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Effect of plant based silica products on biology of bruchid beetle, *Callosobruchus chinensis* (Linnaeus) in chickpea

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Abstract
A lab experiment was carried out at Entomology laboratory, Seed Research and Technology Centre and Central Instrumentation Cell, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad to study the effect of Plant based silica products *viz,* amorphous silica gel @ 250 and 500 ppm, amorphous silica precipitate @ 250 and 500 ppm kg^{-1} seed, paddy husk @ 1000 and 2000 ppm kg^{-1} seed, paddy leaves @ 1000 and 2000 ppm kg^{-1} seed and diatomaceous earth @ 300 and 600 ppm kg^{-1} seed on biology of bruchid beetle beetle, *Callosobruchus chinensis* (Linnaeus) on chickpea during 2020-21. The experiment was laid out in completely randomized design and all the treatments were replicated thrice. Among the plant based silica products, amorphous silica gel @ 500 ppm kg^{-1} seed showed superior performance over other treatments resulting in lowest fecundity (3.67 eggs 100 g^{-1} seed), minimum number of seeds having eggs 100 g^{-1} seed (3.33 seeds), lowest hatchability (55.57 per cent), minimum adult emergence (1.33 adults), short adult span (3.33 days) and minimum seed weight loss (0.34 per cent) and had a great promise in pest management.

Keywords: Chickpea, plant based silica products, biology, *Callosobruchus chinensis* (Linnaeus)

1. Introduction

Chickpea has been a traditional low-input crop in the farming systems of the Indian subcontinent where it is an integral part of the daily diet of the people because of its adaptability to a wide range of environments. There is a growing demand for chickpea due to its nutritional value as it is a good source of carbohydrates and protein, together constituting about 80% of the total dry seed mass.

Globally South and West Asia regions account for about 90 per cent of the world chickpea production. India, Pakistan, Turkey, Iran and Syria are major producers (Joshi *et al*., 2001) [17]. In India it occupies an area of 96.98 m ha with annual production of 110.78 mt and productivity of 1142 kg ha^{-1}. Telangana state accounts for 1.30 m ha of area with production and productivity of 1.99 mt and 1532 kg ha^{-1}, respectively (Indiastat.com, 2019-20). It is grown in Kamareddy, Sangareddy, Jogulamba Gadwal, Nizamabad and Adilabad districts of Telangana.

Post-harvest losses in chickpea were reported to be 6.97 per cent of production (Nag *et al*., 2000). *Callosobruchus chinensis* (L.) is one of the major insect pest of legumes under sub-tropical conditions where, the whole development occurs inside a single seed and adults emerge out by leaving the holed seed behind (Messina and Jones, 2009) [21] which fetches lower market price due to reduced weight. In addition to quantitative losses, the *Callosobruchus chinensis* also causes qualitative losses (Khare and Johari, 1984) [19]. Generally, infestation of bruchids starts in the field, where the adult female lays eggs on green pods which causes only minor damage. The grub penetrates the pod and remain concealed within the seeds as hidden infestation (Southgate, 1979) [26] and the damage is multiplied by several folds under storage.

The extensive application of insecticides is directly related with the development of resistance of stored product insect species, raising serious concerns for human health as a result of food contamination with residues and possible environmental hazards (Boyer *et al*., 2012; Stadler *et al*., 2012) [7, 27]. In this context, the use of plant derived products is considered a promising alternative to currently used traditional pesticides against stored product insects (Weaver and Subramanayam, 2000) [31].

Therefore, the use of rice husk as source of silica products has positive impact on the environment and also economical through use of low value agricultural by-product that can relieve waste disposal problems. Their insecticidal action is due to their ability to adsorb epicuticular lipid from insects moving over treated surfaces, removal of this water proofing layer leads to desiccation and death (Ebeling, 1971) [8]. They are classified as having an "unlimited" acceptable daily intake when used as food additives (Anonymous, 1974) [2] and however, United States Department of Agriculture has declared amorphous silica as biosafe (Stathers *et al*., 2004) [28].

2. Materials and Methods

The experiment was carried out in completely randomized design with three replications in Entomology laboratory, Seed Research and Technology Centre and Central Instrumentation Cell, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, Telangana during 2020-21.

2.1 Preparation of the test seed

The popular variety NBeG-3 was used in the experiment. The chickpea variety was procured from Agricultural Research Station, Tandur. The seeds after procurement, were cleaned thoroughly by removing physical impurities and kept in an incubator at a temperature of 55˚C for a period of four hours to kill the immature stages of the insects if any without affecting viability of the seeds (Soloman, 1952) [29].

2.2 Mass culturing of *Callosobruchus chinensis* (L.)

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

2.3 Collection and preparation of plant materials

Amorphous silica gel and amorphous silica precipitate were collected from Indian Institute of Rice Research, Rajendranagar, Hyderabad where they have been applied individually in two dosages *i.e*. 250 and 500 ppm kg^{-1} seed whereas paddy husk and leaves were collected from rice section, Agriculture Research Institute, Rajendranagar, Hyderabad. The collected leaves were washed and air dried in shade. The dried paddy husk and leaves were ground to a fine powder in a electric mixer and the resulting powder is sieved and kept in air tight containers where these powders were applied individually @ 1000 and 2000 ppm kg^{-1} seed. The diatomaceous earth procured from Pai hygiene and health care, Badgaon, Udaipur were mixed at the rate of 300 ppm and 600 ppm kg^{-1} seed.

The seeds were mixed manually using a drum to get uniform distribution of the test material and later packed in plastic containers. For each replication of the treatment, ten pairs of newly emerged (0-24 hrs) adults (10-♀ and 10-♂) were released into plastic containers containing 100 grams of chickpea seeds and allowed to copulate. The seeds were observed for each concentrations of the test material. Control was maintained by following the same procedure. The bottles were suitably labeled and kept in an incubator at a temperature of 28±1 ºC and 70±5 per cent relative humidity (Hosamani *et al*., 2018) [13]. The data on following parameters was recorded for each concentration of the test material

2.4 Fecundity

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

2.5 Number of seeds having eggs

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

2.6 Hatchability

The formula described by Giga *et al*. (1993) [12] was used to determine per cent hatchability in each replication. The per cent of egg hatch was calculated by recording the number of eggs hatched out of the total number of eggs kept under observation.

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

2.7 Incubation period

The incubation period was recorded from the date of egg laying to date of hatching of the egg which was identified by change in colour from transparent to creamish white due to accumulation of frass inside the egg.

2.8 Larval-Pupal period

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

2.9 Adult emergence

The adult emergence has been recorded by following the method described by Bajiya *et al.* (2011) [6]. The total number of adults emerged after 45 of the treatment were counted and counting was continued till the beetles cease to emerge from the seeds.

2.10 Adult longevity

Longevity of adult beetles was determined by recording the days from the date of adult emergence from pupa to date of death in each replication (Bajiya *et al*., 2011) [6].

2.11 Weight loss

After removing the beetles from each plastic container, weight loss was assessed by calculating the mean percentage of seed weight loss in each treatment as described by Islam *et al*. (2016) [15]. This was worked out by weighing 100 grams seeds after 45 days of the treatment.

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

3 Results and Discussion

3.1 Effect of plant based silica products on fecundity

As observed from the results (Table 1), it was evident that all the treatments were found to be significantly superior in reducing fecundity of *Callosobruchus chinensis* over the untreated control.

The minimum mean number of eggs (3.67 eggs 100 g^{-1} seed) were found in the seeds treated with amorphous silica gel @ 500 ppm kg^{-1} seed followed by diatomaceous earth @ 600 ppm kg^{-1} seed (8.67 eggs 100 g^{-1} seed) and amorphous silica gel @ 250 ppm kg^{-1} seed (9.00 eggs 100 g^{-1} seed) which remained on par with each other. While, mean number of eggs observed in seeds treated with amorphous silica precipitate @ 500 ppm kg^{-1} seed, diatomaceous earth @ 300 ppm kg^{-1} seed and amorphous silica precipitate @ 250 ppm kg^{-1} seed were 14.33, 15.00 and 24.67 eggs 100 g^{-1} seed, respectively. The mean fecundity observed in seeds treated with paddy husk @ 2000 and 1000 ppm kg^{-1} seed were 113.67 and 122.33 eggs 100 g^{-1} seed, respectively. Paddy leaves @ 2000 and 1000 ppm kg^{-1} seed were least effective which resulted mean fecundity of 125.33 and 130.00 eggs 100 g^{-1} seed against untreated control (139.67 eggs 100 g^{-1} seed). Thus, treatments *viz*., amorphous silica gel, diatomaceous earth and amorphous silica precipitate were significantly superior in suppressing egg laying compared to paddy husk and paddy leaves.

The present findings are in line with observation of Arumugam *et al*. (2016) [4], who reported that no eggs were found in chickpea seeds treated with silica nano particles @ 900 and 1000 ppm. The reduced fecundity might be due to suffering of insects because of spiracular blockage and desiccation which could have prevented mating. Similarly, Ali *et al*. (2017) [5] found that eggs per female were significantly lower (5.67) when treated with diatomaceous earth @ 0.25 g g^{-1} against *Tribolium castaneum* in wheat flour as against control (90.67). However, insects may develop a behavioural response to these products and avoid contact (Ebeling, 1971) [8].

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

The results pertaining to effect of plant based silica products on number of seeds having eggs are presented in Table 1.

The mean number of seeds having eggs 100 g^{-1} seed ranged from 3.33 to 117.33 in various treatments as against 125.33 seeds in untreated control. Significantly lowest mean number of seeds having eggs 100 g^{-1} seed (3.33) was found in seeds treated with amorphous silica gel @ 500 ppm kg^{-1} seed. When seeds were treated with diatomaceous earth @ 600 ppm kg^{-1} seed, mean number of seeds having eggs 100 g^{-1} seed were 8.33, which was on par with amorphous silica gel @ 250 ppm kg^{-1} seed with 8.67 seeds having eggs 100 g^{-1} seed. The other treatments *viz*., amorphous silica precipitate @ 500 ppm kg^{-1} seed, diatomaceous earth @ 300 ppm kg^{-1} seed and amorphous silica precipitate @ 250 ppm kg^{-1} seed resulted 11.67, 12.33 and 17.00 seeds having eggs 100 g^{-1} seed, respectively.

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

The results were in agreement with the findings of Prasantha *et al*. (2003) [23] who reported that higher dosages of natural silica powders, Fossil-Shield and Silico-Sec decreases the fecundity and increases the number of seeds without eggs of *Callosobruchus maculatus*. Similarly, Yousefnezhad *et al*. (2019) [30] reported that oviposition deterrence of 87.0 per cent was observed in chickpea seeds treated with Aerosil (silicon dioxide nano particles) @ 300 mg kg^{-1} seed. This reduced number of seeds having eggs might be due to less mobility and lower consumption of oxygen in exposed insects as stated by Krzyzowski *et al*. (2019) [20]. According to Ebeling (1971) [8] insects avoid contact by developing a behavioural response to these particles.

3.3 Effect of plant based silica products on hatchability

The results on effect of plant based silica products on hatchability of bruchid beetle are presented in the Table 1.

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

Highest hatchability per cent of 86.62 was resulted in untreated seeds which was found to be on par with paddy husk @ 2000 ppm kg^{-1} seed (84.72 per cent), paddy husk @ 1000 ppm kg^{-1} seed (84.92 per cent), paddy leaves @ 2000 ppm kg^{-1} seed (85.10 per cent), paddy leaves @ 1000 ppm kg^{-1} seed (85.20 per cent). This revealed that paddy husk and paddy leaves were found to be least effective compared to other treatments with respect to per cent hatchability.

The results were in accordance with the findings by El Halfawy *et al*. (1977) [10] reported that, per cent hatchability of *Rhizopertha dominica* and *Callosobruchus chinensis* reduced when eggs were exposed to light inert dusts. Similarly, Prasantha *et al*. (2003) [23] reported that, there was an increase in the unhatched eggs per cent from 6 to 22 with increase in the application rates of diatomaceous earths, which might be due to the suffocation of the hatching embryo and also treatment with these dusts might have altered the texture of the seed surface causing less attachment of the egg chorion on to the seed. Ali *et al*. (2017) [5] who reported that, natural product, diatomaceous earth when treated with wheat flour @ 0.25 g g^{-1} resulted least per cent hatchability (31.13 per cent) of *Tribolium castaneum* compared to control (91.57 per cent).

3.4 Effect of plant based silica products on incubation period and larval-pupal period

The data on effect of plant based silica products on incubation period and larval-pupal period of bruchid beetle *C. chinensis* are presented in the Table 2 The incubation period and larval-pupal period of *C.* chinensis resulted in all the treatments was more or less similar with the untreated control which indicates that the plant based silica products had little or no effect on the incubation period and larval-pupal period of the test insect. According to Yadav (2016) [32] there was no change in the incubation period, larval and pupal periods of *Sitophilus oryzae* and *Rhyzopertha dominica* in diatomaceous earth treated maize kernels and wheat grains, respectively.

3.5 Effect of plant based silica products on adult emergence

The data on effect of plant based silica products on adult emergence of bruchid beetle *C. chinensis* are presented in the Table 3.

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

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

The results were in agreement with Kabir (2013) [18] who reported that Protect-It (diatomaceous earth) resulted in complete inhibition of adult emergence when applied @ 1000 mg kg^{-1} cowpea seeds against *Callosobruchus maculatus*. Similarly, Jean *et al*. (2015) [16] reported that dust containing amorphous silica particles, Fossil-Shield at all dosage levels completely suppressed F_1 progeny emergence of *Sitophilus zeamais* except for the lowest dosage level of 0.5 g kg^{-1} maize seeds, which resulted 95.50 per cent of progeny inhibition. This reduced progeny production might be due to the increased adult mortality and reduced oviposition as observed by Ibrahim *et al*. (2012) [14]

3.6 Effect of plant based silica products on adult longevity

The data on effect of plant based silica products on adult longevity of bruchid beetle *C. chinensis* are presented in the Table 3.

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

Among the plant based silica products, paddy husk @ 2000 ppm kg^{-1} seed and paddy husk @ 1000 ppm kg^{-1} seed resulted adult span of 7.47 and 7.60 days, respectively. These were followed by paddy leaves @ 2000 ppm kg^{-1} seed (7.73 days) and paddy leaves @ 1000 ppm kg^{-1} seed (7.80 days) that remained to be on par with each other which were found to be least efficient in reducing the adult span of the pest among the treatments. However, highest adult span of 7.87 days was observed in untreated seeds which remained on par with paddy leaves @ 1000 ppm kg^{-1} (7.80 days). Similar trend was also observed in this study where paddy husk and paddy leaves were found to be less effective compared to other treatments.

The present findings are in line with observations of Parsaeyan *et al*. (2012) [24] who reported that adult longevity reduced by 74.7 per cent compared to control when exposed to LC_{20} concentration (0.51 g m^{-2}) of diatomaceous earth. The reduction in adult span might be due to death of insect caused by damage of water barrier which leads to desiccation as reported by Ebeling (1971) [8]. Similarly, Ebeid *et al*. (2013) [9] studied impact of silica nano particles on *Heteracris littoralis* and reported that at all concentrations, mean adult duration did not exceed 12.40 compared to untreated check (31.40). Effectiveness of inert dust depends on speed and amount of the waxy cuticle that the dust can absorb as stated by Fields *et al*. (2001) [11].

3.7 Effect of plant based silica products on weight loss

The results recorded on weight loss after 45 days of treatment due to bruchid beetle, *C. chinensis* are presented in Table 3.

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

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

The results were in agreement with the findings by Patil *et al*. (2018) [25] who reported that, application of rice husk silica nano particles @ 200 ppm resulted no seed weight loss whereas 0.03 per cent weight loss was observed when treated with 175 ppm dosage against *Sitophilus oryzae* in rice stored for a period of 4 days.

Table 1: Effect of plant based silica products on fecundity, number of seeds having eggs and per cent hatchability of bruchid beetle, *Callosobruchus chinensis* (L.)

Treatments	Dosage kg^{-1} seed	Fecundity (No. of eggs 100 g^{-1} seed)	Number of seeds having eggs 100 g^{-1}seed	Percent hatchability
Amorphous silica gel	250 ppm	9.00 (3.16)	8.67 (3.11)	63.06 (52.56)
Amorphous silica gel	500 ppm	3.67 (2.16)	3.33 (2.08)	55.57 (48.23)
Amorphous silica precipitate	250 ppm	24.67 (5.06)	17.00 (4.24)	68.87 (56.08)
Amorphous silica precipitate	500 ppm	14.33 (3.91)	11.67 (3.56)	65.48 (54.02)
Paddy husk	1000 ppm	122.33 (11.09)	113.67 (10.70)	84.92 (67.17)
Paddy husk	2000 ppm	113.67 (10.71)	103.33 (10.21)	84.72 (67.02)
Paddy leaves	1000 ppm	130.00 (11.44)	117.33 (10.87)	85.20 (67.39)
Paddy leaves	2000 ppm	125.33 (11.24)	114.00 (10.72)	85.10 (67.27)
Diatomaceous earth	300 ppm	15.00 (3.99)	12.33 (3.65)	66.67 (54.72)
Diatomaceous earth	600 ppm	8.67 (3.11)	8.33 (3.05)	61.58 (51.70)
Untreated control	-	139.67 (11.858)	125.33 (11.24)	86.62 (68.54)
S.Em±		0.18	0.14	1.49
CD (P=0.05)		0.52	0.41	4.39
CV(%)		4.32	3.58	4.33

The values in parentheses are transformed values

Table 2: Effect of plant based silica products on incubation period and larval-pupal period of bruchid beetle, *Callosobruchus chinensis* (L.)

Treatments	Dosage kg^{-1} seed	Incubation period (days)	Larval-Pupal period (days)
Amorphous silica gel	250 ppm	4.40 (2.32)	26.73 (5.27)
Amorphous silica gel	500 ppm	4.33 (2.31)	26.17 (5.21)
Amorphous silica precipitate	250 ppm	4.07 (2.25)	25.67 (5.16)
Amorphous silica precipitate	500 ppm	4.07 (2.25)	26.07 (5.20)
Paddy husk	1000 ppm	4.53 (2.35)	26.20 (5.22)
Paddy husk	2000 ppm	4.47 (2.34)	26.07 (5.20)
Paddy leaves	1000 ppm	4.40 (2.32)	26.07 (5.20)
Paddy leaves	2000 ppm	4.20 (2.28)	26.07 (5.20)
Diatomaceous earth	300 ppm	4.27 (2.30)	25.47 (5.15)
Diatomaceous earth	600 ppm	4.18 (2.28)	26.55 (5.25)
Untreated control	-	4.13 (2.27)	25.53 (5.15)
S.Em±		0.02	0.03
CD (P=0.05)		N.S.	N.S.
CV (%)		1.78	0.91

The values in parentheses are transformed values

Table 3: Effect of plant based silica products on adult emergence, adult longevity and per cent reduction in seed weight of bruchid beetle, *Callosobruchus chinensis* (L.)

Treatments	Dosage kg^{-1} seed	Adult emergence	Adult longevity (days)	per cent weight loss
Amorphous silica gel	250 ppm	4.67 (2.38)	3.80 (2.19)	1.47 (6.96)
Amorphous silica gel	500 ppm	1.33 (1.52)	3.33 (2.08)	0.34 (3.31)
Amorphous silica precipitate	250 ppm	18.00 (4.35)	4.53 (2.35)	3.78 (11.19)
Amorphous silica precipitate	500 ppm	9.33 (3.20)	4.07 (2.25)	2.30 (8.70)
Paddy husk	1000 ppm	102.33 (10.16)	7.60 (2.93)	10.07 (18.49)
Paddy husk	2000 ppm	95.00 (9.80)	7.47 (2.91)	9.51 (17.95)
Paddy leaves	1000 ppm	106.33 (10.36)	7.80 (2.97)	11.21 (19.55)
Paddy leaves	2000 ppm	104.33 (10.26)	7.73 (2.95)	10.87 (19.24)
Diatomaceous earth	300 ppm	10.00 (3.31)	4.33 (2.31)	2.63 (9.32)
Diatomaceous earth	600 ppm	4.33 (2.31)	3.62 (2.15)	1.30 (6.55)
Untreated control	-	113.00 (10.68)	7.87 (2.98)	11.76 (20.04)
S.Em±		0.12	0.03	0.29
CD (P=0.05)		0.36	0.08	0.85
CV (%)		3.37	1.94	3.89

The values in parentheses are transformed values

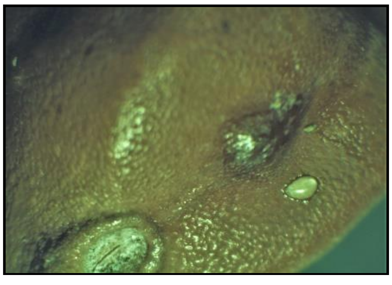

Fig 1: Freshly laid egg

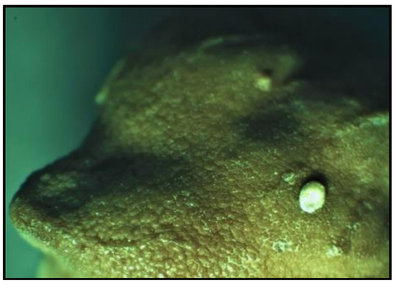

Fig 2: Hatched egg

Fig 3: Adult emerging from seed

4. Conclusion

Plant based silica products when tested at both concentrations resulted significant effect on fecundity, *number of seeds having eggs*, hatchability, adult emergence, adult longevity and reduction in seed weight while non significant effect on incubation period and larval pupal period. The results obtained from these study confirmed that amorphous silica gel @ 500 ppm kg^{-1} seed was considered as the best treatment for control of pulse beetle which resulted in lowest fecundity (3.67 eggs 100 g^{-1} seed), number of seeds having eggs 100 g^{-1} seed (3.33 seeds), hatchability (55.57 per cent), adult emergence (1.33 adults), adult longevity (3.33 days) and minimum weight loss (0.34 per cent).

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