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The Effect of the Extent of the Exposure and Concentration for the Three Types of Surface Treatment in the Mortality of Larvae and Adults of Confused Flour Beetle, *Tribolum confusum* (Du Val)

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Keywords:
T. confusum, Lambda insecticide, Castor oil, mixing ratio, surface treatment.

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ABSTRACT

Two concentrations (0.1, 0.05 Mg/L) of chemical insecticides Lambda cyhalothrine were used in combination with Castor oil (Ricinus communis) in mixtures of 1:1, 1:2 and 1:3 ratio of insecticide: castor oil for their effect to the mortality of larvae and adult of confused flour beetle, *Tribolium confusum* (Du Val) which exposed to different surface substrates (aluminum, cardboard, and wood surfaces). The mortality data were recorded after 24 and 48 hours. The calculated mortality in aluminum surfaces were 53.00%, 56.00% and 62.00% in 1:1, 1:2 and 1:3 mixing ratio, respectively, after 24 hours, in adults. With the cardboard treatment, the mortality were 43.00%, 56.00% and 57.66% in 1:1, 1:2 and 1:3 mixing ratio, respectively, in the same treatment time. Whereas in wood surface the mortality were 56.33%, 58.00% and 61.00% in 1:1, 1:2 and 1:3 mixing ratio, respectively, in the same treatment time. The results showed that 1:3 mixing ratio had the higher mortality ratio and the 1:1 mixing ratio had the least mortality against *T. confusum*. The results also revealed that all tested mix ratios are more efficacies on aluminum surface followed by cardboard and wood surface, respectively. In general, efficacy was the best on non-porous surfaces compared with more porous surfaces.

تأثير مدى التعريض والتركيز لثلاثة انواع من الاسطح المعاملة في موت يرقات وبالغات خنفساء الطحين المحيرة *Tribolum confusum* (Du Val)

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الكلمات المفتاحية:
Lambda ، *T. confusum* *insecticide*، زيت الخروع ، نسبة الخلط، المعاملة السطحية .

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الخلاصــة

تمت دراسة تأثير المبيد الحشري لامبدا بالتركيزين (0,1، 0,05 ملغم / لتر) و وزيت الخروع وبنسب خلط 1:1، 1:2 و 1:3(زيت الخروع : مبيد اللامبدا) ضد يرقات و بالغات خنفساء الطحين المحيرة على اسطح الالمنيوم و الورق المقوى والخشب. وسجلت نسب الوفيات بعد 24 و 48 ساعة من المعاملة. وكانت نسب الوفيات للبالغات على سطح الألومنيوم المعامل 53.00، 56.00 و 62.00٪ عند نسب الخلط 1:1، 1:2 و 1:3 ، على التوالي، بعد 24 ساعة معاملة، اما عند سطح الورق المقوى المعامل فقد كانت نسب الوفيات 43,00، 56,00 و 57,66% عند نسب الخلط 1:1، 1:2 و1:3، على التوالي، عند نفس فترة التعريض. في حين أنه على سطح الخشب المعامل كانت نسب الوفيات 56,33، 58,00 و 61,00٪ عند نسب الخلط 1:1، 1:2 و 1:3 ، على التوالي، عند نفس فترة التعريض.

وأظهرت النتائج اعلى نسبة وفيات عند استعمال نسبة الخلط 1:3، في حين أظهرت نسبة خلط 1:1 اقل نسبة وفيات ضد خنفساء الطحين المحيرة، واظهرت النتائج ايضا ان نسب الخلط المختبرة كانت أكثر كفاءة على سطح الالمنيوم تلاه سطح الخشب وسطح الورق المقوى على التوالي. بشكل عام اظهرت الاسطح غير المسامية كفاءة عالية مقارنة مع الاسطح الاكثر مسامية.

1- Introduction

Damages related to the insect infestation have created many problems in stored-product; especially in developing countries where poor hygiene and inappropriate use of stored equipment encouraged insect attack (Walker, 2007; Rajashekar *et. al*., 2012). Confused flour beetle *Tribolum confusum* is one of the worldwide insect pests of mills, food warehouses, retail stores, and urban homes (Park, 2002; Esmaili *et. al*, 2013). The pest can damage on stored-products by feeding, and severely reducing the quality of crops due to product excrement and larval feces. This pest makes serious damage on flour and crush cereal particularly at larval and adult stages. As well as, the pest causes damage on seeds containing high humidity (usually above 12%), it change the color of the flour to gray and creates a bad smell on nutrient materials. The presence of this pest in flour lead to growth of mold on grain and flour (Weston and Rattlingourd, 2000; Park, 2002).

Research were shown that the pest control operations, in structural facilities or sites containing processed food products, consume and on store, are performed on the variety of surface substrates. The effect of pesticides is different on the variety of surface substrates (Arthur, 1994; Vojoudi, 2012), as well as the effect of different formulations of an insecticide is different (Slominsky and Gojmerac, 1972). Arthur (2008) tested the efficacy of chlorfenapyr against *T. castaneum* and *T. confusum* adults exposed on concrete, vinyl tile, and plywood surfaces, and showed that chlorfenapyr has different effect against red flour beetle compared with various surface substrates. In general, efficacy is best on slick surfaces such as steel or ceramic tile in comparison to more porous surfaces (Arthur, 1994 and 1997).

The aim of the present study was to investigate the effect of combination of lambda and castor oil applied on larva and adult of *T. confusum* exposed on aluminum, cartoon, and plywood surfaces under laboratory condition.

2. Materials and Methods

2.1 Insect Rearing

The confused flour beetle adults were obtained from Biology Department / University of Duhok. The beetles were reared in wide mouth plastic containers one liter volume. The beetles were fed on flour containing 5% yeast. The plastic containers were maintained in the dark an incubator (LAB TECH. Korea) at 30 ± 1 °C, 70 ± 5% RH conditions. The 5^{th} instar larvae of *T. confusum* were used in these experiments. Adults used in the study were one week after emergence.(Esmaili and Ehsan , 2013)

2.2 Insecticides

Lambda-cyhalothrin is a pyrethroid insecticide (Blue field Production Company) which is a synthetic chemical analogues of pyrethrins, and naturally occurring insecticidal compounds produced in the flowers of chrysanthemums (*Chrysanthemum cinerariaefolium*). Insecticidal products containing pyrethroids have been widely used to control pests (Amweg and Weston 2005; Oros and Werner 2005; He *et al*. 2008).

2.3 Bioassays

Three different mixing ratios 1:1, 1:2, and 1:3 (insecticide: Castor oil) respectively, were used for each of the insecticide lambda concentrations 0.1 and 0.05 Mg/L, were used for spraying the 5^{th} instar larvae and adults (one week after emergence) of confused flour beetle. Castor oil was obtained from local market in Zahko and diluted with ethanol 1:1, ten larvae and ten adults (in triplicate) were treated on three different surfaces (7.5*7.5cm areas) (aluminum, cardboard and wood) and covered by a petri dish to prevent insects escaping. Control group was treated with water and ethanol. Treated insects (larvae and adults) in all groups were incubated at 30 ± 1 C° and relative humidity 70% ± 5. Results were calculated after 24 and 48 hours.(Esmaili and Ehsan , 2013).Percentage insect mortality calculated by using the abbott formula (Abbott , 1925)..

2.4 Data Analysis

The data were analyzed using the probit procedures with SAS program with Duncin test (SAS, 2002). To compare toxicity of insecticide in different surfaces, as well as the toxicity of different mixtures (Lambda insecticide: Castor oil).

3. Results and Discussion

1- The effect of the type of surface treatment and different combinations of insecticide and castor oil on mortality rates of larvae of *T. confusum* after exposure periods of 24 and 48 hours.

In table (1) showed a variation in the percentage of mortality rates depending on the mixing ratios and the type of surface treatment and the concentration of the insecticide used in the mixture. At low concentration of the insecticide (0.05 Mg/L), in the aluminum surface treatment, the mortality rates reached 63.00, 63.66 and 84.33 % at mixing ratios 1:1, 1:2, 1;3 respectively, after 24 hours treatment. While the mortality rates after 48 hours treatment at the same mixing ratios were 63.00, 58.00, and 53.33 %, respectively. On the other hand, a higher concentration of the insecticide (0.1 Mg/L) mixed with castor oil in the proportions mentioned previously showed increased mortality rates at the same surface of the aluminum treatment, reaching 84.00, 90.00, 95.66 % at mixing ratios 1:1, 1:2, 1:3, respectively, after 24 hours treatment. While mortality percentages reached after 24 hours to 63.33, 62.00, 63.00 % at the same mixing ratios mentioned previously.

In the cardboard surface at a concentration of 0.05 Mg/L of the insecticide. The mortality were 47.66, 63.33 and 67.66 % at mixing ratios 1:1, 1:2, 1:3, respectively, (after 24 hours treatment). The rate of the mortality increased with the increase of the proportion of mixing, which reached to 67.66 % at the highest mixing ratio of the oil. While after 48 hours treatment on the same cardboard surface, the mortality rates were 52.00, 57.66, and 52.66 % at the same mixing ratios as indicated previously, which differed significantly from the control experiment, which were 0.00, 0.00 and 0.00 % at same mixing ratios respectively. While at a concentration of 0.1 Mg/L of lambda and at the same cardboard surface of treatment and the same mixing ratios mentioned previously, the mortality rates were 63.66, 84.00 and 95.33 % respectively, after 24 hours of treatment. While the mortality percentages decreased to 52.66, 52.66 and 68.33 % at the same mixing ratios, respectively, after 48 hours treatment. I think this decreasing cause by the different of exposure period.

The wood surface treatment at a concentration of 0.05 Mg/L of the insecticide, the mortality were 57.66, 63.33, 67.66 % at mixing ratios 1:1, 1:2, 1:3, respectively, after 24 hours treatment, which differed significantly from the control experiment, which were 0.00, 0.00 and 20.33 % at the same mixing ratios, respectively. At a concentration of 0.1 Mg/L of the insecticide the mortality rates increased to 80.00, 85.33 and 95.33 % at mixing ratios 1:1, 1:2, 1:3, respectively, after 24 hours treatment. While the mortality percentages after 48-hour treatment were 63.00, 63.33, and 62.66 % at the same mixing ratios, respectively. This is consistent with many of the previous results which indicated that some vegetable oils have synergism effect to insecticides and cause high mortality rates of insects (Machial, 2010; Dua *et. al*, 2010; Bachrouch *et al*., 2010).

2- Effect of mixing rates on mortality rates percentages of confused flour beetle larvae.

Table (1) showed the effect of mixing ratios on mortality percentage of insect regardless to the period of exposure and the type of surface treatment. The mortality rates were 52.47, 52.92 and 63.25 % at mixing ratios 1:1, 1:2, 1:3, respectively; there was an increasing in the percentage of the mortality with increasing the proportion of blended castor oil with the insecticide. The mortality percentages were higher at a mixture of 1:3 as compared to a mixture of 1:1 and 1:2 indicating increased efficiency in the toxicity of the insecticide with respect to the increase concentration of castor oil in the proportions of the mixtures. This indicated that using natural plant materials are more efficient and safe to the environment.

The support of the castor oil for Lambda insecticide may be attributed to that the oil increased the permeability of the insecticide through cuticle and then it reaches to the targeted sites (Sun and

Johnson, 1972; Mckinnon *et al.*, 2008). Highly toxic vegetable oils are rich in non-polar saturated fatty acids which penetrate the cuticle layers quickly and then lead to toxic impact (Shufeng *et al.*, 2005). In addition to the persistence the oil on the outer surface of insect body which closes the spiracles and hence obstructing the process of breathing (Fathi and Shakarami, 2014).

3- The effect of the exposure period and the concentration of the chemical insecticide on mortality percentages of larvae.

Table (1) also shows the impact of the exposure period on the mortality percentage of the larvae regardless of the mixing rates and the type of the surface treatment. The mortality percentage reached 63.47% in the first 24 hours and then decreased to 52.39% after 48 hours treatment.

Table (1) also shows the effect of different concentration of the chemical insecticide lambda combined with oil on the mortality percentage of the insect. The mortality percentages were 52.78, 52.24% at concentrations of 0.1, 0.05, respectively, regardless of the rates of mixing and the type of surface of treatment and the period of exposure.

4- The effect of different treatment surfaces on the mortality percentages of the larvae.

Table (1) shows the effect of different surfaces of treatment on the mortality percentages of the larvae of confused flour beetle. The mortality percentages reached 63.72, 61.07, and 63.30 at the surfaces of aluminum, cardboard, wood, respectively. The highest mortality percentage was at the surface of aluminum and this may be attributed the nature of this surface which prevent the absorbance of oil and liquid, compared with the results obtain on surface of cardboard. This result agreed with(Vojoudi ,2012) who stated that the surface of the cartoons had a lower ratio of mortality compared to the surface of the glass, ceramics and plastic treatment. In general, the best efficacy was on non-porous surfaces compared With more porous surfaces.

Table (1) The effect of the treatment surface type, concentration of the insecticide and mixing ratios with castor oil in the mortality percentages of Larva of *T. confusum* after exposure periods of 24 and 48 hours

Type of surface	Concentrations	Mortality						Effect of concentration	Effect of surface type
		Hours 24			48 Hours				
		Mixing ratio			Mixing ratio				
		1:1	1:2	1:3	1:1	2:1	1:3		
aluminum	0.1	84.00	90.00	95.66	63.33	62.00	63.00	52.78a	a 63.72
	0.05	63.00	63.33	84.33	63.00	58.00	53.33	52.24a	
cardboard	0.1	63.66	84.00	95.33	52.66	52.66	68.33		b 61.07
	0.05	47.66	63.33	67.66	52.00	57.66	52.66		
Wood	0.1	80.00	85.33	95.33	63.00	63.33	62.66		a 63.30
	0.05	57.66	63.33	67.66	21.66	52.66	58.33		
Control	0	0	0	20.33	0	0	0		
	0	0	0	20.33	0	0	0		
Effect of Mixing ratios		52.47 b	52.92 ab	63.25 a					
Effect of exposure period		a 63.47			b 52.39				

1- The effect of the type of surface of treatment and different combinations of insecticide and castor oil on mortality percentages of adults *T. confusum* after exposure periods of 24 and 48 hours.

Table (2) shows the results of the effect of mixing ratios of insecticide Lambda with castor oil on the mortality percentage of adult of confused flour beetle. The mortality percentages varied depending on the proportions of mixing ratios and the type of surface of treatment and the concentration of the chemical insecticide used in the mixture. At a concentration of 0.05 Mg/L the insecticide mortality percentage varied depending on the surface. On the aluminum surface the mortality percentages were 32.33, 36.33 and 39.00 % at mixing ratios 1:1, 1:2, 1:3, respectively, after 24 hours treatment. While the mortality percentages after 48-hour of treatment at the same mixing ratios the decreased to 20.33, 30.33 and 33.33 %, respectively.

While at a higher concentration of insecticide Lambda (0.1 Mg/L) with castor oil mixture of the same mixing ratios previously used have increased mortality rates at the same surface of the aluminum, reaching to 53.00, 56.00 and 62.00 %, respectively, after 24 hours treatment. On the other hand, the mortality percentages became 47.00, 50.00 and 58.00 %, respectively, at the same mixing ratios mentioned previously, after 48 hours treatment.

Table (2) also shows the effect on the cardboard surface treatment in mortality percentages, at a concentration of 0.05 Mg/L of the chemical insecticide, the mortality percentages were 22.33, 27.00 and 27.33 % at mixing ratios 1:1, 1:2, 1:3, respectively, after 24 hour treatment. There was an increase in the proportion of the mortality of the insect with increasing the mixing between the insecticide and the castor oil. Since, after 48 hours on the same cardboard surface treatment, the mortality percentages were 20.66, 20.66 and 20.66 % at the same mixing ratios previously described which differ significantly from the control treatment, which were 0.00, 0.00, and 0.00 %, respectively.

While at a concentration of 0.1 Mg/L of the chemical insecticide and at the same mixing ratios previously used the mortality rates were 43.00, 56.00, and 57.66 % respectively, 24 hours after treatment. While after 48 hours of treatment, the mortality percentage became 33.33, 40.00 and 37.00 % at the same mixing ratios mentioned previously, respectively, on the cardboard surface treatment.

The wood surface treatment at a concentration of 0.05 Mg/L of the chemical insecticide lambda the mortality percentage rates were 30.00, 34.33 and 36.33 % at mixing ratios 1:1, 1:2, 1:3, respectively, after 24 hours treatment, which differed significantly from the control treatment, which are 0.00, 0.00 and 0.33 %, respectively, while the mortality percentage after 48-hour treatment were 39.00, 30.66, 30.33% at the same mixing ratios mentioned above, respectively.

At the concentration of 0.1 Mg/L of the insecticide the mortality percentage reached to 56.33, 58.00 and 61.00 % at mixing ratios 1:1, 1:2, 1:3, respectively, after 24 hours of treatment. While the mortality percentages after 48-hour treatment were 70.00, 56.00, 57.66% at the same mixing ratios mentioned earlier, respectively.

2- Effect of mixing rates on mortality rates percentages of confused flour beetle Adults.

Table (2) also shows the effect of mixing rates on the mortality percentage regardless of the period of exposure and the type of surface treatment. The mortality rates reached 34.26, 35.42, and 36.23% at mixing ratios 1:1, 1:2, 1:3, respectively. These results agree with previous studies and possibly due to synergistic effect of vegetable oils on insecticides. (Huang *et al*, 2000; Pavlidou *et. al*, 2004). The High toxic properties of the vegetable oils is due to the existence of non-polar fatty acids that penetrate cuticle layers of insect and lead their influence poison. (Shufeng *et. al*., 2005). Present results also agreed with the result of many researchers who have pointed to the effectiveness of vegetable oils in reducing the number of insect's rate or the impact on life cycle (Lin et al, 2009; Denloye, 2010).

3- The effect of the exposure period and the concentration of the chemical insecticide lambda on mortality percentages of adults.

Regarding to the mixing ratios and the type of treatment surface on mortality percentages ratios of confused flour beetle adults, the mortality percentages were 37.52% after 24 hours treatment, while after 48 hours the treatment was 33.07 % (table 2). According to the effect of the different concentrations of the chemical insecticide lambda mixed with castor oil, the mortality percentage rates of insect reached 39.66, 22.10% at concentrations of 0.1 and 0.05 Mg/L, respectively, also the increasing concentration of insecticide caused the elevation in mortality rate of the insect. (Badii, 2013).

4- The effect of treatment on different surface types on the mortality percentages of adult confused flour beetle.

Table (2) shows the effect of treatment on different surface types on the mortality percentage of adults of confused flour beetle. The mortality percentages were 46.63, 32.22 and 43.13 % at the surface treatment of aluminum, cardboard, wood, respectively. The highest mortality percentage was at the surface of aluminum. This may be attributed to the nature of this surface which prevents the absorbance of oil and liquid compared with the results obtained on cardboard surface. This result agreed with Vojoudi (2012) who stated that the surface of the cartoons had a lower ratio of mortality compared to the surface of the glass, ceramics and plastic treatment. In general, the efficacy was the best on non-porous surfaces compared with more porous surfaces. Our result showed that efficacy of tested insecticides was higher on slick surfaces, (Collins, 2000) such as aluminum compared with more porous surfaces. Similar results were reported by Arthur (1997 and 2008). Who reported that the efficacy, was the best on non-porous surfaces, such as steel or ceramic tile compared with more porous surfaces.

Table (2) The effect of the treatment surface type by concentration of the insecticide and mixing ratios with castor oil in mortality percentages of Adults *T. confusum* after periods of exposure 24 and 48 hours of treatment

Type of surface	Concentrations	Mortality						Effect of concentration	Effect of surface type
		Hours 24			48 Hours				
		Mixing ratio			Mixing ratio				
		1:1	1:2	1:3	1:1	1:2	1:3		
aluminum	0.1	53.00	56.00	62.00	47.00	50.00	58.00	39.66a	46.63a
	0.05	32.33	36.33	39.00	20.33	30.33	33.33	b 22.10	
cardboard	0.1	43.00	56.00	57.66	33.33	40.00	37.00		32.22b
	0.05	22.33	27.00	27.33	20.66	20.66	20.66		
Wood	0.1	56.33	58.00	61.00	70.00	56.00	57.66		43.13a
	0.05	30.00	34.33	36.33	39.00	30.66	30.33		
Control	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0		
Effect of Mixing ratios		34.26ab	35.42b	36.23a					
Effect of exposure period		37.52a			33.07b				

4. Conclusion

In conclusion, the increase of the mixing proportion of castor extract with insecticide lambda increases the mortality percentage of *T. confusum*, and the toxicity varied on different surfaces. In general, the best efficacy was obtained on non-porous surfaces compared with more porous surfaces.

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