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Comparative Evaluation of Green Pesticides Techno Oil and Berna Star vs. Malathion: Impact on Contact Toxicity, Reproduction, and Antifeedant Activity in *Trogoderma granarium* Everts (Fam: Dermestidae)

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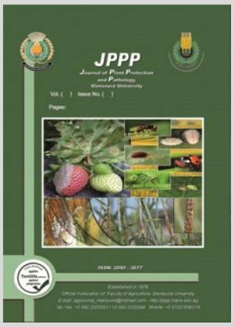

ABSTRACT

Regarding to growing environmental concerns and the need for sustainable pest management strategies, the evaluation of alternative pest control agents assumes critical significance. This study investigates the impact of two environmentally friendly green pesticides, Techno oil and Berna star, on the Khapra beetle (*Trogoderma granarium*), a notorious pest of stored grains, in comparison to the conventional chemical pesticide, Malathion. The contact toxicity revealed that all tested compounds exhibited significant efficacy against Khapra beetles. For adults Malathion had the strongest effect with LC_{50} of 0.91 mg/kg followed by techno oil and Berna star with LC_{50} values 2369.2 and 3486.8 mg/L, respectively after 48 h of exposure using thin film technique. Contact toxicity of tested pesticides increased as the exposure time increased. All tested compounds reduced F_1 progeny of Khabra beetle. Techno oil had the highest reduction effect on adults of khabra beetles with 100% reduction at a concentration of 5000 mg/kg, while Berna star and Malathion achieved 71.25% reduction at concentrations of 5000 mg/kg and 8 mg/kg, recpectively. For weight loss percentages, Malathion application resulted in 3.40% weight loss at the highest concentration (8 mg/kg), followed by Techno oil with 6.80% at the highest concentration of 5000 mg/kg, while Berna star application resulted in 8.10% weight loss in grain weight at the same concentration of Techno oil. This study provides valuable insights into the effectiveness of green pesticides as viable alternatives to chemical pesticides in the context of Khapra beetle control.

Keywords: Stored-product insects; integrated pest management; *Trogoderma granarium*; contact toxicity; antifeedant activity

INTRODUCTION

Trogoderma granarium, commonly known as the Khapra beetle family Dermestidae, is a highly destructive pest for stored grains and cereals. . This beetle is of significant concern due to its ability to cause extensive damage to stored food products, as well as its resistance to many control measures (Athanassiou *et al*., 2019). What sets Khapra beetles apart is their ability to survive for long periods without food, their resistance to many pesticides, and their capability to tolerate adverse environmental conditions. These factors make them extremely difficult to be controlled once they infest stored products or storage facilities (Athanassiou *et al*., 2016; Kavallieratos and Boukouvala, 2019). Integrated Pest Management (IPM) strategies are often recommended, which may include fumigation, heat treatments, physical barriers, and good sanitation practices (Khalique *et al*., 2018; Lucchi and Benelli, 2018).

Malathion is an organophosphate insecticide that has been widely used for the control of various insect pests in agriculture, public health, and residential settings. It's one of the many chemical compounds developed to target and control pest populations, such as the Khapra beetle (Selmi *et al*., 2018). The loss of certain species can have cascading effects throughout the food chain. Over time, some insect populations have developed resistance to malathion and other organophosphate insecticides (Jensen and Whatling, 2010). As sequence of the previous reasons there is a real need to test alternative pest management strategies and the development of new pesticides with different modes of action. Due to concerns about the potential risks associated with malathion and other chemical pesticides, there has been growing interest in the use of integrated pest management (IPM) approaches that incorporate a combination of biological, cultural, and chemical control methods (Nair, 2013). This can help reduce the reliance on chemical pesticides and promote more sustainable pest management practices.

These types of pesticides aim to address the concerns associated with conventional pesticides, such as pollution, toxicity, and the development of resistance in pest populations (Bohinc *et al*., 2020).

Various studies have focused on the use of plant essential oils for pest control. Vegetable oils include oils extracted from plant seeds, leaves, stems or flowers. They contain fatty acids and other lipids. Other common fatty acids in vegetable oils are palmitic, steric, linoleic, and oleic acids (Abouelatta *et al*., 2022).

The objective of this paper focused on the study of the effect of two green pesticides, Techno oil and Berna star, on the contact toxicity, reproduction, and antifeedant activity of the *T. granarium* compared to the chemical pesticide Malathion, determining their respective abilities to induce mortality and the lethal concentrations required for effective control.

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MATERIALS AND METHODS

Source of Khapra beetle

Adults of Khapra beetle (*Trogoderma granarium* Everts) (Fam: Dermestidae) (Order: Coleoptera) were provided by the Department of Stored Product Pests, Plant Protection Institute, Sakha, Kafr El-Sheikh, Egypt.

Rearing Khapra beetle

Wheat grains utilized to rear adult *T. granarium* were subjected to a 50 °C heat treatment for six h, aiming to eliminate any potential prior insect infestations. A 125 g of wheat grains was introduced into a 500-mL glass jar, followed by the introduction of 100 *T. granarium* adults into the same jar. Maintaining consistent conditions, all jars were housed at a temperature of 30±2 °C, relative humidity of 65±5%, and adhered to a light-dark photoperiod of 16:8 hours. Newly emerged adults (1-3-day-old) were gathered by sifting through the diet. The adult insects, which were utilized for all bioassays, encompassed a mix of both sexes.

Sources of used pesticides

In the present study, two green pesticides (bio-insecticides) were evaluated for their efficiency to control *T. granarium* adults.

echno oil

Techno oil is an effective vegetable oil as acaricide and pesticide (Esmail *et al*., 2020). It is also a non-ionic surfactant bio-activator, as well as a water source extracted from a plant source used for agricultural and chemical purposes. Techno oil eliminates insect barriers and fungi (Abouelatta *et al*., 2022), and it contains glutamic acid (El-Khiat *et al*., 2016). Techno oil was purchased from the StarChem Industrial for Chemical (Wellford, South Carolina, USA)

Berna star

Berna star is a plant extract (mainly, coconut fruit core, avocado fruit seed, plant sulfuric components, water, amino acids, proteins, phenols, and antioxidants). It was bought from the Shoura Industrial for Chemical (Cairo, Egypt)

Malathion (50%)

Malation is a chemical pesticide and was bought from Kafr Elzayat Company (Kafr El-zayat, Gharbeya, Egypt)

Contact toxicity

To assess the lethal or harmful effects of green pesticides or Malathion pesticide on Khapra beetles through direct contact two tests were used.

Residue-on-glass test (Thin film)

According to (Abo Arab *et al*., 2020), four different concentrations (i.e., 5,000, 10,000, 15,000, and 20,000 mg/L) of Techno oil and Berna star and three different concentrations (i.e., 2, 4, 6 and 8 mg/L) of Malathion were prepared suing water as a solvent. The contact toxicity test was conducted on films created by evenly spreading a one-mL portion of each concentration on the surface of a 9-cm-diameter petri dish, allowing them to air dry. Once all moisture had evaporated, ten sexually indistinct adult *T. granarium* were introduced into each treated petri dish. An equal number of insects were also placed in petri dishes treated solely with water, serving as the control group. Three replicates of both the treatment and control were established. The mortality rate was documented after 24 and 48 hours of exposure and adjusted using Abbott's formula (Abbott, 1925).

Mixing with medium test of contact toxicity

Based on preliminary experiments, four distinct concentrations (625, 1250, 2500, and 5000 mg/kg) of Techno oil and Berna star, as well as four different concentrations (2, 4, 6, and 8 mg/kg) of Malathion, were prepared by dissolving them in water. These solutions were then combined with 20 g of wheat grains. One mL of each prepared concentration was thoroughly mixed with the wheat grains in glass jars using a rotary shaker for 15 min, ensuring the uniform distribution of the oil onto the wheat grains. It's essential to ensure that the water evaporates before introducing the insects (Hashem *et al*., 2018). Subsequently, ten unsexed adult *T. granarium* were individually placed into glass jars, each sealed with its screw cap. As a control, separate jars were treated with water exclusively. Each treatment and control group was replicated three times. The mortality rates were observed and recorded at intervals of 24, 48, 72, and 96 h from the start of the exposure. The recorded mortality data were adjusted using Abbott's formula (Abbott, 1925) to account for any discrepancies.

Effect on progeny

An experimental setup was established within a laboratory setting to assess the impact of the tested toxic substances on the offspring of *T. granarium* according to (Ndomo *et al*., 2008). Small jars containing 50 grams of wheat grains were utilized, and these grains were subjected to treatment with varying concentrations of toxicants at a rate of 5 mL per jar. Specifically, Techno oil and Berna star were tested at concentrations of 625, 1250, 2500, and 5000 mg/kg, while Malathion was tested at concentrations of 2, 4, 6, and 8 mg/kg. To initiate infestation, each jar was populated with 20 adult Khapra beetles. These jars were then placed within an incubator set to maintain a temperature of 30±1ºC and a relative humidity of 65±5%. The untreated wheat grains served as the control group. The experimental treatments (both treated and control) were replicated three times. Following a span of one week, all initially released insects from the jars were eliminated. The subsequent emergence of new adult beetles was tracked over a two-week period. The extent of reduction was calculated as a percentage and was determined using the following equation:

% Reduction =

$$\frac{\text{number of newly emerged insects in the control} - \text{number of newly emerged insects in the treatment}}{\text{number of newly emerged insects in the control}} x100$$

Antifeedant activity

The antifeedant properties of Techno oil, Berna star, and Malathion were assessed following the methodology described by (Chaubey, 2012). In brief, 20 g of wheat grains were thoroughly mixed with 1 mL of water until they were completely suspended. Subsequently, 200 µL of this mixture were pipetted onto a plastic sheet and left to stand at room temperature for 30 min. The treated wheat grains, each weighing approximately 50 g, were then exposed to different concentrations (i.e., 625, 1250, 2500, and 5000 mg/kg) of Berna star and Techno oil, and (2, 4, 6, and 8 mg/kg) of Malathion. These treated grains were placed in individual 170 cm³ glass jars, and twenty adult *T. granarium* insects were introduced into each jar. After one week, the parental insects were removed, and after one month, the F1 generation insects were also removed. The wheat grains were reweighed at these intervals. The antifeedant activity

(AFA) was determined using the following formula (Huang and Ho, 1998):

$$AFA = \frac{C - T}{C} \times 100$$

Where,

C is the weight of seeds in control and T is the weight of seeds in treatment.

Data analysis

Subsequently, a least significant difference (LSD) test was employed to differentiate means at a significance level of $P \leq 0.05$. This analysis was carried out utilizing the SPSS software program version 23. The parameters including LC_{50}, slope, and 95% confidence limits (CL) were determined by applying Finney's analysis method (Finney, 1971), utilizing the Pc Probit software program. Additionally, the significant differences between LC_{50} values were assessed by considering the overlap of their respective 95% confidence limits.

RESULTS AND DISCUSSION

Results

Contact toxicity of tested insecticides against the *Trogoderma granarium*

Thin film experiment Contact toxicity of the two green pesticides and Malathion against the *T. granarium* adults and larvae was evaluated at 24 and 48 h after exposure via the thin film technique. Results showed that the exposure period and growth stage of the *T. granarium* substantially affected the contact toxicity of the tested oils (i.e., Techno oil and Berna star) and Malathion (Table 1). Contact toxicity of tested pesticides against the *T. granarium* adults increased considerably as the exposure period increased, as proved by LC_{50}. For example, LC_{50} values of Techno oil at 24 and 48 h post-exposure were 7058.6 and 2369.2 mg/L, respectively.

Table 1. Contact toxicity of two green pesticides (i.e., Techno oil and Berna star) and chemical pesticide (Malathion) against adults and larvae of the Khapra beetle (Trogoderma granarium) using the thin film technique.

Pesticide	Exposure period (h)	LC_{50} (mg/L)	95% Confidence limits	Slope value	Chi^2	LC_{90} (mg/L)
			Adults			
Techno oil	24	7058.6	5962.8 – 8030.0	2.69	0.26	21126.10
	48	2369.2	1647.9 – 3287.1	2.23	9.52	8849.10
Berna star	24	4633.6	3231.0 – 5755.5	2.14	5.14	4633.6
	48	3486.8	2334.4 – 4338.4	3.14	1.73	8922.60
Malathion	24	0.91	0.47 – 1.30	2.4	0.22	3.00
	48	0.73	0.08 – 1.38	1.20	1.62	8.60
			Larvae			
Techno oil	24	9893.8	7002.9 – 11457.8	4.24	13.70	19822.8
	48	8298.3	6431.6 – 9846.3	4.06	10.30	17135.1
Berna star	24	10973.8	10235.1 – 11700.8	5.6	3.38	18500.2
	48	7972.2	7426.4 – 8517.8	6.75	3.00	12337.1
Malathion	24	0.73	0.08 – 1.38	1.2	1.62	8.60
	48	0.65	0.19 – 1.10	1.97	3.47	2.92

Likewise, Berna star and Malathion recorded lower LC_{50} values after 48 h of exposure than after 24 h. However, Malathion was the most toxic pesticide to adults of the *T. granarium*, followed by Berna star, and Techno oil was the least toxic pesticide. The *T. granarium* larvae showed higher resistance against Techno oil and Berna star than the adults, while they were more sensitive towards Malathion, as indicated by LC_{50} values after 24 and 48 h post-exposure. The LC_{50} values of Techno oil, Berna star, and Malathion at 24 h were 9893.8, 10973.8, and 0.73 mg/L, respectively, while at 48 h they were 8298.3, 7972.2, and 0.65 mg/L, respectively.

Mixing with medium experiment

Trogoderma granarium adults were grown on mixed wheat grains with different concentrations of Techno oil, Berna star, or Malathion. The contact toxicity of these pesticides was monitored by calculating the LC_{50} and LC_{90} values at 24, 48, 72, and 96 h post-exposure (Table 2).

Table 2. Contact toxicity of two green pesticides (i.e., Techno oil and Berna star) and chemical pesticide (Malathion) against adults of the Khapra beetle (Trogoderma granarium) using the mixing with medium technique.

Pesticides	Exposure period (h)	LC_{50} (mg/kg)	95% Confidence limits	Slope value	Chi^2	LC_{90} (mg/kg)
Techno oil	24	--†	--	--	--	--
	48	5824.0	3255.0 – 21849.0	1.01	2.29	107712.0
	72	2387.3	1423.9 – 10059.0	0.64	0.92	224992.0
	96	117.3	41.6-193.7	1.43	3.90	911.6
Berna star	24	21250.0	10009.0 – 145955.3	1..11	0.72	302385.0
	48	11553.0	7038.0 – 31931.0	1.30	1.72	110177.0
	72	4748.2	3177.8 – 10879.5	0.89	0.53	131083.3
	96	79.2	2.6 – 226.9	0.99	0.83	1554.6
Malathion	24	1.28	0.39 – 1.99	1.19	0.36	15.22
	48	1.16	0.85 – 2.67	1.57	16.9	7.59
	72	1.01	0.43 – 1.51	1.7	4.18	5.50
	96	--	--	--	--	--

† not calculated

We were not able to calculate the LC_{50} and LC_{90} of Techno oil at 24 h post-exposure as it showed a death rate of the *T. granarium* adults below 16%. Also, Malathion at 96 h post-exposure recorded a 100% death rate of the *T. granarium* adults; therefore, LC_{50} and LC_{90} could not be calculated. The LC_{50} values of Techno oil, Berna star, and

Malathion gradually decreased as the exposure period of these pesticides increased. For instance, the LC_{50} value of Techno oil dropped from 5824.0 mg/kg at 48 h to 117.3 mg/kg at 96 h post-exposure. Malathion showed LC_{50} of 1.28 mg/kg at 24 h and reduced to 1.01 mg/kg at 72 h post-exposure. Results of LC_{50} revealed that the Techno oil was more toxic than the Berna star up to 72 h post-exposure; however, at 96 h post-exposure, the Berna star displayed a lower LC_{50} value than Techno oil.

Response of the Khapra beetle progeny to green pesticides

F1-progeny production from Trogoderma granarium adults

The number of newly emerged adults of the Khapra beetle significantly reduced upon treating insects with Techno oil, Berna star, or Malathion, as well as increasing the applied concentration of pesticides (Table 3).

Table 3. Reduction % in the F1-progeny production of the Khapra beetle (Trogoderma granarium) adults exposed to wheat grains mixed with different concentrations of two green pesticides (i.e., Techno oil and Berna star) and chemical pesticide (Malathion). Distilled water was applied as a control.

Pesticide	Concentrations (mg/kg)	Number of Newly emerged adults	Reduction % in F1-progeny
Control	--†	**37.00±7.5a**	**0**
Tehno oil	625	27.00±8.30ab	27.02
	1250	19.00±8.18ab	48.65
	2500	11.00±3.50ab	70.27
	5000	0.00±0.00b	100
Berna star	625	27.30±8.80ab	27.03
	1250	23.00±2.6ab	37.84
	2500	18.00±8.60ab	51.35
	5000	11.30±3.10ab	69.46
Malathion	2	3.70±2.30b	90.00
	4	2.70±1.40b	92.70
	6	1.00±0.00b	97.30
	8	0.70±0.33b	98.10

† not calculated Means in the same column followed by different letter(s) are significant according to the LSD at the level of P≤0.05.

For instance, at the rate of 625 mg/kg, Berna star caused a 27.03% reduction in the F1-progeny of the Khapra beetles; however, this reduction percentage increased to 69.46% when insects were grown in the presence of 5000 mg/kg Berna star. Although low concentration (625 mg/kg) of Berna star and Techno oil recorded almost the same number of newly emerged adults, at the higher concentrations, Techno oil revealed higher reductions in F1-progeny than the Berna star. The decline in the F1-progeny of the T. granarium increased from 27.02% to 100% upon increasing the rate of Techno oil from 625 to 5000 mg/kg. Treating insect adults with 2 mg/kg Malathion recorded a reduction in F1-progeny of 90% that increased to 98.1% upon increasing the Malathion concentration to 8 mg/kg.

F1-progeny production from Trogoderma granarium larvae

The Khapra beetle larvae were more resistant to the applied green pesticides or Malathion than the T. granarium adults, where the reductions in F1-progeny were lower than those reported for the adults of the Khapra beetles (Table 4).

The decline in F1-progeny varied significantly according to the applied concentration and type of pesticide. Berna star resulted in higher reductions in F1-progeny than Techno oil at all the applied concentrations, except for the level of 1250 mg/kg. At the concentration of 625 mg/kg, Techno oil caused a reduction of 30% in the F1-progeny of the Khapra beetle larvae and increased to 53.75% when Techno oil concentration increased to 5000 mg/kg. Likewise, treating larvae with 625 mg/kg of Berna star resulted in a 33.75% reduction in the F1-progeny production, while this reduction increased to 71.25% upon increasing the concentration to 5000 mg/kg. Increasing the rate of Malathion from 2 mg/kg to 8 mg/kg increased the reduction in the F1-progeny from 41.25% to 71.25%. Interestingly, treatments of 5000 mg/kg Berna star and 8 mg/kg Malathion recorded the same reduction percentage (71.25%) in the F1-progeny production of *T. granarium* larvae.

Table 4. Reduction % in the F1-progeny production of the Khapra beetle (Trogoderma granarium) larvae exposed to wheat grains mixed with different concentrations of two green pesticides (i.e., Techno oil and Berna star) and chemical pesticide (Malathion). Distilled water was applied as a control.

Pesticide	Concentrations (mg/kg)	Number of Newly emerged adults	Reduction % in F1-progeny
Control	--†	80±0.57a	0
Tehno oil	625	56±0.88ab	30.00
	1250	43±0.88ab	46.25
	2500	40±0.57ab	50.00
	5000	37±1.85ab	53.75
Berna star	625	53±0.33ab	33.75
	1250	50±1.00ab	37.50
	2500	26±0.66b	67.50
	5000	23±0.33b	71.25
Malathion	2	47±1.2ab	41.25
	4	46±0.66ab	41.50
	6	36±0.66ab	55.00
	8	23±0.33b	71.25

† not calculated Means in the same column followed by different letter(s) are significant according to the LSD at the level of P≤0.05.

Nutritional behavior of the *Trogoderma granarium* in the presence of tested pesticides (Atifeedant activity)

Control treatment (untreated grains) showed a loss % of wheat grain weight of 15.5%. However, treating wheat grains with Techno oil, Berna star, or Malathion markedly decreased the loss % of wheat grain weight, recording a lower loss % of wheat grain weight than the control (Table 5). Treating wheat grains with 625 mg/kg of Techno oil recorded a loss % of wheat grain weight of 13.8%, which dropped to 6.8% upon applying Techno oil at the rate of 5000 mg/kg. Similarly, the loss % of wheat grain weight from 12.8% to 8.1% upon treating wheat grains with Berna star at the rates of 625 and 5000 mg/kg, respectively. Malathion resulted in the lowest loss % of wheat grain weight, where it recorded loss % of 6.3% and 3.4% when wheat grains were treated with 2 and 8 mg/kg of Malathion, respectively.

Table 5. Loss % of wheat grain weight after infestation of 10 unsexed pairs of the Khapra beetle (Trogoderma granarium) after treating with different concentrations of two green pesticides (i.e., Techno oil and Berna star) and chemical pesticide (Malathion). Distilled water was applied as a control.

Pesticide	Concentration (mg/kg)	Weight of wheat grain before infection (g)	Weight of wheat grain after a month of infection (g)	Loss % of wheat grain weight
Control	-†	**10**	**8.45±0.17a**	**15.50**
Techno oil	625	10	8.62±0.52a	13.80
	1250	10	8.83±0.34a	11.70
	2500	10	8.89±0.01a	11.10
	5000	10	9.32±0.34a	6.80
Berna star	625	10	8.72±0.67a	12.80
	1250	10	8.87±0.06a	11.30
	2500	10	9.03±0.14a	9.70
	5000	10	9.19±0.14a	8.10
Malathion	2	10	9.37±0.29a	6.30
	4	10	9.54±0.08a	4.60
	6	10	9.55±0.22a	4.50
	8	10	9.66±0.04a	3.40

† not applicable Means in the same column followed by different letter(s) are significant according to the LSD at the level of P≤0.05.

Discussion

In our present investigation, it was observed that all the examined pesticides demonstrated toxicological effects on both *T. granarium* adults and larvae throughout all exposure durations in the thin film experiment. However, it is noteworthy that in the mixing with the medium experiment, Techno oil exhibited no discernible impact on *T. granarium* adults 24 h after exposure. It is worth mentioning that, even though the effective concentrations of Techno oil and Berna star were found to be higher than those of Malathion, these elevated concentrations remain within an acceptable range. This is primarily due to the fact that Malathion is a synthetic pesticide, whereas Berna star and Techno oil are derived from plant-based extracts, which inherently necessitate slightly higher concentrations for comparable effectiveness.

Consistent with our present findings, Techno oil demonstrates efficacy as both an acaricide and pesticide, as previously noted (Esmail *et al*., 2020). It serves a dual role as a non-ionic surfactant bio-activator and a water source derived from plant origins, primarily employed in foliar applications for agricultural and chemical purposes. Techno oil effectively targets insect barriers and fungi, such as chitin and paraffin waxes, while also containing glutamic acid, specifically L-glutamic amino acid (El-Khiat *et al*., 2016). Both products examined in this study (Techno oil and Berna star) originate from plant sources; however, it is important to distinguish between them. Techno oil is derived from vegetable oil, whereas Berna star is an extract sourced from a combination of coconut fruit and avocado seeds. In our experiments, all tested products demonstrated toxic effects on the studied insects. Regarding the thin film experiment, when considering LC50 values, it was observed that adults exhibited greater sensitivity to Techno oil, Berna star, and Malathion compared to *T. granarium* larvae. Furthermore, the exposure of adult insects and larvae to these tested products resulted in a noteworthy impact on their offspring, manifesting as a reduction of 53.75%, 71.25%, and 71.25% in the case of Techno oil, Berna star, and Malathion, respectively.

In a separate investigation, the efficacy of Techno oil and Berna star was assessed against *Bemisia tabaci* infestations in potato crops, resulting in the death of the insects 14 days post-exposure (Esmail *et al*., 2020). Specifically, the mortality rate for Techno oil reached 67.9%, while for Berna star it was slightly higher at 73.1%. Additionally, the impact on fertility was examined, revealing a complete eradication of *Bemisia tabaci* in potato crops. In the same agricultural context, another study explored the effects of Techno oil and Berna star on *Tetranycus urticae* infestations, with results showing a Berna star mortality rate of 54.93% after 14 days of exposure. In contrast, Techno oil demonstrated a mortality rate of 65.97% following the same exposure period, with both products achieving a complete elimination of the tested components. It is worth noting that vegetable oils, which encompass oils derived from various plant sources, such as seeds, leaves, stems, or flowers, are rich in fatty acids and other lipid compounds. Among the common fatty acids found in vegetable oils are palmitic, stearic, linoleic, and oleic acids. These oils are commonly utilized in both food and feed products (Esmail *et al*., 2020).

Several vegetable oils are not subject to EPA regulations and are marketed for their natural production qualities (Lacoste, 2014). Many oil-based products share a similar mode of action, with their toxicity primarily manifesting physically rather than chemically and having a relatively short-lasting effect. Insect repellents derived from oils operate by interfering with gas exchange, disrupting cell membrane function, or altering insect structure upon contact. Additionally, these repellents can disrupt insects' access to food in areas coated with oil. Certain vegetable oils containing sulfur compounds, such as neem oil, may exhibit heightened fungicidal activity when compared to petroleum-based oils (Plata-Rueda *et al*., 2017). In a separate investigation, the impact of Techno oil and Berna star on the earth snail *Massylaeae vermiculata* was assessed, with Techno oil demonstrating the highest recorded slope value (Abd-Elhaleim *et al*., 2021). Additionally, it was observed that plant extracts, in comparison to synthetic pesticides, have a relatively weaker impact (Abdelmaksoud *et al*., 2020). In a related study, (Abdelmaksoud *et al*., 2020) examined the efficacy of Berna star in controlling thrips and red spider mites infesting strawberry plants. Their findings revealed that Berna star significantly contributed to insect mortality, effectively reducing the populations of all tested insects.

Our findings align with the observations made by (Nath *et al*., 2019), who reported substantial insecticidal activity of *Citrus reticulata* (peel) oil against *Tribolium* *castaneum*. Furthermore, they suggested that given the cost-effectiveness and ready availability of this plant, its extract could serve as a promising alternative to chemical insecticides in pest management initiatives. The mechanism by which essential oils exert their impact on insects might involve the inhibition of acetyl-cholinesterase (AChE), as demonstrated by the presence of five monoterpenes capable of inhibiting AChE activity (Abo Arab *et al*., 2022; Ryan and Byrne, 1988).

CONCLUSION

In conclusion, this study has provided valuable insights into the potential of two green pesticides, Techno oil and Berna star, as effective alternatives to the chemical pesticide Malathion in the context of Khapra beetle (*T. granarium*) management. Our findings have shed light on several critical aspects of pest control, including contact toxicity, reproductive effects, and antifeedant activity. Firstly, our investigations demonstrated that both Techno oil and Berna star exhibited significant contact toxicity against Khapra beetle adults and larvae. These two green pesticides can be used as stored product protectants and can be used in IPM program.

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تقييم مقارن للمبيدات الخضراء (تكنو أويل وبيرنا ستار) مقابل الملاثيون: التأثير عن طريق السمية بالملامسة والتأثير على الخلفة ومنع التغذية في خنفساء الصعيد

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الملخص

في عصر المخاوف البيئية المتزايدة والحاجة إلى استراتيجيات مستدامة لإدارة الآفات، فإن تقييم العوامل البديلة لمكافحة الآفات له أهمية بالغة. تبحث هذه الدراسة في تأثير مبيدين صديقين للبيئة، هما تكنو أويل وبيرنا ستار، على خنفساء الصعيد(*Trogoderma granarium*) ، وهي آفة سيئة السمعة للحبوب المخزنة، مقارنة بالمبيد الكيميائي التقليدي الملاثيون. كشفت سمية التلامس أن كلا من تكنو أويل وبيرناستار أظهرا فعالية كبيرة ضد خنافس الصعيد. كان للملاثيون أعلى تأثير حيث كانت معدل وفيات وقيمة LC_{50} قدره 0.73 ملغم/لتر، في حين أظهر تكنو أويل وبيرنا ستار قيم LC_{50} تبلغ 2369.2 و3486.8 ملغم/لتر، على التوالي. زادت سمية التلامس للمبيدات المختبرة مع زيادة وقت التعرض. أدى التركيز العالي للملاثيون (أي 8 ملغم/كغم) إلى انخفاض في ذرية يرقات F1 بنسبة 71.25%، وهو ما يعادل الانخفاض الناجم عن 5000 ملغم/كغم من بيرنا ستار. كان لتكنو أويل أعلى نسبة خفض في التعداد (100%) في إنتاج ذرية F1 بتركيز 5000 ملجم/كجم، يليه الملاثيون بنسبة 98.10% بتركيز 8 ملجم/كجم. حقق الملاثيون فقد في وزن الحبوب بنسبة 3.40% عند أعلى تركيز (8 ملجم/كجم)، يليه تكنو أويل بنسبة 6.80% عند أعلى تركيز 5000 ملجم/كجم، بينما حقق بيرنا ستار انخفاض بنسبة 8.10% فقد في وزن الحبوب عند نفس التركيز. توفر هذه الدراسة رؤى قيمة حول فعالية المبيدات الخضراء كبدائل قابلة للتطبيق للمبيدات الكيميائية في سياق مكافحة خنفساء الصعيد.