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EFFECT OF MICROWAVE RADIATION ON THE CONTROL OF RED FLOUR BEETLE *Tribolium castaneum* (HERBST).

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ABSTRACT

A study was conducted to evaluate the effect of exposing the stages of the *Tribolium castaneum* beetle to microwaves at power levels of 540, 810, and 1080 watts and exposure times of 60, 90, and 120 seconds. The results of the statistical analysis indicated that there were significant differences between the effects of power levels and exposure times in the third and fifth instar larvae, but not in treatment of pupae and adults. The mortality rates increase with higher energy levels and exposure durations. The highest mortality rate was reached at an energy level of 1080 watts and an exposure duration of 120 seconds in both third instar larvae, fifth instar larvae, pupae, and adults, reaching 100% mortality for the insect stages respectively. The lowest mortality rate was 43.33%, 23.33%, 10%, and 16.33% for the third and fifth instar larvae, pupae, and adults, respectively, at a power level of 540 watts and an exposure time of 60 seconds.

Keywords: microwave radiation, red flour beetle, *Tribolium castaneum.*

تأثير الأشعة المايكروية في مكافحة خنفساء الطحين الحمراء الصدئية(*Tribolium castaneum* (Herbest

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الخلاصة

اجريت تجربة لتقييم تأثير تعريض ادوار حشرة *Tribolium castaneum* إلى الموجات المايكروية بمستويات طاقة 540، 810، 1080 واط وبفترات زمنية 60، 90، 120 ثانية، أشارت نتائج التحليل الإحصائي إلى وجود فروق معنوية بين تأثير مستويات الطاقة والفترات الزمنية في يرقات الطور الثالث والخامس وعدم وجودها في معاملة العذارى والبالغات، وأن نسب الموت تزداد بزيادة مستويات الطاقة ومدد التعريض، وبلغت أعلى نسبة موت عند مستوى طاقة 1080 واط ولمدة تعريض 120 ثانية في كل من يرقات الطور الثالث، يرقات الطور الخامس، العذارى، البالغات، أذ بلغت 100 % لأدوار الحشرة على التوالي، في حين كانت أقل نسبة موت عند مستوى طاقة 540 واط ولمدة تعريض 60 ثانية أذ بلغت نسب الموت 43.33، 23.33، 10، 16.33، لأدوار الحشرة على التوالي.

الكلمات المفتاحية : الأشعة المايكروية، خنفساء الطحين الحمراء *Tribolium castaneum*

[*] **The article is taken from the master's thesis of the first researcher .**

INTRODUCTION

Grains crops, especially wheat, hold great significance in global agriculture and in the lives of many people worldwide due to their connection to food security. Wheat products, including flour, constitute the primary source of nutrition for populations and provide a substantial amount of calories for human consumption (**Alonso-Amelot & Nunez, 2011**). The wheat crop production in Iraq for the year 2021 amounted to approximately 4,233,714 tons, marking a decrease of about 32% compared to the previous year's production. With a cultivated area of 9,464,225 dunums, Wasit province ranked first in terms of production, estimated at 809,645 tons, accounting for 19% of the total production. Additionally, with an area of 1,105,891 dunums **(Central Bureau of Statistics, 2021),** the process of preserving the quality of grains and their food products during the storage period faces the threat of more than 600 types of beetles, 70 types of mites, and 355 types of weevils, causing both qualitative and quantitative losses. Furthermore, these pests consume a significant quantity of grains and their products while contaminating them with their shed skins and waste, diminishing their market value (**Rajendran, & Sriranjini, 2008**) The red flour beetle, *Tribolium castaneum*, is considered one of the most important primary storage insect pests. It lives and feeds on grains, stored materials, and infested flour, causing both quantitative and qualitative losses. It also leads to a reduction in protein, starch, and various vitamins. Infested flour acquires a pungent odor due to the insect's secretions, specifically benzoquinones from the abdominal glands, which results in a decrease in dough viscosity and elasticity, rendering it unsuitable for baking and pastry making **(Rees, 2004).**

Pest control methods against storage insect pests include various approaches, including chemical methods and the use of chemical. However, the excessive use of these chemical pesticides has led to the emergence of pesticide-resistant strains, environmental pollution, damage to the ozone layer, and their impact on human and animal health **(Assie *et al.*, 2007).** Therefore, current efforts have shifted towards finding modern and environmentally friendly alternatives, such as the use pesticides of plant origin, such as powders, plant extracts, and attractive traps **(Mhemed, 2011; Falah *et al.*,2020; Shaker *et al.*, 2023; Bakhroini *et al.*, 2023; Al-Hamadani, & Falah, 2023)** and physical methods for controlling warehouse insects, including aerial disinfestation **(Sabit, 2009).** Additionally, the use of electromagnetic energy for non-ionizing radiation, such as Microwave Ray, Ultra-Violet Ray, and Infrared Ray, is being explored **(Al-Hamdani, 2016; Zwain, 2016; Tarek, 2020; ALabdi & Abood, 2020).** As a result of the above, the importance of the red flour beetle insect is evident. Therefore, the current study aimed to evaluate the efficiency of physical control using microwave radiation and its effect on the stages of the red flour beetle insect at three energy levels of 540, 810, and 1080 watts, and three exposure periods of 60, 90, and 120 seconds.

MATERIALS AND METHODS

Insect Rearing

Adult red flour beetles, *Tribolium castaneum*, were collected from infested flour obtained from one of the flour agents in Wasit Governorate, Al-Kut district. Several farms were prepared for rearing and multiplying the insects in a laboratory setting using a natural diet consisting of flour and crushed bulgur (**AL-Aadhami & Abdulla, 2015; Saad &Mahdi, 2017; Muhammad *et al.*, 2008; Al-Obaidy & Shahrabani, 2020**). For this purpose, 300 grams of

clean sterilized healthy flour were placed in clean plastic containers with a capacity of 500 grams. Prior to using the flour in the study, it had been stored in a freezer at a temperature of -7°C for two days to ensure the elimination of any infestation by pests **(Al-Jabawi, 2014; Mahmoud & Hassan, 2016).** Afterward, 10 pairs of recently emerged adult beetles (males and females) from the pupal stage were added to each container. The upper openings of the containers were covered with gauze cloth secured by an elastic band, and they were then transferred to a breeding incubator under optimal breeding conditions at a temperature of 30 ± 1 degrees Celsius and a relative humidity of 65 ± 5% **(Farah, & Yousef, 2022; Falah *et al.*, 2020; Mahmoud & Laibi, 2014; Al-Obaidy *et al.*, 2019)**.to ensure the development of all insect stages. The colonies were continuously renewed throughout the study period.

Study on the impact of Microwave Rays on biological aspects of the red flour beetle:

Three energy levels of Microwave Rays were tested, which were 540, 810, and 1080 watts. Ten individuals from each developmental stage of the red flour beetle, *Tribolium castaneum* (larvae, pupae, and adults), were treated at each energy level, with three replicates for each energy level and different exposure durations of 60, 90, and 120 seconds. Additionally, a control group (comparison) was included, representing the insect stages not exposed to radiation (dose zero). A Chinese-made microwave device with a power output of 1500 watts produced by STAR SAT, located in the Seed Technology Laboratory under the Department of Field Crops Sciences, College of Agricultural Engineering Sciences, University of Baghdad, was used for this purpose (Figure 1).

Figure (1): Microwave device.

The effect of microwave radiation on the third and fifth instar larvae of the red flour beetle *Tribolium castaneum*:

Ten from third and fifth instar larvae, each reared separately on a food medium, were selected and placed in individual plastic petri dishes with a diameter of 9 cm. The aim was to investigate the direct impact of Microwave Rays on the third and fifth instar larvae. Each ten larva was treated directly with three replicates per treatment. The larvae were then placed inside the microwave device and exposed to energy levels of 540, 810, and 1080 watts for exposure durations of 60, 90, and 120 seconds per energy level. A control treatment without exposure was also included. Subsequently, the petri dishes were removed from the device, placed in sterilized plastic containers with a diameter of 7-12 cm, and covered with a plastic lid containing 10 ventilation holes. These containers were then placed in an incubator at a temperature of 30 ± 2 degrees Celsius and a relative humidity of 70 ± 5%. The larvae were

continuously monitored and observed until they reached the pupal stage, and the percentage of mortality was calculated after 24 hours from the treatment.

The Effect of Microwave Rays on the Pupal Stage of the Red Flour Beetle, *Tribolium castaneum*:

Ten newly pupae of the red flour beetle, which were 24 hours old since pupation, were selected. These pupae were placed in petri dishes with a diameter of 9 cm, with three replicates per treatment. The pupae were then introduced into the microwave device and exposed to different energy levels as mentioned in the previous paragraph. Subsequently, the petri dishes were removed from the device and placed in sterilized plastic containers with a diameter of 7-12 cm. The dishes were covered with a plastic lid containing 10 ventilation holes. These containers were placed in an incubator at a temperature of 30 ± 2 degrees Celsius and a relative humidity of 70 ± 5%. The pupae were continuously examined and monitored until they reached the adult stage. The percentage of mortality was calculated after a period of 14 days from the treatment.

The Effect of Microwave Rays on the Adult Stage of the Red Flour Beetle, *Tribolium castaneum*:

Ten newly emerged adult red flour beetles, which were 24 hours old since emerging from the pupal stage, were selected. These adults were placed in petri dishes with a diameter of 9 cm, with three replicates per treatment. The adult beetles were then introduced into the microwave device and exposed to different energy levels as mentioned in the previous paragraph. Subsequently, the petri dishes were removed from the device and placed in sterilized plastic containers with a diameter of 7-12 cm. The dishes were covered with a plastic lid containing 10 ventilation holes. These containers were placed in an incubator at a temperature of 30 ± 2 degrees Celsius and a relative humidity of 70 ± 5%. The adult beetles were continuously examined and monitored, and the percentage of mortality was calculated after a period of 24 hours from the treatment.

Statistical Analysis

The experimental data were analyzed using the Completely Randomized Design (CRD), and the statistical program SAS (Statistical Analysis System) was employed for data analysis to study the effect of different factors on the measured traits. Significant differences between means were compared using the Least Significant Difference (LSD) test at a probability level of 0.05 to determine the statistical significance of the observed differences **(Al-Rawi, & Khalaf Allah, 2000).**

RESULTS AND DISCUSSION

The effect of Microwave Waves on the Third Instar Larvae of the Red Flour Beetle, *T. castaneum*:

The results presented in Table (1) demonstrate the impact of Microwave Waves on the third instar larvae at energy levels of 540, 810, and 1080 watts, with exposure durations of 60, 90, and 120 seconds. The highest mortality rate reached 100% at energy levels of 810 and 1080 watts, with exposure durations of 90 and 120 seconds. In contrast, the lowest mortality rate was observed at an energy level of 540 watts with an exposure time of 60 seconds, which was 43.33%. Statistical analysis revealed significant differences between the different energy levels as well as significant differences between the exposure durations. It is worth noting that the mortality rate increases with higher energy levels and longer exposure periods, which is

consistent with the findings of **Raju *et al*., (2022).** Raju indicated that increasing energy levels and exposure times lead to increased mortality rates, with a mortality rate of 96% observed in the third instar larvae of the red flour beetle, *T. castaneum*, at an energy level of 800 watts and an exposure duration of 20 seconds.

Table (1): Effect of microwaves on the third larval instar of the red flour beetle *T. castaneum.*

Energy level (watt)	Exposure times (second)			Mean
	60	90	120	
540	43.33	66.67	100.00	70.00
810	46.67	100.00	100.00	8222
1080	83.33	100.00	100.00	94.44
Mean	57.77	*88.89*	100.00	
L.S.D 0.05	Energy level = 1.11 Exposure times = 1.11			

The Effect of Microwave Waves on the Fifth Instar Larvae of the Red Flour Beetle, *T. castaneum*:

The results presented in Table (2) demonstrate the impact of Microwave Waves on the fifth instar larvae at energy levels of 540, 810, and 1080 watts, with exposure durations of 60, 90, and 120 seconds. The highest mortality rate reached 100% at energy levels of 1080 and 810 watts with exposure duration of 120 seconds. In contrast, the lowest mortality rate was observed at an energy level of 540 watts with an exposure time of 60 seconds, which was 23.33%. Statistical analysis revealed significant differences between the means of different energy levels as well as significant differences between the means of different exposure durations. These results agree with what **Al-Hamdani & Salah (2016)** found, indicating that the highest mortality rates from Microwave Waves for first and fourth instar larvae reached 100% at an energy level of 600 watts with exposure duration of 90 seconds for the grain moth, *Sitotroga cerealella*. It is noteworthy that the larvae were more sensitive to Microwave Waves compared to pupae and adults, which is consistent with the findings of **Vadivambal *et al*., (2007**), who observed that larvae were more sensitive to Microwave Waves than pupae and adults.

Furthermore, **Theeb (2018)** studied the effect of Microwave Waves on the first instar larvae of the southern cowpea weevil, *Callosobruchus maculatus*, and the results indicated that the highest mortality rate reached 100% at an energy level of 750 watts with exposure duration of 90 seconds.

Table (2): Effect of microwaves on the fifth larval instar of the red flour beetle *T. castaneum.*

Energy level (watt)	Exposure times (second)			Mean
	60	90	120	
540	23.33	46.67	90	53.33
810	46.67	90.00	100.00	78.89
1080	80.00	100.00	100.00	93.33
Mean	50.00	78.89	90.00	-- --- ---
L.S.D 0.05	Energy level = 1.44 Exposure times = 1.44			

The Effect of Microwave Waves on the pupa stage of the Red Flour Beetle, *T. castaneum:*

The results presented in Table (3) illustrate the impact of Microwave Waves on the Pupae at energy levels of 540, 810, and 1080 watts, with exposure durations of 60, 90, and 120 seconds. The highest mortality rate reached 100% at energy levels of 1080 watts and exposure durations of 90 and 120 seconds. In contrast, the lowest mortality rate was observed at an energy level of 540 watts with an exposure time of 60 seconds, which was 10%. Statistical analysis showed no significant differences between the means of different energy levels and exposure durations. These results are consistent with what **Al-Hamdani (2022)** found regarding the effect of Microwave Waves on the pupae of the southern cowpea weevil, *Callosobruchus maculatus*, at energy levels of 180, 360, 540, and 720 watts with exposure durations of 20, 30, 40, and 60 seconds, respectively. The results indicated that the highest mortality rate for pupae reached 70% at an energy level of 720 watts with a 60-second exposure, while the lowest mortality rate was 16.66% at an energy level of 180 watts with a 60-second exposure.

Additionally, **Ali (2022)** conducted a study on the effect of Microwave Waves on the pupae of the lesser grain borer, *Rhyzopertha dominica*, which revealed that the highest mortality rate reached 100% at an energy level of 620 watts with exposure durations of 60 and 90 seconds, while the lowest mortality rate was 37.1% at an energy level of 220 watts with a 30-second exposure. These findings agree with the results of **Al-Ebady (2020),** who demonstrated the effect of Microwave Waves on the pupae of the khapra beetle, *Trogoderma granary*. The highest mortality rate was 58.61% at an energy level of 800 watts with a 45-second exposure, while the lowest mortality rate was 29.17% at an energy level of 200 watts with a 15-second exposure.

Table (3): Effect of microwaves on the pupa stage of the red flour beetle *T. castaneum.*

Energy level (watt)	Exposure times (second)			Mean
	60	90	120	
540	10	16.67	36.67	21.13
810	56.67	63.33	76.67	65.56
1080	66.67	100.00	100.00	88.89
Mean	44.44	60.00	71.11	-- - ---
L.S.D 0.05	Energy level = 1.36 Exposure times = N.S			

The Effect of Microwave Waves on the Adults of the Red Flour Beetle, *T. castaneum:*

The results presented in Table (4) demonstrate the impact of Microwave Waves on the adults at energy levels of 540, 810, and 1080 watts, with exposure durations of 60, 90, and 120 seconds. The highest mortality rate reached 100% at an energy level of 1080 watts and exposure durations of 90 and 120 seconds. In contrast, the lowest mortality rate was observed at an energy level of 540 watts with a 60-second exposure, which was 16.33%. Statistical analysis showed no significant differences between the means of different energy levels and exposure durations. It is noteworthy that the mortality rate increases with higher energy levels and longer exposure durations, consistent with findings by **Zayed *et al.*, (2002),** which indicate that the effect of Microwave Waves increases with higher energy levels and exposure durations across all stages of the grain weevil, *Sitophilus granarius*.

Salih (2015) studied the effect of Microwave Waves on the adults of the lesser grain borer, *R. dominica*, and the results indicated that the highest mortality rate reached 100% at an energy level of 700 watts with a 90-second exposure. These results agree with Khalaf's findings **(Khalaf, 2021)** regarding the effect of Microwave Waves on the adults of the red flour beetle, *T. castaneum*, which showed that the highest mortality rate reached 100% at an energy level of 800 watts with a 20-second exposure, while the lowest mortality rate was 26.66% at an energy level of 200 watts with a 20-second exposure. **Meenatchi (2015)** conducted a study on the effect of Microwave Waves on the adults of both *T. castaneum* and the maize weevil, *Sitophilus zeamais*, at energy levels of 270, 360, 450, and 540 watts with exposure durations of 20, 25, and 30 seconds. The results indicated that the highest mortality rate reached 100% at an energy level of 540 watts with exposure durations of 20, 25, and 30 seconds for both insects. While, the lowest mortality rate was 76% for the red flour beetle and 40% for the maize weevil at energy level of 270 watts with a 20-second exposure.

Table (4): Effect of microwaves on the adults of the red flour beetle *T. castaneum.*

Energy level (watt)	Exposure times (second)			Mean
	60	90	120	
540	16.33	20	46.67	27.67
810	63.33	73.33	80.00	72.22
1080	73.33	100.00	100.00	91.11
Mean	50.99	64.44	75.56	-- - --
L.S.D 0.05	Energy level = N.S Exposure times = N.S			

REFERENCES

1. Al-Ebady, E. Q. (2020). Effect of food host type, exposure time in responsibility of different stage of *Trogoderma granarium* (Everts) khabra beetle to microwave radiation under storage in bags. *Mesopotamia Journal of Agriculture*, 48(1), 1-11.
2. Al-Hamadani, K. M. and & Falah, A. S .(2023). Evaluation of the Efficiency of Probe and Indicator Device traps for Catch Adults of the Cowpea weevil *Callosobruchus maculatus* Fab. (Coleoptera: Chrysomeloidea). *Kufa Journal for Agricultural Science*. 15(1): 117-123.
3. Al-Hamdani, A. H. A. T. (2016). *The Use of Some Physical and Biological Methods to Control the Wheat Moth (Sitotroga cerealella).* PH.D. Theses, College of Agriculture, University of Baghdad, Iraq.
4. Al-Hamdani, A. H. A., & Saleh, H. A. M. (2016). Laboratory studies on the effect of microwave radiation on the grain moth *Sitotroga cerealella*. Oliver (Lepidoptera: Gelechiidae). *Al-Muthanna Journal of Agricultural Sciences*, 4(2), 1-8.
5. Al-Hamdani, K. M. R. H. (2022). *Effectiveness of Some Physical and Biological Control Methods against the Southern Cowpea Beetle Callosobruchus maculatus (F.) (Coleoptera: Chrysomelidae) on beans. Vicia faba L*. MSc. Theses, College of Agriculture, University of Baghdad, Iraq.
6. Alabdi, A. M. D. & Abood, S. ch.(2020). Microwave-Assisted Extraction Of Inulin From Jerusalem Artichoke And Partial Acid Hydrolyses. *Iraqi Journal of Agricultural Sciences*.v. 51(1):401-410.
7. Al-Aadhami, L. H. & Abdulla, L. M. (2015). The Effectiveness of Hermetic Storage Method In The Population Groups Numbers Of The Red Flour Beetle Tribolium castaneum AND Some Properties Of Stored Grain. *Iraqi Journal of Agricultural Sciences*.v. 46(5): 832-840.
8. Ali, A. M. (2022). Physical control of the Lesser Grain Borer *Rhyzopertha dominica* (Coleoptera: Bostrychidae) using various microwave levels. *Journal of Kerbala for Agricultural Sciences*, 9(2), 70-77.
9. Al-Jabawi, R. K. M. K. (2014). *Testing The Effect of Some Safe Technologies on Some Aspects of the Life Performance of the Rusty Red Flour Beetle Tribolium castaneum and its Associated Fungus Aspergillus flavus (Coleoptea: Tenebrionidae).* MSc. Theses, College of Agriculture, University of Kufa, Iraq.

10. AL-Obaidy, S.H. & Shahrabani, S.M. (2020). Biology of cigarette beetle *lasioderma serricorne* (f.) (coleoptera: Anobiidae) on baker's yeast saccharomyces cerevisiae. *Plant Archives*, 20(1), pp. 1650-1652.
11. AL-Obaidy, S.H., Shahrabani, S.M. & Hamodi, A.A.-F. 2019. New record of anisopteromalus calandrae. (howard, 1881) (hymenoptera: chalcidoidea: pteromalidae) as parasitoid of the cigarette beetle, lasiodermaserricorne (f.) (coleoptera: anobiidae*) Plant Archives,*19(1), pp. 292-294.
12. Alonso-Amelot, J. L., & Nunez, A. (2011). Comparison of seven methods for stored cereal losses to insects for their application in rural conditions. *Journal of Stored Products Research*, 47(2), 82-87.
13. Al-Rawi, K. M., & Khalaf Allah, A. A. M. (2000). *Design and analysis of agricultural experiments.* Dar Al-Kutub for Printing and Publishing, College of Agriculture and Forestry, University of Al Mosul, Ministry of Higher Education and Scientific Research, Iraq.
14. Assie, L. K., Francis, F., Gengler, N., & Haubruge, E. (2007). Response and genetic analysis of Malathion-specific resistant *Tribolium castaneum* (Herbst) in relation to population density. *Journal of Stored Product Research*, 43(1), 33.
15. Bakhroini, H.; Suharto, S.; Wagiyana, W.; Mohammad, H.; Mochammad, W. J.; Sigit, P.; Ankardiansyah, P. P.; Anggi, A. H. N. & Fariz, K. A. 2023. Toxicology of Nuclear polyhedrosis virus, Botanical and Synthetic pesticides on Mortality Rate of *Crocidolomia binotalis* (Zeller). *Baghdad Science Journal* .20(1):17-25.
16. Central Bureau of Statistics. (2021). *Wheat and barley production for the year 2021.* Directorate of Agricultural Statistics, Ministry of Planning, Republic of Iraq, 19.
17. Falah, A. S.; Nareman, R. & Ather, A. (2020). Effect of some plant powders in larvae stage of hairy grain beetle *Trogoderma granarium* (Evest) (Coleoptera: Dermestidae). *Plant Archives* .20(1):1355-1358.
18. Falah, A. S.; Nareman, R. & Ather, A. (2020). Effect of some plant powders in larvae stage of hairy grain beetle *Trogoderma granarium* (Evest). (Coleoptera: Dermestidae). *Plant Archives* .20(1):1355-1358.
19. Farah, H.A. & Yousef, D. R. (2022). Evaluation of the in vitro efficacy of Copparis spinose L. Alcoholic extract in controlling the Hairy Grain Beetle (Khabra) *Trogoderma granarium* (Everts). (Coleoptera: Dermestidae). *Earth and Environment Science.* 1060:12109.
20. Khalaf, J. M. (2021). The use of some insecticides and microwave technology to combat the red rusty meal beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). *Al-Muthanna Journal of Agricultural Sciences*, 8(2), 36-47.
21. Mahmoud, I. A. & Tabarak, A.H. (2016). The effect of the crude alkaloid extract of Cordia myxa leaves in controlling the fourth instar of the lesser grain boring beetle *Rhyzopertha dominica* (F) (Coleoptera: Bostrichidae). *Iraqi Journal of Market Research and Consumer Protection*. 8(1): 138-146.
22. Mahmoud, I.A. & Laibi, W. R. (2014). The effect of alcoholic extract concentrations of terpenes, flavonoids and alkaloids of the seeds of the Calgan plant (Silybum marianum) in controlling the larvae of the lesser grain borer beetle (Rhyzopertha dominica (Fab (Coleoptera: Bostrichidae*). Iraqi Journal of Market Research and Consumer Protection. 6* (2): 106 - 121.

23. Meenatchi, R., Brimapureeswaran, R., & Sujeetha, A. R. P. (2015). Disinfestation of stored maize using microwave energy and its effect on quality. *Bioscience Trends*, 8(8), 1968-1974.
24. Muhammad, A. M., Korkis, N. S., & Ismail, A. Y. (2008). The biological effect of a number of aquatic plant extracts on the rusty flour beetle Tribolium castaneum (Herbst) and the khabra *Trogoderma granarium*(Everts). *Journal of Basic Education College Research*, 7(4), 300-316.
25. Mhemed, A. J. (2011). The Efficacy of Four Seed Powders On Some Biological Aspects And Mortality Of Khapra Beetle. *Iraqi Journal of Agricultural Sciences*. 42 (6) :112 – 123.
26. Rajendran, S., & Sriranjini, V. (2008). Plant products as fumigants for stored-product insect control. *Journal of Stored Products Research*, 44(2), 126-135.
27. Raju, S., Chellappan, M., Bhaskar, H., & Sudheer, P. (2022). Susceptibility of life stages of *Tribolium castaneum* (Herbst) to microwave radiation. *Indian Journal of Entomology*. https://doi.org/10.55446/ IJE.2022.521.
28. Rees, D. (2004). *Insects of Stored Products.* CSIRO Publishing.
29. Sabit, F. A. (2009). *Laboratory Studies on the Use of Heat and Air Discharge in Combating the Hairy Grain Beetle (Khabra), Trogoderma granarium (Everts).* MSc. Theses, College of Agriculture, University of Baghdad, Iraq.
30. Salih, A. B. (2015). *The Use of Some Physical Agents and the Fungicide Isaria Fumosoroseus in Controlling the Lesser Grain Borer Rhyzopertha dominica (F.) (Coleoptera: Bostrichidae).* MSc. Theses, College of Agriculture, University of Kufa, Iraq.
31. Saad, M. T. & Mahdi, K.H. (2017). Using Mixed Gamma and Ultraviolet Radiation for Disinfestiation Of Iraqi Dates Fruit From Ephestia Cautella. *Iraqi Journal of Agricultural Sciences*. (5) 48: 1331-1330.
32. Shaker, S. R.; Hakeem, I. M. & Lilo, H. M. (2023). Evaluation the efficacy of some plant extracts in behavioral and biological response of Khapra beetle *Trogoderma granarium* (Everts) (Coleoptera: Dermestidae). *Iraqi Journal of agricultural Sciences*. v.26(1):56-71.
33. Tarek, A.M. (2020). Biological effect of microwave ray energy's on Khapra Beetle *Trogoderma* granirium . *Indian Ecological Society*.14 (19).
34. Theeb, M. T. (2018). *The Use of Some Physical Agents in Controlling the Southern Cowpea Beetle. Callosobruchus maculatus (Coleoptera: Chrysomelidae).* MSc. Thesis, College of Agriculture, University of Baghdad, Iraq.
35. Vadivambal, R., Jayas, D. S., & White, N. D. G. (2007). Wheat disinfestation using microwave energy. *Journal of Stored Products Research*, 43, 508-514.
36. Zayed, Y. M., Al-Mabrouk, A. H. H., & Muhammad, S. A. R. (2002). A preliminary study on the effect of microwave radiation on the wheat weevil *Sitophilus granarius* (L.) (Coleoptera: Curculionidae). *Arab Plant Protection Journal*, 20, 14-17.
37. Zwain, L.A. H. (2016). The effect of using microwave radiation in some food and laboratory applications. *Iraqi Journal of Market Research and Consumer Protection*. 8 (2):41-52.