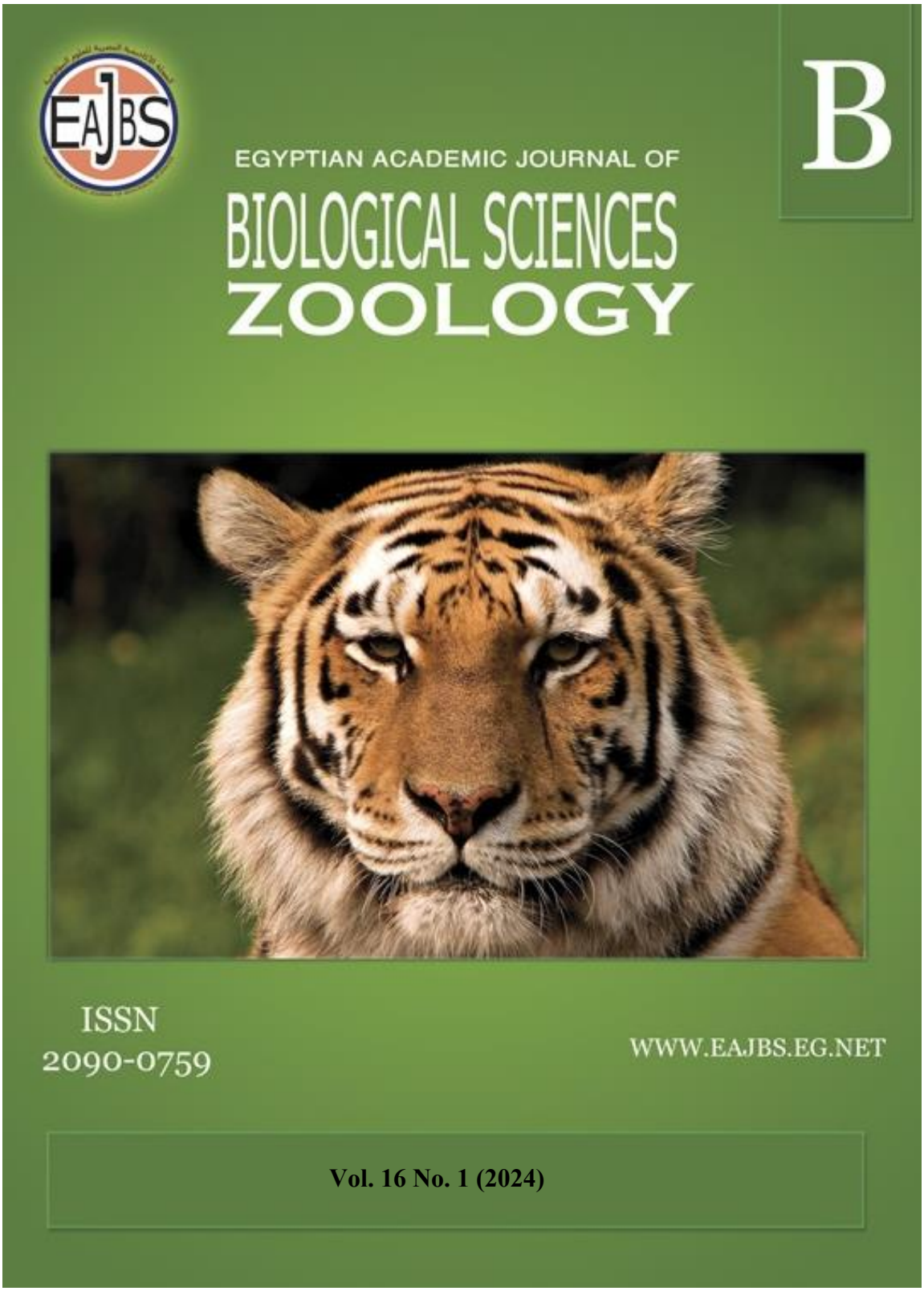

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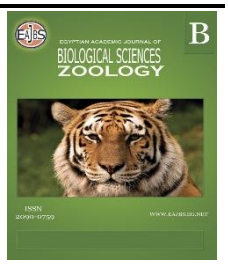

Citrus limon as A Natural Molluscicide against *Eobania vermiculata* and *Monacha cartusiana* Snails

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ABSTRACT

Some exogenous compounds found in nature can control the agricultural pests which cause serious damages to the different crops. Specifically, this study established to assess the molluscicidal effects of crude juice of *Citrus limon* fruit and *Citrus limon* peel on the developmental stages of *Eobania vermiculata* (chocolate band snail) and *Monacha cartusiana* (glassy clover snail). These juices were used individually against the three, six and nine-month-old and adult of both snails in the laboratory and also applied against adult individuals of each snail species in the field for 21 days. Results showed that the juveniles three months old were more susceptible to *C. limon* fruit and *C. limon* peel juices than the other ages of both snails. Moreover, *C. limon* fruit juice was more effective on the two snail species at all ages than the juice of *C. limon* peel. The crude suspension of *C. limon* fruit and *C. limon* peel caused 73.33& 46.66% and 60 & 46.66% mortality of adult snails of *E. vermiculata* and *M. cartusiana* respectively after 14 days of the laboratory experiment. While in the field assay, they were recorded 70.39 & 62.30% and 62.08 & 55.79% reduction of both snail adult individuals consecutively after the same period of application (14 days). Therefore, *E. vermiculata* snails were more affected by the two suspensions than the snails of *M. cartusiana* under both laboratory and field conditions. *C. limon* is a promising potential organic substitute to chemical molluscicide with no harmful impacts on humans and the environment.

INTRODUCTION

The chocolate band snail, *Eobania vermiculata* is an invasive species widely distributed throughout the world especially in the Mediterranean area (Radwan *et al*., 2008; Kandil *et al*., 2020). This snail has negative effects on agriculture and public health, it damages most vegetables, field crops, fruit trees, orchards and ornamental plants (Ali *et al*., 2020). The other terrestrial snail, *Monacha cartusiana* also represents the most abundant species in Egypt and the most destructive to the various agricultural crops (Abou Senna *et al*., 2016; Kadry *et al*., 2018; Shahawy, 2018). Many methods have been used to control these snails including mechanical, chemical and biological means. Chemical control is a common method used to control land snails. These chemicals include metaldehyde, aldehyde, methiocarb, copper sulfate and iron phosphate. These methods are common to

use for their practical and easy to apply. However, these chemicals have toxic effects on the non-target organisms including beneficial invertebrates such as predator beetles and earthworms, and also harmful to humans and the environment in general (Raut and Barker, 2002). Medicinal plants represent the most widespread therapeutic methods known to humans, including the use of plant materials as molluscicides (Salawu and Odaibo, 2011). They are cheap in cost, easily biodegradable, safe and have no harmful influence on the environment. Moreover, plants possess renewable organic defensive chemicals such as alkaloids, phenols, glycosides and tannins which have behavioral and physiological impacts on pests (Singh *et al*., 2010). The use of plant juices to control terrestrial mollusca such as slugs and land snails is a substitute method to reduce plant damage. It can decrease the use of chemical molluscicides and safe for the environment. *Citrus limon* represents one of the most important fruits in the world. The juice of *C. limon* fruit and peels are rich in essential oils and bioactive compounds (Agarwal *et al*., 2022; Palazzolo *et al*., 2013). These juices have significant molluscicidal activity against *M. cartusiana* snails under laboratory and field conditions (Hend, 2018).

This study is carried out to determine the molluscicidal efficacy of crude juices of *C. limon* fruit and peels separately on different developmental stages of *E. vermiculata* and *M. cartusiana* in the laboratory and against the adult individuals of both snail species in the field, which represent an alternative method to the chemical pest control methods used by farmers which are harmful and expensive.

MATERIALS AND METHODS

Experimental Snails:

Adult *E. vermiculata* were collected from navel orange trees at Moshtohor village, Tookh district, Qalyubia Governorate, Egypt. While, adult snails of *M. cartusiana* were collected from clover and cabbage fields in Malames village, Meniet El-Kamh district, Sharkia Governorate, Egypt, during February 2022. Snails of both species were transferred to the laboratory and kept in plastic boxes (3/4 kg capacity) containing humid clay soil and covered with gauze fixed with and elastic band to prevent snails from escaping. Snails in the rearing boxes were provided daily with fresh cabbage leaves for 14 days for adaptation. The boxes were examined daily to observe the egg laying and all deposited egg clutches were carefully isolated and observed until hatching to obtain juveniles 3, 6 and 9 months old from each snail species for the subsequent experiments.

Preparation of Botanical Suspension:

The fruits of *C. limon* (Sapindales, Rutaceae) were obtained from a local market in Zagazig City, Egypt. Fruits were washed with distilled water to get rid of dust and unwanted materials. It was then squeezed to obtain juice and the remaining peels were cut using a knife and were chopped well with an electric mill and the yield was squeezed by using a muslin cloth to obtain crude peel suspension (Hend, 2018).

Scientific name	Common name	Parts used	Image
Citrus limon	Lemon	- Fruit - Peel	

Molluscicidal Effect of Botanical Suspension against Juvenile and Adult Snails:

The molluscicidal effect of crude suspension of *C. limon* fruit and peel was tested separately against juveniles (3, 6 and 9 months old) and adults of *E. vermiculata* and *M. cartusiana* snails by spraying technique under the laboratory conditions. One rate (15 ml) from each crude suspension was used against each age of both snail species. Each treatment included 10 juveniles or adults and ten discs (2 cm diameter) of cabbage leaves were put on the surface of moistened clay soil placed in a plastic box (3/4 kg) capacity. Each suspension was directly sprayed on the soil and cabbage discs, and three replications were prepared for each treatment. The other three control replicates were prepared in the same way for each snail age but without any treatment. All boxes were covered with gauze cloth and secured with elastic bands to prevent snails from escaping. Mortality percentage of juveniles at the different ages and adults of each snail species for treated and control boxes were recorded after 1, 3, 7, 14 and 21 days of the experiment and corrected by Abbott's formula (1925).

Field Performance of Botanical Suspension against Adult Snails:

The molluscicidal activity of crude suspension of *C. limon* fruit and peels was assessed individually against *E. vermiculata* and *M. cartusiana* adult snails under field conditions. This experiment was carried out in April 2023 at two fields; the first is a field of navel orange trees infested with *E. vermiculata* snails at Moshtohor village, Tookh district, Qalyubia Governorate. While, the second field was a clover field, heavily infested with *M. cartusiana* snails and present in Malames village, Meniet El- Kamh district, Sharkia Governorate. In the first field, three infested trees were selected for spraying with each crude suspension. But before any treatment, live *E. vermiculata* snails were counted in four places of 25 × 25 cm under each tested tree, at 1 m high of tree stem and on five branches in different directions of the tree. After counting the snails, crude suspensions were sprayed separately in these areas at a rate of 1000 ml per tree. The other three control trees were designed in the same way but sprayed with water only without any treatment. On the other hand at the second field, three clover samples infested with *M. cartusiana* snails, 50 × 50 cm in size were chosen for spraying with each crude suspension at a rate of 100 ml for each sample. Before the treatment, live snails were counted in each sample. Three control samples were designed in the same manner but kept without any treatment and sprayed with water only.

Live snails were counted in both fields in the areas that were sprayed with each suspension and in the control after 1, 3, 7, 14 and 21 days of trial to calculate the reduction percentages of both snail species according to the formula of Henderson and Tilton (1955).

Data Analysis:

The effects of *C. limon* crude suspension on both land snail species in the laboratory and field experiments were analyzed using the Microsoft Excel Program, expressed as means ± standard error.

RESULTS

Effect of *C. limon* Fruit Suspension against *E. vermiculata* and *M. cartusiana* Snails at the Different Developmental Stages:

Mortality of juveniles (3-, 6- and 9-months age) and adults of *E. vermiculata* snail after the treatment with *Citrus limon* fruit crude suspension was observed for 21 days (**Table 1**). The results indicated that resistance to treatment increased with increasing the age of the snail. So, the 3 months-old juveniles were the most sensitive to the *C. limon* fruit suspension which recorded 80% mortality of juveniles after only one day of treatment. Then the mortality rate increased to 96.66% on the third day of the experiment but this rate was still stable until the end of the experiment. After exposing juveniles at this age to *C. limon* fruit juice, the juvenile shell lost its brown color and became white, the shell also became very

brittle and broken in most places (Fig. 1A). Meanwhile, the suspension of *C. limon* fruit caused 56.66 and 60% mortality of 6 and 9-month-old juveniles on the first day of treatment, respectively. These mortality rates increased gradually with the increase of experiment time and reached their maximum values of 96.66 and 80% for both ages after 21 and 7 days of the treatment, respectively. After treating 6-month-old juveniles with this suspension, they released a lot of mucus accompanied by extending a part of their soft bodies outside the shell aperture (Fig. 1B). On the other hand, adult individuals were the most resistant to *C. limon* fruit suspension with a mortality rate of 46.66% on the first day of the experiment and then this rate increased to 73.33% at 14 days and became relatively stable until the end of the experiment.

The effects of *C. limon* fruit crude suspension against 3, 6 and 9 months-old juveniles and adults of *M. cartusiana* snail were shown in Table 2. From the results, mortality rates of the juveniles 3, 6 and 9 months treated with this suspension on the first day of the experiment were 66.66, 50 and 46.66%, respectively. Then the mortality of juveniles at these ages significantly increased to 93.33, 90 and 76.66% after 21 days of exposure consecutively. Adults were the least affected by *C. limon* fruit suspension with a mortality rate of 33.33% within the first day of treatment, then this suspension showed its potential effects against adult snails with a mortality of 60% at 14 days of exposure and no additional mortality was recorded until the end of the experiment.

Table 1. The efficiency of *C. limon* fruit suspension against *E. vermiculata* snail at different ages

Days	Mortality % (mean ± SE)			
	Juveniles 3 months	**Juveniles 6 months**	**Juveniles 9 months**	**Adults**
1	80.00 ± 1.15	56.66 ± 0.32	60.00 ± 1.00	46.66 ± 0.88
3	96.66 ± 0.33	70.00 ± 0.58	63.33 ± 1.20	50.00 ± 1.16
7	96.66 ± 0.33	83.33 ± 0.34	80.00 ± 0.58	56.66 ± 1.00
14	96.66 ± 0.33	90.00 ± 0.57	80.00 ± 0.58	73.33 ± 0.66
21	96.66 ± 0.33	96.66 ± 0.33	80.00 ± 0.58	73.33 ± 0.66

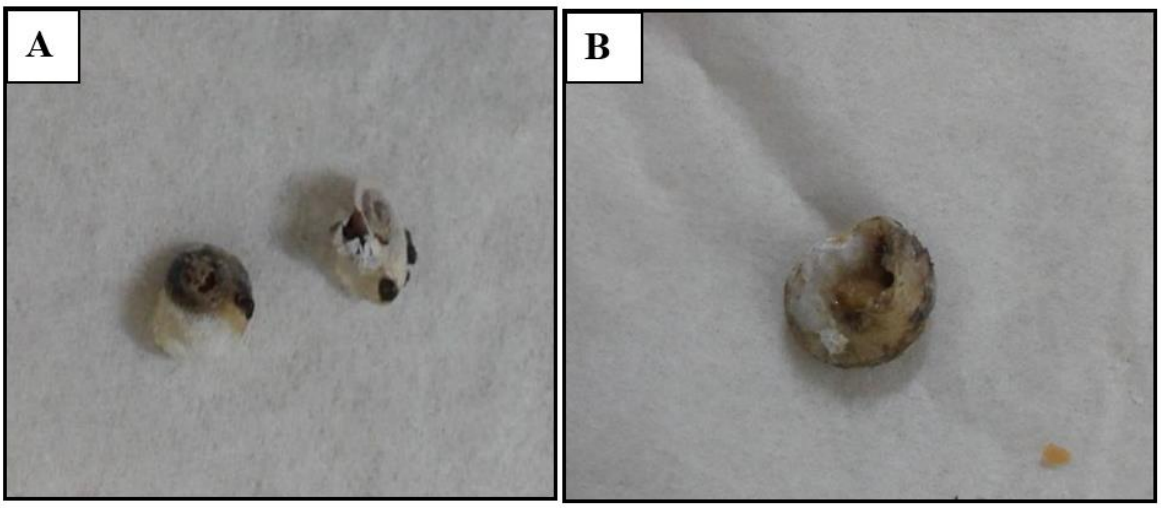

Fig. (1 A, B): *Eobania vermiculata* juveniles after exposure to *Citrus limon* fruit crude suspension. A change in the color of *E. vermiculata* (3 months-old) juveniles shell to white and laceration in its parts after exposure to *C. limon* fruit suspension. B, change in the color of *E. vermiculata* juvenile (6 months-old) shell and it became brittle after exposure to *C. limon* fruit suspension.

Table 2. Effect of *C. limon* fruit suspension against *M. cartusiana* snail at different ages

Days	Mortality % (mean ± SE)			
	Juveniles 3 months	Juveniles 6 months	Juveniles 9 months	Adults
1	66.66 ± 0.87	50.00 ± 1.00	46.66 ± 0.66	33.33 ± 0.32
3	80.00 ± 1.15	63.33 ± 1.20	46.66 ± 0.66	36.66 ± 0.34
7	86.66 ± 0.34	80.00 ± 1.16	63.33 ± 0.87	53.33 ± 0.88
14	93.33 ± 0.66	86.66 ± 0.34	76.66 ± 1.45	60.00 ± 0.57
21	93.33 ± 0.66	90.00 ± 0.58	76.66 ± 1.45	60.00 ± 0.57

Effect of *C. limon* Peel Suspension against *E. vermiculata* and *M. cartusiana* Snails at the Different Developmental Stages:

The efficacy of *C. limon* peel suspension against juveniles of 3, 6 and 9 months old and adults of *E. vermiculata* snail was shown in Table 3. Mortality rates of juveniles 3 and 6 months old treated with this suspension on the first day of exposure were 76.66 and 53.33% consecutively, then slightly increased on the third day of exposure to 80 and 66.66% respectively and after that, all juveniles of both ages survived until the end of the experiment. For juveniles 9 months old, the suspension of *C. limon* peel achieved 50% mortality within the first day of exposure and this rate increased to 63.33% on the seventh day of the experiment and no additional mortality was recorded until 21 days. Adults of *E. vermiculata* were more resistant to *C. limon* peel suspension than juveniles as it caused 36.66% mortality on the first day of treatment and most of the adults' mortality occurred within the seventh day of exposure with achieving 46.66% mortality and then no other mortality of adults recorded. The toxic influence also of *C. limon* peel suspension against *M. cartusiana* 3, 6 and 9 months-old juveniles and adults was investigated. As presented in Table 4. *C. limon* peel suspension showed a significant potency against the 3-month-old juveniles on the first day of the experiment with 73.33% mortality and after that it did not induce any effect and all juveniles survived. After exposure of the juveniles at this age to *C. limon* peel suspension, the shell became white in color and had obvious holes and cracks (Fig. 2).

Table 3. Influence of *C. limon* peel suspension against *E. vermiculata* snail at different ages.

Days	Mortality % (mean ± SE)			
	Juveniles 3 months	Juveniles 6 months	Juveniles 9 months	Adults
1	76.66 ± 0.88	53.33 ± 1.32	50.00 ± 1.00	36.66 ± 1.16
3	80.00 ± 0.57	66.66 ± 0.87	53.33 ± 1.33	40.00 ± 0.58
7	80.00 ± 0.57	66.66 ± 0.87	63.33 ± 0.34	46.66 ± 0.32
14	80.00 ± 0.57	66.66 ± 0.87	63.33 ± 0.34	46.66 ± 0.32
21	80.00 ± 0.57	66.66 ± 0.87	63.33 ± 0.34	46.66 ± 0.32

Table 4. Efficacy of *C. limon* peel suspension against *M. cartusiana* snail at different ages

Days	Mortality % (mean ± SE)			
	Juveniles 3 months	Juveniles 6 months	Juveniles 9 months	Adults
1	73.33 ± 0.66	56.66 ± 0.34	43.33 ± 1.45	30.00 ± 1.00
3	73.33 ± 0.66	56.66 ± 0.34	50.00 ± 0.57	43.33 ± 0.66
7	73.33 ± 0.66	60.00 ± 0.58	56.66 ± 0.33	46.66 ± 1.20
14	73.33 ± 0.66	60.00 ± 0.58	56.66 ± 0.33	46.66 ± 1.20
21	73.33 ± 0.66	60.00 ± 0.58	56.66 ± 0.33	46.66 ± 1.20

Fig. 2: Damage and laceration in the shell of *Monacha cartusiana* juveniles (3 months old) after exposure to *Citrus limon* peel crude suspension.

On the other hand, mortality rates of the juveniles 6 and 9-months-old treated with *C. limon* peel suspension were 56.66 and 43.33% on the first day of exposure, respectively. The mortality of juveniles at both ages increased with the increase in the experimental period and reached 60 and 56.66% on the seventh day consecutively and no additional mortality was recorded until 21 days. With regard to the adults, the suspension of *C. limon* peel induced only 30% mortality in adult individuals, this rate increased to 46.66% on the seventh day of treatment and was still stable until the end of the experiment.

Field Performance of *C. limon* Fruit Suspension against Adult of *E. vermiculata* and *M. cartusiana* Snails:

Reduction of *E. vermiculata* and *M. cartusiana* after spraying with *C. limon* fruit crude juice was observed under field conditions for 21 days (Table 5). From the results, *C. limon* fruit suspension was more potent against *E. vermiculata* snails than *M. cartusiana* individuals. It caused a 51.30% reduction of *E. vermiculata* adults after one day of the field treatment compared with a 39.87% reduction of *M. cartusiana* individuals during the same period. The mean reduction of *E. vermiculata* and *M. cartusiana* by this suspension during the first three days was 54.26 and 43.11%, respectively. The snails of *E. vermiculata* and *M. cartusiana* were significantly reduced by *C. limon* fruit suspension to 70.39 and 62.08% at 14 days, consecutively and no additional reduction of both snails was shown until the end of application. The mean effect of *C. limon* fruit suspension against *E. vermiculata* and *M. cartusiana* snails after the third day of exposure to 21 days was 69.73 and 62.08% reduction, respectively.

Table 5. Field performance of *C. limon* fruit suspension against adult snails

Days	Reduction % (mean ± SE)	
	E. vermiculata	***M. cartusiana***
1	51.30 ± 0.87	39.87 ± 0.70
3	57.22 ± 0.79	46.35 ± 0.82
Initial effect	54.26 ± 0.71	43.11± 0.73
7	68.41± 0.67	62.08 ± 0.86
14	70.39 ± 1.05	62.08 ± 0.86
21	70.39 ± 1.05	62.08 ± 0.86
Residual effect	69.73 ± 0.91	62.08 ± 0.86

Field performance of *C. limon* Peel Suspension against Adult of *E. vermiculata* and *M. cartusiana* Snails:

The molluscicidal potency of *C. limon* peel crude suspension against *E. vermiculata* and *M. cartusiana* adults under field conditions is shown in Table 6. The presented results indicated that *E. vermiculata* snails were more sensitive to *C. limon* peel suspension than *M. cartusiana* snails. The suspension caused 44.07 and 39.88% reduction of *E. vermiculata* and *M. cartusiana* individuals on the first day of application, respectively. The initial effect of *C. limon* peel suspension against both snails was a 48.86 and 43.81% reduction, consecutively. The reduction of both snail species slightly increased to 62.30 and 51.16% on the seventh day of treatment for *E. vermiculata* and *M. cartusiana* snails, respectively. No additional reduction was achieved by the suspension against *E. vermiculata* snails but the reduction rate of *M. cartusiana* increased to 55.79% at 14 days and then remained stable until the end of application.

Table 6. Field performance of *C. limon* peel suspension against adult snails

Days	Reduction % (mean ± SE)	
	E. vermiculata	***M. cartusiana***
1	44.07 ± 1.70	39.88 ± 0.71
3	53.66 ± 0.72	47.75 ± 0.58
Initial effect	48.86 ± 60.0	43.81 ± 0.67
7	62.30 ± 0.45	51.16 ± 1.58
14	62.30 ± 0.45	55.79 ± 0.53
21	62.30 ± 0.45	55.79 ± 0.53
Residual effect	62.30 ± 0.45	54.24 ± 0.41

DISCUSSION

Most studies focused on the use of plant extracts in the control of land snails. Only a few investigations on control land snails such as *Monacha cartusiana* by the suspension of *C. limon* have been reported (Hend, 2018). Therefore, the current study confirmed the molluscicidal potency of *C. limon* fruit and *C. limon* peel suspension against both *E. vermiculata* and *M. cartusiana* snails at different developmental stages including juvenile and adult age. The study results indicated that the resistance to *C. limon* fruit and *C. limon* peel suspension increased with increasing the age of both snails. Thus, three-month-old juveniles were the most affected by these suspensions, followed by six-month-old, nine-month-old and adults, respectively. These findings can be explained by Mohamed *et al*. (2002) mentioned that juveniles of land snails are more sensitive to control methods than the adult stage because they have thin and soft shells.

In this study, *C. limon* fruit suspension caused 80, 56.66 and 60% mortality of three, six and nine-month-old juveniles of *E. vermiculata* respectively within the first day of exposure. These mortality rates increased to 96.66% after 3 and 21 days of the experiment for the three and six-month-old juveniles consecutively and increased to 80% for the juveniles nine months on the 7^{th} day of the treatment. However, this suspension achieved only 46.66% mortality of adult snails on the first day of exposure which increased to 73.33% at 14 days. In the same line, this suspension recorded its highest molluscicidal influence against *M. carusiana* juveniles which were three, six and nine months old with records of 93.33, 90 and 76.66 after 21 days of the experiment, respectively. On the other hand, the suspension of *C. limon* peel induced its maximum activity against three and six-month-old juveniles of *E. vermiculata* achieving 80 and 66.66% mortality of both ages after 3 days of

exposure consecutively. While it caused 63.33 and 46.66% mortality of the juveniles nine months old and adults represents the highest influence of this juice against these ages after 7 days of the experiments. This suspension also achieved 73.33% mortality of the juveniles three months old of *M. cartusiana* after only one day of exposure followed by 60, 56.66 and 46.66% mortality of juveniles six, nine-month-old and adult snails respectively after 7 days of treatment. These results can be reflected in the molluscicidal activity of *C. limon* fruit suspension against all ages of *E. vermiculata* and *M. cartusiana* snails was more than the suspension of *C. limon* peel. Moreover, *E. vermiculata* snail at all ages was more affected by both suspensions than the other snail, *M. cartusiana*. These findings were in accordance with Hend (2018) reported that *C. limon* fruit suspension exhibited a significant mortality of *M. cartusiana* adult snails with a record 80% mortality after 14 days of laboratory treatment. Whereas, the suspension of *C. limon* peel caused 63.33% mortality of the same snail species after the same experimental period. Moreover, this juice caused a clear furan in the shell aperture of *M. cartusiana* individuals after a few hours of exposure. In the same aspect, Meljan *et al*. (2015) stated that *Cymbopogon citratus* (Lemon grass) crude leaf extract induced complete mortality of *Pomacea canaliculata* one-day-old juveniles at both 100% and 50% concentration. The extract possessed the same influence and caused complete mortality of adult snails at the concentration of 100% and achieved 80% mortality of adults at the concentration of 50%. This extract in the lowest concentration of 20% exhibited only 10% mortality of the juveniles and did not induce any mortality of the adult snails at this concentration. *C. citratus* has a lemony characteristic flavor due to it contains citral as a major constituent in this plant, it has also therapeutic and insecticidal properties (Masamba *et al*. 2003; Elifert 2004). In a related study, Guimaraes *et al*. (2010), confirmed that *C. limon* suspension includes flavonoids, carotenoids, phenolics, ascorbic acid and reducing sugar which caused an increase of the antioxidant potential. In other previous studies, *C. limon* peel extract showed a significant molluscicidal potency against the adult snails of *Biomphalaria alexandrina*. Additionally, it negatively affected the biological activity and the growth rate of the snails after four weeks of exposure (Sherin *et al*., 2013). This inhibition in growth rate is probably due to the consumption of snails to their energy for maintenance and survival (Ibrahim, 2006). In this incident, Attia *et al*. (2009) clarified that the toxicity of *Citrus reticulate* peel extract may be attributed to the presence of flavonoids which caused inhibition of the mitochondrial electron transport. The flavonoids present in the citrus peels caused an increase in the blood serum superoxide dismutase activity and decreased serum cholesterols components (Ting *et al*., 2011). On the other hand, the toxic influence of *C. limon* peel oil was due to the presence of limonene which represents 90.06% of the oil of *C. limon* peel content (Mansour *et al*., 2004). Limonene possesses a significant molluscicidal influence against *Biomphalaria glabrata* snail. It caused 100% mortality of the snail individuals at concentrations of 100, 75 and 50 mg L^{-1}. However, the other concentrations of 25 and 10 mg L^{-1} recorded 86.7 and 26.7% mortality of the snails consecutively (Paulo *et al*., 2019). It induced also great molluscicidal activity against *Lymnaea acuminata* snail (Kumar and Singh, 2006). Similarly, Musman *et al*. (2013) revealed that the toxic effect of *Baringtonia racemosa* seed extract and the extract of *C. citratus* against *P. canaliculata* snail was attributed to the presence of flavonoids and saponins. Thus, plants that contain saponins have lethal toxicity and anti-feeding activity against terrestrial mollusca in general (Gonzalez-Cruz and Martin, 2013). Moreover, the anti-feedant property of these plants represents an advantage in pest control, because if the plant extract does not kill the snail, it reduces crop damage (Koul, 2008).

In the current study, *C. limon* fruit suspension achieved 51.30 and 39.87% reduction of *E. vermiculata* and *M. cartusiana* snails respectively within the first day of the field assays. These reduction rates increased to 70.39 and 62.08% for both snail species consecutively at 14 days of the application. On the other hand, the suspension of *C. limon*

peel reduced the *E. vermiculata* and *M. cartusiana* snails to 44.07 and 39.88% after one day of the field experiment. The reduction rate of both snails increased to 62.30 and 55.79% respectively after 14 days of the assay. These results were supported by the study conducted by Hend (2018) showed that under the field conditions, *C. limon* fruit and *C. limon* peel suspension caused 72.1 and 79.04% reduction of *M. cartusiana* snails after seven days of spraying, respectively. In the same aspect, Tangkoonbribun (2009) reported that tobacco waste recorded a 100% reduction of *P. canaliculata* snails in the field environment. Castillo-Ruiz *et al*. (2018) stated that the molluscicidal potency of *Chenopodium quinoa* against *Pomacea maculata* in field assays was lower than in the laboratory assays. In the same trend, Olofintoye (2010) indicated that the crude extract of *Mentha spicata* caused a 44.1% reduction of *M. cartusiana* snails by spraying under field conditions. The chemical properties of the plant extract represent the important reason for the snails' death. In addition, the difference in the molluscicidal impact of plant extracts may be attributed to the concentration used and the phytochemical constituents (Salem *et al*., 2017).

CONCLUSION

C. limon fruit and *C. limon* peel suspension have potential molluscicides effects against *E. vermiculata* and *M. cartusiana* snails at all developmental stages, especially the youngest age (three months old). *C. limon* fruit juice is more potent than the suspension of *C. limon* peel against all stages of both snails, and *E. vermiculata* individuals were more affected by each suspension than *M. cartusiana* snails. In addition, the molluscicidal activity of both juices against the adults of the two snail species in the field is higher than it was under laboratory conditions. Thus, spraying these suspensions on crops could protect them from damage by the snails. Further studies on the use of *C. limon* suspension in land snail control should be conducted to obtain an effective and safe natural means of control instead of chemical molluscicides.

Declarations:

Ethical Approval:Ethical Approval is not applicable.

Competing interests: The author declare no conflict of interest.

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Availability of Data and Materials: All datasets analysed and described during the present study are available from the corresponding author upon reasonable request.

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ARABIC SUMMARY

الليمون كمبيد رخوي طبيعي لمكافحه قواقع إيوبانيا فيرميكيولاتا و موناكا كارتوسيانا

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أجريت هذه الدراسه بهدف تقييم التأثير القاتل للعصير الخام لثمره و قشر الليمون كلا على حدى ضد المراحل العمريه المختلفه لقوقع الحدائق البني إيوبانيا فيرميكيولاتا و قوقع البرسيم الزجاجي موناكا كارتوسيانا. تم إختبار تأثير كل عصير على الأفراد الصغيره للقوقعين عند أعمار ثلاثه و سته و تسعه شهور و أيضا على الطور البالغ لكلا القوقعين تحت الظروف المعمليه و ضد الطور البالغ فقط لنوعين القواقع تحت الظروف الحقليه. أوضحت النتائج أن كلما زاد عمر الأفراد الصغيره لكلا القوقعين إزدادت المقاومه و بالتالي قلت نسبه الموت و العكس صحيح لذلك كانت الأفراد الصغيره عمر 3 شهور من القوقعين هي الأكثر تأثرا بكلا العصيرين. أظهرت النتائج أيضا أن التأثير المميت لعصير ثمره الليمون كان أقوى من عصير قشر الليمون على جميع المراحل العمريه للقوقعين. كما أشارت نتائج التجربه الحقليه إلى أن التأثير القاتل لكلا العصيرين على الطور البالغ للقوقعين تحت الظروف الحقليه كان أقوى منه تحت الظروف المعمليه حيث سجلا العصيران 73،33 و 46،66٪ & 60 و 46،66٪ موت ضد قواقع إيوبانيا فيرميكيولاتا و موناكا كارتوسيانا بعد 14 يوم من التجربه المعمليه بينما حققا كلا العصيران بعد نفس هذه الفتره من التجربه 70،39 و 62،30٪ & 62،08 و 55،79٪ موت للقوقعين تحت الظروف الحقليه. كما أوضحت النتائج أن قوقع إيوبانيا فيرميكيولاتا هو الأكثر تأثرا بالعصيرين مقارنه بقوقع موناكا كارتوسيانا سواءا تحت الظروف المعمليه أو الحقليه. هكدا ألقت هذه الدراسه الضوء على بديل طبيعي امن و فعال في مكافحه القواقع الأرضيه من الممكن إستخدامه بدلا من مبيدات الرخويات الكيميائيه التي لها الكثير من التأثيرات الضاره للإنسان و البيئه.