Toxicity and Repellency of Seven Plant Essential Oils to *Oryzaephilus surinamensis (Coleoptera: Silvanidae) and Tribolium castaneum (Coleoptera: Tenebrioidae*)

Ahmed M. Al-Jabr
Plant Protection Dept., College of Agricultural and Food Sciences,
King Faisal University, Al-Ahssa, Saudi Arabia

Abstract :

Seven essential oils of *Cinnamomum camphora, Cymbopogon winterianus, Matricaria chamomilla, Mentha viridis, Prunus amygdalus var amara, Rosmarinus afficinalis* and *Simmondsia chinensis* were evaluated in the laboratory for their toxicities and repellent effectiveness against adults of saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.) and rust-red flour beetle, *Tribolium castaneum* (Herbst). Five concentrations of every essential oil (0.125, 0.25, 0.5 and 0.75 and 1 %) were tested. Adult beetles were exposed to the treated wheat for 2 weeks. Percent of mortality was recorded after 3 days, one week and two weeks from exposure. The repellent action of the previous essential oils was also studied using same concentrations used in toxicity tests. Results showed that complete mortality of *O. surinamensis was* achieved by M. *viridis, M. chamomilla* and C. *camphora* at concentration more than 0.5%. Although, 1% of *P. amygdalus* or *C. winterianus* gave complete mortality of *T. castaneum* after two weeks of exposure. Conversely, *R. afficinalis* was the least toxic to both insect species. The rest of essential oils gave an adequate toxicity to both insect species. Pronounced increase of mortality was observed for most of essential oils with increasing time of exposure. *Tribolium castaneum* was less susceptible to tested oils compared with *O. surinamensis*. Moreover, *M. chamomilla* exhibited high repellency 81.94% and 84.73% at 1% concentration against *O. surinamensis* and *T. castaneum,* respectively.

Introduction :

Stored product insects are a perennial problem in retail stores, where they damage and contaminate susceptible merchandise such as food products and animal feed. In stored grain, insect damage may account for 10-40% of loss worldwide (Matthews, 1993). *Oryzaephilus surinamensis and Tribolium castaneum* are the most common species attacking stored grain and other products. Insect control in stored product relies heavily on the use of gaseous fumigants and residual insecticides, both of which can pose serious hazards to warm-blooded animals and environment. Natural products are well known to have a range of useful biological properties against insect pests (Arthur, 1996). Recently, research on natural products in the form of extracts has received attention and several were of natural products evaluated for their insecticidal efficacy. For instance, Singh and Singh (1991) screened 31 essential oils from different botanical sources against the house fly *Musca domestica* L., and reported repellent and insecticidal activities against this species. The effectiveness of many botanical oils against stored grain insects has already been demonstrated (Su, 1990, Dunkel and Sears, 1998 and Tripathi *et al*., 2000). Many types of spices and herbs are known to possess anti-insect activities (Tripathi *et al*., 1999) especially in the form of essential oils (Shaaya *et al*., 1995). Also, it may be possible to use botanical extracts, edible oil and/or develop environmental manipulation strategies for effective insects control (Evans, 1987; Jacob and Fleming, 1989; Zewar, 1993; Xie *et al*., 1995; Trematerra and Lanzotti, 1999). In the meantime, the repellent, deterrent and biological effects of some plant materials against stored product insects have been studied by many researches (Harish *et al*., 2000; Tripathi *et al*., 2002; Kim *et al*., 2003).

This study was initiated to evaluate the toxicity and repellency of some essential oils against *T. castaneum* and *O. surinamensis*

Materials and Methods

Insect

Tribolium castaneum and *O. surinamensis* cultures were reared under laboratory conditions (27^{o}C and 70 $\pm$ 5 RH.). Adult insects 1-3 weeks old were collected and used for the bioassay tests.

Plant essential oils

Seven commercially available essential oils were tested in this study. Four of them were obtained from Shanghai Chemical Industrial Co., Shaanghai, China (Mint, *Mentha viridis;* Camphor, *Cinnamomum camphora*; Citronella, *Cymbopogon winterianus;* Hasa Luban, *Rosmarinus afficinalis*), one from Human Provincial Native Co., China (Almond, *Prunus amygdalus var amara*) and two from Givaudan-Roure, France (Babonj, *Matricaria chamomilla* and Jojoba, *Simmondsia chinensis*). These oils were assayed against *O. surinamensis* and *T. castaneum* adults.

Contact toxicity

Five dilutions of each oil (1, 0.75, 0.5, 0.25 and 1.25 % w/w) were prepared in acetone. Aliquots of 1 ml of each dilution were sprayed on twenty grams of wheat by using Potter Precision Laboratory Spray Tower (Burkard, Co. Limited, Rickmansworth, Herts, England) to achieve homogeneous distribution of oil. Wheat moisture content was 12.5%. Treated wheat was placed in 250 cc flasks. After acetone evaporation for an hour, ten unsexed adults of O. surinamensis or T. castaneum were introduced to each flask. Flasks were covered with a piece of muslin by the aid of rubber band. The control and treatments were replicated four times. Flasks were kept under laboratory conditions for two weeks. Insect mortalities were determined and calculated after 3, 7 and 14 days from exposure, according to the formula of Abott (1925).

Repellency

Pervious concentrations of plant essential oils were also assayed for their repellency to *O. surinamensis* or *T. castaneum.* An apparatus consisted of two plastic pipes (5 cm dia. and 25 cm long/ each) was designed. The two pipes were joined together with a T-shape pipe to form one 50 cm long pipe with three openings. Two polyethylene bags contain treated and non-treated wheat was tied to both ends. Groups of twenty newly emerged adults of *O. surinamensis* or *T. castaneum* were released in the test arena between the two joined pipes through converted T-shape tube (╩), then the upper end closed with a piece of muslin by the aid of rubber band. The control and treatments were replicated four times. The apparatus were kept under laboratory conditions for 48 hours then insects were counted in both treated and non-treated bags.

The repellency percentage (RP) was calculated using the method of Jilani *et al*., (1988). All repellency assays were conducted in the laboratory. Insects that died during experimental period were replaced by the same aged adults from the same treatments.

Statistical analysis

Collected data were statistically analyzed according to Gomez and Gomez (1984) method. The Least significant difference (LSD) at 0.05 % level of significant was used to compare treatment means (Waller and Duncan, 1969). Computations were done using SAS (1996).

Results and Discussions

Efficacy of essential oils to *O. surinamensis*

The insecticidal activity of the following essential oils: *C. camphora, C. winterianus, M. chamomilla, M. viridis, P. amygdalus var amara, R. afficinalis* and *S. chinensis* were tested against *O. surinamensis* (Table 1). The data indicated that, *C. winterianus* at a concentration of 0.125 % was the most toxic oil followed by *M. chamomilla*, *M. viridis* and *P. amygdalus* where 90, 88.5, 83.3 and 83.3 % of mortality were achieved, respectively. *Simmondsia chinensis* was the least toxic essential oil among the others (45% of mortality). Complete mortality was achieved at a concentration of 0.75% of *M. viridis* and *M. chamomilla or* at 0.5% of *C. camphora.* The highest concentration (1%) of *S. chinensis* gave 98.3% of mortality followed by *M. viridis, C. camphora,* and *C. winterianus* where 96.7, 93.3 and 90% of mortality were achieved along two weeks of exposure. Mortality percentage increased with exposure time of the same concentration. Statistical analysis (Table 3) revealed that *M. viridis* had a significant efficacy to *O. surinamensis* than other essential oils. Moreover, *O. surinamensis* was more susceptible to tested oils than *T. castaneum*.

Efficacy of essential oils to *T. castaneum*

The insecticidal activity of the previous essential oils against *T. castaneum* is shown in (table 2). Data of the accumulative mortality of *T. castaneum* adult along two weeks of exposure to essential oils revealed that *P. amygdalus* was the most effective essential oil against the adults that gave 95% of mortality at 0.125% concentration and a complete mortality at a concentration of 0.5 %. *Rosmarinus afficinalis* was the least toxic essential oil to *T. castaneum* where < 50% of mortality was achieved at 1% concentration. Complete mortality of *T. castaneum* was achieved at concentration of 1% of *C. winterianus* , 0.75% of *M. viridis* and 0.5 % of *P. amygdalus* and/or *S. chinensis*. Mortality was increased with increasing exposure time. Statistical analysis revealed that *P. amygdalus* along two weeks of exposure had a significant efficacy compared with the other tested essential oils. Data also revealed that *R. afficinalis* was the less toxic essential oils to both insect species (table 3). The effectiveness of many plant extracts and essential oils as repellents, antifeedents and insecticides against *T. castaneum* and *O. surinamensis* has been studied. Those beetles have shown susceptibility to plant-derived chemicals (Jilani *et a.l*, 1988; Tripathi *et al*., 2000; Kim *et al*., 2003). Owsu (2001) on the other hand reported that, extracts of *Ocimum viride* leaves at 0.1 mg/ml proved to be the most effective in the control of *T. castaneum* and *S. oryzae* after ten days of treatments.

Repellent action of essential oils to *O. surinamensis*

The repellent action of the above mentioned essential oils was also studied. Data in (table 4) showed that *M. chamomilla* had strong repellent action (81.94%). Moreover, the statistical analysis revealed a significant difference between this oil and the other oils. However, *M. viridis* had less repellent action (32.96%). The rest of essential oils had a moderate repellent action.

Repellent action of essential oils to *T. castaneum*

The repellent action of the above mentioned essential oils was also studied against *T. castaneum*. Data in (table 5) showed that *M. chamomilla* had the lead in repellent action where repellent percentage reached 84.73% at 1% concentration. Statistical analysis revealed a significant difference between *M. chamomilla* and other tested essential oils in their repellent actions. *Mentha viridis* had less repellent action (22.32%) against *T. castaneum*. The rest of essential oils had moderate repellent actions between 22.32-76.57 %. In general, *M. chamomilla* had strong repellent action and *M. viridis* had a weak one to both insect species. Similar data were obtained by Owsu (2001) who reported that extracts of *Ocimum viride* leaves at 0.1 mg/ml showed strong repellent activity and deterred *T. castaneum* feeding after ten days of treatments.

Table (1) Toxicities of the essential oils against *O. surinamensis*.

Plant oil	Concentration (%)	Mortality (%)			Mean
		3 Days	1 Week	2 Weeks	
C. camphora	0.125	25.0	46.7	58.3	43.3
	0.250	55.0	61.7	88.3	68.3
	0.500	90.0	96.7	100.0	95.6
	0.750	60.0	65.0	78.3	67.8
	1.000	86.7	86.7	93.3	88.9
	Mean	63.3	71.3	83.7	72.8
C. winterianus	0.125	31.7	55.0	90.0	58.9
	0.250	43.3	60.0	66.7	56.7
	0.500	36.7	68.3	73.3	59.4
	0.750	70.0	85.0	88.3	81.1
	1.000	56.7	85.0	90.0	77.2
	Mean	47.7	70.7	81.7	66.7
M. chamomilla	0.125	16.7	55.0	88.3	53.3
	0.250	25.0	61.7	86.7	57.8
	0.500	35.0	66.7	80.0	60.6
	0.750	75.0	98.3	100.0	91.1
	1.000	65.0	93.3	98.3	85.6
	Mean	43.3	75.0	90.7	69.7
M. viridis	0.125	56.7	78.3	83.3	72.8
	0.250	95.0	98.3	98.3	97.2
	0.500	86.7	98.3	98.3	94.4
	0.750	96.7	100.0	100.0	98.9
	1.000	96.7	96.7	96.7	96.7
	Mean	86.3	94.3	95.3	92.0
P. amygdalus	0.125	21.7	51.7	83.3	52.2
	0.250	21.7	45.0	68.3	45.0
	0.500	21.7	41.7	78.3	47.2
	0.750	33.3	73.3	86.7	64.4
	1.000	46.7	90.0	81.7	72.8
	Mean	29.0	60.3	79.7	56.3
R. afficinalis	0.125	13.3	41.7	56.7	37.2
	0.250	23.3	41.7	80.0	48.3
	0.500	41.7	55.0	71.7	56.1
	0.750	25.0	33.3	35.0	31.1
	1.000	38.3	35.0	48.3	40.6
	Mean	28.3	41.3	58.3	42.7
S. chinensis	0.125	28.3	45.0	40.0	37.8
	0.250	35.0	40.0	66.7	47.2
	0.500	46.7	43.3	65.0	51.7
	0.750	66.7	86.7	93.3	82.2
	1.000	75.0	90.0	98.3	87.8
	Mean	50.3	61.0	72.7	61.3

LSD 5% (Oil x Concentration) = 1.51 NLSD 5% (Oil x Killing time) = 11.7
LSD 5% (Concentration x Killing time) = 9.9
LSD 5% (A x B x C) = 26.1

Table (2): Toxicities of the essential oils against *T. castaneum*.

Plant oil	Concentration (%)	Mortality (%) after			Mean
		3 Days	1 Week	2 Weeks	
C. camphora	0.125	15.0	28.3	76.7	40.0
	0.250	35.0	11.7	56.7	34.4
	0.500	40.0	58.3	93.3	63.9
	0.750	38.3	51.7	90.0	60.0
	1.000	33.3	61.7	93.3	62.8
	Mean	32.3	42.3	82.0	52.2
C. winterianus	0.125	5.0	18.3	78.3	33.9
	0.250	18.3	20.0	73.3	37.2
	0.500	13.3	33.3	80.0	42.2
	0.750	38.3	51.7	98.3	62.8
	1.000	41.7	75.0	100.0	72.2
	Mean	23.3	39.7	86.0	49.7
M. chamomilla	0.125	5.0	11.7	63.3	26.7
	0.250	16.7	8.3	33.3	19.4
	0.500	5.0	23.3	83.3	37.2
	0.750	3.3	25.0	88.3	38.9
	1.000	6.7	26.7	90.0	41.1
	Mean	7.3	19.0	71.7	32.7
M. viridis	0.125	6.7	1.7	38.3	15.6
	0.250	31.7	20.0	70.0	40.6
	0.500	23.3	45.0	96.7	55.0
	0.750	13.3	61.7	100.0	58.3
	1.000	46.7	66.7	85.0	66.1
	Mean	5.3	10.0	36.0	17.1
P. amygdalus	0.125	13.3	16.7	95.0	41.7
	0.250	45.0	43.3	95.0	61.1
	0.500	18.3	61.7	100.0	60.0
	0.750	11.7	70.0	100.0	60.6
	1.000	60.0	96.7	100.0	85.6
	Mean	29.7	57.7	98.0	61.8
R. afficinalis	0.125	5.0	5.0	36.7	15.6
	0.250	5.0	6.7	25.0	12.2
	0.500	5.0	8.3	35.0	16.1
	0.750	5.0	13.3	36.7	18.3
	1.000	6.7	16.7	46.7	23.3
	Mean	5.3	10.0	36.0	17.1
S. chinensis	0.125	6.7	15.0	61.7	27.8
	0.250	43.3	16.7	73.3	44.4
	0.500	15.0	38.3	100.0	51.1
	0.750	15.0	58.3	100.0	57.8
	1.000	21.7	48.3	91.7	53.9
	Mean	15.0	28.3	76.7	40.0

LSD 5% (Oil x Concentration) = 13.8
LSD 5% (Oil x Killing time) = 10.7
LSD 5% (Concentration x Killing time) = 9.0
LSD 5% (A x B x C) = 23.9

Table (3)
Toxicities of the essential oils against *O. surinamensis* and *T. castaneum* at different concentrations of essential oils and exposure time

Treatments	Mortality (%)	
	O. surinamensis	*T. castaneum*
Plant oils		
C. camphora	72.8 b	52.2 b
C. winterianus	66.7 bc	49.7 b
M. chamomilla	69.7 b	32.7 c
M. viridis	92.0 a	47.1 b
P. amygdalus var amara	56.3 d	61.8 a
R. officinalis	42.7 e	17.1 d
S. chinensis	61.3 cd	47.0 b
Concentration		
0.125 %	50.8 d	28.7 d
0.250 %	60.1 c	35.6 c
0.500 %	66.4 b	46.5 b
0.750 %	73.8 a	51.0 b
1.000 %	78.5 a	57.9 a
Exposure time		
24 h	49.8 c	20.4 c
48 h	67.7 b	34.7 b
72 h	80.3 a	76.7 a

Table (4)
Repellency of essential oils to *O. surinamensis*.

Plant Oil	Repellency at concentrations (%)					Means
	0.125	0.25	0.5	0.75	1	
C. camphora	39.35	28.46	38.79	39.55	39.46	37.12 c
C. winterianus	30.52	41.32	45.55	45.94	43.33	41.33 c
M. chamomilla	74.15	68.67	69.22	64.9	81.94	71.78 a
M. viridis	33.63	34.23	31.04	31.93	33.99	32.96 c
P. amygdalus	42.35	41.27	68.46	68.72	67.84	57.73 b
R.. officinalis	40.45	45.79	48.44	69.97	61.78	53.29 b
S. chinensis	14.13	32.97	44.92	48.78	64.66	41.09 c
Mean	39.23 b	41.82 b	49.49 a	52.83 a	56.14 a	

LSD (5%) for oil x concentration = 18.40

Table (5)
Repellency of essential oils to *T. castaneum*.

Plant Oil	Repellency at concentrations (%)					Means
	0.125	0.25	0.5	0.75	1	
C. camphora	27.84	40.57	38.95	37.04	54.35	39.75 c
C. winterianus	37.17	34.72	43.4	49.41	42.77	41.49 c
M. chamomilla	75.26	72.31	76.83	73.71	84.73	76.57 a
M. viridis	18.11	24.49	25.34	21.33	22.34	22.32 d
P. amygdalus	47.07	63.25	62.21	65.55	55.2	58.66 b
R.. officinalis	37.69	33.13	46.83	44.71	45.12	41.50 c
S. chinensis	41.49	37.31	41.78	47.74	42.26	42.12 c
Mean	40.66 a	43.68 a	47.91 a	48.50 a	49.54 a	

Means followed by the same letter (s) are not significantly differ at 5% level of probability
LSD (5%) for oil x concentration = N.S

Also, Tripathi *et al*., (1999) reported that fruit oil of *Piper retrofractum* exhibited high repellency against *T. castaneum* (52, 76 and 90 %) at 0.5, 1 and 2% concentrations.

Pasccual-Villalobos (1999) screened wild species of 21 botanical families and reported that compositae species had a tendency to induce either growth inhibition (with or without mortality) or repellency on *T. castaneum*. Moreover, Abubakr *et al*., (2000) reported a repellent and antifeedant properties of *Cyperus articulatus* against *T. castaneum.* From These results it appeared that, complete mortality of *O. surinamensis* was achieved by *M. viridis, M. chamomilla* and *C. camphora* at concentration more than 0.5%, While, 1% of *P. amygdalus* or *C. winterianus* gave complete mortality of *T. castaneum* after two weeks of exposure. Therefore, one can conclude that these potent essential oils might be useful for management control of stored product beetles.

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الخواص الإبادية والطاردة لسبع زيوت نباتية ضد خنفساء الحبوب المنشارية (*Oryzaephilus surinamensis*) وخنفساء الدقيق الصدئية (*Tribolium castaneum*)

أحمد بن محمد الجبر

قسم وقاية النبات، كلية العلوم الزراعية والأغذية - جامعة الملك فيصل
الأحساء – المملكة العربية السعودية

الملخص :

تم تقييم الفعل الإبادي والطارد لسبع زيوت نباتية هي: الكافور، والسترونيلا، اللافندر والنعناع واللوز المر وحصالبان والجوجوبا ضد خنفساء الحبوب المنشارية وخنفساء الدقيق الصدئية تحت الظروف المعملية. حيث تم اختبار خمس تركيزات هي ٠,١٢٥ ، ٠,٢٥ ، ٠,٥ ، ٠,٧٥ ، ١ ٪ . تم تعريض الحشرات الكاملة من خنفساء الحبوب المنشارية وخنفساء الدقيق الصدئية للقمح المعامل بالزيوت النباتية لمدة أسبوعين. سجلت نسب الموت بعد ثلاثة أيام، أسبوع وأسبوعين من التعرض. أوضحت النتائج حدوث نسبة موت ١٠٠٪ من خنفساء الحبوب المنشارية عند تعريضها لتركيزات أعلى من ٠,٥٪ من زيوت النعناع واللافندر والكافور. بينما أظهر تركيز ١٪ من زيوت اللوز المر والسترونيلا ١٠٠٪ موت للطور الكامل من خنفساء الدقيق الصدئية بعد أسبوعين من المعاملة. كان زيت حصالبان هو أقل الزيوت تأثيراً على تلك الحشرتين. كما لوحظ زيادة ملموسة في نسبة الموت بزيادة وقت التعرض. كانت خنفساء الدقيق الصدئية أكثر تحملاً من خنفساء الحبوب المنشارية للزيوت المستخدمة. ومن ناحية أخرى بينت نتائج التأثير الطارد أن زيت اللافندر عند تركيز ١٪ كان أعلى الزيوت النباتية في نسبة الطرد حيث بلغت ٨١,٩٤ ٪ ، ٨٤,٧٣ ٪ لكل من خنفساء الحبوب المنشارية وخنفساء الدقيق الصدئية على التوالي.