jpht

Research Article

Journal of Postharvest Technology
04 (02): S01-S05, April' 2016
www.jpht.info

Fumigant Toxicity of Essential Oil and their Combination against Rhyzopertha dominica and *Tribolium castaneum* at Different Days Interval in Stored Wheat

Ranjeet Kumar[1]* and S. N. Tiwari[2]

[1]Department of Entomology, Bihar Agricultural University, Sabour, Bhagalpur, 813210
[2] Department of Entomology, College of Agriculture, G. B. Pant Uni. Of Agriculture and Technology, Pantnagar, Uttarakhand 263145

Received : 30.01.2016
Revised : 05.03.2016
Accepted : 08.03.2016

Keywords
Essential oil
Fumigant toxicity
Rhyzopertha dominica
Tribolium castaneum
stored wheat

Abstract

The experiment was conducted to find out fumigant toxicity of essential oils and their combination against *Rhyzopertha dominica* (Coleoptera: Bostrichidae) and *Tribolium castaneum* (Coleoptera: Tenebrionidae) at different days interval in stored wheat. In this study four essential oils e.g. *Murraya koenigii, Curcuma longa, Calistimone. citrinus* and *Citrus reticulata* and their suitable combinations were evaluated at different days interval in stored wheat. 100 percent mortality was achieved after twenty four hour of treatment. The essential oils of *Murraya koenigii, Citrus reticulate, Calistimone citrinus* and *Citrus reticulata* either alone at 0.2 percent or their two component combination at 0.1 percent each or three component combination at 0.07 percent each or four component combination at 0.05 percent each as compare to untreated control against *Rhyzopertha dominica*. The *Tribolium castaneum* showed 100 percent mortality by *M. koenigii, C. reticulata, C. citrinus* oil at 0.2 percent, *M. koenigii* + *C. reticulata, M. koenigii* + *C. citrinus* oil at 0.1 percent each and *M. koenigii* + *C. reticulata* + *C. citrinus* oil at 0.07 percent each and *M. koenigii* + *C. reticulate* + *C. longa* + *C. citrinus* oil at 0.05 percent each within 24 hours. The combination containing *C. reticulata* + *C. citrinus* oil at 0.1 percent each and *M. koenigii* + *C. reticulata* + *C. longa* oil at 0.07 percent each caused 93.3 and 86.7 percent mortality, respectively after one days which increased to 100 percent after two days. So, these essential oils may be utilized for the quick fumigation of stored wheat for eco friendly and sustainable management of other stored grain insect pests.

INTRODUCTION

The eco friendly and sustainable stored grain insect pest management through bio active natural compounds from medicinal and aromatic plants is need of current century to provide food and seed reservoir. The lesser grain borer *Rhyzopertha dominica* and red rust flour beetle *Tribolium castaneum* is very serious concern of stored product commodities. The protection of stored commodities by using synthetic chemical fumigants is still important method of preference; even the development of resistance has been reported against these fumigants as well as contamination to the environment. Therefore, there is urgent need to find out suitable alternative methods for sustainable stored commodities protection, especially by bioactive natural compounds from medicinal and aromatic plants. Essential oil from more than seventy five plant species belonging to different families, such as Anacardiaceae, Apiaceae (Umbeliferae), Araceae, Asteraceae (Compositae), Brassicaceae (Cruciferae) Chenopodiaceae, Cupressaceae, Graminaceae, Lamiaceae (Labiatae), Lauraceae, Liliaceae, Myrtaceae, Pinaceae, Rutaceae and Zingiberaceae have been studied for fumigant toxicity against several insect pests of stored grain (Rajendran *et.al.* 2008). Plant essential oils may act as fumigants, contact insecticides, repellents, deterrents and antifeedants (Kumar 2016, Kumar and Tiwari, 2017, Isman, 2000; Shaaya et al., 1997; Singh and Singh, 1991; Huang et al., 1997; Stamopoulos, 1991; Weaver and Subramanyam, 2000; Shakarami et al., 2004; Negahban et al., 2007).

The present study were taken to find out fumigant toxicity of essential oils and their combination against *Rhyzopertha dominica* (Coleoptera: Bostrichidae) and *Tribolium castaneum* (Coleoptera: Tenebrionidae) at different days interval in stored wheat. The selected essential oils

**Email:* rkipm06@gmail.com

ISSN 2348-4330

were extracted from plants that are well known as non toxic and widely used by human.

MATERIALS AND METHODS

Culture of test insects

Pure culture of test insects were developed in the BOD incubator maintained at 27$^{\circ C}$±1 temperature and 70±5 percent relative humidity. Plastic jars of 1.0 kg capacity were used for rearing. At the center of the lid a hole of 1.8 cm diameter was made and covered with 30 mesh copper wire net to facilitate aeration in the jar. The adults of *R. dominica*, were reared on the grains of wheat variety 'PBW-343' while *T. castaneum* was cultured on its flour fortified with 5 per cent yeast powder. Before use, grain was disinfested in the oven at 60°^{C} for 12 hrs. After disinfestation the moisture content of the grain was measured and raised to 13.5 per cent by mixing water in the grains. The quantity of water required to raise the moisture content was calculated by using following formula as described by (Pixton 1967).

Extraction of essential oils

Fresh leaves of *Murraya koenigii, Citrus reticulata* and *Calistimone. citrinus* were collected from MRDC, Pantnagar and peels of *Citrus reticulata* collected from fruit merchant of Pantnagar. Essential oils were obtained by steam distillation, using a Clevenger type apparatus, for approximately 3-4 h in Post Harvest Entomology Laboratory, Department of Entomology, G.B. Pant University of Agriculture and Technology, Pantnagar.

Fumigant toxicity test against *Rhyzopertha dominica and Tribolium castaneum* at different day's interval

The experiment was performed under controlled conditions at 27 $\pm$ 1°^{C} temperature and 70 $\pm$ 5 percent relative humidity. Fifty gram wheat grain variety PBW-343 (moisture content 13.5 percent) was filled in 100 ml capacity plastic vial. Separate sets of vial were prepared for each day. Ten adult insects (0-6 days) of *S. oryzae* were released in each vial. After 24 hours of releasing the adults, required quantity of essential oil soaked on absorbing mat was inserted in each vial after which it was closed and sealed with paraffin wax and each treatment was replicated six times. Observation was recorded every 24 hours of treatment up to fifteen days. The data were analyzed after suitable transformation.

RESULTS

Fumigant toxicity of essential oils and their combination against *Rhyzopertha dominica* at different day's interval

The fumigant toxicity of essential oils and their combination against *R. dominica* is presented in Table 1 which indicates that 100 percent mortality was achieved after twenty four hour of treatment. The essential oils of *Murraya koenigii, Citrus reticulate, Calistimone citrinus* and *Citrus reticulata* either alone at 0.2 percent or their two component combination at 0.1 percent each or three component combination at 0.07 percent each or four component combination at 0.05 percent each as compare to untreated control.

Fumigant toxicity of essential oils and their combination against *Tribolium castaneum* at different day's interval

The fumigant toxicity of essential oils and their combination against *T. castaneum* is presented in Table 2 which indicated that 100 percent mortality was achieved by *M. koenigii, C. reticulata, C. citrinus* oil at 0.2 percent, *M. koenigii + C. reticulata, M. koenigii + C. citrinus* oil at 0.1 percent each and *M. koenigii + C. reticulata + C. citrinus* oil at 0.07 percent each and *M. koenigii + C. reticulate + C. longa + C. citrinus* oil at 0.05 percent each within 24 hours. The combination containing *C. reticulata + C. citrinus* oil at 0.1 percent each and *M. koenigii + C. reticulata + C. longa* oil at 0.07 percent each caused 93.3 and 86.7 percent mortality, respectively after one days which increased to 100 percent after two days. The mortality in grain treated with *C. reticulata + C. longa + C. citrinus* oil at 0.07 percent each was 76.7 percent after one day, however, all insects died after three days. The combination of *C. reticulata + C. longa* at 0.1 percent each caused 73.3 percent mortality after one day which increased to 100 percent after four days of treatment. The *C. longa* oil at 0.2 percent and *C. longa + C. citrinus* oil at 0.1 percent each concentration were found less effective against *T. castaneum* as compare to untreated control.

Table1: Fumigant toxicity of essential oil and their combination against *R. dominica* at different days interval

Essential oil	Conc.%	Percent mortality of *R. dominica* at day after fumigation														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M. koenigii	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. reticulata	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. longa	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. reticulata	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. longa	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. reticulata+C. longa	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. reticulata+C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. longa+C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. reticulata+C. longa	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M.koenigii+C.reticulata+ C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. reticulata+C. longa+C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M.koenigii+C.reticulata+ C. longa+C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
Untreated control		0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
S.Em±		0.001	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CD at 5%		0.003	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Data in parenthesis indicate Square root (X+1) transformed value.

Table 2 Fumigant toxicity of essential oil and their combination against *T. castaneum* at different days interval

Essential oil	Conc.%	Percent mortality of *T. castaneum* at day after fumigation														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M. koenigii	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. reticulata	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. longa	0.2	33.3 (5.2)	33.3 (5.7)	26.7 (5.2)	36.7 (6.1)	40.0 (6.2)	43.3 (6.5)	43.3 (6.4)	20.0 (4.3)	36.7 (5.9)	70.0 (8.4)	70.0 (8.4)	90.0 (9.5)	93.3 (9.7)	100.0 (10.0)	100.0 (10.0)
C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. reticulata	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. longa	0.2	60.0 (7.6)	83.3 (9.1)	70.0 (8.4)	76.7 (8.5)	100.0 (10.0)	70.0 (8.4)	80.0 (9.1)	83.3 (9.1)	76.7 (8.7)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. reticulata+C. longa	0.2	73.3 (8.5)	93.3 (9.7)	93.3 (9.7)	100.0 (10.0)	90.0 (9.5)	93.3 (9.7)	70.0 (8.3)	80.0 (8.9)	96.7 (9.8)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. reticulata+C. citrinus	0.2	93.3 (9.7)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. longa+C. citrinus	0.2	26.7 (5.2)	73.3 (8.5)	36.7 (6.1)	50.0 (6.9)	40.0 (6.3)	100.0 (10.0)	73.3 (8.6)	63.3 (7.9)	66.7 (8.2)	96.7 (9.8)	86.7 (9.3)	90.0 (9.5)	83.3 (9.1)	93.3 (9.7)	100.0 (10.0)
M. koenigii+C. reticulata+C. longa	0.2	86.7 (9.3)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. reticulata+C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
C. reticulata+C. longa+C. citrinus	0.2	76.7 (8.7)	96.7 (9.8)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
M. koenigii+C. reticulata+C. longa+C. citrinus	0.2	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)	100.0 (10.0)
Untreated control		0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
S. Em ±		(0.67)	(0.28)	(0.19)	(0.47)	(0.26)	(0.21)	(0.35)	(0.33)	(0.28)	(0.09)	(0.26)	(0.16)	(0.06)	(0.04)	(0.001)
CD at 5%		(1.95)	(0.81)	(0.57)	(1.37)	(0.75)	(0.61)	(1.01)	(0.96)	(0.83)	(0.28)	(0.76)	(0.46)	(0.18)	(0.12)	(0.003)

Data in parenthesis indicate Square root (X+1) transformed value.

The fumigant toxicity of essential oils have been tested against *Rhyzopertha dominica* and *Tribolium castaneum* and found that the *M. koenigii*, *C. longa*, *C. reticulata*,and *C. citrinus* were highly effective at 0.2 percent (Kumar and Tiwari 2017). Essential oil of Sweet Annie, *Artemisia annua* (Compositae) evaluated by (Tripathi et al. 2002) against *T. castaneum* and *C. maculatus* at 1 percent v/v proved adult repellent and revealed negative correlation between larval or survival and adult emergence of *T. castaneum*. (Tunc et al. 2000) tested fumigant toxicity of essential oil from cumin (*Cuminum cyminum*) against eggs of two stored product insects, *T. confusum* and *Ephestia kuhniella,* it caused 100 percent mortality.

CONCLUSION

Results concluded that the essential oils *Murraya koenigii, Curcuma longa, Calistimone. citrinus* and *Citrus reticulata* and their combinations at 0.2 percent caused 100 percent mortality in *Rhyzopertha dominica* insect within day. 100 percent mortality was achieved by *M. koenigii, C. reticulata, C. citrinus* oil at 0.2 percent, *M. koenigii + C. reticulata, M. koenigii + C. citrinus* oil at 0.1 percent each and *M. koenigii + C. reticulata + C. citrinus* oil at 0.07 percent each and *M. koenigii + C. reticulate + C. longa + C. citrinus* oil at 0.05 percent each after one days of treatment against *Tribolium castaneum*. So these essential oils may utilize for the quick fumigation of stored wheat for eco friendly and sustainable management of other stored grain insect pests.

REFERENCES

Huang. Y. Tan. J. M. W. L. Kini. R. M. and Ho. S. H. 1997. Toxic and antifeedant action of nutmeg oil against Tribolium castaneum (Herbst) and Sitophilus zeamais Motsch. Journal of Stored Product Research, 33, 289-298.

Isman. M. B. 2000. Plant essential oils for pest and disease management. Crop Protection, 19, 603-608.

Kumar. R**.** 2016. Insect pests of stored grain, biology behavior and management strategies. AAP CRC Press USA, pp. 418.

Kumar. R. and Tiwari. S. N. 2017. Fumigant toxicity of essential oils against four major storage insect pests. Indian J. Entomol. 79 (II): 156-159.

Kumar. R. and Tiwari. S. N. 2017. Fumigant toxicity of essential oils against four major storage insect pests. Indian J. Entomol. 79 (II): 156-159.

Negahban. M. Moharramipour. S. and Sefidkon. F. 2007. Fumigant toxicity of essential oil from Artemisia sieberi Besser against three stored-product insects. Journal of Stored Product Research, 43, 123-128.

Pixton. S. W. 1967. Moisture content–its significance and measurement in stored products. Journal of Stored Product Research, (3): 35-37.

Rajendran. S. and Sriranjinia. V. 2008. Plant products as fumigants for stored-product insect control. Journal of Stored Product Research, 44: 126-135.

Shaaya. E. Kostjukovski. M. Eilberg. J. and Sukprakarn. C. 1997. Plant oils as fumigants and contact insecticides for the control of stored- product insects. Journal of Stored Product Research, 33, 7-15.

Shakarami. J. Kamali. K. Moharramipour. S. Meshkatalsadat. M. 2004. Fumigant toxicity and repellency of the essential oil of Artemisia aucheri on four species of stored products pests. Appllied Entomology and Phytopathology, 71(2): 61-75.

Singh. D. and Singh. A. K. 1991. Repellent and insecticidal properties of essential oils against housefly, Musca domestica L. Insect Science and its Application, 12, 487-491.

Stamopoulos. D. C. 1991. Effect of four essential oil vapours on the oviposition and fecundity of Acantoscelides obtectus (Say) (Coleoptera: Bruchidae): Laboratory

evaluation. Journal of Stored Product Research, 27, 199-203.

Tripathi. A. K. Prajapati. V. Verma, N. Bahl. J. R. Bansal. R. P. Khanuja. S. P. S. and Kumar. S. 2002. Bioactivities of the leaf essential oil of Curcuma longa (var. Ch-66) on three species of stored product beetles (Coleoptera). Journal of Economic Entomology, **95**(1): 183-189.

Tunc. I. and Erler. F. 2000. Fumigant activity of anethole, a major component of essential oil of anise Pimpinella anisum L. Bulletin of OILB/SROP Turkey 23 (10): 221-225.

Weaver. D. K. and Subramanyam. B. 2000. Botanicals. Alternatives to Pesticides in Stored-Product IPM (eds.B. Subramanyam and D. W. Hagstrum), Kluwer Academic Publishers, Dordrecht pp. 303-320.