# STUDIES ON BIOLOGY OF BRUCHID BEETLE *Callosobruchus chinensis* (Linnaeus) IN CHICKPEA AND ITS MANAGEMENT THROUGH PLANT BASED SILICA PRODUCTS

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**MASTER OF SCIENCE IN AGRICULTURE**

**(ENTOMOLOGY)**

**2021**

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**THESIS SUBMITTED TO THE PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF**

## MASTER OF SCIENCE IN AGRICULTURE
**(ENTOMOLOGY)**

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**DEPARTMENT OF ENTOMOLOGY**

**COLLEGE OF AGRICULTURE**

**PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY**

**RAJENDRANAGAR, HYDERABAD - 500 030**

**2021**

# DECLARATION

I, **B.V. JAYANTH**, hereby declare that the thesis entitled **"STUDIES ON BIOLOGY OF BRUCHID BEETLE *Callosobruchus chinensis* (Linnaeus) IN CHICKPEA AND ITS MANAGEMENT THROUGH PLANT BASED SILICA PRODUCTS"** submitted to the **Professor Jayashankar Telangana State Agricultural University** for the degree of **Master of Science in Agriculture** in the major field of **Entomology**, is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner

Place: Hyderabad **(B. V. JAYANTH)**
Date: **ID. No: RAM/2019-37**

# CERTIFICATE

Mr. **B.V. JAYANTH** has satisfactorily prosecuted the course of research and that thesis entitled **"STUDIES ON BIOLOGY OF BRUCHID BEETLE *Callosobruchus chinensis* (Linnaeus) IN CHICKPEA AND ITS MANAGEMENT THROUGH PLANT BASED SILICA PRODUCTS"** submitted, is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any University

Date: **(Dr. A. PADMASRI)**

**Place : Hyderabad** Chairperson

# CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON BIOLOGY OF BRUCHID BEETLE *Callosobruchus chinensis* (Linnaeus) IN CHICKPEA AND ITS MANAGEMENT THROUGH PLANT BASED SILICA PRODUCTS"** submitted in partial fulfilment of the requirements for the of degree of "**MASTER OF SCIENCE IN AGRICULTURE**" of the **Professor Jayashankar Telangana State Agricultural University, Hyderabad** is a record of the bonafide original research work carried out by **Mr. B.V. JAYANTH** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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# ACKNOWLEDGEMENTS

*It is by the grace and abundant blessings of **'Almighty'** that I have been able to bring to life this humble piece of work to which I am eternally indebted.*

*It gives me immense pleasure to express my deepest sense of gratitude and sincere indebtedness to chairperson of my advisory committee **Dr. A. Padmasri**, Senior Scientist, Seed Research and Technology Centre, Rajendranagar, Hyderabad for her affectionate guidance, untiring interest, sustained help, constructive criticism and well timed suggestions for successful completion of my research work and in the preparation of manuscript. I owe her a huge debt of gratitude forever for all that I got from her.*

*I deem it is my privilege in expressing my deep sense of reverence, gratitude and indebtedness to **Dr. T. Uma Maheswari**, Associate Dean, Agricultural College, Sircilla and member of the Advisory Committee for her valuable suggestions, immeasurable help, wholehearted support and meticulous attention during the execution of the present study and in preparation of the thesis.*

*I am also obliged to **Dr. Mohibbe Azam,** Principal Scientist, IIRR, Rajendranagar, Hyderabad and member of the Advisory committee for his constant encouragement, keen interest, constructive suggestions and fruitful advice during the execution of the present study.*

*I am thankful to **Dr. S. J. Rahman**, Professor and University Head, **Dr. S. Upendhar,** Associate Professor, **Dr. R. Sunitha Devi**, Associate Professor, **Dr. P. Rajnikanth**, Associate Professor, Department of Entomology, College of Agriculture, Rajendranagar for their teachings and encouragement rendered throughout my P.G programme and research work.*

*I wish to express my thanks to **Dr. Chandra Mohan**, Sr. Scientist, Rice Section, ARI for his valuable suggestions and help in arranging paddy husk and paddy leaves.*

*I am also obliged to **Dr. B. Anil Kumar**, Coordinator, DAATTC, Warangal* for his *valuable suggestions and wholehearted support during my research work.*

*It gives me immense pleasure in extending my sincere thanks to Central Instrumentation Cell staff for their support, co-operation and generous help during the period of my investigation.*

*I allocate my highest respect and heartful regards from my inner core of heart to my ever loving parents,* ***Sri. B. Mahendar*** *and* ***Smt. B. Chandrakala*** *who constantly, guided and moulded me into the present position and whose boundless love, unparallel affection, dedicated efforts, encouragement and moral support is a constant source of motivation for me in shaping up my career. My vocabulary utterly fails in expressing my love to my brother* ***B.V. Yashwanth*** *and aunt* ***B. Padmavathi*** *for their support during shaping up my career.*

*I express my sincere thanks to* ***Nikitha*** *and* ***Manga****, staff of SRTC, Rajendranagar, for their unstincted cooperation to carry out my research work*

*I owe my gratitude to my classmates* ***Priyanka, Lokesh, Pasha, Shivaram, Shiva, Sandhya, Krishnaveni, Bhavana, Sunitha, Raghupathi, Vandana, Kantesh, Chaitanya*** *for their cheerful company, encouragement and co-operation in my P.G programme.*

*I take this opportunity to thank my friends* ***Ganesh, Rameshwar, Ravi, Manibala, Datta, Swetha*** *and my dear seniors* ***Satish, Akshay, Kishore and Bhojendra*** *for their help, support and encouragement whenever I needed.*

*I take it as special privilege to thank all the authorities and staff of Professor Jayashankar Telangana State Agricultural University who provided me an opportunity to undertake the course.*

*I feel elated to express my bountiful thanks to those who directly or indirectly helped me in successful completion of thesis work.*

***Date:***

***Place: Hyderabad*** ***Mr. B. V. Jayanth***

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# LIST OF SYMBOLS AND ABBREVATIONS

| | | |
|---|---|---|
| % | : | Per cent |
| @ | : | At the rate of |
| a.i. | : | Active ingredient |
| °C | : | Degree Celsius |
| & | : | And |
| AOAC | : | Association of Official Analytical Chemists |
| ARI | : | Agriculture Research Institute |
| ARS | : | Agricultural Research Station |
| CD | : | Critical Difference |
| cm | : | Centimetre |
| $cm^2$ | : | Square centimeter |
| CRD | : | Complete randomized design |
| CV | : | Coefficient of Variation |
| DAR | : | Days after release |
| DE | : | Diatomaceous earth |
| *et al.,* | : | And others people |
| $F_1$ | : | First generation |
| Fig. | : | Figure |
| G | : | Gram |
| HCL | : | Hydro-chloric acid |
| Ha | : | Hectare |
| IIRR | : | Indian Institute of Rice Research |
| *i.e.,* | : | That is |
| Kg | : | Kilogram |
| Kg $ha^{-1}$ | : | Kilogram per hectare |
| Mg | : | Milligram |
| m ha | : | Million hectares |
| MOS | : | Months of storage |
| Mt | : | Million tonnes |
| N | : | Normality |

| | | |
|---|---|---|
| $N_2$ | : | Nitrogen |
| No. | : | Number |
| N.S | : | Non-Significant |
| PJTSAU | : | Professor Jayashankar Telangana State Agricultural University |
| Ppm | : | Parts per million |
| RH | : | Relative humidity |
| SEm | : | Standard error of mean |
| SRTC | : | Seed Research and Technology Centre |
| *viz.*, | : | Namely |

| | | |
|---|---|---|
| Name of the author | : | **B.V. JAYANTH** |
| Title of the thesis | : | **"STUDIES ON BIOLOGY OF BRUCHID BEETLE *Callosobruchus chinensis* (Linnaeus) IN CHICKPEA AND ITS MANAGEMENT THROUGH PLANT BASED SILICA PRODUCTS"** |
| Degree | : | **MASTER OF SCIENCE IN AGRICULTURE** |
| Faculty | : | **AGRICULTURE** |
| Department | : | **ENTOMOLOGY** |
| Chairperson | : | **Dr. A. PADMASRI** |
| University | : | **PROFESSOR JAYASHANKAR TELANGANA STATE AGRIULTURAL UNIVERSITY** |
| Year of submission | : | **2021** |

# ABSTRACT

The present investigation on "Studies on biology of bruchid beetle, *Callosobruchus chinensis* (Linnaeus) in chickpea and its management through plant based silica products" was carried out during 2020-21. The studies were conducted under laboratory conditions at Entomology laboratory, Seed Research and Technology Centre and Central Instrumentation Cell, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad.

The aim of the current investigation is to study the biology of the bruchid beetle *Callosobruchus chinensis* (L.) in chickpea and its management through plant based silica products *viz.*, amorphous silica gel @ 250 and 500 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 250 and 500 ppm $kg^{-1}$ seed, paddy husk @ 1000 and 2000 ppm $kg^{-1}$ seed, paddy leaves @ 1000 and 2000 ppm $kg^{-1}$ seed and diatomaceous earth @ 300 and 600 ppm $kg^{-1}$ seed. Biology studies revealed that, among the plant based silica products, amorphous silica gel @ 500 ppm $kg^{-1}$ seed was found as effective protectant in reducing the fecundity, hatchability, adult emergence, adult longevity and weight loss while it had non significant effect on incubation period and larval-pupal periods.

Management of pulse beetle, *Callosobruchus chinensis* with plant based silica products was studied under ambient conditions. Seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed completely reduced seed damage, adult emergence and weight loss which showed its superior performance over other treatments in protecting the seed up to six months of storage. The results revealed that exposure of adult beetles to amorphous silica gel @ 500 ppm $kg^{-1}$ seed had resulted in cent per cent adult mortality within five days after release at two, four and six months of storage.

The effect of plant based silica products on nutritional quality parameters *viz*., carbohydrates, protein and crude fat were also studied. The results showed that exposure of seeds to plant based silica products resulted in significant negative effect on carbohydrate and crude fat besides positive effect on protein content which might be due to the increased infestation of *C. chinensis* and storage period.

The plant based silica products gave protection against pulse beetle *Callosobruchus chinensis* (L.) infestation with no adverse effect on the nutritional quality parameters of chickpea seeds.

## Chapter I

# INTRODUCTION

Pulses are considered as most nutritious and play a crucial role in fulfilling protein deficiency in daily diet of people. Among them, chickpea has been a traditional low-input crop in the farming systems of the Indian subcontinent because of its adaptability to a wide range of environments. The chickpea is of two main types, the desi type and the kabuli type.

There is a growing demand for chickpea due to its nutritional value. It is a good source of carbohydrates and protein, together constituting about 80% of the total dry seed mass. Lipids are present in low quantity but rich in important unsaturated fatty acids like linoleic acid and oleic acid (Jukanti *et al*., 2012).

Globally South and West Asia regions account for about 90 per cent of the world chickpea production. India, Pakistan, Turkey, Iran and Syria are major producers (Joshi *et al*., 2001). In India it occupies an area of 96.98 m ha with annual production of 110.78 mt and productivity of 1142 kg $ha^{-1}$. Telangana state accounts for 1.30 m ha of area with production and productivity of 1.99 mt and 1532 kg $ha^{-1}$, respectively (www. indiastat.com, 2019-20). In Telangana primarily it is grown in Kamareddy, Sangareddy, Jogulamba Gadwal, Nizamabad and Adilabad districts.

Insects extensively cause damage to stored grains and the grain products which accounts to 5 to 10 per cent in temperate and 20 to 30 per cent in tropical zones (Nakakita, 1998). The most important insects damaging chickpea in storage are bruchid or pulse beetle (*Callosobruchus* sp), Rust-red flour beetle (*Tribolium castaneum*), Lesser grain borer (*Rhyzopertha dominica*), Saw toothed grain beetle (*Oryzaephilus surinamensis*). Among the major pulse beetles, *Callosobruchus chinensis* and *Callosobruchus maculatus* are prominently distributed in Asia and Africa which cause more than 50 per cent damage to stored cereals and legumes (Giles, 1977; Sharma, 1984; Bindhu *et al*., 2015; Khan *et al*., 2015). In case of heavy infestation by *Callosobruchus chinensis*, the seeds lose their germination capacity and if exploited as grains, they become unfit for human consumption. In addition to quantitative losses, the *Callosobruchus chinensis* also causes qualitative losses (Khare and Johari, 1984).

Generally, infestation of bruchids starts in the field, where the adult female lays eggs on green pods which causes only minor damage. The grub penetrates the pod and remain concealed within the seeds as hidden infestation (Southgate, 1979) and the damage is multiplied by several folds under storage. In grub stage, the beetle lives inside the grain and fills the burrow with their excretion and dead bodies (Atwal, 1976) which fetches lower market price due to reduced weight.

Currently, the control of stored product pests is primarily based on the use of synthetic pesticides, either as contact insecticides or as fumigants (Arthur, 1996). The extensive application of insecticides is directly related with the development of resistance of stored product insect species, raising serious concerns for human health as a result of food contamination with residues and possible environmental hazards (Boyer *et al*., 2012; Stadler *et al*., 2012). In many countries, cancellation of the registration of approximately all fumigants including aluminium phosphide and methyl bromide are on the way because of their carcinogenic effects on humans. This prompted to develop alternative pest management strategies which are eco friendly in nature.

In this context, the use of plant derived products are considered a promising alternative to currently used traditional pesticides against stored product insects (Weaver and Subramanayam, 2000). Many authors have concluded that rice husk is an excellent source of high grade amorphous silica (Chen and Chang, 1991; Ghosh *et al*., 1991; Nandi *et al*., 1991; Conradt *et al*., 1992; Nayak *et al*.,1996; Real *et al*., 1996). Therefore, the use of rice husk as a source of silica products has positive impact on the environment and also economical through the use of low value agricultural by-product that can relieve waste disposal problems.

Amorphous sorptive silica dusts protect stored grain from the attack by a number of insect species and have the advantage of low mammalian toxicity over conventional chemical control agents. Their insecticidal action is due to their ability to adsorb epicuticular lipid from insects moving over the treated surfaces, removal of this water proofing layer leads to desiccation and death (Ebeling, 1971). They are classified as having an “unlimited” acceptable daily intake when used as food additives (Anonymous, 1974) and however, United States Department of Agriculture has declared amorphous silica as biosafe (Stathers *et al*., 2004). Hence present investigation is proposed to study the efficacy of plant based silica products as a grain protectant with the following objectives.

**OBJECTIVES:**

**1.** To Study the effect of plant based silica products on biology of bruchid beetle *Callosobruchus chinensis* (L.).

2. To study the efficacy of plant based silica products for the management of bruchid beetle.

3. Assessment of nutritional quality parameters of treated chickpea.

# Chapter II

# REVIEW OF LITERATURE

## 2.1 NATURE AND EXTENT OF DAMAGE CAUSED BY BRUCHID

Major constraints in the production of pulse crops is the insect pests which inflict severe losses both in field and storage. About 1300 species of bruchids belonging to fifty six genera from five sub families are present around the world. In India, ninety seven species of bruchids from eleven genera are causing severe damage (Southgate, 1979),

Among the storage insect pests, pulse beetle is one of the serious pest of chickpea causing severe losses in storage besides affecting the nutritional value of the stored grains. It is one of the major insect pest of legumes under sub-tropical conditions where, the whole development occurs inside a single seed and adults emerge out by leaving the holed seed behind (Messina and Jones, 2009). Pulse beetle completes its life cycle within 25 to 34 days during summer while, it takes 40 to 50 days in winter (Ghosh and Dubey, 2003).

## 2.2. EFFECT OF PLANT BASED SILICA PRODUCTS ON BIOLOGY OF BRUCHID BEETLE *Callosobruchus chinensis* (L.).

### 2.2.1 Silica Products

Arumugam *et al*. (2016) studied the efficacy of silica nanoparticles (SNPs) against pulse beetle, *Callosobruchus maculatus* in chickpea as a stored pulse protector and they reported that the seeds treated with 900 and 1000 ppm of SNPs were effective which showed complete inhibition of oviposition, adult emergence and no seed damage compared to untreated control in which number of eggs per female (35±2.3), development period (32±1.0), adult emergence (100 per cent) and seed damage (22±1.5 per cent), respectively.

El-Bendary (2017) studied the effect of silica nanoparticles @ 500 ppm and malathion @ 1gram per kilogram seed on cowpea against *Callosobruchus maculatus* under laboratory conditions. They revealed that there was decrease in egg number with hydrophobic silica nanoparticles. The number of eggs per seed in control was 9.3 ± 0.5 which was significantly higher as compared to seed treated with malathion (1.6 ± 0.6) and nanosilica (2.5 ± 0.5). This investigation revealed the use of silica nanoparticles as an effective tool in managing *Callosobruchus maculatus* under laboratory conditions with low damage to cowpea seeds.

Korunic *et al*. (2017) tested effectiveness of three inert dusts *viz*., disodium octaborate tetrahydrate (DOT), silica gel (Sipernat 50 S) and diatomaceous earth (Celatom Mn 51) @ 200, 300, 400 and 500 ppm against rice weevil, *Sitophilus oryzae* in wheat and they reported that the inhibition of progeny on seeds treated with Sipernat 50 S powder was 100 per cent at all doses while, in treatments where DOT was applied as powder and suspension, the inhibition per cent ranged from 86 to 100 per cent and 85.43 to 99.83 per cent, respectively depending on the concentrations.

### 2.2.2 Paddy husk and Paddy leaves

Loganathan and Ahangama (1996) tested dried plant powders and acetone extracts of *Tridax procumbans*, *Eucalyptus camaldulensis* and *Lantana camara*, paddy husk ash, activated kaolin clay and untreated kaolin clay for their insecticidal activity and ovicidal effects against pulse beetle *Callosobruchus maculatus* on stored green gram seeds. They reported that seeds treated with paddy husk ash @ 5 per cent concentration recorded a 62 per cent reduction in egg laying capacity and 54 per cent reduction in adult emergence.

Naito (1999) tested natural substances *viz*., rice husk ash, wood ash and lime against bruchid beetles in soybean and he reported that number of eggs deposited on soybean seeds were lowest in seeds treated with rice husk ash (10-20 eggs only in 500 grams of soybean seed) compared to seeds treated with wood ash and lime. He also reported that less seed damage (1.4 per cent) was observed in seeds treated with rice husk ash compared to untreated soybean seeds (26.6 per cent).

Adebayo and Ibikunle (2014) conducted experiments to assess the potentials of cowdung ash, rice husk ash and powdered clay @ 1g and 2g per twenty clean seeds against *Callosobruchus maculatus* and *Sitophilus zeamais* in cowpea and maize, respectively. For cowpea, significantly higher number of adults emerged from those seeds treated with powdered clay and control compared with that of seeds treated with cow dung ash and rice husk ash. They further reported that significant higher weight loss was recorded in untreated seeds as compared to seeds treated with rice husk ash and cow dung ash.

Idoko (2016) evaluated rice husk powder, rice husk ash and rice grain powders as anti-ovipositant against *Callosobruchus maculatus* under laboratory conditions @ 0.4, 0.6, 0.8 and 1.0 gram per 20 grams of cowpea seeds. Their experimental findings indicated that these treatments significantly inhibited oviposition among which, the lowest mean number of eggs (73.1) were found in seed treated with rice husk ash followed by rice husk powder and rice grain powder compared to untreated control (103.0). They reported that number of eggs laid by *Callosobruchus maculatus* on seeds decreased with an increase in dosage and also at highest rate of application *i.e.,* 1.0 grams of treatment per 20 grams of seed, oviposition was reduced by more than 50 per cent in comparison with control.

Sharma and Devi (2016) evaluated inert materials namely saw dust, wheat husk, dung cake ash, sand with 6 cm covering of each treatment against pulse beetle *Callosobruchus chinensis* infesting stored chickpea and reported that all the protectants resulted in significantly less number of eggs per 500 seeds as compared to untreated control after 1, 50, 110 and 160 days of storage period.

Ashamo *et al*. (2018) carried out investigation on comparative toxicity of diatomaceous earth, rice husk ash, rice husk powder, *Piper guineense* seeds, pirimphos-methyl dust and *Capsicum annum* seeds against *Callosobruchus maculatus* in cowpea seeds. They reported that the highest oviposition of 68.67 eggs was observed in pirimphos-methyl treated seeds @ 0.2 g 20 $g^{-1}$ seeds while, lowest oviposition of 13.67 eggs was observed in seeds treated with rice husk ash @ 0.2 g 20 $g^{-1}$ seeds. Their findings also indicated that rice husk powder had highest adult emergence per cent of 70.61 @ 0.2 g 20 $g^{-1}$ seeds while, *P*. *guineense* recorded least adult emergence per cent of 35.33 @ 0.2 g 20 $g^{-1}$ seeds.

### 2.2.3 Diatomaceous earth

El-Nahal and El-Halfawy (1973) studied the effect of white clay, diatomaceous earth, kaolin and katelsousse (a rock phosphate dust) @ one per cent concentration against *Sitophilus oryzae* and *Sitophilus granarium* in wheat. They reported that all the treatments resulted in reduced fecundity, fertility in eggs and life span of adult.

Prasantha *et al.* (2003) reported that increasing dosages of diatomaceous earth, Fossil-Shield and Silico-Sec decreases the fecundity of *Callosobruchus maculatus* on mungbean. They also reported that the percentage of unhatched eggs and seeds bearing no eggs increased with increase in diatomaceous earth concentrations.

Stathers *et al*. (2004) studied the insecticidal efficacy and persistence of commercially available diatomaceous earth (DE) products *viz*., Dyracide and Protect-It when admixed with typical host commodities in controlling four tropical stored grain pests, *Callosobruchus maculatus, Sitophilus zeamais, Acanthoscelides obtectus* and *Prostephanus truncates* @ 0.1 and 0.2 per cent. They reported that both these commercially available DEs increased insect mortality and reduced progeny of all four stored grain pest compared to untreated control.

Kabir (2013) evaluated efficacy of diatomaceous earth (Protect-It) on four cowpea cultivars against *Callosobruchus maculatus*. He reported that diatomaceous earth applied at the rate of 1000 mg $kg^{-1}$ seed resulted in complete inhibition of oviposition, adult emergence and grain damage on all cultivars tested.

Kabir and Wulgo (2014) carried out laboratory tests to evaluate efficacy of four diatomaceous earth formulations *i.e.*, Celite 209, DiaFil 610, protect-It, SilicoSec against *Callosobruchus maculatus* in cowpea and reported that mean number of the progeny in untreated control (268.4±18.5) was significantly higher as compared to treated seeds and the production of progeny reduced with increase in diatomaceous earth dose rate. The experimental findings revealed that lowest number of progeny and highest progeny suppression were 3.0 and 98.9 per cent, respectively in seeds treated with Protect-It and the efficacy of four diatomaceous earth formulations was Protect-It > SilicoSec > Celite 209 = DiaFil 610 order.

Jean *et al*. (2015) studied the efficacy of diatomaceous earth (Fossil-Shield) @ of 0, 5, 10, 20 and 40 grams per kilogram and wood ash from *Acacia polyacantha* and *Hymenocardia acida* @ 0, 0.5, 1.5 and 2 g $kg^{-1}$ against *Sitophilus zeamais* in stored maize. They reported that all these products significantly caused reduction in emergence of progeny compared to control, where Fossil-Shield suppressed $F_1$ progeny emergence completely (100 per cent) at all dosages except 0.5 g $kg^{-1}$ which provided 95.50 per cent of inhibition. The two ashes suppressed emergence of $F_1$ progeny at 97.98 per cent and 99.28, respectively.

Sabbour *et al*. (2015) conducted experiments with nano-diatomaceous earth in comparison with natural diatomaceous earth in wheat and reported less number of eggs per female were observed in grains treated with diatomaceous earth (144.6±9.4 and 198.6±2.4) and nano-diatomaceous earth (48.6±9.1 and 58.6±9.4) compared to untreated control (278.6±3.4 and 291.1±1.3) with *Tribolium confusum and Tribolium castaneum*, respectively.

Okonkwo *et al*. (2018) conducted experiments with different diatomaceous earths *viz*., Bularafa, Abakire, Share, Kwami and Insecto against *Callosobruchus maculatus* on two varieties of cowpea *viz*., Ife brown and IT98-12 white. Significantly highest mean number of progeny was observed in untreated control for both IT98-12 white (199 ± 2.5) and Ife Brown (188 ± 7.2) varieties, respectively at 35 days of treatment. They also observed, progeny production was reduced by increasing the diatomaceous earth concentration. They reported a seed damage of less than five per cent was observed in seeds treated with both Insecto and Bularafa @ 1000 ppm whereas seed damage of less than three per cent were recorded in seeds treated with both Insecto and Bularafa @ 1500 ppm for both Ife brown and IT98-12 white varieties compared to control.

Saeed *et al*. (2018) studied the effectiveness of Grain-Guard, an improved form of diatomaceous earth against *Liposcelis paeta*, *Cryptolestes ferrugineus*, *Rhyzopertha dominica* and *Tribolium castaneum* on wheat, rice, maize and sorghum and reported that suppression in progeny was higher at the beginning of post-treatment duration and from 60 days after post-treatment progeny number started to increase with the increase in post-treatment duration.

## 2.3 EFFICACY OF PLANT BASED SILICA PRODUCTS FOR MANAGEMENT OF BRUCHID BEETLE

### 2.3.1 Grain damage and Weight loss

Ibrahim *et al*. (2012) studied effect of raw diatomaceous earth and plant powders against *Callosobruchus subinnotatus* in stored groundnut seeds and reported that per cent damage in diatomaceous earth treated seeds was 9.68 per cent compared to untreated seeds (50.89 per cent). The per cent seed weight loss in diatomaceous earth treated seeds was 6.0 per cent compared to untreated seeds (40.80 per cent).

Badii *et al*. (2014) studied efficacy of diatomaceous earth formulations namely Probe-A, Damol-D1, FossilShield and Diatomenerde against *Callosobruchus maculatus* in kersting’s groundnut and reported that weight loss in untreated seeds was significantly higher than diatomaceous earth treated seeds. Their experimental findings indicated that among the diatomaceous earth treatment, highest weight loss was recorded by the seeds treated with Diatomenerde (1.50 gram) followed by FossilShield (0.90 grams) Damol

(0.49 grams) and Probe-A (0.25 grams) at 0.2 g $kg^{-1}$ seed where mean weight loss in control was 4.26 grams at 50 per cent relative humidity.

Kabir and Wulgo (2014) carried out laboratory tests to evaluate efficacy of four diatomaceous earth formulations *i.e.,* Celite 209, DiaFil 610, protect-It and SilicoSec against *Callosobruchus maculatus* in cowpea and they reported that in diatomaceous earth treated seeds, damage decreased with increase in rate of dosage. Their experimental findings indicated that less than seven per cent seed damage was recorded on seeds treated with Celite 209, protect-It, SilicoSec @ 1000 and 1500 mg $kg^{-1}$ cowpea seeds with the exception of DiaFil 610.

Ashamo *et al*. (2018) carried out investigation on comparative toxicity of diatomaceous earth, rice husk ash, rice husk powder, *Piper guineense* seeds, pirimphos-methyl dust and *Capsicum annum* seeds against *Callosobruchus maculatus* in cowpea seeds and recorded least weight loss and seed damage with rice husk ash (0.40 g and 1.95 g, respectively) and the same for control was 17.08 g and 31.92 g, respectively.

### 2.3.2 Adult emergence

Loganathan and Ahangama (1996) tested dried plant powders and acetone extracts of *Tridax procumbans*, *Eucalyptus camaldulensis* and *Lantana camara*, paddy husk ash, activated kaolin clay and untreated kaolin clay for their insecticidal activity and ovicidal effects against pulse beetle *Callosobruchus maculatus* on green gram seeds and reported that seeds treated with paddy husk ash @ 3 and 5 per cent concentrations reduced adult emergence by 45 and 54 per cent, respectively.

Amin *et al*. (2017) studied the efficacy of silica gel against *Sitophilus oryzae* on rice grains and reported that with the increase in dose there is a corresponding significant decrease in progeny of 14.33, 13, 12.33 and 9 with dosages @ 1, 2, 3 and 4 per cent which were found superior to untreated grains (23.00).

Badii *et al*. (2014) studied efficacy of diatomaceous earth formulations namely Probe-A, Damol-D1, FossilShield and Diatomenerde against *Callosobruchus maculatus* in kersting's groundnut. They reported that seeds treated with dosage rates @ two g $kg^{-1}$, significantly recorded lower number of $F_1$ progenies compared to those of seeds treated with dosages @ 0.5 and one g $kg^{-1}$.

Kabir and Abdullahi (2014) carried out laboratory studies to evaluate the insecticidal efficacy of diatomaceous earth (Protect-It) @ 250, 500, 750 and 1000 mg kg$^{-1}$ against red flour beetle (*Tribolium castaneum)* in Atilla-Gan-Atilla variety of wheat. They reported that, no progeny developed in grains treated @ 750 and 1000 mg kg$^{-1}$, where number of progeny emerged were 0.7 and 0.3 in grains treated @ 250 and 500 mg kg$^{-1}$, which was significantly lower compared to untreated grains (16.7).

Mesbah *et al*. (2017) studied the insecticidal activity of nano silica particles and coarse silica against *Callosobruchus chinensis* in broad bean. Their results indicated that there was no emergence of adults in the seeds treated with nano silica particles @ one and two grams per 100 grams seed where the number of adults emerged in the seeds treated with coarse silica was 5.33 and 2.3 @ one and two grams per 100 grams seed which was found effective compared to control (24.7 adults).

### 2.3.3 Residual toxicity

Naito (1999) tested natural substances namely, rice husk ash, wood ash and lime against bruchid beetles in soybean where he reported rice husk ash at the rate of 0.5 per cent and 1 per cent gave 100 per cent mortality which continued till three months after treatment. He also reported that seeds treated with rice husk ash showed highest suppression effect and smallest number of adults emerged, followed by wood ash and lime.

Paneru and Shivakoti (2001) evaluated the efficacy of plant materials namely sweet flag (*Acorus calamus*), goat weed (*Ageratum conzoides*), lantana (*Lantana camara*), Indian privet (*Vitex negundo*), mug-wort (*Artimisia vulgaris*), chinaberry (*Melia azedarach*), rice husk ash, mustard(*Brassica* spp.) oil and neem (*Azadirachta indica*) oil for the management of *Callosobruchus maculatus* in lentil. The powder or oil were mixed @ 0.5, 1 and 2 per cent w/w or v/w with lentil grains and 25 adult beetles were exposed to grains for each concentration of the main treatment and reported that rhizome powder of sweet flag, rice husk ash and mustard oil showed a significant effect causing 100 per cent mortality of pulse beetle within a week @ 0.5, 1 and 2 per cent concentrations.

Swain and Kanchan (2005) studied the effects of wood ash, bamboo ash, rice straw ash, cow dung ash, fly ash and rice husk ash @ 0.5 grams per 100 grams seeds against *Sitophilus oryzae* and *Callosobruchus chinensis* in wheat and pulses, respectively and reported that these ashes notably hindered the growth of insect populations where the development was normal in untreated control. They revealed that rice husk ash was found more effective in controlling the pest population compared to other treatments.

Shams *et al*. (2011) carried out experiments with diatomaceous earth formulation Silicosec against *Callosobruchus maculatus* and *Sitophilus granaries* in wheat and cowpea at five concentrations and reported that with the increase in the concentration of Silicosec, adult mortality was above 90 per cent. They also observed that *C.maculatus* adults were more susceptible to Silicosec than *S.granarius.*

Athanassiou *et al*. (2013) carried out bioassay to evaluate efficacy of silica gel enhanced with essential oil of *Juniperus oxycedrus* sp. against *Sitophilus oryzae*. They reported that, for a period of seven days exposure, 100 and 98 per cent mortality was observed in *Sitophilus oryzae*, when treated with 500 and 250 ppm of enhanced silica gel, respectively. Similarly for a period of 14 days exposure, all adults were dead both @ 250 and 500 ppm dosages of enhanced silica gel.

Jean *et al*. (2015) studied effectiveness of diatomaceous earth (Fossil Shield) and wood ash from *Acacia polyacantha* and *Hymenocardia acida* against *Sitophilus zeamais* in maize and reported that Fossil Shield @ 0.5 g $kg^{-1}$ achieved 100 per cent mortality within seven days of exposure and was found more effective than the wood ash from *H.acardia* (87.11% mortality) and *A.polycantha* (4.82% mortality) @ 40 g $kg^{-1}$ for the same time point. They concluded that these three dusts caused significant reduction of progeny emergence, damaged grains and weight loss.

Adarkwah *et al*. (2017) evaluaed the efficacy of paddy rice husk Ash (PRHAP) and false yam (*Icacina oliviformis*) leaf powders (FYLP) alone or in combination with enhanced diatomaceous earth against *Sitophilus granarius*, *Tribolium castaneum* and *Acanthoscelides obtectus* in stored grains. They reported that grains treated @ 30000 to 50000 ppm of PRHAP killed all *Tribolium castaneum* and *Sitophilus granarius* at five days of treatment and *Acanthoscelides obtectus* in one day.

Olorunmota *et al.* (2017) studied effect of rice husk and melon shell wastes as grain protectants in stored cowpea against *Callosobruchus maculatus.* The samples treated with rice husk ash (RHA) @ 1.0-2.0 g/20g cowpea recorded 100 per cent mortality followed by melon shell ash (MSA) @ 2g/20g and rice husk powder (RHP) @ 2g/20g which gave 93.33 and 70 per cent mortality, respectively. RHA significantly showed highest percentage oviposition inhibition ($P \leq .05$), followed by MSA and RHP.

Otitodun *et al*. (2017) studied the efficacy of rice husk ash containing 87.1% silica with application rates *viz.*, rice husk ash low (RHAL) and rice husk ash high (RHAH), corresponding to 0.5 and one g $kg^{-1}$ against rice weevil and lesser grain borer on wheat with Insecto, a commercial diatomaceous earth as a standard check. They reported that RHAH caused 10.3 and 91.1 per cent mortality whereas Insecto caused 63.4 and 100 per cent mortality of adult *R.dominica* and *S.oryzae*, respectively after 14 days exposure period. They also reported that Insecto, RHAH and RHAL caused progeny suppression of 95.2, 63.8 and 46 per cent in case of *S.oryzae* whereas 20.3, 64.3 and 92.9 per cent in case of *R.dominica* respectively.

Kumar *et al*. (2017) studied the effect of nanoparticles namely nano silica, nano alumina and nano clay against cigarette beetle *Lasioderma serricorne* in cured turmeric rhizomes and found that out of the three nanoparticles, nano silica @ 0.5 and 0.25 g $kg^{-1}$ recorded superior performance in terms of higher mortality, reduced adult emergence and oviposition at one day after treatment compared to other treatments followed by nano silica @ 0.175 g $kg^{-1}$.

Saeed *et al*. (2018) studied the effectiveness of Grain-Guard, an improved form of diatomaceous earth against *Liposcelis paeta*, *Cryptolestes ferrugineus*, *Rhyzopertha dominica* and *Tribolium castaneum* on wheat, rice, maize and sorghum. They reported that overall mortality of stored grain pests increased with the rise of application rate and exposure intervals of diatomaceous earth and decreased over 120 days of post-treatment period. They observed that during the first 60 days of post treatment, adult mortality increased and later on, a steady decrease in adult mortality was seen.

Singh and Devi (2020) conducted an experiment studying the effect of rice husk ash on controlling insect pests in storage of pea seeds and they observed that seeds when mixed with rice husk ash at the ratios of 1:0.25, 1:0.30, 1:0.35, 1:0.40, 1:0.45 and 1:0.50 showed no damage from insect pests.

## 2.4 ASSESSMENT OF GRAIN QUALITY PARAMETERS OF TREATED CHICKPEA

Pulses are being cultivated by the farmers since time immemorial providing nutritionally balanced diet (Nene, 2006). Chickpea is an excellent source of protein and carbohydrate where its protein is of high quality compared to other legume crops (Ercan *et al*., 1995). Due to insect infestation, seeds undergo biochemical changes which results in the loss of various constituents of seed.

### 2.4.1 Carbohydrates

Anantalaxmi (1978) reported that the carbohydrate contents of red gram and groundnut increased with the storage period. The per cent increase of sucrose was 51 and 47 in red gram and groundnut, respectively at six months of storage.

Sudesh *et al*. (1996) observed that an increase in the infestation of *Trogoderma granarium* in wheat, maize and sorghum grains resulted in decrease of total carbohydrate content compared to control.

Mali and Vir (2000) assessed qualitative and quantitative losses in green gram stored at twelve months of storage. They reported that there was a significant decrease in soluble carbohydrate, total soluble sugars with storage time at room temperature.

Ahmedani *et al*. (2009) studied varietal changes in nutritional composition of wheat kernel (*Triticum aestivum*) caused by infestation of khapra beetle (*Trogoderma granarium)*. They reported that carbohydrate content of wheat decreased from 81.04 to 74.4 per cent at six months of storage.

Saxena and Saxena (2011) carried out analysis of nutritional changes in stored chickpea infested with *Callosobruchus maculatus* after one and six months of storage. They reported that total carbohydrate decreased from 57.82 to 44.39 per cent with increased insect infestation in chickpea seeds.

Lawal and Fagbohun (2012) studied the nutritional composition of millet seeds during storage and revealed that freshly harvested seeds had a carbohydrate content of 72.75 per cent which slightly decreased to 72.54 per cent after 20 weeks of storage.

Abdelfattah and Zein (2019) carried out an experiment to study the effect of Aerosil 200 nanoparticles (fumed silica) on wheat seed components *i.e.*, carbohydrate, crude protein, crude fat after six months of storage. They reported that total carbohydrate per cent in treated seeds was 76.05 as compared to untreated seeds which was 75.23 per cent.

### 2.4.2 Proteins

Venkatrao *et al*. (1970) reported an increase in the total nitrogen content of black gram and field bean infested by *Callosobruchus chinensis* upto a storage period of six months.

Gujar (1975) reported that initial true protein content in healthy green gram seeds was 22.41 per cent while it was 23.79 to 26.77 per cent in seeds infested with *Callosobruchus chinensis*.

Nanda (1990) reported that total protein content in the healthy bengal gram seeds was 23.71 per cent while it was 50.30 per cent in seeds damaged by *Callosobruchus chinensis*.

Sudesh *et al*. (1996) observed that an increase in the infestation of *Trogoderma granarium* in wheat, maize and sorghum grains resulted in an increase in the total protein content compared to control.

Ojimelukwe and Ogwumike (1999) studied the effect of infestation by bruchid beetle (*Callosobruchus maculatus*) on the nutritional quality of Ife-brown cowpea variety. They reported that crude protein content in infested cowpea was 9.93 per cent compared to uninfested cowpea which was 7.73 per cent.

Mali and Vir (2000) assessed qualitative and quantitative losses in green gram stored upto twelve months. They reported that there was a significant increase in crude protein with storage time at room temperature.

Venugopal *et al*. (2000) reported that there exists a positive correlation of protein content with *Callosobruchus maculatus* infestation in stored legumes.

Ahmedani *et al*. (2009) studied varietal changes in nutritional composition of wheat kernel (*Triticum aestivum*) caused by infestation of khapra beetle *Trogoderma granarium*. They reported that crude protein content of wheat increased from 9.2 to 12.03 per cent after six months of storage.

Saxena and Saxena (2011) carried out analysis of nutritional changes in stored chickpea infested with *Callosobruchus maculatus* after one and six months of storage. They reported that protein content increased from 29.87 to 42.72 per cent with increased insect infestation in chickpea seeds.

Lawal and Fagbohun (2012) studied the nutritional composition of millet seeds during storage and revealed that freshly harvested seeds had a crude protein of 11.52 per cent which decreased to 10.86 per cent after twenty weeks of storage.

Abdelfattah and Zein (2019) carried out an experiment to study the effect of Aerosil 200 nanoparticles (fumed silica) on wheat seed components *i.e.*, carbohydrate, crude protein, crude fat after six months of storage. They reported that crude protein per cent in treated seeds was 11.41 as compared to untreated seeds which was 9.83 per cent.

### 2.4.3 Crude fat

Sudesh *et al*. (1996) observed that an increase in the infestation of *Trogoderma granarium* in wheat, maize and sorghum grains resulted in decrease of crude fat content compared to control which was due to the insect infestation.

Ojimelukwe and Ogwumike (1999) studied the effect of infestation by bruchid beetle (*Callosobruchus maculatus*) on the nutritional quality of Ife-brown cowpea variety. They reported that fat content in infested cowpea was 1.51 per cent compared to uninfested cowpea which was 1.27 per cent.

Ahmedani *et al*. (2009) studied varietal changes in nutritional composition of wheat kernel (*Triticum aestivum*) caused by infestation of khapra beetle *Trogoderma granarium* and reported that crude fat content of wheat increased from 1.36 to 2.76 per cent after six months of storage.

Saxena and Saxena (2011) carried out analysis of nutritional changes in stored chickpea infested with *Callosobruchus maculatus* after one and six months of storage. They reported that crude fat content decreased from 4.48 to 3.39 per cent with increased insect infestation in chickpea seeds.

Lawal and Fagbohun (2012) studied the nutritional composition of millet seeds during storage and revealed that freshly harvested seeds had a fat content of 4.55 per cent which decreased to 3.55 per cent after twenty weeks of storage.

Abdelfattah and Zein (2019) studied the effect of Aerosil 200 nanoparticles (fumed silica) on wheat seed components *i.e* carbohydrate, crude protein, crude fat after six months of storage and reported that crude fat per cent in treated seeds was 2.12 as compared to untreated seeds which was 2.69 per cent.

# Chapter III

# MATERIAL AND METHODS

The investigation titled "Studies on biology of bruchid beetle *Callosobruchus chinensis* (Linnaeus) in chickpea and its management through plant based silica products" was conducted in the Entomology laboratory, Seed Research and Technology Centre and Central Instrumentation Cell, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, Telangana during 2020-21. The materials used and the methods followed during the course of investigation are elucidated under the following headings.

## 3.1 TEST SEED

The investigation was carried out with healthy chickpea seeds of NBeG-3 variety procured from Agricultural Research Station, Tandur**.**

## 3.2 DISINFESTATION OF THE SEEDS

The seeds after procurement, were cleaned thoroughly by removing physical impurities and kept in an incubator at a temperature of 55˚C for a period of four hours (Plate 3.1) to kill the immature stages of the insects if any without affecting viability of the seeds (Soloman, 1952).

## 3.3 MASS CULTURING OF THE TEST INSECT

The test insect used in this experiment is pulse beetle, *Callosobruchus chinensis* (L.) (Plate 3.3). The mother culture of *C.chinensis* maintained at Seed Entomology Laboratory, SRTC was obtained and multiplied on chickpea seeds (Plate 3.2). For mass culturing, about 75 adult beetles were released into plastic containers containing 1000 grams of disinfested chickpea seeds and the containers were covered with muslin cloth and fixed with rubber band to prevent escape of beetles as well as to allow aeration. After seven days, all parent beetles were removed from each container and the seeds were kept under the same experimental conditions. The pest population was maintained at an optimum temp of 32±1˚C and 75 % RH throughout the period of investigation (Andrewartha, 1961). The adults emerged from the culture were used for further experimentation.


**Plate 3.1 Disinfestation of chickpea seeds**

**Plate 3.2 Mass culturing of *Callosobruchus chinensis* (L.) on chickpea seeds**

## 3.4 SEXING OF THE TEST INSECT

The male and female sexes of the beetles (Plate 3.4) were recognized according to the characters described by Sathish *et al*. (2020)

**Table 3.1 Sexing of the test insect *Callosobruchus chinensis* (L.) based on the characters described by Sathish *et al*. (2020)**

| **Female** | **Male** |
|---|---|
| Bigger in size | Smaller in size |
| Antennae are serrate | Antennae are pectinate |
| Dark stripes are present on each side of dorsal abdomen | No dark stripes present |
| Pygidium is covered with white coloured setae. | Pygidium without white coloured setae. |

## 3.5 COLLECTION AND PREPARATION OF PLANT MATERIALS

Amorphous silica gel and amorphous silica precipitate were collected from Indian Institute of Rice Research, Rajendranagar, Hyderabad which were extracted and synthesized from paddy husk having particle size of 200-400 mesh (0.074mm-0.037mm) and 100-200 mesh (0.149mm-0.074mm). They have been applied individually in two doses *i.e.*, 250 and 500 ppm $kg^{-1}$ seed whereas paddy husk and leaves were collected from rice section, Agriculture Research Institute, Rajendranagar, Hyderabad. The collected leaves were washed and air dried in shade. The dried paddy husk and leaves were ground to a fine powder in a electric mixer and the resulting powder is sieved with a 20 mesh (0.841 mm) seive and kept in air tight containers. These powders were applied individually @ 1000 and 2000 ppm $kg^{-1}$ seed. The diatomaceous earth procured from Pai hygiene and health care, Badgaon, Udaipur were mixed at the rate of 300 ppm and 600 ppm $kg^{-1}$ seed.

**Table 3.2 Details of the treatments and their dosages**

| **S.No** | **Treatments** | **Dosages** |
|---|---|---|
| $T_1$ | Amorphous silica gel | 250 ppm |
| $T_2$ | Amorphous silica gel | 500 ppm |

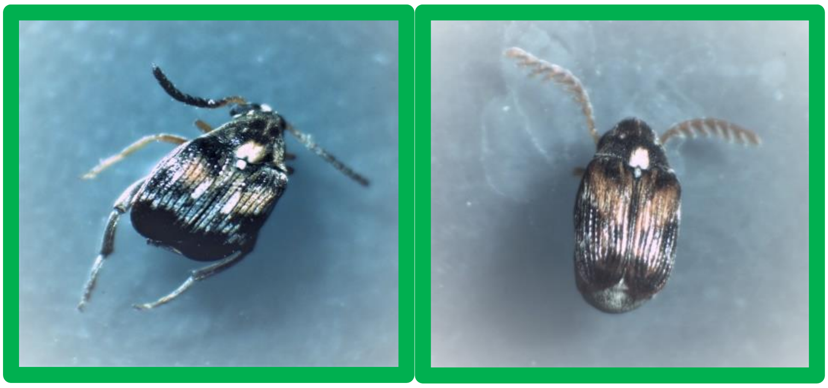
| | | |
|---|---|---|
| $T_3$ | Amorphous silica precipitate | 250 ppm |
| $T_4$ | Amorphous silica precipitate | 500 ppm |
| $T_5$ | Paddy husk | 1000 ppm |
| $T_6$ | Paddy husk | 2000 ppm |
| $T_7$ | Paddy leaves | 1000 ppm |
| $T_8$ | Paddy leaves | 2000 ppm |
| $T_9$ | Diatomaceous earth | 300 ppm |
| $T_{10}$ | Diatomaceous earth | 600 ppm |
| $T_{11}$ | Untreated control | - |

## 3.6 EFFECT OF PLANT BASED SILICA PRODUCTS ON BIOLOGY OF BRUCHID BEETLE, *Callosobruchus chinensis* (L.)

To study the effect of plant based silica products *viz.*, amorphous silica gel, amorphous silica precipitate, paddy husk, paddy leaves and diatomaceous earth on the biology of bruchid beetle, *Callosobruchus chinensis*, an experiment was carried out at Seed Research and Technology Centre and Central Instrumentation Cell, Rajendranagar in CRD with 11 treatments including an untreated control with three replications.

Each plant based silica product *viz*., amorphous silica gel and amorphous silica precipitate were tested at two concentrations *i.e.,* 250 and 500 ppm $kg^{-1}$ seed and paddy husk and paddy leaves were also tested at two concentrations *i.e.,* 1000 and 2000 ppm $kg^{-1}$ seed. Similarly the diatomaceous earth was also tested at two concentrations @ 300 and 600 ppm $kg^{-1}$ seed (Table 3.2 and Plate 3.5). The seeds were mixed manually using a drum to get uniform distribution of the test material and later placed in plastic containers of 250 milli litres capacity. For each replication of the treatment, ten pairs of newly emerged (0-24 hrs) adults (10-♀ and 10-♂) were released into plastic containers containing 100 grams seed and allowed to copulate. Control was maintained by following the same procedure. The containers were suitably labeled and kept in an incubator (Plate 3.6**)** at a temperature of 28±1 ºC and 70±5 per cent relative humidity (Hosamani *et al*., 2018). The data on fecundity, number of seeds having eggs, larval-pupal period, adult

**Plate 3.3 The test insect, *Callosobruchus chinensis* (L.) used in the experiment**



♀ ♂

**Plate 3.4 Female and Male *Callosobruchus chinensis* (L.)**


**Plate 3.5 Plant based silica products used in the experiment**

emergence and weight loss were recorded for each concentration of the test material.

**Observations recorded**

### 3.6.1 Fecundity (eggs per female)

The egg laying capacity of the test insect was worked out by counting the total number of eggs laid by females on the seeds in each replication of the treatment.

### 3.6.2 Number of seeds having eggs (number)

The total number of seeds having eggs in each replication of the treatment has been counted.

### 3.6.3 Hatchability (per cent)

The formula described by Giga *et al*. (1993) was used to determine per cent hatchability in each replication. The per cent of egg hatchability was calculated by recording the number of eggs hatched out of the total number of eggs kept under observation.

$$\text{Hatchability (\%)} = \frac{\text{Number of eggs hatched}}{\text{Number of eggs laid}} \times 100$$

### 3.6.4 Incubation period (days)

The incubation period has been recorded by following the method described by Augustine and Balikai (2019). The incubation period was recorded from the date of egg laying to date of hatching of the egg which was identified by change in colour from transparent to creamish white due to accumulation of frass inside the egg observed under stereozoom microscope.

### 3.6.5 Larval-Pupal period (days)

The larval-pupal period was calculated from the date of hatching of egg to the date of adult emergence. To record larval-pupal period**,** ten seeds with freshly hatched eggs from each replication of the treatment were taken**.** From these ten seeds, each individual seed was kept in a separate plastic container and the number of days taken for adult emergence from egg hatching has been counted.

### 3.6.6 Adult emergence (number of adults)

The adult emergence has been recorded by following the method described by Bajiya *et al.* (2011). The total number of adults emerged from 45th day after treatment to till the beetles cease to emerge from the seeds.

### 3.6.7 Adult longevity (days)

Longevity of adult beetles was determined by recording the days from the date of adult emergence from pupa to date of death in each replication (Bajiya *et al*., 2011).

### 3.6.8 Weight loss (per cent)

After removing the beetles from each plastic container, weight loss was assessed by calculating the mean percentage of seed weight loss in each treatment as described by Islam *et al*. (2016). This was worked out by weighing 100 grams seed after 45 days of the treatment.

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \times 100$$

## 3.7 EFFICACY OF PLANT BASED SILICA PRODUCTS FOR THE MANAGEMENT OF BRUCHID BEETLE:

The experiment was carried out in completely randomized design with three replications to study the efficacy of plant based silica products for the management of bruchid beetle.

To assess the efficacy of plant based silica products as seed protectants against *Callosobruchus chinensis*, one kilogram of disinfested and conditioned chickpea seeds with moisture content less than 10 per cent were taken for each treatment. The necessary preventive measures have been carried out to exclude the field infestation in order to obtain accurate results. The seeds were treated with plant based silica products and diatomaceous earth compared with untreated control. After treating the seeds with required concentration of each treatment as per table 3.2 (amorphous silica gel @ 250 and 500 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 250 and 500 ppm $kg^{-1}$ seed, paddy husk @ 1000 and 2000 ppm $kg^{-1}$ seed, paddy leaves @ 1000 and 2000 ppm $kg^{-1}$ seed and diatomaceous earth @ 300 and 600 ppm $kg^{-1}$ seed), they were dried in shade for one hour and transferred to cloth bags of two kilograms capacity (Plate 3.7).

**Plate 3.6 Experimental setup to study the effect of plant based silica products on biology of *Callosobruchus chinensis* (L.)**


**Plate 3.7 Experimental set up to study the efficacy of plant based silica products for the management of *Callosobruchus chinensis* (L.)**

Three replications were maintained for each treatment and the cloth bags were kept in laboratory under ambient conditions. The performance of plant based silica products against *Callosobruchus chinensis* was assessed based on seed damage (%), weight loss (%), adult emergence and residual toxicity for every two months, for a total period of six months and the data was subjected to statistical analysis.

**Observations recorded**

### 3.7.1 Seed damage (per cent)

The seed damage was calculated by taking a random sample of 100 seeds. Seeds bearing one or more bored holes were considered as damaged seeds. The damaged and healthy seeds were sorted out in each replication. The per cent seed damage was worked out by using following formula

$$\text{Seed damage (\%)} = \frac{\text{Number of damaged seeds}}{\text{Total no. of seeds}} \times 100$$

### 3.7.2 Weight loss (per cent)

For determining the seed weight loss, the count and weight method has been used with the formula

$$W(\%) = \frac{(Wu \times Nd) - (Wd \times Nu)}{Wu \times (Nd + Nu)} \times 100$$

Where, W = Weight loss (%)

Wu = Weight of undamaged seeds

Nd = No. of damaged seeds

Wd = Weight of damaged seeds

Nu = Number of undamaged seeds

### 3.7.3 Adult emergence (number of adults)

Adult emergence was recorded by counting the total number of adults emerged in each replication of the treatment at every two months.

### 3.7.4 Residual toxicity (per cent)

The residual toxicity was worked out by releasing five pairs of *C.chinensis* (L.) adult beetles into 100 grams of treated seeds (Plate 3.8). The mortality was recorded on 1, 2, 3, and 5 days after the release of test insect.

### 3.7.5 Effect of plant based silica products on *Callosobruchus chinensis* (L.) adults by using Scanning Electron Microscopy (SEM)

The amorphous silica gel used for the management of *Callosobruchus chinensis* was studied for its effect on abrasion of the insect cuticle and other parts of the adults. For conducting the experiment, petri plate holding amorphous silica gel at 1 mg $cm^{-1}$ was taken and ten pairs of freshly emerged adults were released into treated plates (Padmasri, 2018). In another set, ten pairs of adults were taken and this served as control. Insects were removed out from the above treatments after 24 hours of exposure. Insect samples were fixed in 2.5 per cent of glutaraldehyde in 0.1 M phosphate buffer (pH-7.2) for a period of 24 hours at 4˚C and there after fixed in 2 per cent aqueous osmium tetroxide for a time period of four hours and then dehydrated in a series of graded alcohols. Later on, they were dried to critical point drying (CPD) with CPD unit. Thereafter, the processed insect samples were mounted on to the stubs with double sided carbon conductivity tape and gold coat was done over the samples in thin layer by using automated sputter coater (model- JEOL JFC 1600) for three minutes (Plate 3.9). They were scanned under scanning electron microscope (SEM Model- JOEL-JSM 5600) (Plate 3.10) at Ruska labs, Rajendranagar, Hyderabad as per standard procedures described by John and Lonnie, 1998.

**Plate 3.8 Experimental set up for carrying out residual toxicity of plant based silica products against *Callosobruchus chinensis* (L.)**

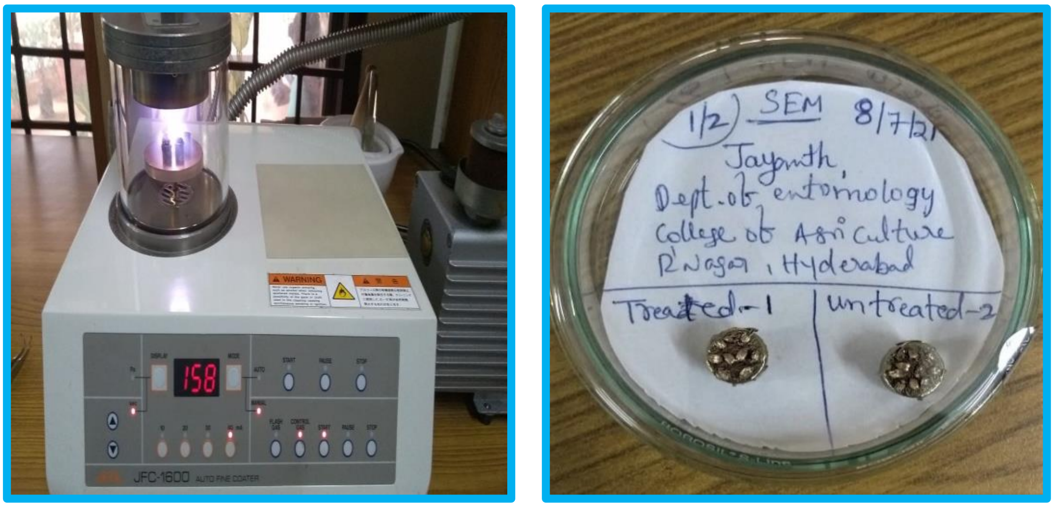



**Plate 3.9 Gold coating of samples by using an automated sputter coater**


**Plate 3.10 Scanning electron microscope used in the image analysis of samples**

## 3.8 ASSESSMENT OF NUTRITIONAL QUALITY PARAMETERS OF TREATED CHICKPEA

The effect of plant based silica products on nutritional quality parameters such as carbohydrate, protein and crude fat were determined before and after treatment by using standard procedures. The quality parameters *viz.*, carbohydrates, protein were determined at Central instrumentation cell and crude fat was determined at Quality control laboratory, Rajendranagar, Hyderabad.

### 3.8.1 Carbohydrates (per cent)

Phenol sulphuric acid method as described by Sadasivam and Manickam (2008 a) has been used for determining carbohydrate content in stored chickpea seeds. 100 grams of sample was taken into a boiling tube and hydrolysed by keeping it in a boiling water bath for nearly about three hours with five ml of 2.5 N HCL. After cooling it to room temperature, it was neutralised with solid sodium carbonate until the effervescence ceased. Then the volume ˚is made to 100 ml and then centrifuged. 0.2, 0.4, 0.6, 0.8 and 1ml of working standards and aliquots (0.1 and 0.2 ml) were pipetted out into a series of test tubes. The volume was made to 1 ml with water and also a blank was set with 1 ml of water. 1 ml of phenol solution and 5 ml of 96 % sulphuric acid was added to each tube and shook well. After shaking the contents in the tubes for ten minutes, they are placed in a water bath for 20 minutes at 25-30˚C. The absorbance has been measured using spectrophotometer at 490 nm and from the standard graph. The amount of carbohydrate content present in the samples was calculated as follows

Absorbance corresponds to 0.1 ml of the test = ‘x’ mg of glucose

$$\text{100 ml of sample solution contains} = \frac{x}{0.1} \times 100 \text{ mg of glucose}$$

=………per cent of carbohydrate present

### 3.8.2 Proteins (per cent)

The protein content was determined by available nitrogen in the sample by micro-Kjeldahl method as described by Sadasivam and Manickam (2008 b) using Kelplus auto analyser. Initially in the presence of 2 grams of catalyst mixture (copper sulphate and potassium sulphate in the ratio of 1: 5) and ten ml of concentrated sulphuric acid, 0.2 g of sample was digested at 420˚C for 2 hours. The distillation has been carried out after cooling in auto distillation system (loaded with 40 per cent sodium hydroxide and 4 per cent boric acid). The obtained distillate was titrated against 0.1 N HCL till pink colour has appeared. The per cent nitrogen has been calculated as follows.

$$N_2\ (\%) = \frac{\left[\begin{array}{l}\text{Titre value of the sample -}\\ \text{Titre value of the blank}\end{array}\right] \text{X 14 X Normality of HCL (0.1)}}{\text{Weight of the sample X 1000}} \text{ X 100}$$

The protein content was estimated in per cent by multiplying the obtained nitrogen per cent with factor 6.25 (Mariotti *et al.*, 2008).

### 3.8.3 Crude fat (per cent)

Crude fat was determined by AOAC 922.06-2006 method in Quality control laboratory, Rajendranagar, Hyderabad. Empty fat extraction beaker along with boiling stones (T) was weighed. Approximately 2 grams of chickpea seed sample was weighed in triplicates and packed into filter paper and placed in the thimbles provided with the instrument. Volume of n-Hexane taken in a beaker was recorded. Required conditions for soxtherm extraction were maintained as per software settings and thimble containing chickpea seed sample was inserted into the slot provided for thimbles. The thimble containing the test portion was immersed into the boiling solvent. The intermixing of the matrix with hot solvent ensure rapid solubilization of extractable. In the second step, the thimble was raised above the solvent and the test portion was further extracted by a continuous flow of condensed solvent for 1 hour, 20 min. The solvent was evaporated and recovered by condensation. After drying, the resulting crude fat residue was determined gravimetrically. Extraction cups were dried at 102˚C ± 2˚C in a hot air oven for 30 minutes to remove moisture. Excessive drying was avoided which can oxidize fat and give erroneous results. The defatted sample was cooled in a desiccator and weighed to the nearest 0.1 mg (F). The per cent crude fat was calculated as follows

$$\% \text{ per cent crude fat, Hexanes / equivalent extract} = \frac{F - T}{S} \times 100$$

Where F = weight of cup + fat residue in grams

T = weight of empty cup in grams

S = Test portion weight in grams.

## 3.9 STATISTICAL ANALYSIS

The statistical methods described by Snedecor and Cochran (1967) were adopted for the present investigation. The data was subjected to square root and angular transformation values wherever necessary and analysed by adopting completely randomized design (CRD). OPSTAT software was used for statistical analysis of the data.

# Chapter IV

# RESULTS AND DISCUSSION

The bruchid beetle, *Callosobruchus chinensis* (L.) is one of the serious post harvest pest of stored legumes throughout tropical and subtropical regions. The control of this stored grain pest mostly rely upon use of broad action insecticides and fumigants. Unfortunately, it seems to be inappropriate approach which leads to contamination of food with toxic residues and also leads to development of resistance in pests. Therefore, in order to replace synthetic pesticides, use of eco-friendly and convenient methods are of growing interest. The results of the investigation "Studies on biology of bruchid beetle, *Callosobruchus chinensis* (Linnaeus) in chickpea and its management through plant based silica products" are presented and discussed in detail in this chapter.

## 4.1 EFFECT OF PLANT BASED SILICA PRODUCTS ON BIOLOGY OF BRUCHID BEETLE, *Callosobruchus chinensis* (L.)

The effect of plant based silica products on biology of bruchid beetle, *Callosobruchus chinensis* (L.) was evaluated based on fecundity, number of seeds having eggs, hatchability, incubation period, larval-pupal period, adult emergence, adult longevity and weight loss.

### 4.1.1 Effect of plant based silica products on fecundity

As observed from the results (Table 4.1 and Figure 4.1), it was evident that all the treatments were found to be significantly superior in reducing fecundity of *Callosobruchus chinensis* over the untreated control.

The minimum mean number of eggs (1.22 eggs) were found in the seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed which indicated its supremacy over other treatments while, diatomaceous earth @ 600 ppm $kg^{-1}$ seed (2.89 eggs) and amorphous silica gel @ 250 ppm $kg^{-1}$ seed (3.00 eggs) remained on par with each other. While, mean number of eggs observed in seeds treated with amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed and diatomaceous earth @ 300 ppm $kg^{-1}$ seed were 4.56 and 4.67 eggs, respectively which were found to be on par with each other followed by amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed which resulted 8.22 eggs. The mean fecundity observed in seeds treated with paddy husk @ 2000 and 1000 ppm $kg^{-1}$ seed were 11.37 and 12.23

eggs, respectively while paddy leaves @ 2000 and 1000 ppm $kg^{-1}$ seed were least effective which resulted mean fecundity of 12.53 and 13.00 eggs against untreated control (13.97 eggs). Treatments *viz*., amorphous silica gel, diatomaceous earth and amorphous silica precipitate were significantly superior in suppressing egg laying compared to paddy husk and paddy leaves.

The present findings are in line with observations of Arumugam *et al*. (2016), who reported that no eggs were found in chickpea seeds treated with silica nano particles @ 900 and 1000 ppm. The reduced fecundity might be due to suffering of insects because of spiracular blockage and desiccation which could have prevented mating. Similarly, Ali *et al*. (2017a) found that eggs per female were significantly lower (5.67) when treated with diatomaceous earth @ 0.25 g $g^{-1}$ against *Tribolium castaneum* in wheat flour as against control (90.67). However, insects may develop a behavioural response to these products and avoid contact (Ebeling, 1971)

### 4.1.2 Effect of plant based silica products on number of seeds having eggs 100 $g^{-1}$ seed

The results pertaining to effect of plant based silica products on number of seeds having eggs are presented in Table 4.2 and Figure 4.2.

The mean number of seeds having eggs 100 $g^{-1}$ seed ranged from 3.33 to 117.33 in various treatments as against 125.33 seeds in untreated control. Significantly lowest mean number of seeds having eggs 100 $g^{-1}$ seed (3.33) was found in seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed. When seeds were treated with diatomaceous earth @ 600 ppm $kg^{-1}$ seed, mean number of seeds having eggs 100 $g^{-1}$ seed were 8.33, which was on par with amorphous silica gel @ 250 ppm $kg^{-1}$ seed with 8.67 seeds having eggs 100 $g^{-1}$ seed.

The other treatments *viz*., amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed, diatomaceous earth @ 300 ppm $kg^{-1}$ seed and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed resulted 11.67, 12.33 and 17.00 seeds having eggs 100 $g^{-1}$ seed, respectively.

**Table 4.1 Effect of plant based silica products on fecundity of bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage kg$^{-1}$ seed | Fecundity (eggs per female) |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 3.00 (1.99) |
| 2. | Amorphous silica gel | 500 ppm | 1.22 (1.49) |
| 3. | Amorphous silica precipitate | 250 ppm | 8.22 (3.03) |
| 4. | Amorphous silica precipitate | 500 ppm | 4.56 (2.36) |
| 5. | Paddy husk | 1000 ppm | 12.23 (3.63) |
| 6. | Paddy husk | 2000 ppm | 11.37 (3.52) |
| 7. | Paddy leaves | 1000 ppm | 13.00 (3.74) |
| 8. | Paddy leaves | 2000 ppm | 12.53 (3.68) |
| 9. | Diatomaceous earth | 300 ppm | 4.67 (2.38) |
| 10. | Diatomaceous earth | 600 ppm | 2.89 (1.97) |
| 11. | Untreated control | - | 13.97 (3.87) |
| | **SEm±** | | 0.06 |
| | **CD (P=0.05)** | | 0.18 |
| | **CV(%)** | | 3.60 |

The values in parentheses are square root transformed values

**Table 4.2 Effect of plant based silica products on number of seeds having eggs of bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage $kg^{-1}$ seed | Number of seeds having eggs 100 $g^{-1}$ seed |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 8.67 (3.11) |
| 2. | Amorphous silica gel | 500 ppm | 3.33 (2.08) |
| 3. | Amorphous silica precipitate | 250 ppm | 17.00 (4.24) |
| 4. | Amorphous silica precipitate | 500 ppm | 11.67 (3.56) |
| 5. | Paddy husk | 1000 ppm | 113.67 (10.70) |
| 6. | Paddy husk | 2000 ppm | 103.33 (10.21) |
| 7. | Paddy leaves | 1000 ppm | 117.33 (10.87) |
| 8. | Paddy leaves | 2000 ppm | 114.00 (10.72) |
| 9. | Diatomaceous earth | 300 ppm | 12.33 (3.65) |
| 10. | Diatomaceous earth | 600 ppm | 8.33 (3.05) |
| 11. | Untreated control | - | 125.33 (11.24) |
| | **SEm±** | | 0.14 |
| | **CD (P=0.05)** | | 0.41 |
| | **CV(%)** | | 3.58 |

The values in parentheses are angular transformed values

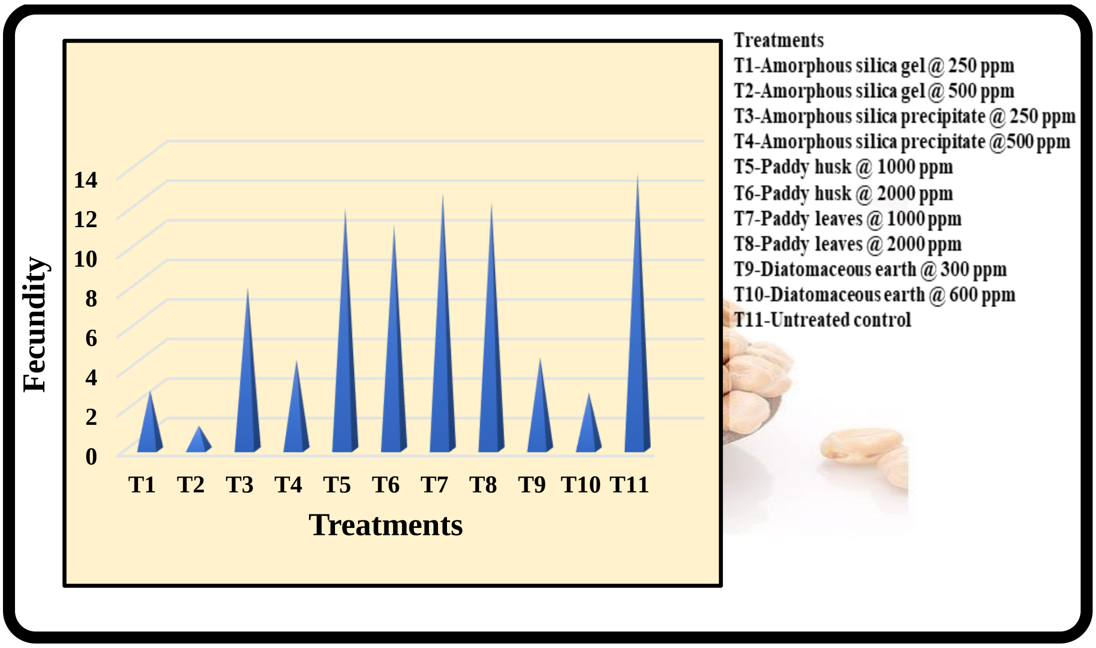



**Fig 4.1 Effect of plant based silica products on fecundity of bruchid beetle, *Callosobruchus chinensis* (L.)**

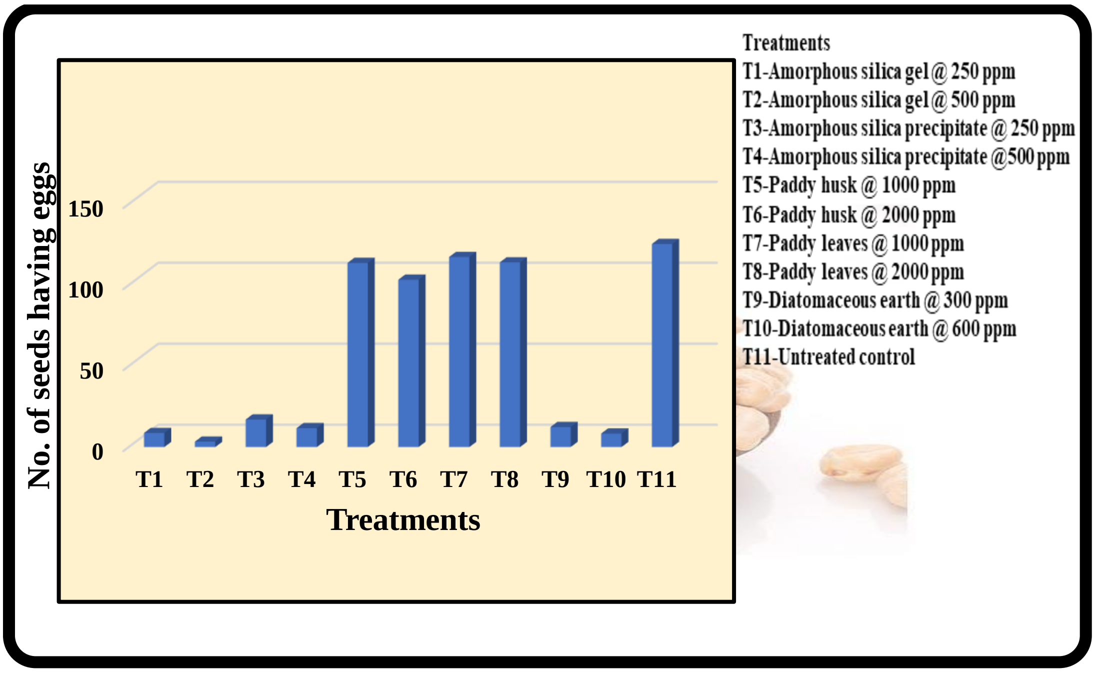



**Fig 4.2 Effect of plant based silica products on number of seeds having eggs of bruchid beetle, *Callosobruchus chinensis* (L.)**

**Plate 4.1 Seed having eggs**

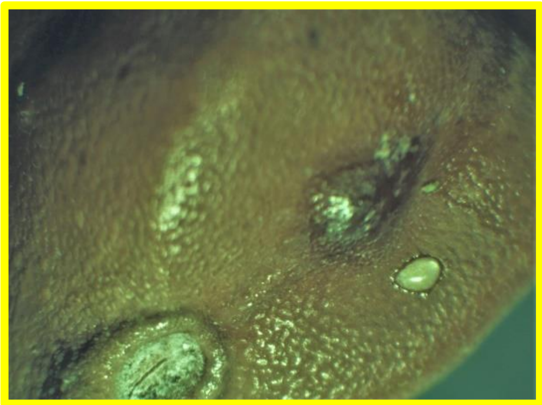


**Plate 4.2 Freshly laid egg**

**Plate 4.3 Hatched egg**

**Plate 4.4 Observation of egg stage of *Callosobruchus chinensis* (L.) under stereozoom microscope**

The mean number of eggs (103.33) were recorded in seeds treated with paddy husk @ 2000 ppm $kg^{-1}$ seed followed by paddy husk @ 1000 ppm $kg^{-1}$ seed (113.67 seeds) and paddy leaves @ 2000 ppm $kg^{-1}$ seed (114.00 seeds) which were found to be on par with each other while seeds treated with paddy leaves @ 1000 ppm $kg^{-1}$ seed resulted 117.33 mean number of seeds having eggs 100 $g^{-1}$ seed. Among the treatments, amorphous silica gel, diatomaceous earth and amorphous silica precipitate at both dosage levels were found to be significantly superior in performance over paddy husk and paddy leaves.

The results were in agreement with the findings of Prasantha *et al*. (2003) who reported that higher dosages of natural silica powders, Fossil-Shield and Silico-Sec decreases the fecundity and increases the number of seeds without eggs of *Callosobruchus maculatus*. Similarly, Yousefnezhad *et al*. (2019) reported that oviposition deterrence of 87.0 per cent was observed in chickpea seeds treated with Aerosil (silicon dioxide nano particles) @ 300 mg $kg^{-1}$ seed. This reduced number of seeds having eggs might be due to less mobility and lower consumption of oxygen in exposed insects as stated by Krzyzowski *et al*. (2019). According to Ebeling (1971) insects avoid contact by developing a behavioural response to these particles.

**4.1.3 Effect of plant based silica products on hatchability**

The results on effect of plant based silica products on hatchability of bruchid beetle are presented in the Table 4.3 and Figure 4.3.

The lowest per cent hatchability (55.57) was recorded in seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed which indicated its supremacy over other treatments while, diatomaceous earth @ 600 ppm $kg^{-1}$ seed had resulted 61.58 per cent which was the next best treatment that was found to be on par with amorphous silica gel @ 250 ppm $kg^{-1}$ seed (63.06 per cent) and amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed (65.48). These were followed by diatomaceous earth @ 300 ppm $kg^{-1}$ seed (66.67 per cent) and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (68.87 per cent).

Highest hatchability per cent of 86.62 was resulted in untreated seeds which was found to be on par with paddy husk @ 2000 ppm $kg^{-1}$ seed (84.72 per cent), paddy husk

**Table 4.3 Effect of plant based silica products on hatchability of bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage $kg^{-1}$ seed | Percent hatchability |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 63.06 (52.56) |
| 2. | Amorphous silica gel | 500 ppm | 55.57 (48.23) |
| 3. | Amorphous silica precipitate | 250 ppm | 68.87 (56.08) |
| 4. | Amorphous silica precipitate | 500 ppm | 65.48 (54.02) |
| 5. | Paddy husk | 1000 ppm | 84.92 (67.17) |
| 6. | Paddy husk | 2000 ppm | 84.72 (67.02) |
| 7. | Paddy leaves | 1000 ppm | 85.20 (67.39) |
| 8. | Paddy leaves | 2000 ppm | 85.10 (67.27) |
| 9. | Diatomaceous earth | 300 ppm | 66.67 (54.72) |
| 10. | Diatomaceous earth | 600 ppm | 61.58 (51.70) |
| 11. | Untreated control | - | 86.62 (68.54) |
| | **SEm±** | | 1.49 |
| | **CD (P=0.05)** | | 4.39 |
| | **CV(%)** | | 4.33 |

The values in parentheses are angular transformed values

@ 1000 ppm $kg^{-1}$ seed (84.92 per cent), paddy leaves @ 2000 ppm $kg^{-1}$ seed (85.10 per cent), paddy leaves @ 1000 ppm $kg^{-1}$ seed (85.20 per cent). This revealed that paddy husk and paddy leaves were found to be least effective compared to other treatments with respect to per cent hatchability.

These results are in accordance with the findings of El Halfawy *et al*. (1977) with *Rhizopertha dominica* and *Callosobruchus chinensis* where per cent hatchability reduced when eggs were exposed to light inert dusts. Similarly, Prasantha *et al*. (2003) reported that, there was an increase in the per cent unhatched eggs per cent from 6 to 22 with increase in the application rates of diatomaceous earths, which might be due to the suffocation of the hatching embryo and also treatment with these dusts might have altered the texture of the seed surface causing less attachment of the egg chorion on to the seed. Ali *et al*. (2017a) reported that, wheat flour when treated with natural product, diatomaceous earth @ 0.25 g $g^{-1}$ resulted least per cent hatchability (31.13 per cent) of *Tribolium castaneum* compared to control (91.57 per cent).

### 4.1.4 Effect of plant based silica products on incubation period

The data on effect of plant based silica products on incubation period of bruchid beetle *C. chinensis* is presented in the Table 4.4 and Figure 4.4. The incubation period of *C.* chinensis recorded in all the treatments was more or less similar with the untreated control which indicated that the plant based silica products had little or no effect on the incubation period of the test insect. The incubation period ranged between 4.07 and 4.53 days in different treatments which was found to follow the normal range or period as like in untreated control. The lowest incubation period of 4.07 days was observed in both dosages of amorphous silica precipitate *i.e.*, 250 and 500 ppm $kg^{-1}$ seed while, highest incubation period of 4.53 days was observed in paddy husk @ 1000 ppm $kg^{-1}$ seed. According to Yadav (2016) there was no change in the incubation period, larval and pupal periods of *Sitophilus oryzae* in maize kernels and *Rhyzopertha dominica* in wheat grains treated with diatomaceous earth.

**Table 4.4 Effect of plant based silica products on incubation period of bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage $kg^{-1}$ seed | Incubation period (days) |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 4.40 (2.32) |
| 2. | Amorphous silica gel | 500 ppm | 4.33 (2.31) |
| 3. | Amorphous silica precipitate | 250 ppm | 4.07 (2.25) |
| 4. | Amorphous silica precipitate | 500 ppm | 4.07 (2.25) |
| 5. | Paddy husk | 1000 ppm | 4.53 (2.35) |
| 6. | Paddy husk | 2000 ppm | 4.47 (2.34) |
| 7. | Paddy leaves | 1000 ppm | 4.40 (2.32) |
| 8. | Paddy leaves | 2000 ppm | 4.20 (2.28) |
| 9. | Diatomaceous earth | 300 ppm | 4.27 (2.30) |
| 10. | Diatomaceous earth | 600 ppm | 4.18 (2.28) |
| 11. | Untreated control | - | 4.13 (2.27) |
| | **SEm±** | | 0.02 |
| | **CD (P=0.05)** | | N.S. |
| | **CV(%)** | | 1.78 |

The values in parentheses are square root transformed values

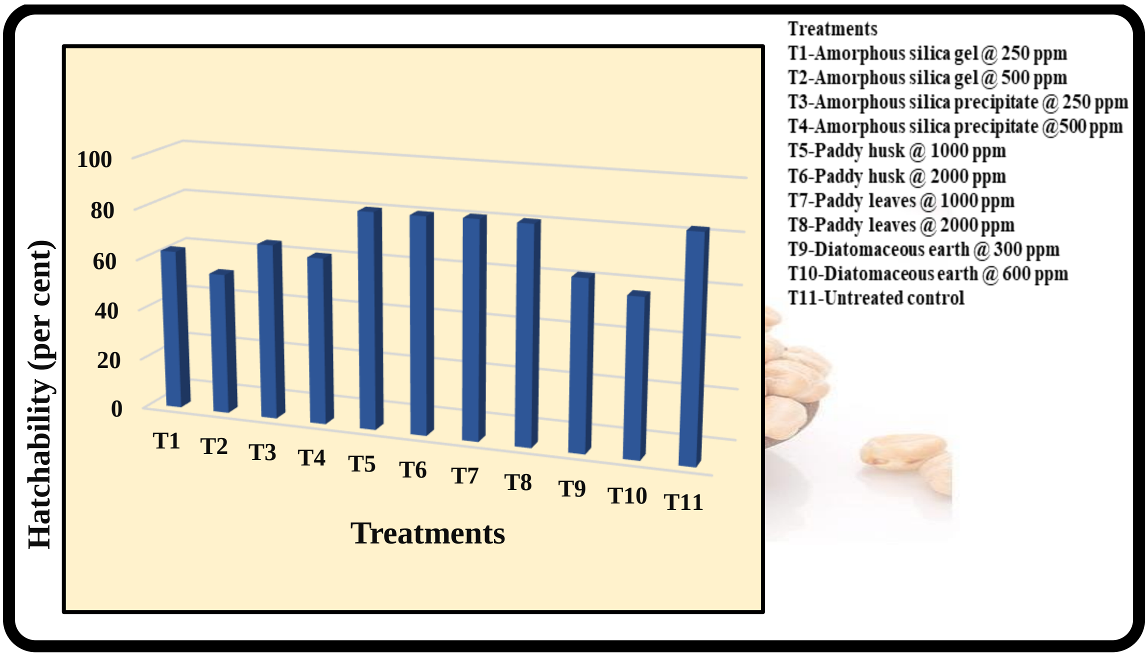



**Fig 4.3 Effect of plant based silica products on hatchability of bruchid beetle, *Callosobruchus chinensis* (L.)**

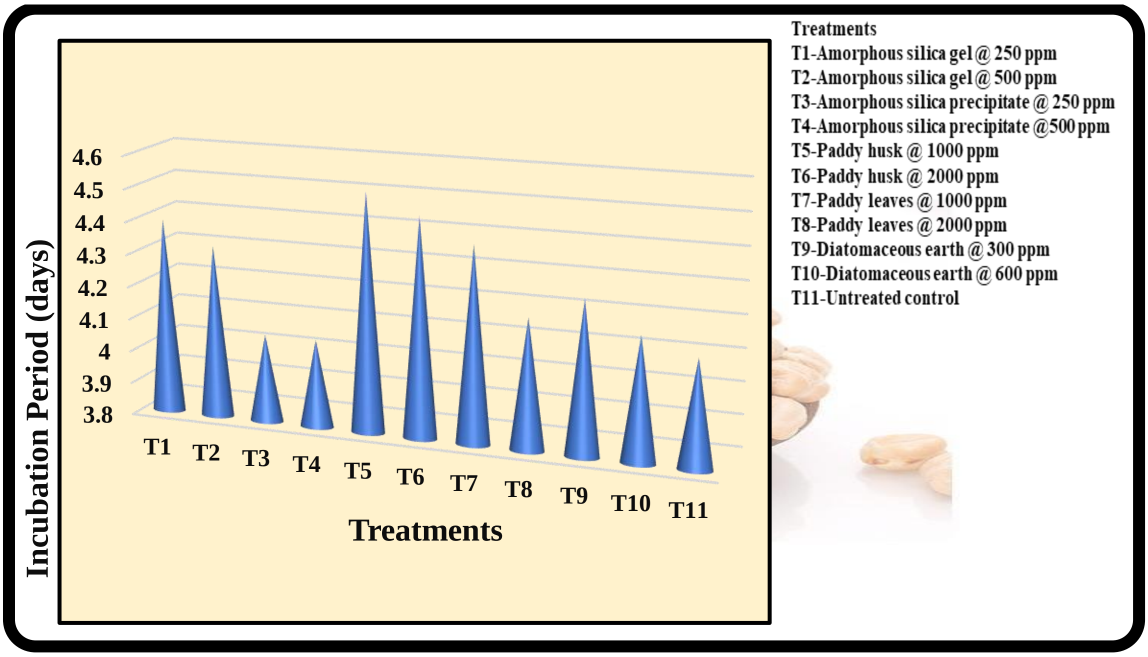



**Fig 4.4 Effect of plant based silica products on incubation period of bruchid beetle, *Callosobruchus chinensis* (L.)**

### 4.1.4 Effect of plant based silica products on larval-pupal period

The data on effect of plant based silica products on larval-pupal period of bruchid beetle *C. chinensis* are presented in the Table 4.5 and Figure 4.5. The larval-pupal period of bruchid beetle on chickpea seeds was not affected in all the treatments and showed non significant effect. The larval-pupal period ranged between 25.47 and 26.73 days in different treatments where lowest number of days were resulted in diatomaceous earth @ 300 ppm $kg^{-1}$ seed and highest number of days resulted in amorphous silica gel @ 250 ppm $kg^{-1}$ seed.

The larval-pupal period was found to follow the normal range or period as similar in untreated control. Since, *C. chinensis* is an internal feeder, larval and pupal development probably occurs inside the grain and is protected from any dust.

### 4.1.5 Effect of plant based silica products on adult emergence

The data on effect of plant based silica products on adult emergence of bruchid beetle *C. chinensis* are presented in the Table 4.6 and Figure 4.6.

A perusal of the table 4.6 showed that at 45 days of storage, significantly minimum mean number of adults (1.33) emerged in seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed which was found to be highly effective followed by diatomaceous earth @ 600 ppm $kg^{-1}$ seed and amorphous silica gel @ 250 ppm $kg^{-1}$ seed which resulted in 4.33 and 4.67 mean number of adults, respectively that remained on par with each other.

However, seeds treated with amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed, diatomaceous earth @ 300 ppm $kg^{-1}$ seed and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed had significantly resulted in mean number of adult emergence of 9.33, 10.00, 18.00 adults, respectively. Seed treatment with other silica products *viz*., paddy husk @ 2000 ppm $kg^{-1}$ seed, paddy husk @ 1000 ppm $kg^{-1}$ seed, paddy leaves @ 2000 ppm $kg^{-1}$ seed and paddy leaves @ 1000 ppm $kg^{-1}$ seed resulted in 95.00, 102.33, 104.33 and 106.33 mean number of adults, respectively. All treatments were found to be statistically superior over untreated check which resulted maximum mean number of adults (113.00).

**Table 4.5 Effect of plant based silica products on larval-pupal period of bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage kg$^{-1}$ seed | Larval-Pupal period (days) |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 26.73 (5.27) |
| 2. | Amorphous silica gel | 500 ppm | 26.17 (5.21) |
| 3. | Amorphous silica precipitate | 250 ppm | 25.67 (5.16) |
| 4. | Amorphous silica precipitate | 500 ppm | 26.07 (5.20) |
| 5. | Paddy husk | 1000 ppm | 26.20 (5.22) |
| 6. | Paddy husk | 2000 ppm | 26.07 (5.20) |
| 7. | Paddy leaves | 1000 ppm | 26.07 (5.20) |
| 8. | Paddy leaves | 2000 ppm | 26.07 (5.20) |
| 9. | Diatomaceous earth | 300 ppm | 25.47 (5.15) |
| 10. | Diatomaceous earth | 600 ppm | 26.55 (5.25) |
| 11. | Untreated control | - | 25.53 (5.15) |
| | **SEm±** | | 0.03 |
| | **CD (P=0.05)** | | N.S. |
| | **CV(%)** | | 0.91 |

The values in parentheses are square root transformed values

**Table 4.6 Effect of plant based silica products on adult emergence of bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage $kg^{-1}$ seed | Adult emergence |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 4.67 (2.38) |
| 2. | Amorphous silica gel | 500 ppm | 1.33 (1.52) |
| 3. | Amorphous silica precipitate | 250 ppm | 18.00 (4.35) |
| 4. | Amorphous silica precipitate | 500 ppm | 9.33 (3.20) |
| 5. | Paddy husk | 1000 ppm | 102.33 (10.16) |
| 6. | Paddy husk | 2000 ppm | 95.00 (9.80) |
| 7. | Paddy leaves | 1000 ppm | 106.33 (10.36) |
| 8. | Paddy leaves | 2000 ppm | 104.33 (10.26) |
| 9. | Diatomaceous earth | 300 ppm | 10.00 (3.31) |
| 10. | Diatomaceous earth | 600 ppm | 4.33 (2.31) |
| 11. | Untreated control | - | 113.00 (10.68) |
| | **SEm±** | | 0.12 |
| | **CD (P=0.05)** | | 0.36 |
| | **CV(%)** | | 3.37 |

The values in parentheses are square root transformed values

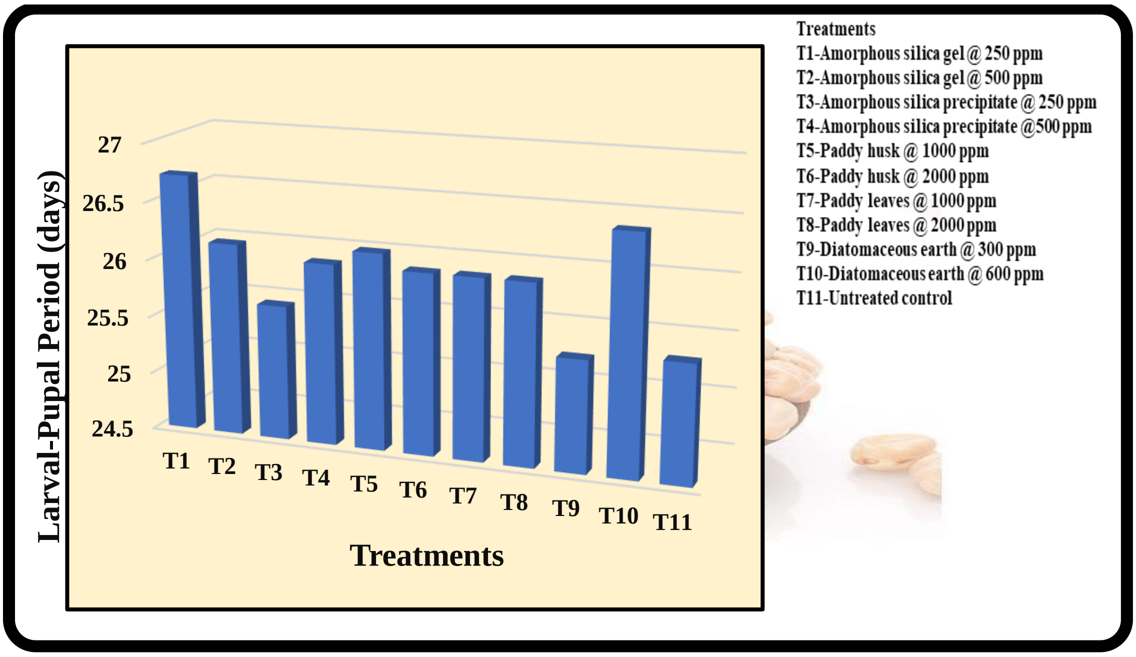



**Fig 4.5 Effect of plant based silica products on larval-pupal period of bruchid beetle, *Callosobruchus chinensis* (L.)**

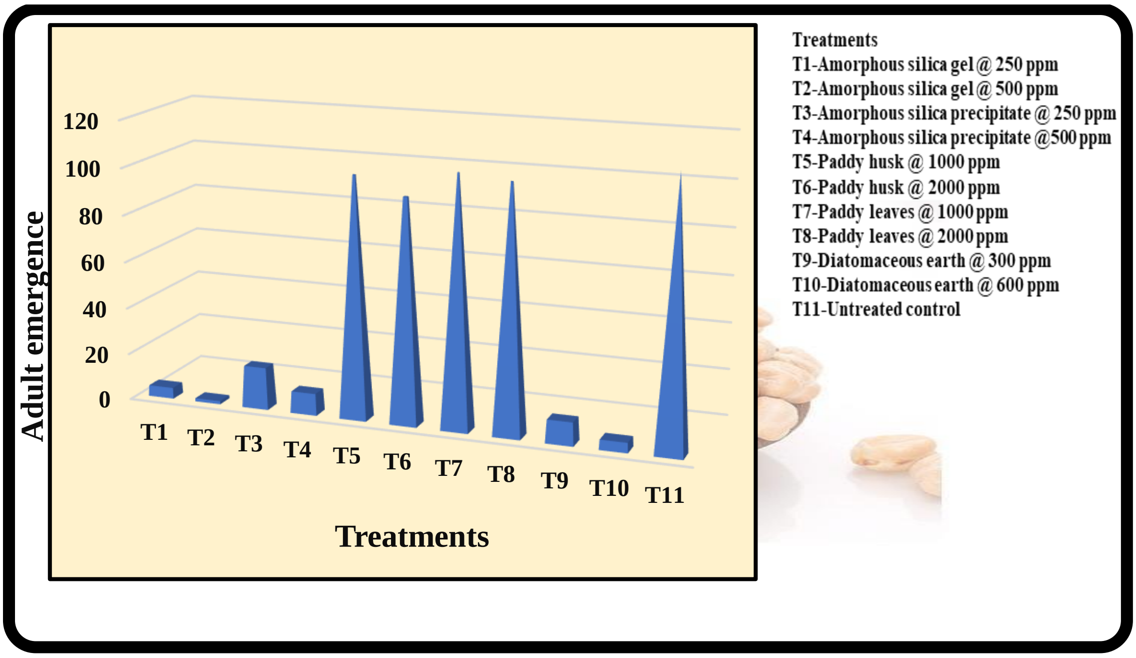



**Fig 4.6 Effect of plant based silica products on adult emergence of bruchid beetle, *Callosobruchus chinensis* (L.)**

**Plate 4.5 Adult emerging from the seed**

The results were in agreement with Kabir (2013) who reported that Protect-It (diatomaceous earth) resulted in complete inhibition of adult emergence when applied @ 1000 mg $kg^{-1}$ cowpea seeds against *Callosobruchus maculatus*. Similarly, Jean *et al*. (2015) reported that dust containing amorphous silica particles, Fossil-Shield at all dosage levels completely suppressed $F_1$ progeny emergence of *Sitophilus zeamais* except for the lowest dosage level of 0.5 g $kg^{-1}$ maize seeds, which resulted 95.50 per cent of progeny inhibition. This reduced progeny production might be due to the increased adult mortality and reduced oviposition as observed by Ibrahim *et al*. (2012).

**4.1.6 Effect of plant based silica products on adult longevity**

The data on effect of plant based silica products on adult longevity of bruchid beetle *C. chinensis* are presented in the Table 4.7 and Figure 4.7.

The adult longevity of *C. chinensis* ranged between 3.33 and 7.80 days in the seeds treated with plant based silica products. The treatment *viz*., amorphous silica gel @ 500 ppm $kg^{-1}$ seed was found to be the effective treatment which resulted lowest span of 3.33 days followed by diatomaceous earth @ 600 ppm $kg^{-1}$ seed (3.62 days), amorphous silica gel @ 250 ppm $kg^{-1}$ seed (3.80 days), amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed (4.07 days), diatomaceous earth @ 300 ppm $kg^{-1}$ seed (4.33 days) and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (4.53 days).

Among the plant based silica products, adult longevity observed in paddy husk @ 2000 ppm $kg^{-1}$ seed and paddy husk @ 1000 ppm $kg^{-1}$ seed were 7.47 and 7.60 days, respectively. These were followed by paddy leaves @ 2000 ppm $kg^{-1}$ seed (7.73 days) and paddy leaves @ 1000 ppm $kg^{-1}$ seed (7.80 days) that remained on par with each other and were found to be least efficient in reducing the adult span of the pest among the treatments.

However, highest adult span of 7.87 days was observed in untreated seeds which remained on par with paddy leaves @ 1000 ppm $kg^{-1}$ (7.80 days). Similar trend was also observed in this study where paddy husk and paddy leaves were found to be less effective compared to other treatments.

The present findings are in accordance with observations of Parsaeyan *et al*. (2012) who reported that adult longevity reduced by 74.7 per cent compared to control

**Table 4.7 Effect of plant based silica products on adult longevity of bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage kg$^{-1}$ seed | Adult longevity (days) |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 3.80 (2.19) |
| 2. | Amorphous silica gel | 500 ppm | 3.33 (2.08) |
| 3. | Amorphous silica precipitate | 250 ppm | 4.53 (2.35) |
| 4. | Amorphous silica precipitate | 500 ppm | 4.07 (2.25) |
| 5. | Paddy husk | 1000 ppm | 7.60 (2.93) |
| 6. | Paddy husk | 2000 ppm | 7.47 (2.91) |
| 7. | Paddy leaves | 1000 ppm | 7.80 (2.97) |
| 8. | Paddy leaves | 2000 ppm | 7.73 (2.95) |
| 9. | Diatomaceous earth | 300 ppm | 4.33 (2.31) |
| 10. | Diatomaceous earth | 600 ppm | 3.62 (2.15) |
| 11. | Untreated control | - | 7.87 (2.98) |
| | **SEm±** | | 0.03 |
| | **CD (P=0.05)** | | 0.08 |
| | **CV(%)** | | 1.94 |

The values in parentheses are square root transformed values

when exposed to $LC_{20}$ concentration (0.51 g $m^{-2}$) of diatomaceous earth. The reduction in adult span might be due to death of insect caused by damage of water barrier which leads to desiccation as reported by Ebeling (1971). Similarly, Ebeid *et al*. (2013) studied impact of silica nano particles on *Heteracris littoralis* and reported that at all concentrations, mean adult duration did not exceed 12.40 compared to untreated check (31.40). Effectiveness of inert dust depends on speed and amount of the waxy cuticle that the dust can absorb as stated by Fields *et al*. (2001).

### 4.1.7 Effect of plant based silica products on weight loss

The results recorded on weight loss after 45 days of treatment due to bruchid beetle, *C.chinensis* are presented in Table 4.8 and Figure 4.8.

The data on weight loss also indicated the superior performance of amorphous silica gel @ 500 ppm $kg^{-1}$ seed over other treatments. Amorphous silica gel @ 500 ppm $kg^{-1}$ seed resulted in minimum weight loss of 0.34 per cent indicating its efficacy in protecting the seed. This was followed by diatomaceous earth @ 600 ppm $kg^{-1}$ seed (1.30 per cent) and amorphous silica gel @ 250 ppm $kg^{-1}$ seed (1.47 per cent) which remained on par with each other. Seeds treated with amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed and diatomaceous earth @ 300 ppm $kg^{-1}$ seed resulted 2.30 and 2.63 per cent weight loss, respectively which were found to be on par with each other followed by amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (3.78 per cent).

Highest seed weight loss was observed in untreated control (11.76 per cent) which was found on par with paddy leaves @ 1000 ppm $kg^{-1}$ seed (11.21 per cent) and paddy leaves @ 2000 ppm $kg^{-1}$ seed (10.87 per cent). These were followed by paddy husk @ 1000 ppm $kg^{-1}$ seed and paddy husk @ 2000 ppm $kg^{-1}$ seed which resulted 10.07 and 9.51 per cent weight loss. Among all the plant based silica treatments, paddy husk and paddy leaves were found less effective in protecting the seed against *C. chinensis* damage.

The results were in agreement with the findings by Patil *et al*. (2018) who reported that, application of rice husk silica nano particles @ 200 ppm resulted no seed weight loss whereas 0.03 per cent weight loss was observed when treated with 175 ppm dosage against *Sitophilus oryzae* in rice stored for a period of 4 days.

**Table 4.8 Effect of plant based silica products on weight loss due to bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage $kg^{-1}$ seed | Weight loss (per cent) |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 1.47 (6.96) |
| 2. | Amorphous silica gel | 500 ppm | 0.34 (3.31) |
| 3. | Amorphous silica precipitate | 250 ppm | 3.78 (11.19) |
| 4. | Amorphous silica precipitate | 500 ppm | 2.30 (8.70) |
| 5. | Paddy husk | 1000 ppm | 10.07 (18.49) |
| 6. | Paddy husk | 2000 ppm | 9.51 (17.95) |
| 7. | Paddy leaves | 1000 ppm | 11.21 (19.55) |
| 8. | Paddy leaves | 2000 ppm | 10.87 (19.24) |
| 9. | Diatomaceous earth | 300 ppm | 2.63 (9.32) |
| 10. | Diatomaceous earth | 600 ppm | 1.30 (6.55) |
| 11. | Untreated control | - | 11.76 (20.04) |
| | **SEm±** | | 0.29 |
| | **CD (P=0.05)** | | 0.85 |
| | **CV(%)** | | 3.89 |

The values in parentheses are angular transformed values

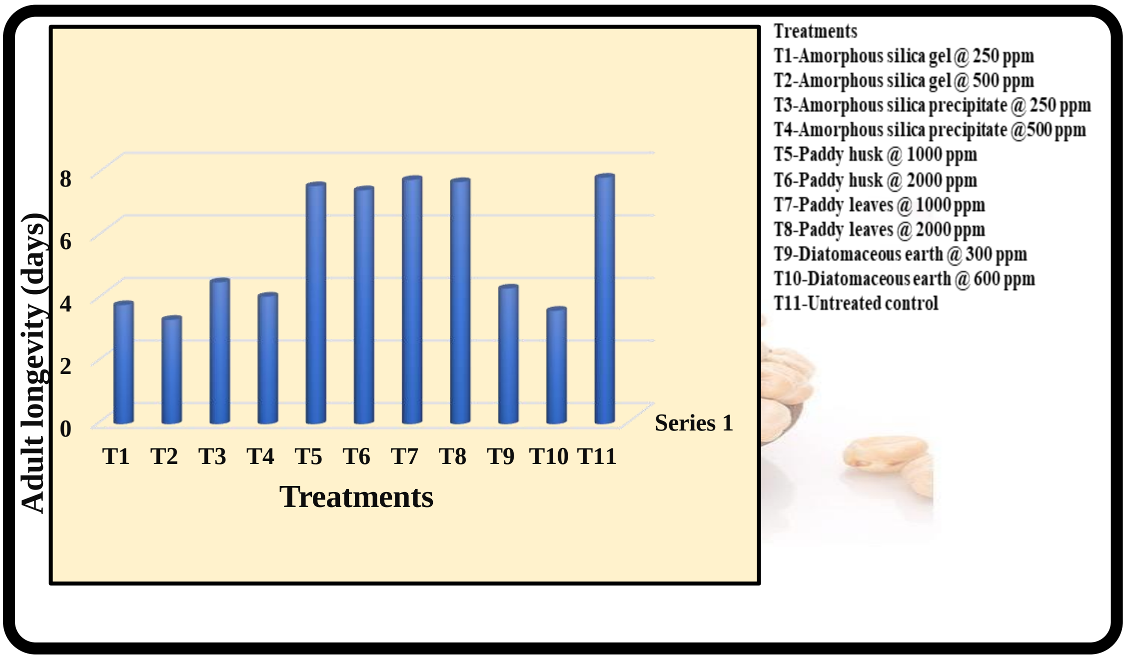



**Fig 4.7 Effect of plant based silica products on adult longevity of bruchid beetle, *Callosobruchus chinensis* (L.)**

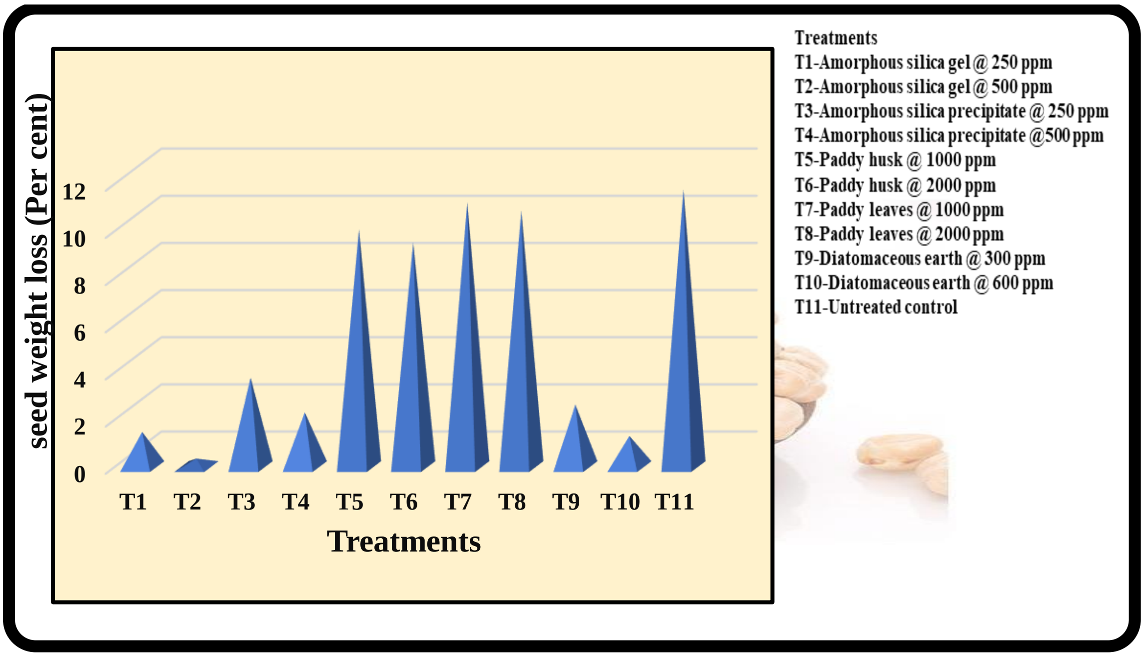



**Fig 4.8 Effect of plant based silica products on per cent weight loss due to bruchid beetle, *Callosobruchus chinensis* (L.)**

## 4.2 EFFICACY OF PLANT BASED SILICA PRODUCTS FOR THE MANAGEMENT OF BRUCHID BEETLE

The effect of plant based silica products for the management of bruchid beetle, *Callosobruchus chinensis* (L.) was assessed based on observations *viz*., seed damage, adult emergence, weight loss and residual toxicity.

### 4.2.1 Effect of plant based silica products on seed damage of chickpea seeds caused by bruchid beetle, *Callosobruchus chinensis* (L.)

The per cent seed damage recorded at two months interval for a period of six months are presented in the Table 4.9 and Figure 4.9.

#### 4.2.1.1 Two months of storage

All the treatments were found to be significantly superior over untreated control. Amorphous silica gel (250 ppm and 500 ppm $kg^{-1}$ seed), amorphous silica precipitate (250 ppm and 500 ppm $kg^{-1}$ seed) and diatomaceous earth (300 ppm and 600 ppm $kg^{-1}$ seed) offered complete protection to chickpea seeds without any damage at two months of storage period. Among the plant based silica products, paddy husk @ 2000 ppm $kg^{-1}$ seed (4.42 per cent) and paddy husk @ 1000 ppm $kg^{-1}$ seed (4.58 per cent) were found to be on par with each other. These were followed by paddy leaves @ 2000 ppm $kg^{-1}$ seed (5.67 per cent) which was on par with paddy leaves @ 1000 ppm $kg^{-1}$ seed (5.92 per cent). Maximum seed damage of 6.25 per cent was observed in untreated seeds which was found to be significantly inferior compared to other treatments.

#### 4.2.1.2 Four months of storage

No seed damage was observed in the seeds treated with amorphous silica gel @ 250 ppm and 500 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed and diatomaceous earth @ 600 ppm $kg^{-1}$ seed. In seeds treated with diatomaceous earth @ 300 ppm $kg^{-1}$ seed and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed, even though no damage was observed during the second month, the per cent damage increased to 1.58 and 1.92 per cent, respectively at four months of storage which were on par with each other. While, paddy husk @ 2000 and 1000 ppm $kg^{-1}$ seed resulted 8.33 and 8.42 per cent damage, respectively and were on par with each other. Significantly highest seed damage was observed in untreated seeds (11.75 per cent) which was found to be on par with paddy leaves @ 1000 ppm $kg^{-1}$ seed (11.50 per cent) and 2000 ppm $kg^{-1}$ seed (11.33 per cent).

#### 4.2.1.3 Six months of storage

**S**imilar trend was observed in case of chickpea seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed which did not record any seed damage even after six months of treatment indicating its superior performance over other treatments. Whereas, per cent seed damage resulted in seeds treated with diatomaceous earth @ 600 ppm $kg^{-1}$ seed (0.83 per cent), amorphous silica gel @ 250 ppm $kg^{-1}$ seed (0.92 per cent) and amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed (1.17 per cent) were on par with each other followed by diatomaceous earth @ 300 ppm $kg^{-1}$ seed (3.08 per cent) and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (3.83 per cent). Whereas, Paddy husk @ 2000 and 1000 ppm $kg^{-1}$ seed resulted 20.83 and 21.25 per cent seed damage, respectively and were on par with each other followed by paddy leaves @ 2000 and 1000 ppm $kg^{-1}$ seed which resulted 23.58 and 23.92 per cent which also remained on par with each other. Per cent seed damage in untreated control was found to be significantly inferior among the treatments, as the seed damage recorded at two months of storage was 6.25 per cent which increased to 24.42 per cent at six months of storage and this was found to be on par with paddy leaves @ 1000 ppm $kg^{-1}$ seed (23.92 per cent). The increase in damage might be due to the larvae feeding inside the seeds and while, Ashamo *et al*. (2013) reported that per cent weight loss and number of damaged seeds increased with increase in the exposure period.

These findings are in accordance with the results of Demissie *et al*. (2008) who reported that per cent seed damage observed in Silico-Sec dust treatment was not more than 2 per cent as against 25 to 46 per cent in untreated control after three months after storage in three different maize genotypes against *Sitophilus zeamais*.

**Table 4.9 Effect of plant based silica products on seed damage of chickpea seeds caused by bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage kg$^{-1}$ seed | Seed damage (per cent) | | |
|---|---|---|---|---|---|
| | | | 2 MOS | 4 MOS | 6 MOS |
| 1. | Amorphous silica gel | 250 ppm | 0.00 (0.00) | 0.00 (0.00) | 0.92 (5.48) |
| 2. | Amorphous silica gel | 500 ppm | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| 3. | Amorphous silica precipitate | 250 ppm | 0.00 (0.00) | 1.92 (7.95) | 3.83 (11.29) |
| 4. | Amorphous silica precipitate | 500 ppm | 0.00 (0.00) | 0.00 (0.00) | 1.17 (6.19) |
| 5. | Paddy husk | 1000 ppm | 4.58 (12.36) | 8.42 (16.86) | 21.25 (27.44) |
| 6. | Paddy husk | 2000 ppm | 4.42 (12.13) | 8.33 (16.77) | 20.83 (27.15) |
| 7. | Paddy leaves | 1000 ppm | 5.92 (14.07) | 11.50 (19.81) | 23.92 (29.27) |
| 8. | Paddy leaves | 2000 ppm | 5.67 (13.76) | 11.33 (19.67) | 23.58 (29.04) |
| 9. | Diatomaceous earth | 300 ppm | 0.00 (0.00) | 1.58 (7.21) | 3.08 (10.11) |
| 10. | Diatomaceous earth | 600 ppm | 0.00 (0.00) | 0.00 (0.00) | 0.83 (5.22) |
| 11. | Untreated control | - | 6.25 (14.47) | 11.75 (20.04) | 24.42 (29.60) |
| | **SEm±** | | 0.10 | 0.17 | 0.19 |
| | **CD (P=0.05)** | | 0.29 | 0.51 | 0.56 |
| | **CV(%)** | | 2.83 | 3.07 | 1.99 |

The values in parentheses are angular transformed values

MOS: Months of storage

### 4.2.2 Effect of plant based silica products on adult emergence of bruchid beetle, *Callosobruchus chinensis* (L.)

The data on effect of plant based silica products on population build up of *C.chinensis* at two months interval for a period of six months are presented in Table 4.10 and Figure 4.10.

#### 4.2.2.1 Two months of storage

All the treatments were found to be be significantly superior over the untreated control (26.33). The treatments *viz*., amorphous silica gel, amorphous silica precipitate and diatomaceous earth irrespective of their two dosages gave complete protection to chickpea seeds by preventing adult emergence upto two months of storage. The treatments *viz*., paddy husk @ 2000 ppm $kg^{-1}$ seed, paddy husk @ 1000 ppm $kg^{-1}$ seed, paddy leaves @ 2000 and paddy leaves @ 1000 ppm $kg^{-1}$ seed resulted 21.00, 22.00, 23.67 and 25.67 mean number of adults, respectively.

#### 4.2.2.2 Four months of storage

After four months of treatment, amorphous silica gel @ 250 and 500 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed and diatomaceous earth @ 600 ppm $kg^{-1}$ seed were equally effective and completely prevented the adult emergence.

Minimum mean number of adults were found in diatomaceous earth @ 300 ppm $kg^{-1}$ seed (7.33) followed by amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (8.33). The treatments *viz*., paddy husk @ 2000, paddy husk @ 1000 ppm $kg^{-1}$ seed, paddy leaves @ 2000 and paddy leaves @ 1000 ppm $kg^{-1}$ seed resulted 35.00, 36.33, 47.00 and 47.67 mean number of adults, respectively and were found to be less effective same as seen at two months of storage. However, maximum mean number of adults (53.00) were observed in untreated seeds which was significantly inferior over all other treatments.

#### 4.2.2.3 Six months of storage

From the results it was evident that amorphous silica gel @ 500 ppm $kg^{-1}$ seed continued its supremacy over other treatments and completely protected the chickpea seeds even at six months of storage.

Whereas seeds treated with diatomaceous earth @ 600 ppm $kg^{-1}$ seed, amorphous silica gel @ 250 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed, diatomaceous earth @ 300 ppm $kg^{-1}$ seed and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed resulted 3.33, 4.00, 6.00, 17.00 and 18.67 mean number of adults, respectively. In rest of the plant based silica product treatments, the mean adult emergence varied from

87.33 to 99.67 as against untreated seeds which increased to 107.67 mean number of adults in control.

The results were in agreement with Doaa and Nilly (2015) reported that when cowpea seeds treated with Aerosil 200 (fumed silica) against *Callosobruchus maculatus* caused cent per cent reduction in $F_1$ progeny at all concentrations (0.25, 0.5, 1, 1.5 g $kg^{-1}$ seed). Similarly, Ali *et al*. (2017b) who reported that broad bean seeds when treated with coarse silica @ 2.0 g 100 $g^{-1}$ seed against *Callosobruchus chinensis* resulted lowest level of adult emergence (2.3 adults) as against untreated seeds (24.7 adults). Accumulation of dust particles on to the insect body resulted in less movement through the treated seeds and uneven egg distribution which might be the reason for fewer progeny emergence (Prasantha *et al*., 2003).

### 4.2.3 Effect of plant based silica products on weight loss of chickpea seeds caused by bruchid beetle, *Callosobruchus chinensis* (L.)

The data recorded at two monthly interval on per cent weight loss due to infestation by *C.chinensis* in chickpea are presented in Table 4.11 and Figure 4.11.

#### 4.2.3.1 Two months of storage

A perusal of data on the per cent weight loss due to *C.chinensis* infestation revealed that no weight loss was observed in seeds treated with amorphous silica gel, amorphous silica precipitate and diatomaceous earth at two dosage levels at two months of storage. The highest per cent weight loss was observed in untreated control (0.98 per cent) which was found to be on par with paddy leaves @ 1000 ppm $kg^{-1}$ seed (0.96 per cent) and paddy leaves @ 2000 ppm $kg^{-1}$ seed (0.94 per cent). Per cent weight loss of 0.48 was observed in both dosage levels of the paddy husk *i.e.*, 1000 and 2000 ppm $kg^{-1}$ seed.

**Table 4.10 Effect of plant based silica products on adult emergence of bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage $kg^{-1}$ seed | Adult emergence | | |
|---|---|---|---|---|---|
| | | | **2 MOS** | **4 MOS** | **6 MOS** |
| 1. | Amorphous silica gel | 250 ppm | 0.00 (1.00) | 0.00 (1.00) | 4.00 (2.23) |
| 2. | Amorphous silica gel | 500 ppm | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) |
| 3. | Amorphous silica precipitate | 250 ppm | 0.00 (1.00) | 8.33 (3.05) | 18.67 (4.43) |
| 4. | Amorphous silica precipitate | 500 ppm | 0.00 (1.00) | 0.00 (1.00) | 6.00 (2.64) |
| 5. | Paddy husk | 1000 ppm | 22.00 (4.80) | 36.33 (6.11) | 89.33 (9.50) |
| 6. | Paddy husk | 2000 ppm | 21.00 (4.69) | 35.00 (5.10) | 87.33 (9.40) |
| 7. | Paddy leaves | 1000 ppm | 25.67 (5.16) | 47.67 (6.98) | 99.67 (10.03) |
| 8. | Paddy leaves | 2000 ppm | 23.67 (4.97) | 47.00 (6.93) | 99.00 (10.00) |
| 9. | Diatomaceous earth | 300 ppm | 0.00 (1.00) | 7.33 (2.88) | 17.00 (4.24) |
| 10. | Diatomaceous earth | 600 ppm | 0.00 (1.00) | 0.00 (1.00) | 3.33 (2.07) |
| 11. | Untreated control | - | 26.33 (5.23) | 53.00 (7.35) | 107.67 (10.42) |
| | **SEm±** | | 0.05 | 0.07 | 0.08 |
| | **CD (P=0.05)** | | 0.14 | 0.20 | 0.24 |
| | **CV(%)** | | 2.86 | 2.98 | 2.38 |

The values in parentheses are square root transformed values

MOS: Months of storage

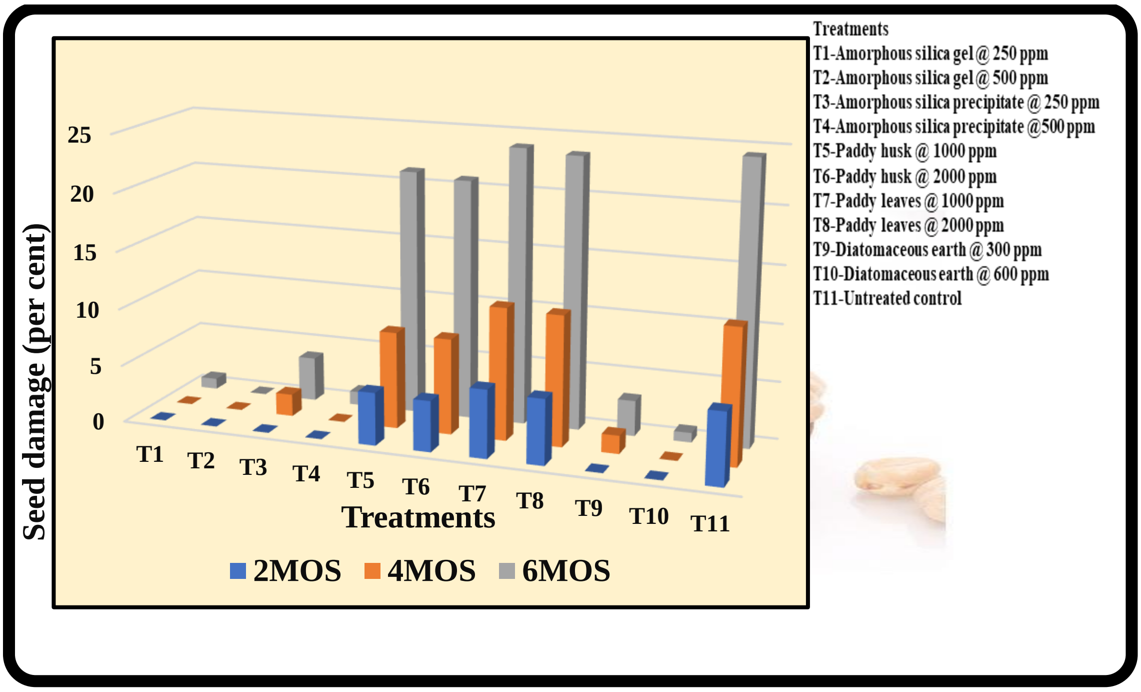



**Fig 4.9 Effect of plant based silica products on seed damage of chickpea seeds caused by bruchid beetle, *Callosobruchus chinensis* (L.)**

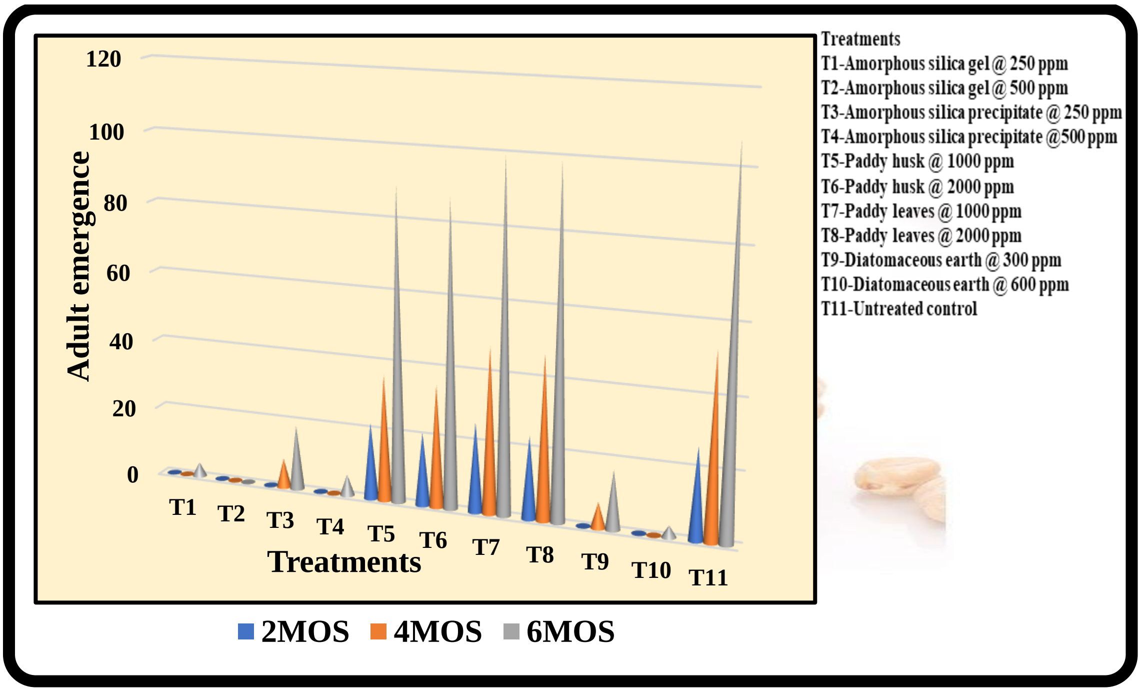



**Fig 4.10 Effect of plant based silica products on adult emergence of bruchid beetle, *Callosobruchus chinensis* (L.)**

#### 4.2.3.2 Four months of storage

The observations recorded after four months of storage also showed similar trend as no weight loss was observed in seeds treated with amorphous silica gel @ 250 and 500 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed and diatomaceous earth @ 600 ppm $kg^{-1}$ seed and these were found to be on par with diatomaceous earth @ 300 ppm $kg^{-1}$ seed (0.17 per cent) and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (0.20 per cent). In rest of the treatments the per cent weight loss ranged between 1.63 to 1.97. While highest per cent weight loss of 2.07 was recorded in untreated seeds and was found to be on par with paddy leaves @ 1000 ppm $kg^{-1}$ seed (1.97 per cent) and paddy leaves @ 2000 ppm $kg^{-1}$ seed (1.96 per cent).

#### 4.2.3.3 Six months of storage

After six months of treatments, similar trend was observed even after six months of storage where no weight loss was observed in seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed and was found to be on par with diatomaceous earth @ 600 ppm $kg^{-1}$ seed (0.07 per cent), amorphous silica gel @ 250 ppm $kg^{-1}$ seed (0.09 per cent) and amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed (0.11 per cent).

While weight loss of 0.37 and 0.48 per cent were observed in diatomaceous earth @ 300 ppm $kg^{-1}$ seed and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed which remained on par with each other followed by paddy husk @ 2000 ppm $kg^{-1}$ seed (3.16 per cent) and paddy husk @ 1000 ppm $kg^{-1}$ seed (3.18 per cent) which were also found on par with each other. Significantly highest weight loss of 3.83 per cent was observed in untreated check and was found to be on par with paddy leaves @ 1000 and 2000 ppm $kg^{-1}$ seed which resulted 3.76 and 3.75 per cent weight loss, respectively.

The present findings are in line with observations made by Nukenine *et al*. (2010) who reported that SilicoSec when applied on maize seeds @ 2 g $kg^{-1}$ seed against *Sitophilus zeamais* resulted seed damage and weight loss of 0.6 and 0.1 per cent, respectively as against untreated control (94.5 and 26.0 per cent) when stored for four months. The reduction in weight loss might be due to early mortality, less ovipositional and emergence performances (Islam *et al*., 2013).


**Plate 4.6 Best plant based silica product treatment compared with untreated check**

**Plate 4.7 Recording observations of seed damage, adult emergence and weight loss**

### 4.2.4 Residual toxicity of plant based silica products on adult mortality of bruchid beetle, *Callosobruchus chinensis* (L.)

Data on the adult mortality of *C.chinensis* were recorded at 1,2,3 and 5 days after release of five pairs of adult beetles into treated seeds at every two months interval are presented in the Table 4.12 & 4.13 and Figures 4.12, 4.13, 4.14 & 4.15.

#### 4.2.4.1 Immediately after treatment

The per cent adult mortality was significantly found highest in seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ (83.33) on first day followed by diatomaceous earth @ 600 ppm $kg^{-1}$ seed (63.33) and amorphous silica gel @ 250 ppm $kg^{-1}$ seed (60.00) which remained on par each other.

However, by third day, cent per cent mortality was recorded in amorphous silica gel @ 500 ppm $kg^{-1}$ seed. The adult mortality recorded in diatomaceous earth @ 300 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed and amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed at first day were 36.67, 36.67 and 40 per cent, respectively and all these treatments resulted cent per cent mortality by fifth day. While, the adult mortality recorded in paddy leaves @ 1000 ppm $kg^{-1}$ seed, paddy husk @ 1000 ppm $kg^{-1}$ seed, paddy leaves @ 2000 ppm $kg^{-1}$ seed and paddy husk @ 2000 ppm $kg^{-1}$ seed were 56.67, 63.33, 63.33 and 70.00 per cent, respectively as against untreated control (50.00 per cent) at fifth day after release.

#### 4.2.4.2 Two months of storage

Amorphous silica gel @ 500 ppm $kg^{-1}$ seed resulted significantly highest mean mortality of 80.00 per cent at first day after three months and by fifth day cent per cent mortality was observed. The mortality recorded at first day in diatomaceous earth @ 600 ppm $kg^{-1}$ seed, amorphous silica gel @ 250 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed and diatomaceous earth @ 300 ppm $kg^{-1}$ seed were 60.00, 53.33, 40.00, 30.00 and 26.67 per cent, respectively and by fifth day all these treatments resulted in 96.67, 90.00, 86.67, 80.00 and 83.33 per cent mortality, respectively. While, the plant based silica products *viz*., paddy leaves @ 1000, 2000 ppm $kg^{-1}$ seed, paddy husk @ 1000 and 2000 ppm $kg^{-1}$ seed resulted 50.00, 50.00, 60.00 and 63.33 per cent mortality, respectively as against untreated check (46.67 per cent) at fifth day after release.

**Table 4.11 Effect of plant based silica products on weight loss of chickpea seeds caused by bruchid beetle, *Callosobruchus chinensis* (L.)**

| S.No | Treatments | Dosage $kg^{-1}$ seed | Weight loss (%) | | |
|---|---|---|---|---|---|
| | | | 2 MOS | 4 MOS | 6 MOS |
| 1. | Amorphous silica gel | 250 ppm | 0.00 (0.00) | 0.00 (0.00) | 0.09 (1.70) |
| 2. | Amorphous silica gel | 500 ppm | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| 3. | Amorphous silica precipitate | 250 ppm | 0.00 (0.00) | 0.20 (2.55) | 0.48 (3.98) |
| 4. | Amorphous silica precipitate | 500 ppm | 0.00 (0.00) | 0.00 (0.00) | 0.11 (1.88) |
| 5. | Paddy husk | 1000 ppm | 0.48 (3.97) | 1.64 (7.34) | 3.18 (10.26) |
| 6. | Paddy husk | 2000 ppm | 0.48 (3.99) | 1.63 (7.34) | 3.16 (10.23) |
| 7. | Paddy leaves | 1000 ppm | 0.96 (5.62) | 1.97 (8.06) | 3.76 (11.18) |
| 8. | Paddy leaves | 2000 ppm | 0.94 (5.55) | 1.96 (8.05) | 3.75 (11.16) |
| 9. | Diatomaceous earth | 300 ppm | 0.00 (0.00) | 0.17 (2.36) | 0.37 (3.49) |
| 10. | Diatomaceous earth | 600 ppm | 0.00 (0.00) | 0.00 (0.00) | 0.07 (1.47) |
| 11. | Untreated control | - | 0.98 (5.68) | 2.07 (8.27) | 3.83 (11.29) |
| | **SEm±** | | 0.03 | 0.09 | 0.10 |
| | **CD (P=0.05)** | | 0.10 | 0.26 | 0.31 |
| | **CV(%)** | | 2.53 | 3.83 | 2.10 |

The values in parentheses are angular transformed values

MOS: Months of storage

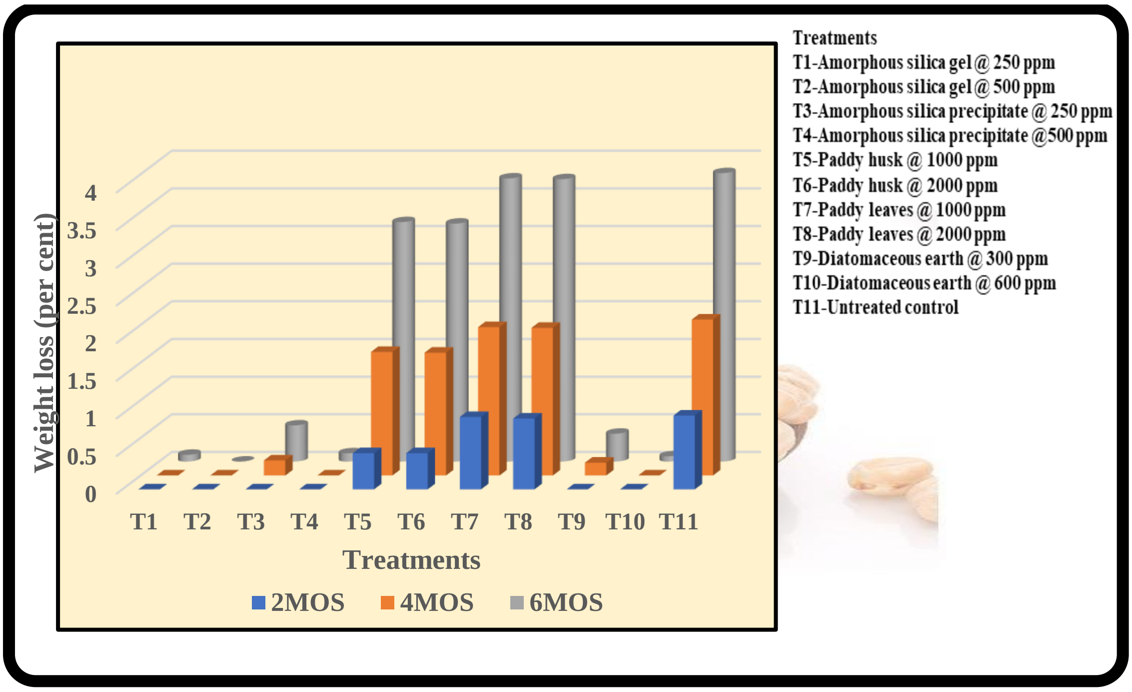



**Fig 4.11 Effect of plant based silica products on weight loss of chickpea seeds caused by bruchid beetle, *Callosobruchus chinensis* (L.)**

#### 4.2.4.3 Four months of storage

The observations recorded at one day after four months of treatment revealed that amorphous silica gel @ 500 ppm $kg^{-1}$ seed resulted significantly highest mortality of 73.33 per cent and by fifth day it resulted in 100 per cent mortality which indicated the trend similar as that of two months of storage. In comparison to two months after treatment, the adult mortality reduced to 23.33, 23.33, 26.67, 40.00 and 46.67 per cent in seeds treated with diatomaceous earth @ 300 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed, amorphous silica gel @ 250 ppm $kg^{-1}$ seed and diatomaceous earth @ 600 ppm $kg^{-1}$ seed, respectively at first day after release.

By fifth day, amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed, diatomaceous earth @ 300 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed and amorphous silica gel @ 250 ppm $kg^{-1}$ seed resulted in 76.67, 76.67, 86.67 and 93.33 per cent mortality where cent per cent mortality was observed in diatomaceous earth @ 600 ppm $kg^{-1}$ seed.

While, the mortality observed in paddy leaves @ 1000 ppm $kg^{-1}$ seed, paddy husk @ 1000 ppm $kg^{-1}$ seed, paddy leaves @ 2000 ppm $kg^{-1}$ seed, paddy husk @ 2000 ppm $kg^{-1}$ seed and untreated seeds were 50.00, 53.33, 53.33, and 56.67 per cent, respectively at fifth day after release.

#### 4.2.4.4 Six months of storage

The adult mortality was found significantly highest in amorphous silica gel @ 500 ppm $kg^{-1}$ seed (70.00 per cent) at first day and by fifth day it resulted in cent per cent mortality which indicated its supremacy even after six months of treatment. The adult mortality recorded in diatomaceous earth @ 300 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed, amorphous silica gel @ 250 ppm $kg^{-1}$ seed and diatomaceous earth @ 600 ppm $kg^{-1}$ seed at first day were 20.00, 23.33, 26.67, 33.33 and 40.00 per cent, respectively and by fifth day the mortality per cent increased to 70.00, 76.67, 83.33, 83.33 and 86.67 per cent, respectively.

While, zero per cent mortality was observed in treatments *viz*., paddy leaves @ 1000 ppm $kg^{-1}$ seed, paddy husk @ 1000 ppm $kg^{-1}$ seed, paddy leaves @ 2000 ppm $kg^{-1}$ seed and paddy husk @ 2000 ppm $kg^{-1}$ seed at first day and by fifth day mortality

**Table 4.12 Residual toxicity of plant based silica products on adult mortality of bruchid beetle, *Callosobruchus chinensis* (L.) (immediately after seed treatment to two months of storage)**

| Treatments & Dosage $kg^{-1}$ seed | Per cent adult mortality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Immediately after seed treatment | | | | Two months of storage | | | |
| | 1 DAR | 2 DAR | 3 DAR | 5 DAR | 1 DAR | 2 DAR | 3 DAR | 5DAR |
| $T_1$-Amorphous silica gel @ 250 ppm | 60.00 (50.75) | 86.67 (68.83) | 93.33 (77.69) | 100.00 (90.00) | 53.33 (46.90) | 73.33 (58.98) | 76.67 (61.20) | 90.00 (71.54) |
| $T_2$-Amorphous silica gel @ 500 ppm | 83.33 (66.12) | 96.67 (83.85) | 100.00 (90.00) | 100.00 (90.00) | 80.00 (63.41) | 90.00 (71.54) | 93.33 (77.69) | 100.00 (90.00) |
| $T_3$-Amorphous silica precipitate @ 250 ppm | 36.67 (37.21) | 73.33 (58.98) | 86.67 (68.83) | 100.00 (90.00) | 30.00 (33.20) | 50.00 (44.98) | 66.67 (54.76) | 80.00 (63.41) |
| $T_4$-Amorphous silica precipitate @ 500 ppm | 40.00 (39.22) | 83.33 (66.12) | 90.00 (71.54) | 100.00 (90.00) | 40.00 (39.13) | 70.00 (56.77) | 76.67 (61.20) | 86.67 (68.83) |
| $T_5$-Paddy husk @ 1000 ppm | 13.33 (21.14) | 26.67 (30.98) | 33.33 (35.20) | 63.33 (52.75) | 10.00 (18.43) | 20.00 (26.55) | 26.67 (30.98) | 60.00 (50.75) |
| $T_6$-Paddy husk @ 2000 ppm | 23.33 (28.77) | 40.00 (39.22) | 50.00 (44.98) | 70.00 (56.98) | 13.33 (21.14) | 23.33 (28.77) | 30.00 (33.20) | 63.33 (52.75) |
| $T_7$-Paddy leaves @ 1000 ppm | 13.33 (21.14) | 20.00 (26.55) | 26.67 (30.98) | 56.67 (48.83) | 10.00 (18.43) | 13.33 (21.14) | 20.00 (26.55) | 50.00 (44.99) |
| $T_8$-Paddy leaves @ 2000 ppm | 13.33 (21.14) | 23.33 (28.77) | 40.00 (39.22) | 63.33 (52.84) | 10.00 (18.43) | 20.00 (26.55) | 20.00 (26.55) | 50.00 (44.98) |
| $T_9$-Diatomaceous earth @ 300 ppm | 36.67 (37.21) | 76.67 (61.20) | 90.00 (71.54) | 100.00 (90.00) | 26.67 (30.98) | 66.67 (54.76) | 66.67 (54.76) | 83.33 (66.12) |
| $T_{10}$-Diatomaceous earth @ 600 ppm | 63.33 (52.75) | 93.33 (77.70) | 96.67 (83.85) | 100.00 (90.00) | 60.00 (50.75) | 83.33 (66.12) | 86.67 (68.83) | 96.67 (83.85) |
| $T_{11}$-Untreated control | 0.00 (0.00) | 13.33 (21.14) | 20.00 (26.55) | 50.00 (44.98) | 0.00 (0.00) | 10.00 (18.43) | 16.67 (23.84) | 46.67 (43.06) |
| **SEm±** | 2.05 | 3.27 | 2.89 | 2.08 | 1.58 | 1.61 | 2.62 | 2.341 |
| **CD (P=0.05)** | 6.06 | 9.64 | 8.54 | 6.14 | 4.67 | 4.75 | 7.72 | 6.91 |
| **CV(%)** | 10.42 | 11.05 | 8.61 | 4.98 | 8.84 | 6.46 | 9.60 | 6.56 |

The values in parentheses are angular transformed values

DAR: Days after release of test insect

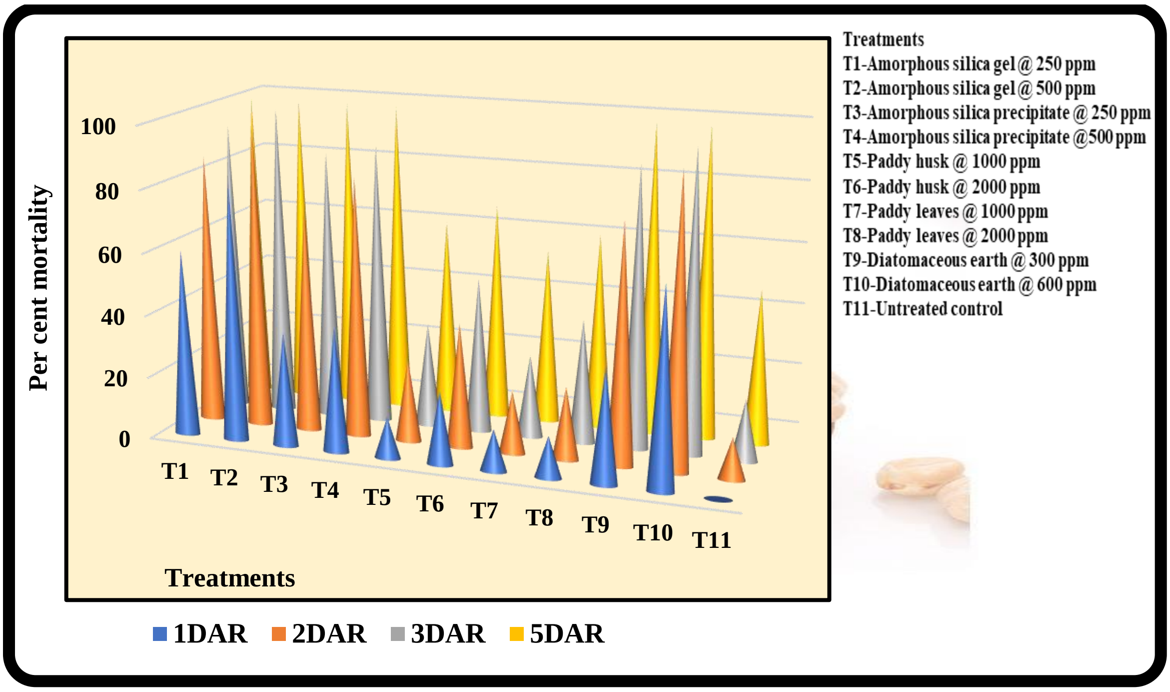



**Fig 4.12 Residual toxicity of plant based silica products on adult mortality of bruchid beetle, *Callosobruchus chinensis* (L.) immediately after seed treatment**

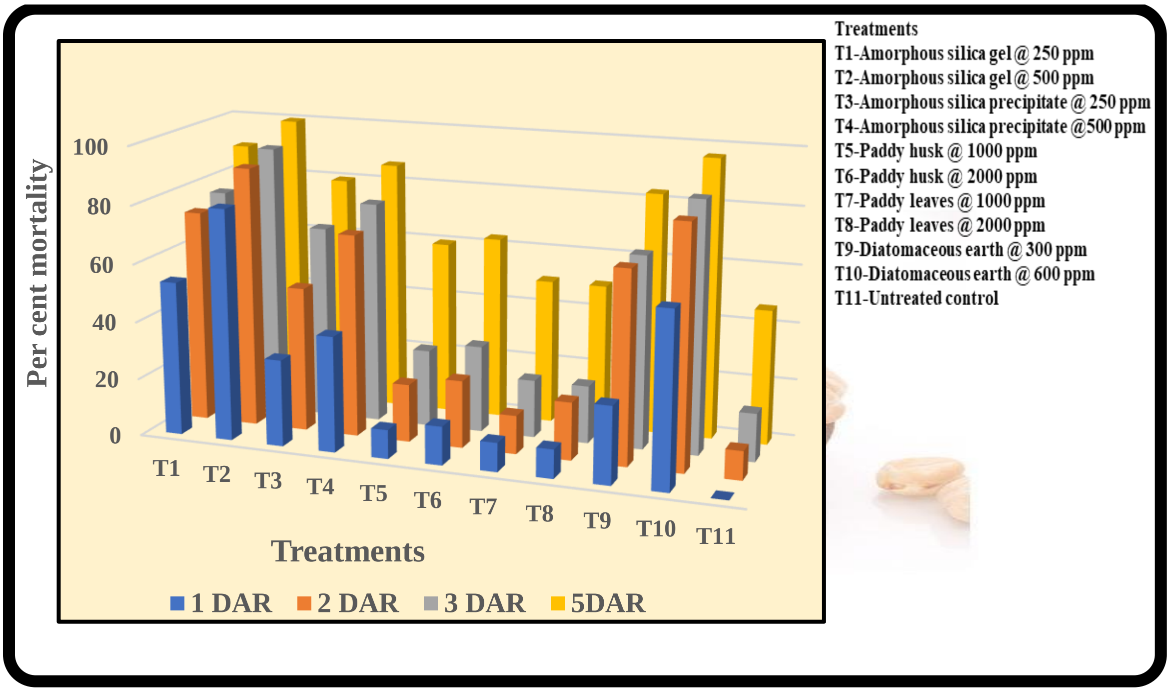



**Fig 4.13 Residual toxicity of plant based silica products on adult mortality of bruchid beetle, *Callosobruchus chinensis* (L.) at two months of storage**

per cent increased to 46.67, 50.00, 50.00 and 53.33 per cent, respectively as against untreated control (43.33 per cent).

The present findings are in line with observations made by Nukenine *et al*. (2010) who reported that SilicoSec when applied on maize seeds @ 2 g $kg^{-1}$ seed against *Sitophilus zeamais* resulted 81.1 and 100 per cent mortality within 3 and 14 days of exposure, respectively. Similarly, Korunic *et al*. (2017) reported that Sipernat 50 S powder (silica gel) @ 200 ppm against *Sitophilus oryzae* in wheat resulted 100 per cent mortality of adults when exposed for a period of eight days and also at all concentrations progeny inhibition was found to be 100 per cent.

Patil *et al*. (2018) reported that application of higher dosages of rice husk silica nano particles @ 175 and 200 ppm against *Sitophilus oryzae* resulted mortality of 10 to 100 per cent and 20 to 100 per cent from first to fourth day, respectively as against 0 to 20 per cent in untreated control. The insect mortality might be due to excess loss of water from the insect body (Athanassiou *et al.*, 2008) and inhibition of respiratory activity through plugging of spiracles (Glenn *et al*., 1999).

### 4.2.5 Effect of plant based silica products on *Callosobruchus chinensis* (L.) by Scanning Electron Microscope (SEM)

The scanning electron microscope (SEM) images of pulse beetle adult exposed to amorphous silica gel @ 500 ppm (1 mg $cm^{-2}$) clearly depicted the abrasion of cuticle of the abdomen over the untreated check (Plate 4.8 and 4.9). The SEM images also revealed that the amorphous silica gel resulted in uniform distribution of the particles over the body which resulted in abrasion of the cuticle there by resulting in loss of water from the body which in turn resulted in death of the insect. This loss of water through desiccation is due to the damage of the water barrier in the insects (Ebeling, 1971).

United States Department of Agriculture (USDA) has declared amorphous silica as the safest grain protectant (Stathers *et al.*, 2004). For the practical use of plant based silica products as novel pesticide to proceed, further research work is required on the safety issues of these materials on human well-being. Other areas demanding attention are its mode of action and development of formulations to improve its efficacy and stability, as well as to reduce cost. This study also could open up newer ways of using plant based technology in pesticide industry.

**Table 4.13 Residual toxicity of plant based silica products on adult mortality of bruchid beetle, *Callosobruchus chinensis* (L.) (four months of storage to six months of storage)**

| Treatments & Dosage kg$^{-1}$ seed | Per cent adult mortality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Four months of storage | | | | Six months of storage | | | |
| | 1 DAR | 2 DAR | 3 DAR | 5 DAR | 1 DAR | 2 DAR | 3 DAR | 5 DAR |
| $T_1$-Amorphous silica gel @ 250 ppm | 40.00 (39.22) | 60.00 (50.75) | 70.00 (56.98) | 93.33 (77.69) | 33.33 (35.20) | 56.67 (48.83) | 66.67 (54.76) | 83.33 (66.12) |
| $T_2$-Amorphous silica gel @ 500 ppm | 73.33 (58.98) | 86.67 (68.83) | 90.00 (71.54) | 100.00 (90.00) | 70.00 (56.77) | 80.00 (63.41) | 86.67 (68.83) | 100.00 (90.00) |
| $T_3$-Amorphous silica precipitate @ 250 ppm | 23.33 (28.77) | 50.00 (44.99) | 63.33 (52.75) | 76.67 (61.20) | 23.33 (28.77) | 46.67 (43.06) | 60.00 (50.75) | 76.67 (61.20) |
| $T_4$-Amorphous silica precipitate @ 500 ppm | 26.67 (30.98) | 56.67 (48.83) | 66.67 (54.97) | 86.67 (68.83) | 26.67 (30.98) | 53.33 (46.90) | 63.33 (52.75) | 83.33 (66.12) |
| $T_5$-Paddy husk @ 1000 ppm | 0.00 (0.00) | 20.00 (26.56) | 20.00 (26.55) | 53.33 (46.90) | 0.00 (0.00) | 10.00 (18.43) | 10.00 (18.43) | 50.00 (44.98) |
| $T_6$-Paddy husk @ 2000 ppm | 10.00 (18.43) | 23.33 (28.77) | 26.67 (30.98) | 56.67 (48.83) | 0.00 (0.00) | 10.00 (18.43) | 13.33 (21.14) | 53.33 (46.90) |
| $T_7$-Paddy leaves @ 1000 ppm | 0.00 (0.00) | 13.33 (21.14) | 16.67 (23.85) | 50.00 (44.98) | 0.00 (0.00) | 10.00 (18.43) | 10.00 (18.43) | 46.67 (43.06) |
| $T_8$-Paddy leaves @ 2000 ppm | 10.00 (18.43) | 16.67 (23.85) | 23.33 (28.77) | 53.33 (46.90) | 0.00 (0.00) | 10.00 (18.43) | 10.00 (18.43) | 50.00 (44.98) |
| $T_9$-Diatomaceous earth @ 300 ppm | 23.33 (28.77) | 53.33 (46.90) | 60.00 (50.75) | 76.67 (61.20) | 20.00 (26.55) | 50.00 (44.98) | 56.67 (48.83) | 70.00 (56.77) |
| $T_{10}$-Diatomaceous earth @ 600 ppm | 46.67 (43.06) | 76.67 (61.20) | 83.33 (66.12) | 100.00 (90.00) | 40.00 (39.22) | 66.67 (54.76) | 76.67 (61.20) | 86.67 (68.83) |
| $T_{11}$-Untreated control | 0.00 (0.00) | 10.00 (18.43) | 10.00 (18.43) | 46.67 (43.06) | 0.00 (0.00) | 10.00 (18.43) | 10.00 (18.43) | 43.33 (41.14) |
| **SEm±** | 1.46 | 1.89 | 2.33 | 2.52 | 1.12 | 1.17 | 1.69 | 1.86 |
| **CD (P=0.05)** | 4.30 | 5.57 | 6.88 | 7.44 | 3.31 | 3.46 | 4.98 | 5.49 |
| **CV(%)** | 10.40 | 8.17 | 9.21 | 7.06 | 9.82 | 5.67 | 7.44 | 5.62 |

The values in parentheses are angular transformed values

DAR: Days after release of test insect

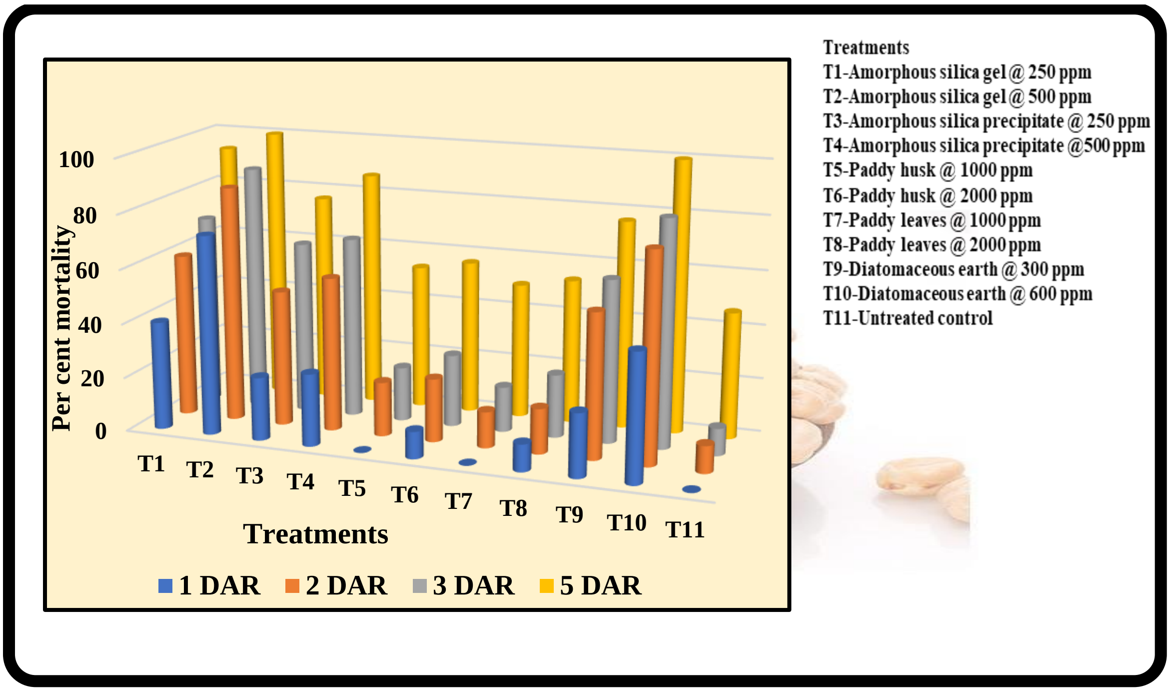



**Fig 4.14 Residual toxicity of plant based silica products on adult mortality of bruchid beetle, *Callosobruchus chinensis* (L.) at four months of storage**

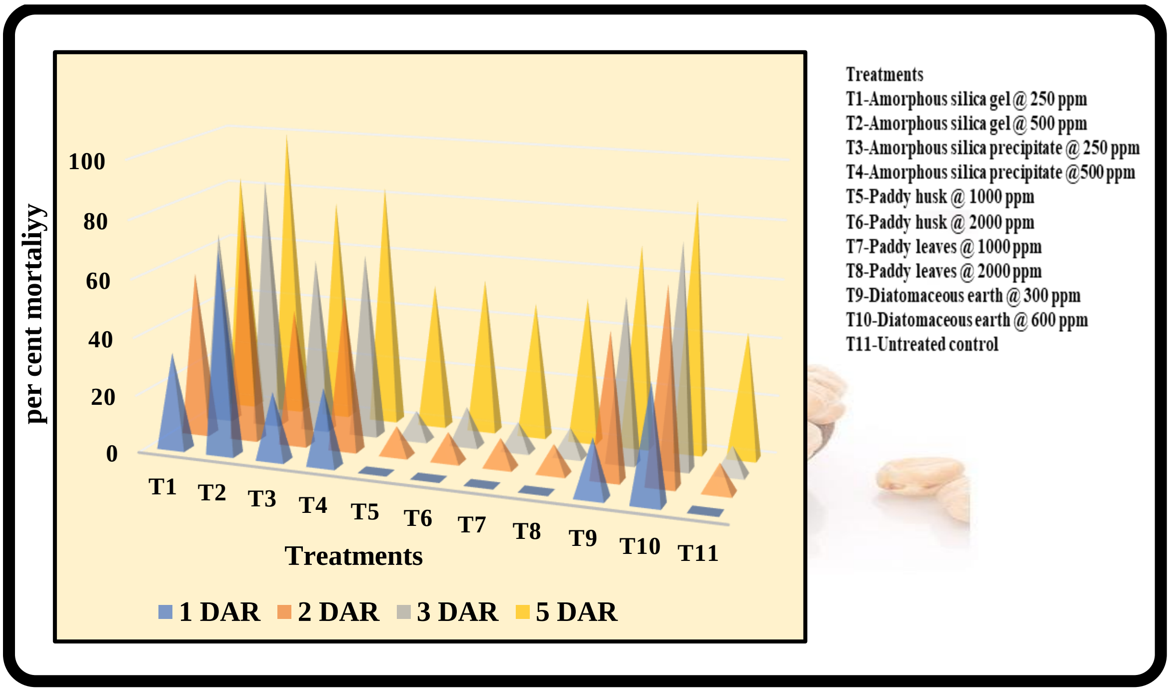



**Fig 4.15 Residual toxicity of plant based silica products on adult mortality of bruchid beetle, *Callosobruchus chinensis* (L.) at six months of storage**

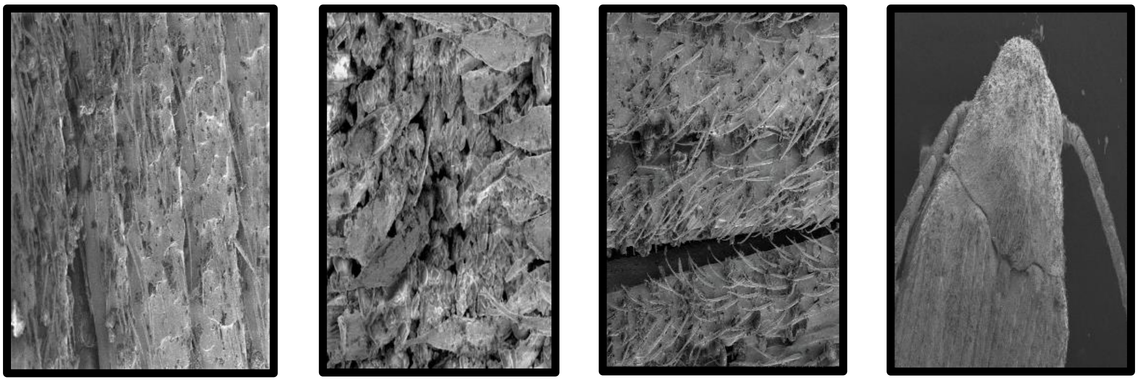


**Plate 4.8 SEM images of cuticle of *Callosobruchus chinensis* depicting abrasion and impregnation of amorphous silica gel**

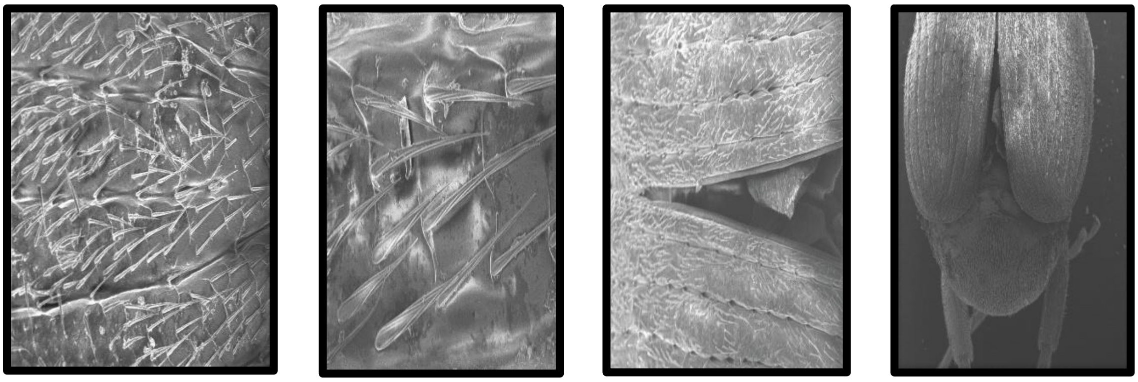


**Plate 4.9 SEM images of normal cuticle of *Callosobruchus chinensis* in untreated check**

## 4.3 ASSESSMENT OF NUTRITIONAL QUALITY PARAMETERS OF TREATED CHICKPEA SEEDS

In the present investigation, the nutritional quality parameters *viz*., carbohydrates, proteins and crude fat in treated chickpea were assessed and the results are presented below

### 4.3.1 Carbohydrates

The results pertaining to the effect of plant based silica products on carbohydrate content of stored chickpea seeds are presented in Table 4.14 and Figure 4.16.

The initial carbohydrate content recorded was 61.78 per cent, where upon increase in the storage period the carbohydrate content was found to decrease in all the treatments. After six months of treatment imposition, significantly highest carbohydrate content (61.11 per cent) was recorded in seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed which was found to be on par with diatomaceous earth @ 600 ppm $kg^{-1}$ seed (60.66). While, lowest carbohydrate content was observed in untreated control (57.96). The reduction might be due to the consumption of endosperm by insects which is rich is carbohydrates (Modgil and Mehta, 1996) and also due to the total depletion of crude cellulose and starch resulted from the metabolic and enzymatic activity of the insect (Allali *et al*. 2020).

The carbohydrate content in other treatments varied from 58.66 to 60.54 per cent. The treatments were *viz*., paddy leaves @ 1000 ppm $kg^{-1}$ seed (58.66) and paddy leaves @ 2000 ppm $kg^{-1}$ seed (58.78) which were found to be on par with each other followed by paddy husk @ 1000 ppm $kg^{-1}$ seed (59.37) and paddy husk @ 2000 ppm $kg^{-1}$ seed (59.88). However, amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (60.50 per cent), diatomaceous earth @ 300 ppm $kg^{-1}$ seed (60.52 per cent), amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed (60.53 per cent), amorphous silica gel @ 250 ppm $kg^{-1}$ seed (60.54 per cent) and diatomaceous earth @ 600 ppm $kg^{-1}$ seed (60.66 per cent) remained on par with each other.

The results are in agreement with Garbaba *et al*. (2017) who reported that, carbohydrate content decreases with increase in the storage duration and insect infestation and the present findings are in agreement with Abdelfattah and Zein (2019) who reported that, carbohydrate content decreased in untreated wheat (75.23 per cent) compared to wheat treated with Aerosil (76.05) after six months of storage period.

### 4.3.2 Protein

The results pertaining to the effect of plant based silica products on protein content of stored chickpea seeds are presented in Table 4.15 and Figure 4.17.

Protein content of 21.98 per cent was found initially in fresh seeds and was found to increase in all the treatments with increase in the storage period. The lowest protein per cent of 24.23 was observed in amorphous silica gel @ 500 ppm $kg^{-1}$ seed followed by diatomaceous earth @ 600 ppm $kg^{-1}$ seed (24.72) and highest protein content of 28.77 per cent was recorded in untreated control after six months of storage.

The protein content in rest of the treatments *viz*., amorphous silica gel @ 250 ppm $kg^{-1}$ seed (24.94), amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed (25.06), diatomaceous earth @ 300 ppm $kg^{-1}$ seed (25.14), amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (25.28) were found to be on par with each other. These were followed by paddy husk @ 2000 ppm $kg^{-1}$ seed (26.71) and paddy husk @ 1000 ppm $kg^{-1}$ seed (27.26). While, paddy leaves @ 2000 ppm $kg^{-1}$ seed (27.98) and paddy leaves @ 1000 ppm $kg^{-1}$ seed (28.10) remained on par with each other.

The increase in the protein content might be due to the accumulation of insect exuviae and frass inside the grains which tends to increase the total nitrogen content of the grains (Bamaiya *et al*., 2006). The present investigations are in conformity with the findings of Omobowale and Akomolafe (2021) who reported that protein content in cowpea increased from 20.4 per cent to 24.6 and 24.4 in untreated control and diatomaceous earth treated seeds, respectively after three months of storage. Jood and Kapoor (1993) also noticed increase in total nitrogen, non protein nitrogen, uric acid and total protein with increased infestation levels.

**Table 4.14 Effect of plant based silica products treatment on carbohydrates of chickpea seeds during storage**

| S.No | Treatments | Dosage kg$^{-1}$ seed | Carbohydrates (per cent) |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 60.54 (51.06) |
| 2. | Amorphous silica gel | 500 ppm | 61.11 (51.40) |
| 3. | Amorphous silica precipitate | 250 ppm | 60.50 (51.04) |
| 4. | Amorphous silica precipitate | 500 ppm | 60.53 (51.06) |
| 5. | Paddy husk | 1000 ppm | 59.37 (50.38) |
| 6. | Paddy husk | 2000 ppm | 59.88 (50.68) |
| 7. | Paddy leaves | 1000 ppm | 58.66 (49.97) |
| 8. | Paddy leaves | 2000 ppm | 58.78 (50.04) |
| 9. | Diatomaceous earth | 300 ppm | 60.52 (51.05) |
| 10. | Diatomaceous earth | 600 ppm | 60.66 (51.14) |
| 11. | Untreated control | - | 57.96 (49.56) |
| | **SEm±** | | 0.17 |
| | **CD (P=0.05)** | | 0.51 |
| | **CV(%)** | | 0.59 |
| | **Initial** | | 61.78 |

The values in parentheses are angular transformed values

**Table 4.15 Effect of plant based silica products treatment on proteins of chickpea seeds during storage**

| S.No | Treatments | Dosage kg$^{-1}$ seed | Proteins (per cent) |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 24.94 (29.95) |
| 2. | Amorphous silica gel | 500 ppm | 24.23 (29.48) |
| 3. | Amorphous silica precipitate | 250 ppm | 25.28 (30.17) |
| 4. | Amorphous silica precipitate | 500 ppm | 25.06 (30.03) |
| 5. | Paddy husk | 1000 ppm | 27.26 (31.46) |
| 6. | Paddy husk | 2000 ppm | 26.71 (31.11) |
| 7. | Paddy leaves | 1000 ppm | 28.10 (31.10) |
| 8. | Paddy leaves | 2000 ppm | 27.98 (31.92) |
| 9. | Diatomaceous earth | 300 ppm | 25.14 (30.08) |
| 10. | Diatomaceous earth | 600 ppm | 24.72 (29.80) |
| 11. | Untreated control | - | 28.77 (32.43) |
| | **SEm±** | | 0.18 |
| | **CD (P=0.05)** | | 0.53 |
| | **CV(%)** | | 1.01 |
| | **Initial** | | 21.98 |

The values in parentheses are angular transformed values

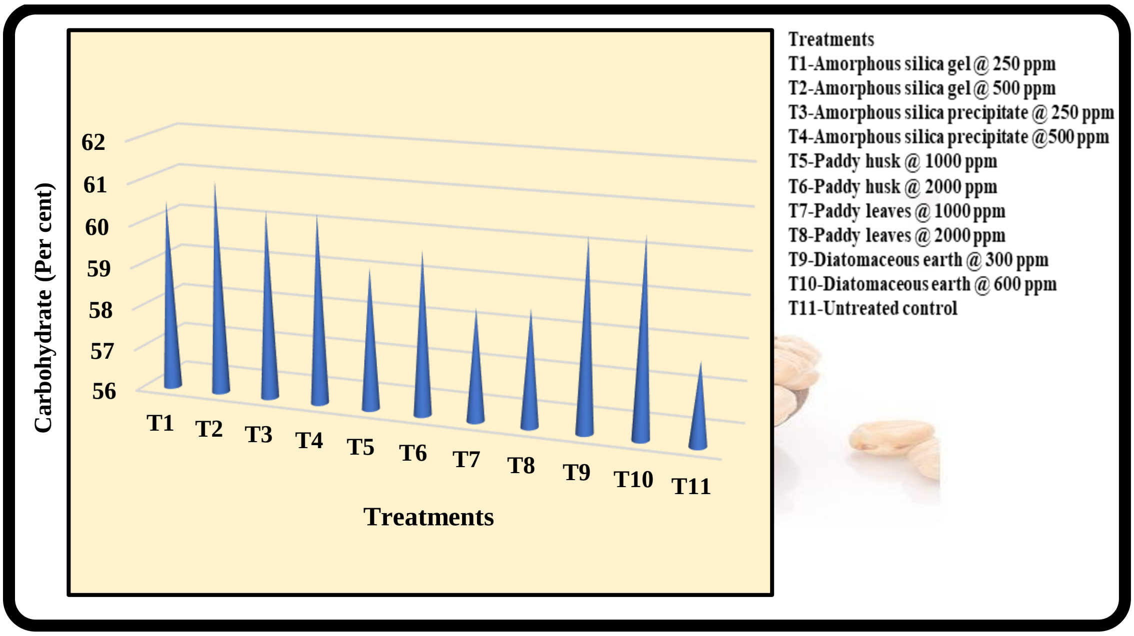



**Fig 4.16 Effect of plant based silica products treatment on carbohydrates of chickpea seeds during storage**

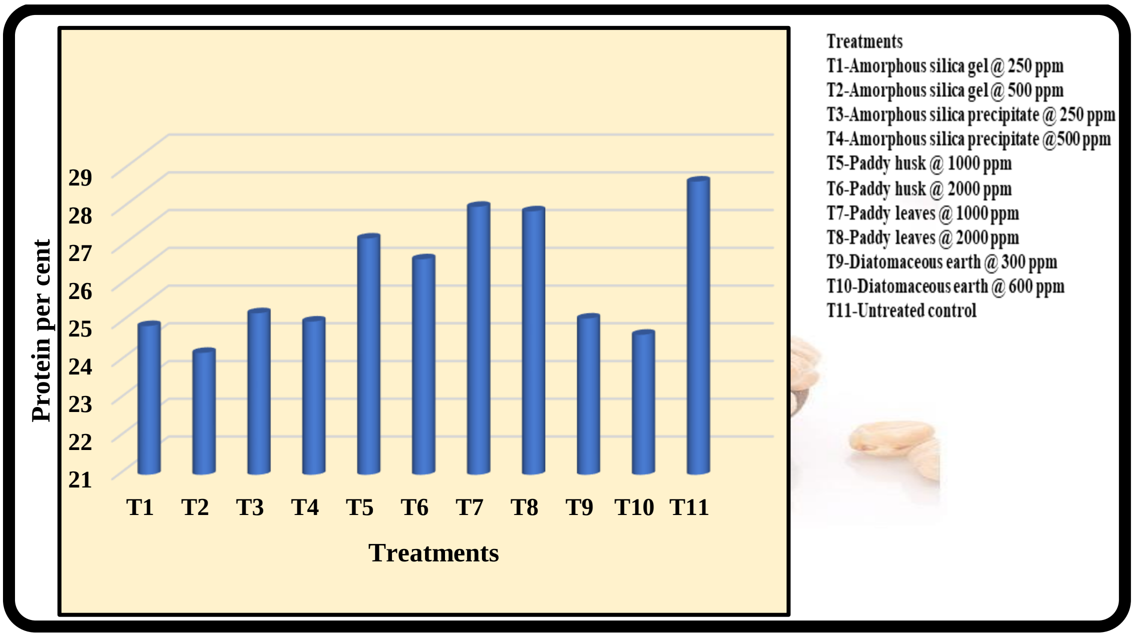



**Fig 4.17 Effect of plant based silica products treatment on proteins of chickpea seeds during storage**

### 4.3.3 Crude fat

The results pertaining to the effect of plant based silica products on fat content of stored chickpea seeds are presented in Table 4.16 and Figure 4.18.

Though, the initial crude fat content recorded was 2.77 per cent, with increase in the storage period, the crude fat content was found to decrease in all the treatments. Six months after treatment imposition, significant differences among the treatments was found but crude fat per cent was found to be highest in amorphous silica gel @ 500 ppm $kg^{-1}$ seed (4.09) which was found to be on par with treatments *viz*., diatomaceous earth @ 600 ppm $kg^{-1}$ seed (4.05), amorphous silica gel @ 250 ppm $kg^{-1}$ seed (3.95) and amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed (3.94). The treatments *viz*., diatomaceous earth @ 300 ppm $kg^{-1}$ seed (3.86) and amorphous silica precipitate @ 250 ppm $kg^{-1}$ seed (3.74) remained on par with each other.

The treatments *viz*., paddy husk 2000 ppm $kg^{-1}$ seed (3.17) and paddy husk @ 1000 ppm $kg^{-1}$ seed (3.10) remained on par with each other. Similarly, paddy leaves @ 2000 ppm $kg^{-1}$ seed (2.96) and paddy leaves @ 1000 ppm $kg^{-1}$ seed (2.89) also remained on par with each other. The lowest crude fat per cent was observed in untreated control (2.77). Insect infestation causes increase in the breakdown of fats into fatty acids which affects the total fat content as reported by Bamaiyi *et al*. (2006).

Present investigations revealed that fat content declined significantly with increased infestation levels of the insect and storage period which is in conformity with Samuels and Modgil (2003). Similarly, Stefanello *et al*. (2015) also showed that fat per cent decreased from 5.8 to 5.0 per cent after storing for a period of nine months.

**Table 4.16 Effect of plant based silica products treatment on crude fat of chickpea seeds during storage**

| S.No | Treatments | Dosage $kg^{-1}$ seed | Crude fat (per cent) |
|---|---|---|---|
| 1. | Amorphous silica gel | 250 ppm | 3.95 (11.45) |
| 2. | Amorphous silica gel | 500 ppm | 4.09 (11.67) |
| 3. | Amorphous silica precipitate | 250 ppm | 3.74 (11.15) |
| 4. | Amorphous silica precipitate | 500 ppm | 3.94 (11.44) |
| 5. | Paddy husk | 1000 ppm | 3.10 (10.13) |
| 6. | Paddy husk | 2000 ppm | 3.17 (10.25) |
| 7. | Paddy leaves | 1000 ppm | 2.89 (9.78) |
| 8. | Paddy leaves | 2000 ppm | 2.96 (9.89) |
| 9. | Diatomaceous earth | 300 ppm | 3.86 (11.32) |
| 10. | Diatomaceous earth | 600 ppm | 4.05 (11.61) |
| 11. | Untreated control | - | 2.77 (9.58) |
| | **SEm±** | | 0.05 |
| | **CD (P=0.05)** | | 0.15 |
| | **CV(%)** | | 0.82 |
| | **Initial** | | 4.26 |

The values in parentheses are angular transformed values

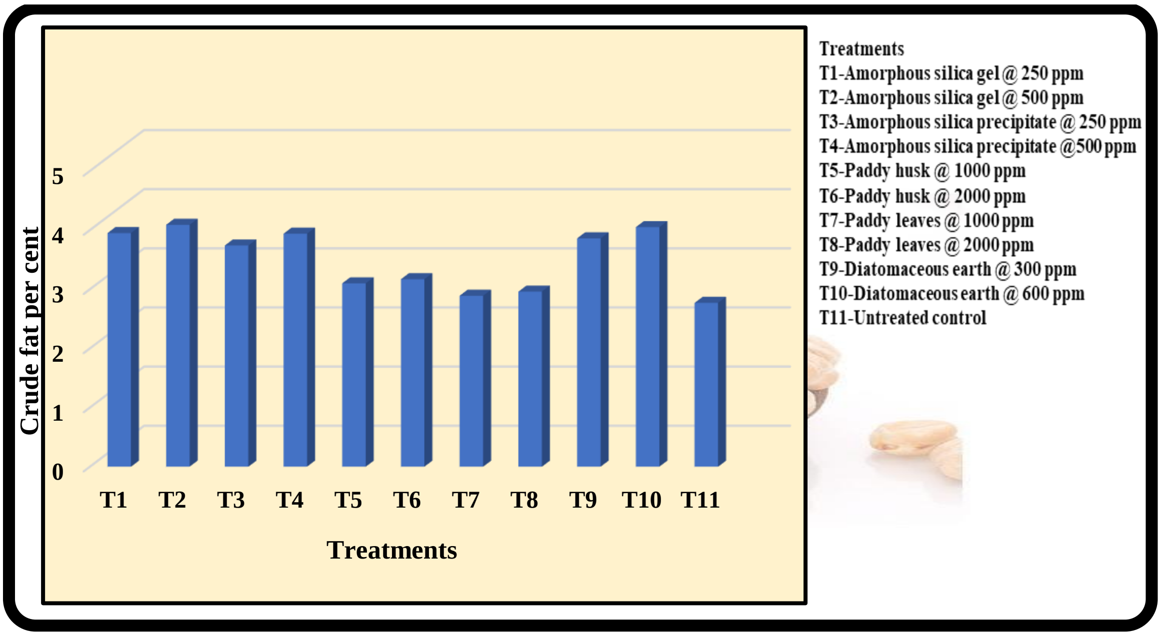



**Fig 4.18 Effect of plant based silica products treatment on crude fat of chickpea seeds during storage**

# Chapter V

# SUMMARY AND CONCLUSION

The present investigation on "Studies on biology of bruchid beetle, *Callosobruchus chinensis* (Linnaeus) in chickpea and its management through plant based silica products" was carried out under laboratory conditions in the Entomology laboratory, Seed Research and Technology Centre and Central Instrumentation Cell, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, Telangana during 2020-21. The results pertaining to the above studies are summarized in this chapter.

Studies on effect of plant based silica products *viz*., amorphous silica gel @ 250 and 500 ppm, amorphous silica precipitate @ 250 and 500 ppm $kg^{-1}$ seed, paddy husk @ 1000 and 2000 ppm $kg^{-1}$ seed, paddy leaves @ 1000 and 2000 ppm $kg^{-1}$ seed and diatomaceous earth @ 300 and 600 ppm $kg^{-1}$ seed on biology of bruchid beetle, *Callosobruchus chinensis* resulted significant effect on fecundity, hatchability, adult emergence, adult longevity and weight loss and have shown non significant effect on incubation period and larval pupal period. The results obtained from this study confirmed that, among the plant based silica products tested, amorphous silica gel @ 500 ppm $kg^{-1}$ seed was considered as the best treatment for control of pulse beetle which resulted in lowest fecundity (1.22 eggs), minimum number of seeds having eggs (3.33 seeds), lowest hatchability per cent (55.57 per cent), minimum adult emergence (1.33 adults), short adult span (3.33 days) and minimum seed weight loss (0.34 per cent).

Management of pulse beetle, *Callosobruchus chinensis* with plant based silica products *viz*., amorphous silica gel @ 250 and 500 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 250 and 500 ppm $kg^{-1}$ seed, paddy husk @ 1000 and 2000 ppm $kg^{-1}$ seed, paddy leaves @ 1000 and 2000 ppm $kg^{-1}$ seed and diatomaceous earth @ 300 and 600 ppm $kg^{-1}$ seed on chickpea seeds kept in laboratory under ambient conditions indicated that seeds treated with amorphous silica gel @ 500 ppm $kg^{-1}$ seed completely reduced seed damage, adult emergence and weight loss which showed its superior performance over other treatments in protecting the seed up to six months of storage. Amorphous silica gel @ 250 ppm $kg^{-1}$ seed, amorphous silica precipitate @ 500 ppm $kg^{-1}$ seed and diatomaceous earth @ 600 ppm $kg^{-1}$ seed protected the seed up to four months of storage period. The results showed that exposure of adult beetles to amorphous silica gel @ 500 ppm $kg^{-1}$ seed had resulted in complete adult mortality within five days after release into treated seeds at two, four and six months of storage.

The effect of plant based silica products *viz*., amorphous silica gel @ 250 and 500 ppm, amorphous silica precipitate @ 250 and 500 ppm $kg^{-1}$ seed, paddy husk @ 1000 and 2000 ppm $kg^{-1}$ seed, paddy leaves @ 1000 and 2000 ppm $kg^{-1}$ seed and diatomaceous earth @ 300 and 600 ppm $kg^{-1}$ seed on nutritional quality parameters like carbohydrates, protein content and crude fat were also studied in chickpea seeds. These plant based silica products have shown significant negative effect on carbohydrate and crude fat while, positive effect on protein content which might be due to the increased infestation of pulse beetle and storage period. Among the plant based silica products, amorphous silica gel @ 500 ppm $kg^{-1}$ seed resulted in highest carbohydrate and crude fat content besides lowest protein content compared to other treatments indicating its effectiveness. However, all the treatments recorded high carbohydrate, crude fat content and low protein content compared to untreated control at six months of storage.

## CONCLUSIONS

Thus, based on the results obtained from the "Studies on biology of bruchid beetle, *Callosobruchus chinensis* in chickpea and its management through plant based silica products" the following conclusions are drawn

- Among the plant based silica products tested, amorphous silica gel @ 500 ppm $kg^{-1}$ seed had significant effect on fecundity, number of seeds having eggs, hatchability, adult emergence, adult longevity and seed weight loss while non significant effect on incubation period and larval pupal period which indicated its supremacy in influencing the biology of *Callosobruchus chinensis* (L.)
- Amorphous silica gel @ 500 ppm $kg^{-1}$ seed tested on chickpea seeds against *Callosobruchus chinensis* (L.) showed its supremacy in completely preventing the seed damage, adult emergence and weight loss up to six months of storage.
- At two, four and six months of storage, among the treatments, amorphous silica gel @ 500 ppm $kg^{-1}$ seed was effective as seed protectant resulted in cent per cent mortality of adult beetles within five days after release.
- All the plant based silica products have shown significant negative effect on carbohydrate and crude fat while positive effect on protein content which might be due to the increased infestation of *C. chinensis* and storage period.

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