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Positive impact of magnetic materials as an ecologically acceptable alternative to control *Monacha cartusiana* land snail

Mona A Ali, Abd El-Khalek M Hussein, Mohamed A Ayyad
Plant Protection Research Institute, Agricultural Research Center, Dokki, Giza, Egypt

Abstract
Magnetic material technology is a recent and environmentally friendly application as a stimulating additive to some potential materials for controlling land snails under laboratory conditions. In this study, some materials such as distilled water, sea water and Agrinate (a recommended substance for controlling terrestrial snails) were magnetized; the study was applied on adult individuals of the land snail *Monacha cartusiana* to measure the toxicity and study their fertility. Results showed that magnetized Agrinate had the highest mortality percentage 89.99, 96.66 using both leaf dipping and contact methods, respectively. In comparison to the control group, tested magnetized materials in general lowered the percentages of eggs hatchability (fertility). Zero hatchability rates were recorded in magnetized Agrinate. The research revealed the possibility of improving the efficiency of magnetized sea water and magnetized Agrinate that may be used to control land snails.

Keywords: magnetized materials, *Monacha cartusiana*, magnetic molluscicide, egg hatchability, incubation period

Introduction
Land snail molluscs belong to phylum Mollusca. One of the largest phyla in the animal kingdom is Mollusca. Terrestrial molluscs are considered a significant threat to sustainable agriculture in many areas around the world [1]**.** They are major pests of a wide range of agricultural and horticultural crops in temperate and humid habitats worldwide [2]. In Egypt, land snails have been increasing as an agricultural hazard, where they attack numerous parts of plants such as vegetables, horticultural fields, decorative plants, and field crops, feeding on it [3]. Economic damage caused by these molluscs is due to feeding and contamination with their bodies, feces, or slime. This leads to deterioration of the product quality, in addition to the financial loss [4]. The glassy clover snail, *Monacha cartusiana* (Müller), is one of the most harmful species, causing damage to vegetables and major field crops in Egypt [5]. Control operations depend mainly on specialized pesticides to keep animals below the critical economic limit level. Pest control activities utilizing magnetized water are, in general, a new method. Magnetized (or magnetically treated) water is produced by passing it through a magnetic field of a known strength [6]. Some studies have reported that exposing water to a known magnetic field affects many of its physical properties such as surface tension, density, viscosity, hardness, conductivity and solubility of solid matter, the biology of the species that utilize the magnetized water is affected by these variations in characteristics [7, 8, 9, 10, 11]. The use of magnetism, in addition to being an effective method, is also a new and promising approach in the field of control [12]. Scanty information is available concerning the effect of magnetic water on land snails, *M. cartusiana.*, therefore, this present work aimed to detect the impact of different magnetized and non- magnetized treatments on the mortality percentage of the adults and also eggs as ovicides of land snails, *M. cartusiana*, through affective and safe physical control methods, e.g., magnetic technology, to achieve a new molluscicide alternative.

Materials and methods
Tested snails
Adult land snail samples were collected manually from many contaminated farms in the Mansoura district of Dakahlia Governorate, Egypt. The snails were transferred directly in muslin bags to the laboratory and were kept in a plastic pot (50× 30 × 25cm) filled with moist sterilized sandy loam soil and covered with muslin to prevent snails from escaping [13]. Fresh lettuce leaves (*Lactuca sativa L.*) were the source of food for 14 days to be laboratory adapted [14]. Dead and weak snails were excluded, and only healthy ones were used in the experiments**.** Laboratory conditions were at 25 C° ± 2 C° and 75 % ± 5 % humid soil.

Magnetization of tested treatments
One liter of distilled water as a control group bottle, sea water solution, as well as the same volume of Agrinate (24% solution), which is a recommended molluscicide, were magnetized by passing them through the magnetic field apparatus, which allowed for a 180 milli-tesla magnetic field (ml.t). Also, the same previous treatments were repeated for each of them (distilled water, sea water, and agrinate 24%) in an equal volume, but without magnetic force. They were placed a meter away from the magnetic treatments. This apparatus was arranged and measured in Faculty of Engineering at Menofiya University, Egypt, using a tesla-meter apparatus.

Magnetized and non-magnetized treatment application procedures against adults *M. cartusiana* snail
Leaf- dipping technique
Fresh lettuce leaves were soaked for one minute in each treatment and then dried [15]. The leaves were placed in plastic containers holding humid sterilized sandy loamy soil. Each box was filled with ten adult *M. cartusiana* snails. To prevent the snails from leaving, each box was covered with muslin cloth and secured with rubber bands. There were

three replicates of each treatment. After one, two, three, and four weeks of treatment, mortality percentages were observed.

Contact technique

It's known as the contact method or thin layer method, and it's been certified as a method for toxicity evaluation [16]. The tested materials were applied to the surface of the Petri-dish (9 cm in diameter) in three replicates, with 10 snails for each replicate. By gently moving the Petri-dish in circles, two mL of each material were distributed all over the inner surface of the dish. The snails were exposed to all treatments and mortality percentages were recorded after one, two, three, and four weeks of application.

Effect of exposure to different magnetized and non-magnetized treatments on snails' egg-laying capacity of treated adult snail *M. cartusiana* (Fertility)

Adult *M. cartusiana* snails were treated with a leaf-dipping procedure, and each treatment was repeated three times. Each container had ten snails weighing the same weight (0.6g). Similar snails were placed in three replicates of containers treated just with distilled water as a control, when snails began to lay eggs, daily, newly hatched (zero-day-old) snails were collected from each pot after close supervision [17], to record the numbers of eggs laid, the date of egg lying, and the percentage of hatchability (fertility). Laid eggs were counted and incubated under controlled conditions to estimate the egg hatchability percentage and the time required for egg hatchability (incubation period). The percentage of egg hatchability was recorded and calculated according to the following equation:

$$\text{Percentage of egg hatchability} = \frac{\text{No.of hatched eggs}}{\text{The total No.of eggs}} \times 100$$

Effect of exposure to different magnetized and non-magnetized treatments on the eggs of *M. cartusiana* snail

An adult land snail, *M. cartusiana,* was placed in a plastic box. Every day, the soil was investigated for new egg clutches. Newly deposited clutches were carefully collected by a fine brush. The eggs were divided into batches of 20 eggs. Each batch of eggs (up to 24 h. old) was placed in a culture dish containing 5 g of sterile moist soil and covered with a black cover. One ml of each treatment was topically applied directly to the egg batches. All the tested treatments and the control group were replicated five times. The eggs were examined daily for a period of one month to record the date of hatching.

$$\text{Rate of hatchability} = \frac{\text{No. of hatched eggs (treated group)}}{\text{No. of hatched eggs (control group)}}$$

Statistical analysis

Data was calculated and analyzed using the analysis of variance technique (ANOVA). A probability of 0.05 or less was considered significant. All statistical analysis was done with Cohort Software [18].

Results and discussion

Effect of different magnetized and non-magnetized treatments on *M. cartusiana* adult snail using leaf dipping technique

The percentage of adult total mortality of *M. cartusiana* after being exposed to various magnetized and non-magnetized treatments using the leaf dipping methodology, as shown in Table (1) and Fig. (1), indicated that the treatment with magnetized Agrinate caused the biggest mortality rate observed after one week, at 66.66 %. It also caused the biggest mortality percentage of 89.99%, followed by Agrinate's 76.66%, which is the main approved molluscicide. Also, results showed that the total mortality percentage was 53.33, 33.33, 16.66, and 0.00 % for magnetized sea water, sea water, magnetized distilled water and distilled water, which was considered the control of the whole experiment, respectively.

Table 1: Mortality percentages of *M. cartusiana* adult snails as a result of exposure to different magnetized and non-magnetized treatments using leaf dipping technique

Tested treatments (Leaf dipping)	Mortality percentages after indicated weeks				Total Mortality %
	One Week	Two Weeks	Three Weeks	Four Weeks	
Distilled water	0.00 c	0.00 c	0.00 b	0.00 b	0.00
Magnetized distilled water	0.00 c	0.00 c	0.00 b	16.66 a	16.66
Sea water	0.00 c	0.00 c	33.33 a	0.00 b	33.33
Magnetized sea water	0.00 c	33.33 a	10.00 b	10.00 ab	53.33
Agrinate	50.00 b	16.66 b	10.00 b	0.00 b	76.66
Magnetized Agrinate	66.66 a	20.00 ab	3.33 b	0.00 b	89.99

Each value presented the mean of three replicates

Values followed by the same letter (s) in a column are not significantly different according to analysis of variance (ANOVA) test at level 0.05.

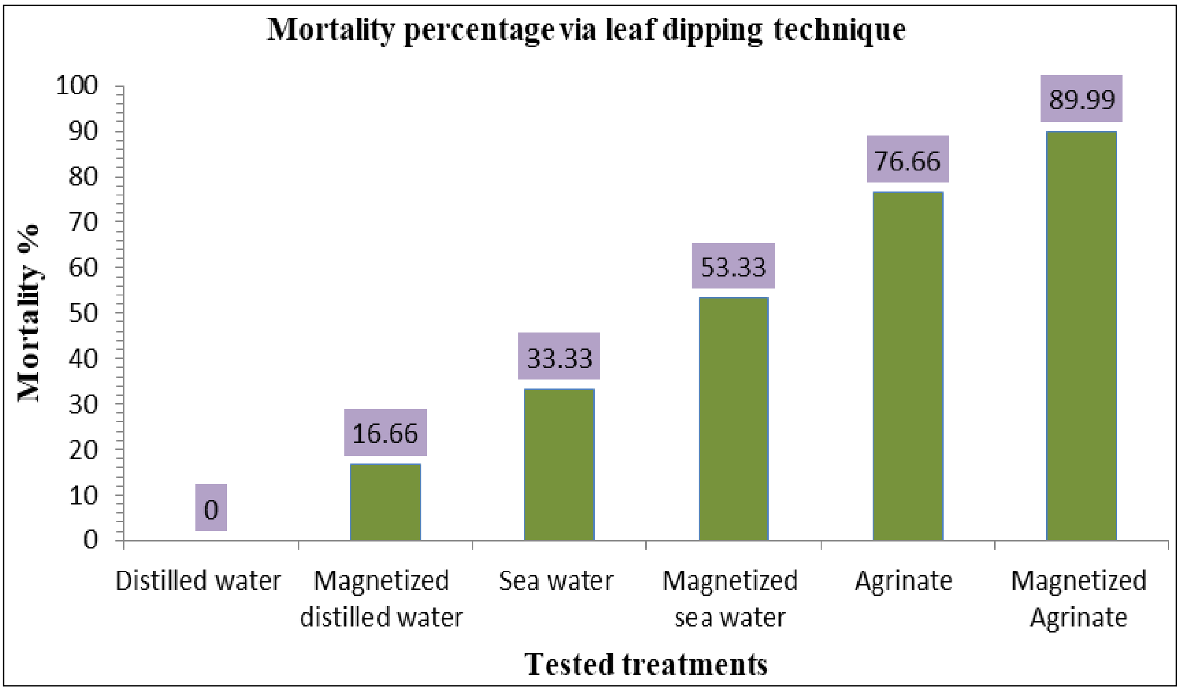

Fig 1: Mortality percentages of *M. cartusiana* adult snails as a result of exposure to different magnetized and non-magnetized treatments using leaf dipping technique

Effect of different magnetized and non-magnetized treatments on *M. cartusiana* adult snail using contact techniques:

The mortality percentages of the land snail, *M. cartusiana*, subjected to different magnetized and non-magnetized treatments utilizing thin layer or contact techniques were 96.66, 93.32, 73.33, 66.65, 33.33%, and 0.0% for magnetized Agrinate, Agrinate, magnetized sea water, sea water, magnetized distilled water, and distilled water, respectively, according to the results summarized in Table (2) and Fig. (2).

The finding was corroborated by that of Abd El-Wahab who found that the toxicity of magnetic water increased significantly, magnetic water has a lower LC50 value than non-magnetized water. With magnetic water, the LC50 of Diafenthiuron and Thiamethoxam were 3300 and 1900 (µl/l), respectively. When employed against adult *Monacha cartusiana* snails under controlled laboratory conditions after 24 hours, they were 6500 and 5300 (µl/l) without using any magnetism [19]. Also, the observations were verified by Juan who demonstrated that the aphid *Sitobion avenae* (Fabricius) had a lower survival rate after being exposed to 0.176 ml.t for 30 minutes and had a higher death rate after being exposed to a static magnetic field (SMF) (0.065 ml.t) for 60 minutes [20].

In addition, Martin and Tian found that a static magnetic field decreased bee flying activity and increased mortality by more than 60% in all treatments [21, 22]. Walker and Bitterman revealed that MF had a significant negative effect on honeybee survival rates and increased percent mortality [23]. Mostafa revealed that *Biomophlaria* exposure to saline solution with concentration of 7.2% led to 100% mortality; while *Biomophlaria* snails kept alive at 5% NaCl saline solution [24].

Table 2: Mortality percentages of *M. cartusiana* adult snails as a result of exposure to different magnetized and non-magnetized treatments using contact technique

Tested treatments (Contact)	Mortality percentages after indicated weeks				Total Mortality %
	One Week	Two Weeks	Three Weeks	Four Weeks	
Distilled water	0.00 d	0.00 b	0.00 b	0.00	0.00
Magnetized distilled water	33.33 c	0.00 b	0.00 b	0.00	33.33
Sea water	33.33 c	16.66 a	16.66 a	0.00	66.65
Magnetized sea water	43.33 bc	10.00 ab	20.00 a	0.00	73.33
Agrinate	66.66 ab	20.00 a	6.66 ab	0.00	93.32
Magnetized Agrinate	83.33 a	13.33 a	0.00 b	0.00	96.66

Each value presented the mean of three replicates.

Values followed by the same letter (s) in a column are not significantly different according to analysis of variance (ANOVA) test at level 0.05.

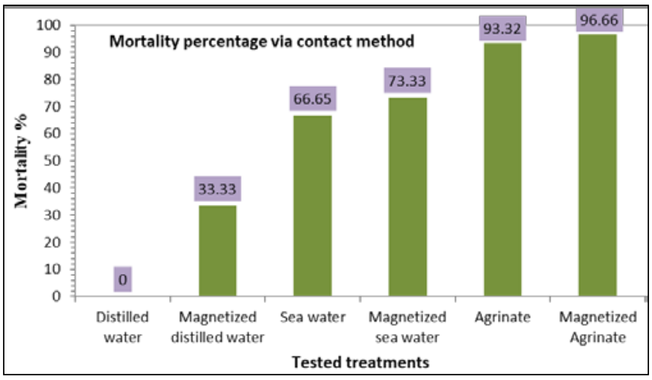

Fig 2: Mortality percentages of *M. cartusiana* adult snails as a result of exposure to different magnetized and non-magnetized treatments using contact technique.

Effect of different magnetized and non-magnetized treatments on the eggs of adult *M. cartusiana* snails (fertility):

Table (3) and Fig (3) demonstrate that exposing *M. cartusiana* snails to different magnetized and non-magnetized treatments lowered the overall number of clutches, the overall number of eggs laid, and the overall number of hatched eggs. Therefore, in comparison to the control group, the tested materials in general lowered the percentages of egg hatchability (fertility). Hatchability percentages were 62.27, 69.18, 91.27, and 95.19% for magnetized sea water, sea water, magnetized distilled water, and distilled water (control group), respectively. Zero hatchability percentage was recorded in both Agrinate and magnetized Agrinate groups.

Results shown in Table (3) and Fig (3) showed that subjecting snails to various magnetized and non-magnetized treatments increased the average incubation period of snail eggs from 17.8 days in the control group to 26.5, 24.1, and 19.0 days in the magnetized sea water, sea water, and magnetized distilled water groups, respectively. Furthermore, data suggested that magnetic Agrinate and Agrinate were the most successful materials in reducing both the hatchability and the incubation period of *M. cartusiana* eggs. The latest results confirmed those of Ali and Hussein who indicated that exposing *M. cartusiana* to a magnetic field reduced the overall number of eggs laid and the number of hatched eggs, according to the same investigation, the percentage of hatchability (fertility) for magnetic field was 62.16 percent, whereas the control groups had 91.01 percent. In addition, as compared to control, the mean incubation period of *M. cartusiana* eggs for magnetic field was 35.5 days, whereas it was 23.5 days in control [25]. Hussein and his team observed a linear negative connection between applied magnetic field force and hatchability percentage in *Sitotroga cerralella* hatching eggs, which reduced from 90% in the control to 22% with the applied magnetic field [12].

Table 3: laid eggs, hatched and incubation period as a result of exposure of the adult of *M. cartusiana* to magnetized and non-magnetized treatments.

Tested treatments	Total No. of clutches	Total No. of laid eggs	No. of hatched eggs	Percentage of hatchability	Reduction in eggs hatching	Average Incubation period (Days)
Distilled water	29	853	812	95.19	4.81	17.8
Magnetized distilled water	22	630	575	91.27	8.73	19.0
Sea water	15	305	211	69.18	30.82	24.1
Magnetized sea water	9	220	137	62.27	37.73	26.5
Agrinate	2	5	0	0	0	0
Magnetized Agrinate	0	0	0	0	0	0

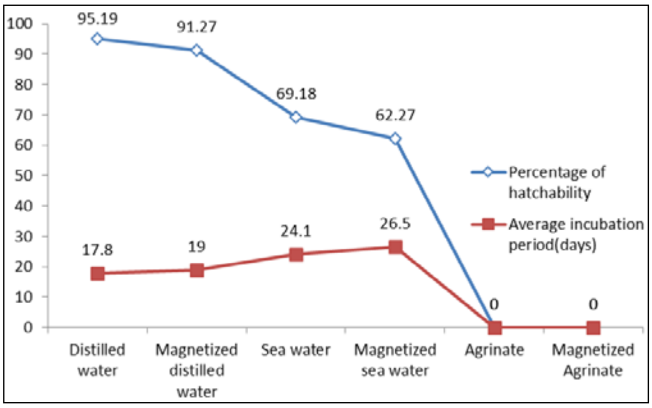

Fig 3: Hatched eggs and incubation period as a result of exposure of the adult of *M. cartusiana* to magnetized and non-magnetized treatments

Effects of different magnetized and non-magnetized treatments on the egg hatchability of *M. cartusiana* snail:

Table (4) and Fig. (4) indicate the hatchability of *M. cartusiana* eggs treated with various magnetic and non-magnetized treatments. When compared to control distilled water (18.6), Agrinate (0.8) had the biggest mean reduction in the number of hatched eggs, followed by magnetized sea water (5.6), sea water (10.2), and magnetized distilled water (16.6). Rate of hatchability showed a similar pattern, with values of 0.04, 0.30, 0.55, 0.89, and 1.00 for Agrinate, magnetic sea water, sea water, and magnetized distilled water, respectively, when compared to control distilled water. *M. cartusiana* eggs did not hatch in the magnetized Agrinate group. In comparison to the control group, Maciej and his co-workers showed that direct exposure of eggs of the two subspecies, *H. aspersa maxima* and *H. aspersa aspersa*, to a continuous magnetic field or an alternated electromagnetic field of 5–10 µT has a negative impact, in comparison to the control group, the influence of the alternating field on the growth and survival rate of *H. aspersa* is positive or neutral, whereas the impact of the direct field is more negative [26]. The biological effects of 7 T MFs were studied on *E. kuehniella* egg hatching. The eggs in the 7 T field took longer to hatch, and the hatching rate was reduced [27]. Levin and Ernst demonstrated that a 30 mT static magnetic field applied to sea urchin eggs changed the time of cell division and induced two developmental abnormalities, exogastrulation and collapsed embryos, when compared to control groups. It takes longer for eggs to hatch [28]. These results are supported by those of Pandir and his team, who found that exposing *E. kuehniella* adults to increasing levels of MFs impacted their daily egg production and resulted in a decrease in offspring development [29]. When *Drosophila* insects were exposed to magnetic fields, they had a significant drop in fecundity and fertility [22]. Walker and Bitterman also discovered a considerable negative impact on *Drosophila* fertility and hatchability [23]. Chun and his team observed that when *Euproctis pseudoconspersa* (EP) adults were subjected to an electromagnetic field, they were severely harmed [30]. *Earias insulana* survival, longevity, viability, and fertility were all affected by high MF levels [31], also longevity, and fecundity of *P. gossypiella* [32].

Also, the positive molluscicide effect was reported using magnetic water in the presence of increasing concentrations of oxygen (O_2) while reducing the concentrations of ozone (O_3), chlorine (Cl_2), and carbon dioxide (CO_2) concentrations, which made an advantage of using this modified magnetic water rather than tap water in the required concentrations preparation. Magnetic water could be used as a safe adjuvant to molluscicides, increasing pesticide effectiveness and uptake, resulting in higher mortality while posing no environmental risk. In a similar manner, magnetized water, which was used as a synergist of both pesticides tested, and magnetic water mixed with molluscicides, could play an important role in increasing toxicity against *Monacha cartusiana*, as evidenced by more amounts picked first and then higher mortality percentages than with other treatments that did not include magnetic water [19].

Scientists have observed that exposing water to a magnetic field alters its molecular and physico-chemical properties (via changing the water nucleus). The effect of magnetic water treatment depends on the composition of the treated water, magnetic field strength, rate of water movement, duration of its stay in the magnetic field and other factors. The magnetically modified chemical and physical properties of water may be the deciding factor for the solubility increase of the dissolved salts [33, 34, 35]. Water temperature affects the hatching process, while water quality, oxygen content, temperature, and water hardness affect the hatching rate [36]. The growth of fish, from embryo to adult, can be affected by the magnetic field [37, 38, 39]. It affects the egg's water uptake after fertilization [40], the developing embryos' motility [41] and the spatial orientation of embryos and larvae [42].

Table 4: Magnetized and non-magnetized treatments effect on the hatchability of *M. cartusiana* snail eggs.

Tested treatments	Aver. no. of exposed eggs	Aver. no. of hatched eggs	Rate of hatchability	egg hatchability (mean ± SE)
Distilled water	20	18.6	1.00	18.6 ± 0.24 ^{a}
Magnetized distilled water	20	16.6	0.89	16.6 ± 0.51 ^{a}
Sea water	20	10.2	0.55	10.2 ± 1.24 ^{b}
Magnetized sea water	20	5.6	0.30	5.6 ± 1.36 ^{c}
Agrinate	20	0.8	0.04	0.8 ± 0.37 ^{d}
Magnetized Agrinate	20	0.0	0.0	0.0

S.E. = Standard Error.
Each value represented mean of five replicates.

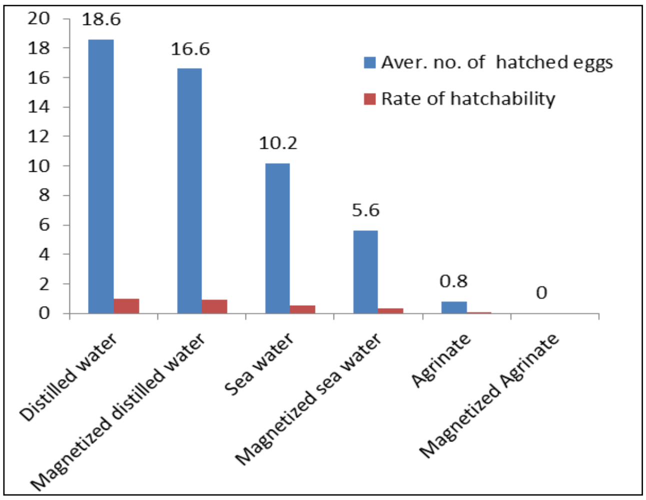

Fig 4: Magnetized and non-magnetized treatments effect on the hatchability of *M. cartusiana* snail eggs.

Conclusion

Magnetic materials approach is a modern, green, and environmentally friendly way to control many types of pests, including land snails, which cause an economic damage to agriculture. Pesticides that are treated with magnetic additives appear to be more effective than non-magnetized ones. However, studies in this field appear to need expansion and further explanations in order to fully understand the nature of these materials and to accurately and effectively determine their methods of action.

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