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FUMIGANT ACTIVITY OF SOME ESSENTIAL OILS AGAINST FOUR MAJOR INSECT PESTS OF STORED GRAINS

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ABSTRACT

Essential oils extracted from *Acacia nilotica*, *Calotropis procera*, *Dodonaea viscosa*, *Cassia fistula*, *Ocimum basilicum*, *Adhatoda vasica* and *Ziziphus jujuba* were tested for their fumigant activity against adults of *Tribolium casatneum* (Coleoptera: Tenebrionidae), *Rhyzopertha dominica* (Coleoptera: Bostrychidae), *Cryptolestes ferrugineus* (Coleoptera: Laemophloeidae) and *Liposcelis paeta* (Psocoptera: Liposcelididae). Essential oils from all plant species were obtained by Clevenger-type water distillation and were evaluated using fumigation method. Adult mortality was recorded after 24, 48 and 72 h of exposure under laboratory conditions. The results revealed that the adult mortality increased with the exposure period and *L. paeta* was the most while *T. castaneum* was the least susceptible than the remaining two insect species. Insecticidal activity also varied with essential oils and *O. basilicum* and *D. viscosa* oils were highly effective against *L. paeta* and *C. ferrugineus* with highest mortality after 24 h of exposure. The results of the current studies suggested that the use of essential oils in stored grain insect management program offer them as environment-friendly insecticides to decrease the injurious effects of synthetic insecticides.

Key words: Fumigation, essential oils, *T. casatneum*, *R. dominica*, *C. ferrugineus*, *L. paeta*, stored grains

INTRODUCTION

Stored products of agricultural and animal origin are infested by more than 600 species of beetles, 70 species of moths and approximately 355 species of mites which cause qualitative and quantitative losses to the produce (Rajendran, 2002). In order to keep these stored-products infestation free, fumigation is one of the major chemical methods to control the stored-product insects. Phosphine and methyl bromide are the broad spectrum fumigants being extensively used against stored grain insect pests (Emekci, 2010). But, the use of methyl bromide is phased out because of its potential hazards to deplete the ozone layer (MBTOC, 1998). On the other hand, the future of phosphine as grain protectant is also endangered by the development of resistant insect strains (Daglish and Collins, 1999).

Various alternatives have been experienced to replace these chemical fumigants with the eco-friendly and natural products for stored grain protection. Consequently, some plants are receiving worldwide attention hence their secondary metabolites have been explored as botanical pesticides against insect pests. The plant based control measures possess low mammalian toxicity and do not leave toxic residues in the environment (Duke, 1985).

The stored product insects differ in their vulnerability to plant compounds (Rajendran and Sriranjini, 2008). The insecticidal potential of several essential oils from various plant species has been evaluated against stored-product insect pests in numerous studies (Negahban and Moharramipour, 2007; Rajendran and Sriranjini, 2008).

In the present studies, we evaluated the fumigant toxicity of *Acacia nilotica* (L.) (Fabaceae: Fabales), *Calotropis procera* (Aiton) (Asclepiadaceae: Gentianales), *Dodonaea viscosa* Jacq. (Sapindaceae: Sapindales), *Cassia fistula* L. (Fabaceae: Fabales), *Ocimum basilicum* L. (Limiaceae: Lamiales), *Adhatoda vasica* (L.) (Acanthaceae: Lamiales) and *Ziziphus jujuba* (L.) (Rhamnaceae: Rosales) essential oils against adults of most damaging insect pests *Rhyzopertha dominica* (F.), *Tribolium castaneum* (Herbst), *Cryptolestes ferrugineus* (Stephens) and *Liposcelis paeta* (Pearman) at different exposure intervals under laboratory conditions.

MATERIALS AND METHODS

Insect culture

The adults of four species used in the bioassays were obtained from infested stored grain samples maintained at 28±1^{o}C and 65±5% rh in the IPM Laboratory, Department of Agricultural Entomology, University of Agriculture, Faisalabad, Pakistan. *T. castaneum* and *C. ferrugineus* were reared on clean, infestation free wheat flour and for *T. castaneum* 5% brewer's yeast was also added (Vayias and Stephou, 2009). Whereas, *R. dominica* was reared on whole wheat (Kavallieratos et al., 2006) and *L. paeta* was maintained in 97% cracked wheat, 2% rice krispies and 1% brewer's yeast in jars (Athanassiou et al., 2009). One week old adults of each insect species were used in the bioassays.

Plant materials

The stems, branches and leaves of all selected plants; *O. basilicum, D. viscosa, A. nilotica, C. procera, C. fistula, A. vasica* and *Z. jujuba* were collected separately in polythene bags from different areas of University of Agriculture, Faisalabad, Pakistan. The plant materials were dried on laboratory worktable at room temperature for 6-7 days and then grounded to powder. The dehydrated materials were stored separately at 24ºC until required and then hydrodistilled to extort their essential oils.

Extraction of essential oils

Extraction of essential oils from the plant samples was carried out by using a Clevenger-type apparatus where 50 g of dehydrated plant samples were gone under the process of hydrodistillation at 1:10 plant materials per water volume ratio for 4 h. The extracts were dehadrated by the use of anhydrous sodium sulphate and then the extracted oils from seven plants were stored in a refrigerator at 4ºC separately till use in the bioassays.

Fumigant toxicity

Whatman No. 1 filter papers (Whatman Inc., Clinfton, N.J.) were cut into pieces of 2 cm diameter and impregnated with oils separately to determine the fumigant toxicity of the oils of *O. basilicum, D. viscosa, A. nilotica, C. procera, C. fistula, A. vasica* and *Z. jujuba* at dose rate calculated to give corresponding fumigant concentration 8 uL/L in air. The impregnated filter papers were fixed to the caps of glass vials which were used separately for each insect species and the oil type. 30 adults of each insect species were released in each vial and the caps of the vials were tightened firmly. There were five replicates for seven oils and one control for each insect species. In this way, there were 40 vials (8 treatments × 5 Reps) for each insect species. The mortality of all adults was calculated after 24, 48 and 72 h.

Data analysis

The adult mortalities were corrected by using Abbott's formula (Abbott, 1925) and data were analyzed with Minitab 13.2 (Minitab, 2002 Software Inc., Northampton, MA) by One-way Analysis of Variance (ANOVA) where means were compared with Tukey Kramer test at 5% level of significance (Sokal and Rohlf, 1995).

RESULTS

In all cases, significant differences in adult mortality rates for all four insect species with different essential oils were observed (Table 1). Insecticidal activity varied with different essential oils and increased with the extending exposure intervals. All oils showed different toxicity levels in the following order: *O. basilicum >D. viscosa >A. nilotica >C. procera >C. fistula >A. vasica >Z. jujuba.*

Table 1. ANOVA parameters for main effects and associated interactions for the mortality levels of *R. dominica*, *T. castaneum*, *C. ferrugineus* and *L. paeta* when treated with different essential oils (total *df* = 419)

Sources of variation	***df***	***F***	***P***
Insect species	3	124.01	<0.01
Plant species	6	111.30	<0.01
Intervals	2	95.75	<0.01
Insect species x plant species	18	0.51	0.95
Insect species x intervals	6	8.77	<0.01
Plant species x intervals	12	1.71	0.06

O. basilicum and *D. viscosa* was more effective against *L. paeta* and *C. ferrugineus* than *R. dominica and T. castaneum* even after 24 h (Figure 1). Both *O. basilicum* and *D. viscosa* yielded 100% mortality of *L. paeta* on all three (24, 48 and 72 h) exposure intervals.

While all adults of *C. ferrugineus* were found to be dead only after 48 and 72 h exposure to *O. basilicum* and *D. viscosa*. The mortalities of adults of *R. dominica* and *T. castaneum* were increased with the increasing exposure intervals (Figure 1, 2 and 3). The lowest mortality rates were achieved with essential oil of *Z. jujuba* for all four testes insect species. But here again, 60% of all exposed adults of *L. paeta and C. ferrugineus* were recorded dead after 24 h of treatment which was just 37% in case of *T. castaneum*. However, after 72 h of exposure, the highest mortality rate for *L. paeta* was 75% while it was just 62% for *T. castaneum*.

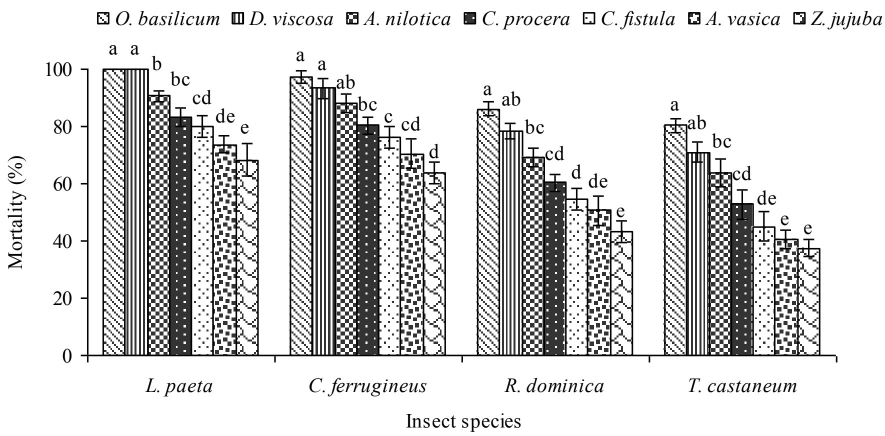

Fig. 1- Mortality (% ± SE) of *L. paeta, C. ferrugineus, R. dominica* and *T. castaneum* 24 h post exposure to seven different essential oils (means having same letters within each essential oil are not significantly different from each other; HSD test $P<0.05$).

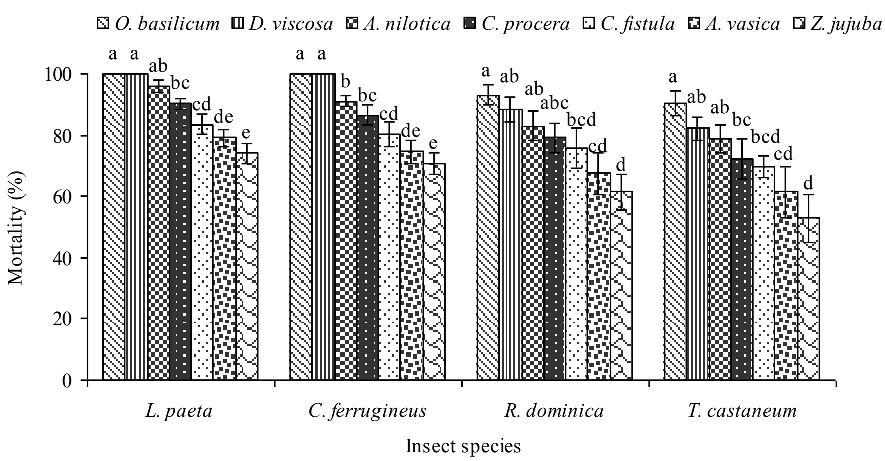

Fig. 2- Mortality (%± SE) of *L. paeta, C. ferrugineus, R. dominica* and *T. castaneum* 48 h post exposure to seven different essential oils (means having same letters within each essential oil are not significantly different from each other; HSD test $P<0.05$).

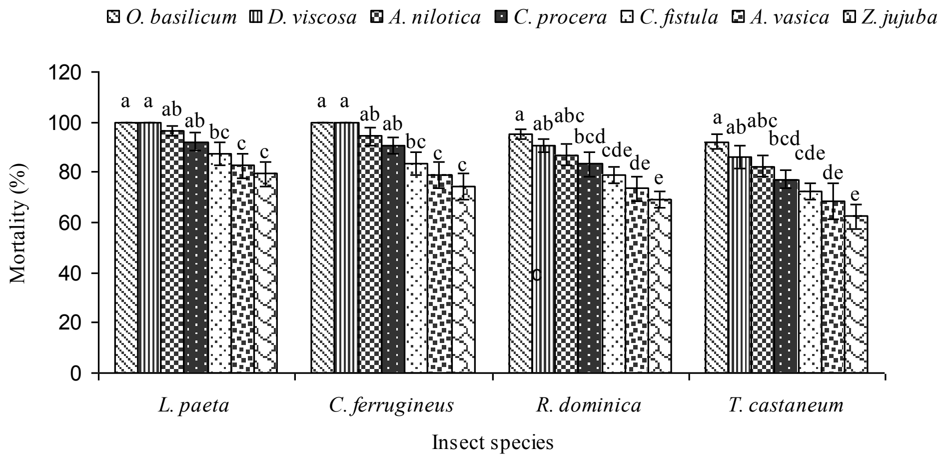

Fig. 3- Mortality (% ± SE) of *L. paeta, C. ferrugineus, R. dominica* and *T. castaneum* 72 h post exposure to seven different essential oils (means having same letters within each essential oil are not significantly different from each other; HSD test $P<0.05$).

DISCUSSION

A wide range of essential oils extracted from various spices and herbs have been screened for their action against several stored-product insect pests (Tunç et al., 2000; Cosimi et al., 2009; Pérez et al., 2010). The toxicity of various essential oils and their constituents, monoterpenes, have been evaluated against stored product insects. Klingauf et al. (1983) studied the fumigant toxicity of 16 essential oils against *Acanthoscelides obtectus* as Rosmarin and caraway oils were most effective and 100% mortality was obtained after 3 h at 31.4 pi/l air. El-Nahal et al. (1989) evaluated the toxicity of essential oil from *Acorus calamus* against various species of stored products. The essential oils investigated in the present study are generally used as pharmaceuticals and in food flavoring, therefore, they are considered to be less harmful to humans than most conventional insecticides. Furthermore, studies have shown that these products are readily biodegradable (Baysal, 1997) and less damaging to non-target organisms than insecticides (Yeğen et al., 1998).

In the present study *L. paeta* and *C. ferrugineus* were the most susceptible towards all the seven essential oils than *R. dominica* and *T. castaneum* for all exposure intervals. Among the tested essential oils, *O. basilicum* and *D. viscosa* showed more toxic effect against tested insect species. The insecticidal constituents of many plant extracts and essential oils are mainly monoterpenoids (Ahn et al., 1998; Cosimi et al., 2009) which due to their high volatility, have fumigant action that might be of importance for the control of stored-product insects. El-Nahal et al. (1989) stated that the period of exposure appears to be more important than the dosage in influencing the efficacy of essential oils against the adults of five stored-product insect species. The use of essential oils is considered as a safe alternative to synthetic insecticides being used for the control of stored grain insect pests, because the oils are derived from natural assets. Such oils could function as a contact repellent, toxic, antifeedant, fumigant and oviposition inhibitor (Stefanazzi et al., 2006). Numerous experiments have verified that essential oils have cytotoxic, phototoxic, neurotoxic and mutagenic activities in different organisms (Bakkali et al., 2008); moreover, essential oils act at many levels in insects, therefore the risk of resistance development is improbable (Pérez et al., 2010). For these reasons, it is suggested that essential oils should be measured as a natural alternative for the control of stored grain insect pests.

CONCLUSION

The use of essential oils is a safe approach to control insects in stored grains as a sustainable alternative to synthetic chemicals and other fumigants. Our experiment added to the literature available on the adulticidal activity of the essential oils but further work has to be done especially to formulate a plant based product to save stored grains.

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