ARTICLE / INVESTIGACIÓN

Study the effect of essential oils of some plants in protection from Cowpea beetle, *Callosobruchus maculatus* in laboratory

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Abstract: The experiments were conducted in laboratory conditions of a temperature of 25± 2C and relative moisture of 40± 5 % to evaluate the effectiveness of the cinnamon, lavender and clove essential oils on some biological life aspects of cowpea beetle, *C. maculates*. Results of the obligative experiment for the effect of the oils on insect adult killing showed that the concentration of 5% caused a mortality percentage averaged 13.33% of the insect males. The mortality percentage of the insect females was 11.3% for the cinnamon and lavender oils. The lavender oil had the lowest effect on adult killing, not exceeding 0. For the effect of the oils on egg laying, clove oil affected the number of eggs highly at the concentration of 5%, resulting in 2.00 eggs on average. The lowest oil effect on egg number was for the lavender oil at the concentration of 1%, leading to an average of 14.73 eggs. The clove oil at the concentration of 5% showed effectiveness in adult emergence prevention as it was not observed that any insect emerged. In contrast, the same oil at the concentration of 1% had less effect, resulting in the highest emergence percentage reaching 13.33%. The same applies to the effect of the plant oils on insect productivity as the clove oil at the concentration of 5% was the most effective; no insect productivity was recorded, unlike the concentration of 1%, recorded productivity of 110.2 %. In the facultative experiment, the highest mortality percentage was recorded using clove oil against females, as the mortality percentage reached 4.00%. In contrast, the lowest mortality percentage was recorded using lavender oil against males, where no killing occurred, as the mortality percentage did not exceed 0.00%. For the effect of the oils on egg laying, the highest affected oil was cinnamon at a concentration of 5% as the number of eggs reached 5.60, while lavender oil at 3% was the least effective; the average number of eggs was 25. Clove oil at a concentration of 5% had the highest effect in reducing the emergence of the insect, so the emergence percentage did not exceed 0.33%. In comparison, its influence was low at 1%, recording the highest emergence percentage (18.67%). The lowest recorded insect productivity average was from the treatment of the clove oil at a concentration of 5%, which did not exceed 5.20%, while the highest productivity average was from the treatment of the lavender oil at 1%, which reached 89.6%.

Key words: Essential oils, Cowpea beetle, *Callosobruchus maculatus*.

Introduction

Cowpea (*Vigna unguiculata*) is one of the essential crops to human nutrition for their grains containing a high percentage of protein similar to that found in other legumes enriched with the amino acids lysine and tryptophan. Cowpea seeds can be eaten directly; they are also used for making flour and nourishing kids. Cowpea contributes to healing malnutrition and the body's weak structure. It also has preventive and curative effects on the diseases of atherosclerosis, arteries and heart muscles, and cancer, as well as the possibility of using it as animal forage[1,2]. The prevalence of cowpea cultivation is the booming growth in different environmental conditions, including high temperatures and poor soils with low rain[3].

The cowpea beetle (*Callosobruchus maculatus* Bruchidae: Coleoptera) is one of the essential pests on stored legumes in the warm and tropical areas of the world[4]. The utilization of cowpea seeds decreases due to the destruction caused by the cowpea beetle infection that decreases the nutrient security of the farmers dependent on this crop because the utilization of cowpea seeds decreases due to their destruction caused by the cowpea beetle infection that reduces the nutrient security of the farmers dependent on this crop because of their weak living levels[5]. Once the insect affects the cowpea crop, it gradually causes multiple damages, leading to a loss in the weight, nutrient value, and quality of the stored seeds[6].

Controlling the stored-grain insects depends mainly upon the manufactured insecticides and broad-range fumigants that are highly expensive and cause food contamination resulting from toxic residues. Moreover, many resistance cases of insecticides used for controlling have been recorded. Thus, controlling the stored insects this way becomes unsuitable and encourages researchers to rely on safer methods for humans with less cost[7], such as plant-origin insecticides, including plant oils, for they are safe and have no side effects. They contain secondary compounds having different biological effects that are toxic, anti-nutritional, repellent or anti-growth[8].

Plant essential plant oils can be used as insecticides in many forms, involving fumigants, contact insecticides, systemic insecticides, or repellents to control stored grain insects[9]. Numerous studies have been conducted on the

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effect of cinnamon, clove and lavender plants in controlling many insect kinds. Cinnamon powder effectively protected wheat grains against the maize weevil (*Sitophilus zeamais*). And it was effective at the concentration of 10 mg/ml against the same insect[10]. Cinnamon oil was also used to control types of mites[11] and showed effectiveness against the red flour beetle (*Tribolium castaneum*)[12]. (13) referred that the lavender oil diluted to 30% in 1, 2- Propanediol repelled the tick nymphs (*Ixodes ricinus*) by 100%. Karamaouna[14] reported that the LD50 of the lavender essential oil was 19.8 mg against the nymphs and adults of grape mealybug (*Planococcus ficus*). Attia, S[15] mentioned that the lavender oil concentration of 25µl/l air killed the adults of the pea aphid (*Acyrthosiphon pisum*) by 100% three days after the treatment. Germinara[16] concluded that direct subjecting the adults of the grain weevil (*Acyrthosiphon pisum*) to the concentration of 449.05 µ/ adult insect of lavender essential oil for 24 and 48 hours killed 91.7 and 100% with LD50 values of 83.8 and 58.3 µl/l respectively while according to the fumigation method, the mortality percentage was 100% at the concentration of 42.52% where the LD50 values were 1.57 mg/l and 10.89mg/l for the absence and presence of wheat grains, respectively. The repellence percentage at the 1.76 mg/cm^2 concentration was 100 % after 120 minutes of treatment. Paranhos[17] reported that the clove essential oil killed a high percentage of the beetle (*Zabrotes subfasciatus*) and remarkably decreased the eggs laid by the adults. Nerio[18] referred to the active effectiveness of using clove oil as an insecticide in contact, repellent or fuming; he reported that it can be an alternative to conventional insecticide in reducing the high densities of legume weevil and corn weevil. Zeng[19] revealed that the repellent effect of clove oil at the concentration of 0.2% against the lesser grain borer (*Rhyzopertha dominica*) reached 68.2%.

In comparison, the lethal percentage reached 80% and 51% for the lesser grain borer and rice weevil, respectively. Jairoce[20] noticed that the two concentrations, 17.9 and 36 µl/g of the clove essential oil, killed 100% of the bean weevil (*Acanthoscelides obtectus*) and maize weevil (*S. oryzae*) after 24 hours of treatment, where its LC50 was 9.45 and 10.15 µl/g respectively, concluding that the clove essential oil is a suitable alternative for controlling the store insects. Oliveira[21] reported that the LC50 of the 0.5% clove oil reached 0.88 and 0.73 µl/l air; it also reduced egg laying and adult emergence by 47.16% and 76.86%, respectively, while the repellence percentage reached 45%.

This study aimed to investigate the efficiency of the cinnamon, clove and lavender plant oils in protecting the cowpea seeds against the infestation by the cowpea beetle.

Materials and methods

Rearing cowpea beetle (*C. maculates*)

The insect was reared on red cowpea seeds inside a plastic container with 10 cm diameter and 13 cm height at 25± 2C. The container was covered with gauze fixed with an elastic band. Healthy ones continually replaced the seeds unsuitable for insect feeding, perpetuating the colony.

Essential oil extraction from each cinnamon, lavender and clove

The essential oils were extracted with a Cleavinger device relying on the steam distillation method at the Medicinal Plants Unit of the College of Agricultural Engineering Sciences / University of Baghdad. For preparing the required concentrations, 2 ml of dimethyl sulfoxide solution was added to every 100 ml of oil, then the concentrations (1, 3, and 5%) were prepared.

Effect of the essential oils of cinnamon, clove and lavender on the life of *C. maculatus*

The cowpea grains infested by *C. maculatus* were isolated inside special containers and kept until new adults' emergence. An amount of 50g of the healthy cowpea seeds suitable for cultivation was placed in Petri dishes and sprayed with the oil concentrations, where each was replaced three times. The treated seeds were placed in a plastic container; next, ten individuals (5 males and 5 females) of the recent emerging adults of the insect were released to the container covered with a piece of gauze tightly fixed with an elastic band. The control treatment was sprayed with just water plus dimethyl sulfoxide solution, which was also applied to the three replicates. The treated seeds were kept under the laboratory temperature. Then, data were recorded every 24 hours for five successive days as the number of dead male and female insects was counted.

Effect of the essential oils of cinnamon, clove and lavender on egg laying by *C. maculatus*

The effect of each oil on the percentage of egg laying was tested by choosing 10 seeds randomly from each replicate and counting the number of eggs laid by the insects on the treated seeds (item 1.3).

Effect of the oils on the number of the emerged adults

In item 1.3 above, the treated seeds with the insect eggs were left until the eggs hatched and the insect reached adulthood. The number of emerged adults was calculated based on the number of holes on the 10 randomly chosen eggs, as each hole represents one adult.

Effect of the oils on the productivity percentage of *C. maculatus*

Having the number of eggs and the number of adults were counted, the percentage of the insect productivity was calculated according to the formula:

Insect productivity = number of emerged insects \ number of egg x 100

Effect of the essential oil of cinnamon, lavender and clove on the life of *C. maculatus*

The method reported by (22) was adopted with some modifications to test the effect of oils on insect adult killing. It is based on joining three hollow transparent plastic arms to a central large plastic bowl. There is a small bowl attached to each arm. An amount of 50g of the healthy cowpea seeds is taken and treated with 1% of the cinnamon oil placed in one of the arms of the chemotropism device. The seeds in the second arm are treated with a concentration of 3%, and in the third arm are treated with a concentration of 5%. This procedure applies to the three replicates and lavender and clove oils. The containers are tightly covered with gauze pieces and tied with elastic bands. Then, 25 pairs of recently emerged adults (25 males and 25 females) of the insect are released in the central container tightly covered with gauze and tied with an elastic band. The device is kept at laboratory temperature for recording data every 24 hours for 5 days. The dead insects of males and females affected

by the different concentrations of the oils are counted in addition to counting the number of eggs laid on 10 seeds taken randomly from each replicate and the number of adults that emerged in 10 seeds taken randomly from each replicate. Finally, the insect productivity is calculated.

Statistical analysis

The laboratory experiments were conducted according to the Completely Randomized Design (R.C.D). The least significant difference (L.S.D) at the probability level of 5% was used to compare the results[23].

Results

Effect of the cinnamon, lavender and clove plant oils on adult killing of *C. maculatus*

Results of Table 1 show a significant effect of the different concentrations of the cinnamon, lavender and clove oils on killing the males and females of *C. maculatus*. They were generally observed that increasing the oil concentration increases its effect. Cinnamon oil at concentrations of 1 and 3% showed a lethal impact on the insect, illustrated by a corrected mortality percentage averaging 4.66 and 10%, respectively, for the males, with a lower effect on the females where the corrected mortality percentage was 1.33 and 6.64 %, respectively. The average corrected mortality percentage was 13.33% for males and 11.33% for females at a concentration of 5%. For the lavender and clove, the clove oil was more effective than lavender oil; however, unlike cinnamon oil, clove oil affecting the females more than the males except for the concentration of 1% as the corrected mortality percentage was 4% for males and 0 % for females, in contrary to the two concentrations of 3 and 5% where the corrected mortality percentage of the females was 8.67 and 11.33% respectively and for the males was 6.67 and 9.33 respectively. Concerning lavender oil, the highest corrected mortality percentage was at the concentration of 5%, reaching 9.33% for males and 4.67% for females. Comparing the oils according to the period, we notice that the highest effect was by the cinnamon oil a day after the treatment, achieving a corrected mortality percentage averaged 30% for males that was lower for females, as the corrected mortality percentage was 23.33%, followed by clove oil where the corrected mortality percentage averaged 26.66 and 25.55% for females and males respectively a day after the treatment. The lavender oil effect was lower in the males and females as the mortality percentage did not exceed 6.66 and 4.44%, respectively. The oil effect began to reduce gradually since the second day after treatment.

Effect of the cinnamon, lavender and clove plant oils on egg laying by the adults of *C. maculatus*

Results in Table 2 refer to significant differences between the plant oils affecting the eggs laid by *C. maculatus*. The clove oil at the concentration of 5% was the most effective in that the average number of eggs in the treated seeds did not exceed 2.06 eggs. The concentration of the 3% clove oil had an influential role in the egg laid by the insect at 3.33 eggs, while the number of eggs on the seeds treated by 1% was 9.33, which also were lower than the control treatment, resulting in 21.33 eggs. Cinnamon oil ranked second in the effect on egg laying on the cowpea seeds. The average number of eggs treated with concentrations 1%, 3%, and 5% was 4.53, 5.20, and 5.13 eggs, respectively. The highest number of eggs (14.73) was on the seeds treated with 1% lavender oil, while the number of eggs resulted from the two concentrations of 3% and 5% was 13.80 and 10.00 eggs, respectively. So, it is observed that the effect of these oils at all concentrations on the egg laid by the beetle was high at the beginning and reduced during the progression of the days. The highest effect of each oil concentration was a day after treatment, while the lowest oil effect was often five days after treatment.

Oil	Conc. %	Males Corrected mortality percentage					mean	Females corrected mortality percentage					mean
		1d	2d	3d	4d	5d		1d	2d	3d	4d	5d	
Cinnamon	1	10	0	10	3.33	0	4.66	3.33	0	0	3.33	0	1.33
	3	30	6.67	3.33	0	10	10	20	3.33	3.33	3.33	3.33	6.67
	5	50	16.67	0	0	0	13.33	46.67	3.33	0	3.33	3.33	11.33
	mean	30	7.78	5.55	1.11	3.33		23.33	2.22	1.11	3.33	2.22	
Lavender	1	0	3.33	0	0	0	0.67	0	0	0	0	0	0
	3	6.67	3.33	3.33	0	3.33	3.33	6.67	6.67	6.67	0	0	4
	5	13.33	6.67	13.33	13.33	0	9.33	3.33	3.33	6.67	3.33	6.67	4.67
	mean	6.66	4.44	5.55	4.44	0		3.33	3.33	4.44	1.11	2.22	
Clove	1	6.67	3.33	3.33	6.67	0	4	0	0	0	0	0	0
	3	26.67	3.33	3.33	0	0	6.67	40	0	3.33	0	0	8.67
	5	43.33	3.33	0	0	0	9.33	40	13.33	3.33	0	0	11.33
	mean	25.55	3.33	2.22	2.22	0		26.66	4.44	2.22	0	0	

L.S.D.	Oil	Conc.	Day	Gender	Oil × Conc.	Oil × Day	Oil × Gender	Oil×Conc.× Day × Gender
0.05	2.11	2.11	2.73	1.72	3.66	4.72	2.99	11.58

Table 1. Effect of the cinnamon, lavender and clove oils on the adult killing of *C. maculatus*.

Effect of cinnamon, lavender and clove plant oils on the adult emergence of *C. maculatus*

Table 3 illustrates the effect of cinnamon, lavender and clove oils on the adult emergence percentage of the beetle, where the differences between the treatments were significant. The concentration of 5% of clove oil showed an effect higher than that of the other two oils in reducing the adult emergence of the beetle, as no adult insect emerged from the seeds treated with this concentration. The exact concentration of the other oils affected the emergence percentage, yet they did not differ significantly from the clove oil at the same concentration. The emergence percentage obtained from cinnamon and lavender was 0.33% at the concentration of 5%, while the emergence percentage of the control treatment was 15.30%. Lavender oil at the concentration of 1% showed the lowest activity as the emergence percentage was 13%, followed by the clove oil at 1%, resulting in an emergence percentage of 10.33%. Comparing the oils according to the average emergence percentage, it is remarkable that cinnamon oil came first with an average emergence percentage that did not exceed 1.78%, followed by clove oil at 4% on average and lavender oil at 5.56% on average.

Effect of cinnamon, lavender and clove plant oils on the productivity of *C. maculatus*

Table 4 demonstrates that treating cowpea seeds with high concentrations of plant oils (cinnamon, lavender and clove) affected the productivity of *C. maculatus*. The concentration of 5% of clove oil had the highest effect, compared to other oils, leading to 0 productivity, followed by lavender and cinnamon oils at the same concentration, producing 3.67% and 6.7%, respectively. The productivity of the control treatment was 75%. The beetle reached the maximum productivity at the concentration of 1% for clove, cinnamon and lavender, recording 110.2, 108.9, and 94.33 %, respectively, whereas treating the seeds with the concentration of 3% reduced the productivity to 21.4%, 23.33, and 41.7% for each oil treatment respectively. Comparing the effect of the oil of these plants in terms of productivity average , it is noticeable that the lowest impact on beetle productivity was recorded by lavender oil, reaching 40.4%, followed by clove oil, producing 43.39%, and finally by cinnamon oil at 52.4% on average.

Effect of cinnamon, lavender and clove plant oils on adult killing of *C. maculatus*

Table 5 illustrates the effect of cinnamon, lavender and clove on killing the adults of *C. maculatus* in the facultative experiment. The clove oil at the concentration of 5% was the most effective in killing the males and females of the insect. The mortality percentage for the males and females was 3.00% and 7.00%, with a total average of 3.33% and 4.00%, respectively, followed by cinnamon oil causing mortality of 1.00% and 1.33% for males and females, respectively. The lavender oil was relatively the least effective as the mortality percentage was 0.33% and 1.00% for the males and females respectively. The concentration of 1% in all oils was the least effective. The oils effect increased at the concentration of 3%, reaching the highest impact at 5%. It is also noted from the same table that insect females were more affected by the oils than males.

Effect of cinnamon, lavender and clove plant oils on egg laying of *C. maculatus*

Results in Table 6 refer to a significant difference in the number of eggs. The minimum egg number was obtained from the treatments with cinnamon and clove oils at 1%, resulting in 10.00 and 9.60 eggs, respectively, while the highest number was 13.00, resulting from the lavender oil

Treat.	Egg No./ conc./day																	
	1 %						3 %						5 %					
	1d	2d	3d	4d	5d	mean	1d	2d	3d	4d	5d	mean	1d	2d	3d	4d	5d	mean
Cinnamon	3.67	4.00	5.67	4.67	4.67	4.53	2.67	4.00	4.67	9.33	5.33	5.20	5.00	11.00	1.33	3.67	4.67	5.13
Lavender	7.33	11.00	11.33	24.00	20.00	14.37	6.67	13.67	15.00	22.00	11.67	13.80	6.00	7.33	12.67	13.33	10.67	10.00
Clove	2.67	9.67	11.67	9.67	13.00	9.33	2.00	1.33	2.67	5.33	5.33	3.33	2.33	1.67	1.00	2.67	2.67	2.06
Control	17.89	19.77	21.55	22.55	24.89	21.33												

L.S.D.	Oil	Conc.	day	Oil ×conc.	Oil ×day	Conc.×day	Oil ×conc.×day
0.05	2.07	1.80	2.32	3.60	4.64	4.02	8.05

Table 2. Effect of cinnamon, lavender and clove plant oils on egg laying by adults of *C. maculatus*.

Treat.	Adult emergence / conc.			mean
	1 %	3 %	5 %	
Cinnamon	4.00	1.00	0.33	1.78
Lavender	13.00	3.33	0.33	5.56
Clove	10.33	1.67	0.00	4.00
control	15.33			

L.S.D.	oil	Conc.	Oil × conc.
0.05	2.39	2.07	4.14

Table 3. Effect of cinnamon, lavender and clove plant oils on adult emergence of *C. maculatus*.

Treat.	Productivity percent. / conc.			mean
	1 %	3 %	5 %	
Cinnamon	108.90	41.70	6.77	52.45
Lavender	94.33	23.33	3.67	40.40
Clove	110.20	21.44	0.00	43.40
Control	75.90			

L.S.D.	oil	Conc.	Oil × conc.
0.05	41.11	35.60	71.21

Table 4. Effect of cinnamon, lavender and clove plant oils on the productivity of *C. maculatus*.

oil	Corrected adult killing percentage./ conc./Gender						mean	
	1 %		3 %		5%			
	male	female	male	female	male	female	male	female
cinnamon	0.00	1.00	1.00	1.00	2.00	2.00	1.00	1.33
lavender	0.00	0.00	0.00	0.00	1.00	3.00	0.33	1.00
clove	1.00	1.00	6.00	4.00	3.00	7.00	3.33	4.00

L.S.D.	Oil	Conc.	Gender	Oil × Conc.	Oil × Gender	Conc. × Gender	Oil × Conc. × Gender
0.05	0.83	0.72	0.58	1.44	1.17	1.01	2.03

Table 5. Effect of cinnamon, lavender and clove plant oils on adult killing of *C. maculatus*.

treatment. The clove oil at the concentration of 3% showed more effectiveness than other oils as the number of eggs did not exceed 7.13 eggs, followed by cinnamon oil and lavender oil, giving 9.20 and 10.60 eggs on average, respectively. Regarding the 5 % concentration treatments, clove oil came at the first rank, reducing the number of eggs to only 5.60 eggs, which increased to 8.80 eggs due to treatment with lavender oil. The effect of clove oil was moderate in decreasing the number of eggs to 6.73 on average.

Effect of cinnamon, lavender and clove plant oils on adult emergence of *C. maculatus*

Table 7 shows significant differences between the plant oils in their effect on the adult emergence of *C. maculatus*. The cinnamon and clove oils were more effective than lavender oil as the emergence percentage affected by the cinnamon and clove oils were 6.78% and 6.22%, respectively (without a significant difference) . The emergence percentage for lavender treatment was 8.11%. It is observed that the emergence percentage at the concentration of 1% was high for all plant oils. The highest emergence percentage level was recorded by clove oil treatment (18.67%), while the lowest level (13.00%) was obtained from the cinnamon oil treatment. The lavender oil treatment at the concentration of 1% gave a 16.00% emergence percentage, and the average emergence percentage at 1% was 15.11%. Concerning the concentration of 3%, the differences between the oils were insignificant since the emergence percentages affected by cinnamon, lavender and clove oils were 6.33%, 6.67 %, and 6.67%, respectively. Also, no significant difference was observed for the treatments of 5% concentration. The emergence percentages at this concentration (5 %) for all oils were the lowest, not exceeding 1.00%.

Effect of cinnamon, lavender and clove plant oils on the productivity of *C. maculatus*

Results in Table 8 refer to significant differences in the effect of the plant oils on the productivity of *C. maculatus*. It is observed that insect productivity was high at the treatment of 1% for oils maximized in the treatment of lavender oil, reaching 89%. In comparison, it was 85.7% and 84.3% (with no significant difference) for cinnamon and clove oils, respectively. Insect productivity decreased at the 3 % concentration for all oils, reaching 58.5, 36.10 and 29.6 % for cinnamon, lavender, and clove oils, respectively. For 5 % concentration, insect productivity was at the minimum level for all oils, reaching 16.00, 21.90 and 5.20 % for cinnamon, lavender and clove oils, respectively. In comparison among oils' effect on insect productivity average, the lowest productivity average (39.7%) was recorded by the treatment of clove oil, followed by lavender oil, which led to a production average of 49% and next by cinnamon oil with a productivity of 53.4% on average.

Discussion

Using insecticides to prevent infection is one of the main

Oil	No. of egg / Conc. / Day																	
	1 %						3 %						5 %					
	1d	2d	3d	4d	5d	M	1d	2d	3d	4d	5d	M	1d	2d	3d	4d	5d	Mean
Cinnamon	4.00	9.00	15.00	10.00	12.00	10.00	1.00	5.00	9.00	13.00	18.00	9.20	2.00	6.00	6.00	6.00	8.00	5.60
Lavender	2.00	15.00	14.00	12.00	22.00	13.00	4.00	14.00	9.00	11.00	25.00	10.60	1.00	5.00	9.00	14.00	15.00	8.80
Clove	4.00	8.00	12.00	8.00	16.00	6.60	1.00	3.00	14.00	9.67	8.00	7.13	3.00	3,00	6.00	8.00	13.67	6.73

L.S.D.	Oil	Conc.	Day	Oil × Conc.	Oil × Day	Conc. × day	Oil × Conc. × Day
0.05	1.04	0.90	1.17	1.81	2.34	2.02	4.04

Table 6. Effect of cinnamon, lavender and clove plant oils on egg laying of *C. maculatus*.

Oil	Adult emergence percent. / Conc.			Mean
	1 %	3 %	5%	
Cinnamon	13.00	6.33	1.00	6.78
Lavender	16.00	6.67	1.67	8.11
Clove	18.67	6.67	0.33	6.22

L.S.D.	Oil	Conc.	Oil × Conc.
0.05	2.48	2.48	4.30

Table 7. Effect of cinnamon, lavender and clove plant oils on adult emergence of *C. maculatus*.

Oil	Productivity percent. / Conc.			Mean
	1 %	3 %	5 %	
Cinnamon	85.70	58.50	16.00	53.40
Lavender	89.60	36.10	21.90	49.20
Clove	84.30	29.60	5.20	

L.S.D.	Oil	Conc.	Oil × Conc.
0.05	22.85	22.85	39.58

Table 8. Effect of cinnamon, lavender and clove plant oils on the productivity of *C. maculatus*.

approaches to protecting stored seeds against pests[24]. Several studies are conducted to evaluate the lethal and repel effects of wild plants and medicinal herbs against insects infecting the stored productions[25]. In this study, the influence of the essential oils of some plants (cinnamon, lavender and clove) on *C. maculatus* killing, egg laying, adult emergence, and productivity was evaluated. Cinnamon oil showed the highest impact on killing the insect males in an obligatory experiment, achieving a mortality percentage of 13.33%. Cinnamon and clove oils showed the highest effect on female mortality percentage, reaching 11.33%. This result is consistent with those referred to by (26): cinnamon oil at 5µl killed 13% of *C. maculatus*. (21) reported that LC50 of cinnamon and clove oils tested against *C. maculatus* was 0.88 and 0.73 5µml/l air, respectively. Lavender oil impact was low in killing the insect females and equal to clove oil in killing the males, where the mortality percentage was 9/33% for each. Ahn *et al.*(1998) referred that the high volatility oils cause insect mortality through fumigation and gaseous effects that may influence the nervous system of *C. maculatus* adults. Studies state that wild aromatic and volatile medicinal plants have essential chemicals inhibiting rice weevil and other insects[27].

Clove oil affected egg laying by repelling the adult insects, relatively more than the other two oils as the number of eggs did not exceed 2.06 egg, a result that is consistent with the results reported by (21), in that clove oil repelled *C. maculatus*, followed by cinnamon oil that affected the number of egg to be 5.13 egg. Lavender oil was less affected than others, where eggs reached 10.00. The insect adult emergence was reduced by cinnamon oil to 1.78%, clove oil to 4.00%, and lavender oil to 5.56%. 21 reported that clove oil decreased the adult emergence percentage of *C. maculatus* by 76.86%. Lavender oil reduced the productivity of *C. maculatus* to 40.4%, while the productivity of clove oil treatments was 43.39%. Cinnamon oil decreased the productivity of *C. maculatus* to 52.4%. The effect of the oils on the emergence percentage may be due to reaching them inside the egg through the opening of the hilum or the eggshell and thus leading to fetus death or incomplete development, or that oil may limit or prevent the entry of oxygen into the egg, as referred by (28). Cinnamon bark extract killed *C.chinensis* by 100% two days after the treatment (29) observed that cinnamon oil had the highest effect in reducing the total content of carbohydrates, proteins and lipids of *C. maculatus*; then, it reduced the whole protein in

the insect. Lavender oil showed the lowest effect resulting in mortality percentage of 0.33% and 1.00% for males and females, respectively, unlike the results obtained by 29 that lavender oil at the concentration of 2mg/cm^2 caused 76% of adults of the rice weevil (*Sitophilus oryzae*) 48 hours after the treatment.

In comparison, the concentration of 0.75ml/cm^2 repelled the insect by 78% 5 hours after the treatment. At the 6 mg/cm2 concentration, the mortality percentage reached 100% after 12 and 48 of the treatment. Concerning the oil effect on egg laying, cinnamon oil reduced the number of laid eggs to 5.60 eggs, followed by clove oil as the number of eggs reached 8.80. Regarding the effect of oils on adult emergence, they converged in their effects; the emergence percentages of adults were 6.22, 6.78 and 8.11% for clove, cinnamon and lavender oils, respectively. For the effect of oils on insect productivity, clove oil had the highest impact on reducing productivity that did not exceed 39.7%; the lavender oil came second, with productivity reaching 49.2%, and finally, cinnamon oil got insect productivity at 53.4%.

From the results of the cinnamon, lavender and clove oils effect, we notice that oil activity generally increases with increasing the concentration, which is in agreement with results referred to by (30), in that the total content of carbohydrates, proteins and lipids inside the larvae of the red flour beetle, decreased as a result of treating with increasing volatile oil concentration of blue giant hyssop (*Agastache foeniculum*) used for treating (31) reported that plant oils' fumigation and contact effects are related to exposure duration and concentration (32) mentioned that the fumigation effect of the clove oil increases with increasing the oil concentration or the period of maize weevil (*Sitophilus zeamais*) exposure to the oil. A study recorded that the toxicity of plant oils is mainly affected by the chemical composition, which usually depends on the plant origin, weather conditions, used method, extraction period and the plant part used for extraction. All of these explain why some oils used in the experiment have a low efficiency or variation in effect against *C. maculatus* involving killing the adults, reducing egg laid by adults, emergence percentage, or productivity[33]. (21) also referred that cinnamon and clove oils are one of the promising approaches for controlling *C. maculatus* by fumigation way.

Conclusions

It can be concluded from this study results that these oils have an evident effect in controlling the insect, so it can be listed among the essential measures of controlling this insect in legume storage conditions dominant in Iraq.

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