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Research Article

The Effect of Aqueous and Oil Extracts of Foeniculum vulgare (Sweet Fennel) on the Larval Stages of Ephestia cautella (Fig Moth)

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Article Info
Article history:
Received 30-9-2024
Received in revised form 5-11-2024
Accepted 24-11-2024
Available online 31 -12 - 2024
Keywords: Extracts, Fennel Seeds, Date Moth, Cold Aqueous Extract, Hot Extract, Oil Extract.

Abstract:

A series of laboratory experiments were conducted in the Graduate Studies Laboratory, Department of Biological Resistance Technologies, Al-Musayyib Technical College, from 1st October 2023 to 1st December 2023. The experiments aimed to assess the effects of hot, cold aqueous, and oil extracts of *Foeniculum vulgare* (sweet fennel) on the various larval stages of *Ephestia cautella* (fig moth). The results indicated that the oil extract of fennel seeds outperformed the cold and hot aqueous extracts, with the highest mortality rate of 66.70% observed for the oil extract at a a concentration of 1% after 72 hours. In comparison, the highest mortality rates for the hot aqueous extract and cold aqueous extract at the same concentration were 40.00% and 53.30%, respectively, after 72 hours. The lowest mortality rate for the oil extract was observed at a concentration of 0.25%, registering 10.00%, while the cold aqueous extract resulted in a minimum mortality rate of 6.70% at a concentration of 0.25% after 72 hours post-treatment.

The findings also revealed that the percentage of mortality increased with higher extract concentrations and longer exposure times.

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Peer review under responsibility of Iraqi Academic Scientific Journal and University of Kerbala.

Introduction

The date moth, *Ephestia cautella*, is a significant insect pest that attacks a wide range of food sources in both the field and storage [1]. It infests various types of stored food, particularly mature dates, whether they remain on the palm trees, have fallen to the ground, or are stored in warehouses. In addition, it feeds on a variety of other stored food items, such as dried figs, raisins, apricots, grains, and legumes, among others. Among the species of the genus *Ephestia* [1], the date moth is highly competitive and dominant in date storage facilities. It is estimated that insect infestations result in global storage losses of approximately 5-10% of stored food products [2]. In Iraq, the date moth is one of the most destructive pests affecting stored dates, causing significant damage from harvest through to market sale and consumption. This pest also presents major challenges for date exports, making it a target of intense focus in pest management efforts [3]

Various control methods are employed against the date moth (*Ephestia cautella*), a significant pest of stored dates, including mechanical and chemical strategies. Among these, date compaction is a widely practiced non-chemical approach, while fumigation with synthetic chemicals such as phosphine gas, methyl bromide (CH_3Br), and carbon tetrachloride (CCl_4) remains a common method in pest management [4]. Methyl bromide, a colorless, odorless, and non-flammable organic compound, is particularly notable as one of the few fumigants still extensively used for treating packed dates due to its high efficacy in eliminating stored-product pests [5] [6]. However, concerns about its adverse environmental impact, including ozone depletion, have prompted regulatory restrictions under the Montreal Protocol [7]. Furthermore, the escalating resistance of pests to synthetic chemical pesticides poses a growing challenge to the sustainability of chemical control methods [8].

As a result, attention has shifted towards alternative approaches, with a significant focus on natural plant-derived products. These botanical extracts are gaining traction due to their biodegradable nature, reduced toxicity to non-target organisms, and minimal environmental footprint. For instance, essential oils and extracts from plants like *Azadirachta indica* (neem), *Eucalyptus globulus* (eucalyptus), and *Foeniculum vulgare* (fennel) have demonstrated insecticidal, repellent, and growth-inhibitory properties against various stored-product pests [9] [10]. In this context, fennel (*Foeniculum vulgare*) seed extracts have emerged as a promising candidate for evaluation as a safer and eco-friendly alternative to synthetic pesticides. This study investigates their efficacy in controlling the date moth, aiming to contribute to the development of sustainable pest management strategies [5] [11].

Materials and Methods:

1. Insect Rearing in the Laboratory:

Different stages of the insect were obtained from the Agricultural Research Center at the Ministry of Science and Technology and were reared in the Biological Control Laboratory, Graduate Studies Department, Al-Musayyib Technical College. The larvae were placed in plastic containers with a diameter of 8 cm and a depth of 15 cm, containing artificial feed composed of 81% cracked wheat, 12% glycerin, 6% molasses, and 1% dry yeast to obtain adult insects, following the method of Benson [12] [13]. The container openings were covered with a piece of muslin cloth and secured with a rubber band. The containers were then placed in an incubator at 25 ± 2°C, 70-80% relative humidity, and a 12:12 light-to-dark cycle, and monitored closely [14].

2. Preparation of Plant Extracts:

Hot aqueous, cold aqueous, and oil extracts of fennel (*F. vulgare*) seeds were prepared as follows:

Hot Aqueous Extract:

A total of 10 g of fennel seed powder was placed in a glass flask, and 200 mL of boiling distilled water was added. The mixture was shaken on an electric shaker for 15 minutes and left for 24 hours. It was then filtered using Whatman No. 1 filter paper, and the filtrate was centrifuged at 3000 rpm for 10 minutes. The resulting supernatant was placed in an electric oven at 45°C until fully dried. This process was repeated several times to obtain the active compound, which was then stored in the refrigerator for later use [14].

To evaluate the bioactivity of the hot aqueous extract, 5 g of the dry residue of each extract was dissolved in 100 mL of distilled water, resulting in a stock solution of 50 mg/mL (5%). Different concentrations (1%, 0.75%, 0.50%, and 0.25%) were prepared using the equation $N_1V_1 = N_2V_2$, with distilled water used as the control treatment [15].

Cold Aqueous Extract:

The same steps used for the hot aqueous extract were followed, except cold distilled water was used instead of boiling water.

Oil Extract:

A total of 500 g of fennel seeds were ground using an electric grinder. From this, 100 g of powder was taken and placed in 700 mL of distilled water in a glass flask, which was fitted into a Clevenger apparatus for oil extraction. The temperature of the device was set to the boiling point of water (100°C). After 20 minutes, the temperature was reduced to 65°C to proceed with the extraction by evaporation and condensation, ensuring the preservation of the active compounds. Each extraction process took three hours, after which the essential oil was collected by draining the water from the calibrated tube using the discharge valve until the oil level reached the valve. The oil was then stored in dark, sealed glass containers and kept in a refrigerator at 3°C [16]. The extraction process was repeated several times to obtain sufficient quantities of oil. Water droplets in the oil were removed using a syringe, and anhydrous sodium sulfate was added to absorb any remaining moisture. The resulting essential oil, with a concentration of 100%, was ready for use. A stock solution of 10% (100 mg/mL) was prepared by diluting 10 mL of the oil with 100 mL of distilled water. Concentrations of 1%, 0.75%, 0.50%, and 0.25% were prepared, while distilled water was used as the control treatment [5].

Effect of Different Concentrations of Fennel Seed Oil Extract on the Second and Fourth Instar Larvae of *Ephestia cautella* (Date Moth):

Ten second- and fourth-instar larvae were placed separately in plastic petri dishes (1.6 × 9 cm) containing a small amount of artificial food. Three replicates were used for each concentration. Each dish was sprayed with 3 mL of the extract and left to dry for two minutes. Distilled water was used as the control treatment with three replicates. The replicates were then transferred to an incubator at 25 ± 2°C, and the number of dead larvae was recorded after 24 and 72 hours of exposure [4].

3. Statistical Analysis:

The Complete Randomized Design (C.R.D.) was employed for designing factorial laboratory experiments, while the Randomized Complete Block Design (R.C.B.D.) was used for field experiments. The Least Significant Difference (L.S.D.) test was applied to determine the significance of differences between various treatments at a probability level of 0.05 [17].

4. Results and Discussion:

Effectiveness of Aqueous and Oil Extracts of Fennel Seeds (*Foeniculum vulgare*) on the Larval Stages of *Ephestia cautella* (Date Moth):

The results presented in Table 1 demonstrate that the oil extract of fennel seeds exhibited superior efficacy compared to the aqueous extracts (hot and cold) of fennel seeds. The highest larval mortality rate for the second instar was observed with the oil extract at 66.70%, followed by the hot aqueous extract at 40.00% and the cold

aqueous extract at 53.30%, all at a 1% concentration after 72 hours of treatment. The lowest mortality rate at a 0.25% concentration was recorded at 6.70% after 72 hours.

After 24 hours of treatment, the highest mortality rates were 33.30%, 26.70%, and 26.70% for the cold, hot, and oil extracts, respectively, at a 1% concentration. The lowest mortality effect at a 0.25% concentration resulted in 0.00% mortality after 24 hours. These findings align with those of Ahmed and *et al.* [4], who reported that mortality rates increase with higher extract concentrations and longer exposure times in their study on the toxicity of seven essential oils: tea tree, cinnamon, clove, lemongrass, eucalyptus, thyme, and jojoba oils, against the rice weevil (*Sitophilus oryzae* L.) and the cowpea beetle (*Callosobruchus maculatus* L.). Their research similarly indicated that mortality rates rise with increasing concentration and exposure duration.

Table 1: Evaluation of the effectiveness of cold aqueous extracts of *Foeniculum vulgare* seeds on larval mortality rates in the second instar after 24 and 72 hours of treatment.

Factors	24 Hours	72 Hours	Average Concentration
Extracts / Concentrations			
Cold Extract	0.25	0.00	13.30
	0.50	3.30	10.00
	0.75	16.70	36.70
	1.00	33.30	53.30
Hot Water Extract	0.25	3.30	6.70
	0.50	6.70	10.00
	0.75	13.30	26.70
	1.00	26.70	40.00
Oil Extract	0.25	10.00	13.30
	0.50	10.00	16.70
	0.75	26.70	43.30
	1.00	26.70	66.70
L.S.D.	Concentrations = 4.26	Time Intervals = 2.69	Interaction = 6.02

The results presented in Table 2 indicate that the highest mortality rate for the fourth instar larvae was 43.30%, 33.30%, and 40.00% for the cold aqueous, hot aqueous, and oil extracts, respectively, at a 1% concentration after 72 hours of treatment. The lowest mortality rate at a 0.25% concentration was 6.70% at the same time interval.

After 24 hours of treatment, the highest mortality rates were 16.70%, 20.00%, and 23.30% for the cold aqueous, hot aqueous, and oil extracts, respectively, at a 1% concentration. The lowest effect at a 0.25% concentration resulted in a mortality rate of 3.30% after 24 hours.

These findings are similar to those reported by Ahmed *et al.* [4], where the mortality rates increased with higher extract concentrations in a study on the toxicity of seven essential oils: tea tree, cinnamon, clove, lemongrass, eucalyptus, thyme, and jojoba oils, against the rice weevil (*S. oryzae* L.) and the cowpea beetle (*C. maculatus* L.). Their research concluded that mortality rates increase with higher concentrations and longer exposure durations [18].

Table 2: Effectiveness of cold aqueous extracts of *Foeniculum vulgare* seeds on larval mortalityrates in the fourth instar after 24 and 72 hours of treatment.

Factors	24 Hours	72 Hours	Average Concentration
Extracts / Concentrations			
Cold Extract	0.25	3.30	6.70
	0.50	6.70	10.00
	0.75	10.00	23.30
	1.00	16.70	43.30
Hot Water Extract	0.25	6.70	6.70
	0.50	13.30	13.30
	0.75	13.30	26.70
	1.00	20.00	40.00
Oil Extract	0.25	6.70	13.30
	0.50	13.30	16.70
	0.75	13.30	23.30
	1.00	23.30	33.30
L.S.D	Concentrations = 3.43	Time Intervals = 2.17	Interaction = 4.86

Conclusions:

1. The oil extract of *Foeniculum vulgare* seeds (sweet fennel) showed superior effectiveness in increasing the mortality rate of the second and fourth larval stages of the fig moth, *Ephestia cautella*.
2. The study demonstrated that all aqueous and oil extracts of fennel seeds have an impact on the second and fourth larval stages of *E. cautella*.
3. The mortality rate of *E. cautella* larvae increases with higher concentrations of both the aqueous and oil extracts and with longer exposure times.

Recommendations

- Investigate the effects of alcoholic extracts on the various larval stages of the date moth (*E. cautella*).
- Study the impact of oil extracts on the adult stage of the date moth.

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