

A laboratory assessment on the effect of powder from *Foeniculum vulgare* and *Eruca sativa* against saw-toothed grain beetle *Oryzaephilus surinamensis* (L.)Hind S. Abdulhay

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Abstract

This study was conducted to determine the insecticidal activity of botanical powders from Fennel, *Foeniculum vulgare* Miller and *Eruca sativa* Miller against saw-toothed grain beetle *Oryzaephilus surinamensis* (L.). Plant powders were admixed with wheat grains at concentrations of 5.0, 10, 20, 40, 60, 80 and 100 g/kg. The mortality was determined after 24 and 48 h after treatment then the flasks were kept to get F₁ progeny. Results showed that all tested concentrations for both *F. vulgare* and *E. sativa* exhibited high toxicity effects on *O. surinamensis* adults and the high toxicity rate was concentration and time dependent. On the basis of lethal toxicity (LC₅₀) value fruit powder from *F. vulgare* were more toxic to *O. surinamensis* adults than seed powder from *E. sativa* at 24 and 48 hrs after treatment. Also, the fruit powder of *F. vulgare* caused a very strong F₁ progeny population inhibition activity against *O. surinamensis* with the highest inhibition rate was counted from the wheat grain treated with 80 g/kg and 100g/kg for *F. vulgare* fruit powder and *E. sativa* seed powder, respectively. Moreover, these plant materials had no adverse effect in the germination percentage of wheat grains treatment. These results indicated that *F. vulgare* fruit powder and *E. sativa* seed powder could be applicable to the management of stored product insects to decrease ecologically detrimental effects of using insecticides.

Key word: saw-toothed grain beetle, insecticidal activity, powder, *Foeniculum vulgare*, *Eruca sativa*.

Introduction

Harvested crops including seeds, grains and cereals suffer a loss of at least 10% from insect pests during storage. Losses of 30% are common throughout large areas of the world [1]. The saw-toothed grain beetle, *Oryzaephilus surinamensis* L. (Coleoptera : Silvanidae), is one of the most common grain and stored product insect pest worldwide, which can cause serious loss to cereals affecting the quantity as well as quality of the grains [2]. Larvae and adults infest cereal, cornstarch, rice, dried fruits, flour, pasta, spices, herbs and various

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other food products especially because of their ability as cosmopolitan invaders of packaged food [3]. The saw-toothed grain beetle is a very small insect has the ability to hide in many places in storage facilities, making it difficult to be controlled by insecticides, although it has built up resistance to several insecticides [4].

Plant materials with insecticidal properties have been used traditionally for generations throughout the world including many traditional medicine plants which have biological activities to many major stored-grain insects [5]. Different kinds of dry plant materials were stored with grain during the storage period and the stored grain could be completely protected from the infestation [6]. Some powders made from fruits, seeds, flowers, leaves, shoot, bark and roots of local medicinal / insecticidal plants have been demonstrated to be effective in protecting stored cereals and legumes against pest depredation [7] especially seeds and flowers as it predicted to be defended constitutively at higher levels than other tissue [8]. Many studies have investigated plants materials for toxicity as potential insecticide. [9] evaluated the fruit powder of *Crescentia cujete* and leaf powder of neem, scented basil, camphor, lemon grass, peppermint, scented coleus against *O. surinamensis*. [10] tested powders obtained from dry ground *Ailanthus altissima* Swingle bark, *Cnidium monnieri* (L.) fruit and *Alpinia officinarum* Hance rhizome for their abilities to protect grains from damage by *O. surinamensis* (L.). [11] studied the toxicity of powders and aqueous extracts from seeds and pericarps of *Jatropha curcas* on *Sitophilus zeamais*, *Rhyzopertha dominica* F., *Tribolium castaneum* Herbst and *O. surinamensis*. The ethanolic extracts of five plants leaves *Melia azedarach*, *Mentha longifolia*, *Myrtus communis*, *Cymbopogon citratus* and *Datura stramonium* were tested against three stored grain pests *O. surinamensis*, *T. castaneum* and *Callosobruchus chinensis* L. [12]. Also, the chemical composition of the essential oil from seeds of *Carum copticum* was studied against adults of *Tribolium confusum* du Val, *R. dominica* and *O. surinamensis* [13].

The present study was carried out to assess the potential insecticidal activities of dry powders obtained from two famous traditional medicine plants the seeds of *Eruca sativa* Miller (Brassicaceae) and the dried fruits (often called seeds) of fennel, *Foeniculum vulgare* Miller belongs to the family Apiaceae (formerly Umbelliferae) against a major insect pests of stored grains *O. surinamensis* adults and progeny production.

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Materials and methods

Insect culture:

Preliminary population of *O. surinamensis* was obtained from infested flour in local stores in Baghdad. Culture were reared in glass containers (1 litter) containing wheat flour mixed with yeast (19:1 w/w), covered by a fine mesh cloth for ventilation. The cultures were maintained in a controlled temperature and humidity ($27 \pm 2^\circ\text{C}$ and $70 \pm 5\%$ relative humidity) in the dark [14]. Insects were reared for three generations before initiation of experiments. Pupae have been isolated from the culture and observed for adult emergence to be used in subsequent experiments. All experimental procedures were carried out under the same environmental conditions as the cultures.

Plant material collection and preparation

Seeds from *E. sativa* and the dried fennel fruits from *f. vulgare* were purchased from the local herbal store, identified by the Biology Department, college of Science, Baghdad University, Iraq.

To prepare the powders, seeds of *E. sativa* and dried fruits from *f. vulgare* were cleaned from dust and dirt, and then ground into powder form by using electrical grinder. The powders were passed through sieve of 0.25 mm mesh size to standardize particles size then preserved in a glass jar and stored in a refrigerator at 4°C until used for insect bioassays.

Contact toxicity test of plant powders

The *O. surinmensis* used for experiment were randomly chosen for bioassays. For each plant powder twenty active unsexed adults about 5 - 7 days were exposed to disinfested broken wheat grains admixed with powdered plant material at concentrations ranging between 5.0,10, 20, 40, 60, 80 and 100 g/kg or without plant material as control in glass flasks covered with muslin held with rubber bands and incubated at $27 \pm 2^\circ\text{C}$ and $70 \pm 5\%$ relative humidity. Four replicates were used of each concentration in addition to control. Insect mortality was determined after 24 and 48 hours from treatment application to assess direct toxicity of powders. Insects that did not move when lightly probed or shaken in the light were considered dead.

F1 progeny assessment

The dead adults were removed and the treated flasks were still kept under the same experimental conditions. All live and dead insects were sieved and discarded after 14 days of introduction. Then the grains were kept until emergence of F1 progeny .After F₁ progeny adults emerged, numbers were counted daily in the flasks (treated and control) then removed to another flask until no longer F₁ progeny adults appeared. The F₁ progeny population

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inhibition rate (FPIR) of both plant powders against *O. surinamensis* was calculated according to:

$$\text{FPIR \%} = [(N_c - N_t) / N_c] 100$$

Where: N_c = the number of the F_1 progeny in the control, N_t = the number of the F_1 progeny in the treated flask.

Germination test

The viability of treated and control grains were tested separately by treated grains with seed powder of *E. sativa* and the dried fruit from *F. vulgare* at the concentration of 100 g/ kg and without powder as a control, then twenty grains were placed separately in Petri dishes containing moistened filter paper (Whatman No. 1). The dishes were kept at $27 \pm 2^\circ\text{C}$ and 12 L: 12 D. Each treatment was replicated three times. The dishes were observed and the number of emerged seedlings from each Petri dish was counted and recorded after 7 days. The percent germination was computed according to the methods of [15] as follows:

$$\text{Viability index (\%)} = (NG * 100) / TG$$

Where NG = number of seeds germinated and TG = total number of seeds tested in each Petri dish.

Statistical analysis

The percentage insect mortality was corrected by [16]. Results were expressed as means \pm Standard deviation (SD) and were separated using least significant differences (LSD) ($P = 0.05$) using the Duncan's test. The LC_{50} values were calculated by standard probit methods [17] using the SPSS software package [18].

Results

The efficacy of different concentration powders in the mortality of *O. surinamensis* adults after 24h and 48h is shown in Table 1. Results showed that all tested concentrations for *F. vulgare* fruit powder and *E. sativa* seed powder were toxic against *O. surinamensis*, and mortality percentages were directly proportional to the powder concentrations and time after treatment. The *F. vulgare* fruit powder was more toxic to insect adults than *E. sativa* seed powder. The lowest concentration (5.0g/kg) elicited a toxicity response being 19.25% and 33% for *E. sativa* and *F. vulgare* after 48h of treatment, respectively, while at 100 g/kg concentration there was a significant toxic effect reaching 92.5% and 100% for *E. sativa* and *F. vulgare* at 48h after treatment, respectively.

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Table 1. Contact toxicity of test plant materials against *O. surinamensis*

Concentration (g/kg)	Insect mortality rate (%) (Mean ± SE)			
	<i>E. sativa</i> After		<i>F. vulgare</i> After	
	24h	48h	24h	48h
5.0	12.5 ± 2.08 c	19.25 ± 3.78 d	25 ± 3.83 c	33 ± 4.97 d
10	22.5 ± 3.69 c	34.5 ± 5.26 cd	35 ± 4.76 c	45.75±4.03 cd
20	32.5 ± 4.65 c	45 ± 6.78 cd	47.5 ± 4.04 c	57.5 ± 4.20 cd
40	45 ± 6.88 bc	60.25 ± 7.83 bc	59 ± 7.83 bc	76 ± 4.89 abc
80	75 ± 3.56 ab	78.25 ± 5.06 ab	88 ± 5.59 ab	95.75±3.09 ab
100	90 ± 5.48 a	92.5 ± 3.79 a	97.5 ± 2.38 a	100 ± 0.0 a

Values followed by the same letter within a column are not significantly different at the P<0.05 level (Duncan test)

The probit statistics, estimate of LC₅₀ for 24 and 48 hours after treatment are presented in Table 2. the result indicates that *F. vulgare* fruit powder was the most toxic on *O. surinamensis*. The LC₅₀ values after 24h was 29.230 g/kg for *E. sativa* seed powder, while it was 16.103 g/kg for the *F. vulgare* fruit powder. LC₅₀ values after 48h for *E. sativa* powder was 20.065 g/kg which is 1.78 times higher than the corresponding value for *F. vulgare* fruit powder.

Table 2. LC₅₀ values of *E. sativa* and *F. vulgare* powders against the adults of *O. surinamensis*

Time	LC ₅₀ (g/kg)	Slope (± SE)	Intercept	R ²
After 24h				
<i>E. sativa</i>	29.230	1.6898± (0.288)	2.5230	0.958
<i>F. vulgare</i>	16.103	1.8757± (0.419)	2.7361	0.932
After 48h				
<i>E. sativa</i>	20.065	1.5933 ±(0.252)	2.9248	0.964
<i>F. vulgare</i>	11.299	2.0351 ±(0.354)	2.8569	0.957

Effect of treatments on the F1 progeny production

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It was obvious from the result in Table (3) that all tested concentration caused significant reduction in the number of F1 adults emerged and the fruit powder of *F. vulgare* was found to be the most effective against *O. surinamensis*. The number of F1 adults emerged was decreased from 50.20 at 5.0 g/kg to 3.0 at 80g/kg for *E. sativa* seed powder, meanwhile the fruit powder of *F. vulgare* decrease the number from 38.32 at 5.0 g/kg to 6.0 at 40 g/kg. Furthermore, no F1 adults were emerged at concentration of 80g/kg for *F. vulgare* and 100 g/kg for *E. sativa*.

As can be seen in table 3 the F1 progeny population inhibition efficacy notably increased with the increasing treatment concentration for the tested plant powders. The fruit powder of *F. vulgare* caused a very strong F1 progeny population inhibition activity against *O. surinamensis* with the highest inhibition rate (FPIR) was counted from the wheat grain treated with 80 g/kg and 100g/kg for *F. vulgare* fruit powder and *E. sativa* seed powder, respectively.

Table 3. The F1 progeny population inhibition rate of *E. sativa* and *F. vulgare* powders against *O. surinamensis* at different concentration.

Concentration (g/kg)	The number of living adults		Number of F1 adults emerged		FPIR (%)	
	<i>E. sativa</i>	<i>F. vulgare</i>	<i>E. sativa</i>	<i>F. vulgare</i>	<i>E. sativa</i> <i>vulgare</i>	<i>F.</i>
5.0	62.82± 4.79 d	50.40 ±6.48 b	50.20± 5.48 c	38.32 ±4.65 b	22.32± 4.35 d	41.05 ± 2.59 c
10	50.0± 7.48 cd	39.34 ± .86 b	36.07± 3.69 c	27.15±7.28 ab	46.32± 5.23 bcd	58.23± 7.34bc
20	40.0± 4.24 bc	31.05 ± 5.5 ab	21.45±4.12 bc	17.67±3.16 ab	68.08± 5.16 abc	72.82± 6.08ab
40	29.20±5.12 abc	18.2 ± 4.03 ab	15.10±2.75 ab	6± 1.41 a	74.55± 4.12 ab	90.77± 2.5 a
80	17.4± 2.08 ab	3 ± 0.82 a	3± 0.82 a	-	95.54± 4.43 a	100 ± 0.0 a
100	6± 1.83 a	-	-	-	100 ± 0.0 a	100 ± 0.0 a

Values followed by the same letter within a column are not significantly different at the P < 0.05 level Duncan test).

Effect of plant powders treatment on the germination

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Percent germination of wheat grains treated with plants powder is presented in Table 4. There was no significant ($P > 0.05$) difference in the germination capacity between wheat grains treated with seed powder of *E. sativa* or the fruit powder of *F. vulgare* and control treatments after 7 days of treatment. Generally, all the treated grains were as viable as the untreated grains.

Table 4. Percent germination of wheat grains after 7 days of treatment

Treatments	germination of grains (% mean \pm SE)
<i>E. sativa</i>	93.3 \pm 1.15 a
<i>F. vulgare</i>	95 \pm 1.0 a
Control (Untreated)	96.67 \pm 0.58 a

Means within a column followed by different letters are significantly different ($P < 0.05$ level)

Discussion

The results demonstrate that powders from *F. vulgare* and *E. sativa* showed different potencies against the adults of *O. surinamensis*. The fruit powder of *F. vulgare* induced higher mortality of *O. surinamensis* adults than seed powder of *E. sativa* in treated grains. Contact toxicity progressively increased with increasing concentration and time after treatment. It indicated that higher concentration and longer exposure periods are needed to achieve appreciable management of adults. LC_{50} values for *O. surinamensis* adults were decreased after 48 hrs after treatment for both *F. vulgare* and *E. sativa* powder (Table 3). [19] stated that the period of exposure appears to be more important than dosage in affecting the efficiency of the vapors of *Acorus calamus* essential oil to adults of five stored-product insect species. Similar results have been reported for the toxicity of methanol extract of the rhizome from *Acorus gramineus* to adults of *S. oryzae* and *Lasioderma serricornis* [20].

Data showed that adult emergence was significantly suppressed by plant powders. Although 92.5 % mortality was obtained after 48 h of treatment at 100 g/kg for *E. sativa*, the *F. vulgare* fruit powder showed higher effect at the same concentration and after 24 h of exposure. The powders of *E. sativa* and *F. vulgare* exhibited the F1 progeny population inhibition rate (FPIR) of 95.54 % and 100 % at the concentration of 80 % and overall decrease in F1 progeny production at concentration of 100 g/kg. [21] and [22] reported that when leaf, bark and seed powder of plants mixed with stored-grains reduce oviposition rate and suppress adult emergence, and also reduced seed damage rate. The plant

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material either suppressed oviposition or killed the insects at different developing stages from eggs, larvae, pupae to adults, preventing feeding and damage on the treated wheat. The differences in responses of the *O. surinamensis* to different plant species could be attributed to the different components of plant powders [10].

Previous studies demonstrated that *E. sativa* as a medicinal plant has several antioxidant constituents including glucosinolates, carotenoids, flavonoids, etc. [23]. Degradation products of glucosinolates are isothiocyanates, thiocyanates, nitriles and other products [24]. Glucosinolates and their breakdown products have been studied because of the possibility of using them as natural pesticides [25]. The volatile and pungent isothiocyanates may be toxic or deterrent to a broad range of organisms like fungi [26], nematodes [27], insect herbivores [28] and stored-grain insects [29]. Also, [25] concluded that glucosinolate were toxic to the larvae of *Musca domestica*. Meanwhile [30] concentrated on the toxicant influence of the extracted alcohols of *E. sativa*, *Raphanus sativus* and *Lactuca sativa* on *Callosobruchus maculatus* (Fab.). Toxicity of isothiocyanates has been attributed to affect the respiratory function by inhibiting certain enzymes in the respiratory electron transport chain of insects, thus reducing the oxygen consumption and perhaps CO₂ production as well [31].

Also, *F. vulgare* are a common traditional herb in pharmacopoeias in Arab, Chinese and Indian, it has many biological activities due to its volatile and nonvolatile compounds [32] and the main active constituents, which include the terpenoid anethole, are found in the volatile oil. [33] indicated that methyl chavicol (= estragole) and Limonene in the essential oil of *F. vulgare* were the major components. [34] reported that estragole is toxic fumigant compound active against insect pests. [35] mentioned that extracts of *F. vulgare* fruit caused over 90% mortality in adults of *S. oryzae* and *C. chinensis* at 3 or 4 days after treatment. Another experiment showed that *F. vulgare* fruit extract gave 67% and 100% mortality in contact action in *Attagenus unicolor japonicus* larvae at 5.2 mg/ cm², 21 and 28 days after treatment respectively [36]. [37] tested the insecticidal activity of essential oils from *F. vulgare* against *Sitophilus granarius* and *Sitophilus oryzae*. Also, [38] investigated the efficacy of *F. vulgare* extract for repellency and oviposition deterrent of cowpea weevil *C. maculatus* under laboratory conditions. [39] studied the aphidicidal activity of *F. vulgare* essential oil against cabbage aphid, *Brevicoryne brassicae* and found that the applications caused a higher offspring mortality rate compared with control treatments.

The mode of action of medicinal/ insecticidal plants include toxicity to adults, reduction of oviposition, ovicidal activity, toxicity to immature stages

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prior or immediately following penetration of plant tissue [40]. Whereas [41] stated that the modes of action of powder vary, but with low to moderate dosages, the effect is always repellent or toxic.

Therefore, the results concluded that the dried fruit from *F. vulgare* and *E. sativa* seed powder have a potential for integrated pest management programs against *O. surinamensis*, and at the same time, these natural products used as culinary and medicinal plants are considered fully biodegradable, less toxic and can pose lesser risks to human health and the environment. Thus, it is candidate to further investigate to improve their efficacy.

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التقييم المختبري لمسحوق نبات الشمر *Foeniculum vulgare* والجرير *Oryzaephilus surinamensis* (L.) ضد حشرة خنفساء الحبوب المنشارية *Eruca sativa*

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الخلاصة

أجريت هذه الدراسة لتحديد فاعلية مسحوق نبات الشمر (حبة حلوة) *Foeniculum vulgare* Miller والجرير *Eruca sativa* Miller ضد حشرة خنفساء الحبوب المنشارية *Oryzaephilus surinamensis* (L.) و 100 غم / كغ . سُجّلت الوفيات بعد 24 و 48 ساعة من المعاملة ومن ثم حفظت للحصول على افراد الجيل الاول. بينت النتائج أن جميع التركيزات المستخدمة لكلا المسحوقين لها تأثير سمي عالي على حشرة *O. surinamensis* وارتبط التأثير السمي الاعلى ايجابيا مع زيادة كل من التركيز والزمن بعد المعاملة . ووجد بالاعتماد على قيم التركيز القاتل 50 % ان مسحوق ثمار الشمر *F. vulgare* أكثر سمية لبالغات الحشرة قياسا بمسحوق بذور الجرير *E. sativa* بعد 24 و 48 ساعة من المعاملة. كما اظهر مسحوق ثمار الشمر كفاءة عالية في تثبيط ظهور افراد الجيل الاول لحشرة خنفساء الحبوب المنشارية، اذ بلغ أعلى معدل تثبيط عند معاملة حبوب القمح بتركيز 80 غم / كغم و 100 غم / كغم لكل من مسحوق ثمار الشمر ومسحوق بذور الجرير على التوالي. اظهرت النتائج امكانية استخدام مسحوق ثمار الشمر ومسحوق بذور الجرير في برامج الادارة المتكاملة لحشرات المخازن لتقليل الآثار البيئية الضارة الناتجة من استخدام المبيدات الحشرية في مكافحة .