



## Joint effect of insecticide and fungicide poison baits against land snail, *Eobania vermiculata* under laboratory and field conditions

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### Abstract

Land snails are significant agricultural pests, and controlling their populations is crucial to protect crops from damage. Insecticides and fungicides have been explored as potential methods for snail control, so the current experiment was carried out at Belbis city, Sharkia governorate in 2024 to study the efficacy of an insecticide and a fungicide and their combinations as baits at different concentrations on land snail, *Eobania vermiculata* (Muller) in both the laboratory and the field. Results showed that 1000 mg methomyl and 750 mg methomyl combined with 1500 mg tetramethylthiuram disulphide were the most effective treatments against the snail species; *E. vermiculata*, achieving average mortality rates of 19.93 and 18.80 dead snails/25 snails, respectively, with no significant differences. At the laboratory conditions, 1000 mg methomyl gave a mortality reduction of 79.70%, followed closely by the combination of 750 mg methomyl + 1500 mg tetramethyl thiuram disulphide with a reduction of 75.12%. In the same time, at the field conditions, the general mean indicated that 1000 mg methomyl was the most toxic to *E. vermiculata*, with a mortality percentage of 44.89%, compared to the lowest effectiveness of 2000 mg tetramethylthiuram disulfide which gave 17.45%. In general, it was observed that as the investigation came to a close, the cumulative mortality percentage of all tested baits gradually increased.

**Keywords:** Land snails, molluscicides, pesticides, mortality

### Introduction

Land snails are pervasive agricultural pests that cause significant damage to crops worldwide, particularly in moist environments where they thrive. Recent studies have explored the efficacy of various insecticides and fungicides in controlling land snail populations, particularly focusing on species like *Eobania vermiculata* (Muller) and *Monacha cartusiana* (Muller) (Ismail *et al.*, 2022) <sup>[1]</sup>. These investigations revealed that certain pesticides can serve as effective molluscicides, potentially replacing traditional methods (Abd El-Hamed *et al.*, 2024) <sup>[2]</sup>. Some insecticides can successfully lower snail populations, while others might have unfavorable or restricted effects.

According to (Shaker *et al.*, 2015) <sup>[3]</sup>, several insecticides, such as methomyl and lambda-cyhalothrin, showed strong action against land snails, indicating the possibility of incorporating them into pest control plans. With LC<sub>50</sub> of 58.6 ppm, Indoxacard showed high effectiveness against *Eobania vermiculata* (Hussein and Sabry, 2019) <sup>[4]</sup>. Also, Methomyl was proven to be the most effective, achieving 100% mortality in land snails like *M. cantiana* and *E. vermiculata* after 7 to 12 days of exposure (Genena, and Mostafa, 2008) <sup>[5]</sup>. *E. vermiculata* and *H. vestalis* exhibited significant mortality rates upon exposure to propineb; at higher dosages, fatality percentages could approach 93% (Mousa *et al.*, 2019) <sup>[6]</sup>. While fungicides like copper sulfate showed some molluscicidal activity, their effectiveness was generally lower compared to dedicated molluscicides (Zidan *et al.*, 2002) <sup>[7]</sup>. New synthetic compounds, including heterocycles, have been developed with promising molluscicidal activity, indicating a potential for integration into pest management strategies alongside traditional pesticides (Abeed *et al.*, 2024) <sup>[8]</sup>.

Under field conditions, snail population reductions ranged from 65% to 94.65%, indicating the efficiency of other pesticides such as neomyl and different biocides (Mortada *et al.*, 2012) <sup>[9]</sup>. Azoxystrobin exposure resulted in reduced food consumption and growth in *Theba pisana*, alongside with oxidative stress markers, suggesting detrimental effects on snail physiology (Radwan *et al.*, 2024) <sup>[10]</sup>. Molluscicidal action can be increased by combining some insecticides with fungicides; the results vary depending on the chemicals employed and their doses. According to the research on *M. cartusiana* and *E. vermiculata*, some combinations were successful in improving control, but others did not produce appreciable gains (Abdel-Rahman and Hegab, 2010) <sup>[11]</sup>. The present investigation was conducted to study the efficacy of an insecticide and a fungicide and their combinations as baits with different concentrations on the land snail; *Eobania vermiculata* in both laboratory and field conditions.

### Materials and methods

The experiments were carried out under laboratory and field conditions in February and March in 2024 to study the efficacy of an insecticide and a fungicide as baits, with different concentrations, on the land snail; *Eobania vermiculata* in both laboratory and field conditions.

### Tested insecticide and fungicide

The tested insecticide and fungicide were applied against the land snail; *E. vermiculata* as follows:

**Treatment 1:** 1000 mg methomyl 90% WP (lannate®)/ 1liter water.

**Treatment 2:** 2000 mg tetramethylthiuram disulphide (thiram 80% WP)/ 1-liter water.

**Treatment 3:** 750 mg methomyl 90% WP (lannate®) + 750 mg tetramethylthiuram disulphide (thiram 80% WP)/ 1-liter water.

**Treatment 4:** 500 mg methomyl 90% WP (lannate®) + 750 mg tetramethylthiuram disulphide (thiram 80% WP)/ 1-liter water.

**Treatment 5:** 750 mg methomyl 90% WP (lannate®) + 500 mg tetramethylthiuram disulphide (thiram 80% WP)/ 1-liter water.

**Treatment 6:** 500 mg methomyl 90% WP (lannate®) + 500 mg tetramethylthiuram disulphide (thiram 80% WP)/ 1-liter water.

**Treatment 7:** Untreated control.

### Bait preparation

The tested insecticide and fungicide were applied as poisonous baits; prepared by the method reported by Shahawy (2019)<sup>[12]</sup> as follows: poisonous baits consisted of **150 g** of wheat bran mixed with an appropriate amount of water containing the tested abovementioned compounds plus 30 ml of sugar cane honey to attract snails. Untreated control contained the bait without pesticides.

### Laboratory experiment

The laboratory experiment was conducted at the laboratory of Harmful Animals Research Department, Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt, in February 2024. Adults of the land snail; *E. vermiculata* were collected from ornamental plants infested with land snails. The collected snails were housed in a glass cage (50 × 50 × 60 cm) filled with mixed sterilized soil (clay: sand) roughly (1:1) with appropriate moisture and closed with a muslin cloth to prevent escape. They were fed on lettuce leaves for 14 days in a lab setting with RH 60%±5 and temperature 25±3°C, with 25 adults of the land snail, *E. vermiculata* per cage. The dead snails were recorded after 1, 3, 5, 7 and 14 days from offering the bait to the snails.

### Field experiment

The molluscicidal activity of baits was tested against the land snail *E. vermiculata* infested ornamental plants in Belbis district, Sharkia governorate, in March 2024. This experiment was laid out in a complete randomized block design (RCBD) with three replicates. The previous tested treatments were applied and offered to the snails on plastic sheet pieces (50 × 50) with 100 g/ sheet.

### Reduction percentage

The number of snails was recorded in a half-meter area close to baits in the untreated control and treatment areas before application, as well as 1, 3, 5, 7, and 14 days post-treatment (Shahawy, 2019)<sup>[12]</sup>. The reduction % was determined using the Henderson and Tilton (1955)<sup>[13]</sup> formula as follows:

Reduction (%) = 1 - (A/B×C/D) × 100, Where:

A = number of living snails before treatment in treated plot.  
B = number of living snails after treatment in treated plot.  
C = number of living snails before treatment in untreated plot.  
D = number of living snails after treatment in untreated plot.

### Statistical analysis

Statistical analysis was performed using Costat Software (1988)<sup>[14]</sup>, with the least significant difference (LSD) utilized at the 0.05 level of probability to compare treatments.

## Results

### 1. Laboratory experiment

#### 1.1. Average numbers of dead snails

Results presented in Table (1) show the average number of dead individuals of *E. vermiculata* at different days after treatment under laboratory conditions, with results divided into initial effects and residual effects over 14 days. Results of initial effect showed that 1000 mg methomyl, 750 mg methomyl + 1500 mg tetramethylthiuram disulphide and 500 mg methomyl + 1500 mg tetramethylthiuram disulphide gave the highest average number of dead snails (14.83, 14.33 and 14.83 / 25 snails), respectively, without significant differences. On the other hand, 750 mg methomyl + 1000 mg tetramethylthiuram disulphide and 2000 mg tetramethylthiuram disulphide gave a mean number of dead snails 12.83 and 10.67/ 25 snails, respectively, with significant differences, but, 500 mg methomyl + 1000 mg tetramethylthiuram disulphide achieved the lowest average number of dead snails 6.83/ 25 snails.

In the same time, results of residual effect showed that 1000 mg methomyl gave the highest average number of dead snails (23.33/ 25 snails), followed by, 750 mg methomyl+ 1500 mg tetramethylthiuram disulphide and 750 mg methomyl + 1000 mg tetramethylthiuram disulphide with average number of dead snails (21.78 and 20.11/ 25 snails, respectively) with significant differences. Also, 500 mg methomyl +1500 mg tetramethylthiuram disulphide and 500 mg methomyl +1000 mg tetramethylthiuram disulphide gave a mean number of dead snails 17.11 and 14.33/ 25 snails, respectively, but, 2000 mg tetramethylthiuram disulphide achieved the lowest average number of dead snail 12.44/ 25 snails, with significant differences among all treatments.

Generally, results showed that 1000 mg methomyl and 750 mg methomyl + 1500 mg tetramethylthiuram disulphide were the most effective bait against *E. vermiculata*, which gave the highest average number of dead snails (19.93 and 18.80/ 25 snails, respectively) with no significant differences. Treatments of 750 mg methomyl + 1000 mg tetramethylthiuram disulphide and 500 mg methomyl + 1500 mg tetramethylthiuram disulphide, achieved average number of dead snails of 17.20 and 16.20/ 25 snails, respectively, without significant differences followed by 2000 mg tetramethylthiuram disulphide (11.73 dead snail/ 25 snails) and 500 mg methomyl +1000 mg tetramethylthiuram disulphide (11.33 dead snail/ 25 snails). In contrast, the treatment of 500 mg methomyl + 1000 mg tetramethylthiuram disulphide exhibited the least effectiveness, which gave an average number of dead snails 11.33/ 25 snails.

**Table 1:** Average number of dead snails, *E. vermiculata* after molluscicidal treatments under laboratory conditions

Bait	Mean No. of snails before treatment	Average number of dead snails after treatment							Overall mean
		Initial effect			Residual effect				
		1 <sup>st</sup> day	3 <sup>rd</sup> days	Mean	5 <sup>th</sup> days	7 <sup>th</sup> days	14 <sup>th</sup> days	Mean	
1000 mg methomyl	25.00	11.67	18.00	14.83 <sup>a</sup>	22.33	23.00	24.67	23.33 <sup>a</sup>	19.93 <sup>a</sup>
2000 mg tetramethylthiuram disulphide	25.00	10.33	11.00	10.67 <sup>c</sup>	11.67	12.67 <sup>e</sup>	13.00	12.44 <sup>f</sup>	11.73 <sup>c</sup>
750 mg methomyl + 1500 mg tetramethylthiuram disulphide	25.00	10.67	18.00	14.33 <sup>ab</sup>	20.33	22.33	22.67	21.78 <sup>b</sup>	18.80 <sup>a</sup>
750 mg methomyl + 1000 mg tetramethylthiuram disulphide	25.00	9.67	16.00	12.83 <sup>b</sup>	18.33	20.67	21.33	20.11 <sup>c</sup>	17.20 <sup>b</sup>
500 mg methomyl + 1500 mg tetramethylthiuram disulphide	25.00	13.33	16.33	14.83 <sup>a</sup>	16.00	17.67	17.67	17.11 <sup>d</sup>	16.20 <sup>b</sup>
500 mg methomyl + 1000 mg tetramethylthiuram disulphide	25.00	5.67	8.00	6.83 <sup>d</sup>	11.00	14.33	17.67	14.33 <sup>e</sup>	11.33 <sup>c</sup>
Untreated control	25.00	0.00	0.00	0.00 <sup>e</sup>	0.00	0.33	0.67	0.33 <sup>g</sup>	0.20 <sup>d</sup>
LSD <sub>0.05</sub>	N.S.	1.87	1.67	1.62	1.21	1.32	1.28	1.27	1.36

\* Means in each column labeled by the same letter (s) are not significantly different at the 0.05 level

**1.2. Percentage of reduction in land snail**

The effectiveness of various toxic baits on the mortality of the land snail; *E. vermiculata* was assessed in a controlled laboratory environment. The results, presented in Table (2), indicated that all tested baits were toxic to *E. vermiculata*, with different levels of effectiveness measured over time. The data is divided into two main effects: initial effect (1<sup>st</sup> and 3<sup>rd</sup> days) and residual effect (5<sup>th</sup>, 7<sup>th</sup>, and 14<sup>th</sup> days).

In terms of initial effect, the treatment with 1000 mg methomyl and 750 mg methomyl + 1500 mg tetramethylthiuram disulphide showed the highest snail reduction of 59.33% for each, followed by the treatment of 750 mg methomyl + 1500 mg tetramethylthiuram disulphide, which achieved a mean reduction of 57.33% (42.67% on the 1<sup>st</sup> day and 72.00% on the 3<sup>rd</sup> day), without significant differences. Treatment of 750 mg methomyl + 1000 mg tetramethylthiuram disulphide had a mean reduction of 51.33%, while 2000 mg tetramethylthiuram disulphide achieved a mean reduction of 42.67%, with significant differences. The least effective treatment during the initial phase was 500 mg methomyl + 1000 mg tetramethylthiuram disulphide, which resulted in a mean reduction of only 27.33%.

The residual effects were notably higher across all treatments. The 1000 mg methomyl treatment exhibited the

highest residual effect, achieving of the reduction of snail with 93.29% after 14 days, followed by 750 mg methomyl + 1500 mg tetramethylthiuram disulphide, with a residual mean of 86.98%, and 750 mg methomyl + 1000 mg tetramethylthiuram disulphide, which had a mean of 80.23% reduction, with significant differences. The treatment with 2000 mg tetramethylthiuram disulphide showed a lower residual effect, achieving a reduction of 49.12%.

Overall, all tested baits showed significant cumulative mortality percentages over time, indicating their effectiveness in controlling the snail population under laboratory conditions. Results showed that 1000 mg methomyl was the most effective bait against *E. vermiculata*, resulting in an overall reduction of 79.70%, followed by 750 mg methomyl + 1500 mg tetramethylthiuram disulphide which achieved a reduction of 75.12%, without significant differences. Also, 750 mg methomyl + 1000 mg tetramethylthiuram disulphide and 500 mg methomyl + 1500 mg tetramethylthiuram disulphide, achieved reductions of 68.67% and 64.56%, respectively, without significant differences. In contrast, the treatment 500 mg methomyl + 1000 mg tetramethylthiuram disulphide exhibited the least effectiveness, resulting in an overall mortality reduction of 45.06%.

**Table 2:** Reduction percentages of land snail; *E. vermiculata* due to molluscicidal treatments under laboratory conditions

Bait	Average reduction percentage							Overall mean
	Initial effect			Residual effect				
	1 <sup>st</sup> day	3 <sup>rd</sup> days	Mean	5 <sup>th</sup> days	7 <sup>th</sup> days	14 <sup>th</sup> days	Mean	
1000 mg methomyl	46.67	72.00	59.33 <sup>a</sup>	89.33	91.89	98.63	93.29 <sup>a</sup>	79.70 <sup>a</sup>
2000 mg tetramethylthiuram disulphide	41.33	44.00	42.67 <sup>c</sup>	46.67	50.00	50.68	49.12 <sup>f</sup>	46.54 <sup>c</sup>
750 mg methomyl + 1500 mg tetramethylthiuram disulphide	42.67	72.00	57.33 <sup>ab</sup>	81.33	89.19	90.41	86.98 <sup>b</sup>	75.12 <sup>a</sup>
750 mg methomyl + 1000 mg tetramethylthiuram disulphide	38.67	64.00	51.33 <sup>b</sup>	73.33	82.43	84.93	80.23 <sup>c</sup>	68.67 <sup>b</sup>
500 mg methomyl + 1500 mg tetramethylthiuram disulphide	53.33	65.33	59.33 <sup>a</sup>	64.00	70.27	69.86	68.04 <sup>d</sup>	64.56 <sup>b</sup>
500 mg methomyl + 1000 mg tetramethylthiuram disulphide	22.67	32.00	27.33 <sup>d</sup>	44.00	56.76	69.86	56.87 <sup>e</sup>	45.06 <sup>c</sup>
Untreated control	0.00	0.00	0.00 <sup>e</sup>	0.00	0.00	0.00	0.00 <sup>g</sup>	0.00 <sup>d</sup>
LSD <sub>0.05</sub>	7.49	6.66	6.49	4.83	5.81	7.18	5.59	5.74

\* Means in each column labeled by the same letter (s) are not significantly different at the 0.05 level

**2. Efficacy of toxic baits on mortality percentages of *E. vermiculata* snail under field conditions**

The mortality percentage of the land snail; *E. vermiculata* after exposure periods to six treatments applied as toxic baits under field conditions, are represented in Table (3). The results were categorized into two main effects: initial

effect (1<sup>st</sup> and 3<sup>rd</sup> days) and residual effect (5<sup>th</sup>, 7<sup>th</sup>, and 14<sup>th</sup> days). All tested baits were found to be toxic against *E. vermiculata* with various extents. Treatment of 750 mg methomyl + 1500 mg tetramethylthiuram disulphide gave the highest initial effect with a mean reduction of 24.36%, followed by treatments of 750 mg methomyl + 1000 mg

tetramethylthiuram disulphide, 1000 mg methomyl and 500 mg methomyl +1000 mg tetramethylthiuram disulphide with mean reductions of 24.05%, 23.42 and 22.84%, respectively, without significant differences. Also, treatment of 2000 mg tetramethylthiuram disulphide gave the least initial effect with a mean reduction of 7.09%.

At the same time, 1000 mg methomyl was highest residual effect against the land snail; *E. vermiculata* with mortality percentage of 73.52%, followed by 500 mg methomyl +1000 mg tetramethylthiuram disulphide, 750 mg methomyl + 1500 mg tetramethylthiuram disulphide and 2000 mg tetramethylthiuram disulphide with mean reductions

45.11%, 41.55% and 31.26%, respectively. But, 500 mg methomyl + 1500 mg tetramethylthiuram disulphide was the lowest one (23.28%).

Generally, it can be concluded that all tested baits showed gradual increases in the cumulative mortality percentage over of the duration of the experiment. There weren't dead snails found in the untreated control during the current experiment. Finally, the general mean showed that 1000 mg methomyl was the highest toxic compound against the land snail; *E. vermiculata* with mortality percentage of 44.89%, whereas 2000 mg tetramethylthiuram disulphide was the lowest one (17.45%).

**Table 3:** Reduction percentages of land snail; *E. vermiculata* due to molluscicidal treatments under field conditions

Bait	Average reduction percentage							Overall mean
	Initial effect			Residual effect				
	1 <sup>st</sup> day	3 <sup>rd</sup> days	Mean	5 <sup>th</sup> days	7 <sup>th</sup> days	14 <sup>th</sup> days	Mean	
1000 mg methomyl	14.02	32.82	23.42 <sup>a</sup>	53.79	68.99	97.78	73.52 <sup>a</sup>	44.89 <sup>a</sup>
2000 mg tetramethylthiuram disulphide	5.90	8.28	7.09 <sup>b</sup>	18.25	24.23	51.28	31.26 <sup>bc</sup>	17.45 <sup>c</sup>
750 mg methomyl + 1500 mg tetramethylthiuram disulphide	19.02	29.70	24.36 <sup>a</sup>	39.67	42.23	42.74	41.55 <sup>b</sup>	31.73 <sup>b</sup>
750 mg methomyl + 1000 mg tetramethylthiuram disulphide	16.90	31.21	24.05 <sup>a</sup>	21.26	41.39	00.00	20.88 <sup>c</sup>	22.69 <sup>c</sup>
500 mg methomyl + 1500 mg tetramethylthiuram disulphide	10.32	24.92	17.62 <sup>a</sup>	33.61	36.24	00.00	23.28 <sup>c</sup>	20.05 <sup>c</sup>
500 mg methomyl +1000 mg tetramethylthiuram disulphide	15.07	30.62	22.84 <sup>a</sup>	45.94	52.69	36.70	45.11 <sup>b</sup>	32.39 <sup>b</sup>
Untreated control	0.00	0.00	0.00 <sup>b</sup>	0.00	0.00	0.00 <sup>c</sup>	0.00 <sup>d</sup>	0.00 <sup>d</sup>
LSD <sub>0.05</sub>	12.12	11.72	9.82	16.37	16.36	33.87	14.68	7.46

\* Means in each column labeled by the same letter (s) are not significantly different at the 0.05 level

## Conclusion

Based on the abovementioned results, the study demonstrated that methomyl, particularly at a concentration of 1000 mg, was highly effective in controlling the land snail species; *E. vermiculata*, under both laboratory and field conditions. The combination of methomyl with tetramethylthiuram disulphide also showed promising results, indicating potential for integrated pest management strategies. All tested baits exhibited increasing cumulative mortality rates over time, revealing their effectiveness as control measures.

## Discussion

Insecticides and fungicides kill land snails through various biochemical and physiological mechanisms. These chemicals disrupt essential metabolic processes, leading to mortality. The effectiveness of different pesticides varies over the time and concentration. Based on the results discussed abovementioned, we can say that the chemicals used had an impact on the molluscicidal activity. These findings agree with those of Daoud (2004) [15], who showed that Neomyl had the most toxic impact on *M. cartusiana* in both laboratory and field conditions. Additionally, Ismail *et al.*, (2022) [16] and El-Nasharty *et al.*, (2024) [17] found that methomyl had a more significant effect on population decrease than metaldehyde in field conditions. Insecticides like methomyl and organophosphates inhibit key enzymes such as acetylcholinesterase, leading to neurotoxicity and eventual death (Shaker *et al.*, 2015) [3]. Compared to lambda, methomyl caused a significantly greater mortality rate in land snails (Bashandy and Awwad, 2023) [18], which agrees with the current results as methomyl at 1000 mg gave the highest efficiency against the snail, *E. vermiculata*. Fungicides like Biozed cause structural damage in digestive and reproductive tissues, resulting in impaired function and mortality (Abd El-Atti *et al.*, 2020) [19]. Studies show that mortality rates increase with prolonged exposure to

biocides, with significant effects observed after 28 days (Geasa *et al.*, 2013) [20]. Fungicides like Difenoconazole caused necrosis in reproductive tissues, affecting the snails' reproductive capabilities (El-Deeb *et al.*, 2016) [21]. It was proven that fungi-derived compounds, including 3-octanone, have demonstrated quick lethality to snails, reaching 100% mortality in less than one hour (Khoja *et al.*, 2019) [22].

Land snails can be effectively controlled by combining insecticides and fungicides, especially when their molluscicidal efficiency increases due to synergistic effects. According to research, certain combinations can increase toxicity and speed the mortality rates of the snail species they are intended for. These fungicides can be effectively used in bait formulations, enhancing their molluscicidal properties when combined with other active ingredients (EL Sadany *et al.*, 2009) [23].

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## Declaration of competing interest

The authors declare that they have no known financial conflicts or connections that might have impacted the work described in the current investigation.

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