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Fumigant Effect of Plant Essential Oils against Lesser Grain Borer *Rhyzopertha dominica* (Fabricius) and Red Flour Beetle *Tribolium castaneum* (Herbst)

S V S Gopala Swamy and Venkata S P Bitra

Post Harvest Technology Centre, Bapatla, A. P.

ABSTRACT

The bioefficacy of plant essential oils, namely, eucalyptus oil, orange oil and clove oil was evaluated against lesser grain borer (*Rhyzopertha dominica* Fabricius) in sorghum and red flour beetle (*Tribolium castaneum* Herbst) in rice. Each essential oil at 0.5, 1.0 and 1.5 mL was impregnated on plywood cube of one inch and placed on the surface of grain (250 g) in a plastic jar. Eucalyptus oil and orange oil showed very good fumigant activity at all the doses tested against lesser grain borer and recorded no progeny emergence. Clove oil showed significantly ($p<0.05$) few numbers of adult emergence compared to the untreated control which recorded a total emergence of 215.67 adults after 120 days of insect release. Similarly, eucalyptus oil and orange oil treatments recorded no emergence of red flour beetles at all the doses tested at 40-day after release of the insects. Subsequently, except in the highest dose of eucalyptus oil and orange oil treatments, progeny adult emergence was observed in all other treatments. The untreated control recorded a total of 91.33 adults after 200 days of insect release. However, there was a dose-dependent effect on progeny emergence of both test insects. The results indicated that the red flour beetle was more tolerant to fumigant effects of the essential oils compared to the lesser grain borer. The doses of essential oils at which no emergence of lesser grain borer insects was noticed, could not exert similar effects on red flour beetle. The use of fumigant plant oils without direct mixing to grain may be economical and may provide a better option to protect grain from storage insects. However, sorption of the odors of the essential oils by the food grains has to be addressed.

Key words: *Plant essential oils, Tribolium castaneum, Rhyzopertha dominica*

The red flour beetle, *Tribolium castaneum* (Herbst), is a major pest commonly found in stored cereals, processed grains including millets, oilseeds, nuts and dried fruits (Swamy *et al.*, 2020a,b). The lesser grain borer, *Rhyzopertha dominica* (Fabricius), mainly attacks whole kernels of rice, wheat, maize and millets as a primary pest. Adult beetles and larvae of both insect species feed on stored food stuffs and cause considerable losses. The potential of botanicals against various stored grain insect pests is well established. Plant products are readily available, biodegradable and less toxic to mammals, hence, they can be used in the form of powders, crude or purified extracts or essential oils in stored grain protection insects (Swamy *et al*., 2015; Sarada *et al*., 2017; Swamy and Wesley, 2019). Botanicals act in different modes such as contact toxicity, fumigant, repellent, anti-feedant, oviposition inhibition and growth inhibition against insects (Perez *et al*., 2010; Stefanazzi *et al*., 2011; Ravi *et al*., 2019) and can be used as alternatives to chemical insecticides for the control of stored grain

insects. Smearing of plant oils directly to the grain at different doses is a common practice and found very effective for pulses grain protection against bruchid (Kumar *et al.*, 2018; Preetipuja *et al*., 2021), although development of rancidity and loss of germination have been noticed up on storage. Ranjeet *et al.* (2020) exposed *Sitophilus oryzae* (L.) and *R. dominica* in wheat to the essential oils soaked on blank mat. Similarly, a plywood cube impregnated with essential oils even at very low doses and placed on surface offered better protection to grain legumes from pulse beetles (Swamy and Sandeep, 2018; Swamy and Wesley, 2022). Therefore, efficient application of botanicals through a technique which can minimize direct contact to the grain is very important. Keeping this in view, efficacy of certain essential oils applied through wooden cube was assessed against lesser grain borer and red flour beetle.

MATERIAL AND METHODS

The bioefficacy of essential oils namely, eucalyptus oil, orange oil and clove oil at three different doses was assessed against lesser grain borer (*R. dominica*) in sorghum and red flour beetle (*T. castaneum*) in milled rice during 2020-21 at Post Harvest Technology Centre, Bapatla, Guntur District, Andhra Pradesh, India. Freshly harvested of sorghum (local variety) and rough rice (cv. BPT 5204) was obtained and sun dried for 3-5 days to remove field infestation. Freshly milled rice was used for experiment with red flour beetle. The test insects required for the experiments were cultured on fresh produce introducing few insects collected from the local warehouses and maintained at ambient conditions. Essential oils of clove (*Syzygium aromaticum*), eucalyptus (*Eucalyptus globulus*), orange (*Citrus sinensis*) were purchased from M/s Deve Herbes, New Delhi. For each treatment, disinfested grain (250 g) was taken in plastic jars of 500 mL capacity. A plywood plank was cut into cubes of one inch. Required quantity (0.5, 1 or 1.5 mL) of essential oil was taken using a micropipette and slowly poured on the wooden cube. After allowing complete absorption of oil by the wooden cube, it was inserted in a small perforated box and placed over the grain surface to avoid direct contact of oil to the grain and insects. Later, ten pairs of adult insects were released into each treatment and secured with lid. An untreated control was also maintained for comparison. The experiment was replicated thrice with completely randomized design. Data on the adult emergence was recorded at 40 days interval and finally total population build up was worked out. The data obtained were subjected to ANOVA after transforming the values suitably and the means were tested for significance.

RESULTS AND DISCUSSION

Among the three essential oils, eucalyptus and orange oils showed very good fumigant activity at all the doses tested against lesser grain borer in sorghum and recorded zero emergence (Table 1). Though clove oil showed significantly less numbers of adult emergence compared to the untreated control which recorded a total emergence of 215.67 adults after 120 days of insect release; dose dependent effect in adult emergence was observed with the increase of dose from 0.5 to 1.5 mL per wooden cube at all the times of observation. The mean number of total population decreased from 121.67 in lower dose to 38.67 in higher dose in clove oil treatment. The results indicated that eucalyptus oil and orange oil were effective in containing lesser grain borer in sorghum even at lower doses.

Similarly, eucalyptus and orange oil treatments recorded nil emergence of red flour beetles in rice at all the doses tested at 40 days after release of the

Table 1. Effect of fumigant oils on lesser grain borer (*R. dominica*) in sorghum

Essential oil	Dose (mL) in 500 mL container	Adult emergence (No.)			
		At 40 DAR	At 80 DAR	At 120 DAR	Total
Eucalyptus oil	0.5	0.0 (0.7)^{d}	0.0 (0.7)^{d}	0.0 (0.7)^{e}	0.0 (0.7)^{e}
Eucalyptus oil	1.0	0.0 (0.7)^{d}	0.0 (0.7)^{d}	0.0 (0.7)^{e}	0.0 (0.7)^{e}
Eucalyptus oil	1.5	0.0 (0.7)^{d}	0.0 (0.7)^{d}	0.0 (0.7)^{e}	0.0 (0.7)^{e}
Orange oil	0.5	0.0 (0.7)^{d}	0.0 (0.7)^{d}	0.0 (0.7)^{e}	0.0 (0.7)^{e}
Orange oil	1.0	0.0 (0.7)^{d}	0.0 (0.7)^{d}	0.0 (0.7)^{e}	0.0 (0.7)^{e}
Orange oil	1.5	0.0 (0.7)^{d}	0.0 (0.7)^{d}	0.0 (0.7)^{e}	0.0 (0.7)^{e}
Clove oil	0.5	5.0 (2.27)^{b}	46.33 (6.84)^{a}	70.33 (8.41)^{b}	121.67 (11.04)^{b}
Clove oil	1.0	2.67 (1.77)^{c}	38.33 (6.22)^{b}	51 (7.16)^{c}	92 (9.6)^{c}
Clove oil	1.5	1.33 (1.35)^{c}	23.67 (4.92)^{c}	13.67 (3.76)^{d}	38.67 (6.25)^{d}
Control	-	10.33 (3.3)^{a}	51.67 (7.21)^{a}	153.67 (12.4)^{a}	215.67 (14.69)^{a}
SEm±		0.15	0.16	0.21	0.27
CD ($p<0.05$)		0.43	0.46	0.63	0.79

* Figures in parentheses are square root transformed values; DAR: Days after release of insects. In each column values with similar alphabet do not vary significantly at $p = 0.05$

insects (Table 2). Later on, population emergence was noticed in all the treatments except in the highest dose (1.5 mL) treatment of eucalyptus oil and orange oil. However, there was dose dependent effect; *i.e.*, decrease in the population with the increase in the dose of essential oil was observed. The mean total adult emergence in the clove oil treatment ranged from 60.67 in 1.5 mL dose to 88.33 in 0.5 mL dose per wooden cube in 200 days of insect release. The untreated control recorded a total emergence of 91.33 adults after 200 days of insect release.

Further, the results indicated that the red flour beetle was more tolerant to the effects of essential oils compared to the lesser grain borer. The doses of essential oils at which nil emergence of lesser grain borer insects was noticed, could not exert similar effects on red flour beetle. Only the highest doses of eucalyptus oil and orange oil were effective in preventing population build up of red flour beetle. The

Table 2. Effect of fumigant oils on red flour beetle (*T. castaneum*) in rice

Essential oil	Dose (mL) in 500 mL container	Adult emergence (No.)					
		At 40 DAR	At 80 DAR	At 120 DAR	At 160 DAR	At 200 DAR	Total
Eucalyptus oil	0.5	0.0 (0.70)^{c}	5.0 (2.29)^{d}	41.67 (6.49)^{a}	8.0 (2.91)^{c}	2.67 (1.76)^{d}	57.33 (7.58)^{b}
Eucalyptus oil	1	0.0 (0.70)^{c}	0.0 (0.70)^{e}	0.67 (0.99)^{e}	1.33 (1.35)^{d}	1.0 (1.23)^{de}	3.0 (1.84)^{c}
Eucalyptus oil	1.5	0.0 (0.70)^{c}	0.0 (0.70)^{e}	0.0 (0.70)^{e}	0.0 (0.70)^{e}	0.67 (1.05)^{e}	0.67 (1.05)^{d}
Orange oil	0.5	0.0 (0.70)^{c}	16.33 (4.10)^{b}	15.67 (4.0)^{c}	16.33 (4.10)^{b}	13.0 (3.67)^{b}	61.33 (7.85)^{b}
Orange oil	1	0.0 (0.70)^{c}	10.33 (3.30)^{c}	21.67 (4.70)^{b}	8.67 (3.03)^{c}	18.33 (4.32)^{a}	59 (7.71)^{b}
Orange oil	1.5	0.0 (0.70)^{c}	0.0 (0.70)^{e}	0.0 (0.70)^{e}	0.0 (0.70)^{e}	0.0 (0.70)^{e}	0.0 (0.70)^{d}
Clove oil	0.5	2.67 (1.74)^{b}	44.0 (6.65)^{a}	15.0 (3.94)^{c}	20.67 (4.59)^{a}	6.0 (2.53)^{c}	88.33 (9.42)^{a}
Clove oil	1	12.33 (3.57)^{a}	39.33 (6.28)^{a}	12.0 (3.53)^{c}	16.0 (4.06)^{b}	0.33 (0.87)^{e}	80 (8.96)^{a}
Clove oil	1.5	13.33 (3.7)^{a}	42.33 (6.54)^{a}	2.33 (1.68)^{d}	1.67 (1.46)^{d}	1.0 (1.18)^{e}	60.67 (7.82)^{b}
Control	-	12.0 (3.53)^{a}	18.67 (4.36)^{b}	39.33 (6.30)^{a}	8.67 (3.03)^{c}	12.67 (3.61)^{b}	91.33 (9.57)^{a}
SEm±		0.14	0.22	0.19	0.11	0.18	0.22
CD ($p<0.05$)		0.38	0.68	0.58	0.33	0.57	0.66

* Figures in parentheses are square root transformed values; DAR: Days after release of insects. In each column values with similar alphabet do not vary significantly at p = 0.05

findings are in conformation with the earlier reports (Swamy and Wesley, 2022; Yusuf *et al*., 2011; Kafle and Shih, 2013). Oviposition inhibition, repellent activity and insecticidal effects were observed against pulse bruchid with various plant essential oils (Upadhyay *et al.*, 2007; Preetipuja *et al*., 2021). Swamy and Wesley (2017) observed strong repellence with clove, sweet flag and tobacco powders against pulse beetle adults under free choice condition, whereas Kumar *et al*, (2018) noticed inhibition of oviposition and progeny development of pulse beetles in pea seeds treated with essential oils of eucalyptus and sweet flag at 2.5 mL/kg. Aziz and Shadia (2001) reported highest mortality of *C. maculatus* when foam sprayed with clove oil was placed between the grain sacks. Similarly, there was no infestation of *S. oryzae* in stored wheat with applications of clove and sweet flag oils at 500 ppm (Sharma and Meshram, 2006). However, the essential oils vary in their toxicity, depending on the target insect and its stage as well as method of application (Isabel *et al*., 2020). Ranjeet *et al*. (2020)

found that the essential oils of *Murraya koenigii*, *Citrus reticulata*, *Curcuma longa* and *Callistemon citrinus* either alone at 0.2% or their two component combinations at 0.1% each were highly effective against *S. oryzae* and *R. dominica*. Feeding and breeding suppression of *S. oryzae, R. dominica* and *T. castaneum* have been reported with essential oils of citrus and clove (Ranjeet *et al.*, 2019).

Essential oils of clove, eucalyptus and orange impregnated on wooden cube at doses of 0.5, 1.0 and 1.5 mL were found to have very good effect against lesser grain borer in sorghum and red flour beetle in rice. Use of essential oils without direct mixing to grain may be economical and may provide a better option to protect grain from storage insect pests. However, sorption of the falvours/odours of the essential oils by the food grains needs to be addressed. For exploiting the essential oils that are effective, other possibilities such as development of insecticide-impregnated nets to repel grain insects may be searched.

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