Use of Castor and Garlic Oils to Control the Red Flour Beetle, *Tribolium castanium*

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Abstract

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This study investigated the repellency effect and killing efficiency of castor and garlic oils to control adults and larvae of the red flour beetle, *Tribolium castanium*. The results obtained showed a significant repellency effect of plant oils on the insect adults with a higher repelling effect of garlic oil, which reached 100%, 20 minutes after treatment with 30% concentration, as compared to 100% for castor oil, 30 minutes after treatment at the same concentration. The results obtained also indicated the superiority of garlic oil's effect on larval mortality (first, second, and last instars), which reached 86.6, 90.0 and 73.3%, 5 days after treatment with 30% concentration, for the different larval stages, respectively. Furthermore, the highest mortality rate of insect adults (76.7%) was also reached when garlic oil was used at a concentration of 30%, 5 days after treatment, followed by castor oil (66.7%) at the same concentration and period after treatment.

Keywords: Red flour beetle, *T. castaneum*, stored grains, plant oils.

Introduction

The red flour beetle, *Tribolium castaneum* (Herbst) is one of the most common pests around the world, as it causes 10-40% loss of the total stored grain crops (Gharsan *et al*., 2018). The insect adults and larvae attack a wide range of stored foodstuffs, including legumes, cereals and their products, cocoa beans, dried fruits, dried meat, and tobacco among other products (El-Gizawy *et al*., 2019). This insect causes especially severe economic losses to wheat flour, since the flour infested with the insect produces an unpleasant smell which makes the flour unfit for human consumption (Aslam, 2020).

In controlling insect pests that infect agricultural crops for a long time, humans have relied on the use of chemical insecticides, and despite the effectiveness of these pesticides against a wide range of insects, the excessive and indiscriminate use has a negative impact on the ecosystem and human health (Phillips *et al*., 2012; Wijayaratne & Rajapakse, 2018). In addition, insects that infect stored products have shown resistance against some chemical insecticides, such as pyrethroids and organophosphorous pesticides, due to their constant exposure to these pesticides (Aktar *et al*., 2009). This led to search for environmentally friendly ways away from the use of chemical pesticides to manage pests (Van Veen, 1999).

Among the natural and biological products are plant oils, as these oils can be a successful alternative as an agent of insect pest control that are easily biodegradable in nature, and safe for the environment (Pavela, 2016). The castor bush oil contains a group of compounds such as alkaloids, phenols, terpenes and sterols, as well as linoleic acid and oleic acid (Kelly *et al*., 2013). Garlic oil contains a group of compounds, including thymine (B1) and pantothenic acid (B5), as well as minerals such as calcium, iron and zinc, in addition to sulfur compounds such as allyl polysulfide, and phenyldithene (Block, 2010).

Al-Hamdani *et al*. (2019) used some plant oils to protect cowpea seeds from infection with the southern cowpea beetle *Callosobruchus maculatus*. Castor oil had the highest effect, as the protection rate reached 100%. Some studies have shown that the effect of plant oils in killing insects is due to its toxicity by fumigation (Koutsaviti *et al*., 2018; Shaaya *et al*., 1991), or by contact (Bett *et al*., 2017; Patiño-Bayona *et al*., 2021). This study aimed to investigate the repellent effect of plant oils on the insect adults, as well as their effect on the mortality rate of both adults and larvae of the red flour beetle.

Materials and Methods

Insect collection, breeding and diagnosis

The insect adults were collected from grain stores infested with the insect in Muthanna Governorate, and reared on flour medium in the laboratory during 2021-2022. For the purpose of obtaining a pure insect culture, certain numbers of adults were placed in glass flasks of 1.5 liters with 100 g of flour, and their opening covered with cheese cloth and tightened by a rubber band and placed in an incubator at a temperature of 30±2°C and 75% humidity.

Preparation of plant oils concentrations

Garlic and castor oils were used in this study. Three concentrations for each oil (10, 20 and 30%) were prepared by diluting the oil with acetone.

Study of the repellent effect of plant oils on insect adults

McDonald *et al*. (1970) adopted the method of using plastic plates with a diameter of 9 cm. The plate was divided into two equal halves, and a circle with a diameter of 2 cm was drawn in the middle. One of the halves was wiped with a piece of cotton moistened with 1 ml of oil and the other half was wiped with acetone and the dish was left to dry in the air. Ten adult insects were placed in the middle area, and the

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plate opening was covered with a piece of cheese cloth, tied with a rubber band, and transferred to the incubator at a temperature of 30±2°C and relative humidity of 75%, and the repellence rate was determined 10, 20 and 30 minutes after treatment. The number of insects were counted in the untreated half (C), with three treatments for each oil in addition to the control treatment (using acetone only), with three replicates for each treatment, and the repellence rate was calculated through the following equation:

$$PR = 2(C - 50\%)$$

Where PR = Parcel repellence rate (%), C = % of insects in the untreated half of the plate. If C is more than 50%, the PR becomes positive, and the vegetable oil has a repellent effect and vice versa.

Effect of plant oils on the mortality rate of insect adults

Plant oils were added to the flour medium, with the three concentrations mentioned above, placed in plastic plates, 5 g of flour and 10 one day old adult insects/plate, with three replicates for each treatment, in addition to the control treatment. The mortality rate was determined 1, 3 and 5 days after treatment.

Effect of plant oils on mortality of some larval stages of the insect

Plant oils were added to the flour medium, in the three concentrations mentioned above, and then placed in plastic plates at the rate of 10 g of flour + 10 larvae (24 hours old). Similar treatments were made to the second, and last larval instars of the insect. Treatments were made in three replicates in addition to the control treatment. The mortality rate was determined 1, 3 and 5 days after treatment.

Statistical analysis

The experimental design used was the complete random design (CRD), and the data obtained was statistically analyzed using the Gen Stat 2012 software and the Abbot's method Abbot (1925).

Results and Discussion

Repellency effect of plant oils on the insect adults

The results obtained (Table 1) showed the presence of a repellency effect for both plant oils on the adults of the insect. When 30% oil concentration was used, 20 minutes after treatment, castor oil gave the highest repellency effect (100%), followed by garlic oil (86.7%). These results are in agreement with previous reports (Al-Hamdani *et al*., 2019; Huma & Butt, 2021; Khalaf, 2016). The reason for the insect repellency effect of oils may be due to their possession of effective compounds that have a repellent effect on insects or their possession of toxic compounds that act by contact against many insects, including insects of stored products (Tripathi *et al*., 2002).

Effect of plant oils on the mortality rate of insect adults

The results obtained (Table 2) showed that the highest mortality rate was achieved 5 days after treatment. The results showed that the insect mortality rates when using 30% oil concentration reached 23% and 20% for each of the two oils (garlic and castor), respectively. The results also indicated the superiority of garlic oil in controlling the insect adults, where the highest mortality when using 30% oil concentration, 3 and 5 days after treatment, reached 50.0 and 76.7%, respectively, followed by castor oil, which reached 46.7 and 66.7%, respectively, compared with the control treatment (0.00%). The highest mortality rate was reached 5 days after treatment with both oils, and these results were in agreement with previous reports (Al Mansour & Farahani, 2010; Ebadollahi & Ebrahim, 2019; Papanikolaou *et al*., 2022). Daoud *et al.* (1991) indicated earlier that the lethal effect of plant oils in killing adult insects may be due to a nervous shock they cause, followed by adults paralysis and consequently their death.

Table 1. The repellency effect of plant oils on adults of the red flour beetle, *T. castanium.*

Name of oil	Oil concentration %	Percentage of adults repellence after X minutes		
		10	20	30
Castor	30	80.0	100.0	100.0
Garlic	30	66.7	86.7	93.3
Control	0	00.0	00.0	00.0
The repellence rate based on exposure time		48.9	62.2	64.4
$LSD_{0.05}$		8.33	4.67	6.19

$LSD_{0.05}$ for the interaction between oil concentration and time= 7.69

Table 2. Effect of plant oils on the mortality of the adults of red flour beetle, *T. castanium.*

Name of oil	Oil concentration %	Adult mortality rate (%) after (days)			Average mortality rate per oil concentration
		1	3	5	
Castor	10	13.3	33.3	46.7	31.1
	20	20.0	40.0	60.0	40.0
	30	23.3	50.0	76.7	50.0
Garlic	10	10.0	30.0	40.0	26.7
	20	13.3	43.3	56.7	37.8
	30	20.0	46.7	66.7	44.5
Control		00.0	00.0	00.0	00.0
Mortality rate (%) per exposure time		14.3	34.8	49.5	
$LSD_{0.05}$		3.12	4.11	5.96	

$LSD_{0.05}$ for the interaction between oils and their concentrations = 10.8

Effect of plant oils on the mortality rate of some larval stages of the insect

Results obtained (Table 3) indicated that garlic oil and castor oil gave good results in controlling the larval stages of the red flour beetle, *T. castanium* at all concentrations used, with garlic oil giving better results than castor oil. Treatment of first, second and last instars larvae with 30% garlic oil produced 86.6, 90.0, and 73.3% mortality of the three instar stages, respectively, 5 days after treatment. Whereas castor oil produced a mortality rate of 66.6, 66.7 and 53.3%, respectively, for the three instar stages under the same conditions. The lowest mortality rates of the insect larval ages were obtained when using 10% concentration of each of the garlic and castor oil, which amounted to 26.6, 26.7, and 20.0% and 13.3, 16.7, and 10.0% after one day of treatment, respectively, compared with the control treatment, which amounted to 00.0% for the three instar stages. The results also showed that the highest mortality rate for the larval instars (first, second and last instar) of the insect treated with both garlic and castor oils reached 67.7 and 48.5% when treated with a concentration of 30%, 5 days after treatment, respectively. The results also showed that the first and second larval ages of the insect were more affected than the last larval stage when treated with both oils. The reason may be due to the fact that the young larval stages may have weak defense, and their thin skin makes them vulnerable to the penetration of active compounds that plant oils possess, and consequently affecting and damaging the vital activities of the insect leading to its death (Al-Hamdani *et al.* 2019; Bachrouch *et al*., 2010).

Table 3. Effect aromatic plant oils on the mortality of some larval stages of the red flour beetle, *T. castanium* 5 days after treatment.

Name of oil	Oil concentration (%)	% mortality of first instar larvae after (days)			% mortality of second instar larvae after (days)			% mortality of last instar larvae after (days)			Average mortality rate per oil concentration
		1	3	5	1	3	5	1	3	5	
Garlic	10	26.7	50.0	63.3	26.6	46.7	63.3	20.0	40.0	50.0	42.9
	20	36.6	66.7	76.7	33.3	66.7	73.3	26.7	50.0	60.0	54.0
	30	43.3	86.6	90.0	43.3	83.3	86.6	36.6	66.7	73.3	67.7
Castor	10	16.7	30.0	46.7	13.3	30.0	43.3	10.0	20.0	33.3	27.0
	20	23.3	43.3	56.7	20.0	40.0	53.3	16.7	30.0	43.3	36.3
	30	36.7	56.7	66.7	33.3	53.3	66.6	26.6	43.3	53.3	48.5
Control		00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
Average mortality rate per exposure time		26.2	47.6	57.2	24.3	45.7	55.2	19.5	35.7	44.7	
$LSD_{0.05}$			11.81			10.89			8.77		
$LSD_{0.05}$ for the interaction between oils and their concentrations			7.91			6.78			4.97		

الملخص

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تناولت هذه الدراسة التأثيرات الطاردة وكفاءة القتل لزيوت الخروع والثوم في مكافحة بالغات ويرقات خنفساء الدقيق الحمراء (*T. castaneum*). أظهرت النتائج التي تمّ الحصول عليها وجود تأثير طارد معنوي للزيوت النباتية على بالغات الحشرة. لوحظ ارتفاع نسبة التأثير الطارد لزيت الثوم والتي بلغت 100% بعد 20 دقيقة من المعاملة بتركيز 30%، مقارنة بـ 100% لزيت الخروع بعد 30 دقيقة من المعاملة بالتركيز نفسه. كما أشارت النتائج إلى تفوق تأثير زيت الثوم في معدل موت اليرقات (العمر الأول والثاني والأخير)، حيث بلغ 86.6، 90.0 و 73.3% بعد 5 أيام من المعاملة بتركيز 30% للأطوار اليرقية المختلفة، على التوالي. كما تمّ بلوغ أعلى معدل قتل للحشرات البالغة (76.7%) عند استخدام زيت الثوم بتركيز 30% بعد 5 أيام من المعاملة، يليه زيت الخروع (66.7%) عند التركيز نفسه والمدة ذاتها.

كلمات مفتاحية: خنفساء الدقيق الحمراء، حبوب مخزونة، زيوت نباتية، *T. castaneum*.

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