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Effect of mutagenic ultraviolet radiation on adult *Monosteira buccata* Horv. (Hemiptera: Tingidae) isolated from poplar trees in Nineveh Forest

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Abstract

Objective

Physical agents especially the ultraviolet radiation have become a viable option in the control of insect pests. It has been found to have negative impacts on insects, causing direct DNA damage such as the formation of pyrimidine dimers, and provoking oxidative stress and subsequent dysfunction, reduced survival and cell death. The aim of this study was to estimate the effect of the ultraviolet radiation in the control of the poplar bug and also assess its efficacy as an alternative or supplement to conventional pesticides.

Materials and methods

In this study, adult *M. buccata* insects were collected from poplar leaves. After that, they were stored in sterile glass bottles and then transferred to the entomology laboratory of the University of Mosul. The toxicity of Finch insecticide at three concentrations (25, 50 and 100%) was investigated by leaf immersion method and placing 10 insects per Petri dish. The effect of ultraviolet radiation with a wavelength of 254 nm was also evaluated at different times. Finally, the synergistic effect of ultraviolet radiation and insecticide on insect mortality was also measured.

Results

Insect mortality increased with increasing insecticide concentration with the mortality rate increasing with the 25% concentration up to 100% concentration to 55.5 and 95.5 % respectively. The exposure times to UV have an important effect on the rising mortality. The mortality rate was 48% at an exposure time of five minutes to 100 at the exposure time of 20 minutes. This shows the enhancing effect of UV radiation in the toxicity of the insect. In addition, the synergistic effect of the UV radiation versus the chemical insecticide Fentanol in 100 % concentration exhibited a complete synergy as the adult insects' poplar bugs were found to be completely dead at 15 minutes and 20 minutes of exposure. All these findings demonstrate that treatment by physical agents like

UV radiation in combination with chemical agents enhances the control efficacy, reduces the dosage of pesticides required.

Conclusion

It can be concluded that the use of Finch pesticide, especially when combined with ultraviolet radiation, represents a promising option within integrated pest management programs and has a great potential in decreasing the density of the adult insects (poplar bug) *Monosteira buccata*.

Keywords: insecticide, *Monosteira buccata*, mutagenic, pest control, ultraviolet radiation

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Introduction

Poplar trees are forest trees belonging to the willow family (Salicaceae) that are widespread in the northern and central regions of Iraq. They are important in most countries of the world because they are fast-growing, very fond of light, and are characterized by their ability to tolerate growth in hot, dry climatic conditions (Cotrina Cabello *et al.*, 2023). In addition to their numerous economic, medical, and environmental benefits, their wood is used in the manufacture of wood chips, and their leaves are good fodder for animals. They also play a role in protecting and stabilizing the soil on the banks of rivers and streams (Esperschuetz and Bloomberg, 2022). Poplar trees are exposed to many bacterial, fungal, and insect pathogens that lead to a reduction in annual growth and consequently economic losses that reduce their commercial value, such as the poplar bug *M. buccata*, which feeds on the plant sap found in the leaves. As the infection progresses and the number of adult insect's increases, the trees lose their leaves and their metabolic processes decline, leading to the cessation of their growth and their death, which makes controlling them a continuous challenge (Heckel, 2012). For decades, pest control programs have relied on chemical pesticides as the most common and effective means of reducing insect populations. Although these pesticides have been somewhat successful in controlling the infestation, their excessive and extensive use has also caused a lot of issues such as insect resistance to pesticides, environmental

pollution, and adverse effects on human health and non-target organisms. Such issues have stimulated the researchers to find safer and more sustainable options (Li et al., 2007). In this regard, physical agents especially the ultraviolet radiation have become a viable option in the control of insect pests. It has been found to have negative impacts on insects, including direct damaging of DNA, including by a form of pyrimidine dimers, and provoking oxidative stress and subsequent dysfunction, inability to survive or death of cells (Rastogi et al., 2010; Cadet et al., 2015). It may also be used together with other forms of control in the context of integrated pest management, which will decrease dependence on chemical pesticides and contain their adverse impact on the environment. According to this, this paper will estimate the impact of the ultraviolet radiation in the control of the poplar bug and also illustrate its efficacy as an alternative or supplement to conventional pesticides.

Materials and methods

Collection and rearing of *M. buccata*: Adult *M. buccata* were collected and placed in clean glass bottles (25 cm high and 12 cm in diameter, containing fresh poplar leaves). The bottles were covered with a cotton cloth to prevent the insects from escaping and to ensure ventilation, and were secured with a rubber band and kept until the experiments were conducted. The collected insects were then transferred to the Entomology Laboratory, Department of Life Sciences, College of Science, University of Mosul, Iraq.

Laboratory bioassay of the insecticide Finch in *M. buccata* adult insects: The toxicity of the insecticide Finch (100%, pyrethroid group) from the pyrethroid group at three different concentrations (25%, 50%, and 100%) was conducted. A leaf was dipped in the insecticide solution for 30 s, and after dipping, the leaf was allowed to dry in a 9 cm diameter Petri dish. Ten adult *M. buccata* were placed in each Petri dish, which was covered with a piece of muslin cloth secured with a rubber band. The control treatment consisted of leaves treated with distilled water. Three replicates were used for each tested concentration. The dishes were kept in the laboratory at a temperature of $22 \pm 3^\circ\text{C}$ and a relative humidity of $41 \pm 3\%$. After 24 hours of treatment, the mortality rate was determined using the following equation (Abbott, 1925).

$$\text{Corrected mortality (\%)} = \frac{(\text{Treatment mortality} - \text{Control mortality})}{(100 - \text{Control mortality})} \times 100$$

The mutagenic effect of short-wavelength ultraviolet radiation on the mortality *M. buccata* adult insects: The irradiation process was carried out in a dark chamber according to the method of Sabockytè et al. (2023). Ten poplar bug adult insects were placed in a clean, sterile Petri dish, with three dishes per treatment. They were exposed to ultraviolet light after removing the cover from a lamp emitting a wavelength of 254 nm, with the distance between the lamp and

the dish surface being 20 cm. Five time periods (0, 5, 10, 15, and 20 minutes) of irradiation, as well as a control treatment (no irradiation), were also done. The dish was then irradiated and after the irradiation time, the dish was taken out and covered with aluminum foil and kept in darkness for one hour to avoid photoreactivation. Each dish was supplied with water-moistened filter paper and fragments of poplar leaves. The dish was covered with muslin cloth using a rubber band and left at the laboratory temperature. The percentage of fatalities after 7 days, the number of survivors and the percentage of survivors were determined using the following equations:

$$\text{Survival (\%)} = (\text{Number of surviving insects} / \text{Total number of insects}) \times 100$$

$$\text{Mortality (\%)} = 100 - \text{Survival (\%)}$$

Synergistic effect between ultraviolet radiation and the chemical pesticide Finch on *M. buccata* adult insects: Ten poplar adult insects were placed in a clean, sterile Petri dish (3 dishes/treatment) and exposed to ultraviolet radiation after removing the cover from a lamp emitting 254 nm wavelength. The distance between the lamp and the dish surface was 20 cm. Irradiation was carried out for five time periods (0, 5, 10, 15, and 20 minutes), in addition to a control treatment (no irradiation). The dish was then taken out after the required irradiation time was taken and covered with aluminium foil and allowed to stay in darkness after which the dish was not to be exposed to sunlight to avoid reactivating of photos. After irradiation, the insects were treated with the insecticide solution. Each Petri dish was fed with a water-moistened piece of filter paper and the pieces of poplar leaves. It was bounded with a cotton cloth using a rubber band and then left it at laboratory temperature. The percentage of mortality, the number of surviving insects and the percentage of survivors were calculated after 7 days using the following equations (Sabockyté et al., 2023):

$$\text{Survival (\%)} = \frac{\text{Number of surviving insects after treatment}}{\text{Total number of insects per dish}} \times 100$$

$$\text{Mortality (\%)} = 100 - \text{Survival (\%)}$$

Results and discussion

In vitro bioassay of the insecticide Finney in *M. buccata* adult insects: Efficacy evaluation of Finney against adult insects *M. buccata* insects presented decisively positive correlation between the concentration of the insecticide and the mortality with the mortality rates ranging between 55.5 at 25 % insecticide concentration and 95.5 % insecticide concentration (Table 1). These findings are a clear indication that the efficacy of insecticides directly depend

on the dosage applied, which is usually the trend with the toxicity response of insects to chemical pesticides (Finney, 1971). The 95.5 % mortality rate at the highest concentration is indicative of good to high efficacy of the insecticide on poplar bug adult insects but the low rate of survival implies that the highest dose could not lead to full elimination. This can be explained by the fact that there may be physiological or genetic differences between the members of the insect population, including variations in the efficacy of the pesticide intake or activity of the detoxification enzymes, including cytochrome P450 and carboxyesterase, which are important in lowering the endotoxin toxicity of the pesticides (Li et al., 2007). On the other hand, the lethality rate of 55.5% at the concentration of 25 % is quite small, which means that this concentration cannot effectively control the population of adult insects and population can still exist to replenish the population density at a later time. Research indicates that application of low doses can become a cause of faster resistance development of insecticides (Heckel, 2012). Based on the set standards in terms of assessing the effectiveness of pesticides, a lethality rate of 70 and above is deemed to be acceptable, whereas a rate above 90 is viewed as high effectiveness (Dritz et al., 2025). Thus, a 100 % concentration of Finch insecticide is in the range of high efficacy, which is less in the range of moderately effective. It means that the efficiency of controlling can be enhanced by raising the concentration to the recommended level, re-treating, or integrating the insecticide with other strategies in an integrated pest management (IPM) system (Thirawut et al., 2023). Therefore, the existing findings validate the assumption that Finch insecticide possesses a good capacity to decrease the density of poplar bug adult insects. Nevertheless, it might not be enough to ensure full control by using it and it is necessary to combine it with other pest management tools that will help to minimize the risk of developing the resistance and will guarantee its effectiveness in the long term.

Table 1. Effect of the insecticide Finch on the mortality percentage of adult *M. buccata* insects

Pesticide concentration (%)	Treatment	Number of insects	Mortality (%)
25	Control	10	55.56
25	Finch	10	60
50	Control	8	75
50	Finch	8	77
100	Control	9	95.5
100	Finch	9	95

The Mutagenic Effect of Short-Wave Ultraviolet Radiation on *M. buccata* adult insects:

Table 2 shows a clear positive correlation between the duration of UV exposure and the percentage of insect mortality. The death rate rose to 100 % at 20 minutes since it was 48 % at the 5 minutes exposure time. This finding suggests that time is an important factor in the accumulation of detrimental biological impacts of UV radiation. The more time of exposure, the higher the absorbed dose of radiation, and therefore multiple cellular and molecular damage. UVC radiation (200-290nm) is one of the most harmful forms of radiation to genetic material (Sage, 1993) because it is high energy which does not only alter the DNA structure but also causes an immediate alteration. This kind of radiated material is highly absorbed by purine along with pyrimidine bases, particularly thymine and cytosine creating an external factor that causes the electrons to be excited and go to higher energy levels. The molecules get into a condition of chemical instability and pyrimidine dimers are produced particularly thymine dimers (T=T). Amongst some of the most eminent molecular damages caused by exposure to ultraviolet radiation is that these dimers result in the distortion of the helical structure of DNA and inhibition of the actions of replication and transcription enzymes. In case cellular repair mechanisms, e.g. nucleotide excision repair, fail to do so, the damage or the damage can be permanent mutations and that can be fatal to the cells or even minuscule organisms like insects. This is why the higher the exposure time the higher the mortality rate becomes. Besides the direct impact on DNA, the ultraviolet radiation provokes the generation of reactive oxygen species (ROS), or free oxygen radicals. Even though such radicals are generated in cells at lower concentrations and are exposed to an antioxidant system, ultraviolet radiation exposure causes generation of quantities that are beyond the capacity of the cell to neutralize them. This results in oxidative stress, leading to oxidation of nitrogenous bases, breaks in DNA strands, and damage to proteins and membrane lipids, which accelerates cell death and enhances the lethal effect of radiation (Venitt and Parry, 1984). Ghanem and Shamma (2007) found that treating the eggs of the hairy grain beetle *Trogoderma granarium* with ultraviolet radiation damaged the egg placenta, leading to leakage of the egg's internal contents. Faruki *et al.*, (2007) found that when treating 1, 2, and 3 day-old eggs of the southern cowpea weevil *C. maculatus* with 254 nm ultraviolet radiation, older eggs were more sensitive to the radiation than younger eggs.

The Synergistic Effect Between Ultraviolet Radiation and the Chemical Pesticide Fentanol in mortality of *M. buccata* adult insects: Table 3 shows that the interaction between ultraviolet radiation and the chemical pesticide Fentanol at a concentration of 100% resulted in a significant increase in the mortality intensity of poplar bugs, reaching 100% at exposure times of 15 and 20 minutes. This finding shows that there are the synergetic action of ultraviolet radiation and the pesticide, which increases with time of exposure. This depends on the findings of Rastogi

et al., (2010) on the cumulative effect of the ultraviolet radiation on the living organisms. Excessive exposure or the excessive amount of the mutagenic agent causes the death of the cells that are exposed.

Table 2. Effect of UV radiation exposure time on mortality of adult *M. buccata*

UV exposure time (min)	Number of insects	Surviving insects (%)	Mortality (%)
Control	25	100	0
5	12	52	48
10	8	32	68
15	3	12	88
20	0	0	100

The higher lethality is due to the molecular injury by ultraviolet radiation of insect cells resulting in the development of pyrimidine dimers of DNA, especially thymine dimers. It leads to the deformation of the DNA helix and disrupts replication and transcription (Cadet et al., 2015). Moreover, UV radiation causes the formation of reactive oxygen species (ROS), leading to the occurrence of oxidative stress, such as the destruction of DNA, proteins, and lipids of the membrane (Wei et al., 2024; Obaida and Ramadan, 2020). Conversely, the insecticide fentol blocks acetylcholinesterase enzyme within the insect nervous system and consequently causes development of acetylcholine and a neurological imbalance that eventually kills the insect (Tomizawa and Casida, 2005). The reaction between this insecticide and ultraviolet (UV) radiation causes cell membranes and the cuticle layer damage that raises the insect permeability to the insecticide, raising the rate of absorption, and biotoxicity (Rastogi *et al.*, 2010). Also, recent researchers note that UV radiation suppresses the activity of insect detoxification enzymes, including cytochrome p450 and Glutathione-S-transferase, which lowers the efficacy of insects to metabolize and excrete pesticides and increases the persistence of pesticides in the active form in the insect body (Li et al., 2007). This inhibition is part of the explanation of the accomplishment of full mortality rates during relatively short exposure times as recorded at 15 and 20 minutes. The outcome of the interaction between the ultraviolet radiation and the chemical pesticide of achieving 100% mortality rate is an expression of the combination of the genetic and oxidative action of the radiation and the acute neurological activity of the pesticide that is in line with the concept of synergy between physical and chemical factors in integrated pest management programs (Heckel, 2012). The findings affirm that it is possible to invest in such interaction to decrease the doses of used pesticides and still achieve control effectiveness.

Table 3. Combined effect of UV radiation and Fentanol on mortality of adult *M. buccata*

UV exposure time (min)	Number of insects	Surviving insects (%)	Mortality (%)
Control	25	100	0
5	7	28	72
10	4	16	84
15	0	0	100
20	0	0	100

Conclusion: The results of the experiment indicate that the insecticide Finch is very efficient against adult poplar bugs and the mortality rate indicates a definite increasing trend with the concentration of the insecticide and the period of UV exposure. Moreover, the combined with the chemical insecticide in 100% concentration led to the complete mortality of adult insects which implied that there was a powerful synergistic effect. Thus, it is possible to recommend the combination of the insecticide with physical agents as a strategy within integrated pest management (IPM) programs to increase the efficiency and minimize the possibility of resistance development.

Author contributions

S. T. F. designed the study, performed the experiments, analyzed the data and wrote the paper.

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Data Availability

The data that contributes to the results of this study is provided by the researcher responsible for the request.

Ethical Considerations

No human or animal participants were used in this study. All laboratory procedures were performed according to standard guidelines.

Conflict of Interest


The authors declare that there is no competing interest.

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اثر تابش اشعه ماوراء بنفش جهش‌زا بر حشرات بالغ *Monosteira buccata* Horv. جمع‌آوری شده از درختان صنوبر در جنگل‌های نینوا (Hemiptera: Tingidae)

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چکیده

هدف: عامل‌های فیزیکی، به ویژه تابش اشعه ماوراء بنفش (UV)، به گزینه‌ای مؤثر در کنترل آفات حشرات تبدیل شده‌اند. این اشعه می‌تواند اثرات منفی مستقیم بر حشرات، از جمله آسیب DNA مانند تشکیل دیم‌های پیریمیدین، تحریک استرس اکسیداتیو و کاهش عملکرد سلولی، بقای کمتر و مرگ سلولی داشته باشد. هدف این مطالعه ارزیابی اثر تابش UV در کنترل حشره *Monosteira buccata* و بررسی اثربخشی آن به‌عنوان جایگزین یا مکمل سموم شیمیایی بود.

مواد و روش‌ها: حشرات بالغ *M. buccata* از برگ‌های صنوبر جمع‌آوری شدند و در بطری‌های شیشه‌ای استریل نگهداری شدند، سپس به آزمایشگاه حشره‌شناسی دانشگاه موصل منتقل گردیدند. سمیت سم حشره‌کش Finch در سه غلظت ۲۵، ۵۰ و ۱۰۰ درصد با روش غوطه‌وری برگ و قرار دادن ۱۰ حشره در هر پتری دیش بررسی شد. اثر تابش UV با طول موج ۲۵۴ نانومتر در زمان‌های مختلف نیز ارزیابی شد. نهایتاً، اثر هم‌افزای تابش UV و حشره‌کش بر مرگ و میر حشرات نیز سنجیده شد.

نتایج: مرگ و میر حشرات با افزایش غلظت سم افزایش یافت، به طوری که نرخ مرگ و میر از ۵۵/۵ درصد در غلظت ۲۵ درصد تا ۹۵/۵ درصد در غلظت ۱۰۰ درصد رسید. زمان‌های تابش UV تأثیر مهمی بر افزایش مرگ و میر داشت؛ به طوری که مرگ و میر ۴۸ درصد در ۵ دقیقه و ۱۰۰ درصد در ۲۰ دقیقه مشاهده شد. این نشان‌دهنده اثر تقویت‌کننده UV در سمیت حشره است. علاوه بر این، اثر هم‌افزا در ترکیب تابش UV و حشره‌کش Fentanol در غلظت ۱۰۰ درصد کامل بود. حشرات بالغ *M. buccata* در ۱۵ تا ۲۰ دقیقه کاملاً کشته شدند. این نتایج نشان می‌دهد که استفاده ترکیبی از عوامل فیزیکی مانند UV و عوامل شیمیایی، کارایی کنترل را افزایش داده و میزان مصرف سموم را کاهش می‌دهد.

نتیجه‌گیری: می‌توان نتیجه گرفت که استفاده از سم Finch، به‌ویژه در ترکیب با تابش UV، یک گزینه مؤثر و امیدوارکننده در برنامه‌های مدیریت یکپارچه آفات است و پتانسیل بالایی در کاهش جمعیت حشرات بالغ *Monosteira buccata* دارد.

کلمات کلیدی: تابش ماوراء بنفش، جهش‌زا، حشره‌کش، کنترل آفات، *Monosteira buccata*

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