Journal of Kerbala for Agricultural Sciences Issue (1), Volume (11), (2024)

Studying the effect of the pesticides Tondexir and Emamectin benzoate on some biological aspects of the southern cowpea beetle *Callosobruchus maculatus*

Sundus Yaseen Shneen*, Muna Ibrahim Jassem, Kiaser Abdulsajjad M. Hussain

Department of Biology, College of Education for Pure Sciences, Kerbala University, Karbala, Iraq.
***Corresponding author: Email :sundusyaseen727@gmail.com**
https://doi.org/10.59658/jkas.v11i1.1441

Received: Nov. 30, 2023

Accepted: Jan. 18, 2024

Published: Mar. 18, 2024

Abstract

The study aimed to evaluate the effectiveness of Tondexir and Emamectin benzoate pesticides on the southern cowpea beetle, *Callosobruchus maculatus*. Experiments were conducted using three different concentrations (1, 1.5, 2) ml/1 liter (distilled water) of Tondexir and Emamectin benzoate on 10 selected insects (5 males, 5 females) placed on 10 grams of treated cowpea seeds. The results showed that Tondexir effectively eliminated *C. maculatus*, achieving a 100% mortality rate after 5 days at a concentration of 2 mL. In contrast, the biopesticide Emamectin benzoate showed high mortality rates for adult southern cowpea beetles, reaching 100% after one day at the same concentration. This confirms the effectiveness and superiority of Emamectin benzoate compared to the control group, which did not show any fatalities. Different concentrations of pesticides had varying effects on spawning rates, with significant differences observed between the treatment and control groups. These results indicate the effect of the pesticides Tondexir and Emamectin benzoate on the egg-laying process of the Southern Cowpea beetle. The study showed that different concentrations of Tondexir and Emamectin benzoate did not lead to egg hatching, while the control group showed a high hatching rate of about 90-93%. This confirms the ability of these pesticides to combat the southern cowpea beetle. In conclusion, the study highlighted the effectiveness of Emamectin benzoate in combating the Southern Cowpea beetle, as the pesticide Emamectin benzoate showed superior results. It also greatly affected egg productivity and hampered the egg-hatching process. These results indicated the possibility of using tondexir and Emamectin benzoate as effective substances to control *Callosobruchus maculaus* in Cowpea crops.

Keywords: Tondexir Emamectin benzoat, *Callosobruchus maculau*

Introduction

Legumes play a wide role in the human diet and are distinguished by their great economic importance. This plant family contains an ideal balance of carbohydrates, proteins, minerals, and vitamins [1]. In addition to the vital role that grains play in meeting nutritional requirements, approximately one-third of stored grains are vulnerable to attacks by harmful insects, posing a threat to food security [2,3]*C. maculatus*, commonly known as the bean beetle or cowpea weevil, is a widespread pest of agricultural storage facilities around the world, found on every continent except Antarctica. It is believed to have originated in West Africa and spread globally through trade in grains and other crops [4]. This pest belongs to the order Coleoptera and family Bruchidae, and targets stored legumes [5]

C. maculatus is capable of causing significant losses in grain quantity and quality [6]. The effects are manifested in seed perforation, reduced weight, reduced market value, and decreased ability of seeds to germinate [7]. This damage directly affects stored grains and processed products by reducing their nutritional quantity and quality, making them unfit for human consumption and other agricultural purposes [8]. This necessitates taking measures and precautions to combat it and maintain the quality of crops in Iraq and other countries [9].Crop pest control has become a pressing issue, especially in light of synthetic pesticides' environmental and health risks. Therefore, botanical insecticides quickly gained popularity due to their low cost and minimal environmental impact, effectively eliminating harmful insects without leaving side effects on food or the environment. Plants have been used for pest control for a long time and have environmental benefits. In developing countries, botanical insecticides have been adapted for organic food production, and have played a more important role in post-harvest food protection in developed countries [10].Plant-derived insecticides are a suitable alternative to synthetic insecticides [11]. These insecticides possess environmentally friendly, often species-specific, biodegradable, and non-toxic properties to humans. They also exhibit diverse working methods, enabling them to achieve a comprehensive and swift improvement in storage losses [12]. Botanical insecticides are desirable alternative to traditional chemical insecticides in agriculture to control pests, enhancing our health and environmental well-being [13]

Biological pesticides are environmentally friendly insecticides acquired from natural sources such as biochemicals, microorganisms, and plants. They are classified into three main categories and offer substantial benefits in agriculture and public health programs. However, we must consider some challenges, such as genetic variations in plant populations and the negative impacts on the environment and other organisms [14].

Materials and Methods

Collection, diagnosis, and breeding of the southern cowpea beetle *C. maculatus.*

Adults of the Southern Cowpea beetle were collected during May 2023 from the seeds of cowpea *Vigna unguiculata* infected with this insect from the local markets of

Karbala Governorate. The diagnosis of the insect was confirmed by Assistant Professor Dr. Haider Naeem Al-Ashbal from the College of Education for Pure Sciences / University of Karbala, as it was diagnosed to reduce the type and found that it follows the type of *C. maculatus*, farms worked permanent farms for the insect by distributing four kilograms of healthy beans on four transparent plastic containers of 4500 cm3 each and weighed each of these containers in 300 pairs of adult beetles (males and females) taken from the infected seeds.

Preparation of different concentrations of pesticides of plant and biological origin Different concentrations of Tondexir and Emamectin benzoate (2,1,5,1) ml were prepared, and each of the above concentrations was diluted with 1 liter of distilled water and shaken well. Then each concentration of each pesticide was placed separately with a 100 ml hand sprayer.

Study the effect of different concentrations of Tondexir and Emamectin benzoate on southern cowpea beetle adults' mortality and egg laying.

The weight of groups of Cowpea seeds and each bunch weighing 10 g laid out on filter paper. Then they were sprayed with concentrations (1,1.5,2) ml, and each pesticide was separately used with a 100 ml hand spray. The treated seeds were left on filter paper for 15 minutes. After the seeds had dried, they were transferred to transparent plastic containers of 200cm3. Then, the adults of the southern cowpea beetle were placed by 10 adults (5 males, 5 females) for (1-2) days and the nozzles of the containers were covered with a Tulle cloth and tighten with rubber bands, the process was repeated three times for each concentration and both pesticides as well as the control treatment, the seeds of which were sprayed with distilled water only. The mortality of the adult insect and the number of eggs laid were calculated after (1,3,5,7) days after the start of the test. Ten followed the replicates untill the adult emerged.

Study of the repellent and attractive effect of the pesticides Tondexir and Emaectin Benzoate on adults of the southern cowpea beetle using a chemotropism device.

Use a chemotropism device based on the design [15]which includes a wooden box 48 cm long and 20 cm high, containing a movable lid. In the middle of the box, are two opposite holes through which a glass tube 100 cm long and 3 cm in diameter passes, through which the tube is divided into centimeters. Cover both ends of the tube with pieces of cotton.

As a result of the choice of attraction and repulsion, the piece of cotton on the right side of the tube was immersed in the Tondexir pesticide, while the piece of cotton on the left side was immersed in distilled water only. 10 adults of the southern cowpea beetle were placed in the middle of the tube and were monitored for 20 minutes, during which the number of insects attracted to the insect was calculated. The above experiment was repeated with all treatments, and each treatment was repeated three times, and between each treatment and another, the device tube was cleaned. After that, the results were calculated according to the equations explained in previous studies, [16].

$$\text{Percentage of attraction} = \frac{\text{The number of insects heading toward the material}}{\text{Total number of insects}} \times 100\%$$

$$\text{Percentage of expulsion} = \frac{\text{The number of insects is in the opposite direction of the material}}{\text{Total number of insects}} \times 100\%$$

Statistical analysis

A group of factorial laboratories was implemented using a complete random design (C.R.D. Design) using the statistical analysis program for the Statistical Analysis System (SAS), version 2012, and the results were confirmed using the least significant difference (LSD) test at the probability level 0.05[17].

Results and Discussion

Evaluation of the effectiveness of the plant-based pesticide Tondexir on the mortality adult southern cowpea beetles (*C. maculatus*) 1-2 days

The study's results in Table (1) showed that the insecticide Tondexir effectively kills the southern cowpea insect *C. maculatus*. Three different concentrations of the pesticide (1 ml, 1.5 ml, 2 ml) were tested and compared with the control group.

As the days passed, the mortality rate increased significantly at all concentrations tested. The mortality rate at the lowest concentration (1 ml) was 79.16%. At the highest concentration (2 ml), the mortality rate reached 91.67%. It is noted that the higher concentration showed a higher mortality rate in each time compared to other concentrations. These results indicate that Tondexir is highly effective in eliminating the southern cowpea insect *C. maculatus*. A concentration of 2 ml can be considered the most effective due to the high mortality rate it causes over a short time.

Compared to the control group, no deaths were recorded in insects treated with the weak solution. Which enhances the effectiveness of Tondexir as an insecticide in eliminating southern bedbugs. The least significant difference (LSD) test values indicate statistically significant differences between the different concentrations concerning mortality. This supports the conclusions drawn from the results and confirms that there are differences between the effects of different concentrations of Tondexir on the southern cowpea beetle. In general, it can be said that Tondexir is an effective insecticide in combating the Southern beetles *C. maculatus*. The results indicate that increasing the pesticide concentration leads to increased mortality rates and better results in a shorter time. Using a concentration of 2 ml is recommended to achieve the highest effectiveness in eliminating the southern cowpea beetle. The use of botanical insecticides is an effective alternative to synthetic chemical pesticides that pose a threat to environmental health. Using botanical pesticides is safe for the environment and human health, as they do not pose any danger, according to studies [18,19]The effectiveness of insecticides is due to their content of oils and volatile compounds that can penetrate and spread within the insect’s body, unlike contact insecticides. These chemical compounds penetrate the insect's body through its sensitive areas, causing paralysis and death [20]Phytoncides contain toxic compounds and alkaloids or active ingredients that inhibit feeding and ultimately lead to the death of insects. In addition, phytoncides penetrate the insect's spiracles, affecting the insect's nervous and digestive systems [21]. Phytoncides contain hormone-like compounds that disrupt cell functions and ultimately lead to the insect's death [22].

Table (1): Evaluation of the effectiveness of the plant-based pesticide Tondexir on the mortality adults of Southern Cowpea beetles (*C. maculatus*) 1-2 days

The treatment	Corrected percentage of depreciation over time periods (days)				Average mortality rate for each concentration	Average percentage of death for the total concentrations
	1	3	5	7		
1	36.66	83.33	96.66	100.00	79.16	84.16
1.5	40.00	86.66	100.00	100.00	81.67	
2	70.00	96.66	100.00	100.00	91.67	
Control	0.00	0.00	0.00	0.00	0.00	
Time rate	36.67	66.66	74.17	75.00		
L.S.D 0.05	The treatment		the time		Interference	
	2.5531		2.5531		5.1062	

Bioevaluation of Emamectin benzoate in the death of adults of the southern cowpea beetle *C. maculatus* at the age of (1-2) day.

The study's results in Table (2) showed that the biobased pesticide Emamectin benzoate has an effective effect in causing the mortality of the Southern Cowpea beetle *C. maculatus*. Three different concentrations of the pesticide (1 ml, 1.5 ml, and 2 ml) were tested and compared to the control group. Over days, mortality increased significantly at all concentrations tested. At the lowest concentration (1 ml), group mortality was 85% after 7 days of treatment. At the higher concentration (2 ml), 100% mortality was achieved after 7 days. It is noted that the highest concentration showed the highest mortality rates in all periods compared to other concentrations.

These results indicate that Emamectin benzoate is effective on the mortality *C. maculatus*. A concentration of 2 milliliters is considered the most effective because 100% mortality is achieved in a short time. Compared to the control group, there was no mortality recorded on the beetles which treated with the weak solution. This supports the effectiveness of Emamectin benzoate as a powerful insecticide in eliminating the Southern beetles. The values of the least significant difference (LSD) statistical test indicate significant differences between the different concentrations regarding the mortality rate. This strengthens the conclusions drawn from the results and confirms that there are differences between the effects of different concentrations of Emamectin benzoate on the southern cowpea beetle.

Overall, it can be said that Emamectin benzoate is a powerful insecticide in for controlling the Southern Cowpea beetle *C. maculatus*. The results indicate that increasing the pesticide concentration leads to increased mortality rates and better results in a shorter time. Using a concentration of 2 milliliters is recommended to achieve the highest effectiveness in eliminating the *C. maculatus*.

The results of our current study showed that Emamectin benzoate has an effective effect in causing the highest mortality rate. The results of our study were consistent with the results of another study, as the effect of Emamectin benzoate on the mortality rate was large and insignificant. Influenced by the time [23]. The insecticide Emamectin benzoate was used to destroy the larval stages of the grain beetle Trogoderma granarium, with a mortality rate of 91.48%.

This study is consistent with the research results conducted by [24], who evaluated three insecticides (Emamectin benzoate, indoxacarb, and chlorantraniliprole) based on their effectiveness. In field applications, Emamectin benzoate showed superior initial and survival activity, resulting in 100% larval mortality, while indoxacarb showed fewer efficacies in controlling cutter larvae of Agrotis ipsilon .

Table (2): Bio evaluation of Emamectin benzoate on the mortality of adults of the Southern Cowpea beetle *C. maculatus*.

The treatment	Corrected percentage of depreciation over periods (days)				The average mortality rate for each concentration	Average percentage of death for the total concentrations
	1	3	5	7		
1	53.33	86.66	100	100	85	91.94
1.5	66.66	96.66	100	100	90.83	
2	100	100	100	100	100	
Control	0	0	0	0	0	
Time rate	55	70.83	75	75		
L.S.D 0.05	the focus		the time		Interference	
	3.2125		3.2125		6.425	

Study of the effect of different concentrations of Tondexir and Emamectin benzoate on the Spawning of the Southern bean beetle.

The study results in Table 3 show the effect of different concentrations of Tondexir and Emamectin benzoate on the egg-laying productivity of the southern cowpea beetle. The study evaluated the average spawning rate and percentage for each treatment and compared tondexer, Emamectin benzoate, and the control group.

Tondexir's proliferation rate is lower at all concentrations tested compared to the control. At the upper concentration (1 mL), the proliferation rate was 8.44%, while at the upper concentration (2 mL) it was 5.33%. It is noted that increasing the concentration of Tondexer can lead to the reproduction of the southern cowpea beetle.

In contrast, Emamectin benzoate showed a much lower prevalence. At the half concentration (1 ml), the reproduction rate was 5.22%, while at the maximum concentration (2 ml) it was 1.00%. These results indicate that Emamectin benzoate has a greater effect on the reproduction of southern pest insects than Tondexir.

Finally, in the control group, sales targets were significantly higher. The prevalence in the overall control group was between 42.00% and 47.66%. This indicates that the compounds used (Tondexir and Emamectin benzoate) significantly increased proliferation compared to control.The values of the least significant difference (LSD) statistical test indicate significant differences between different concentrations concerning reproducibility variances. This is supported by the data extracted from the results and confirms that there are differences between the effects of different concentrations of manufacturers specialized in reproducing southern insects.

Table (3) :study the effect of different concentrations of Tondexir and Emamectin benzoate on the productivity of Southern Cowpea beetle adults.

The treatment	Average spawning rate for each concentration			Average spawning percentage for each treatment
	1	1.5	2	
Tondexir	11.33	8.66	5.33	8.44
Emamectin benzoate	11.00	3.66	1.00	5.22
Control	37.33	47.66	42.00	42.33
Time rate	19.33	19.99	16.11	18.66
LSD 0.05	Transaction	the focus		Interference
	0.9985	0.9985		1.997

Study of the effect of different concentrations of the herbicide Tondexir and the herbicide Emamectin benzoate on inhibiting the hatching of adult eggs of the Southern Cowpea beetle.

The study's results in Table (4) showed the strength of the effect of both Tondexir benzoate and Emamectin, with statistically significant differences between the two pesticides and the control group. The data presented show the average hatching rates for different concentrations (1, 1.5, and 2) ml/ 1L under Tondexir and Emamectin benzoate treatments. The control group, representing the baseline, displays varying hatching ratios across concentrations. The results showed that Tondexir and Emamectin benzoate treatments inhibited the hatching process (0.00%) at all concentrations (1, 1.5, and 2) ml/ 1L. This indicates a strong inhibitory effect on the hatching process, confirming the effectiveness of these treatments in preventing egg development. In contrast, the control group displays hatching rates ranging from 86.83% to 90.99%. This difference indicates the significant effect of Tondexir benzoate and Emamectin in hatching suppression compared to untreated samples.

A gradual increase in hatching rates was observed across concentrations. This indicates a possible effect of time on the hatching process. Time-dependent differences highlight the importance of considering temporal factors in evaluating the effectiveness of treatments. The least significant difference (LSD) at a significance level of 0.05 provides a statistical tool to distinguish between significant differences. Attention should be paid to concentrations and treatments where the observed differences exceed the LSD value of 1.1514. This ensures a robust interpretation of results and identifies concentrations or treatments that differ significantly.

We conclude that the results indicate a significant inhibitory effect of Tondexir and Emamectin benzoate on hatching rates. The results of our current study agreed with the results of another study conducted by [25], which indicate that Emamectin benzoate appears to be a highly effective agent in suppressing the fertility of F0 and F1 generations of Spodoptera frugiperda [26]. Exposure to high concentrations of LC10 and LC25

Reducing the egge number, thus the reducing overall production in the future Generations. This decrease in fertility was more pronounced compared to control. A group demonstrating the effectiveness of Emamectin benzoate in reducing Reproduction. As an effective option to combat these pests and limit their spread, it was consistent with the results [25].

According to the study resulet [27], pesticides prevent the hatching of insect eggs and eliminate the larvae. Permiphos-methyl and alpha-cypermethrin are most effective against *T. granarium*.

Table (4) Study of the effect of different concentrations of the herbicide Tondexir and the herbicide Emamectin Benzoate on inhibiting the hatching of adult eggs of the Southern Cowpea beetle eggs.

The treatment	Average hatching percentage for each concentration			Average hatching percentage for each treatment
	1	1.5	2	
Tondexir	0.00	0.00	0.00	0.00
Emamectin benzoate	0.00	0.00	0.00	0.00

Control	86.83	93.08	93.06	90.99
Time rate	28.94	31.02	31.02	30.33
LSD 0.05	Transaction	the focus		Interference
	1.1514	1.1514		2.3028

Study of the repellent and attractive effect of the insecticides Tondexir and Emamectin Benzoate on adults of the Southern Cowpea beetle.

The results of the study showed in Table (5) the number of insects attracted and repelled, the rates of attraction, the rates of expulsion, and the balance ratios for both Tondexir and Emamectin benzoate. Tondexir showed an 80% higher attraction rate than Emamectin Benzoate, which attracted only 30% of insects. This indicates that Tondexir has a stronger ability to attract insects. However, it is important to note that Tondexir also repelled 20% of the insects, resulting in a balance of 60%. Emamectin benzoate, on the other hand, successfully repelled 50% of insects, resulting in a negative balance ratio of -20%. The balance ratio reflects the treatment's net effect, considering both attraction and repulsion. In the case of Tondexir, a positive balance indicates general attraction, albeit with some aversion. For Emamectin benzoate, the negative balance highlights a stronger repellent effect, outweighing its attractive properties. Data suggest that Tondexir has a more balanced effect on insect behaviour, attracting a larger proportion while repelling a smaller proportion. On the other hand, Emamectin benzoate has a stronger repellent effect, resulting in a negative balance.

The data presented demonstrate the contrasting effects of Tondexir benzoate and Emamectin on insect behavior. Tondexir shows a more balanced effect, while Emamectin Benzoate tends toward a stronger disharmony. These results contribute to our understanding of the behavior-altering properties of these compounds and guide future considerations for pest control strategies.

Table (5): Study of the repellent and attractive effect of the pesticides Tondexir and Emamectin Benzoate On adults of the Southern Cowpea adults.

Transactions	Number of Attracted Insects	Number of Repelled Insects	Attraction Rate %	Repulsion Rate %	Balance %
Tondexir	80	20	80%	20%	60%
Emamectin benzoate	30	50	30%	50%	-20%

References

1) Miah, M. A., Ali, M. R., Husna, A., & Mollah, M. M. (2013). Efficacy of some botanicals against pulse beetle, *Callosobruchus maculatus* (Fab.) on stored green-gram, *Vigna radiata*. *Bangladesh Journal of Entomology*, 23(1), 11–201.
2) Ali, M. A. M., El-Sayed, F. M. A., & El-Bishlawy, H. M. I. (2005). Damage and quantitative loss caused by *Callosobruchus maculatus* (Coleoptera: Bruchidae) to some cowpea and faba bean varieties. *Egyptian Journal of Agricultural Research*, 83, 563-5812.
3) Musa, A. K., & Adeboye, A. A. (2017). Susceptibility of some cowpea varieties to the seed beetle *Callosobruchus maculatus* (f.) (Coleoptera: Chrysomelidae). *Journal of Agricultural Sciences Belgrade*, 62(4), 351-3603.
4) Tran, B. M., & Credland, P. F. (1995). Consequences of inbreeding for the cowpea seed beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *Biological Journal of the Linnean Society*, 56(3), 483-5034.
5) Mssillou, I., Saghrouchni, H., Saber, M., Zannou, A. J., Balahbib, A., Bouyahya, A., Allali, A., Lyoussi, B., & Derwich, E. (2022). Efficacy and role of essential oils as bio-insecticide against the pulse beetle *Callosobruchus maculatus* (F.) in post-harvest crops. *Industrial Crops and Products*, 189, 115786. .
6) Lale, N. E. S., & Mustapha, A. (2000). Potential of combining neem (*Azadirachta indica* A. Juss) seed oil with varietal resistance for the management of the cowpea bruchid, *Callosobruchus maculatus* (F.). *Journal of Stored Products Research*, 36(3), 215–222. .
7) Naseri, B., & Hamzavi, F. (2021). Effects of chemical and bio-fertilizers on cowpea resistance to cowpea weevil, *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae). *Journal of Stored Products Research*, 92.
8) Stathers, T. E., Arnold, S. E. J., Rumney, C. J., & Hopson, C. (2020). Measuring the nutritional cost of insect infestation of stored maize and cowpea. Food Security, 12, 285–3081.
9) Aslam, M., Khan, K. A., & Bajwa, M. Z. H. (2002). Potency of some spices against Callosobruchus chinensis Linnaeus. Journal of Biological Sciences, 2(7), 449–4522.
10) Ahmed, N., Alam, M., Saeed, M., Ullah, H., Iqbal, T., Al-Mutairi, K. A., Shahjeer, K., Ullah, R., Ahmed, S., & Ahmed, N. (2021). Botanical insecticides are a non-toxic alternative to conventional pesticides in the control of insects and pests. Global Decline of Insects, 1–193.
11) Souto, A. L., Sylvestre, M., Tölke, E. D., Tavares, J. F., Barbosa-Filho, J. M., & Cebrián-Torrejón, G. (2021). Plant-derived pesticides as an alternative to pest management and sustainable agricultural production: Prospects, applications, and challenges. Molecules, 26(16), 48354.
12) Wink, M. (2015). Modes of action of herbal medicines and plant secondary metabolites. Medicines, 2(3), 251–286. .

13) Damalas, C. A., & Koutroubas, S. D. (2020). Botanical pesticides for eco-friendly pest management: Drawbacks and limitations. Pesticides in Crop Production: Physiological and Biochemical Action, 181–193. .

14) Srijita, D. (2015). Biopesticides: An ecofriendly approach for pest control. World Journal of Pharmacy and Pharmaceutical Sciences, 4(6), 250–265. .

15) Folsom, J. W. (1931). A chemotrophometer. Journal of Economic Entomology, 24, 827–833. .

16) Shaaban, A., & Al-Mallah, N. M. (1993). Pesticides. Dar Al Kutub Printing & Publishing Est. University of Al Mosul. 520 pages. Technical Journal - Technical Research, 15(93), 122-128.

17) Alrawi, K. M., & Abd al-Aziz, M. K. (2000). Design and analysis of experiments. Agricultural Ministry of Higher Education and Scientific Research, Dar Al-Kutub for Printing and Publishing - University Mosul, 488 pages.

18) Isman, M. B. (2006). Botanical insecticide deterrents and repellants in modern agriculture and on an increasingly regulated world. *Annual Review of Entomology*, 51, 45–66.

19) Maia, M. F., & Moore, S. J. (2011). Plant-based insect repellents: A review of their efficacy, development, and testing. *Malaria Journal*, 10(1), 1-15.

20) Afifi, F. A. A., & Atti, M. A. (2002). Plant extracts and bio-effectiveness. Library of Religious Culture. Cairo, Arab Republic of Egypt, p. 338.

21) Romeilah, R. M., Fayed, S. A., & Mahmoud, G. I. (2010). Chemical composition, antiviral, and antioxidant activities of seven essential oils. *Journal of Applied Sciences Research*, 6(1), 50-62.

22) Rattan, R. S. (2010). Mechanism of action of insecticidal secondary metabolites of plant origin. *Crop Protection*, 29(9), 913-920.

23) Al-Rubaie, E. I. M. (2022). Using HS-SPME Fiber technology to detect volatile organic compounds of the Khabra hair beetle (*Everts Trogoderma granarium*) (Coleoptera: Dermestidae) on wheat and using some biocides to combat it. Master Thesis. College of Agriculture, University of Karbala, Department of Plant Protection. Number of pages 85.

24) Ismail, S. M. (2021). Field persistence of certain new insecticides and their efficacy against black cutworm, *Agrotis ipsilon* (Hufnagel). *Bulletin of the National Research Centre*, 45, 1-7. .

25) Zhang, X., Hu, C. W. L., & Chen, W. (2023). Transgenerational sublethal effects of chlorantraniliprole and emamectin benzoate on the development and reproduction of *Spodoptera frugiperda*. *Insects*, 14(6), 537.

26) Habib, N. J. (2022). Evaluation of the efficiency of some nanocomposites and pesticides of plant origin, and the commercial biological preparation Naturalis-L in controlling the red rusty flour beetle Tribolium castaneum (Herbst.) (Coleoptera: Tenebrionidae). Master Thesis. College of Agriculture, University of Karbala, Department of Plant Protection.

27) Boukouvala, M. C., & Kavallieratos, N. G. (2020). Effect of six insecticides on egg hatching and larval mortality of Trogoderma granarium Everts (Coleoptera: Dermestidae). Insects, 11(5), 2631.