Bio-efficacy of Diatomaceous Earth against Pulse Beetle, *Callosobruchus chinensis* (L.)

दलहन भृंग, ***Callosobruchus chinensis*** **(L.)** के प्रति डायटोमेसियस मृदा की जैव–क्षमता

GEETA KUMARI MEENA

Thesis

Master of Science in Agriculture

(Entomology)

2021

DEPARTMENT OF ENTOMOLOGY

RAJASTHAN COLLEGE OF AGRICULTURE

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE & TECHNOLOGY

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Thesis

Submitted to the

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In partial fulfilment of the Requirement for the degree of

Master of Science in Agriculture

(Entomology)

By

GEETA KUMARI MEENA

2021

RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE & TECHNOLOGY, UDAIPUR

CERTIFICATE-I

CERTIFICATE OF ORIGINALITY

The research work embodied in the thesis titled "**Bio-efficacy of Diatomaceous Earth against Pulse Beetle, *Callosobruchus chinensis* (L.)**" submitted for the award of degree of **Master of Science in Agriculture** in the subject of **Entomology** to Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan), is original and bonafide record of research work carried out by me under the supervision of **Dr. Hemant Swami**, Assistant Professor, Department of Entomology, Rajasthan College of Agriculture, Udaipur. The contents of the thesis, either partially or fully, have not been submitted or will not be submitted to any other institute or university for the award of any degree or diploma.

The work embodied in the thesis represents my ideas in my own words and where others' ideas or words have been included. I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the university and can also evoke panel action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Date: / /2021

This is to certify that the thesis entitled **"Bio-efficacy of Diatomaceous Earth against Pulse Beetle, *Callosobruchus chinensis* (L.)"** submitted for the degree of Master of Science in Agriculture in the subject of Entomology, embodies bonafide research work carried out by **Miss Geeta Kumari Meena** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on / /2021.

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This is to certify that **Miss Geeta Kumari Meena** student of Master of Science in Agriculture, **Department of Entomology** has made all the corrections/modifications in the thesis **"Bio-efficacy of Diatomaceous Earth against Pulse Beetle, *Callosobruchus chinensis* (L.)"** which were suggested by the external examiner and the advisory committee in the oral examination held on …./…./2021. The final copies of the thesis duly bound and corrected were submitted on …./…./2021 are enclosed here with for approval.

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1. INTRODUCTION

Pulses are an important constituent of daily Indian diet as a source of protein including carbohydrates, fiber, calcium, potassium, zinc, magnesium and iron in small traces. They also have inherent efficiency to fix atmospheric nitrogen, which improve soil fertility. India ranks first in pulse production in the world with an annual production of 23.15 million tons and contributes 70 per cent to total world pulse production with an average productivity of 817 kg/ha in 28.34 million ha area during 2019-20 (GOI, Data bank 2020). In India, Rajasthan stands at third position in the production of pulses with an annual production of 3.68 million tons and productivity of 622 kg/ha (Agricultural Statistics at a Glance, 2020). Among the pulse crops chickpea, *Cicer arietinum* Linnaeus is the most dominant pulse having a share of around 40 per cent in the total production followed by pigeon pea *Cajanus cajan* (L.) Millsp (20%), green gram, *Vigna radiata* (L.) Wilczek (8%) and black gram, *Vigna mungo* (L.) Hepper (10%) (NABARD Rural Pulse, 2015).

The production of pulses have increased at a much slower rate compared to cereals, oil seeds and other crops over the last two decades, due to several limiting factors contributing to low production of pulses. The pest infestation in field and storage are responsible for the huge losses to the pulses. Pulses undergo chemical changes *i.e.* into change in flavor and nutritive value of grains due to the attack of insect pests during storage. Post-harvest losses at farm level ranged between 2.20 per cent (pigeon pea) to 7.14 per cent (lentil) (DMI, 2002). In storage, as many as twenty five species of insect pests have been recorded to infest pulses in India of which the important storage pests are *Callosobruchus chinensis* Linnaeus, *Pachymerus quadrimaculatus* Fabricius, *Bruchus analis* Fabricius, *Bruchus albocallosus* Pic, *Bruchus phaseoli* Gyllenhal, *Laria affinis* Froelich and *Laria pisorum* Linnaeus (Pruthi and Singh, 1950). Among these the pulse beetle, *C. chinensis* (Bruchidae: Coleoptera) is one of the important storage pest which causes heavy quantitative and qualitative losses (Prabhakar, 1979; Pandey and Singh, 1997). It causes 55-60 per cent seed weight loss and 45.50 to 66.30 per cent protein content loss (Hosamani *et al.*, 2018).

The three species of pulse beetle *viz. Callosobruchus chinensis* Linnaeus, *Callosobruchus analis* Fabricius and *Callosobruchus maculatus* Fabricius have been reported to cause damage in different kinds of pulses in India (Raina, 1970). The pest is distributed throughout the tropics and subtropics areas of the world. As the beetles can actively fly, the infestation can start in the fields itself. The damage is unnoticed until the beetle emerges out from the infested grain through the emergence holes. Grubs of pulse beetle feeds on endospermic portion of the seed and destroys it completely leaving only seed coat. Thus stored grains become non-viable and loose its nutritive value. These types of grains become unfit for human consumption as well as for sowing. In the hilly areas, it is a notorious pest of stored pulses with annual loss of approximate 0.21 MT estimating to Rs. 315 million (Rathore and Sharma, 2002).

The type of pulses plays a very important role in determining the pattern of pest's life cycle, the damage caused and their distribution. Therefore, it has been recommended that the development and growth of *C. chinensis* lies on the nutritional value of the seeds or grains. To check the increasing population of *Callososbruchus* sp. in stored pulses it is desirable to gain the information about the different facts of life cycle, such as ovipositional behavior, developmental period and capacity of newly hatched larvae to make use of different host for their further development. The biological parameters of *C. chinensis* and its host preference help to ascertain the most preferred host. Hence the biology of pulse beetle, *C. chinensis* on different hosts was studied on chickpea, *C. arietinum*; pigeon pea, *C. cajan*; green gram, *V. radiata*; black gram, *V. mungo*; kabuli gram, *C. arietinum*; lentil, *Lens culinris* Medik and cowpea, *Vigna unguiculata* (L.) Walp.

The uses of chemical pesticides have proved to be most powerful and highly effective tool for control of this pest. Though pesticides are adaptable to wide situations, flexible in almost all agronomic and ecological condition and relatively economical, the uses of these pesticides have also been associated with many problems as they are not ecologically sound. These situations tend to envisage finding a safe and ecological sound material for pest control in storage at farm level, which could easily be achieved by using diatomaceous earth (DE), the fine powder of DE adsorbs lipids from the outer waxy layer of the exoskeleton of insect, thus causing death due to desiccation.

Keeping in view above facts to ascertain the most preferred host for pulse beetle, *C. chinensis* and to find out a sensible non-pesticide remedy for the management of pulse beetle, the present study on, **"Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.)"** was conducted during 2020-21 under laboratory condition in Department of Entomology, RCA, Udaipur with the following objectives;

1. To study the biology of pulse beetle, *Callosobruchus chinensis* (L.) on different hosts.
2. To evaluate the bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.) infesting chickpea.

2. REVIEW OF LITERATURE

All the available literature relevant to the present investigations on **"Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.)"** have been viewed and arranged in a systematic order in relation to present investigation as under in the following sub heads.

2.1 Biology of Pulse Beetle, *Callosobruchus chinensis* (L.) on different hosts

Borikar and Pawar (1996) recorded the average maximum duration of eggs, larvae and pupae of *C. chinensis* development on *mung* were 5, 17 and 6 days, respectively. Similarly, Pandey and Singh (1997) reported the incubation, combined larval and pupal period of *C. chinensis* lasted for 4 to 5 and 20 to 28 days, on black gram (*Vigna mungo*) and chickpea (*Cicer arietinum*) seeds. Minimum incubation, larval and pupal period of *C. maculatus* on green gram varying 3.46±0.05, 10.60±0.06 and 5.02±0.66 days, respectively, was recorded by Gill and Ramzan (1998). Incubation period and combined larval and pupal period of *C. chinensis* on cowpea and gram seeds was 4 to 5 and 20 days at 4.28±2°C temperature and 70-75 per cent relative humidity (Singh and Kumari, 2000). Singh and Borah (2001) noticed an average pre-oviposition, oviposition, post-oviposition periods and life span of female and male beetles of pulse beetle on *Cajanus cajan* (L.) seeds were 7.8±0.46 h, 4.8±0.25, 1.4±0.11, 6.2±0.36 and 6.8±0.25 days, respectively. The incubation, larval, pupal, and total developmental period of pulse beetle was observed to be 6.8 ± 0.13, 16.2 ± 0.16, 7.2 ± 0.18, and 30.4 ± 0.62 days, respectively.

The oviposition and sex ratio remains independent of growth and development on different hosts in comparison to other developmental parameters. The developmental period of 19.2 days was recorded on green gram and split gram, while 23 days was recorded on pea. Percentage of adult emergence, damage and weight loss were highest on green gram *i.e.* 28.6, 79.55 and 36.64 per cent, respectively and on black gram 27.6, 98.15 and 26.03 per cent respectively; whereas lowest *i.e.* 5.2, 11.54 and 5.32 per cent, respectively on pea. The pest neither developed nor inflicted any damage or loss to lentil and kidney bean (Sadozai *et al.*, 2003). Meghwal and Singh (2005) recorded mean ovipositional, incubation, larval+pupal and total developmental period for egg+adult of *C. chinensis* was 5.20, 4.69, 20.79 and 25.49 days,

respectively on *moth* bean. On the basis of the biology of pulse beetle (*C. chinensis*) on different hosts Patel *et al.* (2005) revealed that incubation, larval+pupal, total developmental period and adult longevity varied significantly in different hosts, green gram and cowpea were recorded to be the most favored hosts. The minimum incubation period of 4.10 days, was recorded for lentil. The total developmental period and longevity were higher on pea *i.e.* 23.49 and 14.83 days, respectively as compared to green gram and cowpea (17.19 and 11.75 days; 18.12 and 11.37 days, respectively). The period of the lifecycle was higher on pea (43.85 days) and shorter on green gram and cowpea *i.e.* 33.51 and 34.02 days, respectively. Qazi (2007) also conducted host preference studies for oviposition on green gram, black gram, lentil, white gram, Bengal gram, soybean, pea and cowpea and revealed that soybean (199 eggs) was most preferred for oviposition followed by pea (109), green gram (97.2), bengal gram (98.2), black gram (83.5), cowpea (71.7) and white gram (66.3). No eggs were recorded on lentil and in control. Bhargava *et al*. (2008) noticed the mean incubation period, larval - pupal period and total development period of *C. chinensis* ranged from 4.40 to 7.20, 14.80 to 26.20, 5.40 to 11.40 and 24.60 to 44.80 days, respectively on different pulses. The fecundity, emergence of adults and their longevity of *C. chinensis* was highest on cowpea and the lowest on soybean; larval, pupal and developmental periods were shortest on cowpea and longest on soybean. The male and female longevity of *C. chinensis* varied from 6.20 to 8.80 days and 5.60 to 8.40 days, respectively, minimum in soybean and maximum on cowpea for both male and female. An average developmental period for *C. chinensis* on different chickpea cultivars ranged from 26.33 to 27 days (Gatoria and Gill, 2008). Badoor *et al*. (2009) reported that cowpea seeds were the most favored by *C. chinensis* and *C. maculatus* for feeding, followed by faba bean seeds, while bruchid infestation was not observed on soybean and common bean seeds. Outcomes of the research revealed that *C. maculatus* deposited more eggs on all tested leguminous seeds and gave more emerged adults with heavier weights than *C. chinensis.*

Verma and Anandhi (2010) observed that mean incubation, larval+pupal and adult longevity duration of male and female of *C. chinensis* were 4.0, 16.4, 11.0 and 9.6 days, respectively and total developmental duration from egg to adult was 25.2 days and pre-oviposition, oviposition and post-oviposition duration was 0.4, 8.0 and 2.2 days, respectively. Average oviposition by female was 85.6 eggs with 94 per cent

viability. Pokharkar and Mehta (2011) recorded that the mean adult longevity of the male of *C. chinensis* on chickpea was 7.07±0.84 and ranged from 5 to 9 days. The mean adult longevity of the male of *C. chinensis* on chickpea was 8.8±1.14 and ranged from 6 to 12 days. Such difference in adult longevity may be due to differences in temperature and relative humidity. The average oviposition of *C. chinensis* on chickpea was 80-89. The sex ratios (Male: Female) of *C. chinensis* were higher on chickpea (1: 0.92). Ramazeame *et al*. (2012) recorded the maximum larval period of 21.66 days on bengal gram whereas minimum on black gram of 20.00 days for *C. chinensis*.

Thakur and Pathania (2013) studied the biology of pulse beetle on the stored black gram and revealed the total growth period of bruchid was 31 days for the duration of July-August and 38.3 days for the duration of April-May. On an average, incubation, larval, pupal and total growth period *i.e.* egg to adult was of 8.0, 18.39, 8.11 and 34.5 days, respectively. Chakraborty and Mondal (2015) observed the male pulse beetle duration 4.76±0.64 days whereas for female 8.36±0.12. Bharathi *et al.* (2016) evaluated the population development and grain damage by *C. chinensis* on green gram, black gram, red gram, bengal gram, cowpea, soybean, pea and pillipesara. Among all the legumes, maximum oviposition was recorded on black gram (7.75 eggs/ 5g grain). Survival was highest in bengal gram (86.43) and mean development period was shortest on green gram (28.47 days) which were on par with that on pillipesara (28.77 days) whereas index of susceptibility was highest on green gram (6.09) and was followed by pillipesara (6.03). Among the entire legumes, bengal gram recorded significantly maximum percentage of grain damage (90.65%) and weight loss of grains (58.55%). Sharma *et al.* (2018) recorded the average fecundity of *C. chinensis* as 74.8±1.8 eggs/female. The average incubation duration was 4.2±0.2 days with 98.2±0.3 per cent hatching. Average larval+pupal, oviposition, post-oviposition, total life and adult duration were 21.3±0.3, 8.2±0.5, 2.8±0.5, 33.3 ±2.4 and 12.0±2.1 days, respectively. Singh (2017) recorded the average hatching duration, larval-pupal duration and adult longevity of male and female of *C. chinensis* to the extent of 4.17, 27.7, 7.07 and 8.8 days respectively. The average of the total developmental period (egg to adult) was 34.62 days.

Hosamani *et al.* (2018) reported that the mean incubation, larval-pupal period and total life cycle of *C. chinensis* were 4.0, 12.0+7.0 and 29.0, respectively. Jaiswal *et al.* (2018) observed the incubation period, larval period and pupal period of 4.15±0.85, 22.30±3.05 and 8.65±0.86 days, respectively. The adult longevity for male was 9.30±1.08 days whereas for female was 10.15±0.98 days. The total developmental period was 32.85±3.42 days. The pre oviposition, oviposition and post oviposition periods were 6.55±0.93 hours, 8.10±1.24 days and 1.85±0.47 days, respectively. The average eggs laid by female were 84.15. Similarly, Augustine and Balikai (2019) observed that total development period of 26 to 40 days with a mean of 30.90±4.28 days for *C. chinensis.* Jaiswal *et al.* (2019) conucted a research trial to find out the host preference of pulse beetle on chickpea, green gram, cowpea, red gram and black gram and reported the fecundity of 87.07, 98.67, 93.33, 100.33 and 79 eggs on 50 grains. The incubation period was 4.15, 4.10, 4, 4, 3.83 days. Larval+pupal period was 26.70, 25.60, 25.20, 26.45 and 24.90 days. Developmental period was 31, 29.05, 29, 30.60 and 29.45 days. Duration of total life cycle was 39.50, 35.90, 36.83, 37.75 and 35.25 days. Dalal *et al.* (2020) studied life cycle of *C. chinensis* on *V. mungo* and recorded the mean hatching period, mean larval+pupal period, mean pre-oviposition, oviposition and post oviposition period of 4.10, 26.56, 5.83, 4.78 and 1.76 days, respectively. The mean male and female duration was 8.43 and 12.35 days, respectively. Total life cycle of male and female beetles was completed in 39.03 and 42.97 days, respectively. The mean fecundity of female was 89.30 eggs and ranged from 81 to 96 eggs. Similarly, Kumari *et al.* (2020) recorded 78.9$\pm$4.83 eggs per female with incubation period of 4.33$\pm$0.97 days on *mung* bean, the larval and pupal duration varied from 20 to 23 days with an average of 21.73$\pm$0.96 days. The average oviposition and post oviposition period was 7.93$\pm$1.27 and 2.2$\pm$0.67 days, respectively. The longevity of adult female and male beetle observed with an average 8.8$\pm$1.56 and 11.33$\pm$1.98 days, respectively. The total life cycle of *C. chinensis* was 32.73$\pm$2.96 days and the sex ratio of female and male beetle was 0.83:1.21. Sekender *et al*. (2020) studied about the vulnerability of stored pulses *i. e.* gram, pea and *mung* infested by *C. chinensis*. The higher incubation, larval, pupal duration of pulse beetle was recorded in gram *i.e.* 5.4$\pm$0.29, 12.6$\pm$0.25, 5.5$\pm$0.32 days, respectively and the shortest was recorded in mungbean 4.6$\pm$0.25, 11.3$\pm$0.28, 4.2$\pm$0.19 days, respectively.

2.2 Bio-efficacy of Diatomaceous Earth against Pulse Beetle, *Callosobruchus chinensis* (L.) infesting Chickpea

Diatomaceous Earth (DE) is a non-toxic chemical-free and pest resistance free insecticide which can be used for stored grain protection. The fine powder of DE adsorbs lipids from exoskeleton of insects, thus causing death due to desiccation. The insecticidal efficacy of DE varies among its products and can be affected by physical properties of the DE, the temperature and relative humidity (Golob, 1997 and Kournic, 1998). DE is inert dust derived from the fossil remains of diatom skeletons. Diatoms are a type of white to dark greys that grown in fresh water lakes and marine estuaries. DE is also known as diatomite or kieselgur / kieselguhr composed of fractured silica particles has proved to be so far most effective dust against stored insect-pests. DE consist 80-93 per cent silicon oxide, minerals, organic matter, quartz, calcium and magnesium carbonate (Korunic, 1998).

Cook and Armitage (2000) reported that 25 kg of wheat at 16 and 17 per cent moisture content were treated with 'Dryacide', a DE, at 3 and 5 g per kg and stored in metal bins. The bins were then infested with mixed populations of mites (*Acarus siro* and *Lepidoglyphus destructor*) and insects (*Sitophilus granarius* and *Oryzae philussurinamensis*), at approximately 100 and 10 per kg respectively. At 17 per cent moisture content, mites took 5 weeks for kill and F_1 adults of *S. granarius* emerging within 22 weeks were controlled after a further 5 weeks. After 23 weeks the bins were re-infested with mites and these were completely suppressed after a further 3 weeks. There was no decline in efficacy throughout experiment. Arthur (2002) reported that when red winter wheat was treated with 300 ppm of Protect-It formulation of DE and 10, 20 or 30; 1-2 weeks old mixed sex adult weevil were exposed on 35 g of wheat for one week at combination of 22^{o}C, 27^{o}C, or 32^{o}C, 40, 57 and 75 per cent relative humidity. No weevils are survived when exposed at 40 or 57 per cent relative humidity at 75 per cent survival was related to both population density and temperature. No F_1s were produced at any relative humidity on wheat held at 22^{o}C. At 27^{o}C, 32^{o}C, the maximum numbers of F_1s were produced on wheat held at 75 per cent relative humidity. Prasantha *et al.* (2003) reported that bruchids were exposed to DE Fossil shield on treated *mung* beans and common beans at the rate of 1020 mg per kg and 1080 mg per kg, respectively. DE's treated bruchids were kept at 20^{o}C, 25^{o}C, 30^{o}C, 35^{o}C temperature and 43, 52, 64, 75 and 84 per cent relative humidity,

respectively. Mortality of bruchids generally increased as temperature increased but reverse was true with relative humidity. Athanassiou *et al.* (2003) evaluated the insecticidal effect of DE formulations against *S. oryzae* and *T. confusum* on stored wheat by releasing adults of these two species on wheat treated with DE at four different doses *i.e.* 0.25, 0.5, 1 and 1.5 g per kg of wheat, respectively. For each dose the treated wheat was kept at 22^{o}C, 25^{o}C, 27^{o}C, 30^{o}C and 32^{o}C. Dead adults were collected after 24 and 48 hours, 7 and 14 days after exposure. After the 14 days interval, the live adults were removed and placed for 7 days in untreated wheat, in case of *S. oryzae* or untreated flour, in the case of *T. confusum*, and the progeny of F_1 was recorded. For both the species, dose, temperature and exposure interval significantly affected mortality ($P<0.001$). Mortality was higher at longer exposure intervals. The efficacy of SilicoSec against *S. oryzae* increased with temperature, but for *T. confusum* mortality was lower at 32^{o}C, for 24 and 48 hour exposure intervals. *T. confusum* proved less susceptible to SilicoSec than *S. oryzae*. In general, the rates of 1 and 1.5 g per kg of wheat provided a satisfactory level of protection against the two species examined. For *S. oryzae*, F_1 emerged only at 22^{o}C, in wheat treated with 0.25 or 0.5 g per kg. However, for *T. confusum*, F_1 were recorded at 22^{o}C for 0.5 g per kg and at 22^{o}C, 25^{o}C, 27^{o}C and 30^{o}C for 0.25 g per kg.

The higher concentration of DEs can be the more effective, because dust applied to cover containers and grain surface will have greater chances of picking up by the insects and cause enough damage (Masiiwa, 2004). Arnaud *et al*. (2005) the efficacy of DE to control pest of stored products was examined against several populations of the red flour beetle, *T. castaneum*. Four commercially accessible DE formulations were evaluated *viz*., INSECTO, Perma-Guard, Diatomite and Protect-It, each at six concentrations (100-1000 ppm). Variation of efficacy was observed among the DE formulations tested. Protect-It at the concentrations up-to 400 ppm was found to be the most effective to control red flour beetle population. However, concentration of 1000 ppm of Protect-It controlled all the population of adults. More than 90% adults controlled with INSECTO.

Badii *et al*. (2014) conducted an experiment to evaluate the efficacy of the DEs, Fossil shield, Probe-A, Diatomenerde, and Damol-D1 against *C. maculatus* in seeds of *M. geocarpum.* Each DE was applied at 0.50, 1.00, 1.50, and 2.00 g per kg, and each treatment infested with newly emerged *C. maculatus.* The set up was

maintained at 50 and 80 per cent RH regimes at ambient temperature. Data were collected on adult mortality (at 24 h, 48 h, 7 days, and 14 days), oviposition, and progeny emergence of the beetles, and their effects on weight loss and viability of seeds. Probe-A prove to be the most effective against the beetle, followed by Damol-D1 and Fossil shield. Mortality of adults increased progressively with the increasing dose of DE and exposure time. Seeds treated at 2.00 or 1.50 g per kg recorded significantly lower number of eggs and F_1 emergence compared with the lower dosages in all DEs. Increased DE concentration consistently decreased seed weight loss due to low beetle infestation. Shah and Khan (2014) concluded that DE is the most efficient among all inert dusts for the management of stored-product pests. However, inclusion of different classes of low toxicity insecticides with DE formulations enables control at lower doses, although results vary with target species. Thus, the best combinations need to be worked out for each situation and only then enhanced DE formulations will find a place in the market in competition with currently used synthetic insecticides.

Besheli *et al*. (2017) investigated the repellency effect of Sayan formulation of DE on adult *S. oryzae*, *Oryzae philussurinamensi*, and *T. castaneum* through bioassay and recorded the LC_{50} values were 2.5, 1.9 and 12 g per kg food for *S. oryzae, O. surinamensi* and *T. castaneum*, respectively, at 96 h post-treatments. Consequently, *O. surinamensi* and *T. castaneum* had the highest and the least sensitivity to this compound, respectively. The maximum mean of the repellency effect of Diatomaceous Earth on *S. oryzae* L was 48.95%. Overall, the results of this research have shown that Diatomaceous Earth can be used against stored products pests and it presents an alternative way for the chemical control of these pests. Alkan *et al*. (2019) reported that local DE Turco 000 caused 100% mortality of *Acanthoscelides obtectus* (Say.) adults on chickpea at 1000 ppm 4 DAT and can be used as a valuable tool in stored product pest management. Besides, complete mortality of *T. confusum* and *S. oryzae* can be achieved at lower concentrations ranging from 500 to 900 ppm of local DE formulation (ACN-1) and this DE has potential to be used for control of stored-grain insects reported by Şen *et al*. (2019).

Delgarm *et al.* (2020) evaluated the insecticidal activity of three DE products, SilicoSec, Protect- It and Mamaghan. The silica aerogel was mixed to enhance the efficacy of Mamaghan DE with 10, 15, and 20 per cent rates. The DE products were

applied at treatment rates of 100, 200, and 400 ppm against adults of *T. confusum* and *R. dominica*. In the second experiment, 0.1 and 0.5 per cent deltamethrin was added to Mamaghan DE-10 per cent silica aerogel to enhance the activity of the DE. Adult mortality was recorded 2, 5, 7, 10 and 14 d after exposure. Parental adults were removed after 14 d exposure time and progeny developed was evaluated after 65 d. Mamaghan-15 and 20 per cent silica aerogel caused the highest mortality (>97%) against *T. confusum* after 10 d of exposure at the highest dose of 400 ppm which exceeded to 100% mortality after 14 d. However, the toxicity of Mamaghan DE against *R. dominica* was lower than that of the two commercial formulations at all dose rates. The presence of 0.1 per cent deltamethrin increased the insecticidal activity of Mamaghan DE and significantly suppressed progeny production of both species. Even at the lowest dose of Mamaghan-10% + 0.1% deltamethrin, progeny production of both species was very low (four or less individual per vial). However, no progeny was recorded in Mamaghan-10% + 0.5% deltamethrin. Thus, adding low rates of silica aerogel and deltamethrin considerably enhanced the efficacy of Mamaghan DE in controlling *T. confusum* and *R. dominica*. Commercially available DE (SilicoSec) formulation against *S. granarius, R. dominica* and *T. confusum*on wheat at four dose rates (500–2000 mg per kg) during a 360-day period of storage was assessed by Mortazavi *et al*. (2020) and recorded the mortality of *S. granarius* was 76.0, 88.4, 93.2 and 95.6% at 7, 14, 21, and 28 days, respectively at 0 month at a dosage of 2000 mg per kg, whereas the corresponding values were 31.5%, 71.3, 87.2 and 96.8 at 12 months with the same dosage. Mortality of *R. dominica* were 48.0, 79.6, 86.4 and 90.0 per cent at 7, 14, 21, and 28 days, respectively at 0 month at a dosage of 2000 mg per kg, whereas the corresponding values were 82.7, 95.2, 98.0 and 98.8% at 12 months with the same dosage. Mortality of *T. confusum* was 82.1, 96.8, 98.8 and 100.0% at 7, 14, 21, and 28 days, respectively at 0 month at a dosage of 2000 mg per kg, whereas the corresponding values were 32.8, 99.6, 100.0 and 100.0 per cent at 12 months with the same dosage. The increase in mortalities obtained from 1500 to 2000 mg per kg for each of the three species was mostly insignificant at 28 d exposure. Therefore, wheat treated with SilicoSec at a dosage of 1500 mg/kg could be satisfactorily protected against *S. granarius, T. confusum* and *R. dominica* for a year. Whereas, Kilic and Mutlu (2020) found the highest biological activity with local DE Aydın on Khapra larvae followed by Ankara DE, while SilicoSec had the lowest activity at 30°C. Oztekin and Mutlu (2020) reported that the

highest mortality rate (100%) on the cowpea beetle was recorded for Ankara DE on 5 DAT at 25°C with 600 ppm followed by Aydın and SilicoSec DE (84.97% and 63.47%). The biological activity of local DE increased with increasing application dose, exposure time and temperature. The highest mortality at 30°C was determined for SilicoSec (100%) with 600 ppm on 2. DAT followed by Ankara and Aydın (94.95 and 94.59% respectively). After 3 DAT, 600 ppm dose showed the highest efficacy all three DEs.

3. MATERIALS AND METHODS

The experiments on **"Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.)"** were conducted under laboratory conditions at the Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur during 2020-21. The materials used and methodologies adopted to carry out the present investigations have been detailed as below:

General details of experiment

Maintenance of Insect Culture

The nucleus culture of pulse beetle, *C. chinensis* was obtained from Department of Post-Harvest Technology, CTAE, Udaipur for mass multiplication. The sound and healthy black gram grains were sieved and sterilized at 60±5^{o}C for eight hours to eliminate both apparent and hidden infestation, if any present. These grains were conditioned at least for a week in an environmental chamber maintaining 33±2^{o}C and 60±5 per cent relative humidity to raise their moisture content. The beetles from nucleus culture were transferred on these grains in to the plastic jars of one liter capacity and the mouths of jars were covered tighten with muslin cloth. These jars were kept at a temperature of 33±2°C and 60±5 per cent relative humidity. The adults from the progressive generations so emerged from the culture were used for further experimentation.

3.1 Biology of pulse beetle, *C. chinensis* on different hosts

The experiment to study the biology of pulse beetle was conducted in Completely Randomized Design with three replications in UG laboratory at Department of Entomology, RCA, Udaipur during 2020-21 utilizing grains of different pulse as host *viz.* green gram, black gram, chick pea, cow pea, pigeon pea, lentil and kabuli gram. The observations were recorded on different biological parameters of stored grain insect pest *C. chinensis*.

To study the fecundity of adult female, two pairs of freshly emerged male and female adults (0-24 hrs. old) were isolated from stock culture and released in jars, containing 100 grains of relevant host separately and each host grains containing jars were replicated three times. The mouth of the jars was covered with a muslin cloth with the help of rubber band for aeration and to prevent escape of the adult. The jars

were kept at room temperature for observation. The released beetles were allowed to mate and oviposit for 24 hours, the grains containing eggs were replaced with the fresh healthy grains. The process of replacing the grains of the host was carried out till the death of adults and the total numbers of eggs laid by the female on grains were counted from these jars.

The grains containing the eggs laid by the female were transferred into another sets of jars after the counting number of eggs and observed daily until the emergence of grubs. After hatching, the total duration (in days) of larval and pupal period was recorded, by splitting-open the whole grain with the help of the needle and forceps as most of the period is spent in the grains.

Observations

i. **Incubation period:** The time (in days) taken by the eggs to hatch was recorded. The hatching of eggs were determined by the change in colour of the eggs. The hatched eggs turned to creamish white colour due to the accumulation of frass inside the egg.

ii. **Larval and pupal period:** Larval and pupal period (in days) within the grain was recorded by gently splitting-open the whole grain with the help of the needle and forceps to observe the stage of insect under a stereo-zoom binocular.

iii. **Pre-oviposition period of female:** The duration (in days) before laying eggs by female was recorded.

iv. **Oviposition period of female:** The duration (in days) after the emergence of female beetle and before the state of egg laying was recorded.

v. **Post-oviposition period:** The duration (in days) after the cease to oviposition till the death of adults were recorded.

vi. **Adult longevity:** The longevity of male and female adults (in days) after the emergence up to their death was recorded.

vii. **Life cycle completed (days):** Single generation time period was calculated.

viii. **Fecundity:** Grains with fresh eggs were separated and total numbers of eggs were counted from each jar.

ix. Adult survival (%): A sample of 100 grains of each host was exposed to pulse beetle in jars and checked for adult emergence. The grains of different host with freshly laid eggs were separated and number of eggs were counted and kept in different jars and the observations on number of adult emergence were recorded from different hosts. The per cent survival of the test insect on each host was calculated by the formula (Howe, 1971):

$$\text{Per cent survival} = \frac{\text{No. of adults emerged}}{\text{No. of eggs laid}} \text{ x } 100$$

3.2 Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.) infesting chickpea

The experiment to study the bio-efficacy of diatomaceous earth against *C. chinensis* was conducted on chickpea grains in laboratory of Department of Entomology, RCA, MPUAT Udaipur during 2020-21. There were nine treatments *viz.* diatomaceous earth at @1, 2, 3 and 4 per cent (w/w bases) along with mustard oil and groundnut oil (v/w) @ 2%, neem seed kernel powder (w/w) @ 1% and neem leaf powder (w/w) @ 4%, replicated three times. Healthy grains of chickpea were sterilized at 60±5°C temperature for eight hours with the help of heavy duty oven to clear off any hidden infestation. These grains were conditioned at least for a week in an environmental chamber maintaining 33±2°C and 60±5 per cent relative humidity to raise moisture content from this 500 gram chickpea grains were taken and the pre-treatment observations like moisture percent in grains and weight of 100 sound grains were recorded before treatment. The moisture content of each sample was determined with the help of digital moisture meter as per the procedure given in the manual of the equipment and the weight of grains was recorded with the automatic electrical weighing machine. After the pre-treatment observations the 500 gram grains of chickpea for each treatment were treated with diatomaceous earth @ 1, 2, 3 and 4 per cent (w/w) , mustard and groundnut oil (2%, v/w), neem seed kernel powder (1%, w/w) and neem leaf powder (4%, w/w). These treated 500 gram grains for each treatment were kept in one liter capacity of plastic jars and were replicate three times under Completely Randomized Design (CRD) and ten pairs of freshly emerged adults from stock culture were released into the treated host grains for each treatment and were kept in laboratory for the 120 days. The mouth of jars was covered with muslin cloth and tightened with rubber band.

Table 3.1: Treatments details

S. No.	Treatment	Dose (%)
1.	Diatomaceous earth	4.0 (w/w)
2.	Diatomaceous earth	3.0 (w/w)
3.	Diatomaceous earth	2.0 (w/w)
4.	Diatomaceous earth	1.0 (w/w)
5.	Mustard oil	2.0 (v/w)
6.	Groundnut oil	2.0 (v/w)
7.	Neem seed kernel powder	1.0 (w/w)
8.	Neem leaf powder	4.0 (w/w)
9.	Control	-

Observations

The observations to evaluate the bio-efficacy of different treatments were recorded on per cent mortality, per cent grains damage and per cent weight loss of grains. The data so obtained from different treatments were subjected to suitable statistical analysis to find out the most effective treatment for the management of pulse beetle infestation in storage chickpea. The observations on different parameters were recorded as under.

i. Mortality counts of pulse beetle (%)

Ten pairs of pulse beetle were released in each jar to assess the efficacy of the different treatments on the mortality of pulse beetle. The number of dead beetles in each replicate jar was counted after 24, 48, 72 and 96 hours after release of insect and adult mortality per cent was calculated by using following formula:

$$\text{Mortality per cent} = \frac{\text{No. of insect died}}{\text{Total number of insect released}} \text{ x } 100$$

ii. Grains damage by pulse beetle (%)

The numbers of grain damaged by pulse beetle in each treatment replication were counted after 30, 60, 90 and 120 days after treatment. Per cent grain damage was computed as suggested by Adams and Schulten method (1978):

$$\text{Grain damage } (\%) = \frac{\text{Number of holed grains}}{\text{Total grains}} \text{ x } 100$$

iii. Weight loss in grains (%)

Weight loss in grains was calculated by using the following equation:

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

Statistical analysis

The experimental data were tabulated and statistically analyzed as per the standard procedure for analysis of variance through the method appropriate for experiment carried out in Completely Randomized Design. The comparison in the treatment mean was tested by critical difference (CD) at 5% level of significant.

Plate 3.1: General experimental setup for biology of pulse beetle on different host

Plate 3.2: General experimental setup for bio-efficacy of diatomaceous earth against pulse beetle

a) Experimental setup
b) Diatomaceous earth, oils and neem products
c) Damaged grains of chickpea
d) Digital moisture meter

4. RESULTS

The results of present investigations on **"Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.)"** carried out at Department of Entomology, RCA, Udaipur by evaluating efficacy of the various plant products, oils and diatomaceous earth against the pulse beetle (*Callosobruchus chinensis*) infesting chickpea during storage along with the laboratory experiment to study the biology of pulse beetle (*C. chinensis*) on various pulse host *viz*., green gram, black gram, pigeon pea, chickpea, cowpea, kabuli gram and lentil during 2020-21 and have been presenting under sub heads:

4.1 Biology of pulse beetle, *Callosobruchus chinensis* on different hosts

The experiment to study the effect of different pulse host *viz*., green gram, black gram, pigeon pea, chickpea, cowpea, kabuli gram and lentil on biology of pulse beetle (*C. chinensis*) in terms of incubation period, larval and pupal period, pre-oviposition period, oviposition period, post-oviposition period, total life cycle, fecundity and adult survival was carried out by releasing ten pair of pulse beetles on respective pulses by maintaining the optimum laboratory conditions. The results of experiment have been presented in Table 4.1 which shows that the most preferred host by the pulse beetle was green gram with the shortest life cycle whereas the black gram was found least preferred with longest life cycle.

4.1.1 Incubation period (Days)

The observations recorded on incubation period of pulse beetle, *C. chinensis* on different pulses ranged from 4 to 6 days with the minimum incubation period of 4.33 days on green gram, cowpea and lentil followed by 4.67 days on chickpea, pigeon pea and kabuli gram. The maximum incubation period of 5.00 days was recorded on black gram. (Table 4.1)

4.1.2 larval-pupal period (Days)

The mean larval-pupal period of pulse beetle, *C. chinensis* recorded on different pulse varied from 17 to 28 days with the minimum larval-pupal period of 18.33 days on cowpea, followed by green gram with 18.67 days, lentil with 20.33 days, pigeon pea with 21.00 days, chickpea with 21.67 days. The maximum larval-pupal period of 26.33 days was recorded on black gram and 26.00 days on kabuli

gram which were statistically at par to each other and higher from rest of the pulses. (Table 4.1)

4.1.3 Pre oviposition period (Days)

The observations recorded on pre oviposition period of pulse beetle, *C. chinensis* varied from 0.67 to 2.00 days on different pulses. The minimum pre oviposition period of 0.67 days was recorded on green gram followed by cowpea with 1.00 days, lentil with 1.33 days, pigeon pea with 1.67 days and chickpea with 1.67 days. The maximum pre ovipositional period of 2.00 days was recorded on black gram and kabuli gram. (Table 4.1)

4.1.4 Oviposition period (Days)

The oviposition period of pulse beetle, *C. chenensis* observed on different pulses ranged from 6 to 8.33 days. The minimum oviposition period of 6.00 days was recorded on kabuli gram followed by chickpea with 7.00 days, 7.33 days on green gram, black gram and lentil, 7.67 days on cowpea, while maximum oviposition period 8.33 days was recorded on pigeon pea. (Table 4.1)

4.1.5 Post oviposition period (Days)

The post oviposition period of pulse beetle, *C. chinensis* recorded on different pulses varies from 2 to 3.67 days. The minimum post oviposition period of 2.00 days was recorded on chickpea followed by kabuli gram with 2.33 days, green gram with 3.00 days and 3.33 days on lentil. The maximum post oviposition period of 3.67 days was recorded on black gram, cowpea and pigeon pea. (Table 4.1)

4.1.6 Adult longevity period (Days)

There was significant differences in female and male longevity of pulse beetle, *C. chinensis* reared on different pulses hosts. The longevity of male beetles varied from 8.00 to 9.33 days; whereas, in female beetles it ranged from 9.33 to 11.00 days. The maximum duration 9.33 days of male longevity was recorded on black gram, chickpea and cowpea followed by 9.00 days on pigeon pea, 8.67 days on green gram, 8.33 days on kabuli gram and the minimum male longevity period of 8.00 days was recorded on lentil. In case of female beetles, the maximum duration of 11.00 days was recorded on cowpea and black gram, followed by 10.67 days on chickpea and pigeon

Table 4.1: Observations on different parameters for biology of pulse beetle, *Callosobruchus chinensis* on various pulses during 2020-21

Hosts	Incubation period (day)		Larval – pupal period (day)		Pre oviposition period (day)	Oviposition period (day)	Post oviposition period (day)	Adult longevity period (day)		Total life period (day)				Fecundity (no. of eggs/ female)	Adult Survival (%)
								Male	Female	Male		Female			
	Range	Mean	Range	Mean						Range	Mean	Range	Mean		
Green gram	4-5	4.33	17-20	18.67	0.67	7.33	3.00	8.67	10.00	42-44	42.67	42-46	44.00	97.33 (9.89)*	86.77 (68.69)**
Black gram	4-6	5.00	25-28	26.33	2.00	7.33	3.67	9.33	11.00	52-54	53.67	54-57	55.33	86.33 (9.32)	72.95 (58.68)
Chickpea	4-6	4.67	20-23	21.67	1.67	7.00	2.00	9.33	10.67	45-48	46.33	46-50	47.67	89.00 (9.46)	90.37 (71.96)
Cowpea	4-5	4.33	17-20	18.33	1.00	7.67	3.67	9.33	11.00	42-47	44.33	44-47	46.00	97.67 (9.91)	84.87 (67.57)
Pigeon pea	4-5	4.67	18-23	21.00	1.67	8.33	3.67	9.00	10.67	47-50	48.33	48-51	50.00	95.67 (9.81)	83.14 (65.92)
Lentil	4-5	4.33	19-22	20.33	1.33	7.33	3.33	8.00	9.33	42-49	44.67	43-51	46.00	73.33 (8.59)	79.85 (63.64)
Kabuli gram	4-5	4.67	25-27	26.00	2.00	6.00	2.33	8.33	9.67	48-50	49.33	48-52	50.67	78.67 (8.90)	81.34 (64.42)
S.Em ±	-	0.488	-	0.968	0.398	0.471	0.418	0.418	0.630	-	1.162	-	1.397	0.111	2.170
C.D. (p =0.05)	-	1.480	-	2.935	1.208	1.430	1.267	1.267	1.911	-	3.523	-	4.238	0.335	6.583

* Figures in parentheses are square root transformed values

** Figures in parentheses are retransformed per cent values

pea, 10.00 days on green gram, 9.67 days on kabuli gram and minimum female longevity period of 9.33 days was recorded on lentil. (Table 4.1)

4.1.7 Total life period (Days)

The total life period of pulse beetle recorded on different pulses which were ranged from 42 to 54 days in male beetles and from 42 to 52 days in female beetles. The shortest life cycle of pulse beetle, *C. chinensis* was recorded on green gram (42.67 days for male and 44.00 days for female) followed by cowpea (44.33 days for male and 46.00 days for female), lentil (44.67 days for male and 46.00 days for female), chickpea (46.33 days for male and 47.67 days for female), pigeon pea (48.33 days for male and 50.00 days for female), kabuli gram (49.33 days for male and 50.67 days for female). The longest life cycle of male and female pulse beetle was recorded on black gram i.e. 53.67 and 55.33 days, respectively. (Table 4.1)

4.1.8 Fecundity of pulse beetle (no. of eggs/female)

The mean number of eggs laid by female pulse beetle recorded on different pulses varied from 73.33 to 97.67, The maximum mean number of eggs per female recorded on cowpea was 97.67 followed by 97.33 on green gram, 95.67 on pigeon pea, 89.00 on chickpea, 86.33 on black gram and 78.67 days on kabuli gram. The minimum mean number of eggs per female observed 73.33 on lentil. (Table 4.1)

4.1.9 Adult survival (%)

The mean adult survival observed on different pulses which were ranged from 72.95 to 90.37 per cent. The maximum adult survival of 90.37 per cent on chickpea followed by 86.77 per cent on green gram, 84.87 per cent on cowpea, 83.14 per cent on pigeon pea, 81.34 per cent on kabuli gram, 79.85 per cent on lentil and minimum on black gram with 72.95 per cent. (Table 4.1)

4.2 Bio-efficacy of diatomaceous earth against pulse beetle, *C. chinensis*

The bio-efficacy of different products *viz.*, diatomaceous earth (w/w) @ 4 per cent, 3 per cent, 2 per cent and 1 per cent, mustard oil and groundnut oil (v/w) @ 2 per cent, neem seed kernel powder (w/w) @ 1 per cent and neem leaf powder (w/w) @ 4 per cent against pulse beetle, *C. chinensis* on chickpea grains were evaluated under laboratory conditions. The observations on mortality pulse beetle at 24, 48, 72 and 96 hours after release; moisture per cent, grain damage per cent and weight loss

per cent at 30, 60, 90 and 120 days after treatment were observed and the results showed that use of all the products against pulse beetle were found superior over control.

4.2.1 Mortality (%) of pulse beetle

24 hours after release

It was evident from Table 4.2 and Fig. 5.1 that the diatomaceous earth and botanicals caused significantly more pulse beetle mortality as compared to control. The application of diatomaceous earth @ 4 per cent was found most effective which resulted in 23.33 per cent mortality of adult pulse beetle and it was recorded significantly at par with the diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent which resulted in 21.67 per cent and 20.00 per cent mortality of adults of pulse beetle, respectively. The application of diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent caused 13.33, 11.67, 10.00, 8.33 and 6.67 per cent adult pulse beetle mortality at 24 hours after release, respectively and were found at par with each other.

48 hours after release

The data presented in Table 4.2 and Fig. 5.1 revealed that diatomaceous earth @ 4 per cent resulted maximum mortality of 38.33 per cent and it was recorded significantly at par with diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent which resulted in 36.67 per cent and 35.00 per cent adult mortality of pulse beetle. The next effective treatments were diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent resulted in 26.67, 25.00, 23.33, 20.00 and 18.33 per cent mortality, respectively. Among all the treatments, application of neem leaf powder @ 4 per cent was found least effective treatment.

72 hours after release

The data presented in Table 4.2 and Fig. 5.1 revealed that all the treatments were resulted significant mortality of pulse beetle over control. Diatomaceous earth @ 4 per cent was found most effective in which resulted in 50.00 per cent mortality of pulse beetle was followed by diatomaceous earth @ 3 per cent (48.33%) and diatomaceous earth @ 2 per cent (46.67%) at 72 hours after release of adult beetle.

Table 4.2: Bio-efficacy of different treatments on per cent mortality of pulse beetle, *Callosobruchus chinensis* on chickpea during 2020-21

S.No.	Treatment	Mortality per cent of pulse beetle (%)			
		24HAR*	**48 HAR**	**72 HAR**	**96 HAR**
T_1	Diatomaceous earth @ 4% (w/w)	23.33 (28.86)**	38.33 (38.24)	50.00 (45.00)	73.33 (58.93)
T_2	Diatomaceous earth @ 3% (w/w)	21.67 (27.71)	36.67 (37.26)	48.33 (44.04)	68.33 (55.82)
T_3	Diatomaceous earth @ 2% (w/w)	20.00 (26.57)	35.00 (36.27)	46.67 (43.09)	65.00 (53.76)
T_4	Diatomaceous earth @ 1% (w/w)	13.33 (21.34)	26.67 (31.07)	35.00 (36.24)	55.00 (47.88)
T_5	Mustard oil @ 2% (v/w)	10.00 (18.43)	23.33 (28.86)	30.00 (33.21)	46.67 (43.09)
T_6	Groundnut oil @ 2% (v/w)	8.33 (16.60)	20.00 (26.57)	26.67 (31.07)	45.00 (42.13)
T_7	Neem seed kernel powder @ 1% (w/w)	11.67 (19.89)	25.00 (30.00)	33.33 (35.25)	48.33 (44.04)
T_8	Neem leaf powder @ 4% (w/w)	6.67 (14.76)	18.33 (25.31)	23.33 (28.86)	45.00 (42.12)
T_9	Control	0.00	1.67 (4.31)	3.33 (8.61)	5.00 (12.92)
	S.Em ±	1.229	1.651	1.815	1.330
	C.D. (p =0.05)	3.651	4.906	5.392	3.951

* HAR: Hours after release; ** Figures in parentheses are retransformed per cent values

Application of diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent were caused 35.00, 33.33, 30.00, 26.67 and 23.33 per cent adult pulse beetle mortality and found at par with each other; while neem leaf powder @ 4 per cent was found least effective treatment.

96 hours after release

From the Table 4.2 and Fig. 5.1, it was revealed that application of diatomaceous earth @ 4 per cent showed maximum adult mortality (73.33%) and it was recorded significantly at par with diatomaceous earth @ 3 per cent (68.33%) and diatomaceous earth @ 2 per cent (65.00%) at 96 hours after release and found significantly superior over the other treatments. Grain treatment with diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent caused 55.00, 48.33, 46.67, 45.00 and 45.00 per cent mortality, respectively. The minimum mortality of pulse beetle was recorded from the treatment of groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent which is 45.00%.

4.2.4 Moisture content (%)

30 days after treatment

The data presented in Table 4.3 indicated that there were no significant variations in level of per cent moisture among various treatments. The minimum moisture content of grain 8.20 per cent was recorded in diatomaceous earth @ 4 per cent followed by diatomaceous earth @ 3 per cent (8.23%), diatomaceous earth @ 2 per cent (8.27%), ground nut oil 2 per cent (8.30%), mustard oil 2 per cent (8.37%), diatomaceous earth @ 1 per cent (8.40%), neem seed kernel powder 1 per cent (8.43%), neem leaf powder 4 per cent (8.47%); whereas, maximum moisture content of grains 8.50 per cent was recorded in control.

60 days after treatment

The data tabulated in Table 4.3 exhibited that there were no significant variations in level of per cent moisture among various treatments. The minimum moisture content of grains was recorded in diatomaceous earth @ 4 per cent (8.20%) followed by diatomaceous earth @ 3 per cent, diatomaceous earth @ 2 per cent, ground nut oil 2 per cent, mustard oil 2 per cent, diatomaceous earth @ 1 per cent,

neem seed kernel powder @ 1 per cent, neem leaf powder @ 4 per cent *i.e*. 8.23, 8.30, 8.37, 8.40, 8.43, 8.47 and 8.50 per cent respectively. whereas maximum moisture content of grains 8.53 per cent was recorded in control.

90 days after treatment

The data recorded in Table 4.3 indicates that there were no significant variations in level of per cent moisture among various treatments. The minimum moisture content of grains 8.40 per cent was recorded in diatomaceous earth @ 4 per cent followed by diatomaceous earth @ 3 per cent (8.43%), diatomaceous earth @ 2 per cent (8.47%), ground nut oil 2 per cent (8.50%), mustard oil 2 per cent (8.53%), diatomaceous earth @ 1 per cent (8.57%), neem seed kernel powder @ 1 per cent (8.60%), neem leaf powder @ 4 per cent (8.63%) whereas maximum moisture content of grains was recorded in control *i.e.* 8.67%.

120 days after treatment

The data presented in Table 4.3 exhibited that there was no significant variation in level of per cent moisture among various treatments. The minimum moisture content of grains 8.47 per cent was recorded in diatomaceous earth @ 4 per cent followed by diatomaceous earth @ 3 per cent, diatomaceous earth @ 2 per cent, ground nut oil @ 2 per cent, mustard oil @ 2 per cent, diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent and neem leaf powder @ 4 per cent *i.e.* 8.50, 8.53, 8.60, 8.63, 8.67, 8.70 and 8.73 per cent whereas maximum moisture content of grains 8.77 per cent was recorded in control..

4.2.2 Grain damage (%)

30 days after treatment

The data tabulated in Table 4.4 and Fig. 5.1 indicate that all the different treatments significantly reduced per cent grain damage caused by *C. chinensis* as compared to untreated control. The minimum grain damage 2.33 per cent by *C. chinensis* was recorded in diatomaceous earth @ 4 per cent which was found significantly at par with diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent which resulted in 2.67 and 3.00 per cent grain damage. The application of diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent recorded 4.67, 5.00, 5.00, 5.67 and 6.00 per cent grain damage, respectively at 30 days after

Table 4.3: Bio-efficacy of different treatments on per cent moisture content of chickpea during 2020-21

S.No.	Treatment	Moisture content (%)			
		30 DAT*	**60 DAT**	**90 DAT**	**120 DAT**
T_1	Diatomaceous earth @ 4% (w/w)	8.20 (16.64)**	8.20 (16.64)	8.40 (16.85)	8.47 (16.92)
T_2	Diatomaceous earth @ 3% (w/w)	8.23 (16.67)	8.23 (16.67)	8.43 (16.88)	8.50 (16.95)
T_3	Diatomaceous earth @ 2% (w/w)	8.27 (16.71)	8.30 (16.74)	8.47 (16.92)	8.53 (16.98)
T_4	Diatomaceous earth @ 1% (w/w)	8.40 (16.85)	8.43 (16.88)	8.57 (17.02)	8.67 (16.12)
T_5	Mustard oil @ 2% (v/w)	8.37 (16.81)	8.40 (16.85)	8.53 (16.98)	8.63 (17.09)
T_6	Groundnut oil @ 2% (v/w)	8.30 (16.74)	8.37 (16.81)	8.50 (16.95)	8.60 (17.05)
T_7	Neem seed kernel powder @ 1% (w/w)	8.43 (16.88)	8.47 (16.92)	8.60 (17.05)	8.70 (17.15)
T_8	Neem leaf powder @ 4% (w/w)	8.47 (16.92)	8.50 (16.95)	8.63 (17.09)	8.73 (17.19)
T_9	Control	8.50 (16.95)	8.53 (16.98)	8.67 (17.12)	8.77 (17.22)
	S.Em ±	0.071	0.079	0.068	0.090
	C.D. (p =0.05)	0.211	0.234	0.203	0.268

* DAT: Days after treatment; ** Figures in parentheses are retransformed per cent values

Table 4.4: Bio-efficacy of different treatments on per cent grain damage due to pulse beetle, *C. chinensis* on chickpea during 2020-21

S.No.	Treatment	Per cent grain damage (%)			
		30 DAT*	**60 DAT**	**90 DAT**	**120 DAT**
T_1	Diatomaceous earth @ 4% (w/w)	2.33 (8.74)**	3.67 (10.76)	5.00 (12.81)	6.67 (14.78)
T_2	Diatomaceous earth @ 3% (w/w)	2.67 (9.27)	4.33 (12.00)	5.67 (13.76)	7.33 (15.68)
T_3	Diatomaceous earth @ 2% (w/w)	3.00 (9.97)	5.00 (12.92)	6.33 (14.57)	8.00 (16.41)
T_4	Diatomaceous earth @ 1% (w/w)	4.67 (12.46)	7.00 (15.32)	8.67 (17.08)	11.67 (19.95)
T_5	Mustard oil @ 2% (v/w)	5.00 (12.92)	7.67 (16.07)	9.67 (18.11)	13.33 (21.41)
T_6	Groundnut oil @ 2% (v/w)	5.67 (13.69)	8.33 (16.77)	10.33 (18.75)	13.67 (21.69)
T_7	Neem seed kernel powder @ 1% (w/w)	5.00 (12.75)	7.33 (15.70)	9.33 (17.78)	12.00 (20.26)
T_8	Neem leaf powder @ 4% (w/w)	6.00 (14.18)	8.33 (16.77)	10.67 (19.05)	14.33 (22.24)
T_9	Control	23.67 (29.10)	37.33 (37.66)	50.67 (45.38)	70.67 (57.21)
	S.Em ±	0.810	0.707	0.705	0.788
	C.D. (p =0.05)	2.408	2.099	2.095	2.343

* DAT: Days after treatment; ** Figures in parentheses are retransformed per cent values

treatment and were recorded significantly at par with each other. The treatment with neem leaf powder @ 4 per cent was least effective treatment among all the protectants having 6 per cent grain damage. However, the maximum grain damage was recorded in untreated control *i.e.* 23.67 per cent.

60 days after treatment

The data presented in Table 4.4 and Fig. 5.1 revealed that diatomaceous earth @ 4 per cent had minimum grain damage due to pulse beetle (3.67 %) which was recorded significantly at par with diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent which resulted 4.33 and 5.00 per cent grain damage. The next effective treatments were diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent with 7.00, 7.33, 7.67, 8.33 and 8.33 per cent grain infestation by pulse beetle at 60 days after treatment, respectively. The applications of groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent were found least effective having 8.33 per cent grain damage; whereas, untreated control had maximum grain damage *i.e.* 37.33 per cent.

90 days after treatment

The data in Table 4.4 and Fig. 5.1 exhibited that diatomaceous earth @ 4 per cent had minimum grain damage of 5.00 per cent followed by diatomaceous earth @ 3 per cent (5.67 %) and diatomaceous earth @ 2 per cent (6.33 %) at 90 days after treatment. The application of diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent had grain damage of 8.67, 9.33, 9.67, 10.33 and 10.67 per cent, respectively and found at par with each other. The treatment with neem leaf powder @ 4 per cent recorded 10.67 per cent grain damage and was least effective against pulse beetle; whereas, the maximum grain damage of observed in untreated control *i.e.* 50.67 per cent.

120 days after treatment

The application of Diatomaceous earth was recorded to be superior over all the other treatment in minimizing the grain damage by pulse beetle during storage. The treatments with diatomaceous earth @ 4 per cent recorded minimum grain damage of 6.67 per cent, which followed by diatomaceous earth @ 3 per cent (7.33 %) and

diatomaceous earth @ 2 per cent (8.00 %) at 120 days after treatment. The application of diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent had 11.67, 12.00, 13.33, 13.67 and 14.33 per cent grain infestation, respectively and were found next effective treatment. The neem leaf powder @ 4 per cent was found least effective in the management of pulse beetle having 14.33 per cent grain damage whereas, untreated control had maximum grain damage *i.e.* 70.67 per cent. (Table 4.4 and Fig. 5.1)

4.2.3 Weight loss (%)

30 days after treatment

The data tabulated in Table 4.5 and Fig. 5.1 showed that all the treatments significantly reduced per cent weight loss of grain caused by *C. chinensis* as compared to untreated control. The minimum weight loss 0.33 per cent was recorded in diatomaceous earth @ 4 per cent and it was recorded significantly at par with diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent resulted in 0.67 and 1.00 per cent grain weight loss. The application of diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent had 3.00, 3.33, 3.67, 4.00 and 4.33 per cent grain weight loss at 30 days after treatment, respectively and were found statically at par with each other. The treatment with neem leaf powder @ 4 per cent was least effective treatment among all the treatments having 4.33 per cent weight loss. However, the maximum weight loss was recorded in untreated control *i.e*. 8.67 per cent.

60 days after treatment

The data presented in Table 4.5 and Fig. 5.1 revealed that diatomaceous earth @ 4 per cent had minimum grain weight loss 1.00 per cent due to pulse beetle followed by diatomaceous earth @ 3 per cent (1.33 %) and diatomaceous earth @ 2 per cent (1.67 %), these three treatments were recorded significantly at par with each other. The next effective treatments were diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent with 3.33, 3.67, 4.00, 4.33 and 4.67 per cent weight loss at 60 days after treatment, respectively. The treatments of neem leaf powder @ 4

Table: 4.5. Bio-efficacy of different treatments on per cent weight loss of chickpea due to pulse beetle, *C. chinensis* during 2020-21

S.No.	Treatment	Per cent weight loss (%)			
		30 DAT*	**60 DAT**	**90 DAT**	**120 DAT**
T_1	Diatomaceous earth @ 4% (w/w)	0.33 (1.91)**	1.00 (5.74)	1.33 (6.54)	2.00 (7.95)
T_2	Diatomaceous earth @ 3% (w/w)	0.67 (3.83)	1.33 (6.54)	2.00 (8.13)	2.33 (8.74)
T_3	Diatomaceous earth @ 2% (w/w)	1.00 (5.74)	1.67 (7.33)	2.33 (8.74)	2.67 (9.27)
T_4	Diatomaceous earth @ 1% (w/w)	3.00 (9.97)	3.33 (10.50)	4.00 (11.48)	5.00 (12.88)
T_5	Mustard oil @ 2% (v/w)	3.67 (10.53)	4.00 (11.28)	4.67 (12.36)	6.00 (14.15)
T_6	Groundnut oil @ 2% (v/w)	4.00 (11.54)	4.33 (12.00)	5.00 (12.88)	6.33 (14.57)
T_7	Neem seed kernel powder @ 1% (w/w)	3.33 (10.40)	3.67 (10.96)	4.33 (11.94)	5.33 (13.34)
T_8	Neem leaf powder @ 4% (w/w)	4.33 (12.00)	4.67 (12.46)	5.33 (13.30)	6.67 (14.95)
T_9	Control	8.67 (17.12)	14.00 (21.91)	17.00 (24.34)	21.67 (27.73)
	S.Em ±	1.279	0.923	0.803	0.753
	C.D. (p =0.05)	3.800	2.742	2.386	2.236

* DAT: Days after treatment; ** Figures in parentheses are retransformed per cent values

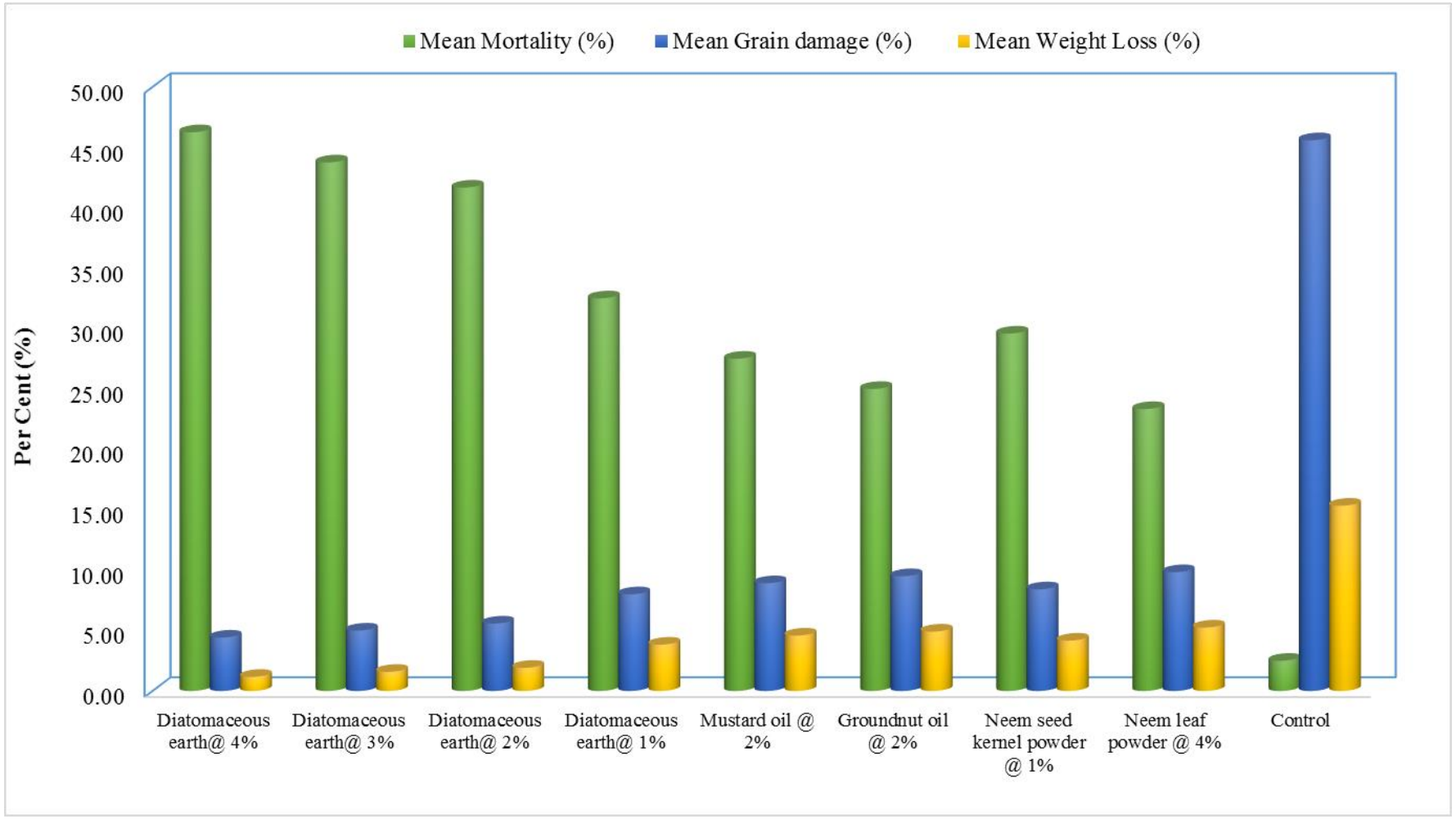

Fig.5.1: Bio-efficacy of different treatments against pulse beetle, *Callosobruchus chinensis* infesting chickpea during 2020-21

per cent were found least effective having 4.67 per cent grain weight loss; whereas, untreated control had maximum grain weight loss *i.e.* 14.00 per cent.

90 days after treatment

The data in Table 4.5 and Fig. 5.1 exhibited that diatomaceous earth @ 4 per cent had minimum grain weight loss of 1.33 per cent followed by diatomaceous earth @ 3 per cent (2.00 %) and diatomaceous earth @ 2 per cent (2.33 %) at 90 days after treatment. The application of diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent had of 4.00, 4.33, 4.67, 5.00 and 5.33 per cent grain weight loss, respectively and recorded statistically at par with each other. The treatments of neem leaf powder @ 4 per cent recorded 5.33 per cent grain weight loss which was least effective against pulse beetle; whereas, the maximum grain weight loss observed in untreated control *i.e.* 17.00 per cent.

120 days after treatment

The application of Diatomaceous earth was recorded to be superior over all the other treatment in minimizing the weight loss of grains during storage of chickpea. The treatments with diatomaceous earth @ 4 per cent recorded minimum weight loss of 2.00 per cent, which followed by diatomaceous earth @ 3 per cent (2.33 %) and diatomaceous earth @ 2 per cent (2.67 %) at 120 days after treatment. The next effective treatments were diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent having 5.00, 5.33, 6.00, 6.33 and 6.67 per cent grain weight loss, respectively. The neem leaf powder @ 4 per cent was found least effective in the management of pulse beetle having 6.67 per cent grain damage whereas, untreated control had maximum grain damage *i.e.* 21.67 per cent. (Table 4.5 and Fig. 5.1)

5. DISCUSSION

The results of the present investigation **"Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.)"** carried out at Department of Entomology, RCA, Udaipur 2020-21 have been discussed in the light of all available literature and are presented in following sub heads as detailed under:

5.1 Biology of pulse beetle, *Callosobruchus chinensis* (L.) on different hosts

The results of the present investigation to evaluate the host preference by the pulse beetle (*C. chinensis)* revealed that green gram, cowpea and lentil (4.33) were found most preferred host in terms of incubation period, cowpea as most preferred host in terms of larval-pupal period (18.33) and fecundity (97.67), green gram was recorded as most preferred host in terms of pre-oviposition period (0.67) and total life cycle (42.67 for male, 44.00 for female), kabuli gram (6.00) was recorded as most preferred host in terms of oviposition period and chickpea (2.00) was found preferred host in terms of post-oviposition period.

The fecundity of pulse beetle, *C. chinensis* exhibited that the order of host preference as cowpea (97.67) > green gram (97.33) > pigeon pea (95.67) > chickpea (89.00) > black gram (86.33) > kabuli gram (78.67) > lentil (73.33). The higher egg laying on cowpea might be due to its larger seed size and smooth surface in comparison to other pulses as reported by Satya vir (1980). The results of present investigation confirms the finding of Rathee (2008) who also reported the similar fecundity of pulse beetle on different hosts with maximum egg laying on cowpea and minimum on lentil. Similary, Jaiswal *et al.* (2019) also reported that the order of preference for oviposition on different pulses for *C. chinensis* was *Cajanus cajan* (red gram) > *Vigna radiata* (green gram) > *Vigna unguiculata* (cowpea) > *Cicer arietinum* (chickpea) > *Vigna mungo* (black gram) which is in alignment with the findings of present investigation.

The mean incubation period of pulse beetle on green gram, black gram, chick pea, cowpea, pigeon pea, lentil and kabuli gram were 4.33, 5.00, 4.67, 4.33, 4.67, 4.33 and 4.67 days, respectively. These results are in conformity with the finding of Raina (1970) and Dhepe *et al.* (1993) who reported incubation period 4 days and 4 to 4.6 days on green gram, respectively. Chandra and Ghosh (2006) reported an average

incubation period of 4.0 to 4.6 days of *C. maculatus* on green gram seeds and 3.87 days on bengal gram, 4.73 days on lentil, 4.32 days on black gram and 4.12 days on kabuli gram which confirms the results of present investigation. Similary, the findings of Rathee (2008) who reported that incubation period ranged between 3 to 7 days with minimum period on lentil (4.0) and maximum on black gram (4.6) is in alignment with the findings of present investigation.

The mean larval-pupal period of pulse beetle on green gram, black gram, chickpea, cowpea, pigeon pea, lentil and kabuli gram were 18.67, 26.33, 21.67, 18.33, 21.00, 20.33 and 26.00 days, respectively. Similar results for the larval-pupal period were reported by Raina (1970) and Dhepe *et al.* (1993) and the results confirmes the findings of Chandra and Ghosh (2006) who recorded the larval-pupal period of pulse beetle on different pulses and reported it to be 21.09 days on lentil, 34.02 days on black gram, 21.98 days on bengal gram and 27.92 days on kabuli gram which are in close conformity with the present findings.

The mean pre-oviposition, oviposition and post-oviposition period on green gram, black gram, chickpea, cowpea, pigeon pea, lentil and kabuli gram were 0.67, 7.33 and 3.00; 2.00, 7.33 and 3.67; 1.67, 7.00 and 2.00; 1.00, 7.67 and 3.67; 1.67, 8.33 and 3.67; 1.33, 7.33 and 3.33; 2.00, 6.00 and 2.33 days, respectively. Singh (2017) reported that pre-oviposition, oviposition and post-oviposition period of female pulse beetle on green gram as 5.8 ± 1.62 days, 4.9 ± 1.66 days and 3.6 ± 0.97 days, respectively. Similary, Jaiswal *et al.* (2018) reported that the pre-oviposition, oviposition and post-oviposition periods on chickpea were 6.55 ± 0.94 hours, 8.10 ± 1.25 days and 1.85 ± 0.48 days, respectively. These findings are in line with the present results.

The average male and female adult longevity of 8.67 and 10.00 days on green gram, 9.33 and 11.00 days on black gram, 9.33 and 10.67 days on chickpea, 9.33 and 11.00 days on cowpea, 9.00 and 10.67 days on pigeon pea, 8.00 and 9.33 days on lentil; 8.33 and 9.67 days on kabuli gram, respectively. These results confirm the finding of Patel *et al*. (2005) who reported that the adult longevity of *C. chinensis* varies between 11.37 to 14.83 days on different pulses. Similary, Singal & Borah (2001) and Singh (2017) reported that mean longevity of female was 6.2±0.36 and 8.6 days, while male beetle longevity was 6.8±0.25 days and 6.2 days, respectively which is in alignment with the findings of present investigation. Hosamani *et al.* (2018) also

reported that adult longevity of pulse beetle ranged from 7-14 days with the mean of 8 days on black gram. Augustine and Balikai (2019) reported that the females lived for a period of 8-12 days with a mean of 9.50±1.58 days whereas the males lived for 7 to 11 days with a mean of 8.30±1.25 days. Dalal *et al.* (2020) reported that the mean male and female longevity were 8.43 and 12.37 days on black gram ranged from 7-9 and 10-14 days, respectively on black gram.

The total life period of male and female pulse beetle, *C. chinensis* exhibited that the order of host preference as green gram (42.67 and 44.00 days) > cowpea (44.33 and 46.00 days) > lentil (44.67 and 46.00 days) > chickpea (46.33 and 47.67 days) > pigeon pea (48.33 and 50.00 days) > kabuli gram (49.33 and 50.67 days) > black gram (53.67 and 55.33 days). The findings of Rathee (2008) favors the present result who reported that the total development period varied from 28.0 to 42.0 days on different pulses and the mean development period from egg to adult was 33.6, 33.0, 40.6, 35.0, 37.0, 29.0, 34.3 and 40.6 days on lentil, green gram, black gram, red gram, bengal gram, kabuli gram, cowpea and pea, respectively. Singh (2017) also observed that total developmental period of pulse beetle on green gram varied from 29 to 38 days (average: 33.7 days) and Dalal *et al.* (2020) reported that total life cycle was completed in 39.03 days on black gram, which are in close confirmation with the present results.

The adult survival on different pulses ranged from 72.95 to 90.37 per cent with the maximum adult survival on chickpea (90.37 %) followed by green gram (86.77 %), cowpea (84.87 %), pigeon pea (83.14 %), kabuli gram (81.34 %), lentil (79.85 %) and minimum adult survival on black gram (72.95 %). These results are in accordance with the findings of Bhadauria and Jakhmola (2006) who observed similar pattern of mean adult survival as maximum in cowpea (91.00 %) followed by green gram (90.33 %) and red gram. Similary, Jaiswal *et al.* (2019) reported that the mean adult survival on test pulses (red gram, green gram, cowpea, chickpea and black gram) ranged from 78.00 to 90.33 per cent being maximum on chickpea and cowpea followed by red gram and minimum on black gram, which confirmed the results of present findings.

5.2 Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.) infesting chickpea

The bio-efficacy of different treatments products *viz.,* diatomaceous earth (w/w) @ 1 per cent, 2 per cent, 3 per cent and 4 per cent, mustard oil and groundnut oil (v/w) @ 2 per cent, neem seed kernel powder (w/w) @ 1 per cent and neem leaf powder (w/w) @ 4 per cent against pulse beetle, *C. chinensis* on chickpea grains were evaluated under present investigation. The results of bio-efficacy of different treatments against pulse beetle are discussed as under:

5.2.1 Mortality (%) of pulse beetle

The application of all the treatments resulted in significantly increasing the adult mortality during storage of chickpea. Chickpea grains treated with diatomaceous earth @ 4 per cent resulted in maximum mortality at 24, 48, 72 and 96 hours after release of pulse beetle, with a mean mortality per cent ranging from 23.33 to 73.33 per cent. The next effective treatment with increasing mortality was diatomaceous earth @ 3 per cent (21.67 to 68.33 %) which was followed by the treatment diatomaceous earth @ 2 per cent (20.00 to 65.00 %), diatomaceous earth @1 per cent (13.33 to 55.00 %) and neem seed kernel powder @ 1 per cent (11.67 to 48.33 per cent). The treatment of mustard oil @ 2 per cent (10.00 to 46.67 %) and groundnut oil @ 2 per cent (8.33 to 45.00 %) were next in order to increase the mortality of pulse beetle during the storage of chickpea. The treatment of neem leaf powder @ 4 per cent (6.67 to 45.00 %) resulted the minimum mortality per cent. All the treatments were found to be superior over control in increasing the mortality per cent as compare to control. (Fig. 5.1)

These findings are in line with the result of Parasantha *et al.,* (2002); Parsaeyan *et al.,* (2012); Badii *et al.,* (2013); Kabir and Wulgo (2014) who recorded that mortality of *C. maculatus* increased with increasing exposure interval and temperature. Prolonged exposure time may be needed to increase mortality in adults because more dust particles are trapped by insect bodies with increasing exposure time and in turn insects lose more water and died of desiccation (Arthur, 2001; Fields and Korunic, 2000; Rigaux *et al.,* 2001; Shams *et al.,* 2011).

Similary, Singh (2017) reported that custard apple leaf powder @ 5 gm/kg seed, neem leaf powder @ 5 gm/kg, diatomaceous earth @ 5 gm/kg seed and cow

dung ash @ 5 gm/kg seed treated green gram seeds resulted in pulse beetle mortality of 10.49, 8.64, 23.61 and 5.52 per cent at 7 days after release, which also confirms the results of the present investigation.

5.2.2 Moisture content (%)

There were no significant effect of various treatments on the moisture content per cent of chickpea after the storage period. The grains treated with diatomaceous earth @ 4 per cent resulted in minimum moisture content of grains at 30, 60, 90 and 120 days after treatment having 8.20, 8.20, 8.40 and 8.47 per cent moisture, respectively. The next effective treatments were diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent, which resulted in 8.23, 8.23, 8.43 and 8.50; 8.27, 8.30, 8.47 and 8.50 per cent moisture content in grains at 30, 60, 90 and 120 days after treatment application, respectively. Application of groundnut oil @ 2 per cent, mustard oil @ 2 per cent, diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent resulted in 8.30, 8.37, 8.50 and 8.60; 8.37, 8.40, 8.53 and 8.63; 8.40, 8.43, 8.57 and 8.67; 8.43, 8.47, 8.60 and 8.70 per cent moisture content in grains at 30, 60, 90 and 120 days after treatment application, respectively. The maximum moisture content in grains was observed in treatments of neem leaf powder @ 4 per cent, which was 8.47, 8.50, 8.63 and 8.73 per cent at 30, 60, 90 and 120 days after treatment, respectively. The data showed no significant variation in level of per cent moisture among various treatments.

The findings confirming the results of present investigation have been reported by Gularte (2005), who observed that the use of diatomaceous earth on conventionally processed or parboiled rice did not interfere in the assessed gravimetric yield parameters. Moras *et al.* (2006) also stated that the all diatomaceous earth treated grain had statically equivalent water absorption and yield.

5.2.3 Grain damage (%)

All the treatments application significantly reduces the grain damage of chickpea grains during storage. Chickpea grains treated with diatomaceous earth @ 4 per cent resulted in minimum per cent damage at 30, 60, 90 and 120 days after treatments, with mean grain damage per cent ranging from 2.33 to 6.67 per cent, it was followed by the treatments of diatomaceous earth @ 3 per cent (2.67 to 7.33 %) and the treatments diatomaceous earth @ 2 per cent (3.00 to 8.00 %), which were

statistically at par with each in terms of reducing the grain damage of chickpea during storage. The treatments of diatomaceous earth @1 per cent (4.67 to 11.67 %) neem seed kernel powder @ 1 per cent (5.00 to 13.33 %), mustard oil @ 2 per cent (5.00 to 13.33 %) and groundnut oil @ 2 per cent (5.67 to 13.67 %) proved next effective treatment in reducing the grain damage during the storage of chickpea. The treatments of neem leaf powder @ 4 per cent (6.00 to 14.33 %) proved least effective in reducing the grain damage during the storage of chickpea. All the treatments were found to be superior over control in minimizing per cent grain damage compared to control. (Fig. 5.1)

The results corroborate the findings of Singh (2017), who reported that green gram seed/grain damage in treatments comprising of diatomaceous earth @ 5 gm/kg seed, custard apple leaf powder @ 5 gm/kg seed, neem leaf powder @ 5 gm/kg seed and cow dung ash @ 5 gm/kg seed were 3.28, 20.99, 24.98 and 28.99 per cent, respectively. Similary, Oztekin and Mutlu (2020) also suggested that the local diatomaceous earth product (Ankara and Aydin) have a high potential to be used for control of *C. maculatus* adults damage for storage bean.

5.2.3 Weight loss (%)

All the treatments significantly reduce the weight loss of chickpea grains during storage. Chickpea grains treated with diatomaceous earth @ 4 per cent resulted minimum per cent weight loss at 30, 60, 90 and 120 days after treatments with a mean weight loss per cent ranging from 0.33 to 2.00 per cent and the next effective treatments were diatomaceous earth @ 3 per cent (0.67 to 2.33%) followed by diatomaceous earth @ 2 per cent (1.00 to 2.67%), which were statistically at par with each in terms of reducing the weight loss of chickpea during storage. The treatments of diatomaceous earth @1 per cent (3.00 to 5.00%), neem seed kernel powder @ 1 per cent (3.33 to 5.33%), mustard oil @ 2 per cent (3.67 to 6.00%) and groundnut oil @ 2 per cent (4.00 to 6.33%) proved to be next effective treatments. The treatment of and neem leaf powder @ 4 per cent (4.33 to 6.67%) proved least effective in reducing the weight loss during the storage of chickpea. All the treatments were found to be superior over control in minimizing per cent grain weight loss of chickpea compared to control. (Fig. 5.1)

Singh (2017) reported that weight loss of green gram seeds due to pulse beetle infestation in treatments of diatomaceous earth @ 5 gm/kg, custard apple leaf powder @ 5 gm/kg seed, neem leaf powder @ 5 gm/kg seed and cow dung ash @ 5 gm/kg seed treated seeds were 3.28, 6.27, 13.46 and 13.65 per cent, respectively. Similarly, Ramya *et al*. (2017) reported that minimum per cent weight loss was recorded in neem oil treatments at all three dosages (3, 5, 7 ml/kg seed) of 2.36, 0.41 and 0.16 followed by karanj oil (2.73, 0.91 and 0.58%), castor oil (3.33, 1.83 and 1.33%), mustard oil (4.56, 2.66 and 1.53%) and sunflower oil (4.90, 2.93 and 2.36%), which confirms the present results and supports the findings of present investigation.

The result of the experiment on host preference by the pulse beetle, *Callosobruchus chinensis* revealed that shortest life cycle of pulse beetle was observed on green gram, resulting in more number of generations as compared to other host, causing more damage during storage. Thus, among the seven different pulses green gram was observed to be most preferred host by the pulse beetle and is subjected to heavy damage. The application of various treatments *viz.* diatomaceous earth (w/w) @ 1, 2, 3 and 4 per cent, mustard oil and groundnut oil (v/w) @ 2 per cent, neem seed kernel powder (w/w) @ 1 per cent and neem leaf powder (w/w) @ 4 per cent during storage proved to be superior over control in reducing grain damage and weight loss with maximum adult mortality. The diatomaceous earth at various concentrations @ 4, 3 and 2 per cent found to be effective against pulse beetle infestation. However the use of diatomaceous earth 2 per cent should be recommended due to cost feasibility, low residual effect and low health risk.

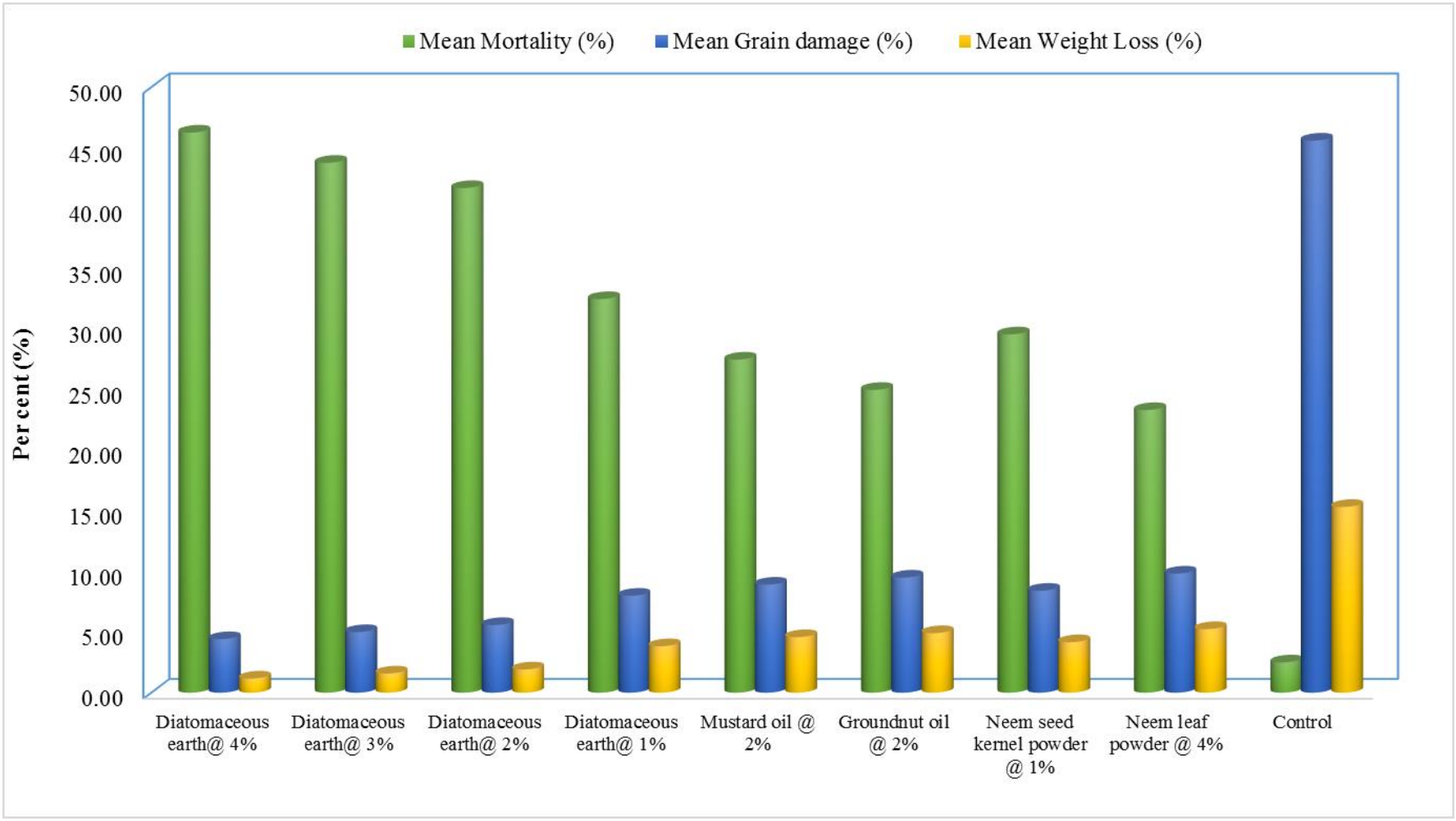

Fig.5.1: Bio-efficacy of different treatments against pulse beetle, *Callosobruchus chinensis* infesting chickpea during 2020-21

6. SUMMARY

The present investigation on **"Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.)"** was carried out under laboratory conditions at Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur during 2020-21.

The studies on the biology pulse beetle, *Callosobruchus chinensis* on different pulses host reveals that the order of host preference in terms of mean fecundity was in order cowpea (97.67) > green gram (97.33) > pigeon pea (95.67) > chickpea (89.00) > black gram (86.33) > kabuli gram (78.67) > lentil (73.33). The mean incubation period and larval-pupal period on green gram, black gram, chickpea, cowpea, pigeon pea, lentil and kabuli gram were 4.33 and 18.67; 5.00 and 26.33; 4.67 and 21.67; 4.33 and 18.33; 4.67 and 21.00; 4.33 and 20.33; 4.67 and 26.00 days, respectively. The mean pre oviposition, oviposition and post oviposition period on green gram, black gram, chickpea, cowpea, pigeon pea, lentil and kabuli gram were 0.67, 7.33 and 3.00; 2.00, 7.33 and 3.67; 1.67, 7.00 and 2.00; 1.00, 7.67 and 3.67; 1.67, 8.33 and 3.67; 1.33, 7.33 and 3.33; 2.00, 6.00 and 2.33 days, respectively.

The average adult longevity of male and female pulse beetle was 8.67 and 10.00 days on green gram, 9.33 and 11.00 days on black gram, 9.33 and 10.67 days on chickpea, 9.33 and 11.00 days on cowpea, 9.00 and 10.67 days on pigeon pea, 8.00 and 9.33 days on lentil; 8.33 and 9.67 days on kabuli gram, respectively. The average male and female life period was 42.67 and 44.00 days on green gram, 53.67 and 55.33 days on black gram, 46.33 and 47.67 days on chickpea, 44.33 and 46.00 days on cowpea, 48.33 and 50.00 days on pigeon pea, 44.67 and 46.00 days on lentil; 49.33 and 50.67 days on kabuli gram, respectively. The adult survival on different pulses ranged from 72.95 to 90.37 per cent with maximum adult survival on chickpea (90.37 %) followed by green gram (86.77 %), cowpea (84.87 %), pigeon pea (83.14 %), kabuli gram (81.34 %), lentil (79.85 %) and minimum adult survival on black gram (72.95 %).

The results of bio-efficacy of different treatments *viz.*, diatomaceous earth (w/w) @ 4, 3, 2 and 1 per cent,, mustard and ground nut oil (v/w) @ 2 per cent, neem seed kernel powder (w/w) @ 1 per cent and neem leaf powder (w/w) @ 4 per cent

against pulse beetle, *C. chinensis* infesting chickpea grains showed that the treatments with diatomaceous earth @ 4 per cent resulted in maximum mortality of pulse beetle at 24, 48, 72 and 96 hours after release of adult beetle with 23.33, 38.33, 50.00 and 73.33 per cent mortality, respectively. The next effective treatments in order of effectiveness was diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent, which caused 21.67, 36.67, 48.33 and 68.33; 20.00, 35.00, 46.67 and 65.00 per cent mortality at 24, 48, 72 and 96 hours after release of adult beetle, respectively.

The chickpea grains treated with diatomaceous earth @ 4 per cent resulted in minimum moisture content of grains at 30, 60, 90 and 120 days after treatment which were 8.20, 8.20, 8.40 and 8.47 per cent, respectively. It was followed by treatments of diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent, which recorded 8.23, 8.23, 8.43 and 8.50; 8.27, 8.30, 8.47 and 8.50 per cent moisture content in grains at 30, 60, 90 and 120 days after treatment, respectively. The application of groundnut oil @ 2 per cent, mustard oil @ 2 per cent, diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent resulted in 8.30, 8.37, 8.50 and 8.60; 8.37, 8.40, 8.53 and 8.63; 8.40, 8.43, 8.57 and 8.67; 8.43, 8.47, 8.60 and 8.70 per cent moisture content in grains at 30, 60, 90 and 120 days after treatment, respectively. Among the various treatments, neem leaf powder @ 4 per cent recorded maximum moisture content in grains, which was 8.47, 8.50, 8.63 and 8.73 per cent at 30, 60, 90 and 120 days after treatment, respectively. The data showed no significant variation in level of per cent moisture content among various treatments.

The minimum grain infestation of 2.33, 3.67, 5.00 and 6.67 per cent, by *C. chinensis* was recorded in diatomaceous earth @ 4 per cent at 30, 60, 90 and 120 days after treatment, respectively. The treatment of diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent were next in order to reduce the grain infestation by pulse beetle with 2.67, 4.33, 5.67 and 7.33; 3.00, 5.00, 6.33 and 8.00 per cent recorded at 30, 60, 90 and 120 days after treatment, respectively. The minimum grain weight loss was recorded in treatments of diatomaceous earth @ 4 per cent at 30, 60, 90 and 120 days after treatment with 0.33, 1.00, 1.33 and 2.00 per cent grain weight loss, respectively. The treatments of diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent resulted in grain weight loss of 0.67, 1.33, 2.00 and 2.33; 1.00, 1.67, 2.33 and 2.67 per cent at 30, 60, 90 and 120 days after treatment, respectively and were intermediate in reducing the weight loss. The treatments of

diatomaceous earth @ 1 per cent, neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent and groundnut oil @ 2 per cent were next in order to reduce weight loss with 3.00, 3.33, 4.00 and 5.00; 3.33, 3.67, 4.33 and 5.33 and 3.67, 4.00, 4,67 and 4.00, 4.33, 5.00 and 6.33 per cent. However, among all the treatments maximum grain infestation and weight loss were recorded in neem leaf powder @ 4 per cent.

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Bio-efficacy of Diatomaceous Earth against Pulse Beetle, *Callosobruchus chinensis* (L.)

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ABSTRACT

The present investigation on "Bio-efficacy of diatomaceous earth against pulse beetle, *Callosobruchus chinensis* (L.)" was carried out under laboratory conditions at Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur during 2020-21.

The study on biology of pulse beetle (*C. chinensis*) on various pulse host *viz.* green gram, black gram, chickpea, cowpea, pigeon pea, kabuli gram and lentil under laboratory conditions revealed that the order of host preference was cowpea (97.67) > green gram (97.33) > pigeon pea (95.67) > chickpea (89.00) > black gram (86.33) > kabuli gram (78.67) > lentil (73.33) in terms of mean fecundity by female. The mean incubation period and larval-pupal period on green gram, black gram, chickpea, cowpea, pigeon pea, lentil and kabuli gram were 4.33 and 18.67; 5.00 and 26.33; 4.67 and 21.67; 4.33 and 18.33; 4.67 and 21.00; 4.33 and 20.33; 4.67 and 26.00 days, respectively. The maximum adult survival was recorded on chickpea (90.37 %) followed by green gram (86.77 %), cowpea (84.87 %), pigeon pea (83.14 %), kabuli gram (81.34 %), lentil (79.85 %) and minimum on black gram (72.95 %).

The different organic products evaluated against pulse beetle infesting chickpea in storage condition showed that diatomaceous earth @ 4 per cent was found most effective treatment in management of pulse beetle with highest adult mortality (73.33 %), lowest grain damage (6.67 %) and lowest weight loss of grains (2.00 %) and it was significantly at par with diatomaceous earth @ 3 per cent and diatomaceous earth @ 2 per cent. The next effective treatments were diatomaceous earth @ 1 per cent followed by neem seed kernel powder @ 1 per cent, mustard oil @ 2 per cent, groundnut oil @ 2 per cent and neem leaf powder @ 4 per cent. All the treatments were found to be superior over control in terms of increasing the adult mortality, reducing grain damage and weight loss.

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दलहन भृंग, *Callosobruchus chinensis* (L.) के प्रति डायटोमेसियस मृदा की जैव–क्षमता

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अनुक्षेपण

''दलहन भृंग, *Callosobruchus chinensis* (L.) के प्रति डायटोमेसियस मृदा की जैव–क्षमता'' के लिए 2020–21 में राजस्थान कृषि महाविद्यालय, एम.पी.यू.ए.टी., उदयपुर के कीट विज्ञान विभाग की प्रयोगशाला में अन्वेषण किया गया।

प्रयोगशाला स्थितियों में मादा दलहन भृंग *C. chinensis* की औसतन अण्डे की क्षमता के अनुसार इसका विभिन्न दलहनों पर वरीयता क्रम क्रमशः चवंला (97.67) > मूंग (97.33) > अरहर (95.67) > चना (89.00) > उड़द (86.33) > काबूली चना (78.67) > मसूर (73.33) दर्ज किया गया। दलहन भृंग का मूंग, उड़द, चना, चवंला, अरहर, मसूर एवं काबुली चना पर औसत ऊष्मायन एवं लार्वा–प्यूपा काल क्रमषः 4.33 एवं 18.67, 5.00 एवं 26.33, 4.67 एवं 21.67, 4.33 एवं 18.33, 4.67 एवं 21.00, 4.33 एवं 20.33, 4.67 एवं 26.00 दिन दर्ज किया गया। अधिकतम वयस्क भृंग जीविता चने (90.37 %) पर, इसके बाद क्रमशः मूंग (86.77 %), चवंला (84.87 %), अरहर (83.14 %), काबुली चना (81.34 %), मसूर (79.85 %) एवं न्यूनतम उड़द (72.95 %) पर दर्ज की गयी।

भण्डारण परिस्थतियो में चने पर दलहन भृंग के प्रति विभिन्न जैविक उत्पादों का प्रयोग किया गया जिसमें डायटोमेसियस मृदा @ 4 प्रतिशत सबसे अधिक प्रभावी पायी गई, जिसमें अधिकतम वयस्क भृंग मृत्यु दर (73.33 %), न्यूनतम ग्रसित दाना (6.67 %) एवं न्यूनतम वजन ह्रास (2.00 %) रहा और यह डायटोमेसियस मृदा @ 3 प्रतिशत एवं डायटोमेसियस मृदा @ 2 प्रतिशत के समकक्ष पाये गये। इनके बाद क्रमशः डायटोमेसियस मृदा @ 1 प्रतिशत नीम बीज गुठली चूर्ण @ 1 प्रतिशत, सरसों का तेल @ 2 प्रतिशत, मूंगफली तेल @ 2 प्रतिशत एवं नीम पत्ती चूर्ण @ 4 प्रतिशत उपचार प्रभावी पाये गये। सभी उपचार व्यस्क भृंग मृत्यु दर को बढ़ाने, ग्रसित दाना एवं वजन ह्रास को कम करने में नियंत्रण से प्रभावी पाए गए।

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APPENDIX

APPENDIX I

Analysis of variance for incubation period of pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	0.056	0.009	0.262	2.848	0.109	0.330
Error	14	0.498	0.036	-	-	-	-

APPENDIX II

Analysis of variance for larval-pupal period of pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	2.068	0.345	10.444	2.848	0.105	0.318
Error	14	0.462	0.033	-	-	-	-

APPENDIX III

Analysis of variance for pre-oviposition period of pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	0.715	0.119	1.622	2.848	0.156	0.475
Error	14	1.028	0.073	-	-	-	-

APPENDIX IV

Analysis of variance for oviposition period of pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	0.300	0.050	2.304	2.848	0.085	0.258
Error	14	0.304	0.022	-	-	-	-

APPENDIX V

Analysis of variance for post-oviposition period of pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	0.674	0.112	2.718	2.848	0.117	0.356
Error	14	0.579	0.041	-	-	-	-

APPENDIX VI

Analysis of variance for male adult longevity (day) of pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	0.144	0.024	1.690	2.848	0.069	0.209
Error	14	0.199	0.014	-	-	-	-

APPENDIX VII

Analysis of variance for female adult longevity (day) of pulse beetle, *C. chinensis* on different hosts.

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	0.190	0.032	1.133	2.848	0.096	0.292
Error	14	0.390	0.028	-	-	-	-

APPENDIX VIII

Analysis of variance for total life period (day) of male pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	1.296	0.216	9.874	2.848	0.085	0.259
Error	14	0.306	0.022	-	-	-	-

APPENDIX IX

Analysis of variance for total life period (day) of female pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	1.311	0.218	7.190	2.848	0.101	0.305
Error	14	0.425	0.030	-	-	-	-

APPENDIX X

Analysis of variance for fecundity of pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	4.739	0.790	21.552	2.848	0.111	0.335
Error	14	0.513	0.037	-	-	-	-

APPENDIX XI

Analysis of variance for adult survival (%) of pulse beetle, *C. chinensis* on different hosts

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	6	319.901	53.317	3.773	2.848	2.170	6.583
Error	14	197.841	14.131	-	-	-	-

APPENDIX XII

Analysis of variance for bio-efficacy of different treatments on adult mortality (%) of pulse beetle, *C. chinensis* on chickpea at 24 hours after release

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	1861.320	232.665	51.374	2.510	1.229	3.651
Error	18	81.518	4.529	-	-	-	-

APPENDIX XIII

Analysis of variance for bio-efficacy of different treatments on adult mortality (%) of pulse beetle, *C. chinensis* on chickpea at 48 hours after release

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	2520.228	315.028	38.511	2.510	1.651	4.906
Error	18	147.243	8.180	-	-	-	-

APPENDIX XIV

Analysis of variance for bio-efficacy of different treatments on adult mortality (%) of pulse beetle, *C. chinensis* on chickpea at 72 hours after release

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	2973.299	371.662	37.614	2.510	1.815	5.392
Error	18	177.858	9.881	-	-	-	-

APPENDIX XV

Analysis of variance for bio-efficacy different treatments on adult mortality (%) of pulse beetle, *C. chinensis* on chickpea at 96 hours after release

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	4332.780	541.598	102.111	2.510	1.330	3.951
Error	18	95.472	5.304	-	-	-	-

APPENDIX XVI

Analysis of variance for bio-efficacy different treatments on moisture (%) of chickpea at 30 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	0.294	0.037	2.437	2.510	0.071	0.211
Error	18	0.271	0.015	-	-	-	-

APPENDIX XVII

Analysis of variance for bio-efficacy different treatments on moisture (%) of chickpea at 60 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	0.350	0.044	2.361	2.510	0.079	0.234
Error	18	0.334	0.019	-	-	-	-

APPENDIX XVIII

Analysis of variance for bio-efficacy different treatments on moisture (%) of chickpea at 90 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	0.210	0.026	1.876	2.510	0.068	0.203
Error	18	0.252	0.014	-	-	-	-

APPENDIX XIX

Analysis of variance for bio-efficacy different treatments on moisture (%) of chickpea at 120 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	0.279	0.035	1.430	2.510	0.090	0.268
Error	18	0.438	0.024	-	-	-	-

APPENDIX XX

Analysis of variance for bio-efficacy different treatments effect on grain infestation (%) by pulse beetle, *C. chinensis* on chickpea at 30 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	895.799	111.975	56.820	2.510	0.810	2.408
Error	18	35.472	1.971	-	-	-	-

APPENDIX XXI

Analysis of variance for bio-efficacy different treatments on grain infestation (%) by pulse beetle, *C. chinensis* on chickpea at 60 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	1538.525	192.316	128.401	2.510	0.707	2.099
Error	18	26.960	1.498	-	-	-	-

APPENDIX XXII

Analysis of variance for bio-efficacy different treatments on grain infestation (%) by pulse beetle, *C. chinensis* on chickpea at 90 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	2349.589	293.699	196.956	2.510	0.705	2.095
Error	18	26.841	1.491	-	-	-	-

APPENDIX XXIII

Analysis of variance for bio-efficacy different treatments on grain infestation (%) by pulse beetle, *C. chinensis* on chickpea at 120 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	4067.893	508.487	272.622	2.510	0.788	2.343
Error	18	33.573	1.865	-	-	-	-

APPENDIX XXIV

Analysis of variance for bio-efficacy different treatments on grain weight loss (%) by pulse beetle, *C. chinensis* on chickpea at 30 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	521.134	65.142	13.278	2.510	1.279	3.800
Error	18	88.308	4.906	-	-	-	-

APPENDIX XXV

Analysis of variance for bio-efficacy different treatments on grain weight loss (%) by pulse beetle, *C. chinensis* on chickpea at 60 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	550.687	68.836	26.943	2.510	0.923	2.742
Error	18	45.988	2.555	-	-	-	-

APPENDIX XXVI

Analysis of variance for bio-efficacy different treatments on grain weight loss (%) by pulse beetle, *C. chinensis* on chickpea at 90 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	631.027	78.878	40.754	2.510	0.803	2.386
Error	18	34.838	1.935	-	-	-	-

APPENDIX XXVII

Analysis of variance for bio-efficacy different treatments on grain weight loss (%) by pulse beetle, *C. chinensis* on chickpea at 120 days after treatment

Source of Variation	D.F.	SS	MSS	F (cal)	F(tab) 5%	SEm+	CD 5%
Treatment	8	832.540	104.068	61.253	2.510	0.753	2.236
Error	18	30.582	1.699	-	-	-	-

Plagiarism Report

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