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Evaluation of Eco-friendly Seed Protectants Against Lesser Grain Borer, *Rhizopertha dominica* in Paddy, *Oryza sativa* L. under Storage

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ABSTRACT: Safe storage of grains against insect damage is a serious concern. Usage of chemicals are detrimental effect on human as well as environment so plants parts are known to be a potential source of insecticidal properties with safer to human. Keeping in this view the effectiveness of plant derived products for the management of the lesser grain borer, *Rhizopertha dominica* Fab, a laboratory experiment was carried out during 2018 in stored paddy. Seeds were treated with inorganic insecticides include Emamectin benzoate 5SG @ 2 ppm kg^{-1} and Delatmethrin 2.8 EC @ 1 ppm/kg and botanicals such as Neem azal 1.0 EC 10000 ppm, *Karanji* oil at 5 ml/kg, Citronella oil at 5 ml/kg and *Acorus calamus* at 10 ml/kg seed and untreated check. All treatments were found to be superior in controlling pest population in storage condition. Among the botanicals treated, *Acorus calamus* was found to be best in recorded maximum germination percentage (95.00%), moisture content (11.89%), adult morality (90.54%), 100 seed weight (1.38) and minimum number of live adults (0.01%), weight loss (1.47%) and grain damage (6.00%) upto 90 days of storage. Therefore, *Acorus calamus* @ 10 ml kg^{-1} seed has found effective in maintaining the seed quality with minimum seed infestation up to ninety days of storage in paddy grains.

Keywords: paddy, lesser grain borer, *Rhizopertha dominica,* management, botanicals.

INTRODUCTION

India stands second position in production of rice globally after China. Rice is a significant food grain crop in, and among the countries that trade rice internationally, it ranks second only to Thailand in terms of exports. However, grains were kept on hand for both domestic consumption and retail sales. It was reported that 80 % of all grain produced is thought to be stored on farms or in small towns. Insects, microbes, and vertebrates (birds and rodents) are the main causes of losses to food grain in storage. Post-harvest loss includes direct, physical and quality losses that reduce the crop's economic value or may render it unfit for human consumption. In the worst-case circumstances, those certain losses could represent up to 80% of the total output. The losses of stored grains accounted for 7 to 8% of all economic losses, or about Rs. 600 to 700 crores (Jadhav, 2006).

Cereal grains are the main component of the average human diet, but losses from storage can amount up to 50% of the total harvest, with insect damage to paddy fields accounting for the majority of both quantitative and qualitative losses. *Rhizopertha dominica*, a storage pest known as the lesser grain borer, was regarded as a major pest because both its larva and adult stage feed on whole, sound grains and cause major damage (Chandel *et al*., 2021). The adult beetle is a strong flyer and can migrate quickly to start a new infestation elsewhere (Obretenchev *et al*., 2020). This pest's adults and larvae damage sound grains by consuming the starchy matter of the endosperm and leaving behind hollow grains with irregular holes, as well as the formation of fine dust, which produces an unpleasant odour and renders the grain un-consumable (Mahroof *et al*., 2010).

Using of various synthetic chemicals resulted on negative impact on human and as well as environment.

Over reliance on pesticide with our regard to the complexities of agro ecosystem had created well known pollution problem. It has caused the emergence of new pests, the development of pesticide resistance, secondary outbreak of pest, the death of non-target organisms like parasitoids as well as predators, and direct toxicity to humans and the environment (Negahban and Moharramipour 2007). To resolve these issues, an alternative strategy is required. Recent pest management strategies have recommended using insecticides from plant origins because they are less expensive, target specific more environmentally friendly to meet sustainability (Ileke and Olotuah 2012). Due to their diverse phytochemical components and effectiveness as oviposition deterrent, antifeedant, repellant, toxicant and fumigant activities, essential oils from plant species are increasingly gaining attention among the diverse pool of plant secondary metabolites (Singh *et al.,* 2014). The insecticidal activity of *A. calamus* against *R. dominica, C. chinensis* and other stored coleopterans has been reported previously (Kim *et al*., 2003; Nandi *et al.,* 1991). Many of such chemicals belonging to various groups such as terpenoids, phenolic compounds and glucosinolates have been found to possess significant pest control properties against fields and storage pests (Rajendran and Sriranjini 2008). They are believed to be easily biodegradable and not toxic to non-targeted organisms. Moreover, prior to the discovery of the organochlorine and organophosphate insecticides in the late 1930s and early 1940s, botanical insecticides have remained an important weapon in the farmer's armory in managing insect pests of their farm produce (Fernandes *et al.,* 2012). Keeping in view above, the present studies were planned to evaluate various botanicals and insecticide against *R. dominica* in stored rice grain.

MATERIALS AND METHODS

To investigate the effectiveness of botanicals and insecticides against the lesser grain borer, *Rhizopertha dominica* a supervised laboratory experiment was conducted during 2018 in the Department of Agricultural Entomology, Pandit Jawaharlal Nehru college of Agriculture and Research Institute, Karaikal, Union Territory of Puducherry. 250 grams of seeds of ADT 45 rice variety was treated with botanicals and insecticides and shade dried for one hour. The treated seeds were further transferred into containers (16 × 9 cm) of 750 ml capacity. 10 pairs of adults (1-2 days old) were released into the containers. Experiments were laid out in a statistical design - Completely Randomized Block Design (CRBD) with 7 treatments and 3 replications.

Assessment of biological parameters. The biological parameters such as germination percentage, weight loss, percentage of infestation live adults, mortality, moisture content, hundred seed weight were analysed.

Germination percentage. The germination test was carried out with 50 seeds selected from three replications of each treatment in petri plate method prescribed by ISTA (Anon, 1976). The temperature was maintained at 20- 30º C and germination period of 7 days was adapted throughout the study. The germination test was conducted at before treatment and after treatments (Patel, 2001).

$$\text{Percentage of germination} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds used}} \times 100$$

Estimation of Moisture content. The estimation of seed moisture content was done using Indosaw digital moisture meter and expressed in percentage.

Hundred Seed weight. Randomly selected 100 seeds were weighed using electrical weighing balance and expressed in grams.

Number of live adults. The data on number of live adults was taken for 15, 30 and 60 days after release of beetle was calculated in percentage (Odeyemi and Daramola 2000).

$$\text{Number of live adults} = \frac{\text{Number of live adults}}{\text{Total number of adult allowed}} \times 100$$

Adult mortality. The data on adult mortality was taken for 15, 30 and 60 days after release of beetle. Formula for calculating percentage mortality was given below (Odeyemi and Daramola 2000).

$$\text{Percentage of mortality} = \frac{\text{Number of adult dead}}{\text{Total number of adult allowed}} \times 100$$

Percentage of infestation. From each treatment 100 seeds were taken and total number of grains, number of bored grains were counted with formula (Odeyemi and Daramola 2000).

$$\text{Percentage of infestation} = \frac{\text{No. of bored grains}}{\text{Total no. of grains in the sample}} \times 100$$

Weight loss. 100 seeds were selected randomly and the initial and final weight in each of the treatments were noted and expressed in percentage (Padin *et al.,* 2002).

Percentage weight loss =

$$\frac{\text{Initial weight of grains - Final weight of grains}}{\text{Initial weight of grains}} \times 100$$

Statistical analysis. For statistical analysis, the percentage data for germination, weight loss, and infestation were converted into the corresponding angular transformation (Arcsine), and 100 seed weight number of live adults were calculated if the values were converted into the corresponding square root transformation, which ranged from 0 to 100. A completely random block design was used to analyse the laboratory experiment's data and perform a "F" test to determine its significance (Panse and Sukhatme 1985). The treatment mean values of the experiments were compared using Duncan's Multiple Range Test (DMRT), and Standard Error of Difference (S. Ed) values were computed at the 5% probability level (Gomez and Gomez 1984)

RESULTS AND DISCUSSION

Germination percentage. Efficacy of botanicals and insecticides were treated over 90 days of paddy grain in storage showed significant difference among all treatments. Before treatment, the germination ranged from 97.00 to 98.00 per cent. At 30 days after treatment, the per cent germination ranged from 88.67 to 97.00 percent and it was in a decreasing trend. A higher germination was observed in the treatment with *Acorus calamus* @10ml (96.33%), neem azal 1EC @ 10000ppm (95.00%), citronella oil @ 5ml (95.00%), karanji oil @ 5ml (94.00%) when compared to other treatments. Whereas lower germination was observed in the treatment with insecticidal treatments about 88.67 and 90.00 percent germination on deltamethrin 2.8EC @ 1ppm and emamectin benzoate 5SG @ 2ppm recorded compared to untreated check. Similar trend was observed in 60 DAT. At 90 DAT, it was found that the germination was more in the treatment with untreated check with 96.00 percent germination and are at par with *Acorus calamus*@ 10 ml (95.00 %), citronella oil @ 5ml (91.67 %), neem azal 1.0 EC @ 10000ppm (92.67%), karanji oil@ 5ml (90.33%) and lowest was recorded with deltamethrin 2.8EC @ 1ppm (69.67 %) and emamectin benzoate 5SG @ 2ppm (75.67%). It was concluded that botanicals were superior and found to be effective represented in Table 1.

Table 1: Effect of botanicals and insecticides on germination and moisture content against the lesser grain borer *Rhizopertha dominica* in the paddy variety ADT 45.

Sr. No.	Treatments	Dose / conc (per kg of seed)	Germination (%)				Moisture (%)			
			Before treatment	30 DAT	60 DAT	90 DAT	Before treatment	30 DAT	60 DAT	90 DAT
1.	Emamectin benzoate 5SG	2 ppm	97.67 (81.25)	90.00 (71.56)^{e}	82.67 (65.40)^{d}	75.67 (60.44)^{c}	13.96 (21.93)	13.95 (21.92)^{g}	13.92 (21.90)^{f}	13.88 (21.87)^{e}
2.	Deltamethrin 2.8 EC	1 ppm	97.67 (81.25)	88.67 (70.33)^{d}	79.67 (63.19)^{d}	69.67 (56.58)^{d}	14.04 (22.00)	13.78 (21.79)^{f}	13.71 (21.73)^{e}	13.68 (21.70)^{d}
3.	Neem azal 1.0 EC	10000 ppm	97.67 (81.25)	95.00 (77.07)^{b}	94.33 (76.24)^{b}	92.67 (74.29)^{ab}	14.04 (22.00)	12.68 (20.86)^{c}	12.00 (20.73)^{b}	11.97 (20.24)^{b}
4.	Karanj oil	5 ml	97.00 (80.02)	94.00 (75.82)^{c}	93.00 (74.65)^{c}	90.33 (71.89)^{ab}	13.96 (21.93)	12.86 (21.01)^{d}	12.75 (20.92)^{d}	12.04 (20.30)^{bc}
5.	Citronella oil	5 ml	97.33 (80.64)	95.00 (77.07)^{b}	94.33 (76.24)^{b}	91.67 (73.22)^{ab}	14.04 (22.00)	13.10 (21.21)^{e}	12.20 (20.44)^{c}	12.00 (20.26)^{bc}
6.	*Acorus calamus*	10 ml	97.33 (80.64)	96.33 (78.98)^{b}	95.00 (77.07)^{b}	95.00 (77.82)^{a}	13.98 (21.95)	12.45 (20.65)^{b}	12.00 (20.68)^{b}	11.89 (20.16)^{a}
7.	Control	-	98.00 (81.87)	97.00 (80.02)^{a}	96.67 (79.50)^{a}	96.00 (78.46)^{a}	14.03 (22.00)	12.21 (20.45)^{a}	11.89 (20.16)^{a}	12.00 (20.26)^{bc}
S.E(d)			NS	1.32	1.72	1.42	NS	0.20	0.22	0.36
CD				0.51*	1.11*	0.87*		0.03*	0.01*	0.03*
C.V %				0.68	0.86	0.71		0.10	0.20	0.18

In a column mean followed by a common letter are not significantly different by DMRT (P=0.05)
Values in Parentheses are Arc sine transformed values
* - Significant at P = 0.05; NS – Non-Significant
DAT – Days after treatment; #-Mean of 3 replications

Moisture percentage. The moisture content was recorded from before treatment and continued upto 90 DAT in storage condition. Before the treatments, the moisture content ranged from 13.96 to 14.03 per cent were in decreasing trend (Table 1). After the 30, 60 and 90 DAT, the moisture content ranged from 12.21 to 13.95, 11.89 to 13.92 and 11.89 to 13.88, respectively. At 30 DAT, highest moisture content was recorded with untreated check (12.21 %) followed *Acorus calamus*@ 10 ml with 12.45 percent of moisture content and neem azal 1.0EC @ 10000ppm (12.68 %) compared to other treatments and lowest was recorded with synthetic chemicals. At 60 DAT, untreated check (11.89 %) followed *Acorus calamus*@ 10 ml with 12.00 percent of moisture content and citronella oil @ 5ml (12.20 %) were superior among the treatments and lowest was recorded with deltamethrin 2.8EC @ 1ppm (13.71%) and emamectin benzoate 5SG @ 2ppm (13.92%) at 30 and 60 DAT. At 90 DAT, *Acorus calamus*@ 10 ml (11.89%), followed by neem azal 1.0EC @ 10000ppm (11.97 %) and at par with citronella oil @ 5ml (12.00 %), karanji oil @ 5ml (12.04 %), untreated check (12.00%) and least recorded with deltamethrin 2.8EC @ 1ppm (13.68%) and emamectin benzoate 5SG @ 2ppm (13.88 %).

100 seed weight. Initial 100 seed weight ranged from 1.46 to 1.48 g and it was found that there was no significant difference among the treatments (Table 2). At 30 days after treatment, the 100 seed weight was in a decreasing trend and ranged from 1.29 to 1.42g. The 100 seed weight was higher in the treatment in the neem azal 1EC @ 10000ppm (1.42g) followed by *Acorus calamus* @ 10ml (1.38g), untreated check (1.39g), deltamethrin 2.8EC @ 1ppm (1.35g), citronella oil @ 5ml (1.35g) and lower seed weight was observed in karanji oil @ 5ml (1.33g) and emamectin benzoate

5SG @ 2ppm (1.29g). A higher seed weight was observed in the treatment with neem azal 1EC@ 10000 ppm (1.42g) compared to other treatments. At 60 DAT, there was a slight difference in among the treatments but *Acorus calamus* @ 5ml and neem azal 1EC @ recorded highest 100 seed weight of 1.39g compared to other treatments and there was no significant difference among the treatments. At 90 DAT, the 100 seed weight was in a decreasing trend and ranged from 1.27 to 1.38g. The 100 seed weight was higher in the treatment with *Acorus calamus* @ 5ml (1.38g), followed by neem azal 1EC @ 10000ppm (1.33g) and at par with citronella oil @ 5ml and untreated check. The minimum seed weight of 1.31, 1.30 and 1.27g recorded in deltamethrin 2.8EC @ 1ppm, karanji oil @ 5ml and emamectin benzoate 5SG @ 2ppm and there was no significant difference among the treatments.

Live adults. At 30 DAT, the number of live adults ranged from 0.01 to 51.66 percent. A higher number of live adults was observed in the treatment with deltamethrin 2.8 EC@ 1ppm (20.00%) and are at par with neem azal 1.0 EC @ 10000ppm (18.33%), karanj oil @ 5ml (13.33%), citronella oil @ 5ml (10.00%), while a lower number of live adults was recorded in *Acorus Calamus* @ 10 ml (3.33%) (0.01%) compared to control (51.66%). At 60 DAT, the number of live adults ranged from 0.01 to 41.66 percent and it was in a decreasing trend. A higher number of live adults was observed in the treatment with karanj oil@ 5ml (13.33%) and are at par with neem azal 1.0 EC @ 10000ppm (8.33%), citronella oil @ 5ml (3.33%) and lower number adults was observed in emamectin benzoate 3G @ 2ppm (0.01%), deltamethrin 2.8EC @ 1ppm (0.01%), *Acorus calamus* @ 10ml (0.01%), compared to control (41.66%). At 90 DAT, the number of live adults was in a decreasing trend and ranged from 0.01 to 33.33 per cent was in a decreasing trend. A lower number of live adults was observed in the treatment with *Acorus calamus* @ 10ml and at par with citronella oil @ 5m, neem azal 1.0 EC @ 0000ppm, emamectin benzoate 3SG @ 2ppm with 0.01 percent, followed by karanj oil@ 5ml (2.33%) and deltamethrin 2.8EC @ 1ppm (0.01%) compared to control (33.33%) (Table 2).

Adult Mortality. The calculated percent mortality at 30, 60 and 90 days of the storage period were presented in Table 2. At 30 DAT, the adult mortality ranged from 14.98 to 46.08 per cent. Adult mortality was higher in the treatment with *Acorus calamus* @ 10ml (46.08%) and neem azal 1EC@ 10000 ppm (45.89%) and at par with citronella oil @ 5ml (43.80%), deltamethrin 2.8EC @ 1ppm (43.91%) and emamectin benzoate 5SG@ 2ppm (42.29%), whereas lower adult mortality was observed in the treatment karanji oil @ 5ml with 33.70 per cent compared to control (14.98%). At 60 and 90 DAT, the adult mortality ranged from 11.01 to 66.48 and 90.54 to 10.22 per cent. A lower adult mortality was observed in the treatment with *Acorus calamus* @ 10ml (66.48 and 90.54 %) at par with other treatments compared to the control (11.01%) and deltamethrin 2.8EC @ 1ppm showed least mortality with 63.29 and 73.64 per cent, respectively (Table 2).

Grain damage. The grain damage was recorded after treatments and continued upto 90 days in storage condition (Table 3). After the 30, 60 and 90 DAT, the grain damage ranged from 4.00 to 13.33, 4.33 to 9.66 and 6.00 to 19.67, respectively. At 30 DAT, lowest grain damage was recorded with *Acorus calamus*@ 10 ml with 4.00 percent and at par with karanj oil@ 5ml (5.00%), deltamethrin 2.8EC @ 1ppm (5.66%) and neem azal 1EC@ 10000 ppm (8.33 %) compared to untreated check and highest was recorded with citronella oil @ 5ml (12.00%), emamectin benzoate 3SG @ 2ppm (13.33%). At 60 DAT, *Acorus calamus*@ 10 ml with 4.33 per cent recorded minimum grain damage and at par with karanji oil @ 5ml (2.66 %), neem azal 1.0EC @ 10000ppm (4.66%), citronella oil @ 5ml (7.33%), emamectin benzoate 5SG @ 2ppm (5.33%) were superior among the treatments and highest damage was recorded with deltamethrin 2.8EC @ 1ppm (7.00%). At 90 DAT, least damage was recorded with *Acorus calamus*@ 10 ml (6.00%) and citronella oil (6.66%) and at par with emamectin benzoate 5SG @ 2ppm (8.00%), neem azal 1.0EC @ 10000ppm (9.00 %) and karanj oil@ 5ml (10.00 %) compared to untreated check (15.67%) and height grain damage with deltamethrin 2.8EC @ 1ppm (19.67%), respectively.

Weight loss. Among different botanicals and insecticides evaluated, the seeds treated with *A. calamus* @ 10 ml was recorded significantly lowest weight loss of 1.49, 1.47 and 1.47 per cent at 30, 60 and 90 DAT, while significantly maximum loss was observed in untreated check (Table 3). At 30 DAT, minimum weight loss was recorded with *Acorus calamus* @ 10ml (1.49 %) and at par with neem azal 1EC@ 10000 ppm (1.48%), emamectin benzoate 5SG@ 2ppm (1.48%) citronella oil @ 5ml (1.48%) and karanji oil @ 5ml (1.46%) and maximum loss was observing with deltamethrin 2.8EC @ 1ppm (1.48%) compared to untreated check. Among all treatments evaluated weight loss were slightly in decreasing trend at 60 DAT. At 90 DAT, *Acorus calamus* @ 10ml (1.47%) and at par with citronella oil @ 5ml (1.45%), neem azal 1EC@ 10000 ppm (1.47%), emamectin benzoate 5SG@ 2ppm (1.47%) and deltamethrin 2.8EC @ 1ppm (1.44%). Lowest weight loss was recorded with karanji oil @ 5ml (1.45 %) compared to untreated check.

All the botanicals and insecticide evaluated were superior in controlling lesser grain borer, *R. dominica.* The overall order of efficacy for all biological parameters were *Acorus calamus* oil @ 10 ml > citronella oil @ 5ml > neem azal 1.0EC @ 10000ppm >

karanji oil @ 5ml > emamectin benzoate 5SG @ 2ppm > deltamethrin 2.8EC @ 1ppm.

Essential volatile compounds commonly contain mono- and sesquiterpenoids, which cause neuromascular toxicity in insects by inhibiting acetylcholine esterase activity, GABA gated ion channels, and octopamine receptors (Cao *et al.,* 2019). The cytotoxic intermediate product methylglyoxal has been shown to be inhibited by essential oils and bioactive substances, indirectly lowering aflatoxin secretion in preserved food products (Das *et al.,* 2021). Form our present findings *A. Calamus* caused the less damage with the least amount of beetle population growth, which is consistent with (Yao *et al.,* 2008) who discovered that *A. calamus* contains a active compound called β-asarone that has excellent insecticidal properties against storage pest. Similarly, rhizome of *A. calamus* contains 7493.59 ml/kg of volatile compounds, of which 46.78 per cent were β-asarone compounds (Gyawali and Kim 2009). Essential oils from sweet flag and their plant extracts act as antimicrobial, antifeedant and insecticidal property. Secondary metabolites from sweet flag oil showing effects on stored grain insects, such as repellent, deterring insects from feeding, killing, preventing the development or growth of insects and sterilizing them (Hyldgaard, *et al.,* 2012).

Highest adult mortality and germination percentage was recorded in *Acorus calamus* rhizomes @ 2 percent with 91.11 % of mortality and 76.67 per cent germination found to be significantly superior among botanicals with up to 180 days for the management of *R. dominica* in stored maize seed (Swamy *et al*., 2019). Maize grains were stored for 10 months were treated against maize pest, resulted that grains treated with *Acorus calamus* @ 10 g per kg of seeds had recorded higher germination (87.3%), vigour index (2864), dry weight of seedlings (2.01g) with less infestation (3.60%) was reported by (Sandeep *et al.,* 2013). At a dose of 0.1 mL/mL, the fumigant toxicity of 32.6% and 97.3% repellent properties were recorded when grains treated *Acorus calamus* essential oil, whereas 100% mortality was observed with EO against *C. chinensis* (Shukla *et al.,* 2016). When compared to other treatments against rice weevil, *Sitophilus oryzae* seeds treated with *Acorus calamus* rhizome powder at 10 g/kg seed had the highest germination percentage (85.67) followed by other botanicals treated (Padmasri *et al.,* 2016). On laboratory bioassay conducted *Acorus calamus* @10 gm/kg was the most effective botanical powder to reduce grain damage (1.15%), 100 seed weight (1.22%), weight loss (0.84%) and population (1.54) of rice weevil on 90 days of storage (Pal *et al*., 2021).

Table 2: Effect of botanicals and insecticides on seed weight, number of live adults and adult mortality against the lesser grain borer *Rhizopertha dominica* in the paddy variety ADT 45.

Sr. No	Treatments	Dose / conc (per kg of seed)	100 seed weight (gms)				No. of live adults (10 pairs/ container)			Adult Mortality (%)		
			Before treatment	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
1.	Emamectin benzoate 5SG	2 ppm	1.48 (1.41)	1.29 (1.33)[e]	1.28 (1.33)[f]	1.27 (1.12)[e]	0.01 (0.64)[a]	0.01 (0.64)[a]	0.01 (0.57)[a]	42.29 (6.50)[b]	64.22 (8.01)[a]	89.26 (9.44)[ab]
2.	Deltamethrin 2.8 EC	1 ppm	1.46 (1.40)	1.35 (1.35)[c]	1.33 (1.35)[d]	1.31 (1.15)[c]	20.00 (15.52)[b]	0.01 (0.64)[a]	0.01 (8.56)[b]	43.91 (6.62)[ab]	63.24 (7.95)[a]	73.64 (9.14)[c]
3.	Neem azal 1.0 EC	10000 ppm	1.48 (1.41)	1.42 (1.38)[a]	1.39 (1.37)[a]	1.33 (1.51)[b]	18.33 (20.19)[b]	8.33 (13.74)[ab]	0.01 (0.57)[a]	45.89 (6.77)[a]	63.29 (7.96)[a]	90.52 (9.51)[a]
4.	Karanj oil	5 ml	1.46 (1.40)	1.33 (1.35)[d]	1.31 (1.34)[e]	1.30 (1.14)[d]	13.33 (20.46)[b]	13.33 (20.76)[b]	2.33 (8.56)[b]	33.70 (5.80)[c]	63.65 (7.97)[a]	86.42 (9.29)[bc]
5.	Citronella oil	5 ml	1.48 (1.41)	1.35 (1.35)[c]	1.33 (1.35)[d]	1.33 (1.52)[ab]	10.00 (17.47)[b]	3.33 (8.83)[ab]	0.01 (0.57)[a]	43.80 (6.61)[ab]	65.09 (8.06)[a]	89.87 (9.48)[ab]
6.	*Acorus calamus*	10 ml	1.49 (1.40)	1.39 (1.37)[b]	1.39 (1.37)[a]	1.38 (1.17)[a]	3.33 (8.61)[b]	0.01 (0.64)[a]	0.01 (0.57)[a]	46.08 (6.78)[a]	66.48 (8.15)[a]	90.54 (9.51)[a]
7.	Untreated check	-	1.48 (1.40)	1.39 (1.37)[b]	1.35 (1.36)[b]	1.32 (1.52)[ab]	51.66 (45.97)[b]	41.66 (43.41)[c]	33.33 (35.02)[c]	14.98 (3.86)[d]	11.01 (3.31)[b]	10.22 (3.19)[d]
S.E(d)			NS	0.32	0.24	0.05	5.13	3.54	2.52	3.72	3.26	2.50
CD				0.004*	0.003*	0.10*	0.03*	0.03*	0.02*	0.21*	0.21*	1.00*
C.V %				0.16	0.12	0.002	3.67	2.80	1.75	1.86	1.63	1.25

In a column mean followed by a common letter are not significantly different by DMRT (P=0.05)

Values in Parentheses are $\sqrt{X + 0.5}$ transformed values; Values in Parentheses are Arc sine transformed values

* - Significant at P = 0.05 ; NS – Non-Significant

DAT – Days after treatment; #-Mean of 3 replications

Table 3: Effect of botanicals and insecticides on grain damage and weight loss against the lesser grain borer *Rhizopertha dominica* in the paddy variety ADT 45.

Sr. No	Treatments	Dose / conc (per kg of seed)	Grain Damage (%)			Weight Loss (%)			
			30 DAT	60 DAT	90 DAT	Before treatment	30 DAT	60 DAT	90 DAT
1.	Emamectin benzoate 5SG	2 ppm	13.33 (21.31)^{d}	5.33 (13.27)^{ab}	8.00 (16.25)^{ab}	1.48 (1.41)	1.48 (6.95)^{ab}	1.47 (6.95)^{a}	1.47 (6.91)^{abc}
2.	Deltamethrin 2.8 EC	1 ppm	5.66 (13.76)^{ab}	9.66 (17.92)^{b}	19.67 (26.00)^{bc}	1.46 (1.40)	1.46 (6.91)^{c}	1.45 (6.90)^{b}	1.44 (6.90)^{bc}
3.	Neem azal 1.0 EC	10000 ppm	8.33 (16.76)^{bc}	4.66 (12.46)^{ab}	9.00 (17.23)^{abc}	1.48 (1.41)	1.48 (6.97) ^{a}	1.47 (6.95)^{a}	1.47 (6.93)^{ab}
4.	Karanj oil	5 ml	5.00 (12.65)^{ab}	2.66 (9.36)^{a}	10.00 (17.52)^{abc}	1.46 (1.40)	1.46 (6.93)^{bc}	1.46 (6.91)^{b}	1.45 (6.88)^{c}
5.	Citronella oil	5 ml	12.00 (20.24)^{dc}	7.33 (15.26)^{ab}	6.66 (14.62)^{a}	1.48 (1.41)	1.48 (6.94)^{bc}	1.46 (6.92)^{b}	1.45 (6.94)^{a}
6.	*Acorus calamus*	10 ml	4.00 (11.32)^{a}	2.33 (12.00)^{a}	6.00 (13.65)^{a}	1.49 (1.40)	1.49 (6.97)^{a}	1.47 (6.69)^{a}	1.47 (6.94) ^{a}
7.	Untreated check	-	10.66 (19.06)^{ab}	7.00 (14.90)^{ab}	15.67 (26.80)^{c}	1.48 (1.40)	1.50 (6.02)^{d}	1.10 (5.44)^{c}	0.90 (5.18)^{d}
S.E(d)			1.613	2.182	4.18		0.48	0.49	0.68
CD			0. 05*	0.03*	0.10*	NS	0.02*	0.02*	0.03*
C.V %			3.45	5.67	7.77		0.24	0.24	0.30

In a column mean followed by a common letter are not significantly different by DMRT (P=0.05)
Values in Parentheses are Arc sine transformed values
* - Significant at P = 0.05; NS – Non-Significant
DAT – Days after treatment; #-Mean of 3 replications

CONCLUSIONS

It was concluded that *A. calamus* showed highest effectiveness in protecting rice grains from *R. dominca* infestation upto 90 days of storage. Plant-derived insecticides have long been a potent tool in farmers' weapon systems for controlling insect pests on their agricultural production. A greener alternative to synthetic preservatives with chemical origin, essential oils and insecticidal rich bioactive components from plants have strong insecticidal property, fungitoxicity in application and mycotoxin inhibitory activity, against pest, so therefore botanicals especially essential oil can be recommended in future for integrated pest management systems and IPM modules as ecofriendly and promoting sustainable agricultural production.

FUTURE SCOPE

One of the main topics of study for post-harvest engineers and entomologists is the safe handling and protection of stored items. Both emerging and developed nations are currently concerned with issues related to food safety and security. Given that modern botanical pesticides have fostered modern agriculture and are gradually replacing conventional insecticides, their potential on a global scale is larger. Draw attention to the rising demand for organic goods and other eco-friendly alternatives to some of the conventional pesticides. Due to their low risk to the environment and humans, botanical pesticides have long been regarded as viable alternatives to synthetic pesticides. When manufactured locally, botanical insecticides are less expensive than chemical pesticides. In the long run, they may be more effective than chemical insecticides. The market for biopesticides is modest in India. Due of their high cost, variable field effectiveness, short shelf life, and delayed benefits, farmers are reluctant to substitute biopesticides for chemical pesticides. Due to a lack of facilities for large-scale production, the market for biopesticides is also impacted. The lengthy and expensive registration procedure in India inhibits the advancement of biopesticides. Commercial manufacturing of botanical pesticides is more expensive than that of chemical pesticides because of the high cost of raw ingredients and the extraction procedure. However, there are significant obstacles in the development of biopesticides that should be taken into account in the future, including a lack of understanding about the advantages of biopesticides, product expertise, farmer confidence, an unpredictable supply, and inconsistent performance. If overcoming these issue, the use of plant products in pest management reaches sustainability and ecofriendly to farmer.

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