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Laboratory assessment and prospects of repellent potentiation of naturally occurring plant extractives against the lesser grain bore, *Rhizopertha dominica* Fabricius (Bostrichidae: Coleoptera)

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Abstract
Prevention of food losses during postharvest storage is of paramount economic importance. The use of synthetic chemical insecticides is either not permitted or used restrictively because of the residue problem and health risks to consumers. In view of the above, there is a need for plants that may provide potential alternatives to the currently used insect control agents as they constitute a rich source of bioactive molecules. Available literature indicates that plant extractives could be source for new insecticides. This paper focuses on the current state of new biorational agents for repellent as grain protectants applied in insect-pest management. A screening five naturally occurring indogenous botanicals namely: *Acorus calamus* Linn. (rhizomes), *Annona squamosa* Linn.(unripe fruites) and *Vitex negundo* Linn. (leaves), *Gynendropsis gynendra* Linn., (seeds) and *Ocimum basilicum* Linn.(leaves) were formulated in distilled water. Triton X-100 at the rate of 0.5 percent as emulsifier and benzene at the rate of 5 percent as solvent were used were tested for their larval repellent biopotency against *Rhizopertha dominica* Fabricius and two control were also used in the present investigation. Over all, the highest R. *dominica* larval repellency was calculated *A. squamosa* extract showed the highest larval repellency (99.77 per cent) and placed on top followed by *O. basilicum* (99.54 per cent), *A. calamus* (99.38 per cent) *G. gynendra* (99.22 per cent), *V. negundo* (99.10 per cent) where as in control using Benezene was showed (99.38 per cent) and in absolute control was seen only 79.25 percent larval repellency and placed at bottom of merit.

Keywords: Grain protectants, *Annona squamosa, Ocimum basilicum* and *Annona squamosa*

1. Introduction
Agriculture is the major occupation of most of the people all over the world and more than 70% of Indian population depends on agriculture for their livelihood (Chandrasekar *et al.* 2005, Jeeva *et al.* 2005 and Kiruba *et al.* 2005) [1, 2, 3]. Food grain losses due to insect infestation during storage are a serious problem, particularly in the developing countries (Talukder *et al.* 2004 and Dubey *et al.* 2008) [4, 5] Seventy per cent grain losses due to insect infestation are the most serious problem in storage, particularly in villages and towns of developing countries like India (Talukdar and Howse,1993) [6]. It has been estimated that about 15-20% of the world agricultural production is lost every year due to insect infestation (Roy *et al.* 2005) [7]. In India losses caused by insects accounted for 6.5% of stored grain (Kumar 2009) [8]. Their attacks reduce both the quantity and quality of stored seed. *Rhizopertha dominica* Fab. (Coleptera: Bostrichidae) is the most common and injurious to stored grains having an important position among the storage pests (Jacobson 2004) [9].

The test insect lesser grain borer, *Rhyzopertha dominica* Fabricius, is a cosmopolitan pest of a wide variety of food granries mainly cereals but also include grains from families Poeaceae (e.g. rice, wheat, sorghum, oats, pearl, millet, malt, barley) and Fabaceae (e.g. chickpeas, peanuts, beans). The lesser grain borer is one of the great economic importance in the Indian sub-region of oriental region and many other zoogeographical regions of the world[]. The economically most important beetles infesting cereal grains on a worldwide scale, and its feeding can reduce kernels to the pericarp. Stored product *R. dominica* beetles are resistant to many grain protectants. *Rhyzopertha dominica* females lay eggs on the surface and newly born larvae bore into the kernels, preferring breaks or the germ area where the covering testa is loose. On damaged kernels, first instar larvae mortality decreases and progeny production A lot of research was conducted which dealt with the influence of the species and variety of the plant on the development of R. dominica and occurrence of the progeny.

Synthetic chemical pesticides have been used for many years to control stored grain pests (Salem *et al.* 2007) [10]. Fumigation of stored food grains with toxic gases is effective but not applicable at the farm level because the storage structures are not airtight. Furthermore, control of insects by insecticides has serious drawbacks, such as the toxic residues on stored grains, development of resistance by target species, pest resurgence and lethal effects on non-target organisms in addition to direct toxicity to users and health hazard (Adedire and Lajide 2003, Adedire *et al*. 2011, Ileke and Olotuah 2012, [11, 12, 13]. This situation indicates the need for safe but effective, biodegradable pesticides with no toxic effects on non-target organisms for pest control in storage.

Botanical insecticides are naturally occurring insecticides which are derived from plants (Golob *et al*., 1999; Isman, 2000) [14, 15]. Botanical insecticides are used in several forms, such as powders, solvent extracts, essential oils and whole plants, these preparations have been investigated for their insecticidal activity including their action as repellents, anti-feedants and insect growth regulators (Weaver and Subramanyam, 2000) [16]. The introduction of powdered leaves of *Salvia officinalis* L. and *Artemisia absinthium* L. to wheat grains was very effective in reducing population size and delaying development time of *R. dominica* (Klys, 2004) [17].

Compared to synthetic compounds they are less harmful to the environment, generally less expensive, and easily processed and used by farmers and small industries. Recently, there is a steady increase in the use of indigenous plant products as a cheaper and ecologically safer means of protecting stored products against infestation by insects (Ashamo and Odeyemi 2001, Akinkurolere *et al*. 2009) [18, 19] and this lead to the present study. The objectives of this study are to assess the larval feeding preferences for the varieties of wheat and to evaluate their susceptibility/resistance to *R. dominica* Fabr.

2. Materials and Methods

Material and methods

Examination of the influence of different wheat grain varieties ie; (x) on the emergence of the progeny of *R. dominica*, on stored wheat grains, as well as effect of their presence on chemical properties of grains were conducted in bio-pesticide and toxicological laboratory, Department of Zoology, D.B.S, College, Kanpur which ***is*** located in between latitudes 25.26º and 26.58º North and longitudes 19.31º and 84.34º East, Kanpur is situated at an elevation of about 127.117º metres above the mean sea level and has a semi-arid subtropical zone during, 2004-2005.

2.1 Tested insect and their rearing

The lesser grain borer, *Rhyzopertha dominica* Fabricius was reared on wheat kernels 450 g, and 100 adults were put in a glass jar (13 cm Diameter x 20 cm height) with the bottom covered with black. Adults of *R. dominica* of both sexes and 2-4-weeks old were used during the experiment with temperature (T) 29±1 °C and relative humidity (RH) 70±5% and a photoperiod of 16:8 (light/dark).Adults were allowed to oviposit for three days and were then removed in the bio-pesticide and toxicological laboratory, Department of Zoology, D.B.S, College, Kanpur.

Mixed wheat kernels, The lid of glass jar provided with a hole (3 cm Diameter) closed by a stainless steel wire mesh to allow gaseous exchange and checked daily. After three days of eggs hatches into larvae. The first instar larvae characterized by a terminal median spine.

2.2 Preparation of plant extracts

Fresh plant parts of *Acorus calamus* Linn., *Annona squamosa* Linn. (unripe fruites) and *Vitex negundo* Linn. (leaves), *Gynendropsis gynendra* Linn., (seeds) and *Ocimum basilicum* Linn. (leaves) extracts were used against *R. dominica* in the Biopesticide laboratory, Department of Zoology (Entomology), D.B.S.College, Kanpur affiliated to CSJM University, Kanpur, U.P. They were washed in running water and kept in laboratory for 7 days air drying. After drying they were made powder separately by an electric grinder. The extracts were prepared according to (Bapai and Chandel, 2020) [25] with minor modifications. For making extracts, 100 g of different plant powders were dissolved in 300 ml of petroleum ether solvent and stirred for 30 min. in a magnetic stirrer. The mixture was allowed to stand for 72 hours and shaking several intervals. It was filtered through a filter paper (Whatman no. 1) and to evaporate the solvents. The condensed extracts were preserved in tightly corked-labeled bottles and stored in a refrigerator until their further use.

Table 1: List of indigenous plant materials and their details

Scientific Name	Vernacular Name	Part Used	Faimly
Acorus calamus Linn.	Sweetflag	rhizome Asarone, choline, eugenol, ethyl ether, heptanoic acid, methylamine, saponin, tannic acid and trimethylamine	Acoraceae or Araceae Chander *et al*. (1990) [20].
Annona squamosa Linn.	Bullocks heart	Unripe fruites Anonaine, corydine, isocorydine and aporphine	Annonaceae Ashok kumar *et al*. (2010) [21].
Gynendropsis gynendra Linn.	Hulhul	Seeds Erpenolene, 1-α – terpeneol, pentacosane, humulene, phytol	Capparidaceae Ndungu *et al*. (1995) [22]
Ocimum canum Sims.	Sweet Basil	Leaves Anethole, camphor, carvacrol, cineole, citral, esdragole, eugenol, linalool, safrole, sapenin and thymol	Lamiaceae Mishra *et al*. (2012) [23].
Vitex negundo Linn.	Nirgundi	Leavesβ-caryophyllene, protocatechuic acid and oleanolic acid	Vebenaceae Rana *et al*. (2005) [24].

The calculated amount of various ingredients required to make different concentrations from the stock solution was prepared with the help of following formula and amount of ingredients taken are presented in the table (Table 2).

$$\text{Amount of Stock Solution} = \frac{\text{Amount required x Concentration required}}{\text{Concentration of Stock Solution}}$$

Table 2: Preparation of different formulations of the selected plant materials

Concentration (%)	Amount of Stock Solution (ml)	Amount of Benzene (ml)	Amount of Emulsifiable Water (ml)	Total Amount (ml)
0.50	5.00	20.00	475.00	500.00
1.00	10.00	15.00	475.00	00.00
1.50	15.00	10.00	475.00	500.00

2.3 Collection of wheat grains
Only healthy sound and free from injury grains will take for study. Healthy wheat grains, *Triticum aestivum* (L.) were purchased from the local market of galla mandi, Kanpur, cleaned thoroughly and sun dried. The grains were cooled at 8-10% moisture level and stored at room temperature in air tight plastic bag for experimental use.

3. Experimental Protocol
The tests were carried out by placing 40 wheat kernels in glass containers (35 mm Ø; height 20 mm) with 10 first instars larvae, 0–24 h old. Such containers, closed with a net (120 mesh) to provide ventilation, were placed in an incubator at 29 ± 1 °C, 70 ± 5% R.H. and 16 h of light alternating with 8 h of darkness. Repellent test was conducted according to (Rajani and Chandel, 2016) [26] with minor modifications. The extracted materials were weighed and dissolved in petroleum for making different concentration (0.5, 1.0 and 2.0% along with control). Pilot experiments were done to obtain the appropriate concentrations of each extractive (0.5, 1.0 and 2.0%). Before applying extracts to the thorax of the insect, 10 minutes chilling were done with 4 0C in refrigerator. Then 1 µl of prepared solution was applied to the dorsal surface of each insect using a micropipette (volume digital micropipets, bio-rad, India).

3.1 Experimental Protocol
Repellent activity were studied at 0.5, 1.0 and 0, 1.5 per cent concentration treated for two minutes for testing. The repellent effect stored wheat, *Triticum aestivum* (L.) mixed in parts per 100 parts of seeds (W/W) and extract were used as food for the larvae of lesser grain borer, *Rhyzopertha dominica* Fabricius. Repellent test was conducted according to (Rajani and Chandel, 2016) [26] with minor modifications. The treated seed were left under electric fan for about half an hour, to make a dry film of the extracts on the seeds for each set of extract and one control. The treated seeds were kept in jar (23cm x 10cm) on moist filter paper. The untreated seeds were dipped in Benzene + emulsified water only. Ten larvae of *Rhyzopertha dominica* was introduced into a cage having treated stored wheat, *Triticum aestivum*. Ten starved *Rhyzopertha dominica* larvae were released in each jar along with control. Three replicates per treatments were maintained. The treated jars either repelled the insects or forced them to move from treated jars (T) to an empty jar(C) through the plastic pipe. The ones found in plastic pipe were considered repelled individuals. Total number of larvae reached to the food/repelled to untreated empty jars were recorded at an interval of 24 hours for each observation recorded and computed as per Abbott formula. (Abbott W. S. 1925) [27].

4. Statistical analysis
The observed data of repellent test was analyzed using following formula

$$\text{Percent Repellency} = \frac{A - B}{A} \times 100$$

Here,
A = Average Number of insects present on untreated portion
B = Average Number of insects present on treated portion
The data were corrected according to Abott's (1987) formula. This observed value of 'F' is compared with the theoretical value of 'F' given by Finney, (1952) [19] for testing the significance [28].

5. Results and Discussions
5.1 Results
The results are summarized in Table-3 and Fig.1-4 which showed that all the plant extracts have proved to more or less repulsive against the emerging larvae of larvae of *Rhyzopertha dominica*. All selected plant extracts gave promising repellent activity the larvae of *Rhyzopertha dominica*. On the basis of mean per cent of larval repellency and their order of merit as per concentration of each extractives are described in the following ways and in the last final results also given below.

Table 3: Mean percent of *R. dominica* repellency against plant products on wheat seeds.

Extracts of plants	Average percentage of *R. dominica* repelled when extract mixed in parts per 100 parts of seeds (W/W)							
	0.5 per cent		1.0 per cent		1.5 per cent		Mean% Repellency	
	T_1	TBV_1	T_2	TBV_2	T_3	TBV_3	T	TBV
A. calamus	99.00	84.39 b	99.50	86.73 a	99.66	87.33 a	99.38	85.48
A. squamosa	99.66	87.33 a	99.66	87.33a	100.00	90.00 a	99.77	87.25
G. gynendra.	99.00	84.39 b	99.16	84.82 a	99.50	86.73 a	99.22	84.93
O. basilicum	99.3	85.35ab	99.66	87.33 a	99.66	87.33 a	99.54	86.11
Vitex negundo	98.83	84.39 b	99.16	84.82 a	99.33	85.38 a	99.10	84.56
Absolute control	79.00	62.77 c	79.00	62.77 b	79.77	62.77 b	79.25	62.87
Benezene control	99.33	85.38ab	99.33	85.38 a	99.50	86.73 a	99.38	84.35
S.E.	±1.33		±1.99		±2.55			
C.D. at 5%	2.85		4.09		5.48			

From table 3, it is evident that all the plant extracts at three doses repelled the lesser grain borers from 98.83 to 100.00 per cent, i.e., those adults *R. dominica* did not enter into the sacklets containing the treated wheat grains, while in the absolute control, this was about 79.00 per cent. Benzene proved to have a potent repellent effect keeping 99.00 per cent lesser grain borers away from sacklets

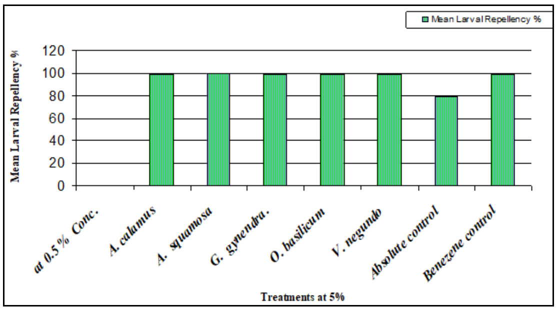

Fig 1: Mean% of *R. dominica* larvae repellency extract /100 parts of seeds (W/W)

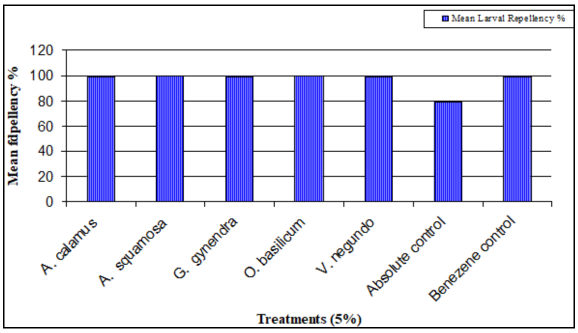

Fig 2: Mean% of *R. dominica* larvae repellency extract /100 parts of seeds (W/W)

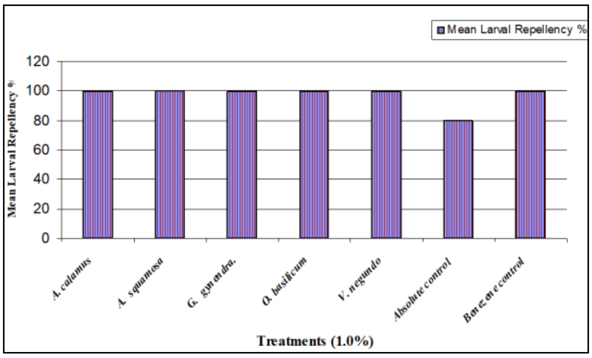

Fig 3: Mean% of *R. dominica* larvae repelled from 1.5% conc. extracts /100 parts of seeds (W/W)

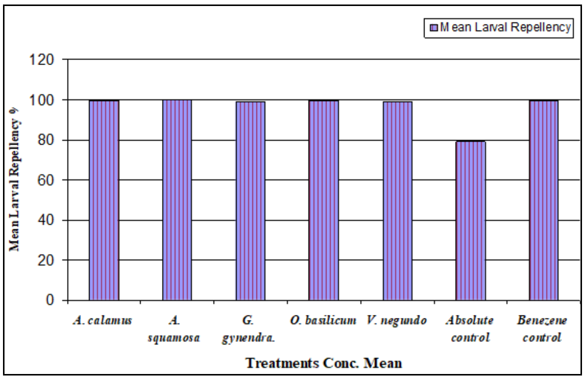

Fig 4: Mean% of *R. dominica* larvae repelled from plant extract /100 parts of seeds (W/W)

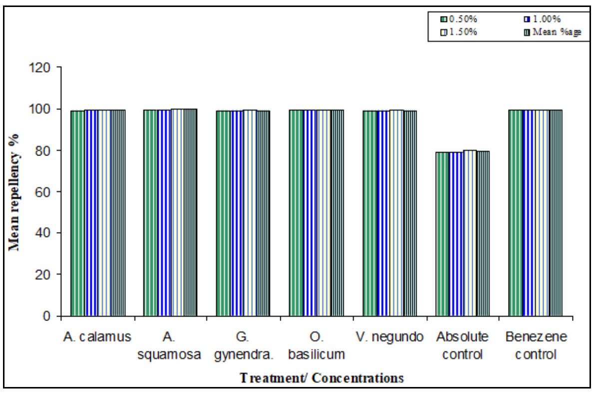

Fig 5: Over all mean% of *R. dominica* larvae repelled from plant extractives /100 parts of seeds (W/W)

In case of 0.5 per cent concentration of *A. squamosa* extract showed the highest larval repellency (99.66 per cent) and placed on top followed by *O. basilicum* (99.30 per cent), *A. calamus* and *G. gynendra* (99.00 per cent), *V. negundo* (98.83 per cent), and *O. basilicum* (99.30 per cent),wheras in Benezene control was showed (99.33 per cent)and in Absolute control was seen only 79.00 percent larval repellency and placed at bottom of merit.

In case of 1.0 per cent concentration of *A. squamosa* and *O. basilicum* extract showed the highest larval repellency (99.66 per cent) and both placed on top followed by *A. calamus* (99.50 per cent), *G. gynendra* and *V. negundo* (98.16 per cent) where as in control using Benezene was showed (99.33 per cent) and in absolute control was seen only 79.00 percent larval repellency and placed at bottom of merit.

In case of 1.5 per cent concentration of *A.squamosa* extract showed the highest larval repellency (100.00 per cent) and placed on top followed by), *A. calamus* and *O. basilicum* (99.66 per cent), *G. gynendra* (99.50 per cent), *V. negundo* (99.33 per cent) where as in control using Benezene was showed (99.50 per cent) and in absolute control was seen only 79.77 percent larval repellency and placed at bottom of merit.

Over all the cumulative results showed that the highest R. *dominica* larval repellency was calculated *A. squamosa* extract showed the highest larval repellency (99.77 per cent) and placed on top followed by *O. basilicum* (99.54 per cent), *A. calamus* (99.38 per cent) *G. gynendra* (99.22 per cent), *V. negundo* (99.10 per cent) where as in control using Benezene was showed (99.38 per cent) and in absolute control was seen only 79.25 percent larval repellency and placed at bottom of merit.

5.2 Discussions

it is evident that all the plant extracts at three doses repelled the lesser grain borers from 98.83 to 100.00 per cent, i.e., those adults *R. dominica* did not enter into the sacklets containing the treated wheat grains, while in the absolute control, this was about 79.00 per cent. Benzene proved to have a potent repellent effect keeping 99.00 per cent lesser grain borers away from sacklets. Plant essential oils and solvent extracts are the most studied botanical methods of controlling stored grain insect infestations reported by Bekele and Obeng-Ofori, 1996, Rao and Prakash, 3002, Park *et al.* 2003, Dubey *et al.* 2004, Talukde *et al.* 2004, Talukder *et al.* 2004, Mohal *et al.* 2006, Isman, 2006, Wang *et al.* 2006, Huang *et al.* 2007, Viglianco *et al.* 2008, Islam *et al.* 2009 and Bajpai, and Chandel, 2009 [29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40]

From very early times, different plant materials have been used as natural protectants of stored grains. Worldwide reports indicate that when plant extractives mixed with stored grains, reduce damage of stored product by stored grain insects-pest reported by Geng *et al.*2011, Gandh *et al.* 2011, Ukeh and Umoetok, 2011, Wekes *et al.* 2011, Khemira *et al.* 2012, Lakshmi *et al.* 2012 and 2013, Singh *et al.* 2013 and Shah *et al.* 2013 [41, 42, 43, 44, 45, 46, 47, 48, 49]. In the support of the above findings Bekele *et al*. 1996 tested essential oil extract of *Ocimum suave* Wild at higher doses against storage insects of maize and found 100.0% mortality of *S. cerealella* and *R. dominica*. Moreover, the tested plant materials were highly repellent to *S. zeamais* and provided good protection [33]. Park *et al.* 2003 reported the promising repellent biopotential of *Acorus gramineus* rhizome isolated ingredient to stored grains insect pest. Talukder *et al.* 2009 reported that during the investigations on the toxic properties of combination of *Acorus calamus* L. rhizomes and *The vetia neriifolia* Juss. seed extract, the lowest LC_{50} values (43.27 µgcm^{-1}) were found against *S. oryzae* at 24 h after treatment (Talukder and

Khanam 2009). Lakshmi Soujanya *et al*. 2012 observed that leaf powders of *Vitex negundo* L., *Adathoda vasica* L., *Catharanthus roseus* L. and *L. camara* at 5% *w*/*w* were evaluated against *S. oryzae* in stored maize. All the treatments proved to be very toxic towards *S. oryzae* adults.

6. Conclusion

This study proved that the leaf extract of indigenous plants like *A.squamosa*, *O. basilicum*i,), *A. calamus* and *G. gynendra* can be used to protect stored grain pests. From table 3, it is evident that all the plant extracts at three doses ie, 0.5 percent, 1.0 percent and 1.5 percent concentrations repelled the lesser grain borers, *Rhyzopertha dominica* Fabricius larvae from 98.83 to 100.00 per cent. The adults *Rhyzopertha dominica* did not enter into the sacklets containing the treated wheat grains, while in the absolute control, this was about 79.00 per cent. Benzene proved to have a potent repellent effect keeping 99.00 per cent lesser grain borers, *Rhyzopertha dominica* away from sacklets.

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References

1. Chandrasekar B, Ambrose G, Jayabalan N. In□uence of biofertilizers and nitrogen source level on the growth and yield of Echinochloa fru- entacea (Roxb) Link. J Agric Technol. 2005; 1(2):223-34.
2. Jeeva S, Laloo RC, Mishra BP. Traditional agricultural practices in Me- ghalaya, North East India. Indian J Tradit Knowledge. 2006; 5(1):7-18.
3. Kiruba S, Mishra B, Stalin SI, Jeeva S, Dhas SSM. Traditional pest management practices in Kanyakumari district, southern peninsular India. Indian J Tradit Knowledge. 2006; 5(1):71-4.
4. Talukder FA, Islam MS, Hossain MS, Rahman MA, Alam MN. "Toxicity effects of botanicals and synthetic insecticides on *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (F.)," Bangladesh Journal of Environment Science. 2004; 10(2):365-371.
5. Dubey A, Gupta R, Chandel BS. Efficacy of *Acorus calamus*, Vitex *negundo* and *Ageratum conyzoides* against tobacco caterpillar *Spilarctia obliqua* walker". Indian. J Entomology. 2004; 66(3):238-240.
6. Dubey NK, Srivastava BA, Kumar A. "Current status of plant products as botanical pesticides in storage pest management," Journal of Biopesticide. 2008; 1(2):182-186.
7. Talukdar FA, Howse PE. Deterrent and insecticidal effect of extract of pithraj, *Aphanamixis polystacha* against *Tribolium castaneum.* J. Chem. Ecel. 1993; 19:2463-2471.
8. Roy B, Amin R, Uddin MN. Leaf extracts of Shiyalmutra (Blumea lacera) as botanical insecticides against lesser grain borer and riceweevil. J Biol. Sci. 2005; 5:201-204.
9. Kumar H. Diatomaceous earth in Croatia. Diatom Research and Consulting Inc., Guelph, Canada. ZbornikRadova-Seminar-DDD-i-ZUPP, 2009, 325-333.
10. Jacobson HV. Nutritional preferences of the lesser grain borer, Rhizopertha dominica (F.) (Coleoptera: Bostrichidae) under conditions of free choice of food. J Plant Prot Res. 2004; 46(4):359-367.
11. Salem SA, Abou-Ela RG, Matter MM, El-Kholy MY. Entomocidal effect of Brassica napus extracts on two store pests, Sitophilus oryzae (L.) and Rhizopertha dominica (Fab.) (Coleoptera). J Appl Sci Res. 2007; 3:317-322.
12. Adedire CO, Lajide L. Ability of extract of ten tropical plant species to protect maize grains against infestation by the maize weevil Sitophilus zeamais during storage. Nigerian J Expt. Biol. 2003; 4(2):175-179.
13. Adedire CO, Obembe OO, Akinkurolele RO, Oduleye O. Response of Callosobruchus maculatus (Coleoptera: Chysomelidae: Bruchinae) to extracts of cashew kernels. J Plant Dis Protect. 2011; 118(2):75-79.
14. Ileke KD, Olotuah OF. Bioactivity of *Anacardium occidentals* and *Allium sativum* powders and oils extracts against cowpea bruchid, *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae). Intern J Biol. 2012; 4(1):96-103
15. Golob P, Moss C, Dales M, Fidgen A, Evans J, Gudrups I. The use of spices and medicinals as bioactive protectants for grains. F.A.O. Agricultural Services Bulletin, No, 1999, 137:252.
16. Isman MB. Plant essential oils for pest and disease management. Crop Protection [XIVth International plant protection congress, Jerusalem, Israel. 1999; 19(8/10):603-608.
17. Weaver D, Subramanyam BH. Botanicals. In: Alternatives to Pesticides in Stored-Product IPM [ed. by Subramanyam Bh, \Hagstrum, D.]. Dordrech, Netherlands: Kluwer Academics Publisher, 2000, 303-320.
18. Klys M. Feeding inhibitors in pest control: Effect of herb additions to food on the population dynamics of the lesser grain borer Rhyzopertha dominica F. (Coleoptera, Bostrychidae). Polish Journal of Ecology. 2004; 52(4):5757-581.
19. Ashamo MO, Odeyemi OO. Protection of maize against Sitophilus zeamais using seed extracts from some indigenous plants. J Plant Dis Prot. 2001; 108(3):321-326.
20. Akinkurolere RO, Sebastien B, Haoliang C, Hongyu Z. Parasitism and host location preference in Habrobracon hebetor (Hymenoptera:Braconidae): Role of refuge, choice and host instar. J Econ Entomol. 2009; 102(2):610-615.
21. Chander H, Kulkarni SG, Berry SK. *Acorus calamus* rhizomes as a protectant of milled rice against *Sitophilus oryzae* and *Tribolium castaneum*. J Food Sci Technol. 1990; 27:171-174.
22. Ashok kumar J, Rekha T, Shyamala Devi S, Kannan M, Jaswanth A, Gopal V. Insecticidal activity of ethanolic extract of leaves of *Annona squamosa*. J Chem Pharm Res. 2010; 2:177-180.
23. Ndungu M, Lwande W, Hassanali A, Moreka L, Chabra SC. *Cleome monophylla* essential oil and its components as tick (*Rhipicephalus appendiculatus*) and maize weevil (*Sitophilus zeamais*) repellents. Entomologia Experimentalis et Applicata. 1995; 76:217-222.

24. Mishra BB, Tripathi SP, Tripathi CPM. Repellent effect of leaves of essential oils from *Eucalyptus globulus* (Mirtaceae) and *Ocimum basilicum* (Lamiaceae) against two major stored grain insect pests of Coleopterons. Nat Sci. 2012; 10:50-54.
25. Rana VS, Rashmi Rameshwar D. Antifeedant and ovipositional activities of *Vitex negundo* leaves against *Sitophilus oryzae* and *Callosobruchus chinensis*. Shashpa. 2005; 12:117-121.
26. Bajpai Shail, Chandel BS. An assessment of ecofriendly insecticidal toxicity of *Ocimum sanctum*, *Croton tiglium* and *Zingiber officinale* extractives against Bihar hairy caterpillar, *Spilarctia obliqua* Walker (Lepidoptera: Arctiidae), 2020.
27. International Journal of Advanced Academic Studies 2020; 2(3):98-103
28. Rajani BS Chandel. Insecticidal biopotentials of *Ageratum conyzaides, Azadirachta indica* and *Chenopodium ambrosioides* essential oils against leaf webber, *Eucosma critica* Meyrick (lepidoptera: Eucosmidae). International Journal of fauna and Biological studies, 2016; 3(1).
29. Abbott WS. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 1925; 18:266-267
30. Finney DJ. Probit analysis. Cambridge University Press, Cambridge, 1952, 318.
31. Bekele AJ, Obeng-Ofori D, Hassanali A. Evaluation of *Ocimum suave* (Willd) as a source of repellents, toxicants and protectants in storage against three stored product insect pests. Int J Pest Manag. 1996; 42:139-142.
32. Tripathi AK, Prajapati V, Aggarwal KK, Khanuja SP, Kumar S. Repellency and toxicity of oil from *Artemisia annua* to certain stored-product beetles. J Econ Entomol. 2000; 93:43-47.
33. Rao J, Prakash A. Evaulation of new botanicals on paddy grain protectants against lesser grain borer, *Rhyzopertha dominica* Fabr. J Appl Zool Res. 2002; 13:258-259.
34. Park C, Kim SI, Ahn YJ. Insecticidal activity of asarones identified in *Acorus gramineus* rhizome against three coleopteran stored-product insects. J Stored Prod Res. 2003; 39:333-342.
35. Talukder FA, Islam MS, Hossain MA, Rahman MM, Alam MN. Toxicity effects of botanicals and synthetic insecticides on *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (F.) Bangladesh J Environ Sci. 2004; 10:365-371
36. Mohal N, Islam W, Mondal K, Parveen S. Deformities produced by some plant powders in *Rhyzopertha dominica* (F) Coleoptera (Bostrichidae) J Biol Sci. 2006; 14:69-72.
37. Isman MB. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Ann Rev Entomol. 2006; 51:45-66
38. 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.
39. Huang Y-Z, Yang C-J, Xue D, Rotimi OA, Ying-Juan YAO. Contact and repellency activities of ethanol extracts from twenty medicinal plants against *Rhizopertha dominica* (Fab.) (Coleoptera: Bostrichidae) Acta Entomol Sin. 2007; 50:118-124
40. Viglianco AI, Novo RJ, Cragnolini CI, Nassetta M, Cavallo NA. Antifeedant and repellent effects of extracts of three plants from Cordoba (Argentina) against *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) BioAssay. 2008; 3:4
41. Islam MS, Hasan MM, Xiong W, Zhang SC. Fumigant and repellent activities of essential oil from *Coriandrum sativum* (L.) (Apiaceae) against red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) J Pest Sci. 2009; 82:171-177.
42. Bajpai R, Chandel BS. Evaluation of *Adhatoda vasica, Acorus calamus and Vitex nugendo* as a source of phago-antifeedant against cabbage butterfly, *Pieris brassicae* Linn. (Lepidoptera: Pieridae) on mustard, *Brassica campestris* (Linn.). International Journal of Biotechnology and Biochemistry. 2009; 5($):451-459.
43. Geng ZF, Liu ZL, Wang CF, Liu QZ, Shen SM, Liu ZM, Du SS, Deng ZW. Feeding deterrents against two grain storage insects from *Euphorbia fischeriana*. Molecules. 2011;16:466-476
44. Gandhi N, Pillai S. Control of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) by pulverized leaves of *Punica granatum* (lythraceae) and *Murraya koenigii* (Rutaceae) Int J Agric Biol. 2011; 13:535-540
45. Ukeh DA, Umoetok SBA. Repellent effects of five monoterpenoid odours against *Tribolium castaneum* (Herbst) and *Rhyzopertha dominica* (F.) in Calabar 4. Nigeria. Crop Protec. 2011; 30:1351-1355
46. Wekesa I, Onek LA, Deng AL, Hasanali A, Othira JO. Toxicity and repellency potency of *Hyptis spicigera* extracts on *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) J Stored Prod Post Harvest Res. 2011; 2:113-119.
47. Khemira S, Mediouni-Ben Jemaa J, Haouel S, Khouja ML. Repellent activity of essential oil of *Eucalyptus astringens* against *Rhyzopertha dominica* and *Oryzaephilus surinamensis*. Acta Hort. 2012; 997:207-213
48. Lakshmi Soujanya P, Sekhar JC, Kumar P, Suby SB. Bioactivity of four plant extracts against Angoumois grain moth *Sitotroga cerealella* (Oliv.) (Lepidoptera: Gelechidae) in stored maize grain. Maize J. 2012; 1:79-81
49. Lakshmi Soujanya P, Sekhar JC, Kumar P. Maize grain losses due to *Sitophilus oryzae* L. and *Sitotroga cerealella* (Oliv.) infestation during storage. Maize J. 2013; 2:57-59
50. Singh AN, Soumya R, Raghavendra D, Rajendra PS. Plant extracts as repellents against adults of *Tribolium castaneum*, *Rhyzopertha dominica* and *Sitophilus oryzae*. Indian J Plant Protec. 2013; 41:296-300
51. Shah TB, Saeed M, Khan I, Khan A, Khan GZ, Farid A, Khan SM. Repellency evaluation of selected indigenous medicinal plant materials against *Rhyzopertha dominica* (Herbst) (Coleoptera: Tenebrionidae) J Entomol Zool Studies. 2015; 3:65-68