I	3	4	3	4	14	21.88
II	5	4	4	4	17	20.48
III	3	5	6	5	19	24.05
IV	6	4	7	6	23	22.77
V	7	6	7	3	23	25.27
Average	4.8	4.6	5.4	4.4	19.20	

Appendix VI. Day specific mortality of pupae of saw-toothed grain beetle on cashew nut in laboratory condition

Sample	Mortality of pupae				Total Mortality of pupa	Percent of pupal mortality
	1st day	2nd day	3rd day	4th day		
I	4	4	3	4	15	30.00
II	5	5	5	8	23	34.84
III	3	4	4	8	19	31.67
IV	6	5	8	10	29	37.17
V	8	5	5	3	21	30.88
Average	5.2	4.6	5	6.6	21.40	