

Research Article

Efficacy of Selected Compounds Against the Glassy Clover Snail, *Monacha cartusiana* (Müller), in Al-Qadisiyah District, Iraq

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Abstract | Chemical control remains an essential component of integrated pest management programs aimed at maintaining pest populations below economically damaging levels without adversely affecting crop productivity. However, prolonged reliance on a limited number of pesticides often leads to reduced susceptibility and the development of resistance. Rotating compounds with different modes of action is therefore considered an effective strategy to delay resistance development. In the present study, the field efficacy of three compounds, Metaldehyde, Diazinon, and FePO₄ was evaluated against the glassy clover snail, *Monacha cartusiana*, in alfalfa fields in Al-Qadisiyah District, Iraq, during the 2024 and 2025 growing seasons. The results demonstrated that Metaldehyde achieved the highest mortality and reduction percentages of *M. cartusiana*, whereas Diazinon exhibited the lowest effectiveness. Based on general mean values, Metaldehyde proved to be the most effective compound, recording reduction percentages of 82.85% and 81.15% in the two respective seasons. FePO₄ resulted in reductions of 79.77% and 77.52%, while Diazinon showed comparatively lower reductions of 77.42% and 71.23%. The residual effects of the tested compounds followed a similar trend. Metaldehyde produced residual reductions of 76.02% and 74.54%, followed by FePO₄ (72.52% and 70.18%) and Diazinon (66.94% and 64.78%) during the 2024 and 2025 seasons, respectively. Overall, Metaldehyde exhibited superior efficacy against *M. cartusiana* under field conditions and can be considered the most effective compound among those evaluated.

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Keywords | Glassy clover snail, *Monacha cartusiana*, Metaldehyde, Diazinon, FePO₄, Alfalfa



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Introduction

Alfalfa (*Medicago sativa* L.) is a major forage crop widely adapted to the diverse soil types and climatic conditions of Iraq. As a perennial species, it persists in the field for approximately three to

four years, providing sustained production of high-quality green biomass. Its forage is rich in protein and essential nutrients, contributing significantly to improved animal health, growth, and overall productivity Ali (2020). Terrestrial snails are among the most destructive pests affecting field crops,

vegetables, and fruit orchards worldwide. In addition to their agricultural significance, land snails also pose medical and veterinary concerns, as they serve as intermediate hosts for several parasitic helminths that infect humans and domestic animals (Godan, 1983; Wang *et al.*, 2022). In many regions, land snails cause substantial economic losses by feeding on a wide range of crops, including vegetables, horticultural plants, and field crops (Mahrous *et al.*, 2002; Gaber *et al.*, 2006; Liu *et al.*, 2024).

The glassy clover snail, *Monacha cartusiana*, is considered one of the most prevalent terrestrial snail species in several agricultural areas, where it causes severe damage to crops. Previous surveys have reported that this species is particularly abundant in cultivated fields, resulting in significant reductions in crop yield and quality (Shetaia, 2010). The feeding activity of *M. cartusiana* leads to noticeable losses in the fresh weight of Egyptian clover shoots and causes extensive damage to the leaves of cabbage and lettuce crops (Ismail *et al.*, 2005; Zedan *et al.*, 2005; Castro-Gutierrez *et al.*, 2022).

The application of poisonous baits is widely regarded as one of the most effective and commonly used methods for controlling terrestrial gastropods (El-Massry, 1997; Somuncu *et al.*, 2024). Baits formulated with attractants such as wheat bran and sugarcane syrup have been shown to effectively lure *M. cartusiana* snails over considerable distances, making this approach particularly suitable for reducing snail populations in agricultural fields (Ismail *et al.*, 2014). Due to their efficiency and ease of application, bait formulations remain the preferred chemical control method against land snails (Barker, 2002; Wang *et al.*, 2022).

Despite the availability of various control measures, management of land snails and slugs still relies heavily on chemical pesticides to maintain pest populations below damaging thresholds. Synthetic molluscicides are currently among the most effective tools for controlling terrestrial gastropods in agricultural systems (Genena, 2003; Abd-El-All, 2004; Zedan *et al.*, 2006). Therefore, continuous evaluation of commonly used and newly available compounds under field conditions is essential.

Infestations of *M. cartusiana* represent a growing economic constraint on alfalfa production in central and southern Iraq, where heavy snail populations

cause substantial defoliation, reduced forage quality, and significant yield losses, thereby increasing production costs and threatening farmers' income. Despite the expanding prevalence of this pest, comprehensive field-based evaluations of commonly used and environmentally safer molluscicides under Iraqi agroecological conditions remain limited. Most available studies are restricted to laboratory bioassays or short-term trials, creating a critical knowledge gap regarding their long-term effectiveness and practical suitability in real farming systems. Therefore, the present study hypothesized that metaldehyde, diazinon, and ferric phosphate would significantly differ in their field efficacy against *M. cartusiana*, with at least one compound providing superior and sustainable population suppression under local conditions.

Materials and Methods

Chemicals used

Three compounds were evaluated in this study: Metaldehyde, Diazinon, and FePO_4 . All tested materials were obtained from the Agricultural Research Station, Al-Qadisiyah District, Iraq.

Field experiments

Field trials were conducted in alfalfa fields located in Al-Qadisiyah District, Iraq, during the growing seasons 2024 and 2025. The study followed a randomized complete block design (RCBD) with four replicates per treatment, including an untreated control.

Each experimental unit (plot) measured 20×20 m (400 m^2) and was separated from adjacent plots by 2-m buffer zones to minimize bait interference and snail movement between treatments. Plots were uniformly distributed within each block, and treatments were randomly assigned to experimental units to ensure unbiased estimation of treatment effects. The experiment aimed to determine the reduction percentages of *M. cartusiana* populations at 1, 3, 7, 14, 21, and 28 days after treatment. Each compound was applied at its recommended field rate. Poisonous bait formulations were prepared by thoroughly mixing the appropriate amount of each compound with 3.5 parts of black sugarcane syrup, followed by the addition of wheat bran to obtain 500 g of bait mixture. Control baits were prepared using the same ingredients but without the addition of any chemical compound. Methylene blue was

added to the bait formulations to distinguish treated baits, following the method described by Hanafy *et al.* (1998). Each treatment, including the control, was replicated four times. Approximately 125 g of bait was placed on plastic sheets in each replicate. Live snails were counted in both treated and control plots before bait application and at each sampling interval (1, 3, 7, 14, 21, and 28 days post-treatment) until the end of the experiment. Population reduction percentages were calculated using the formula of Henderson and Tilton (1955).

$$\% \text{ Reduction} = (1 - t_2 \times r_1) \times 100$$

$t_1 \times r_2$, r_1 = number of alive snails before treatment in untreated plots, r_2 = number of alive snails after treatment in untreated plots, t_1 = number of alive snails before treatment in treated plots, t_2 = number of alive snails after treatment in treated plots.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using a generalized linear model appropriate for repeated measures. Percentage data were arcsine square-root transformed prior to analysis to meet assumptions of normality and homogeneity of variance. Treatment means were separated using Tukey's honestly significant difference (HSD) test at $p \leq 0.05$. All statistical analyses were performed using

SPSS software (version XX, IBM Corp., USA).

Results

Pesticides used

Three pesticides commonly applied for the control of various pests in field crops were assessed in the present study. Details regarding the chemical class, common name, trade name, chemical structure, and scientific name of each tested pesticide are presented in the following:

1-Metaldehyde (Gastrotex 5 % G): Molluscicide

Data presented in Tables 1 and 2 demonstrate clear differences in the field efficacy of the three compounds in controlling *Monacha cartusiana* populations on alfalfa. The tested compounds varied considerably in their ability to reduce snail populations during both the initial and residual periods following application. Based on the overall performance, Metaldehyde and FePO_4 exhibited higher efficacy than Diazinon. The maximum initial reduction percentages were recorded shortly after application, reaching 97.88% and 95.61% for Metaldehyde, 95.98% and 93.42% for FePO_4 , and 87.49% and 85.21% for Diazinon during the two growing seasons, respectively. Subsequently, the reduction percentages of all tested compounds gradually declined up to fourteen days after treatment.

Table 1: Efficacy of selected insecticides and biocides against the land snail *monacha cartusiana* under field conditions in Al-Qadisiyah District during the 2024 growing season.

Tested Pesticides	Reduction after indicated days							R.E	Mean of reduction %
	1 day	3 day	I.E	7 days	14 days	21 days	28 days		
Diazinon 10% GR	87.49b	85.29b	86.39	80.51c	75.64b	61.48b	50.13a	66.94	73.42
Fepo4 10%	95.61a	92.96a	94.29	87.34b	81.62ab	67.93a	53.18a	72.52	79.77
Metaldehyde 5%G	97.88a	95.15a	96.52	90.84a	85.17a	70.04a	58.01a	76.02	82.85
LSD0.05	3.437	6.450		3.154	7.309	5.392	7.757		

I.E.: Mean percentage reduction of snails during the first and third days after treatment. R.E.: Mean percentage reduction of snails during subsequent sampling intervals.

Table 2: Effect of selected insecticides and biocides on the land snail *Monacha cartusiana* under field conditions in Al-Qadisiyah District during the 2025 growing season.

Tested pesticides	Reduction after indicated days							R.E	Mean of reduction %
	1 day	3 day	I.E	7 days	14 days	21 days	28 days		
Diazinon 10% GR	85.21b	83.05b	84.13	78.35c	73.65b	59.05b	48.05a	64.78	71.23
Fepo4 10%	93.42a	90.98 a	92.20	85.28b	79.01ab	65.75a	50.68a	70.18	77.52
Metaldehyde 5%G	95.96a	92.79a	94.38	89.86a	83.82a	68.19a	56.28a	74.54	81.15
LSD0.05	4.028	5.896		3.015	5.614	5.267	6.978		

I.E.: Mean percentage reduction of snails during the first and third days after treatment. R.E.: Mean percentage reduction of snails during subsequent sampling intervals.

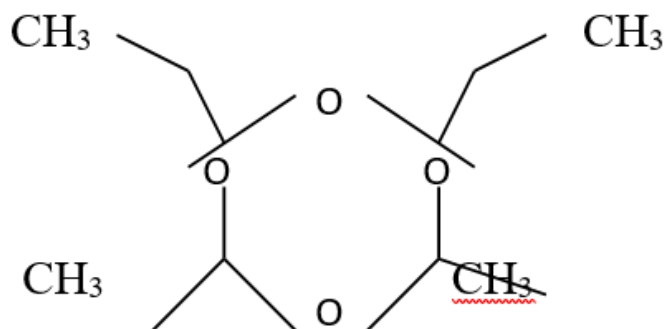


Figure 1: Chemical formula: 2, 4, 6, 8, tetramethyl – 1, 3, 5, 7- tetraoxacyclooctane; acetaldehyde tetramer

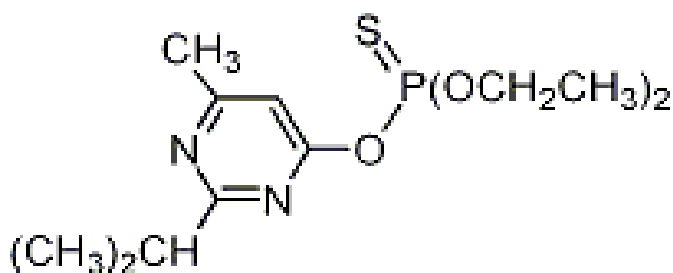


Figure 2: 2-Diazinon (10% E.C.) organophosphate.

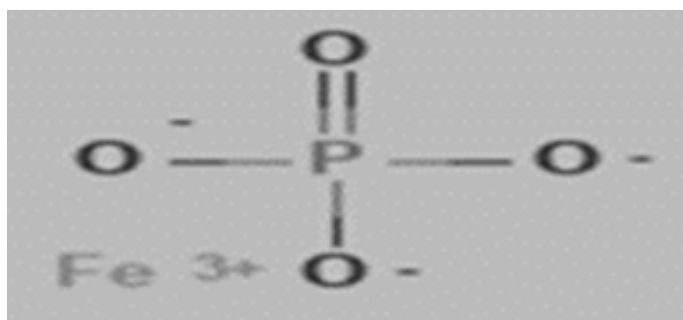


Figure 3: 3-Fepo4 10% Ferric phosphate (Iron 3+phosphate).

Metaldehyde consistently showed superior toxicity against *M. cartusiana* during both the initial and residual phases. It achieved reduction percentages of 96.52% and 76.02% in the first season and 94.38% and 74.54% in the second season for the initial and residual effects, respectively. FePO_4 ranked second in effectiveness, producing reduction percentages of 94.29% and 79.77% during the first season and 92.20% and 70.12% during the second season for the same periods. In contrast, Diazinon exhibited comparatively lower efficacy, with reduction percentages of 86.39% and 66.94% in the first season and 84.13% and 64.78% in the second season for the initial and residual effects, respectively. Based on the overall mean values, Metaldehyde proved to be the most effective compound, surpassing both FePO_4 and Diazinon. Overall reduction percentages reached 82.85% and 81.15% for Metaldehyde, followed by

79.77% and 77.52% for FePO_4 , while Diazinon resulted in the lowest reductions of 73.42% and 71.23% during the 2024 and 2025 seasons, respectively. These findings confirm that Metaldehyde was the most effective compound among those evaluated under field conditions.

Discussion

The results obtained from the present field trials revealed clear and consistent differences among the tested compounds in their ability to suppress populations of *Monacha cartusiana* in alfalfa fields. Across the two successive growing seasons, Metaldehyde provided the highest level of control, followed by ferric phosphate (FePO_4), whereas Diazinon exhibited comparatively weaker performance. These findings emphasize that the choice of molluscicide is a decisive factor in achieving effective and sustained reduction of land snail populations under field conditions.

All tested compounds produced high population reductions during the early post-treatment period, indicating rapid toxic action following bait consumption. However, the degree of persistence varied markedly among treatments. Metaldehyde and FePO_4 maintained relatively higher reduction percentages over time, while Diazinon showed a faster decline in effectiveness during the residual phase. Such reductions in residual activity are commonly attributed to bait degradation, environmental exposure, and reduced availability of active ingredients under open-field conditions.

Metaldehyde consistently demonstrated superior efficacy against *M. cartusiana* during both the initial and residual periods of assessment. Its strong performance may be linked to its well-documented mode of action, which interferes with mucus secretion and causes severe dehydration in gastropods, ultimately leading to rapid mortality. The present results are in close agreement with earlier studies that reported high toxicity and reliable field performance of Metaldehyde against *M. cartusiana* and other terrestrial snail species (Ghamry *et al.*, 1993; Ismail and Mohamed, 2009; Abd El-Aal and Hamed, 2010). Ferric phosphate ranked second in effectiveness and exhibited relatively stable population suppression throughout the experimental period. Although its initial impact was slightly lower than that of Metaldehyde, its sustained residual effect suggests

that FePO_4 can serve as a practical alternative in snail management programs. In addition, ferric phosphate is generally considered environmentally safer, as it breaks down into naturally occurring soil components and poses minimal risk to non-target organisms. These characteristics support its potential integration into environmentally conscious pest management strategies.

In contrast, Diazinon showed the lowest overall efficacy against *M. cartusiana*, particularly during the residual phase. As an organophosphate insecticide primarily designed for insect control, its limited effectiveness against terrestrial snails is not unexpected. Similar observations have been reported by previous researchers, who noted that organophosphates often exhibit lower molluscicidal activity when compared with compounds specifically developed for gastropod control (Radwan and El-Wakil, 1991; Aioub *et al.*, 2000).

Differences in compound performance may also be explained by variations in chemical structure and physiological impact on snail metabolism. Several studies have demonstrated that molluscicides capable of disrupting key biochemical processes such as enzyme activity, protein synthesis, and lipid metabolism tend to produce higher mortality rates in land snails (El-Gohary and Genena, 2011). The strong and consistent efficacy of Metaldehyde observed in this study is in line with these findings and further confirms its high molluscicidal potential.

The current results are consistent with numerous field investigations reporting effective population reduction of *M. cartusiana* and *Eobania vermiculata* using Metaldehyde and related compounds (Ismail *et al.*, 2005; Gaber *et al.*, 2020). Although some studies have shown superior performance of methomyl under specific conditions (Ismail *et al.*, 2010), the present two-season field evaluation confirms that Metaldehyde remains a dependable option under the agro-ecological conditions of southern Iraq. Additional studies by Farag (2012) and Botelho *et al.* (2020) reported notable residual effects of Methomyl and Metaldehyde against *M. cartusiana*, resulting in population reductions of 71.48% and 64.35%, respectively. Additionally, Frank and Friedli (1998); Abd El-Wahed *et al.* (2025) demonstrated that applying metaldehyde in a 50-cm-wide band effectively protected rapeseed crops from slug damage

caused by *Arion lusitanicus* and *Deroceras reticulatum*. Lokma (2007) also confirmed that increasing application rates of Metaldehyde significantly enhanced its efficacy against *M. cartusiana*, with mean reduction percentages of 32.24%, 43.64%, and 51.54% at application rates of 0.43, 0.50, and 0.62 g/m², respectively.

Recent studies by Liu *et al.* (2024), Dong *et al.* (2017) and Ibrahim *et al.* (2023) further emphasized the effectiveness of Metaldehyde in controlling *Pomacea canaliculata*. Acute toxicological investigations revealed that Metaldehyde significantly altered enzyme activities and induced histopathological changes in adult snails within 24 and 48 hours of exposure, supporting its strong molluscicidal action.

Overall, the observed variation in efficacy among the tested compounds highlights the importance of selecting appropriate molluscicides based on both immediate toxicity and residual performance. The superior results achieved by Metaldehyde, followed by ferric phosphate, indicate their suitability for managing *M. cartusiana* infestations in alfalfa fields. At the same time, the gradual reduction in effectiveness observed for all treatments underscores the necessity of proper application timing, compound rotation, and integration with non-chemical control methods to ensure long-term and sustainable snail management. Weather conditions, soil moisture, snail behavioral variability, and bait degradation collectively influenced molluscicide performance, explaining the high initial efficacy and the gradual decline in residual control under field conditions (Mahrous *et al.* 2002).

Conclusion

This study confirmed that the tested compounds differed significantly in their effectiveness against the glassy clover snail, *Monacha cartusiana*, under field conditions in Al-Qadisiyah District, Iraq. Over two successive growing seasons, Metaldehyde consistently achieved the highest initial and residual population reductions, followed by ferric phosphate (FePO_4), while Diazinon showed the lowest efficacy. These results indicate that Metaldehyde remains the most reliable option for rapid and sustained control of *M. cartusiana* in alfalfa fields.

Ferric phosphate demonstrated satisfactory and stable performance, suggesting its potential as a

safer alternative within integrated pest management programs, particularly where environmental considerations are important. The gradual decline in effectiveness observed for all compounds highlights the need for proper timing, compound rotation, and integration with non-chemical control methods. Future research should focus on long-term environmental impacts, resistance development, and the integration of molluscicides with cultural and biological control strategies to achieve sustainable snail management.

Novelty Statement

This study provides the first comprehensive, two-season field evaluation of Metaldehyde, Diazinon, and ferric phosphate (FePO_4) against the glassy clover snail *Monacha cartusiana* in alfalfa fields of Al-Qadisiyah District, southern Iraq. Unlike previous investigations that were largely confined to laboratory assays or single-season trials, the present work integrates both initial and residual population reduction effects under realistic field conditions across consecutive growing seasons. In addition, the study offers a direct comparative assessment of a conventional molluscicide, an organophosphate insecticide, and an environmentally safer iron-based compound using a standardized bait formulation. The generated data represent the first location-specific evidence on the relative efficacy and persistence of these compounds against *M. cartusiana* in this agro-ecological region. These findings contribute new insights that support informed compound rotation and selection within integrated pest management programs aimed at improving snail control while reducing excessive chemical dependence.

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Novelty Statement

This study provides the first field comparison of Metaldehyde, Diazinon, and ferric phosphate (FePO_4) against *Monacha cartusiana* in southern Iraq, providing location-specific evidence to support effective and sustainable snail management within

integrated pest management (IPM) programs.

Author's Contribution

Ahmed. S. Jabbar: Conceptualization, Methodology, Investigation, Data curation, Writing-original draft. Husam Majeed Kadhim Al- Saadi: Writing-review & editing, Visualization. Ali Ahmed Waheed: Writing-review & editing, Resources. Ahmed Saeed Mohamed: Validation, Supervision, Resources, Project, administration, Formal analysis.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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