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EFFICACY OF SELECTED PLANT EXTRACTS AS INSECTICIDAL FUMIGANT AGAINST CERTAIN STORED GRAIN INSECT PESTS UNDER LABORATORY CONDITIONS

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Abstract

To replace the use of synthetic fumigants in the stored product pest management, an attempt was made to identify the suitable alternative bio fumigants, the present investigation was carried out. There were 25 pesticidal plant species selected and their leaves or plant parts having pesticidal effect collected and extracted using Solvent Acetone following Soxhlet apparatus extraction method. The extracts were tested against the target insects *viz*., *Sitophilus oryzae* and *Tribolium castaneum* to find out their fumigant effect under laboratory conditions using filter sponge in closed plastic containers. The maximum mean mortality of *S. oryzae* was observed with *A. vulgaris* treatment caused 66.33% followed by *E. globulus* and *M. piperita* with 64.67% and 63.00%, respectively. The treatments *viz*., *V. negundo* and *B. juncea* were found with 59.66% and 59.33% mortality, respectively. The results revealed that the maximum mean mortality of *T. castaneum* was found with *E. globulus* (48.00%). The plant extracts namely, *C. nardus*, *O. bacillum* and *M. piperita* were followed suit with 44.67% each and 44.33% mortality, respectively. The effect of plant extracts were found gradually increased from a day after treatment.

Key words : Stored grain pests, fumigant, plant extracts.

Introduction

Since ancient time pests have been damaging and causing heavy losses to stored grains both quantitatively and qualitatively (Tripathi *et al*., 2009). In India, most of the food grains produced is being stored at farmers level under the most primitive conditions of storage and hence, they are easily accessible to the attack by a variety of insect pests and other agents in storage (Radhakrishnan *et al*., 1983). The quantitative and qualitative damage to stored grains and grain product from the insect pests may amount to 20-30% in the tropical zone and 5-10% in the temperate zone (Rajendran and Sriranjini, 2008). Food grain production in India has reached 250 million tonnes in the year 2010-2011, in which nearly 20-25% food grains are damaged by stored grain insect pests (Rajashekar *et al*., 2012). Our country is, therefore, loosing on an average of 9.33 per cent stored grains. This reflects on the magnitude of the pest problem in storage (Singh *et al*., 2001). Among the pests, the insects cause heavy food grain losses in storage, particularly in tropical and sub tropical countries. The rice weevil, *Sitophilus oryzae* Linn. is a serious insect pest of various food grains under storage is largely responsible for damage and frequently harbouring in stores, mills and ware-house (Koura and E1-Halfway, 1967). Red flour beetle, *Tribolium castaneum* (Herbst) is a small, reddish brown and flat beetle and it attacks grains, seed, vegetable powders, dry fruits, oil cakes, nuts, museum specimens like dry insects and stuffed materials (Malek *et al*., 1996).

Synthetic insecticides have been used extensively in grain facilities to control stored product insect pests. Fumigants such as methyl bromide, phosphine, cyanogens, ethyl formate, or sulfuryl fluoride rapidly kill all life stages of stored product insects in a commodity or in a storage structure since 1950. Fumigation is still one of the most effective methods for the prevention of stored product losses from insect pests. But pests develop resistance, not stored products were showing a slow upsurge in fumigation resistance. Resistance to phosphine is so high in Australia and India, it may cause control failures (Donahaye, 2000). Although, chemical insecticides are effective, their repeated use has led to residual toxicity, environmental pollution and an adverse effect on food besides side effect on humans. Their uninterrupted and indiscriminate use not only has led to the development of resistant strains, but also accumulation of toxic residues

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on food grains used for human consumption that has led to the health hazards. In view of all these problems, several insecticides have either been banned or restricted in their use. The increasing serious problems of resistance and residue to pesticides and contamination of the biosphere associated with large-scale use of broad spectrum synthetic pesticides have led to the need for effective biodegradable pesticides with greater selectivity. This awareness has created a worldwide interest in the development of alternative strategies, including the discovery of newer insecticides. The use of synthetic chemical insecticides is either not permitted or used restrictively because of the residue problem and health risks to consumers. 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 (Rajashekhar *et al*., 2012). These concerns have encouraged researchers to look for alternative solutions to synthetic pesticides. Botanical insecticides have long been touted as attractive alternatives to synthetic chemical insecticides for pest management. Hence, attention has been paid towards exploitation of plant products (Mishra and Dubey, 1994). Further, in the context of organic food production, botanical insecticides are best suited in the post-harvest protection of food (Isman, 2006). In addition, resistance development in insects due to phosphine treatment is a matter of serious concern (Bell and Wilson, 1995; Daglish and Collims, 1999 and Benhalima *et al*., 2004). Bearing in mind the deleterious effect of synthetic insecticides, botanicals have been tested against insects (Pandey *et al*., 1976 and Shivanna *et al*., 1994).

Biopesticides obtained from plant sources are safer, devoid of residue problems and almost negligible application risks as compared to synthetic chemical pesticides. It has been demonstrated by many workers that numerous plant species showed insecticidal, antifeedant, repellent antigrowth and oviposition inhibiting properties. Although, the plant products do not possess quick knock down effect unlike synthetic contact insecticides, which are currently being recommended for the control of stored grain insect pests, they possess the least or less mammalian toxicity and thus constitute no health hazards, surface persistence lasts for long time with no adverse effects on seed germinability, cooking quality and milling, less expensive and are easily available. Using plant products to control storage pests is an age old practice in India. In many countries, plant tissues or crude products of the plants, such as aqueous or organic solvent extracts are used directly as protectants of stored products (Talukder, 2006). It has been suggested that fumigants from plant origins could have a great potential on the basis of their efficacy, economic value and use in large scale storage. Several types of aromatic plants are being investigated for their antifeedant and insecticidal activity including their fumigant action (El-Nahal *et al*., 1989 and Rao *et al*., 2005).

Considering the need for safe, ecofriendly and cheap insecticide to manage the stored product insects, the present study was under taken to determine the fumigant action of selected plant extracts against stored product pests under laboratory conditions.

Materials and Methods

a. Mass culturing of test insects

The test insects namely, *S. oryzae* and *T. castaneum* adults were obtained from the storage insects culture from Department of Entomology and were mass cultured in 1 kg capacity glass jars of size 15 × 10 cm containing respective food materials (500g) as a nutritional source at 60-70 per cent relative humidity and temperature range from 30-35^{0}C . Then glass jars were covered with a fine muslin cloth and secured with a rubber band. With the interval of two generation, half of the completely infested grains/ flour were replaced with the same quantity of uninfested materials. Thus, a continuous culture was maintained throughout the study period. The freshly emerged adult beetles were used for experiments.

b. Collection and preparation of botanicals

The following pesticidal plant species were collected from in and around Annamalai Nagar area and also from other places and shade dried for 45 days (table A). Shade drying is to prevent the loss of active principle from the plant. The dried plant materials were powdered using electric blender and sieved through strainer and the fine powder was used for extraction using Soxhelt extraction apparatus. The powders were extracted with the solvent acetone and the extracts were evaluated against the above target pests for their fumigant action.

c. Soxhlet extraction

The ordinary method of extraction was not efficient to yield good amount of active principle of the plant material. To extract more active principle from all the plant materials, Soxhlet extraction was used. The dried plant material (500g) of each species was filled into the Soxhlet apparatus. A cotton plug was used at the place of thimble to stop the entry of the crude material into the siphoning tube. The required solvent (Acetone) was filled up five times more than total amount of the sample material into the flask of the apparatus. The apparatus was then connected with the water supply to the condenser. The

Table A : List of plant species with their botanical and family name.

S. no.	Common name	Botanical name	Family
1.	Marigold	*Tagetes erecta L.*	Asteraceae
2.	Coriander	*Coriandrum sativum* L.	Apiaceae
3.	Indian privet	*Vitex negundo* L.	Verbenaceae
4.	Lemon grass	*Cymbopogon nardus* Spreng.	Poaceae
5.	Garlic	*Allium sativum* L.	Amaryllidaceae
6.	Cinnamon	*Cinnamomum verum* J. Presl	Lauraceae
7.	Holy basil	*Ocimum canum* L.	Lameaceae
8.	Curry leaf	*Murraya koenigii* L.	Rutaceae
9.	Black Pepper	*Piper nigrum* L.	Piperaceae
10.	Tobacco	*Nicotiana tobacum* L.	Solanaceae
11.	Lemon	*Citrus limon* L.	Rutaceae
12.	Jatropha	*Jatropha curcas* L.	Euphorphiaceae
13.	Worm wood	*Artemisia vulgaris* L.	Asteraceae
14.	Bael	*Aegle marmelos* L.	Asparanjanaceae
15.	Oleander	*Neerium oleander* L.	Aposayanaeceae
16.	Cumin	*Cuminum cyminum* L.	Apiaceae
17.	Mint	*Mentha piperita* L.	Lameaceae
18.	Eucalyptus	*Eucalyptus globulus* Latrill	Myrteaeceae
19.	Mustard	*Brassica juncea L.*	Brassicaceae
20.	Sweet basil	*Ocimum bacillum* L.	Lameaceae
21.	Adathoda	*Adathoda vasica* L.	Acanthaceae
22.	Acorus	*Acorus calamus* L.	Acoraceae
23.	Neem	*Azadiracta indica* A.Juss	Meliaceae
24.	Milk weed plant	*Calotropis gigantia* L.	Apocynaceae
25.	Pongam	*Pongamia glabra* L.	Fabaceae

temperature of the heating mantle was maintained at 60-65°C (boiling point of Acetone). The process was carried out for 5 to 6 hours for each sample. The extract was transferred to Petri plates and solvent was allowed to evaporate. The evaporated material was taken in conical flasks and stored in the refrigerator for further use.

d. Fumigant effect of extracts against test insects in laboratory

The fumigant activity of the plant extracts were tested according to a protocol suggested by Singh *et al*. (1989). Small Rectangles of (2 × 3 cm) of filter sponge were treated with plant extracts. Each small piece was placed inside a plastic cylinder cup (3 × 6 cm) and both ends were covered with nets. Each cylinder cup was placed inside large plastic containers (5 × 12 cm) that contained 10 freshly emerged adult target insects with their nutritional source. The plastic containers were tightly closed to avoid leakage of plant volatiles and the lid was transparent to observe the activity of insects from the top to count the mortality without opening the containers. An untreated control was maintained separately to compare with the treatments. Three replications were maintained and the mortality was checked daily for 7 days. The experiment was set up following Completely Randomized Block Design.

e. Statistical analysis

The data on the fumigant effect of selected plant extracts against test insects were analysed as per Goulden (1952). Analysis of variance was worked out and the mean values were compared using least significant difference (LSD). All the percentage data were subjected to arc sine transformation.

Results and Discussion

The results of the fumigant action of various plant extracts were evaluated against *S. oryzae* is furnished in table 1. The maximum mean mortality of weevils were observed with *A. vulgaris* treated insects causing 66.33% followed by *E. globulus* and *M. piperita* with 64.67% and 63.00%, respectively and there were no significant difference was found in both the treatments. The results are corroborate with the findings of Mahendiran *et al.* (2009) reported that *A. vulgaris* treatment have caused 83.56% mortality at 5% concentration against pulse beetle

Table 1 : Efficacy of selected plant extracts as fumigants against *Sitophilus oryzae* under the laboratory condition

S. no.	Treatments	% Mortality of insects (days after treatment)							
		1st DAT	2nd DAT	3rd DAT	4th DAT	5th DAT	6th DAT	7th DAT	Mean mortality
1.	*Tagetes erecta*	0.00 (0.90)^{f}	6.66 (12.59)^{ef}	23.33 (28.78)^{ef}	30.00 (33.21)^{jkl}	40.00 (39.14)^{eg}	53.33 (46.92)^{efg}	73.33 (59.21)^{defg}	32.33 (34.36)^{ghi}
2.	*Coriandrum sativum*	6.67 (12.59)^{e}	23.33 (28.78)^{bcd}	30.00 (33.21)^{e}	43.33 (41.15)^{fghi}	53.33 (46.92)^{cde}	56.66 (54.99)^{cde}	73.33 (59.21)^{defg}	42.33 (40.58)^{def}
3.	*Vitex negundo*	23.33 (28.78)^{abc}	43.33 (41.15)^{a}	43.33 (46.92)^{ab}	56.66 (48.84)^{bcde}	70.00 (56.99)^{ab}	80.00 (63.93)^{ab}	90.00 (74.70)^{abc}	59.66 (50.60)^{ab}
4.	*Cymbopogon nardus*	10.00 (18.43)^{e}	20.00 (26.56)^{cd}	30.00 (33.00)^{e}	40.00 (39.23)^{ghij}	50.00 (45.00)^{de}	60.00 (50.85)$_{cdef}$	73.33 (59.00)^{defg}	40.33 (39.42)^{efg}
5.	*Allium sativum*	33.33 (35.21)^{ab}	43.33 (41.15)^{a}	50.00 (45.00)^{a}	56.67 (48.93)^{bcde}	70.00 (56.99)^{ab}	73.33 (59.21)^{abc}	73.33 (74.70)^{abc}	59.66 (50.63)
6.	*Cinnamomum verum*	6.66 (12.59)^{e}	13.33 (21.14)^{e}	26.66 (30.99)^{f}	36.67 (37.22)^{ijk}	46.67 (43.07d)^{e}	56.67 (48.84)^{deg}	63.33 (52.77)^{fgh}	35.66 (36.63)^{abfgh}
7.	*Ocimum canum*	13.33 (21.14)^{ce}	20.00 (26.07)^{cd}	30.00 (33.21)^{e}	43.33 (41.15)^{bfgh}	56.67 (48.84)^{cd}	66.67 (54.78)^{cde}	80.00 (63.93)^{cdef}	44.33 (41.73)^{def}
8.	*Murraya koenigii*	0.00 (0.90)^{f}	6.66 (12.59)^{ef}	13.33 (21.14)	26.67 (30.99)^{kl}	36.67 (37.22)^{g}	46.66 (43.07)^{fg}	53.33 (46.92)^{h}	26.33 (30.84)^{i}
9.	*Piper nigrum*	13.33 (21.14)^{ce}	23.33 (28.78)^{bcd}	30.00 (33.21)^{e}	40.00 (39.15)^{ghij}	50.00 (45.00)^{de}	63.33 (52.77)^{cde}	73.33 (59.00)^{defg}	42.00 (40.38)^{ef}
10.	*Nicotiana tobacum*	6.66 (12.59)^{e}	16.66 (23.85)^{cd}	26.66 (30.99)^{ef}	33.33 (35.21)^{ijkl}	46.67 (43.07)^{de}	60.00 (50.85)^{cdef}	66.66 (54.78)^{efgh}	36.67 (37.22)^{fgh}
11.	*Citrus limon*	20.00 (26.07)^{bc}	30.00 (33.00)^{abcd}	43.33 (41.15)^{bc}	53.33 (46.92)^{cdef}	60.00 (50.77)^{bcd}	73.33 (59.00)^{ab}	80.00 (63.43)^{cdef}	51.33 (45.76)^{bcd}
12.	*Jatropha curcas*	6.66 (12.59)^{e}	16.66 (23.85)^{cd}	26.67 (30.99)^{ef}	36.66 (37.22)^{hijk}	50.00 (45.00)^{de}	56.67 (48.84)^{cdefg}	66.66 (54.78)^{efgh}	37.33 (37.64)^{fgh}
13.	*Artemisia vulgaris*	36.66 (26.07)^{a}	43.33 (41.15)^{a}	60.00 (50.85)^{a}	70.00 (56.99)^{a}	73.33 (59.00)^{a}	83.33 (66.14)^{a}	96.66 (83.25)^{a}	66.33 (54.57)^{a}
14.	*Aegle marmelos*	6.66 (12.59)^{e}	13.33 (21.14)^{e}	33.33 (35.21)^{ce}	43.00 (41.15)^{fghi}	50.00 (45.00)^{de}	63.33 (52.77)^{cde}	76.66 (61.22)^{defg}	41.00 (39.81)^{efg}
15.	*Neerium oleander*	16.66 (23.85)^{c}	26.66 (30.99)^{bcd}	43.33 (41.15)^{bc}	46.67 (43.07)^{efg}	56.67 (48.84)^{cd}	70.00 (56.99)^{bcd}	80.00 (63.93)^{cdef}	48.33 (44.03)^{cde}
16.	*Cuminum cyminum*	10.00 (18.43)^{e}	23.33 (28.78)^{bcd}	33.33 (35.21)^{ce}	40.00 (39.23)^{ghij}	53.33 (46.92)^{cde}	60.00 (50.77)^{cdef}	66.66 (54.78)^{efgh}	40.67 (39.62)^{efg}
17.	*Mentha piperita*	33.33 (35.21)^{ab}	43.33 (41.15)^{a}	53.33 (46.92)^{ab}	63.33 (52.77)^{ac}	70.00 (56.99)^{ab}	83.33 (66.15)^{a}	93.33 (80.54)^{ab}	63.00 (52.58)^{a}
18.	*Eucalyptus globulus*	36.66 (37.22)^{a}	43.33 (41.05)^{a}	53.33 (46.92)^{ab}	66.67 (54.78)^{ab}	73.33 (59.00)^{a}	83.33 (66.15)^{a}	96.66 (83.25)^{a}	64.67 (53.56)^{a}
19.	*Brassica juncea*	26.66 (30.99)^{abc}	36.67 (37.22)^{ab}	50.00 (45.00)^{ab}	60.00 (50.77)^{abcd}	66.67 (54.78)^{abc}	80.00 (63.93)^{ab}	86.67 (68.85)^{bcd}	59.33 (50.38)^{ab}
20.	*Ocimum bacillum*	20.00 (26.07)^{bc}	30.00 (33.00)^{abc}	43.33 (41.15)^{bc}	56.66 (48.84)^{bcde}	60.00 (50.85)^{bcd}	66.66 (54.99)^{cde}	80.00 (63.93)^{cdefh}	53.67 (47.11)^{bc}
21.	*Adathoda vasica*	0.00 (0.90)^{f}	6.66 (12.59)^{ef}	16.67 (23.85)^{f}	23.33 (28.78)^{l}	33.33 (35.01)^{g}	43.33 (41.15)^{g}	50.00 (45.00)	24.66 (29.71)^{i}

Table 1 continued...

Table 1 continued...

22.	*Acorus calamus*	20.00 (26.07)c	26.66 (30.78)bcd	33.33 (34.92)ce	50.00 (45.00)defg	60.00 (50.85)bcd	66.67 (54.99)cde	80.00 (63.93)cdef	48.00 (43.85)cde
23.	*Azadiracta indica*	16.66 (23.36)c	26.66 (30.78)bcd	40.00 (39.14)bc	50.00 (45.00)defg	56.67 (48.93)cd	66.67 (54.99)cde	83.33 (66.14)cde	48.00 (44.04)cde
24.	*Calotropis gigantia*	6.66 (12.59)e	13.33 (21.15)cde	23.33 (28.78)ef	33.33 (35.21)ijkl	40.00 (39.14)e	53.33 (46.92)efg	60.00 (50.85)gh	33.00 (34.98)ghi
25.	*Pongamia glabra*	6.66 (12.59)e	13.33 (21.15)cde	16.67 (23.85)f	33.33 (35.21)ijkl	40.00 (39.23)eg	43.33 (41.15)g	53.33 (46.92)h	29.66 (32.98)hi
26.	Control	0.00 (0.90)f	3.33 (6.75)f	3.33 (6.75)h	6.66 (12.59)m	6.67 (12.59)h	13.33 (21.15)h	13.33 (21.14)	7.00 (15.31)j
	S.E.D	5.30	4.83	3.91	3.51	3.97	4.34	5.86	2.66
	CD (0.05)	10.64	9.69	7.84	7.05	7.96	8.72	11.77	5.34

*Mean of three replications. * Means with same alphabet do not vary significantly according to LSD.
*Figures in parentheses are arc sine transformed values.

Table 2 : Efficacy of selected plant extracts as fumigants against *Tribolium castaneum* under the laboratory condition.

S. no.	Treatments	% Mortality of insects (days after treatment)							
		1st DAT	2nd DAT	3rd DAT	4th DAT	5th DAT	6th DAT	7th DAT	Mean mortality
1.	*Tagetes erecta*	0.00 (0.91)e	0.00 (0.91)e	13.33 (21.15)g	23.33 (28.78)efg	33.33 (35.22)gh	43.33 (41.15)e	70.00 (56.99)ab	26.00 (30.61)g
2.	*Coriandrum sativum*	0.00 (18.43)e	10.00 (18.43)d	23.33 (28.78)de	33.33 (35.22)cde	36.67 (37.23)fgh	53.33 (46.92)bcde	76.67 (61.21)a	33.00 (35.04)de
3.	*Vitex negundo*	10.00 (21.15)b	23.33 (28.78)ab	33.33 (35.22)ac	43.33 (41.15)abc	50.00 (45.00)bcd	60.00 (50.77)abc	63.33 (52.77)bd	40.33 (39.42)bc
4.	*Cymbopogon nardus*	13.33 (0.91)b	23.33 (28.78)ab	33.33 (35.22)abc	46.67 (43.07)ab	56.67 (48.84)ab	66.67 (54.78)a	76.67 (61.71)a	44.67 (41.93)a
5.	*Allium sativum*	0.00 (18.43)e	20.00 (26.07)bc	30.00 (33.21)bcd	46.67 (43.07)ab	53.33 (46.92)abc	60.00 (50.77)abc	70.00 (56.99)ab	39.67 (39.03)bc
6.	*Cinnamomum verum*	10.00 (18.43)b	13.33 (21.14)cd	26.67 (30.99)cde	43.33 (41.15)abc	53.33 (46.92)abc	60.00 (50.77)abc	70.00 (56.79)ab	39.67 (39.03)bc
7.	*Ocimum canum*	10.00 (0.91)b	16.67 (23.85)bcd	30.00 (33.00)bcd	43.33 (28.78)abc	50.00 (45.00)bcd	66.67 (54.99)a	80.00 (63.93)a	42.00 (40.39)ab
8.	*Murraya koenigii*	0.00 (0.91)e	3.33 (6.75)e	13.33 (21.15)g	23.33 (33.21)efg	30.00 (33.21)h	43.33 (41.15)e	60.00 (50.85)de	24.66 (29.72)g
9.	*Piper nigrum*	0.00 (0.91)e	16.67 (23.85)bcd	26.67 (30.99)cde	30.00 (35.22)cdef	43.33 (41.07)def	60.00 (50.77)abc	70.00 (56.79)ab	35.00 (36.26)cde
10.	*Nicotiana tobacum*	0.00 (0.91)e	10.00 (18.43)d	20.00 (26.57)e	33.33 (37.23)cde	40.00 (39.23)efg	50.00 (45.00)cde	63.33 (52.77)bd	30.33 (33.42)efg
11.	*Citrus limon*	0.00 (0.91)e	16.67 (23.25)bcd	26.67 (30.99)cde	36.67 (37.23)bcd	43.33 (41.15)def	60.00 (50.85)abc	63.33 (52.77)bd	35.33 (36.44)cde
12.	*Jatropha curcas*	0.00 (0.91)e	10.00 (18.43)d	13.33 (21.15)g	20.00 (26.56)fg	26.67 (30.99)j	43.33 (41.07)e	73.33 (59.00)a	26.67 (31.05)fg
13.	*Artemisia vulgaris*	10.00 (18.43)b	20.00 (26.56)abc	30.00 (33.21)bcd	36.67 (37.14)bcd	50.00 (45.00)bcd	60.00 (50.77)abc	70.00 (56.79)ab	39.00 (38.64)bcd

Table 2 continued...

Table 2 continued...

14.	*Aegle marmelos*	0.00 (0.91)[e]	10.00 (18.43)[d]	20.00 (26.57)[e]	33.33 (35.22)[cde]	40.00 (39.23)[efg]	46.67 (43.07)[de]	63.33 (52.77)[bd]	30.00 (33.21)[efg]
15.	*Neerium oleander*	6.67 (0.91)[e]	13.33 (21.14)[cd]	20.00 (26.57)[e]	33.33 (35.22)[cde]	43.33 (41.15)[def]	53.33 (46.92)[bcd]	63.33 (52.77)[bd]	32.33 (34.63)[ef]
16.	*Cuminum cyminum*	13.33 (12.15)[c]	13.33 (21.15)[cd]	26.67 (30.97)[cd]	36.67 (37.22)[bcd]	46.67 (43.07)[cde]	56.67 (48.84)[bcd]	63.33 (52.77)[bd]	35.67 (41.73)[bcde]
17.	*Mentha piperita*	20.00 (21.14)[b]	20.00 (26.07)[bc]	30.00 (33.21)[bcd]	43.33 (41.15)[abc]	56.67 (48.84)[ab]	66.67 (54.78)a	80.00 (63.93)[a]	44.33 (43.85)[a]
18.	*Eucalyptus globulus*	0.00 (26.56)[a]	30.00 (33.21)[a]	40.00 (39.23)[a]	50.00 (45.00)[a]	60.00 (50.77)[a]	63.33 (52.77)[ab]	73.33 (59.00)[ab]	48.00 (39.61)[a]
19.	*Brassica juncea*	13.33 (0.91)[e]	16.66 (21.85)[bcd]	33.33 (35.22)[abcd]	43.33 (41.15)[abc]	53.33 (46.92)[abc]	66.67 (54.78)[a]	73.33 (59.00)[ab]	40.67 (41.93)[bc]
20.	*Ocimum bacillum*	0.00 (21.15)[b]	23.33 (28.78)[ab]	33.33 (35.22)[abc]	46.67 (43.07)[ab]	56.67 (48.84)[ab]	66.67 (54.78)[a]	76.67 (61.71)[a]	44.67 (29.54)[a]
21.	*Adathoda vasica*	3.33 (0.91)[e]	10.00 (18.43)[d]	13.33 (21.15)[eg]	23.33 (28.78)[efg]	30.00 (50.77)[h]	43.33 (41.15)[e]	53.33 (46.92)[de]	24.33 (36.44)
22.	*Acorus calamus*	0.00 (0.91)[d]	13.33 (21.15)[cd]	26.67 (30.99)[cd]	36.67 (37.22)[bcd]	46.67 (43.07)[cde]	56.67 (48.84)[bcd]	63.33 (52.77)[bd]	35.33 (39.44)[bcde]
23.	*Azadiracta indica*	0.00 (0.91)[e]	16.60 (23.85)[bcd]	36.67 (37.23)[ab]	40.00 (39.15)[abcd]	53.33 (46.92)[abc]	66.67 (54.78)[a]	73.33 (59.00)[ab]	41.00 (39.80)[bc]
24.	*Calotropis gigantia*	0.00 (0.91)[e]	0.00 (0.91)[e]	13.33 (21.15)[eg]	23.33 (28.78)[efg]	33.33 (35.22)[gh]	43.33 (41.15)[e]	70.00 (56.99)[ab]	26.00 (30.61)[g]
25.	*Pongamia glabra*	0.00 (0.91)[e]	10.00 (18.43)[d]	10.00 (18.43)[g]	13.33 (21.15)[g]	20.00 (26.56)[j]	30.00 (33.21)[f]	46.67 (43.07)[e]	18.33 (25.34)[i]
26.	Control	0.00 (0.91)[e]	0.00 (0.91)[e]	0.00 (0.91)[h]	3.33 (6.75)[h]	3.33 (6.74)[k]	10.00 (18.43)[g]	10.00 (18.93)[f]	3.33 (10.49)[j]
S.Ed.		2.63	3.41	2.76	3.82	2.87	2.95	3.89	1.85
CD (0.05)		5.28	6.84	5.55	7.67	5.76	5.92	7.80	3.73

*Mean of three replications. * Means with same alphabet do not vary significantly according to LSD.
*Figures in parentheses are arc sine transformed values.

adults. The essential oils of *Artemisia* species showed toxic, repellent and development inhibitory activities against two economically harmful stored insects (Tripathi *et al*., 2000). The results are in tune with the findings of Tunc *et al*. (2000), who reported that the essential oil vapours distilled from Eucalyptus were reported as fumigants and caused 100% mortality of the eggs of stored product pests. The similar results were also obtained by Singh *et al*. (2010), who reported that a natural menthol based tablet formulation containing natural binder and carrier agent, liquid preservation-acetic acid and solid powder preservative applied, once was found to be suitable for the management of adzuki bean beetle, *C. chinensis* adults. The treatments *viz*., *V. negundo* and *B. juncea* have caused 59.66% and 59.33% mortality, respectively were followed suit. The treatment *O. bacillum* have caused 53.67% mortality of the test insect. The present findings are similar to the reports of Kathirvelu *et al*. (2012), they found that the *V. negundo* made biotablets flared better in causing mortality when compared to other treatments. The results were obtained from the preliminary screening of the plant species in the study. The *C. limon* treated insects were showed 51.33% mortality and *N. oleander*, *A. calamus* and *A. indica* were found on par with each other causing 48.00% mean mortality of the test insects each. The results are in accordance with the findings Ravi Nandi *et al*. (2008), who stated that the insecticidal property of vasambu rhizome (*Acorus calamus*) formulation with cowdung ash as a carrier against *C. chinensis* in pigeon pea reduced the beetle population with 16.33% as against 41.11% in untreated check. Park *et al*. (2006) tested the contact application and fumigation effect of *Acorus gramineus* rhizome extract against the adults of *S. oryzae*, *C. chinensis* and *Lesioderma serricorne.* It was observed that the insecticidal activity of the compound was largely credited to its fumigation action. In *S. oryzae*, the fumigant action of plant species were found even after a day of treatment and there were mortality of the test insects gradually increased to the last day of the experiment. During 7th DAT, a maximum of 96.66% mortality was observed in *E. globulus* and *A. vulgaris* each and 93.33% in *M. piperita*.

The plant extracts tested against *T. castaneum* under the laboratory condition for their fumigant toxicity is furnished in table 2. The results revealed that the maximum mean mortality was found with *E. globulus* (48.00%). This is confirmative with the reports of Giga *et al*. (1992) eucalyptus leaves are used for bruchid control in Uganda. The plant extracts namely, *C. nardus*, *O. bacillum* and *M. piperita* were followed suit with 44.67 each and 44.33% mortality of Red flour beetle, respectively. Many species of the genus *Ocimum* oils, extracts and their bioactive compounds have been reported to have insecticidal activities against various insect species (Keita *et al.*, 2001 and Obeng-Ofori *et al*., 1998). The treatments *viz*., *O. canum* was witnessed 42.00% mean mortality followed by *A. indica* and *B. juncea* were found statistically on par with each other caused 41.00 and 40.67% mean mortality of target insects, respectively. The treatments namely, *O. canum* and *O. bacillum*, *E. globulus*, *A. indica* and *B. juncea* were found causing 76.67 and 73.33, 73.33, 73.33% mortality each respectively against the target insect during 7 DAT. The effect of plant extracts were found gradually increased from 1 DAT to 7 DAT.

Conclusion

The plant extracts obtained from *A. vulgaris*, *E. globulus* and *M. piperita* were found as promising plant spices showed fumigant action to minimize the insect population in the grains during storage. Exploiting these biofumigants may lead to no fear of poisoning, easy handling and safer to the environment. Further research works in the same line of study is being undertaken to develop a formulation and evaluation at the field level to find out the effectiveness of above plants. After enriching the formulation with the suitable plant species, it is planned to come out with a product to commercialize for the usage of farmers to safe gourd the grains free from insect damage in the small and large scale storages.

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