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Insecticidal effect of different botanical oils against *Tribolium Confusum* (Jacquelin du val) (Coleoptera: Tenebrionidae) adults

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Abstract
The confused flour beetle, *Tribolium confusum* is one of the serious insect pests infesting grain and other stored food products. In this study the insecticidal activity of eight botanical oils, Citronella, Clove, Eucalyptus, Jojoba, Lemon, Orange, Rosemary, Spearmint were evaluated against the adults of *T. confusum*. The results showed that all used oils have potential of protection to control storage product pests, *T. confusum*. The highest percentage mortality was observed on Clove, Orange, Citronella, Spearmint, Jojoba and Eucalyptus. The mortality was increased with increase of concentration levels and the duration dependent increased percent mortality was observed in all botanical oils after interval of different exposure time. The present study suggested that botanical oils (Clove, Orange, Citronella, Spearmint, Jojoba, and Eucalyptus) exhibited a possibility to be an alternative to the synthetic insecticides in the management of stored product pests, especially *T. confusum.*

Keywords: stored food products, control, botanical oils, insecticidal activity, *t. confusum*

1. Introduction
Food security is very vital for the health of nations among the society in the world and it is equally important on the national as well as worldwide level. According to World food Summit (WFS) indication, more than 800 million people do not have enough food for their basic national needs, mainly in the developing countries of the world. Short-fall in food grain production and it is preservation in the storage can lead to peace upsetting in the world. The global stored product grain losses range from 10-40%, by infestation of insect and other bio agents damage. Insect pests are a major concern. It is estimated approximately 35% of crops all over the world [1]. The confused flour beetle, *Tribolium confusum* is one of the serious insect pests' for grain and other food products stored in silos, warehouses, grocery store and homes which are cases considerable losses [2]. Many methods have been used for control stored grain insect pest to prevent post-harvest losses included chemical, physical and biological treatments [3]. Chemical insecticides extensively used for stored product could have undesirable effects such as environmental pollution, pest resistance, toxicity to non-target organism, pesticide residues, and direct toxicity to user, in addition to increasing cost of application [3, 4, 5, 6]. Therefore, the development of biodegradable pesticides such as plant derived material has been focused as viable pest control strategy in recent years [7, 8, 9]. Plants may provide potential alternative to currently used synthetic insecticides due to their rich sources of bioactive chemicals [10]. Botanical oils are known to exhibit low toxicity to mammals, and have even been approved as flavoring agents in food [8, 11]. The nematicidal [12], antibacterial [13] and insecticidal [14, 15, 16] effects of botanical oils have previously been reported. Abbas khani and Tahere Rahdari [17] also evaluated the insecticidal activity of botanical oil against two stored product pests *T. confusum* and *C. maculatus*, which they observed considerable differences in mortality of insects in different concentrations and exposure times.
The present study was carried out to determine the insecticidal activity of different botanical oils, Citronella, Clove, Eucalyptus, Jojoba, Lemon, Orange, Rosemary and Spearmint extracted from different part of different plants against adult stage of *T. confusum*.

2. Material and Methods
A study on the Efficacy of botanical oils against *T. confusum* adults was conducted in the laboratory of plant protection during February to March, 2016.

Rearing of insects
The whole wheat flour was sieved and cleaned from husks or any inert material. Samples of wheat flour were placed in glass jars, covered and sterilized by heating at 70ºC for 1hr and it was cooled and allowed to reabsorb moisture before use. Then transferred to separately sterilized culture jar to a depth of 4 cm, and a band of fluon or Vaseline painted around the inside edge of the jar to prevent the escaping of insects. Adults of flour beetle, *Tribolium confusum* (150-200 insects) from natural infested wheat grain from a local market were added in to each jar and the jars were sealed with muslin and placed at 30ºC± 2.0 and 75± 5.0 RH. After two weeks, the insects were sieved out, discarded or transferred to another jar. The period from egg laying to adult emergence was about 5-6 weeks. Adult insects (10-15 days after emergence) were used for experiment work.

Plant oils
Eight plant oils (healthy and fresh) were used in this investi-gation. Botanical oils, scientific names of plants, used parts in extraction of oils and sources of oils are listed in Table 1.

Table 1: Plant oils and their scientific names, used part in extraction of oil and sources.

Oils	Scientific name of plants	Used parts	sources
Citronella	*Cymbopogon winterianus*	Leaves	From the market
Clove	*Eugenia aromatic*	Flowers	″
Eucalyptus	*Cinnamomum camphora*	Leaves	″
Jojoba	*Simmondsia chinensis*	Seeds	″
Lemon	*Citrus limonun var hisso*	Fruit peels	″
Orange	*Citrus sinensis var Valencia*	Fruit peels	″
Rosemary	*Rosmarinus officinalis*	Leaves	
Spearmint	*Mentha viridis*	Leaves	″

Mortality test

The insecticidal efficacies of different botanical oils (Table 1) were carried out by residual film technique against the *T. confusum* beetle. The residual film was done directly on petri dish (9 cm) without any food media according to Qi and Burkholder [18]. Oil concentrations were 0.5, 0.75 and 1%, which was prepared in acetone. One ml of each concentration was pipetted in petri dish. After evaporation of acetone, 20 adults were placed in each petri dish. Three replicates were carried out of each concentration and control. Mortality percentages were recorded after 24, 48 and 72 hours. Four Oils that caused higher mortality% after 72 hr. at 0.5% against *T. confusum* were considered potent oils. The average mortality percentages were plotted against the concentrations mortality regression lines were eye fitted. The LC50 values were determined. Data were subjected to probit analysis.

3. Results

Insecticidal activity of eight botanical oils on adult insects of T. confusum

This experiment was conducted in order to determine the insecticidal activity of used botanical oils on *T. confusum* adult at different concentration and different exposure times for each concentration. The residual film was done directly on petri dish (9 cm) without any food media. The efficacies of eight botanical oils (Jojoba, Clove, Eucalyptus, Lemon, Rosemary, Orang, Spearmint and Citronella) were compared with each other. Three concentration dosages; 0.5, 0.75 and 1.00 % were compared for each oil and three exposure periods; 24, 48 and 72 hours were compared for each concentration, to find out the effective botanical oils and there suitable concentration dosage and exposure time for the control of confused flour beetle. The efficacy of each treatment was determined by comparing numbers of mean mortality percentage with those in the treated control.

The mean mortality percentage of *T. confusum* adult treated with different botanical oils at different concentration and different exposure periods for each concentration are shown in Table 2, 3 and 4.

Complete mortalities (100%) of adult insects were given by clove and orange at concentration 0.5%, after 24 hours of exposure time. other oils also gave protection but spearmint and citronella oils appeared to be superior to jojoba, eucalyptus, lemon and rosemary. Mortality percentages of confused flour beetle were shown by spearmint and citronella at 24 hours 90.3 and 60.0%, 48 hours 99.0 and 80.2% and 72 hours 100.0 and 98.3% respectively followed by the jojoba treated treatments at 24 hours 35.0%, 48 hours 95.6% and 72 hours 98.2% and eucalyptus 30.0, 74.2 and 95.4% at 24, 48 and 72 hours of exposure time respectively. The mean mortality percentage was lower among the used oils, in lemon and rosemary at 24, 48 and 27 hours of exposure periods (Table 2). The results showed that Orang and clove at concentration dosage used (0.5%) gave the highest mortality percentages at lower exposure times.

At concentration 0.75% complete mortality percentage was recorded in clove, orang, spearmint and citronella. The mean percentage mortality of *T. confusum* was also higher in eucalyptus followed by Jojoba at 24 hours 85.8 and 80.0%, 48 hours 97.3 and 91.0% and 72 hours 100.0 and 100.0% respectively. Lemon and rosemary also showed appreciable mortality percentage of 75.3 and 68.2% at 24 hours, 80.0 and78.5% at 48 hours and 89.2 and 85.3% at 72 hours of exposure times respectively (Table 3).

The mortality percentages at concentration 1.0%, in Eucalyptus and lemon treated treatment were 90.2 and 82.3% at 24 hours, 95.5 and 90.0% at 48 hours and 100.0 and 98.3% at 72 hours of exposure periods followed by rosemary 80.2, 88.2 and 97.1% at 24, 48 and 72 hours of exposure times respectively. Complete mortality was recorded at all used exposure times in clove, jojoba, orange, spearmint and citronella (Table 4).

The results of this experiment showed that, all used oils have potential of protection to control storage product pest, *T. confusum*. The use of clove and orange are more effective for the control of these insects followed by spearmint, citronella and jojoba. The mortality was increased with increase of concentration dosages and the duration dependent increased percent mortality was observed in all botanical oils after interval of different exposure time. There were significant different in mean percentage mortalities in all treated treatment compare with untreated control.

Table 2: Effect of some botanical oils at concentration 0.5 % against *T. confusum* at different exposure time by using residual film technique.

Oil	Mortality (%) after		
	24 hr. ± SD	**48 hr. ± SD**	**72 hr. ± SD**
Jojoba	35.0 ± 4.1	95.6 ± 3.5	98.2 ± 2.8
Clove	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Eucalyptus	30.0 ± 1.5	74.2 ± 2.1	95.4 ± 2.7
Lemon	10.0 ± 2.3	29.3 ± 2.4	40.3 ± 2.9
Rosemary	7.0 ± 0.0	61.3 ± 4.3	80.6 ± 5.4
Orange	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Spearmint	90.3 ± 4.3	99.0 ± 1.3	100.0 ± 0.0
Citronella	60.0 ± 5.1	80.2 ± 2.5	98.3 ± 2.7
Control	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
LSD < o.o5	6.9	10.5	9.4

Table 3: Effect of some botanical oils at concentration 75 % against *T. confusum* at different exposure time by using residual film technique.

Oil	Mortality (%) after		
	24 hr ± SD	48 hr ± SD	72 hr ± SD
Jojoba	80.0 ± 3.5	91.0 ± 4.1	100.0 ± 0.0
Clove	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Eucalyptus	85.8 ± 2.5	97.3 ± 3.6	100.0 ± 0.0
Lemon	75.3 ± 7.3	80.0 ± 5.2	89.2 ± 4.1
Rosemary	68.2 ± 4.8	78.5 ± 3.2	85.3 ± 3.7
Orange	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Spearmint	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Citronella	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Control	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
LSD < o.o5	13.5	6.8	4.3

Table 4: Effect of some botanical oils at concentration 1.0 % against *T. confusum* at different exposure time by using residual film technique.

Oil	Mortality (%) after		
	24 hr ± SD	48 hr ± SD	72 hr ± SD
Jojoba	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Clove	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Eucalyptus	90.2 ± 2.3	100.0 ± 0.0	100.0 ± 0.0
Lemon	82.3 ± 5.1	90.0 ± 0.0	98.3 ± 2.4
Rosemary	80.2 ± 2.5	88.2 ± 4.2	97.1 ± 6.3
Orange	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Spearmint	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Citronella	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
Control	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
LSD < o.o5	8.9	9.5	2.4

Efficacy of four potent botanical oils against Tribolium confusum

This study was carried out by residual film directly on petri dish (9 cm) without any food media, in order to determine the insecticidal activity of used potent botanical oils on *T. confusum* adult at different concentration. Five concentration dosages; 0.20, 0.25, 0.30, 0.35 and 0.40 % were compared for each oil at 72 hours of exposure time, to find out the effective botanical oils and there suitable concentration dosage for the control of confused flour beetle. The LC50 values were determined.

The data obtained on mortality percentage of *T. confusum* adult treated with different potent botanical oils at different concentration after 72 hours of exposure period were combined (Table 5 and 6).

The values of mean percentage mortality of *T. confusum* adult were presented in Table 5. The most toxic botanical oil effect was obtained in citronella that gave 18.32, 50.00, 70.00, 85.11 and 94.33% mortality at 0.20, 0.25, 0.30, 0.35 and 0.40% concentration levels respectively and the least toxic botanical oil was orange that gave 8.3, 30.0, 44.3, 55.4 and 70.3% mortality at 0.20, 0.25, 0.30, 0.35 and 0.40% concentration levels respectively followed by spearmint and jojoba. Considerable differences were recorded among all treated treatment.

Parallel response to the level of concentration that the mortality percentage increased with increase in concentration level in most cases. The concentration proved able to induce maximum percentage mortality of adult 88.1, 94.33, 85.5 and 70.3 at 0.40% in jojoba, citronella, spearmint and orange respectively. As shown in the same table the order of different concentration of oils on mortality of *T. confusum* adult increased with increase of concentration level in all treated treatment. The concentration 0.40% was most toxic to *T. confusum* and caused 88.1, 94.33, 85.5 and 70.3% mortality in jojoba, citronella, spearmint and orange respectively, followed by 0.35, 0.30, 0.25 and 0.20%.

Table 5: Efficacy of the potent botanical oils against *T. confusum* adults

Concentration%	Mortality % after 72hrs			
	Jojoba	Citronella	Spearmint	Orange
0.20	17.41	18.32	10.3	8.3
0.25	46.00	50.00	36.5	30.00
0.30	58.00	70.00	50.00	44.3
0.35	76.1	85.11	67.3	55.4
0.40	88.1	94.33	85.5	70.3

The LC50 value of the botanical oils displays that citronella oil is subsequently toxic against *T. confusum* followed by jojoba and spearmint oils while orange oil has shown the lowest toxicity (Table 6).

Table 6: LC50 values of the botanical oils against *T. confusum*.

Oils	Slope function	LC 50	Confidence limits		Slope	$(Chi)^2$	
			lover	Upper		Calculate	Tabulate
Jojoba	1.37	0.250	0.270	0.270	7.11	0.41	7.81
Citronella	1.42	0.114	0.103	0.125	6.13	5.91	7.81
Spearmint	1.33	0.290	0.270	0.310	8.01	2.55	7.81
Orange	1.30	0.300	0.290	0.400	9.01	2.61	7.81

4. Discussion

The botanical oils investigated in this study are considered less harmful to humans than most conventional insecticides. Furthermore, studies have been reported that they are readily biodegradable and less detrimental to non-target organisms than pesticides [19].

Botanical oils can play an important role in stored product pests control. The toxicity of a large number of botanical oils extracted from various spices and herb plants was assessed against several major stored product insects [20-26]. However, Qi and Burkholder [18] showed that botanical oils could protect wheat from the granary weevil, *Sitophilus granarius* (L.). Zhang and Zho [27] also demonstrated the effectiveness of such oils in protecting rice from *Sitophilus oryzae* (L.) and *S. zeamais*

The result of this study has shown that all applied botanical oils significantly affected the mortality percentages of *T. confusum* adults compared with control, Not all the botanical oils tested showed satisfactory activity, but the botanical oils of clove, citronella, jojoba, spearmint orange, and eucalyptus, proved to

be promising as control against stored-product insects, especially *T. confusum*. Our results and those reported earlier indicate variations in the activity of botanical oils regarding the plant origin of the oils, concentration level of the oils and exposure time. The results of the present work confirmed those of earlier report [17, 18, 28] that considerable differences in mortality of insect due to botanical oils treatment were observed in different concentrations and exposure times. The mortality increased with rising concentrations and exposure times.

Although the toxicity levels achieved are lower than those that would be expected from the use of commercial insecticides [29], it would seem worthwhile to explore the possible joint action of oils and conventional synthetic insecticides in simple mixtures as a means of making their use more cost effective and attractive. Such an approach would have the added advantage of minimizing the use of synthetic insecticides thereby reducing possible deleterious side effects associated with their use on stored food produce.

5. Conclusion

Result of the study show that all used botanical oils can play an important role in stored food products protection. The percentage mortality was increased with increase of concentration level and exposure time. Not all the botanical oils tested showed satisfactory activity, but the botanical oils of clove, citronella, jojoba, spearmint, orange and eucalyptus, proved to be promising as control against stored-product insects, especially *T. confusum.* Therefore botanical oils can become an interesting alternative to conventional chemical control strategies.

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