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EFFICACY OF SOME INDIGENOUS PLANT SMOKE AGAINST RED FLOUR BEETLE, *TRIBOLIUM CASTANEUM* (L.)

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ABSTRACT

Red flour beetle, *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) is one of the major insect pests of stored grains. Due to export legislation and zero-tolerance for live insects in trade commodities, extensive use of synthetic insecticides is in practice to eliminate pest infestations from the lots. Currently, the only acceptable chemical to be used in stored grain is phosphine but due to its excessive usage, the stored grain pests are becoming resistant to it. Hence, the discovery of alternative compounds is much needed. In this study, we have compared the repellency of different plants smoke from five commonly found plants of Pakistan, viz. neem *Azadirachta indica* (Meliaceae), costus *Saussurea lappa* (*Asteraceae),* turmeric *Curcuma longa* (Zingiberaceae), sweet flag *Acorus calamus* (Acoraceae) and valerian *Valeriana officinalis* (Caprifoliaceae) against *T. castaneum*. After two hours of smoke, *Azadirachta indica* showed a maximum 75.89±2.14% repellency followed by *Saussurea lappa* (44.15±1.87%), *Curcuma longa* (43.22±2.51%), *Acorus calamus* (23.15±1.75%;) and *Valeriana officinalis* (18.40±1.40%). This is a baseline study for the management of *T. castaneum*, further research on this aspect is required to be investigated. The results of this study support the use of botanicals alternative to synthetic insecticides for stored product pest management.

Keywords: *Acorus calamus, Azadirachta indica*, *Curcuma longa,* red flour beetle, repellency, *Saussurea lappa, Valeriana officinalis*

INTRODUCTION

Stored grains, cereals, and their products are important sources of world food, therefore, effective conservation of this prime resource is important for the subsistence of mankind (Stejskal *et al*., 2015). Maize, rice, and wheat are a few of the most consumed grains. While, chickpea supplement world food demands and is also a major source of animal feed (Wondatir *et al*., 2015). All of these crops are traditionally included in the cropping patterns of Pakistan and after harvesting, these commodities are stored for up to a year for getting good market rates for the produce. This prolonged storage leaves the precious resources vulnerable to various losses, especially caused by insect pest infestations.

Globally, insect pests of stored grains cause the highest qualitative and quantitative losses to stored commodities (Fields, 2006) which may range from 10 to 40% (Lorini and Filho, 2004). Most of this damage is caused by rust-red flour beetle, *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) causing up to 40% reduction in grain weight (Ajayi and Rahman, 2006, Rees, 2007). It consumes the endosperm of the seeds leaving them with coagulating consistency and moldy smell (Keskin and Ozkaya, 2013). To save these grains from spoilage, there is a need for an efficient control measure.

The stored grain industry currently relies upon synthetic grain protectants. Not only do these chemicals have severe effects on the environment but also cause serious health issues to the consumers (Salem *et al*., 2007). Also, their extensive and indiscriminate use against stored grain pests has resulted in the development of strong resistance in these insects against such chemicals. Such detrimental impacts of chemical control of insects warrants evaluation of natural but equally effective compounds that can be used for these pests without posing much threat to

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human health and deteriorating grain quality (Mahdi and Rahman, 2009, Salem *et al*., 2007, Fields, 2006). Currently, the only acceptable chemical to be used in stored grain is phosphine (PH_3) but due to its excessive usage, the stored grain pests are becoming resistant to it (Opit *et al*., 2012).

In this regard, recent studies have identified several promising natural extracts of a plant exhibiting insecticidal activities in stored grain systems (Tatun *et al*., 2014, Tripathi *et al*., 2009). Such botanical extracts may have various modes of action and can help in pest management by repelling the pest away, may act as feeding and oviposition deterrent, and at the same time may act as insecticides (Mohan and Fields, 2002). A well-documented example of a such botanical compound is Azadirachtin, derived from *Azadirachta indica* seeds. Studies have proved its efficacy against aphids, lepidopteran larvae, several stored grain pests and mealy bugs (Morgan, 2009). It works as a feeding deterrent, insect-growth regulator, repellent and sterilant, and may inhibit oviposition (Isman, 2006). Therefore, it is worth comparing their efficacy with other commonly available plant species (Nadra, 2006, Talukder, 2005, Udo, 2005, Aslam *et al*., 2002). The essential oil extracted from the roots of *Valeriana officinalis* showed notable contact effect (Feng *et al*., 2019), *Acorus calamus* contact toxicity (Chen *et al.,* 2015), acetone extracts of *Saussurea lappa* and *Curcuma longa* exhibited repellency against *T. castaneum* (Chander *et al*., 1999).

Indigenous plants are being used to manage insect pests during primitive times. Plant-based insecticides are simply decomposed through different kinds of micro-organisms commonly found in soil, as a result, they help to decrease the environmental pollution. They also help biological control agents by maintaining the biological diversity of natural enemies that are often destroyed by persistent synthetic insecticides (Grainge and Ahmed, 1988). The importance of environmental as well as health issues about persistent insecticides and associated nuisance of pest resistance led several scientists to the idea of natural plant derivatives (biopesticides), which are a safe and harmless alternative to conventional insecticides.

Smoke emitted by blazing plant materials to prevent insects is an ancient practice. Many studies have reported evidence of repellent activities of plant extracts or essential oils against malaria vectors around the world (Asadollahi *et al*., 2019). There are several reports on the use of local plant smoke whereas, prolonged use of smoke produced by burning synthetic mosquito coil and submicron particles covered by a considerable number of heavy metals has produced a negative effect on the consumers. This study aimed to provide timely information about the repellency of the smoke of five indigenous plants against the red flour beetle.

MATERIALS AND METHODS

Azadirachta indica (neem seed)*, Valeriana officinalis* (valerian root)*, Acorus calamus* (sweet flag rhizomes)*, Curcuma longa* (turmeric), and *Saussurea lappa* (kuth) samples were obtained from the Hamdard University, Karachi. All plant materials were air dried for 3 days inside the laboratory for fine powder. The plant materials were crushed by an electric chopper to a fine powder (30-60 mesh size). Smoke is emitted by flaming dried plant materials separately to check for repellency. Red flour beetle, *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae) were obtained from Laboratory, Southern-zone Agricultural Research Centre, Pakistan Agricultural Research Council, University of Karachi and used in the experiment. Twenty adults of *T. castaneum* were released in a two-chambered glass cage separated by a sliding partition. The smoke was released by blazing 5 g of plant material on fired charcoal left in the first chamber. The charcoal was left in the chamber till the complete burning of plant material. The repellency was observed after 2, 4, 6, and 8 h intervals. The second chamber was open to a size of 2 mm for the movement of adult flour beetle for any movement into the second chamber, away from the smoke. Each treatment was replicates four times with a control. In control, only burned charcoal was used.

RESULTS

The treatment with smoke from burnt plant materials is used as a method of insect pest control by many rural farmers (Prasantha, 2002). The repellency (%) of five different plants smoke against *T. castaneum* is presented in (Tables 1, 2 and 3). Neem smoke showed the best results among all the treatments as compared to the control. After two hours of treatment, neem smoke produced 73.17 ± 6.05% repellency which continuously increased to 80.23 ± 4.54% after four hours, 87.42 ± 2.25% after six hours, and 93.13 ± 1.82% after eight hours, respectively. After neem smoke, costus smoke showed better results with 39.43 ± 2.39% repellency after two hours of treatments which stay continued after six hours.

However, it decreased after eight hours. Turmeric smoke exhibited 40.44 ± 1.73% repellency after two hours which gradually declined till the eighth hour to 39.86 ± 3.53%. Sweet flag produced 22.63 ± 2.50% repellency after two hours which turn into 16.44 ± 2.72% after eight hours. Valerian smoke produced the least repellency among all treatments. After two hours, valerian smoke-developed 19.48 ± 1.61% repellency which stays persistent till six hours however repellency increases to 23.29 ± 2.17% after eight hours. Total repellency (%) of different plant smoke on *T. castaneum* is presented in Figure 1. The maximum repellency (%) was found in neem followed by costus, turmeric, sweet flag, and valerian, respectively. Repellency (%) of Sdifferent plant smoke on *T. castaneum* with time concern is presented in Figure 2. In neem and valerian, repellency (%) of *T. castaneum* increases time concern whereas, repellency (%) decreases in other treatments.

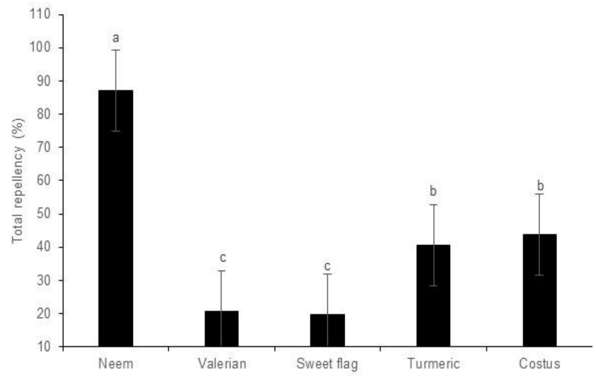

Figure 1. Total repellency (%) of different plant smoke on *Tribolium castaneum*

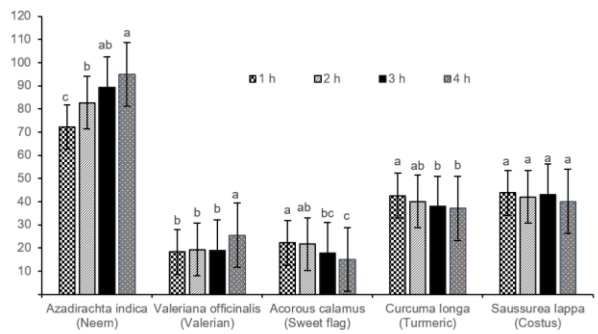

Figure 2. Total repellency (%) of different plant smoke on *Tribolium castaneum* concerning time

DISCUSSION

In this study, smoke from plant powders was found very effective as it repels red flour beetle. Smoke from neem powder showed the best results with a continuous increase of repellency after four, six, and eight hours respectively. The second-best results were found in costus powder repellency after two and six hours whereas a decline after eight hours repellency. The plant smoke proved to be an excellent repellent against the stored grains insect *T. castaneum*.

Table 1. Effect of different plant smokes on the repellency of *Tribolium castaneum*

Treatment (Plant Smoke)	Time (hours)			
	2 h	4 h	6 h	8 h
Azadirachta indica (Neem)	73.17±6.05^{a}	80.23±4.54^{a}	87.42±2.25^{a}	93.13±1.82^{a}
Valeriana officinalis (Valerian)	19.48±1.61^{c}	17.94±1.21^{c}	20.04±1.40^{c}	23.89±2.17^{c}
Acorus calamus (Sweet flag)	22.63±2.50^{c}	23.22±1.98^{c}	20.14±1.66^{c}	16.44±2.72^{c}
Curcuma longa (Turmeric)	40.44±1.73^{b}	38.85±2.36^{b}	36.65±1.19^{b}	39.86±3.53^{b}
Saussurea lappa (Costus)	39.43±2.39^{b}	42.98±2.87^{b}	42.80±2.51^{b}	40.11±1.63^{b}
Control (Charcoal)	0.0±0.0^{d}	0.0±0.0^{d}	0.0±0.0^{d}	0.0±0.0^{d}

Table 2. ANOVA on the effect of different plant smoke on the repellency of *Tribolium castaneum*

Time (hours) x Interactions		Sum of Squares	df	Mean Square	F value	Significance
After 2 h	Between Groups	9097.039	4	2274.260	41.855	0.00
	Within Groups	1086.720	20	54.336	-	-
	Total	10183.759	24	-	-	-
After 4 h	Between Groups	11973.925	4	2993.481	75.014	0.00
	Within Groups	798.110	20	39.906	-	-
	Total	12772.035	24	-	-	-
After 6 h	Between Groups	15252.887	4	3813.222	216.385	0.00
	Within Groups	352.447	20	17.622	-	-
	Total	15605.334	24	-	-	-
After 8 h	Between Groups	18005.782	4	4501.446	146.528	0.00
	Within Groups	614.414	20	30.721	-	-
	Total	18620.196	24	-	-	-

Table 3. ANOVA on total repellency (%) of different plant smoke on *Tribolium casteneum* concerning the time

Treatments x Interactions		Sum of Squares	df	Mean Square	F value	Significance
Azadirachta indica (Neem)	Between Groups	1440.207	3	480.069	29.414	0.00
	Within Groups	261.134	16	16.321	-	-
	Total	1701.342	19	-	-	-
Valeriana officinalis (Valerian)	Between Groups	166.483	3	55.494	11.352	0.00
	Within Groups	78.217	16	4.889	-	-
	Total	244.700	19	-	-	-
Acorus calamus (Sweet flag)	Between Groups	169.550	3	56.517	12.934	0.00
	Within Groups	69.912	16	4.370	-	-
	Total	239.462	19	-	-	-
Curcuma longa (Turmeric)	Between Groups	90.913	3	30.304	4.972	0.013
	Within Groups	97.519	16	6.095	-	-
	Total	188.432	19	-	-	-
Saussurea lappa (Costus)	Between Groups	40.128	3	13.376	2.526	0.094
	Within Groups	84.721	16	5.295	-	-
	Total	124.849	19	-	-	-

Pedro (1985), Makanjuola (1989), and Malaka (1996) studied the different insecticidal properties of different smoke of the plant. They use citrus and neem smoke for the management of insect pests in Nigeria. They reported that people used to burn plants for smoke that prevents them from insects. They also proposed the burning of plants to prevent insects and discourage the use of harmful insecticides. Liu *et al.* (1987) studied the prolonged use of smoke produced by burning mosquito coil, submicron particles covered by a considerable number of heavy metals and other organic solvents which are producing a negative effect on the users. Akingbade (1991) described that the smoke of mosquito coils harms humans and contains various toxic insecticidal components. Moreover, they advised using natural plant products to repel mosquitoes. Likewise (Kumar, 1984; Denloye and Makanjuola, 2001; Pates *et al*., 2002; Boroffice and Boroffice 1993) recommended that smoke from plants comprising pyrethroids and other terpenoids compounds can be used as insecticides for non-endurance nature and safe to humans. Prasantha *et al.* (2002) also studied the smoke produced by *Azadirachta. indica, Lantana camara, Ocimum sanctum* and *Oryza saliva,* for the management of rice weevils *Sitophilous oryzae.* After two days, 100% mortality was observed in *A. indica, L. camara,* and *O. sanctum* excluding *O. saliva.*

The smoke of burning plant material to prevent insects is an ancient and popular exercise in many communities. The smoke by scorching dry plant material gave substantial repellent properties to *T. castaneum,* though this is primary research and needs additional assessments in the field to authenticate the repellent activity of smoke and is intended for commercialization to prevent stored grain and public health pests. Selvaraj *et. al*. (1995) confirmed that the smoke produced by mixing leaves powder of *Adhatoda vasica*, *Azadirachta indica* and *Ocimum sanctum* on burning charcoal can repel the *Armigeres subalbatus* and *Culex quinquefasciatus* biting activity for 6-8h and it was highly toxic to these adult mosquitoes.

Kiruba *et al*. (2012) presented a study on the efficacy of fumigation using the smoke of two rhizomes, *Curcuma aromatica* Salisbury 1807, *C*. *longa* (Linnaeus 1753) and leaves of *Hyptis suaveolens* (Linnaeus) Poiteau 1806, on the eggs, larvae and adults of *T. castaneum*. The adult mortality (%) when exposed for 24h to *A*. *planifrons* smoke was 13.0 ± 2.12, *C*. *aromatica* 96.6 ± 3.0, *C*. *longa* 73.4 ± 3.2, *H. suaveolans* 88.6 ± 2.3 and mixed fumigation, 97.8 ± 1.3. Thus, it was proved that plant smoke fumigation is a suitable alternative to chemical fumigation. Yadav and Tiwari (2018) evaluated the effect of cow dung smoke and neem leaves smoke on the mortality of various storage insects. It was observed that 50% of the insects died after 72 hours of neem leaves smoke exposure and 96 hours of cow dung smoke exposure. Tyagi *et al*. (2019) studied the effect of botanical smokes against pulse beetle under storage conditions and the result indicated adult mortality of 0.4 to 98.4% was observed when smokes of different by-products were tested. Among these, the smoke from mustard seed cake was found to be most effective followed by karanj and neem seed cake. Kishor *et al*. (2021) studied the effect of cow dung smoke on mortality of pulse beetle, *C*. *chinensis* and on quality parameters on different pulse commodities viz., green gram, black gram and red gram and the result showed more than 50% insect mortality was observed after 96 hours to 120 hours exposure to cow dung smoke.

CONCLUSION

Based on our findings, we concluded that, *Azadirachta indica* showed better results against *T. castaneum.* The current study provide baseline for the management of *T. castaneum.* This smoke is much less injurious compared to the harmful chemicals used for fumigation or spraying. Plant material smoke should be tried in other pests of stored products and commercial exploitation of the technique could be tried.

AUTHOR'S CONTRIBUTION

S. A. Tariq: Design and run the experiment

A. Sultan: Has written the first version of manuscript

M. F. Khan: All the activities of experiment were supervised

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