



Research article

Use Some of The Physicochemical Methods in Protecting Beeswax combs from The Greater Wax moth.

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ABSTRACT

The study aimed to identify physicochemical methods to protect beeswax from damage by the greater wax moth, ensuring the sustainable safety of honey bee products in Basrah Governorate. Results showed that low temperatures increased moth mortality proportionally with exposure time with lower temperatures. The highest mortality, at -18 °C and exposure times of 3 and 6 hours, was significantly higher ($P \leq 0.01$) than other treatments. Smoking with carbon dioxide also increased mortality with higher rates and longer exposure, with the highest mortality at a 98% smoking rate and 3, 6-hour exposure, again with significant differences. Fumigation using Phostoxin tablets showed mortality rising with both the number of tablets and duration, peaking at 1.5 tablets and 3 and 6-hour exposure, with significant differences. Dipping wax moths in sodium chloride solution revealed mortality increasing with salt concentration, dipping time, reaching 100% mortality at 25% salt concentration over 2, 3, 6 hours. Mortality at 25% salt with significantly different at 3 and 6 hours. Dipping wax moths in sodium chloride solution with electric shock, reaching 100% mortality at 5% salt concentration and electric shock over 5, 10, and 30 minutes. without significantly different. Biological treatments with oxalic acid at 75% and 50% concentrations for 24 and 48 hours, and with 75% acetic acid for 24 and 48 hours, achieved 100% mortality, all with significant differences. In the biological repellent and attractant tests, oxalic and acetic acids showed 100% repellency, while castor oil attracted moth larvae at 80.67%, with significant differences from other treatments.

1. Introduction

Beeswax is the basic material for building wax combs in honeybee colonies. Beeswax is produced from special glands in worker bees called wax glands. These glands complete their development in workers between 12 - 18 days old, and their activity decreases as the bees get older. The largest quantities of wax are produced during the growth stage of bee colonies in the spring, under moderate climatic conditions. However, the wax synthesis process can be reactivated in emergencies when needed (1). Among its many uses, beeswax is commonly used in the food manufacturing sector as a food additive

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and to extend the shelf life of food products. It is also widely used in the pharmaceutical, nutritional supplement, therapeutic, chemical, and cosmetic industries, among others, and is registered in the European Union under code E901 (2,3). Wax combs are damaged by feeding on them by the greater wax moth, *Galleria mellonella* L. They also build tunnels and spin their threads on wax combs (4), and the solid mass of silken webbing may fill the preserved honeycomb, leading to its destruction. Wax combs can become useless in about a week as the wax moth grows under ideal conditions (5). The wax moth continues to reproduce throughout the year in warm countries, as it is a serious pest to beehives, and its danger is greater to wax combs in weak cells in the apiary and in poorly maintained warehouses. Infection with it also leads to the appearance of deformed bees, as it destroys both the wax combs and the brood (6,7). Severe infection with the wax moth leads to the migration of bees or the loss of small colonies, while the level of the strongest bee colonies drops rapidly, which leads to their destruction later (8). European honeybee colonies (*Apis mellifera* L.) are exposed globally to many pests and diseases that cause serious economic damage to both bees and plants, as they have greatly reducing the number of colonies for beekeepers, in addition to the loss of bee products (9,10). Currently, wax moth infestation of bee colonies has become a serious phenomenon in many parts of the world and has proven to be more important than other bee diseases (11). Beekeepers all over the world have developed strict colony management procedures for wax moth control, to reduce its damage by following various pest control practices promptly, as the extent of this pest's damage is enormous worldwide, causing significant loss of wax combs, damage to the contents of beehives, and spoilage of their products (12,13). Various chemical and non-chemical methods have been used to control wax moths on stored combs. Freezing, heating, and fumigation using carbon monoxide are examples of non-chemical control methods for protecting stored items. Acetic acid, Ethylene cyanide, Ethylene dibromide, Methyl bromide, and Fostoxin have all been used chemically to control wax moths and have been successfully used as fumigants in warehouses (14). The excessive and continuous use of pesticides in insect pest control has led to various negative environmental consequences, including the extinction of some beneficial species such as parasites and pest predators, damage to honeybees, contamination of bee colonies, and residual toxicity in bee products (15). Unlike chemicals, the use of natural products such as biocides is an excellent alternative to reduce harmful environmental and health impacts, as they are less polluting and less toxic to non-target organisms, in addition to being cheaper due to their easy availability locally, their effectiveness even in small quantities, and their ease of biological decomposition (16). Therefore, essential oils have been used in the past and present as insecticides or regulators of insect behavior, reproduction, and growth (17). The study aimed to find alternatives from suitable natural sources for preserving beeswax and combating wax moths that are environmentally friendly and safer for bees and their products, and thus for humans.

2. Materials and Methods

The experiment was conducted under laboratory conditions, and the experimental work commenced on March, 2026. The study included the collection and rearing of the greater wax moth, preparation of bio-extracts, and evaluation of different methods for preserving wax combs and controlling the greater wax moth, as described below.

1- Collection of wax combs and rearing of the greater wax moth, *Galleria mellonella* L.

Healthy and infested wax combs containing the greater wax moth, *Galleria mellonella* L., were obtained from local apiaries in Basrah Governorate. The collected larvae and pupae were transferred to the laboratory and reared under controlled conditions. For egg collection, adult moths were provided with pieces of cardboard as an oviposition substrate. The eggs deposited on the cardboard

pieces were collected and transferred to wax combs as a natural diet for subsequent development. The wooden rearing boxes used for rearing *Galleria mellonella* L. were clean and previously unused. Before the beginning of the experiment, the boxes were thoroughly cleaned and disinfected with 70% ethanol and left to dry completely under laboratory conditions. The beeswax combs used as the natural diet were inspected carefully to ensure that they were free from other insect stages and visible contaminants. The wax combs were then disinfected by freezing at -18°C for 48 h to eliminate any pre-existing eggs, larvae, or pupae of *G. mellonella*. After treatment, the combs were allowed to return to room temperature before being introduced into the rearing boxes. The insects were reared in an insect incubator at $30 \pm 2^{\circ}\text{C}$ and 65% relative humidity. The fifth larval instar was identified based on the width of the head capsule. The head capsule width was measured using a calibrated ocular micrometer under a stereomicroscope, and larvae corresponding to the fifth instar were selected for use in the subsequent experiments. The pupae used in the experiments were newly formed pupae, and their age was standardized by selecting pupae within 24 hours after pupation.

2- Preparation of bio-extracts

The seeds of *Peganum harmala* and castor (*Ricinus communis* L.), as well as the pesticides, propolis, oxalic acid, acetic acid, and other materials used in the experiments, were obtained from local markets and agricultural supply stores in Basrah Governorate, Iraq. The plant materials were purchased as commercially available seeds. To obtain the oil extracts, the seeds were initially ground. To obtain oil extracts from the seeds of *Peganum harmala* and *Ricinus communis* L., the seeds were initially collected and ground using an electric laboratory grinder until a fine and homogeneous powder was obtained. The grinding process was performed intermittently to avoid excessive heating of the plant material and continued until the desired particle size was achieved. A 50-g sample of the finely ground seeds was weighed and placed in a Soxhlet extraction apparatus. Hexane was used as the extraction solvent, and the extraction process was continued for 4 h. The solvent was repeatedly circulated through the plant material to extract the oil (18). Hexane was used as the extraction solvent, which repeatedly passed through the plant material to extract the desired compounds. After 4 h of extraction, the resulting extracts were collected in a flask.

Ethanol was used to extract the active compounds from propolis. The propolis was mixed with ethanol and placed in the extraction apparatus for 4 h. The extract was then separated from the precipitated material by centrifugation. Oxalic acid and acetic acid were diluted with distilled water. Three concentrations (25%, 50%, and 75%) were prepared for each of the above-mentioned preparations.

3- Using low temperatures to preserve wax and control the greater wax moth:

Three low temperatures were tested using a refrigerator at 4°C and freezers at -7°C and -18°C . The treatments were conducted under static conditions inside the refrigeration and freezing units, without forced air circulation or an external airflow system. Fifth-instar larvae and pupae were exposed to each temperature treatment, with 10 insects per replicate and three replicates. In addition to the control treatment, which was maintained under laboratory conditions at approximately 24°C , the average number of live larvae and pupae was recorded after 2, 3, and 6 h. The pupae were subsequently allowed to complete their life cycle, and the average number of adults emerging from the pupae was recorded.

4- Using CO₂ fumigation to preserve wax and control the greater wax moth:

Wax combs were placed in tightly sealed wooden beehives (swarming boxes) at a rate of 5 frames, arranged randomly inside the box. The boxes were then covered with a lid lined with plastic film to seal any gaps, leaving a small opening at the top. Fifth instar larvae and pupae were exposed to CO₂ fumigation produced from burning cardboard paper passed from the bottom of the box until it came out of the top opening of the box for 2, 4, and 6 hours, with three replicates for each. In addition to the control treatment, the average number of live insects, larvae, and pupae was recorded after 2, 3, and 6 hours. As for the pupal stage insects, they were left to complete their life cycle, and the average number of insects emerging from them was recorded.

5- Using fumigation with Phostoxin gas to preserve wax and control the greater wax moth:

Wax combs were placed in airtight swarming boxes at a rate of 5 combs, arranged randomly inside the box. The boxes were covered with a lid on the top and bottom, lined with plastic film to seal the openings without any gaps. The fifth instar larvae and pupae were exposed to fumigation with Phostoxin tablets by placing 0.5, 1, and 1.5 tablets of it at the bottom of the box and closing it tightly for 2, 3, and 6 hours, with three replications for each. In addition to the control treatment, the combs were placed without treatment and the average number of live insects, larvae and pupae, was recorded ⁽¹⁹⁾. For pupal stage insects, they were left to complete their life cycle, and the average number of insects emerging from them was recorded.

6- Treating wax with a sodium chloride solution controlling the greater wax moth:

The wax combs were placed in a cylindrical plastic container 50 cm in diameter and 70 cm high. A total of 2.0 L of sodium chloride solution was prepared and added to the container to ensure complete immersion of the wax combs. Five wax combs were placed inside the container and arranged vertically. The wax combs were immersed from top to bottom in sodium chloride solutions at concentrations of 5%, 10%, and 25%. Fifth-instar larvae and pupae were exposed to the respective salt solutions for 2, 3, and 6 h, with three replicates for each treatment. For the pupal stage, the insects were allowed to complete their life cycle, and the average number of emerging adults was recorded..

7-Treating wax with a sodium chloride solution and electric shock controlling the greater wax moth:

The electric shock was also used with a 5% saline solution by passing an electric current from a 110V transformer through the electrodes for 5 minutes, applying the wax combs with 5-minute intervals between each application. It was added to the saline solution at a concentration of 5%, and the dead larvae and pupae were counted after 5, 10, 15, 20, 25 and 30 minutes, in addition to the control treatment. The average number of dead insects, larvae, and pupae was recorded after the specified time, with three replicates for each. As for the pupal stage insects, they were left to complete their life cycle, and the average number of insects emerging from them was recorded.

8-Treatment of wax with biological preparations and control of the greater wax moth:

Uninfected stored wax combs were cut into 1 x 1 cm² pieces and dipped in preparations of harmal, castor, propolis, oxalic acid, and acetic acid at concentrations of 25%, 50%, and 75%. After dipping, the combs were gently shaken to remove any excess of the suspended material, then dried at room temperature and placed in a 10 cm diameter Petri dish. Ten wax moth larvae were added to each dish using sterile forceps, and data were recorded at 1-, 24-, and 48-hours post-treatment with three replicates, while the control treatment was left untreated.

9- The mortality rate:

It was calculated for all the treatments mentioned in paragraphs 3 to 6, and then the results were corrected according to the corrected equation of ⁽²⁰⁾.

$$\text{Corrected Mortality}\% = \frac{\% \text{ treatment mortality} - \% \text{ control mortality}}{100 - \% \text{ control mortality}} \times 100$$

10- Measuring the attractant and repellent effects of biological extracts:

A chemotopometer, as mentioned by ⁽²¹⁾, was used. This involved a 100 cm long, 3 cm diameter glass tube with an opening 50 cm in the middle for introducing insects. The tube is divided into centimeters to calculate the distance the insects travel towards or away from the tested material. The ends of the tube are blocked with pieces of cotton. The tube is placed inside an opaque box 110 cm long and 8 cm in diameter. To conduct the test, a piece of cotton was treated with 1 ml of each preparation and placed on the right side of the tube, while the piece of cotton was left empty on the left side without any treatment with the preparation. Behind, 10 insects were introduced into the mid-length opening of the tube and waited for 20 minutes. The number of insects attracted or repelled in the aforementioned device was then counted. The process was repeated three times for all preparations used in the study, and the results were calculated using the following equation:

$$\text{Attraction}\% = \frac{\text{Number of larvae heading to pesticide and moving 50cm from the center}}{\text{Total Number of larvae}} \times 100$$

$$\text{Repellent}\% = \frac{\text{Number of larvae moving against the pesticide}}{\text{Total Number of larvae}} \times 100$$

11. Design and Statistical Analysis

The results were analyzed using the statistical software SPSS and a completely randomized design (CRD). The studied factors were tested using the least significant difference (LSD) test at a probability level of 0.01.

Results and Discussion

Effect of Low Temperatures on Wax Preservation and Control of the Greater Wax Moth:

The results in Table (1) show the effect of low temperatures on the fifth larval and pupa stages of the greater wax moth after exposure to temperatures of 4, -7, and -18 °C for exposure times of 2, 3, and 6 hours. The table shows that the mortality rate of larvae and pupae increased proportionally with the increase in exposure time and inversely with temperature, and that the highest average number of dead larvae and pupae was at a temperature of -18 °C and exposure times of 3 and 6 hours, with a significant difference from the other treatments ($P \leq 0.01$). The mortality rate for both larvae and pupae was 100% at a 6-hour exposure time, followed by 91.35% and 87.77% for larvae and pupae, respectively, at a 3-hour exposure time. The lowest mortality rate was observed with the 4 °C temperature treatment during the first two hours of the treatment, reaching 22.65% and 18.77% for

larvae and pupae, respectively, without a significant difference compared to the other treatments at the same 4 °C temperature.

Table (1) Mortality of larvae and pupae treated at low temperatures

temperature	larval mortality%			Pupae's mortality%		
	After	After	After	After	After	After
	2 hours	3 hours	6 hours	2 hours	3 hours	6 hours
4 C°	22.65	29.44	32.46	18.77	26.68	30.01
-7 C°	38.41	43.22	71.12	35.22	38.70	44.81
-18 C°	59.79	91.35	100	55.07	87.77	100

LSD temperature =16.21 LSD time = 13.34 LSD temperature * time =21.46

Larval growth usually lasts 6 to 7 weeks at a temperature between 29-32°C and high humidity, as the larval stage of the large wax moth goes through 8-9 molts during its growth at a temperature of 33.8°C⁽²²⁾. The wax moth is active during the warm, sunny months of the year, and it is at this time that damage often occurs. However, it is possible that significant damage can occur during the mild period of late autumn and early spring. The combs do not appear to contain wax moth eggs at the time of storage that eventually hatch, unless they are treated before storage, so they should be checked regularly for any signs of moth infestation⁽²³⁾.

Fumigation with carbon dioxide gas in wax preservation and control of the greater wax moth:

Table (2) shows the results of the fumigation effect with carbon dioxide gas on the fifth larval and pupa stages of the greater wax moth and the control treatment after exposure to fumigation at 35%, 70%, and 98%, and exposure times of 2, 3, and 6 hours. It is evident that the mortality rate of larvae and pupae increased proportionally with the increase in the smoking rate and exposure time, and that the highest average number of dead larvae and pupae was at a smoking rate of 98% and exposure times of 3 and 6 hours, with a significant difference from the other treatments ($P \leq 0.01$). The mortality rate for both larvae and pupae reached 100% at an exposure time of 6 hours. This was followed by a 3-hour exposure period with mortality rates of 97.31% and 90.89% for larvae and pupae, respectively. The lowest mortality rate was observed at a 30% smoking concentration two hours after treatment, reaching 19.21% and 15.98% for larvae and pupae, respectively, with no significant difference compared to the other treatments at the same smoking concentration.

Table (2) Mortality of larva and pupae smoking with Co2

Smoking	larval mortality%			Pupae's mortality%		
	After	After	After	After	After	After
	2 hours	3 hours	6 hours	2 hours	3 hours	6 hours

35%	19.21	30.36	46.78	15.98	22.54	38.40
70%	49.22	55.89	88.42	45.22	75.99	81.81
98%	76.34	97.31	100	68.18	90.89	100
LSD smoking% =11.44 LSD time = 15.12 LSD smoking% * time =33.55						

⁽²⁴⁾ recommended, through a study of fumigating colonies with tobacco leaf smoke to reduce wax moth infestation in Ethiopia, taking care not to smoke for more than two to three minutes and with a maximum of 5-10 puffs of smoke, with the necessity of using supplemental feeding to ensure an increase in the number of bees and the formation of strong colonies capable of protecting themselves from wax moths. Taking into account good colony management, reducing unoccupied combs, top combs, and infected combs to match the number of bees with the occupied combs, especially during periods of scarcity, working to clean the hive and its surroundings regularly, using appropriate heat treatments, and regularly replacing old combs to maintain healthy and strong colonies.

Effect of fumigation with Phostoxin tablets on wax preservation and control of the greater wax moth:

Table (3) shows the effect of fumigation with Phostoxin tablets on the fifth larval and pupa stages of the greater wax moth, as well as the control treatment, after exposure to fumigation with amounts of 0.5, 1.0, and 1.5 tablets and exposure times of 2, 3, and 6 hours. It appears that the mortality rate of larvae and pupae increased proportionally with the increase in the amount of toxic substance and the duration of fumigation exposure. The highest average number of dead larvae and pupae was observed at a concentration of 1.5 tablets and fumigation durations of 3 and 6 hours, with a significant difference from the rest of the other treatments ($P \leq 0.01$). The mortality rate for both larvae and pupae reached 100% at a fumigation duration of 6 hours. This was followed by 95.77% and 93.63% for larvae and pupae, respectively, after a fumigation period of 3 hours. The lowest mortality rate was observed at a dose of 0.5 tablets two hours after treatment, reaching 10.35% and 7.56% for larvae and pupae, respectively, without a significant difference compared to the other treatments at the same fumigation dose.

Table (3) Mortality of larva and pupae Fumigation with Phostoxin

Fumigation	larval mortality%			Pupae's mortality%		
	After	After	After	After	After	After
	2 hours	3 hours	6 hours	2 hours	3 hours	6 hours
0.5 tablet	10.35	14.23	18.55	7.56	11.34	16.61
1.0 tablet	55.17	63.21	96.11	49.90	52.17	91.81
1.5 tablet	79.69	95.77	100	71.57	93.63	100

LSD fumigation =12.36 LSD time = 9.18 LSD Fumigation * time =26.21

Chemical fumigation has been traditionally used to control wax moths in large warehouses. However, the availability and suitability of chemical fumigants are constantly changing. Among the most important of these substances are Aluminum phosphide, Magnesium phosphide, Phosphine gas, and Methyl bromide. There is a constant possibility that these chemicals will contaminate wax and honey. These products may require special training or a license for their use, and companies producing these materials must provide complete information about their use in beekeeping ⁽²⁵⁾. Fumigators and other synthetic insecticides are currently the main tools used to control the large wax moth. Consequently, the widespread use of these substances has led to serious problems, including increased insecticide resistance, environmental harm, and adverse effects on human health ⁽²⁶⁾.

Effect of sodium chloride salt dipping on wax preservation and control of the greater wax moth:

The results shown in Table (4) demonstrate the effect of sodium chloride salt dipping on the fifth larval and pupa stages of the greater wax moth at salt concentrations of 5%, 10%, and 25%. The mortality rate of larvae and pupae increased proportionally with increasing salt concentration and dipping duration, with a significant difference with the treatment of 25%, 10%, and 5%, at dipping periods of 3 and 6 hours. The lowest mortality rate was at a salt concentration of 5%, reaching 79.89% and 77.22% after two hours of dipping for both larvae and pupae, respectively, with a significant difference compared to the other treatments at the same salt concentration and the other concentrations.

Table (4) Mortality of larva and pupae Salting with NaCl and Electric shock

Concentration	larval mortality%			Pupae's mortality%		
	After	After	After	After	After	After
	2 hours	3 hours	6 hours	2 hours	3 hours	6 hours
5 %	79.89	95.42	100	76.22	93.98	100
10%	97.44	100	100	96.23	100	100
25%	100	100	100	100	100	100

LSD Concentration = 6.91 LSD time = 7.12 LSD Concentration * time =19.88

Effect of sodium chloride salt dipping and electric shock on wax preservation and control of the greater wax moth:

The results shown in Figure (1) the effect of sodium chloride salt dipping with electric shock on the mortality rate of larvae and pupae. The highest mortality rate of larvae and pupae was 100% at a salt concentration of 5% with electric shock, after 30 minutes without a significant difference.

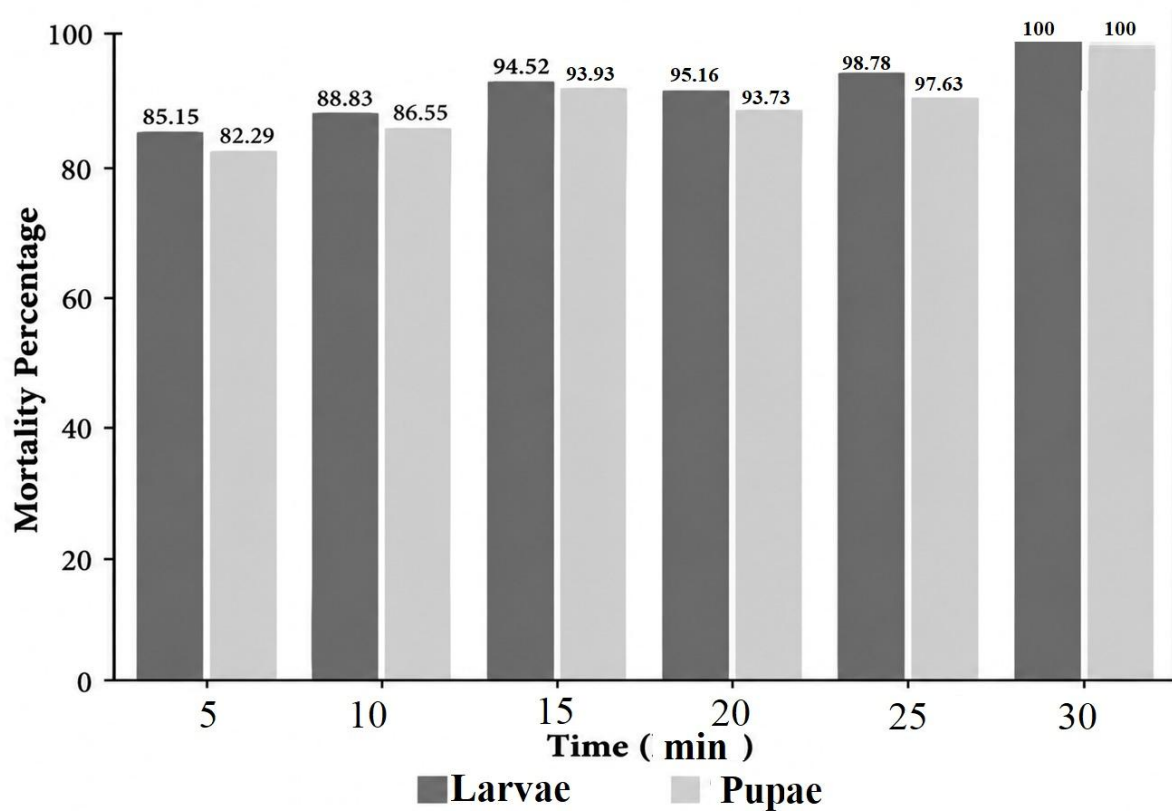


Figure (1) Effect of sodium chloride salt with electric shock on wax preservation and control of the greater wax moth:

Various methods have been used, all of which have succeeded in controlling the wax moth and reducing its activity. The most important of these are: freezing, fumigation, and the use of ozone gas, and other methods that all participate in breaking and changing the ideal conditions in which the pest thrives (27,28,29).

Effect of biological preparations on wax preservation and control of the greater wax moth:

The results in Table (5) show the effect of biological preparations of harmal oil, castor oil, propolis extract, and oxalic and acetic acids in killing the fifth larval and pupa stages of the greater wax moth, as well as the control treatment, with exposure times of 1, 24, and 48 hours. The table shows that the highest average number of dead larvae and pupae was 100% with oxalic acid at concentrations of 75% and 50% and exposure times of 24 and 48 hours, as well as with acetic acid at a concentration of 75% and exposure times of 48 hours, with a significant difference from the other treatments ($P \leq 0.01$). The lowest mortality rate of larval and pupal was at a concentration of 25% in all treatments and a concentration of 50% for both harmal oil, castor oil, and propolis extract, which reached 0% for all exposure time periods, and with a significant difference from the other treatments. The effect of the plant extract on the mortality rate of wax moth larvae increases with increasing concentration of the extract, and the reason is likely due to its neurotoxic mechanism of action, as it interferes with the

activities of the enzymes acetylcholinesterase and octopamine ⁽³⁰⁾. This killing effect may be due to the various secondary chemical components produced by the plants, which can be absorbed through the skin, inhaled, or ingested by insects ⁽³¹⁾. Moreover, ⁽³²⁾ found a decrease in the number of emerging adults two months after treating the southern cowpea beetle with extracts of neem leaf, almond oil, coconut oil, and oil, finding that coconut oil was the most effective of them in controlling this insect.

Table (5) Mortality of Wax moth Larvae Treated with Biological Preparations

Preparations	Concentration	Time		
		After 1 hour	After 24 hours	After 48 hours
Harmal oil	25%	0	0	0
	50%	0	0	0
	75%	21.71	21.71	21.71
Castor oil	25%	0	0	0
	50%	0	0	0
	75%	0	20.18	20.18
Propolis	25%	0	0	0
	50%	0	0	0
	75%	0	18.36	33.17
Oxalic acid	25%	0	0	0
	50%	0	100	100
	75%	80.70	100	100
Acetic acid	25%	0	0	0
	50%	10.33	20.72	100
	75%	20.51	30.35	100
LSD Concentration =22.08 LSD time = 19.50 LSD Concentration * time =27.88				

The use of the plant extract from mint has led to effective results, as it has an important role as an insect growth regulator, and has a significant effect on egg hatching, growth period, development, maturity, and fertility ⁽³³⁾. The results obtained by ⁽³⁴⁾ showed that when using peppermint oil and thyme oil, all treatments demonstrated the ability to affect egg hatching, and the larval mortality rate

increased with increasing treatment concentrations. Basil oil (4%) showed the highest mortality rate for third-instar larvae (76.67%) and seventh-instar larvae (56.67%), respectively. All treatments resulted in a reduction in larval lifespan, while pupation and emergence times were delayed compared to the control group. This study demonstrated the potential of plant-based pesticides in controlling wax moth infestations, offering a more environmentally friendly alternative to synthetic pesticides.

Study of the repellent and attracting effect of biological preparations on the larvae of the greater wax moth:

The results in Table (6) show that oxalic and acetic acids showed the highest percentage of repelling wax moth larvae, reaching 100% for each, followed by harmal oil and propolis extract at 82.27% and 75.51%, respectively. The highest percentage of attraction was recorded with castor oil, reaching 80.67%, with a significant difference from the other treatments.

Table (6) Attraction and Repulsion for Wax moth larvae against Biological Preparations

Preparation	Attraction	Repellent
Harmal oil	17.73%	82.27%
Castor oil	80.67 %	19.33%
Propolis	24.49 %	75.51%
Oxalic acid	0.0 %	100 %
Acetic acid	0.0 %	100 %
LSD = 26.11		

The property of attraction to substances by insects is used to attract and trap them in the place where the toxic substance is present, to kill and get rid of them, while the property of repulsion is useful in keeping insects away from places and materials that are to be protected from infection ⁽³⁵⁾. Some commercial preparations made from Matriline affect the nervous system of insects, and they have a repellent and antifeeding effect, resulting in the inhibition of all vital activities and consequently the weakening and death of the insect ⁽³⁶⁾. In this area, thyme oil was used with the larvae of the greater wax moth for its feeding-preventing and insect-growth-inhibiting properties ^(37,38). The most accepted explanation for the non-lethal effects of plant products is that their secondary metabolites can act as insect repellents and may disrupt insect growth, possibly causing deformities in parental generations and their transmission to offspring ^(39,40).

Recommendation

Preventing wax moth infestation requires continuous follow-up and monitoring of the early stages of infestation to allow for preventive measures to be taken in advance before any damage occurs, including ensuring the strength of the colonies and providing sufficient food supplies, narrowing the entrance to the hive and closing cracks in the walls, and removing excess wax residue accumulated on the lower panels of the beehives. Besides, to treat the infestation, future research could explore

the development of insecticides of plant origin designed to control wax moths without affecting the lives of bees in colonies, and ensure their compatibility with integrated pest management strategies to achieve sustainable beekeeping.

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