

**Traditionally used Botanicals: The potential source of *Tribolium castaneum* (Herbst) management**

**Abstract**

To solve the problem of *Tribolium castaneum* Herbst in wheat storage a study was conducted in Jorhat-13, Assam Agricultural University's Department of Entomology, in 2018. Wheat is widely used as staple food in the world including India. But storage condition wheat grains are infected by several coleopteran pests. *Tribolium castaneum* Herbst is a ubiquitous and pestiferous pest among all. Adult and larva both are harmful for wheat storage which often demolishes stored grains. Dry powders of *A. indica*, *C. roseus*, *C. heptaphylla*, *D. stramonium*, *E. tereticornis*, *M. struthiopteris*, and *V. negundo* were used against *T. castaneum* to get rid of problematic local medicinal plants. The highest LD<sub>50</sub> value was found in *A. indica* (1.49%) followed by *D. stramonium* (1.52%) and *E. tereticornis* (2.02%) and lowest LD<sub>50</sub> in *Matteuccia struthiopteris* (11.72%). In repellency test, highest rate of repellency was observed in *A. indica* (82.21%) followed by *D. stramonium* (72.59%), *E. tereticornis* (70.36%) and lowest in *Matteuccia struthiopteris* (32.58%). Based on LD<sub>50</sub> and mean repellency top three botanicals (*A. indica*, *D. stramonium*, *E. tereticornis*) were selected for further work e.g., mortality and weight loss. Mortality study recorded 100% mortality after 35 days of treatment in case of *A. indica*, *D. stramonium*, *E. tereticornis*. During the trial in 2018, *A. indica* (5.76%) had the lowest grain weight loss, followed by *D. stramonium* (12.05%) and *E. tereticornis* (12.05). The highest grain weight loss was observed in control with 62.33 per cent.

**Key word-** Wheat, *Tribolium castaneum*, Botanicals, LD<sub>50</sub> and Repellency.

**Introduction**

Wheat is one of the most important cereal grains, used widely as staple food in many countries for high nutritive values. The population is expected to grow to 9.1 billion people by the year 2050, and about 70% extra food production will be required to feed those (Godfray *et al.*, 2010). But the major constrains of storage wheat is the insect infestation and more than 600 different species of beetles, 70 species of moths, 355 species of mites, 40 species of rodents, and 150 species of fungi (Nattudurai *et al.*, 2017) attack wheat. Among them, *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) is a ubiquitous and pestiferous storage pest which often demolish stored grains specially wheat causes 328mg weight loss due to infestation of adults and larvae (Rathore, 2022). Due to infestation of this insect flour turns grayish and mouldy with pungent odour (Good, 1936; Roorda *et al.*, 1982; Hagstrum and Subramanyam, 2006).

Finding more effective and healthy substitutes has become required due to synthetic insecticide toxicity and resistance issues. Presently, plant extracts are the most commonly tested alternative products (Papachristos and Stamopoulos 2002; Umoetok and Gerard 2003; Ferrero *et al.*, 2006; Chopa *et al.*, 2006; Wang *et al.*, 2006). Botanicals contain many alkaloids and other secondary metabolites which have insecticidal and antifeedant properties against several storage pest (Khaleqzaman and Sultana, 2006; Anita *et al.*, 2012; Ramya *et al.*, 2008; Islam and Talukder, 2005); Kumral *et al.*, (2009) also described about the acaricidal, repellent, and oviposition deterrent activities of various botanicals.

To overcome the problems of synthetic pesticides, there is urgent needs of an eco-friendly, economically viable alternative pest control method which is affordable for poor farming communities, safe for workers health and higher returns (Sighamony *et al.*, 1990; Cobbinah and Appiah-Kwarteng, 1989; Niber, 1994; Jembere *et al.*, 1995; Lajide *et al.*, 1998;). Talukder (2006), listed 43 plant species as insect repellents, 21 plants as insect feeding deterrents, 47 plants as insect toxicants, 37 plants as grain protectants, 27 plants as insect reproduction inhibitors and 7 plants as insect growth and development inhibitors. Among the medicinal plants, several domestic plant species has been reported to be repellent and toxic to *T. castaneum* (Mareggiani *et al.*, 2000; Nikkon *et al.*, 2009; Suthisut *et al.*, 2011). Therefore, in the present study seven locally available and farmer's used plants dry powders were tested against *Tribolium castaneum* (Herbst) in Department of entomology, AAU Jorhat- 13 during 2018.

## **MATERIALS AND METHODS**

To find out the dry powders efficacy of seven botanicals *viz.* *Azadirachta indica*, *Catharanthus roseus*, *Clausena heptaphylla*, *Datura stramonium*, *Eucalyptus tereticornis*, *Matteuccia struthiopteris*, and *Vitex negundo* against *Tribolium castaneum* (Herbst). An experiment was carried out in 2018, in the Toxicology Laboratory of the Department of Entomology at AAU Jorhat-13.

Adults stage of *Tribolium castaneum* (Herbst) were collected from Post Harvest Laboratory, Department of Agricultural Engineering, Jorhat-13 for mass rearing (Abbasipour *et al.*, 2011). The fresh wheat seed (HD- 3086) was provided for feeding in eight different plastic containers (2 No's 29cm×12cm, 2 No's 32cm×13.50, 2 No's 25cm×12cm, 2 No's 22cm×11cm). The insect culture was maintained in toxicology laboratory, Department of Entomology, AAU Jorhat- 13, on room temperature 27- 30<sup>0</sup>C.

Leaves were collected and washed with tap water and kept in shade for air- drying. After complete drying, electric blender was used to make and fine powder and obtained by sieving through kitchen strainer (Agha *et al.*, 2017). For each plant leaf powder was used as 0.25, 0.50, 0.75, 1.00, 1.25, 1.75 and 2.50 gm / 25g seed were thoroughly mixed which correspondence to 1, 2, 3, 4, 5, 7 and 10 per cent (wt./wt.), (Ojo and Ogunleye, 2013). The treated seeds were stored in plastic containers (7 cm × 6 cm) at room temperature with three replications and 20 adults for each treatment. After 24, 48, and 72 hours of therapy, the mortality was calculated. If there was

mortality in control, Abbott's formula (1925) was used to rectify it. To get the LD50 value (wt/wt), probit analysis was used on the mortality data that was obtained.

For repellency test, 9 cm diameter petri dish was divided into three parts, treated, untreated and without grain part (Karakas, 2016). In treated part of the plate filled with 0.3gm of dry powder from each plant were mixed with 3gm of wheat seed (10% wt/wt) (Dhaniya and Dayanandan, 2016).

Test chamber with one side treated and the other untreated. Each petri dish middle area received ten insects, which were then released while being protected by a cover plate. Then, up until the sixth hour, the number of insects on each chamber was counted hourly. The formula below was used to get the percent repellency.

$$PR (\%) = (Nc-50) \times 2$$

Where: PR= % repulsion,

Nc= Percentage of weevils present in the control half.

According to Mc Donald et al. 1970, the grades of repellency (% repellency rate) were categorized. One ANOVA with the JMP SAS and IBM SPSS 20 packages was used to examine differences between distinct means.

Repellency rate (%) Class

> 0.01	-	0.1	0
0.1	-	20	I
20.1	-	40	II
40.1	-	60	III
60.1	-	80	IV
80.1	-	100	V

The four most effective botanicals were chosen from the LD50 testing. 10 gm dry powder of these botanicals was mixed with 100gm (10% w/w) seeds (Ojo and Ogunleye, 2013). The treated seeds were subsequently released along with 20 individuals (male and female, in a 1:1 ratio) to observe *T. castaneum* mortality. At 1, 3, 7, 14, 21, 28, 35, and 45 days, the number of dead insects was counted in order to assess mortality. Counting was stop after 45 days to avoid the overlapping generation (Devi *et al.*, 2014:). If mortality was found in control subjected to percentage of corrected mortality by Abbott's (1925).

The following formula was used to determine the weight loss of grains.

$$\% WL = (IW - FW) \times 100 / IW$$

Where, WL: Weight loss index.

IW: Initial weight and FW is the final weight.

## Results and discussion

### Dry powders' effectiveness in combating *Tribolium castaneum*

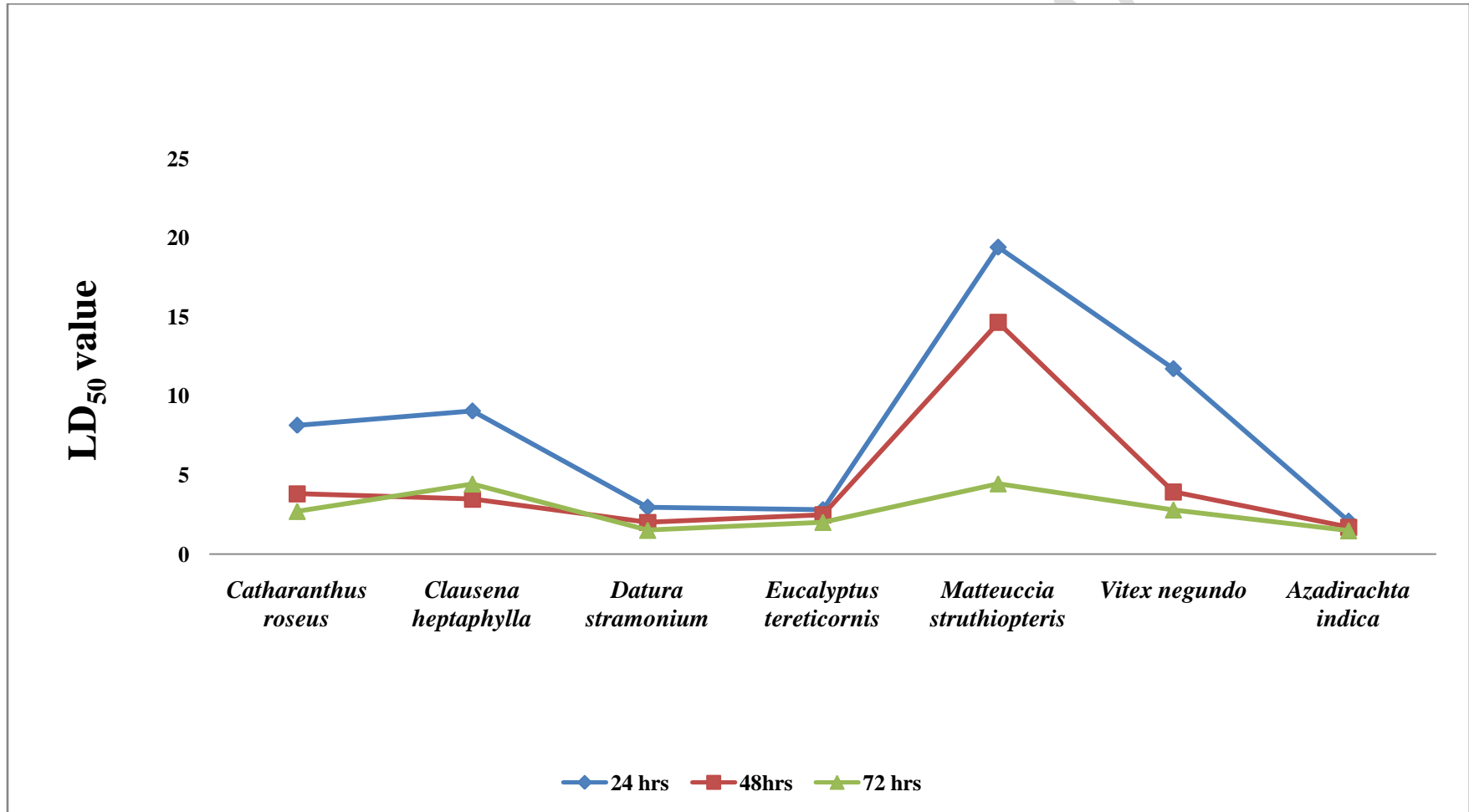
The assessment of the comparative toxicity and LD<sub>50</sub> of seven plant leaf powders were saw in 2018. Relative lethality has been expressed as a percentage and LD<sub>50</sub> has been expressed as a percentage with weight/weight g. In 2018, result of experiment of laboratory efficacy and relative toxicity were described below. After 24 hours of exposure, *A. indica*, *C. roseus*, *C. heptaphylla*, *D. stramonium*, *E. tereticornis*, *M. struthiopteris*, and *V. negundo* had LD50 values of 2.09, 8.15, 9.05, 2.97, 2.81, 19.40, and 11.72 percent (wt/wt) against *T. castaneum*, respectively. After 48 hr of exposure it was 1.71, 3.82, 3.48, 2.01, 2.49, 14.64, 3.94 per cent and after 72 hr 1.49, 2.71, 4.44, 1.52, 2.02, 4.45, 2.80 per cent respectively (Fig.1).

The toxicity order of diverse plant powders against *Tribolium castaneum* (Herbst) was *A. indica* > *E. tereticornis* > *D. stramonium* > *C. roseus* > *C. heptaphylla* > *V. negundo* > *M. struthiopteris* when *A. indica* was considered as standard for the exposure period of 24 hr. After 48 hr and 72 hr of exposure, the order of toxicity was *A. indica* > *D. stramonium* > *E. tereticornis* > *C. heptaphylla* > *C. roseus* > *V. negundo* > *M. struthiopteris* and *A. indica* > *D. stramonium* > *E. tereticornis* > *C. roseus* > *V. negundo* > *C. heptaphylla* > *M. struthiopteris*, respectively (Fig. 1).

In the present investigation, *A. indica* was considered as standard to evaluate the relative toxicity of selected botanicals. After exposure for 24, 48, and 72 hours, respectively, the respective toxicities of *C. roseus*, *C. heptaphylla*, *D. stramonium*, *E. tereticornis*, *M. struthiopteris*, and *V. negundo* were all found to be significantly less toxic than *A. indica* (Fig. 1). In bioassay study, it was perceived that the per cent mortality of *Tribolium castaneum* (Herbst) due to the botanicals action was raised gradually with increase in concentrations as well as exposure period.

During the experiment, it was discovered that the relative toxicity and LD<sub>50</sub> of the plants *Azadirachta indica*, *Catharanthus roseus*, *Clausena heptaphylla*, *Datura stramonium*, *Eucalyptus tereticornis*, *Matteuccia struthiopteris*, and *Vitex negundo* varied significantly. Comparing these botanicals to other botanicals, *A. indica*, *D. stramonium*, and *E. tereticornis* produced the best results. *A. indica* leaf powder was found to have the maximum toxicity against *T. castaneum* (Herbst) based on LD<sub>50</sub> and relative toxicity, which was consistent with findings by Mamun *et al.* in 2009 and Rehman *et al.* in 2019. Different authors described the toxicity of *A. indica* against numerous storage pests. They reported that the presence of triterpenoid /secondary metabolites azadirachtin, salanin, meliantriol (Mbailao *et al.* 2006, Ileke and Oni 2011) were responsible for antifeedant, ovicidal,

Figure 1. LD<sub>50</sub> and Relative toxicity of different plant powder against *Tribolium castaneum* (Herbst) after 24, 48 and 72 hours of treatment (2018)



The data were found to be significantly heterogeneous at = 0.05

Y = Probit kill, X = log dose

Mortality based on 4 replications each with 20 individuals

larvicidal, insect growth regulatory and repellent activity (Chaudhary *et al.*, 2017) of *A. indica*. *Eucalyptus tereticornis* leaf powder found effective against *T. castaneum* (Herbst) based on LD<sub>50</sub> experiment. Earlier workers also observed that eucalyptus was effective against *T. castaneum* (Siddique *et al.*, 2017) and *Trogoderma granarium* (Agha *et al.*, 2017). Jawalkar *et al.*, 2016; Al Bachchu; Jahan *et al.*, 2019 also used *D. Stramonium* and *A. indica* against storage pests and found similar result.

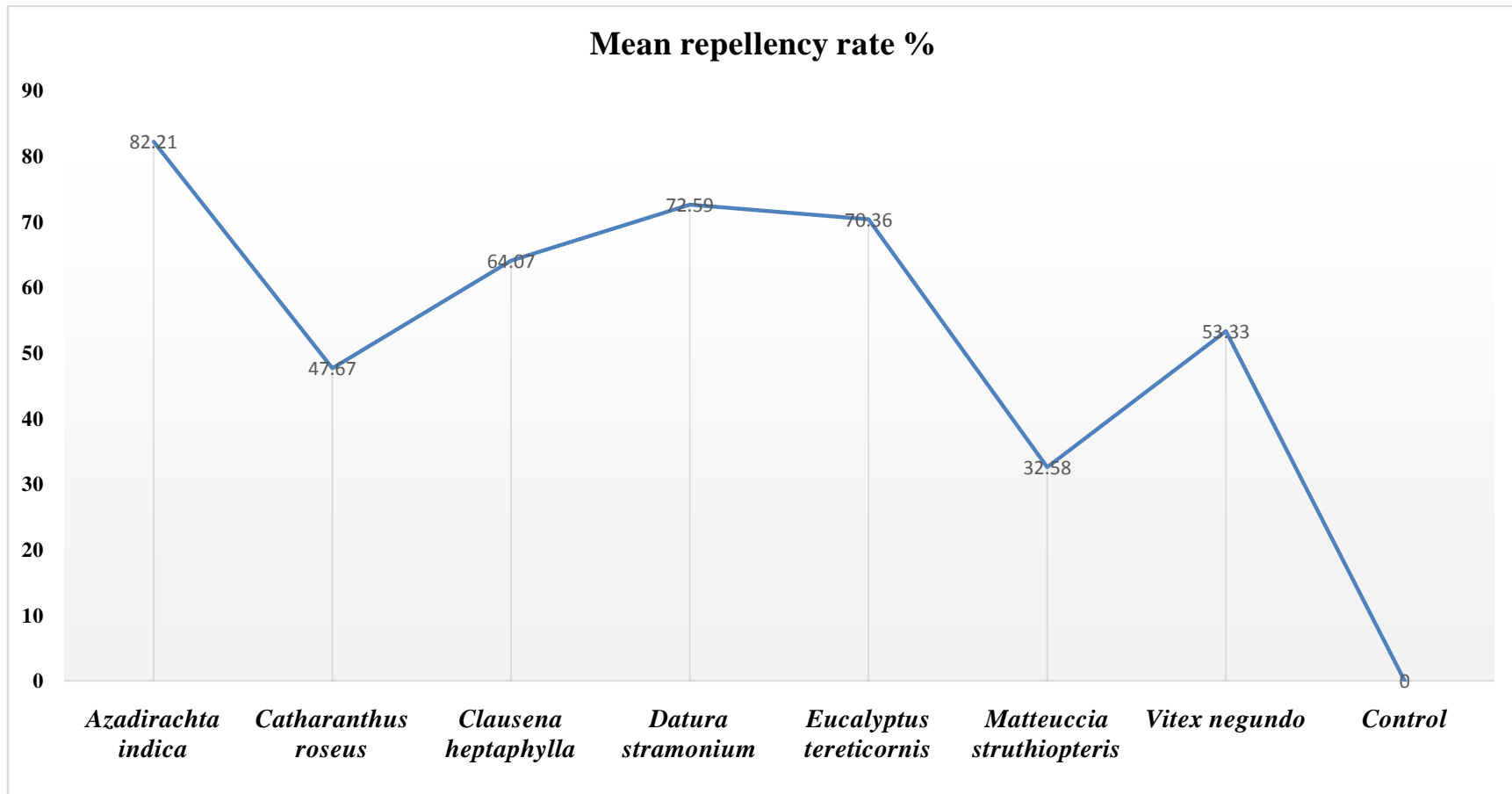
### **Repellency of against *Tribolium castaneum***

The repellency rate was observed highest in *A. indica* (86.66%), which was significantly different from other treatment, followed by *D. Stramonium* (73.33%), *E. tereticornis* (73.33%), and *C. heptaphylla* (66.66%), which were statistically similar with each other. *C. roseus* (46.66%) showed comparatively less repellency rate, while *V. negundo* (33.33%), *M. struthiopteris* (26.66%) gave significantly less repellency rate in comparison to other treatments. After 2 hr onward the repellency rate gradually increased and found highest in case of *D. struthiopteris* (80.00%) after 72 hr of treatment. After 72 hours of treatment, there was no discernible difference in the repellency of *A. indica* (80.00%), *C. roseus* (33.33%), *C. heptaphylla* (60.00%), and *E. tereticornis* (73.33%). After 72 hours, *M. Struthiopteris* (40.00%) and *V. negundo* (40.00%) likewise recorded lower repellency rates (Fig. 2).

After observation of 1, 2, 3, 4, 5, 6, 24, 48 and 72 hr the mean repellency rate was found in *A. indica* (82.21%) which was under the repellency class V (based on scale given by Mc Donald *et al.*, 1970) followed by *D. stramonium* (72.59%), *E. tereticornis* (70.36%), *C. heptaphylla* (64.07%) and *V. negundo* (53.33%) (class IV), while *C. roseus* (47.67%) was found under (class III). The less mean repellency was observed in case of *M. struthiopteris* (32.58%) under repellency (class II). There was no repellency observed in control treatment. (Fig. 2) After *D. stramonium*, *A. indica*, leaf powder shown greater repellency against *T. castaneum* (Herbst) in treated wheat grains. The significant toxicity of *D. stramonium* against storage pest was also noted in earlier works by various researchers (Abbasipour *et al.*, 2011, and Jawalkar *et al.*, 2016). Another study by Manzoor *et al.* (2011) found that *D. stramonium* had the highest level of repellency toward *Callosobruchus chinensis*.

Hanif *et al.*, (2016) also reported the highest rate of repellency advocated by *A. indica* and *D. stramonium* (77.66%, 81.48% and 76.43%) against *T. castaneum*, *Rhyzopertha dominica* and *Trogoderma granarium*. Many workers reported that *D. stramonium* has both poisonous and medicinal properties (Soni *et al.*, 2012; Mukhtar *et al.*, 2019). All parts of *D. stramonium* are toxic to mammals. (Mukhtar *et al.*, 2019). In Ayurvedic, *D. stramonium* is described (Kirtikar and Basu, 1999; Soni *et al.*, 2012) as remedial medicine for various human ailments. *Eucalyptus tereticornis* leaf powder found effective against *T. castaneum* (Herbst) based on repellency. Naseem and Khan (2011) showed that higher concentration (60%) of *E. camaldulensis* recorded 75.83% repellency of *T. castaneum* after three hrs of treatment.

Figure 2. In 2018, the effect of several plant leaf powders at repelling *Tribolium castaneum* (Herbst).



Figures with in parentheses are transformed values

Data are based on 3 replications each with 10 individuals

Zero and cent per cent values were subjected to the formula  $\frac{1}{4}n$  before angular transformation (after Steel and Torrie, 1960), where n= number of insects

### **Mortality of *Tribolium castaneum***

The results in the year 2018 revealed that *A. indica* dry leaf powder had given maximum (32.50%) mortality of *T. castaneum* followed by *D. stramonium* (31.25%) and *E. tereticornis* (28.75%), which were statistically similar to each other and significantly different from control one day after treatment, while no mortality was found in control. Similarly, at 3, 7 and 14 days after treatment also, *A. indica* showed highest mortality (42.50, 52.50 and 62.50%, respectively) then *D. stramonium* (40.00, 50.00 and 60.00%, respectively) and *E. tereticornis* (35.00, 40.00 and 55.00%, respectively). They were registered comparatively less mortality than *A. indica*. At 21 and 28 days after treatment it was observed that all the treatments mortality increased gradually and found 100% at 35 days after treatment. *A. indica* showed significantly highest mortality (80.00% and 92.50%, respectively), followed by *D. stramonium* (77.50% and 90.00%, respectively) and *E. tereticornis* (75.00% and 87.50%, respectively) which were statistically apart. No mortality was observed in case of control (Fig. 3). Effect of botanicals on stored grain pests were also observed in previous studies by Kumar *et al.* (2008) and Perera and Karunaratne (2012). *D. stramonium* leaf powder also demonstrated increased mortality in treated wheat grains when compared to *A. indica* when compared to *T. castaneum* (Herbst). Previous works of many workers also reported the high toxicity of *D. stramonium* against storage pest (Jawalkar *et al.*, 2016 and Abbasipour *et al.*, 2011). Another study by Manzoor *et al.* (2011) found that *Tribolium castaneum* was where *D. stramonium* caused the greatest amount of mortality. Based on mortality, *Eucalyptus tereticornis* leaf powder was proven to be efficient against *T. castaneum* (Herbst). Earlier workers also observed that eucalyptus was effective against *T. castaneum* (Siddique *et al.*, 2017) and *Trogoderma granarium* (Agha *et al.*, 2017). *E. globulus* registered 100 per cent mortality (Rupp *et al.*, 2006) and 71 per cent (Chagas *et al.*, 2002) feeding inhibition activity of *S. oryzae*.

### **Weight loss of wheat grains**

All of the released insects died after 35 days in 2018 when wheat grains were treated with *A. indica*, *D. stramonium*, and *E. tereticornis* to observe the mortality of *T. castaneum*.

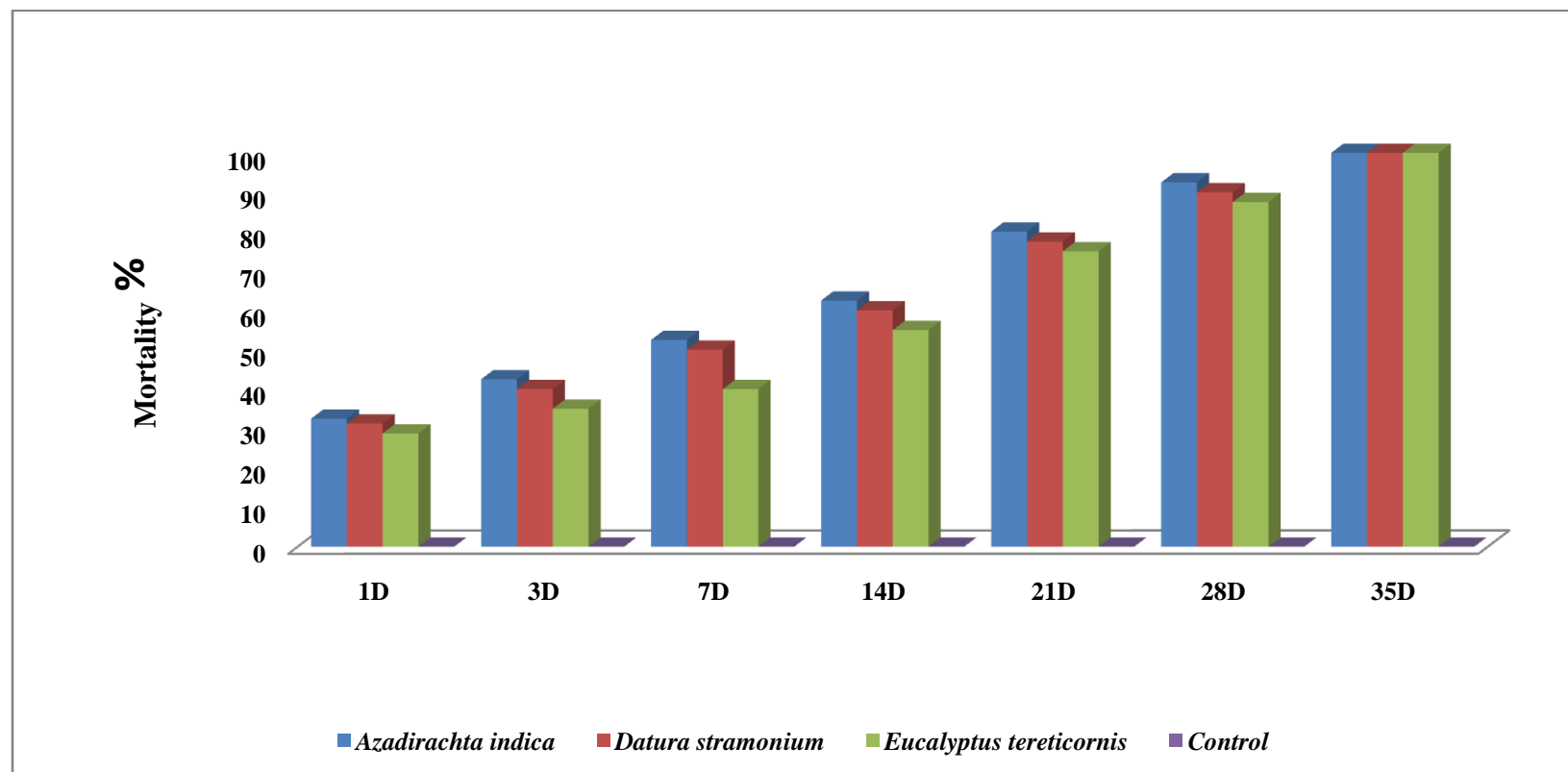
So, 35 days later, the weight reduction of the grains was determined. The lowest grain weight loss was seen in *A. indica* (5.76%), followed by *D. stramonium* (12.05%) and *E. tereticornis* (12.05) throughout the experiment in 2018. *T. castaneum* discharged plant dry powder treated containers.

The control group experienced a significant grain weight decrease in 2018 (62.33%), which was significantly higher than that of the other botanicals treatments (Fig. 4). Most of the secondary metabolites are highly effective against insect pests, ecofriendly, easily extractable and biodegradable, with low or no mammalian toxicity. (Tisserand and Balacs 1995; Isman 2000;

Amer and Mehlhorn 2006a, b; Shaaya and Rafaeli 2007; Abdel- Ghaffar and Semmler 2007; Bagvan *et al.*, 2008 and Lucia *et al.*, 2012).

UNDER PEER REVIEW

**Figure 3. Mortality of *Tribolium castaneum* (Herbst) after using different plants powder in 2018**



D= Day after spraying

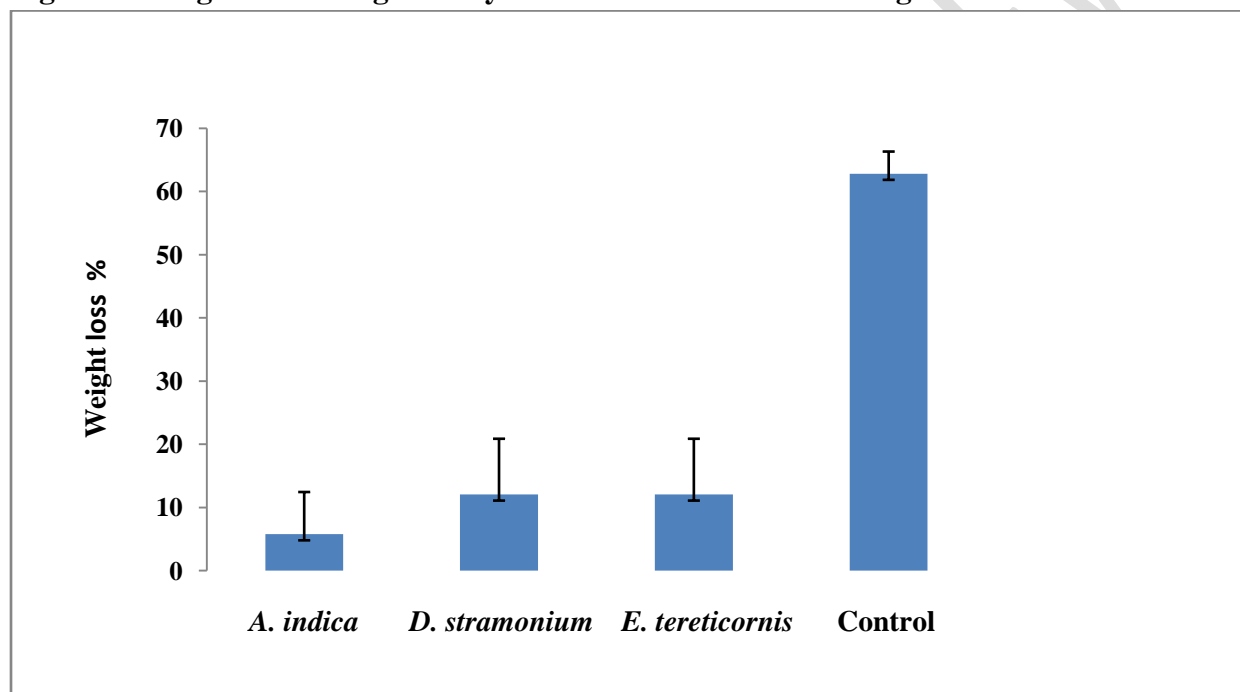
Figures are average corrected mortalities of 4 replications with 20 insects

Figures with in parentheses are transformed values

Zero and cent per cent values were subjected to the formula  $\frac{1}{4}n$  before angular transformation (after Steel and Torrie, 1960), where n= number of insects

Most of the plant terpenoids showed repaid knockdown effect indicating neurotoxic mode of action (Enan 2001 and Isman 2006). Effect of botanicals on stored grain pests were also observed in previous studies by Kumar *et al.* (2008) and Perera and Karunaratne (2012). *D. stramonium* leaf powder also demonstrated with higher weight loss results in treated wheat grains when compared to *A. indica* against *T. castaneum* (Herbst). Based on a weight loss experiment, *Eucalyptus tereticornis* leaf powder was proven to be efficient against *T. castaneum* (Herbst). The earlier weight loss studies (Haq *et al.*, 2005; Khanzada *et al.*,2017) are also showing similarity with present study.

**Figure 4. Weight loss brought on by *T. castaneum* in wheat during 2018**



## References

Abbasipour H, Mahmoudvand, M, Rastegar, F and Hosseinpour, M H. Bioactivities of jimsonweed extract, *Datura stramonium* L. (Solanaceae), against *Tribolium castaneum* (Coleoptera: Tenebrionidae). Turkish Journal of Agriculture and Forestry, 2011; 35(6): 623-629.

- Abbasipour H, Rastegar F, Mahmoudvand M and Hosseinpour MH. Insecticidal activity of extract from *Datura stramonium* (F.) (Solanaceae) against *Callosobruchus maculatus*'. Integrated Protection of Stored Products, 2011;69: 251-256.
- Abbott, WS. A method of computing the effectiveness of an insecticide. J. econ. Entomol, 1925;18(2), 265-267.
- Abdel-Ghaffar F and Semmler M. Efficacy of neem seed extract shampoo on head lice of naturally infected humans in Egypt. Parasitol Res 2007; 100:329–332.
- Agha WN, Amin AH, Khidr SK and Ismail AY. Entomocidal activity of microwave energy and some aqueous plant extracts against *Tribolium castaneum* Herbst and *Trogoderma granarium* Everts. In *AIP Conference Proceedings*. 2017;1888 (1) 020005-13. AIP Publishing LLC.
- Al Bachchu MA, Ara K, Uddin MN and Ara R. Larvicidal Efficacies of Four Indigenous Plant Extracts Against Red Flour Beetle, *Tribolium Castaneum* (Herbst) (Coleoptera: Tenebrionidae). Journal of the Asiatic Society of Bangladesh, Science, 2017;43(2), 223-232.
- Amer A and Mehlhorn H. Larvicidal effects of various essential oils against *Aedes*, *Anopheles* and *Culex* larvae (Diptera, Culicidae). Parasitol Res 2006a;99: 466-472,
- Amer A and Mehlhorn H. Repellency effect of forty-one essential oils against *Aedes*, *Anopheles* and *Culex* mosquitoes. Parasitol Res. 2006b; 99:478-490.
- Anita S, Sujatha P, and Prabhudas P. Efficacy of pulverised leaves of *Annona squamosa* (L.), *Moringa oleifera* (Lam.) and *Eucalyptus globulus* (Labill.) against the stored grain pest, *Tribolium castaneum* (Herbst.). Recent Research in Science and Technology, 2012;4(2) 19-23.
- Bagvan A, Rahuman AA, Kamraj C and Geetha K. Larvicidal activity of saponin from *Achyranthes aspera* against *Aedes aegypti* and *Culex quinquefasciatus* (Diptera: Culicidae). Parasitol Res 2008;103: 223-229.
- Chagas ACS, Passos WM, Prates HT, Leite RC, Furlong J and Fortes ICP,. Efeito acaricida de óleos essenciais e concentrados emulsionáveis de *Eucalyptus* spp em *Boophilus microplus*. Braz. J. vet. Res. anim. Sci. 2002;39: 247-253.
- Chaudhary S, Kanwar RK, Sehgal A, Cahill DM, Barrow CJ, Sehgal R and Kanwar JR. Progress on *Azadirachta indica* based biopesticides in replacing synthetic toxic pesticides. Frontiers in Plant Science, 2017;8: 610.
- Chopa CS, Alzogaray R. and Ferrero A. Repellency of *Schinus molle* var. *areira* (Anacardiaceae) essential oils to the German cockroach (Blattodea: Blattellidae). Bioassay 2006;1: 6.

- Cobbinah JR and Kwarteng JA. Effects of some neem products on stored maize weevil, *Sitophilus zeamais* (Motsch.). *Insect Sci. Appl.*, 1989;1: 89-92.
- Devi MB, Devi NV and Singh SN. Effects of six botanical plant powder extracts on the control of rice weevil, *Sitophilus oryzae* L. in stored rice grains. *International Journal of Agriculture Innovations and Research*, 2014;2(5): 683-686.
- Dhaniya MV and Dayanandan S. Common Medicinal Plants as Repellents against Stored Grain Insects- *Sitophilus oryzae* and *Tribolium castaneum*. *IOSR Journal of Agriculture and Veterinary Science*. 2016;9 (8): 71-77.
- Enan. Insecticidal activity of essential oils: octopaminergic sites of action. *Comp Biochem Physiol Part C* 2001;130: 325-337.
- Ferrero AA, Werdin González JO, Sánchez C.C.. Biological activity of *Schinus molle* on *Triatoma infestans*. *Fitoterapia* 2006;77: 381-383.
- Godfray HC, Beddington JR, Crute, IR, Haddad, L, Lawrence, D, Muir, JF, Pretty J, Robinson S, Thomas SM and Toulmin C. "Food security: The challenge of feeding 9 billion people". *Science*, 2010;327(5967): 812-8.
- Good N The Flour Beetles of the Genus *Tribolium*. United States Department of Agriculture, Economic Research Service. Tech. Bull, 1936;498.
- Hagstrum DW, Subramanyam B. *Fundamentals of Stored-product Entomology*. AACC International. Howe, R.W., 2006;1962.
- Hanif CMS, Ul-Hasan, M, Shagger M, Saleem S, Akthar S and Ijaz M. Insecticidal and repellent activities of essential oils of three medicinal plants towards insect pests of stored wheat. *Bulgarian Journal of Agricultural Science*, 2016;22(3): 470-476.
- Haq T, Usmani NF, and Abbas T. Screening of plant leaves as grain protectants against *Tribolium castaneum* during storage. *Pakistan Journal of Botany*, 2005;37(1):149-153.
- Ileke KD and Oni MO. Toxicity of some plant powders to maize weevil, *Sitophilus zeamais* (Coleoptera: Curculionidae) on stored wheat grains. *African J Agricul Res.*, 2011;6(13): 3043-3048.
- Islam MS, and Talukder FA. Toxic and residual effects of *Azadirachta indica*, *Tagetes erecta* and *Cynodon dactylon* seed extracts and leaf powders towards *Tribolium castaneum*. *Journal of Plant Diseases and Protection*, 2005;112(6):594-601.
- Isman M. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annu. Rev. Entomol.*, 2006;51: 45-66.
- Isman MB. Plant essential oils for pest and disease management. *Crop Prot*, 2000;19: 603-608.

- Jahan AMM, Bachchu MAA, Rahman MH, Ara R and Al Helal MM. Bioactivities of four botanical extracts against rice. *Journal of Science and Technology*, 2019;32:44.
- Jawalkar N, Zambare S and Zanke S. Insecticidal property of *Datura stramonium* L. seed extracts against *Sitophilus oryzae* L. (Coleoptera: Curculionidae) in stored wheat grains. *Journal of Entomology and Zoology Studies* 2016;4(6): 92-96.
- Jembere BD, Ofori O and Hassanali A 1995. Products derived from the leaves of *Ocimum kilmandscharicum* (Labiatae) as post-harvest grain protectants against the infestation of three major stored insect product pests. *B. Entomol. Res.*, 1955;85: 361-367.
- Karakas M. Toxic, repellent and antifeedant effects of two aromatic plant extracts on the wheat granary weevil, *Sitophilus granarius* L. (Coleoptera: Curculionidae). *International Journal of Entomology Research*, 2016;1(6): 24-28.
- Khalequzzaman M and Sultana S. Insecticidal activity of *Annona squamosa* L. seed extracts against the red flour beetle, *Tribolium castaneum* (Herbst). *Journal of Bio-Science*, 2006;14:107-112.
- Khanzada H Sarwar M and Lohar M. Repellence activity of plant oils against red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in wheat. *International Journal of Animal Biology*, 2015;1:86-92.
- Kirtikar KR and Basu BD. *Indian medicinal plants*. 2nd ed. Volume III. Dehradun: International Book Distributors. 1999;1783-1787.
- Kumar R, Kumar A, Prasad CS, Dubey NK and Samant R 2008. Insecticidal Activity *Aegle marmelos* (L.) Correa Essential Oil Against Four Stored Grain Insect Pests. *Internet Journal of Food Safety*, 2008;10: 39-49.
- Kumral NA, Cobanoglu S and Yalcin C 2009. Acaricidal, repellent and oviposition deterrent activities of *Datura stramonium* L. against adult *Tetranychus urticae* (Koch). *J. Pest Sci* 2009;21: 23-30.
- Lajide L, Adedire CO, Muse WA and Agele SO. Insecticidal activities of powders of some Nigerian plants against the maize weevil *Sitophilus zeamais* (Motsch.). *Entomol. Soc. Niger. Occ. Pub.*, 1998;31: 227-235.
- Lucia A, Juan LW, Zerba EN, Harrand L, Marcó, M and Masuh, HM Validation of models to estimate the fumigant and larvicidal activity of Eucalyptus essential oils against *Aedes aegypti* (Diptera: Culicidae). *Parasitology Research*, 2012;110(5): 1675-1686.
- Mamun MSA, Shahjahan M and Ahmad M. Laboratory evaluation of some indigenous plant extracts as toxicants against red flour beetle, *Tribolium castaneum* Herbst. *Journal of the Bangladesh Agricultural University*, 2009;7(1): 1-5.

- Manzoor F, Nasim G, Saif S and Malik SA. Effect of ethanolic plant extracts on three storage grain pests of economic importance. *Pakistan Journal of Botany*, 2011;43(6): 2941-2946.
- Mareggiani G, Bado S, Picollo MI and Zerba E. Efecto tóxico de metabolitos aislados de plantas solanáceas sobre *Tribolium castaneum*. - *Acta Toxicológica Argentina*, 2000;8: 69-71.
- Mbailao M, Nanadoum M, Automne B, Gabra B and Emmanuel A . Effect of six common seed oils on survival, egg laying and development of the cowpea weevil, *Callosobruchus maculatus*. *J. Biol. Sci.* 2006;6(2): 420-425.
- Mc Donald LL, Guy RH and Speirs RD. Preliminary evaluation of new candidate materials as toxicants, repellents and attractants against stored product insects. Marketing Res. Report No. 882. Agric. Res. Serv., U.S. Dept. Agric. Washington, D.C. 1970;8.
- Mukhtar Y, Tukur S and Bashir RA. An Overview on *Datura stramonium* L. (Jimson weed): A Notable Psychoactive Drug Plant. *American Journal of Natural Sciences*, 2019;2(1): 1-9.
- Naseem MT and Khan RR. Comparison of repellency of essential oils against red flour beetle *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae). *Journal of Stored Products and Postharvest Research*, 2011;2(7): 131-134.
- Nattudurai G, Arulvasu C and Baskar K. Indigenous Knowledge in Stored Product Pests Management *Entomol Ornithol Herpetol* 2017;6(2).
- Niber TB. The ability of powders and slurries from ten plant species to protect stored grains from attack by *Prostephanus truncates* Horn (Coleoptera: Bostrichidae) and *Sitophilus oryzae* L. (Coleoptera: Curculionidae). *J. Stored Prod. Res.*, 1994;30(4): 297-301.
- Nikkon F, Habib MR, Karim MR, Ferdousi Z, Rahman MM and Haque ME. Insecticidal activity of flower of *Tagetes erecta* L. against *Tribolium castaneum* (Herbst). *Research Journal of Agriculture and Biological Sciences* 2009;5: 748-753.
- Ojo DO, and Ogunleye, RF. Comparative effectiveness of the powders of some underutilized botanicals for the control of *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae). *International Journal of Pure and Applied Sciences and Technology*, 2013;16 (2): 55.
- Papachristos DP and Stamopoulos DC. Toxicity of vapours of three essential oils to the immature stages of *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae). *J Stored Prod Res* 2002;38: 365-373.
- Perera MTHP and Karunaratne MMSC. *Olex zeylanica*: An environmentally safe bio-pesticide for the control of the maize weevil *Sitophilus zeamais* mots. (curculionidae). *Proceedings of International Forestry and Environment Symposium*. 2012;15.

- Ramya S. Biopesticidal effect of leaf extracts of *Catharanthus roseus* L. (G) Don. on the larvae of gram pod borer-*Helicoverpa armigera* (Hübner). *Ethnobotanical Leaflets*, 2008;(1): 145.
- Rathore M, Gupta JP, Pathak SK, and Ahmad T. Effect of Storage Containers to Stabilize the Seed Quality in Wheat (*Triticum aestivum* L.). *International Journal of Environment and Climate Change*, 2022;12(11): 2729-2735.
- Rehman H, Qurban ALI, Mirza S, Sharif S, Hasan M and Yasir M. Comparative toxic potential of some plant extracts and spinetoram against *Tribolium castaneum* (Herbst, 1797) (Coleoptera: Tenebrionidae). *Türkiye Entomoloji Dergisi.*, 2019;43(2): 201-210.
- Roorda FA, Schulten GGM and Andriessen EAM. Laboratory observations on the development of *Tribolium castaneum* Herbst (Col., Tenebrionidae) on millet at different temperatures and relative humidities. *J. Appl. Entomol.* 1982;93:446-452.
- Rupp MMM, Cruz MDS, Collella JCT, Junior SS, Schwan-Estrada, KRF, Cruz MDS and Fiori-Tutida, AC. Evaluation of toxic effect of plant extracts on adults of *Sitophilus oryzae* L., 1763 (Col., Curculionidae). In 9th International Working Conference on Stored Product Protection, 2006;15-18.
- Shaaya E and Rafaeli A. Essential oils as biorational insecticides potency and mode of action. In: Ishaaya I, Nauen R, Horowitz R (eds) *Insecticides design using advanced technologies*. Springer, Berlin, 2007;249-261.
- Siddique S, Parveen Z, Butt A, Chaudhary MN and Akram M. Chemical Composition and Insecticidal Activities of Essential Oils of Myrtaceae against *Tribolium castaneum* (Coleoptera: Tenebrionidae). *Polish Journal of Environmental Studies*, 2017;26(4): 1653-1662.
- Sighamony S, Anees I, Chandrakala T S and Kaiser J. Indigenous plant products as grain protectants against *Sitophilus oryzae* (L) and *Rhyzopertha dominica* (F). *J. Stored Prod. Res.*, 1990;22: 21-23.
- Soni P, Siddiqui AA, Dwivedi J and Soni. Pharmacological properties of *Datura stramonium* L. as a potential medicinal tree: an overview. *Asian Pacific journal of tropical biomedicine*, 2012;2(12): 1002-1008.
- Steel RGD and Torrie JH. *Principle and procedures of statistics*. New York: McGraw- Hill Book Company INC. 1960;481.
- Suthisut, D, Fields PG and Chandrapatya A. Contact toxicity, feeding reduction, and repellency of essential oils from three plants from the ginger family (Zingiberaceae) and their major components against *Sitophilus zeamais* and *Tribolium castaneum*. *Journal of Economic Entomology*, 2011;104: 1445-1454.

- Talukder FA. Plant products as potential stored product insect management agent-a mini review. Emir. J. Agric. Sci., 2006;18(1): 17-32.
- Tisserand R and Balacs T. Essential oils safety: a guide for health care professionals. Churchill Livingstone, London. 1995;2-216.
- Umoetok SBA and Gerard MB. Comparative efficacy of *Acorus calamus* powder and two synthetic insecticides for control of three major insect pests of stored cereal grains. Global J Agric Sci 2003;2: 94-97.
- Wang J, Zhu F, Zhou XM, Niu CY, Lei CL. Repellent and fumigant activity of essential oils from *Artemisia vulgaris* to *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). J Stored Prod Res 2006;42: 339-347.

UNDER PEER REVIEW