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K Govindan
Department of Crop Protection, Agricultural College and Research Institute, Valavachanur, Thiruvannamalai, Tamil Nadu, India

S Geethanjali
Department of Crop Improvement, Agricultural College and Research Institute, Valavachanur, Thiruvannamalai, Tamil Nadu, India

G Brundha
Department of Crop Protection, Agricultural College and Research Institute, Valavachanur, Thiruvannamalai, Tamil Nadu, India

M Pandiyan
Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Valavachanur, Thiruvannamalai, Tamil Nadu, India

Corresponding Author:
K Govindan
Department of Crop Protection, Agricultural College and Research Institute, Valavachanur, Thiruvannamalai, Tamil Nadu, India

Effect of plant powders on pulse beetle, *Callosobruchus maculatus* (F.) and seed weight loss in stored black gram

K Govindan, S Geethanjali, G Brundha and M Pandiyan

Abstract
Laboratory studies were conducted at Department of Crop Protection, Agricultural College and Research Institute, Valavachanur – 606 753, Thiruvannamalai District to study the effect of various plant powders tested against, *Callosobruchus maculatus* (F.) Infesting stored black gram. Pulse beetle, *C. maculatus* are the most serious pests in stored legumes in majority of tropical countries. Attention has been given to the possible use of plant products or plant dry powders as promising alternatives to synthetic insecticides in controlling insect pests of stored products. Present study seven plant species evaluated for their bio activity to pulse beetle. The experiments were conducted on seven plant dry powders compared with untreated control. Among the plant powders evaluated by mixing with the seeds @ 2 percent w/w, among them results show *Acorus calamus* 2 percent rhizome powder was found to be significantly the best compared to other treatments and caused 100 percent mortality two days after treatment, which was followed by *Solanum nigrum* (37.77 %), *Leucas aspera* (18.88%), *Cardiospermum helicacabum* (21.11%) and *Achranthes aspera* (14.44%) and whereas untreated control recorded only 8.88 percent mortality was recorded. At six days after treatment highest mortality was seen *S. nigrum* (78.88 %) which was statistically on par with *C. helicacabum* (69.99%) and *A. aspera* (68.88 %) were observed and same trend was observed at 7 DAT. The experiment, on oviposition (egg laying) results showed that there was no egg laying in *A. calamus* 2 percent rhizome powder treated black gram seeds. The toxicity level different plant powders effect showed that *Ocimum canum* (42.44 eggs) > *Solanum nigrum* (47.66 eggs) > *Coriandrum sativam* (49.66 eggs) > *Leucas aspera* (72.33 eggs) > *Achranthes aspera* (81.66 eggs) as compared to untreated control (121.00 eggs) were laid. Complete inhibit of adult emergence observed in *A. calamus* than next to *O. canum* (16. 66), *S. nigrum* (26.66) and *C. sativam* (35.55) as compared with untreated control (100.66Nos) adult beetles were emerged. No seed weight loss was recorded in *A. calamus* at 30, 45 and 60 days after treatments. Next best plant powders reduce the seed weight loss in *O. canum* at 30 DAT (10.28%), 45 DAT(14.83%) and 60 DAT(19.24%) while, in 30.91 at (30 DAT), 35.25 (45 DAT) and 40.26 (60 DAT) per cent loss was registered. Different concentration of *A. calamus* experiment results concluded that all the four dose of *A. calamus* (0.50, 1.00, 1.50 and 2.00 %) highly effective against *C. macultus viz*., mortality, oviposition adult emergence and seed weight losses.

Keywords: Plant powders, *Callosobruchus maculatus*, black gram

Introduction
Pulses are an important part of the vegetarian diet of Indian subcontinent, being a rich source of protein (20–30 %) and high nutritional value, offer the most practical means of solving malnutrition in our country Vasanthakumar [1]. Per capita requirement of Pulses (60 gm for male and 55 gm for female) is less than the availability (42 gm). Globally, India stands first in terms of area and production of Pulses. Black gram is (4.05 lakh ha), Production (3.10 lakh tonnes) and Productivity (851 kg/ha) [1]. Black gram and green gram account for about 71 percent of the area in Tamil Nadu [1]. Black gram *Vigna munga* (L.), an important legume crop suffers losses both qualitatively and quantitatively due to the attack by bruchids in the post harvest [2]. Black gram is one of the main pulse crop in the India, it is widely cultivated throughout the Asia, including India. Black gram is an excellent source of high quality protein (25%) having high digestibility [2]. Black gram should be stored to meet home consumption as well as for sale. Major constraints for the production and protection of pulses are pest infestation in the field and in storage. Infestation begins in the field but causes serious damage to the seeds during storage [3]. Stored products are frequently damaged by insect pests and this may account to 5-10% in temperate zones and 20-30% in the tropics [4].

Infestation begins in the field but causes serious damage to the seeds during storage and bruchids are known to inflict quantitative and qualitative losses to stored pulses [3]. Black gram is seriously infested by pulse beetles *Callosobruchus maculatus* (F.) and *Callosobruchus chinensis* (Coleoptera: Bruchidae) all over the world (Dimetry *et* [5]. *C. maculatus* is one of the most serious pests brought into storage containers with harvested black gram that can cause total loss of the stored crop in a few months. The estimated post-harvest losses caused by bruchids to the pulses ranged from 30-40% within 6 months and when left unattended losses could be up to 100 percent [6]. *Callosobruchus spp.* can cause damage of legume seeds up to 100 per cent during storage [7].

Many synthetic insecticides have been found effective against stored product pests but proved to be hazardous to men and domestic animals. The over reliance on and non judicious use of synthetic pesticides especially insecticides since last four decades led to wide spectrum of pests problem like pests resistance to chemicals, resurgence of pests, residues in food and soil and risks to human and animal health, besides environmental pollution [8]. Musa and Uddin, [9] who reported that many plants possess activities against stored grain pests. To solve this problem, many researchers have discovered alternative pest management products derived from plants [10]. Plant products are cheap and are easily accessed by farmers and small-scale industries in the form of crude or partially purified extracts. It was indicated that mixing storage pulses and plant products such as leaf, bark, powder or extracted oils reduced the oviposition rate, inhibited the adult emergence of bruchids, and decreased the seed damage rate [11-14]. Therefore, present study seven plant powders were tested for the mortality, adult emergence and seed weight loss against caused by *C.maculatus* infesting stored black gram seeds.

Materials and Methods

Laboratory experiments were carried out at of Crop Protection, Agricultural College and Research Institute, Vazahavacnur during 2018-2019 study the effect of seven plant powders on *C.maculatus.*

Rearing of test Insect

Adults of *Callosobruchus maculatus* were initially collected from villages of vanapuram, Perunduraipattu and Vazhavachanur infested stored black gram seeds from the farmers. granaries and brought to the laboratory at Department of Crop Protection, Agricultural College and Research Institute, Valavachanur – 606 753. The pulse beetle, *Callosobruchus maculatus* was reared on black gram seeds in glass jars covered with muslin cloth by following the method developed by Credland and Wright [15]. *C. maculatus* were maintained at ambient laboratory temperature (28 ± 2ºC) and relative humidity (70 ± 5%) conditions.

Preparation of plant powders

Seven insecticidal plants are indicated below in (Table 1) collected, washed with distilled water and shade dried at room temperature for seven days and crushed a pulverizer model of fritsch rotor speed mill pulverisette 14 with motor load is normal and rotational speed 14, 000 rpm using in to fine powder using a pulveriser (0.05 mm mesh sieve) [16]. All the powders were kept in plastic containers at room temperature and properly sealed to prevent quality loss and used for conducting experiments.

Table 1: The plant species evaluated against *Callosobruchus maculatus*

S. No	Common name	Botanical name	Family	Parts used
1	Sweet flag	*Acorus calamus* L.	Aeraceae	Rhizomes
2	Manttakkali	*Solanum nigrum* L.	Solanaceae	Leaves
3	Naiurivi	*Achyranthes aspera* L.	Amranthaceae	Leaves
4	Coriander	*Coriandrum sativam* L.	Apiaceae	Seeds
5	Tumbai	*Leucas aspera* Spreng	Lameaceae	Leaves
6	Mudukkottan	*Cardiospermum halicacabum* L.	Sapindaceae	Leaves
7	Tulasi	*Ocimum canum* L.	Lameaceae	Leaves

Effect of insecticidal plant powders on the adult mortality of pulse beetle, *Callosobruchus maculatus* (F.)

Twenty grams of black gram seeds were taken in petridishes. The powder of various plant parts at the rate of 2: 100 (w/w) were added to black gram seeds and shaken thoroughly. Thirty newly emerged adults were released in to each petridish and kept in laboratory. Mortality (lack of locomotion and or response to repeated probing) was recorded at one day intervals up to seven days [16].

Percent mortality was calculated by the following formula

$$\text{Per cent mortality} = \frac{\text{Number of } C.\ maculatus \text{ dead}}{\text{Number of } C.\ maculatus \text{ introduced}} \times 100$$

Effect of insecticidal plant powders on oviposition, egg hatching and adult emergence of *C. maculatus*

Oviposition

Twenty grams of black gram seeds were taken in glass bottles. The powder of various plant parts at the rate of 2 :100 (w/w) were added to black gram seeds and shaken thoroughly. Then the glass bottles were covered firmly using muslin cloth. Five pairs of newly emerged adults of male and females *C. maculatus* were released to each glass bottle, covered firmly and kept in laboratory at ambient conditions. Three replications were maintained for each treatment. Numbers of eggs laid on the seeds were counted on third day after the release of beetles [16].

Egg hatching

On 5th day after the release of beetles counts on translucent unhatched eggs and opaque hatched eggs were taken and hatchability percentage was worked out [16].

Adult emergence

On 15 th day after the release of beetles all the dead insects were removed from the bottles to prevent them from the mixing with first generation (F1) offspring. The number of newly emerged adults were counted and removed from the bottle once in three days till the complete emergence of F1 offspring (up to 30 days after treatment) [16].

Seed weight loss

The weight of the seed was taken on 30, 45 and 60 after the

treatment and seed weight loss percentage was worked out [16].

$$\text{Percent weight loss} = \frac{\text{Initial weight of grain} - \text{Final weight loss of grain}}{\text{Initial weight of grain}} \times 100$$

The experiment was laid out in Completely Randomized Design (CRD) with three replication were maintained for each treatments.

Statistical analysis

The methods of Gomez and Gomez [17] were followed in scrutinizing the data from various experiments. Square root and angular transformations were adopted for the data in numbers and percentage respectively [18]. Means in simple CRD analysis were separated by Duncan's multiple range test [19].

Results and Discussion

Effect of plant powders on the adult mortality of *Callosobruchus maculatus*

The results of experiments conducted to study the effect of seven insecticidal plants against *Callosobruchus maculatus* and presented. The results clearly indicated that all the treatments revealed a wide variation in mortality compared to untreated control. The insecticidal action experiment powders seven plant (S. No 1 -7 plants in Table 1) 2.00 percent (w/w) were tested for their insecticidal action in comparison with untreated control. Data on mortality of *C. maculatus* after 1, 2, 3, 4, 5, 6 and 7 days after treatment (DAT) were recorded and furnished in (Table 2). Among the insecticidal plant powders tested for pulse beetle, *Acorus calamus, Ocimum canum* and *Solanum nigrum* 2 percent powder registered 40.55, 7.77 and 5.55 per cent mortality respectively, at 1 DAT while in untreated control no mortality was observed. The results were in agreement the findings of Kaur *et al.* [20] who stated that sweet flag, *Acorus calamus* rhizome powder (5 g/100 g pea seeds) resulted in 98.89 per cent mortality of the pulse beetle, *C. chinensis* at two days after treatments. At 2 DAT, *A. calamus* 2 percent rhizome powder caused 100 per cent mortality within 24 hours after the treatment, the bio activity of *A. calamus* in the present study could be substantiated with the findings of Jilani *et al.,* [21] who reported that sweet flag rhizome powder at 1.00 percent possessed high insecticidal activity against *C. analis*. The *S. nigrum* 2 percent (37.77%), *C. helicacabum* (21.11%), *L. aspera* (18. 88%) and in untreated control 8.88 percent mortality was recorded after 2DAT. At 3 DAT, 52.22, 28.22 and 27.77 percent mortality were recorded in *S. nigrum*, *C. helicacabum* and *L. aspera* 2 percent, respectively. Similar results were observed by [22]. Seed extract of *Solanum elaeagnifolium* had the greatest effect in causing mortality of 34 percent for the red flour beetle and solanum and their bio activity is mainly attributed to the glycoalkaloids (solamargine, solasonine and solasodine) causing the mortality of red flour beetle *Tribolium castaneum*. Similar trend of mortality observed 4 DAT also. At 5 DAT, the maximum adult beetle mortality was seen in *S. nigrum* 2 percent 68.88 percent then next to best treatment is *C. helicacabum* (67.77 %) followed by *A. aspera* (54.44%) and *L. aspera* (47.77%) among the different insecticidal plant powders minimum percent mortality was recorded in *C. sativam* and untreated check registered 31.11 percent at five days after treatment. Hamouda *et al.* [22] who reported *S. nigrum* that repellent activity against *T. castaneum*. The highest mortality (78.88%) was observed in *S. nigrum* followed by *C. helicacabum* (69.99 %) which was statistically on par with *A. aspera* (68.88 %) and *O. canum* (59.99 %) and *L. aspera* (53.33%) where as minimum mortality was observed in *C. sativam* (47.55%) as compared to untreated control 36.66 percent mortality was recorded after 6 DAT. Similar results were documented and concluded by Sathyaseelan *et al*. [23] who observed that *Ocimum canum* leaf powder at 5 percent treated green seeds and caused 68.70 percent mortality to *C. maculatus*. At 7 DAT, highest mortality was seen in *S. nigrum* 2 percent (89.99%) which was statistically on par with *A. aspera* (83.33%), *C. helicacabum* (78.88%) and *O. canum* (73.33 %), among the insecticidal plant powders minimum mortality was observed in *C. sativam* (48. 88%), where as compared t6o untreated control 51.11 percent mortality was recorded after 7 DAT. Among the insecticidal pant powders *A. calamus*, 2 percent rhizome powder was significantly different from all other treatments. *A. calamus* have high insecticidal activity due to active compound called β-asarone (cis-2, 4, 5-trimethoxy-1-propenylbenzene) is a sesquiterpenoid, is a major active principle found in oil of the rhizomes and it is the responsible for the killing the *C. maculatus* [24]. Several scientist tested their efficacy of sweet flag, *A. calamus* rhizome powder against the adults of *C. maculatus* [25-28].

Effect of plant powder on oviposition, adult emergence of *Callosobruchus maculatus* and seed weight losses

The number of eggs laid by female, hatchability per cent and adult emergence of *C. maculatus* and seed weight loss of the black gram seeds treated with seven plant powders in the (Table 1. S. No: 1 to 7) and results were significantly different from each other (Table 3). There was egg laying completely inhibited by *Acorus calamus* 2 percent rhizome powder treated black gram seeds. The present findings are in line with the already reported oviposition deterrent effect of Kaur *et al.* [20] who found that *A. calamus* at 1g / 100 g of treated pea seeds no damage was observed and also Rathod *et al.* [29] who found that *A. calamus* at 3g / kg of green gram seeds results showed no eggs were laid. Insecticidal plants toxic level to Eggs as: *Ocimum canum* (42.44) > *Solanum nigrum* (47.66) > *Coriandrum sativam* (49.66) > *Leucas aspera* (72.33) > *Achranthes aspera* as compared to untreated control (121.0) eggs were laid. Present findings line with finding of Rathod *et al.* [29] who found that *O. canum* leaf powder @ 3g/kg of green gram treated seeds results showed less numbers of eggs were laid.

Regarding the hatchability, insecticidal plant powder reduced the egg hatching significantly. Hatchability in *A. calamus* 2 percent rhizome powder *Ocimum canum, Solanum nigrum Achranthes aspera and Leucas aspera* were significantly different from untreated check (78.41%). Kaur *et al.* [20] who found that *A. calamus* at 1g/100g of treated pea seeds no damage was observed. Regarding adult beetle emergence, no adult beetles emerged from *A. calamus* 2 percent rhizome powder treated black gram seeds which was followed by *O. canum* (16. 66 Nos), *S. nigrum* (26.66 Nos) and *Coriandrum sativam* (35.00Nos) among the different insecticidal plant powders highest adult beetles was emerged from *L. aspera* (51.55 Nos) as compared with untreated control 100.66 adult beetles were emerged (Table 3). The results were in agreement the findings of Rathod *et al.* [29] who stated that *A. calamus* rhizome powder @ 10g/kg of green gram treated seeds results showed that no emergence of *C. maculatus*.

Regarding the seed weight loss, no seed weight loss was recorded. *A. calamus* 2 per cent rhizome powder treated black gram seeds, This studies agreement with findings of Kaur *et al.*, [20] stated that No seed damage and weight loss was recorded in pea seeds treated with sweet flag powder at 3g/100g and 5g/100g doses next best treatment is *Ocimum canum* (10.28 %), *Cardiospermum helicacabum* (11.63 %), *Solanum nigrum* (17.20 %) and *Coriandrum sativam* (18. 58 %) among the insecticidal plants maximum seed weight loss was observed in *Leucas aspera* (27.50 %) while, 30.91 percent loss was registered in control.

At 45 DAT, minimum seed weight loss was (14.83%) observed in grain treated with *O. canum* which was statistically on par effect with *C. helicacabum* (15.86%) followed by followed by *S. nigrum* (19.20%) > *C. sativam* (20.95%) > *A. aspera* (23.64%) and *L. aspera* (29.50%), respectively as compared untreated (35.25%). Present study already documented and confirmed by Rathod *et al.* [29] who found that *O. canum* leaf powder @ 3g / kg of green gram treated green gram seeds results showed least weight losses observed. At 60 DAT, minimum percentage of seed weight loss was observed in *O. canum* (19.24 %) which was statistically on par effect with *C. helicacabum* (21.50%), *C. sativam* (22.84%) and *S. nigrum* (23.64%) as compared to untreated (40.26%) (Table 4). *A. calamus* was significantly superior to all other treatments in inhibiting the oviposition, hatchability, adult emergence and seed weight loss.

Effect different concentration of *Acorus calamus* rhizome powder on *C. maculatus*

Insecticidal action on *C. maculatus*

The screening on insecticidal plant powders tested against *C. maculatus* (Table 2) based on screening results showed the *Acorus calamus* rhizome powder have 100 percent mortality within 24 hrs. This plant have highly effective and controlling the pulse beetle. *Acorus calamus* selected for further experiment on different concentrations tested for insecticidal action against *C. maculatus*. *A. calamus* rhizome powder at 0.50, 1.00, 1.50 and 2.00 percent concentrations. Data on mortality of *C. maculatus* after 1, 2 and 3 days after treatments were recorded. Results (Table 4) revealed that *A. calamus* at 2.00 percent was significantly different from all other treatments with 56.55 percent mortality after 1 DAT next best dose 1.50 percent (50.97) and 1.00 percent (44.55) among the four concentrations minimum mortality was observed in lowest dose at 0.50 percent. All the beetles were dead in *A. calamus* at 1.50 and 2.00 per cent except in *A. calamus* at 0.50 percent (98.77%) and 1.00 percent (99.00%) at 2 DAT. At 3 DAT, cent percent mortality was seen in A. *calamus* 0.50 and 1.00 per cent also. The present finding could be substantiated with the findings of Kaur *et al.* [20] who found that A. *calamus* 1.50 and 2.00 percent treated peas seeds showed 100.0 percent mortality with in three days after treatment.

Effect different concentration of *Acorus calamus* rhizome powder on oviposition, hatchability and adult emergence of *C. maculatus* and seed weight loss

Callosobruchus maculatus laid significantly variable number of eggs on black gram seeds treated with different concentrations of *A. calamus viz*., 0.50, 1.00, 1.50 and 2.00 percent (Table 5). Few eggs were laid by female in *A. calamus* 2.00 percent (9.00Nos) which dose statistically on par with *A. calamus* 1.50 percent (10.60 Nos) and *A. calamus* 1.00 percent (12.00 Nos). Similar results were reported by Kaur *et al.* [20] who found that *A. calamus* 1.50 and 2.00 percent treated peas seeds showed only few eggs laid compared to untreated control. Among the four different concentrations of *A. calamus*, maximum eggs were laid by female in *A. calamus* 0. 50 percent (17.55 Nos) as compared to untreated 265 eggs were laid.

Regarding the egg hatchability was significantly less in *A. calamus* 2.00 percent. No adult beetle emergence was observed in all the treatments *viz*., *A. calamus* 1.00, 1.50 and 2.00 percent except in *A. calamus* 0.50 percent as compare with untreated 148 adult beetles were emerged. The present findings also collaborate with the findings of Kaur *et al.* [20] who found that *A. calamus* 2.00 percent coated black gram seed showed complete inhibition of pulse beetle *C. chinensis* adult emergence in pea. Regarding the seed weight loss no weight loss was observed in *A. calamus* 1.00, 1.50 and 2.00 percent. Lower dose of *A. calamus* 0.50 percent caused 30 DAT (1.15 %), 45DAT (2.25 %) and 60 DAT (3.55 %) as compare with untreated 30 DAT (26.25%), 45DAT (29.44%) and 60 DAT (38.22%). The results were in agreement the findings of Rathod *et al.*, [29] who observed that *Acorus calamus* rhizome powder @ 2.00 per cent treated green gram seeds results showed that no seed weight loss were observed.

Conclusion

Study the effect of seven insecticidal plant powders against *C. macultus* infesting the stored black gram the results revealed that the efficacy of various powders among them, *Acorus calamus* 2 per cent rhizome powder caused 100.00 percent mortality to pulse beetle two days after treatment. *A. calamus* caused complete inhibited egg laying and progeny development and also no weight losses recorded up to 60 days after treatment. Different concentration of *A. calamus* experiment results concluded that all the four dose of *A. calamus* (0.50, 1.00, 1.50 and 2.00 %) highly effective against *C. macultus* viz., mortality, oviposition adult emergence and seed weight loss. Therefore, the resource poor farmers can use botanicals namely, sweet flag, *A. calamus* powder in controlling pulse beetle is stored black gram as they may not afford to buy chemical pesticides due to high cost. Furthermore, the use of botanical pesticides to control pulse beetle is an appropriate strategy to avoid environmental pollution and other hazards, since the chemical pesticides are used by farmers and in agro industries currently.

Table 2: Effect of insecticidal plant powders on the adult mortality of pulse beetle, *Callosobruchus maculatus* (F.)

S. No.	Treatments*	% Adult mortality**							Mean
		1 DAT	2 DAT	3 DAT	4 DAT	5 DAT	6 DAT	7 DAT	
1	*Acorus* calamus 2 %	40.55 (38.59)a	100. 00) (89.47)a	100.00 (89.47)a	100.00 (89.47)a	100.00 (89.47)a	100.00 (89.47)a	100.00 (89.47)a	91.42 (82.20)
2	*Solanum nigrum* 2%	5.55 (13.47)b	37.77 (37.92)b	52.22 (46.28)b	57.77 (49.49)b	68.88 (56.10)b	78.88 (62.71)b	89.99 (71.72)b	54.91 (47.42)
3	*Achranthes aspera* 2 %	4.44 (11.99)b	14.44 (21.87)d	27.77 (31.79)c	33.33 (35.24)cd	54.44 (47.56)c	68.88 (56.10)c	83.33 (65.97)b	41.90 (39.47)
4	*Coriandrum sativam* 2%	4.44 (11.99)b	8.88 (17.27)e	17.77 (24.91)d	24.44 (29.61)d	31.11 (33.89)e	47.55 (43.58)e	48.88 (44.36)e	26.15 (29.37)

5	*Leucas aspera* 2%	4.44 (11.99)b	18.88 (25.68)c	27.77 (31.76)c	44.44 (41.80)c	47.77 (43.72)cd	53.33 (46.91)d	65.65 (54.06)d	37.45 (36.56)
6.	*Cardiospermum helicacabum* 2 %	7.77 (16.11)c	21.11 (27.33)c	28.88 (32.50)c	39.99 (39.22)c	67.77 (51.41)b	69.99 (56.81)c	78.88 (62.66)c	44.91 (41.43)
7.	*Ocimum canum* 2%	7.77 (16.11)c	11.11 (19.42)d	19.99 (26.51)d	29.97 (33.17)d	43.33 (41.11)d	59.99 (50.77)d	73.33 (58.93)c	35.07 (35.15)
8.	Control	0.00 (0.52)d	8.88 (17.27)f	14.44 (22.30)e	17.77 (24.91)e	31.11 (33.89)f	36.66 (37.25)e	51.11 (45.63)f	22.85 (25.97)

DAT- Days after treatments
***** Mean of three replications
**Figures in parentheses are transformed arcsine values
In a column means followed by same letter(s) are not significantly different (p=0.05) by DMRT

Table 3: Effect of insecticidal plant powders on oviposition, hatchability and adult emergence of *Callosobruchus maculatus* (F.)

S. No.	Treatments***	No. of eggs laid /5 females *	Hatchability** %	No. of adults emerged *	% Seed weight loss **		
					30 DAT	45DAT	60 DAT
1	*Acorus calamus 2 %*	0.00 (0.00)a	0.00 (0.52)a	0.00 (0.00)a	0.00 (0.52)a	0.00 (0.52)a	0.00 (0.52)a
2	*Solanum nigrum* 2%	47.66 (1.67)c	75.28 (60.25)c	26.66 (1.42)c	17.20 (24.49)c	19.20 (25.36)c	23.64 (26.91)b
3	*Achranthes aspera* 2 %	81.66 (1.91)d	73.07 (58.79)c	45.00 (1.56)e	20.45 (27.96)cd	23.64 (26.90)c	27.14 (31.34)c
4	*Coriandrum sativam* 2%	49.66 (1.70)c	87.08 (72.41)de	35.55 (1.55)d	18.58 (25.53)c	20.95 (26.93)c	22.84 (25.39)b
5	*Leucas aspera* 2%	72.33 (1.24)d	82.59 (65.65)d	51.55 (1.74)f	27.50 (31.71)d	29.50 (32.75)d	30.91 (33.85)d
6	*Cardiospermum halicacabum*	80.00 (1.90)e	70.47 (57.08)c	39.00 (1.58)d	11.63 (19.93)b	15.86 (23.41)b	21.50 (31.66)b
7	*Ocimum canum* 2%	42.44 (1.64)b	56.67 (48.86)b	16.66 (1.28)b	10.28 (18.78)b	14.83 (22.42)b	19.24 (25.38)b
8	Control	121.00 (2.14)f	78.41 (62.55)f	100.66 (2.00)g	30.91 (33.85)e	35.25 (36.83)d	40.26 (42.88)^{e}

DAT- Days after treatments
*Figures in parentheses are transformed square root values
** Figures in parentheses are transformed arcsine values
*** Mean of three replications
In a column means followed by same letter(s) are not significantly different (p=0.05) by DMRT

Table 4: Insecticidal action of different concentration of *Acorus calamus* rhizome powder on *Callosobruchus maculatus* (F.).

S. No.	Treatments*	% Adult mortality**			
		1DAT	2 DAT	3DAT	Mean
1	*A. calamus* 0.50%	35.66 (37.25)d	98.77 (82.80)b	100.00 (89.47)a	78.14 (69.84)
2	*A. calamus* 1.00%	44.55 (42.44)c	99.00 (89.47)a	100.00 (89.47)a	81.85 (73.80)
3	*A. calamus* 1.50%	50.97 (44.99)b	100.00 (89.47)a	100.00 (89.47)a	83.32 (74.65)
4	*A. calamus* 2.00%	56.55 (48.18)a	100.00 (89.47)a	100.00 (89.47)a	85.18 (75.71)
5	Control	4.44 (3.85)e	8.88 (17.27)e	17.77 (24.91)e	10.36 (15.34)

DAT- days after treatments
* Mean of three replications
** Figures in parentheses are transformed arcsine values
In a column means followed by same letter(s) are not significantly different (p=0.05) by DMRT

Table 5: Effect of different concentration of *Acorus calamus* rhizome powder on oviposition, hatchability and adult emergence of *C. maculatus* and seed weight loss

S. No.	Treatments***	No. of eggs laid *	Hatchability % **	No. of adults emerged *	% Seed weight loss **		
					30 DAT	45DAT	60DAT
1	*A. calamus* 0.50%	17.55 (1.29)c	55.70 (48.80)b	2.00 (0.46)b	1.15 (5.99)b	2.25 (5.99)b	3.55 (5.99)b
2	*A. calamus* 1.00%	12.00 (1.11)b	54.40 (48.70)b	0.00 (0.00)a	0.00 (0.52)a	0.00 (0.52)a	0.00 (0.52)a
3	*A. calamus* 1.50%	10.60 (1.06)a	58.70 (31.76)a	0.00 (0.00)a	0.00 (0.52)a	0.00 (0.52)a	0.00 (0.52)a
4	*A. calamus* 2.00%	9.00 (0.90)a	57.85 (49.50)a	0.00 (0.00)a	0.00 (0.52)a	0.00 (0.52)a	0.00 (0.52)a
5	Control	265.00 (2.42)d	75.20 (60.85)c	148.50 (2.17)c	26.25 (30.78)c	29.44 (32.82)c	38.22 (36.82)c

DAT – days after treatments,
*Figures in parentheses are transformed logarithmic values
** Figures in parentheses are transformed arcsine values
*** Mean of three replication
In a column means followed by same letter(s) are not significantly different (p=0.05) by DMRT

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