Biological and Ecological Studies on Land Snails and Their Control

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1. Introduction

Mollusca are the second largest phylum of the animal kingdom, forming a major part of the world fauna. The Gastropoda is the only class of molluscs which have successfully invaded land. They are one of the most diverse groups of animals, both in shape and habit. Among gastropods, land snails (subclass: Pulmonata) are one of the most numerous with almost 35,000 described species of the world. The present study dealt also with the chemical analysis of the mucus of three common land snails, *Eobania vermiculata* (Müller), *Theba pisana* (Müller) and *Monacha obstructa* (Montagu), and identification of the chemical compositions by using GC-MS. Results revealed that several variations in composition were observed between all species. Oxime, methoxy-phenyl and cyclotrisiloxane, hexamethyl were major components found that in three species, the total areas detected were 86.23, 76.83 and 70.83, respectively. This different composition of mucus may be due to differences from one species to another; different mechanical properties (function) are influenced by external factors such as temperature, humidity, light intensity, soil conditions and food supply. On reviewing literature conducted on land snails of Egypt, as far as can be ascertained, most studies were focused on Lower Egypt but Upper Egypt was neglected. So, the present investigation was designed to fulfil this gap and to promote and enhance the studies of land snails, especially those which have economic importance.

The Phylum Mollusca is probably the third most important animal group after the arthropods and vertebrates (South, 1992) Snails and slugs belong to the class Gastropoda. Snails and slugs are molluscs, a group of invertebrate animals with soft unsegmented bodies. Slugs are often described as snails without a shell, while snail bodies are enclosed in calcareous shells (Barker, 2001; Ramzy, 2009). The terrestrial mollusca including snails and slugs are destructive agricultural pests causing economic damage to a wide variety of plants including horticulture, field crops, and forestry. In addition they are of importance in medical and veterinary practice, since they serve as intermediate hosts for certain

Three common land snails, *E. vermiculata, T. pisana* and *M. obstructa*, are important crop pests and cause considerable damage in agriculture and horticulture, especially in areas where they find the conditions necessary for rapid multiplication, as shown in Fig. (1).

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Damage caused by snails depends not only on their activity and population density, but also on their feeding habits, which differ from one species to another. Damage involving considerable financial loss is inflicted on cereal, vegetables, Egyptian clover as well as other agricultural and field crops. The land snails feed on leaves, roots, tubers and ornamental plants (Bishara et al., 1968; El-Okda, 1981). In addition, during movement snails cause an undesirable smell which prevents men and even animals from feeding on these contaminated plants (El-Okda, 1984; Kassab & Daoud, 1964). Crops contaminated by snail slime lose their marketability and hence their export potential in many countries (Baker & Hawke, 1990; Ittah & Zisman, 1992). Land snails cause also a heavy damage to seed of oil plants and leaves of ornamental plants, as well as, citrus, peach, plam and vegetable, i.e. cabbage, carrot and bean. (El-Deeb et al., 1999; El-Okda, 1979, 1981; Ismail et al., 2003; Lokma, 2007; Shahawy et al., 2008).

The snail movement is rather slow and sluggish for a short distance depending upon temperature, food and natural of soil. They were active during optimum temperature, Humidity and moistened soil. They aestivate during the hot summer and hibernate during the cold winter (Kassab & Daoud, 1964). In Egypt, the land snails dispersing in northern Governorate, i.e. Alexandria, Kafr El-Shikh, Behera, and Domiate, Egypt (El-Okda, 1980; Hashem et al., 1993; Kassab & Daoud, 1964) At the present time these snails distribute in Ismaellia, Sharkia, Monofia, Gharbia, Minia, and Assiut Governorates, Egypt (El-Deeb et al., 2004; El-Massry, 1997; Metwally et al., 2002; Ramzy, 2009; Shoieb, 2008).

Gastropods such as slugs and snails secrete a trail of mucus from their pedal gland while traveling across a surface (Denny, 1983). The unique mechanical properties of snail pedal mucus enable the animal's locomotion while also causing the mucus to function as an adhesive to the substrate. The mucus trail performs a number of other functions, including the provision of mechanisms for re-tracing a path and for finding a mate of the same species by following a trail (Al-Sanabani, 2008). An understand ding of the functionality of trail mucus, including its interactions with water vapour, can therefore lead to a means of controlling the reproduction of snails and thereby limiting their impact on the environment, especially vegetable crops. When freshly deposited by terrestrial snails, trails of pedal mucus are reported to be in the range of 10 – 20 mm thick (Denny, 1989). But since the mucus typically consists of between 90 and 99.7% water by weight (Denny 1983), the trails dry to leave a much thinner solid film. It is generally believed that the fundamental structure of mucus gels consists of giant protein– polysaccharide complexes. This complex is usually classified into the broad categories of mucopolysaccharides and glycoproteins (Davies & Hawkins, 1998; Denny, 1983); mucus secretions can function as effective adhesives due to their viscoelasticity (Abd El-wakeil, 2005; Daoud, 2004; Grenon & Walker, 1980).

It is clearly known that successful control methods of terrestrial mollusca depend greatly on the broad base of knowledge of biological and ecological aspects of mollusca particularly in integrated approaches (El-Deeb et al., 2003a; Gabr et al., 2006; Ramzy, 2009; Shoieb, 2008). In Egypt, there is currently no information on the biochemical structure of *E. vermiculata, T. pisana* and *M. obstructa* mucus. A part of this work focuses on identifying the chemical composition of the mucus of three species of mollusks, i.e. *E. vermiculata, T. pisana* and *M. obstructa* under Egyptian conditions, and to compare the compositions between them. This book chapter is an attempt to gain information on land snails as agricultural pest and their control.

(A) Shell of *Eobania vermiculata* (Müller, 1770).


a b c
20 mm↔
(B) Shell of *Theba pisana* (Müller, 1774).

(C) Shell of *Monacha obstructa* (Montagu, 1803)

Fig. 1. Land snail types in Egyptian Agricultural fields (Cited from Ramzy, 2009).

2. Calssification of gastropods

The identification of terrestrial mollusca species could be classified according to the full description of Godan (1983) as follows:

Kingdom	:	Animalia
Sub Kingdom	:	Metazoa
Phylum	:	Mollusca
Class	:	Gastropoda
Sub class	:	Pulmonata
Order	:	Stylomatophora
Super Family	:	Helicoidae (Rafinesque, 1815)
Family	:	Helicidae (Rafinesque, 1815)
Genus	:	Cochlicella (Férussac, 1820)
Species	:	*Cochlicella acuta* (o.f. Müller, 1974)
	:	Cochlicella barbara (L., 1758)
	:	*Cochlicella ventricosa* (Draparnoud, 1801)
Genus	:	Helicella (Férussac, 1820)
Species	:	*Helicella obvia* (Hartman, 1840)
	:	Helicella bolenensis (Locard, 1884)
	:	*Helicella vestials* (Locard, 1882)
Sub family	:	Monacheae (Fitzinger, 1833)
Genus	:	Monacha (Fitzinger, 1833)
Species	:	*Monacha cantiana* (Montagu, 1803)
	:	*Monacha cartusiana* (o.f. Müller, 1774)
	:	*Monacha obstructa* (Pfeiffer, 1842)
Sub family	:	Helicinae (Rafinesque, 1815)
Genus	:	Theba (Riss, 1826)
Species	:	*Theba pisana* (o.f. Müller, 1774)
Genus	:	Cepaea (Held, 1837)
Species	:	*Cepaea hortensis* (o.f. Müller, 1774)
	:	*Cepaea silvatica* (Draparnoud, 1801)
	:	*Cepaea vindobonensis* (Férussac, 1821)
Genus	:	Eobania (Hesse, 1915)
Species	:	*Eobania Vermiculata* (o.f. Müller, 1774)
Genus	:	Helix (L., 1658)
Species	:	*Helix pomatia* (L., 1658)
	:	*Helix cantareus* (Risso, 1826)
	:	*Helix aperta* (Born, 1778)
	:	*Helix aspersa* (o.f. Müller, 1774)
Super family	:	Limacoidae (Rafinesque, 1815)
Family	:	Zonitidae (Mörch, 1864)
Sub family	:	Zonitinae (Mörch, 1864)
Genus	:	Oxychilus (Fitzinger, 1833)
Species	:	*Oxychilus alliarius* (Müller, 1822)
Family	:	Succinidae

Genus	:	Succinea
Species	:	Succinea ovalis
Family	:	Limacidae (Rafinesque, 1815)
Genus	:	Limax (L., 1758)
Species	:	*Limax maximus* (L., 1758)
	:	*Limax tenellus* (o.f. Müller, 1774)
	:	*Limax flavus* (L., 1758)
Genus	:	Deroceras (Rafinesque, 1820)
Species	:	*Deroceras reticulatum* (o.f. Müller, 1774)
	:	*Deroceras laeve* (o.f. Müller, 1774)
	:	*Deroceras caruanae* (Pollonera, 1891)
Family	:	Arionidae (Gray, 1840)
Sub family	:	Arioninae (Gray, 1840)
Genus	:	Arion (Férussac, 1819)
Species	:	*Arion ater* (L., 1758)
	:	*Arion rufus* (L., 1758)
	:	*Arion hortensis* (Ferussac, 1819)

3. Identification of snails

For identification of snails, the height and breadth of the shell as well as its shape and color are the main features (Fig. 2). The number of whards of the shell is established by observing the shell from above and counting downwards from the apex, which is clearly the beginning of the spire (Fig. 3). The dotted line indicates the extent of the first whorl. Compared with the shells of older snails, those of younger animals have a sharp edge, which is, moreover, neither thickened, folder back, nor enlarged. In those families in which these characteristics are not shown in the shells of older animals, the shell edge of younger snails is soft, flexible and without calcium deposits. The edge of the mouth (peristome) is the growing region of the shell and may be regarded as being composed of an outer lip (Godan, 1983).

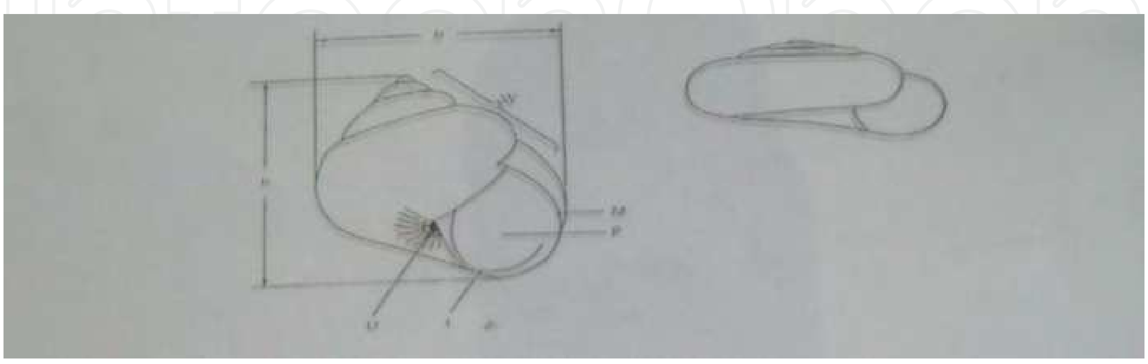


Fig. 2. Left shell concial to globular: right shell flat-conical. L. lip; *M. mouth* of shell (aperture), *P. peristome* (shell mouth edge); U. umbilicus; W. whorls; B. breadth; H. height (cited from Godan, 1983).

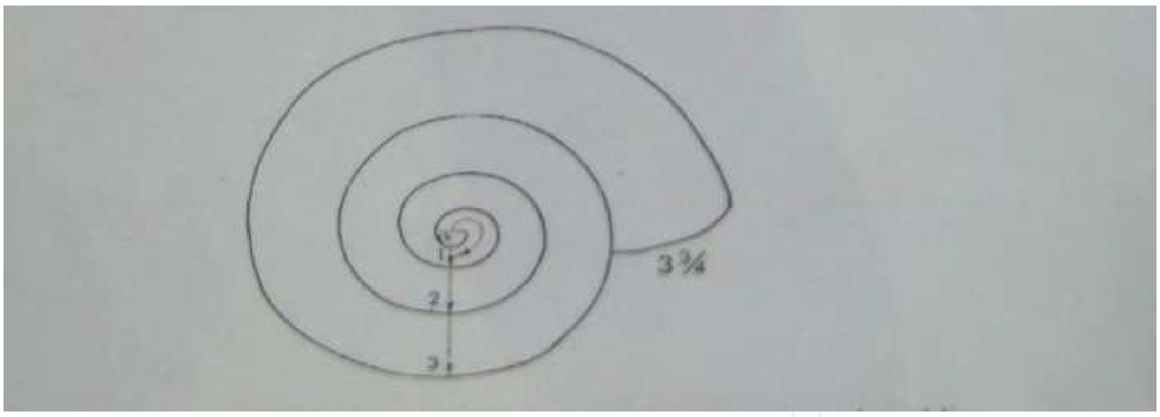


Fig. 3. Spire of the shell, Scheme, a apex; dotted line indicates extent of first whorl (cited from Godan, 1983).

4. Biology of terrestrial snails

Snails and slugs are simultaneously hermaphroditic, self incompatible. Five phases can be distinguished in the reproductive cycle of snails and slugs: Courtship, copulation, nest – building, egg – laying and embryonic development followed by egg hatching. Reproductive behaviour begins only when the humidity is high (80 – 85% for snail and 90 – 95% for slug).

Biological aspects of the land snails have been studied by many researches; for example, Kassab & Daoud (1964) found that the life cycle of *Helicella vestalis* was a relative simple. It laid the eggs in clutches, each contained from 25 to 30 eggs or more in the soft soil and were deposited in small cavities or holes in the soil. Eggs deposited at any time during spring season. The eggs were round and white in colour with calcareous or limy shell. Under normal conditions, the incubation period lasted from 12-15 days on the average. Soon after emerged from the eggs the young snails which were seen with their small and mucous shells began to move about in search for food. They were a little bit bigger than the head of a pin. Gradually, they added coils to the shell as they grew and rate of growth depended to some extent on the abundance of food and weather conditions. *H. lucorum* were sexually mature three years after hatching when the largest diameter of their shell was equal to greater than 25 mm as reported by Ramzy (2009) and Staikou et al. (1988).

Staikou & Lazaridou– Dimitriadou (1990) found that *M. cartusiana* (M.) reached maturity within one year at a size of 8 – 10 mm and could lay eggs immediately upon maturation. The reproductive period started in the beginning, middle or end of autumn depending on the weather condition which also effect on the growth of newly hatched individuals. While El–Massry (1997) revealed that *M. cartusiana* began to lay clutches from mid November to mid February. Number of clutches and clutch size were changed during breeding season.

Mohamed (1999) rearing snail *E. vermiculata* and slug *Limax flavus* (L.) at 20ºC ± 1 and 80% R. H. for snail and 90% R. H. for slug and feeding on lettuce + cucumber and carrot. Investigated that some biological observation such as: Mating, egg laying and growth development.

Mating usually takes place at night, frequently on the soil surface. The snail *E. vermiculata* needs introductory behaviour (foreplay) with reciprocal lactile, oral contract and curving turns to reach on optimal position with respect to the genital opening of the partner (Fig. 4). This is followed by dart shooting, the pushing of a calcareous dart into the mating partner of body, which is assumed to facilitate meeting by increasing behavioural synchrony. Finally, the copulation is reciprocal; spermatophores are transferred after simultaneous intromission (Baur & Baur, 1999).

Fig. 4. Mating behaviour in snails (Cited from Godan, 1983).

Mating behaviour in slug *Limax flavous* is the two slugs twist around one another, like structure averted and intertwined to from a light spiral, and spermatophore are transferred. Courtship may last 3 – 4 hours in snail and slug (Fig. 4) (Godan, 1983).

Slug eggs are usually laid into soil holes and crevices into or on the soil, under stones and on decaying wood (Figs. 5, 6 and 7).

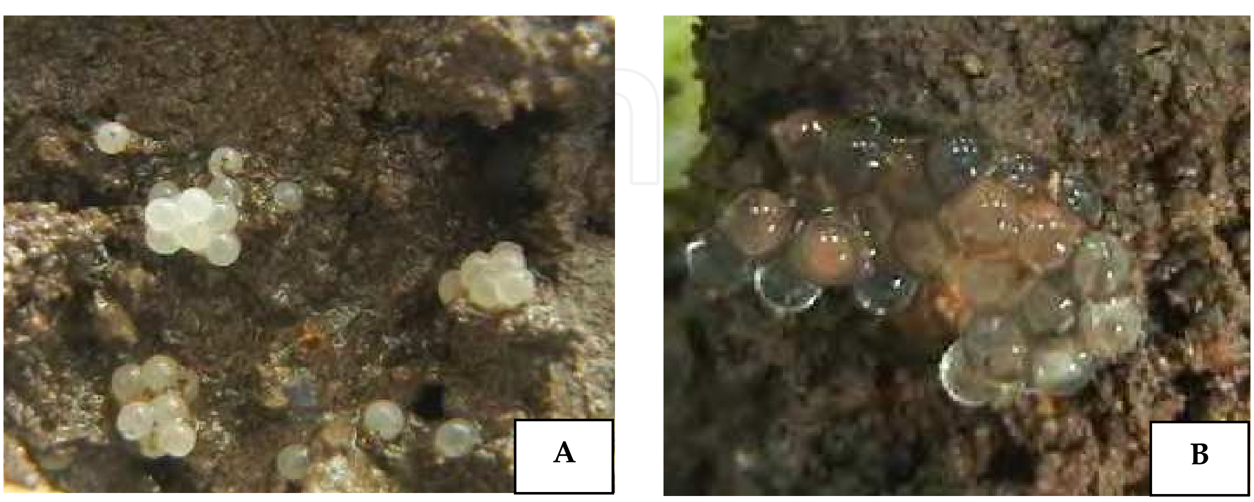
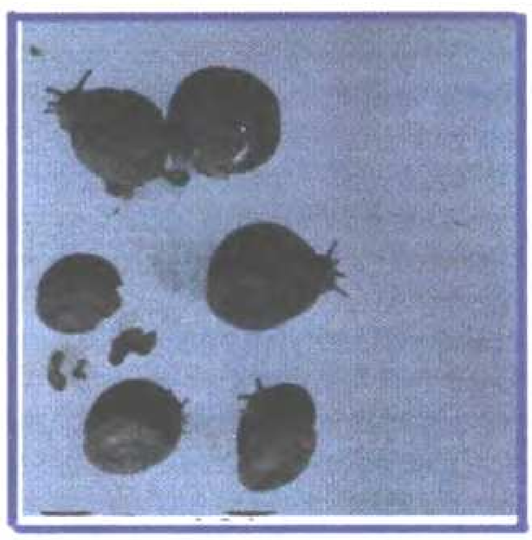


Fig. 5. The clutches of eggs of *Monacha obstructa* (A) and *Oxyloma elegans* (B) in soil (Cited from Ramzy, 2009).

(1) Clutch of eggs of *E. vermiculata*

(2) Hatching

(3) Adult stage



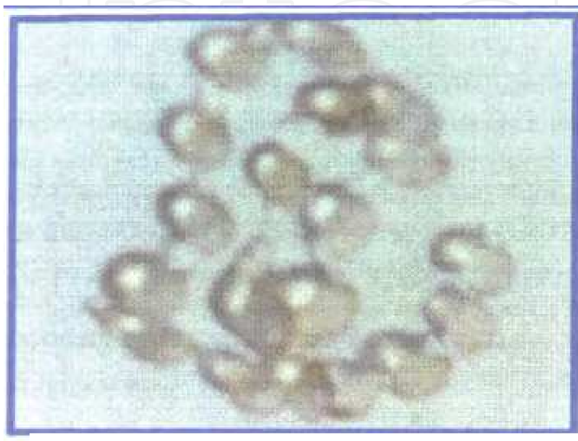
(4) The development of juveniles

Fig. 6. Life–cycle of *E. vermiculata* (cited from Mohamed, 1999).

Adult snail prepares to lay a clutch of eggs by excavating a deep hole in moist soil (Fig. 6). The animal pushes much effort in digging down with the anterior part to foot. Snails make a circular chamber about 5.7 – 6.1 cm. in deep. There is relationship between the body length and hole depth. This hole of egg – deposition is preparing after 10 hours of copulation.

During this time the snail is relatively conspicuous as the shell remains visible at the surface of nest. After that, egg deposition process takes place about 24 hours. Once egg – lying has finished the snail with draws, its foot and covers over the entrance of the hole with soil.

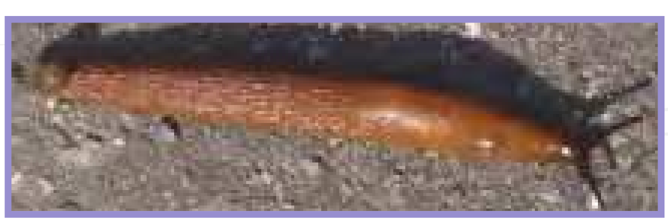
Snail eggs are whitish in colour and spherical shaped (2.9 – 3.0 mm diameter), while slug eggs are oval and strung along a thread (4.9 – 5.6 mm diameter). Snail and slug young does grow at a steady and relative fast. Growth continues at an almost constant rate even after animal maturation, by which time the slug has reached to weight 13 g. while the snail to 8.4 g. and the shell of snail is equal of 1/5 of a body weight. Animal snails and slugs arrive to adulthood after 321 to 364 days in average and their size and weight are more slowly increased (Figs. 6 and 7).



(1) Clutch of eggs of *L. flavus*

(2) Hatching

(3) The development of juveniles



(4) Adult stage

Fig. 7. Life-cycle of *L. flavus* (cited from Mohamed, 1999).

Generally, the highest number of eggs, hatchability percentage and longer life span were recorded in snail *E. vermiculata* and slug *L. flavus* in December followed by January, November, February and October, while these were decreased as temperature increased in March. The results are summarized in Table (1).

Type of land snail	Parameters			References
	No. of eggs/cultch	Hatchability	Life span(day)	
Eobnia vermiculata	80.92±5	91.43±3.2	1379±9.8	Mohamed, 1999
Limax flavus	62.23±2.7	91.882.1	677.87±10.4	Mohamed, 1999
Helicella vestalis	71.68	93.66	468.58	El-Massray, 1997
Helicella sp.	37.6	51.2	----------	Arafa, 1997
Eobania sp.	19	38.4	----------	Arafa, 1997
Monacha sp.	22.8	100	----------	Arafa, 1997
Monach cartus	22.55	99.1	----------	Ismail, 1997

Table 1. Some biological data of certain land snails.

5. Ecology of terrestrial snails

Terrestrial snails are mainly nocturnal, but following a rain may come out of hiding during the day. Temperature and moisture, rather than light, are the main factors to account for their nocturnal habits. Native snails may be found everywhere but prefer habitats offering shelter, adequate moisture, an abundant food supply and an available source of lime. Forested river valleys generally provide such habitats, and those with outcrops of limestone usually show the most abundant and varied mollusk faunas. Snails are very adaptable to times of drought and adverse climatic conditions. During these periods, the snails close the shell aperture with a mucus flap (epiphragm) which hardens and prevents desiccation. Snails can remain in this dormant state (aestivation) for years, breaking dormancy when climatic conditions are favorable again. Some ecological observation such as: Survey, population dynamic and movement, daily activity and dispersal of land snails, have been studied by many researchers (Bishara et al., 1968; Daoud 2004; El–Deeb et al., 1996, 2004; El–Okda, 1984; Metwally, et al., 2002; Ramzy, 2009).

5.1 Survey of land snails species

Bishara et al. (1986) found that *Euparypha pisana* (Müller), *Theba sp*., *E. vermiculata*, *Rumina decolata*, *Helicella sp*., and *Cochlicella acuta* were common species in field and orchards of the northern Delta Nile in Egypt.

El–Okda (1984) stated that *Monacha* sp. and *Oxychilus* sp. were found in Ismaellia Governorate on the Egyptian clover (*Trifolium alexandrium*), mango orchards, citrus and ornamental nurseries, in addition to wheat fields. He added that beans, watermelon, maize and tomato were attacked by land snails. El–Deeb et al. (1996) and (2003b) surveyed different terrestrial snails on the field crops, vegetables, ornamental plants and in orchards at Kafr El–Shekh and Dakahlia Governorate, Egypt. The obtained results showed that in Kafr El- Shekh Governorate, *E. vermiculata, Succinia putris* and *Cepaea nemoralis* snails were common. In Demietta Governorate *M. cartusiana, E. vermiculata, Cepaea nemoralis, C. acuta, Oxychilus aliavus* and *Helicella* sp. were recorded on different host plants. *M. cartusiana, Succinia putris, E. vermiculata, C. acuta* and *C. nemoralis* were recorded on different host plants at Dakahlia Governorate.

Metwally et al. (2002) found that six species of terrestrial mollusca belonging to families Helicidae and limacidae were recorded on different crops at 23 locatities representing 10 districts at Monofia and Gharbia Governorate. These species were *M. cartusiana*, (the glassy clover snail), *E. vermiculata*, (the Brown garden snail), *C. acuta*, (the conical snail), *O. alliarus*, the slugs, *Limax flavus* and *Deroceras reticulatum*, (the gray garden slug). *M. cartusiana* snail have the upper hand on snail incidence compared to other species; similar results were obtained by El-Deeb et al. (2003b). In Upper Egypt, Ramzy (2009) identified nine land snail species in Assiut governorate, Egypt. All the species recorded belong to order: Pulmonata from eight families. These species were *Pupoides coenopictus, Vallonia pulchella, Oxyloma elegans, Vitrea pygmaea, E. vermiculata, T. pisana, M. obstructa, Helicodiscus singleyanus inermis, and Cecilioides acicula.* The results are summarized in Table (2).

Species	Governorate	Referenceq
1- *Monacha sp.*; and *Oxychilus sp.*	Ismaellia	El- Okda, 1984
2- *E. vermiculata; Succinia putris*; and *Cepaea nemoralis*	Kafer El-Shekh	El-Deeb et al., 1996
3- *M. cartusina.; E. vermiculata.; C. nemoralis,; C. acuta.; Oxchilus aliavus.*; and *Helicella sp*	Demietta	El-Deeb et al., 1996
4- *M. cartusina.; Succinia putris.; E. Vermiculata.; C. acuta.; and C.nemoralis*	Dakahlia	El-Deeb et al., 1996
5- *M. Cartusina.*; *E. Vermiculata.*; *C. Acuta.*; *O. Aliavus.*; *Limax flavus* and *Deoceras reticulatum*	Monofia & Gharbia	Metwally et al., 2002
6- *Pupoides coenopictus, Vallonia pulchella, Oxyloma elegans, Vitrea pygmaea, Eobania vermiculata, Theba pisana, Monacha obstructa, Helicodiscus singleyanus inermis,* and *Cecilioides acicula*	Assiut	Ramzy, 2009

Table 2. Survey of land snail species in Egypt Governorates

5.2 Population dynamics of land snails

The population of *Monacha obstructa* in Egyptian clover field began to increase gradually from the end March to the middle of April, whenever the suitable temperature and humidity (Kady, 1983).

The life cycle, population dynamics and secondary production of the land snail *M. cartusina* in northern Greece was studied by Staikou & Lazaridou– Dimitriabou (1990). Demographic analysis of populations of *M. cartusina* revealed that (a). From two to three cohorts existed in the field throughout the year. (b). The reproductive period started in the beginning middle or end of autumn depending upon weather conditions. (c). Growth of the newly hatched individuals was also influenced by weather conditions. Population fluctuation of the land snails, *T. pisana*, *H. vestalis* and *C. acuta* in citrus orchards were noticed by Hashem et al. (1992). The main activity season collapsed from February to November for *T. pisana* and *C. acuta*. They added that the land snail *H. vestalis* proved to be the most abundant species reaching the peak during March to June (Shoieb, 2008).

5.3 Movement, daily activity and dispersal of land snails

Snail activity differs from one species to another; it is influenced by external factors such as temperature, humidity, light intensity, soil conditions and food supply. The migratory behavior of land snails is greatly affected by the microclimatic conditions in their habitat. Activity increased as a result fall in temperature below 21ºC and arise till 30ºC. Moisture also influenced the activity of land snails. The mucus of land snails consists of 98% water. At high temperature activity is inhibited by water lack. Light influences the activity of land snails. They remain in their hides during the day and only after dusk; they emerge to go in search of food. A decrease in light intensity with a fall in temperature below 21ºC and a rise in humidity through dew fall at dusk, resulted in the animal moving on to vegetation, while in the morning and during the day the snails returned to the upper soil or between the earth clods where it is cool and shady (Godan, 1983). The dispersal of the land snail *T. pisana* in South Australia was influenced by variation in habitat; snails moved on free way average where grassy vegetation was scattered. Snails moved out of a well grazed permanent pasture to adjacent weedy roadside vegetation and trees in early summer. They returned to the pasture in autumn. Average movement varied between 0.1 m. and 1.1 m. per day, some snails moved > 55 m in a month in spring – autumn and 75 m in three month in autumn – winter (Baker, 1988; El-Deeb et al., 2003b).

The effect of moon light, temperature and relative humidity on daily activity of the small sand snail, *H. vestalis* was studied by El–Massry (1997). It was found that the activity of *H. vestalis* investing navel orange trees was significant different from time to time during the day and from season to another during the year. Also, moon light showed a significant effect on the daily activity of *H. vestalis*. The lowest number of active snails was recorded in summer, while the highest one was recorded in spring (Lokma et al., 2007). On the other hand, the time from 10 to 2 o'clock represented the time of the lowest activity, while the highest activity was recorded between the mid night and the six o'clock in the morning (Ismail et al., 2003).

6. Chemical analysis of mucus land snails

6.1 Sample collection

Mature snails, i.e. *E. vermiculata, T. pisana and M. obstructa* were collected in the field from different locations in Egypt during the winter and spring of 2005. These animals were transported in white cloth bags to the laboratory. Healthy individuals were kept in round plastic boxes (13 cm in diameter) containing moistened soil and feeding on cabbage paper from the market for one year under laboratory conditions (25±5°C temperature and 70±5% R.H.). Mucus (5 ml) was collected from roughly 100 individuals by stimulating the surface of live snails by small plastic syringe (5 ml). The samples were stored at -20°C in a deep freezer until analysis according to Sallam et al. (2009).

6.2 Chemical analysis

Mucus from *E. vermiculata, T. pisana*, and *M. obstructa* were analysed by GC-MS which was performed with an agilent 6890 gas chromatograph equipped with a mass spectrometric detector (MSD) model agilen 5973. A fused silica capillary column (HP-5MS), 5% phenyl polysiloxane as non-polar stationary phase (30 m x 0.25 mm x i.d) and 0.25 µm film thickness was used. Operating conditions were as follows: injector port temperature, 2508C. Helium was used as a carrier gas at a flow rate of 1.0 ml/min pulsed splitless mode programmed at 8°C/min to 260°C, and held for 18 min. The total analysis time was 41 min. A 1 ml volume was injected splitless. The mass spectrometric detector (MSD) was operated in electron impact ionization mode with an ionizing energy of 70 eV, scanning from m/z 50 – 500. The ion source temperature was 230°C and the quadruple temperature was 150°C. The electron multiplier voltage (EM voltage) was maintained at 1100 V above autotune, and a solvent delay of 3 min was employed. The instrument was manually tuned using perfluorotributylamine (PFTBA). Identification was based on comparison with the MS computer library (NIST Software Package, Finnigan) and on the respective retention indices. The separated components were identified by matching data with those of the data published by Wiley7n.1.

6.3 Chemical components of mucus

Chemical constituents of mucus from *E. vermiculata, T. pisana* and *M. obstructa* GC-MS analysis of mucus from *E. vermiculata* detected the presence of the following compounds: iso-valeric acid, methyl, 3-methoxyamino-propanoate, oxime, methoxy-phenyl, pantanolic acid, 4-methyl, cyclotrisiloxane, hexamethyl, tetradecanal, furan, 2-isobutenyl-4vinyl, and di-n-octylphthalate (Table 3). Data showed that eight compounds were identified in this mucus after comparison with library data by Wiley7n.1. Both oxime, methoxy-phenyl, and iso-valeric acid were mainly characterized by a high concentration of total compounds (81.58 and 8.76%, respectively), while methyl, 3-methoxyaminopropanoate, and di-n-octylphthalate were characterized by low concentration of total compounds (0.63 and 0.56%), respectively.

Peak No.	Name of compounds	Chemical formula	Molecular weight (MW)	Area %	Retention time (RT)
1	Iso-valeric acid	$C_5H_{10}O_2$	102.07	8.76	3.45
2	Methyl, 3-methoxyamino-propanoate	$C_5H_{11}NO_3$	133.07	0.63	3.51
3	Oxime-, methoxy-phenyl	$C_8H_9NO_2$	151.06	81.58	4.01
4	Pantanolic acid, 4-methyl	$C_6H_{12}O_2$	116.08	1.26	4.36
5	Cyclotrisiloxane, hexamethyl	$C_6H_{18}O_3Si_3$	222.06	4.65	6.63
6	Tetradecanal	$C_{14}H_{28}O$	212.21	1.01	16.45
7	Furan, 2-isobutenyl-4-vinyl	$C_{10}H_{16}O$	152.12	1.55	16.85
8	Di-*n*-octylphthalate	$C_{24}H_{38}O_4$	390.28	0.56	26.64
9	Total			100.00	

Table 3. Chemical composition of mucus from *E. vermiculata* (cited from Sallam et al., 2009).

Data in Table 4 show the chemical constituents of mucus from *T. pisana.* Ten compounds were identified in this mucus after comparing with library data from Wiley7n.1. Both oxime, methoxy-phenyl, and cyclotrisiloxane, hexamethyl were mainly characterized by a high concentration of total compounds (56.28 and 20.55%, respectively). In contrast, 1,2,4-trichloroacetophenone and pyridine, 1-acetyl-5-(3.4.-dihydro-2H-pyrrol-5-yl) 1,2,3.4-tetrahydro were characterized by a low concentration of total compounds (1.36 and 1.10%), respectively.

Peak No.	Name of compounds	Chemical formula	Molecular weight (MW)	Area %	Retention time (RT)
1	Butanoic acid, 2-methyl	$C_5H_{10}O_2$	102.07	2.89	3.62
2	Oxime-, methoxy-phenyl	$C_8H_9NO_2$	151.06	56.28	4.11
3	Cyclotrisiloxane, hexamethyl	$C_6H_{18}O_3Si_3$	222.06	20.55	6.69
4	1-Butyl-2,4,6-trimethyl benzene	$C_{13}H_2O$	176.16	5.81	7.60
5	Thymyl methyl ether	$C_{11}H_{16}O$	164.12	2.98	8.02
6	Pyridine,1-acetyl-5-(3,4-dihydro-2H-pyrrol-5-yl) 1.2.3.4-tetrahydro	$C_{11}H_{16}N_2O$	192.13	1.10	8.41
7	Cyclotetrasiloxaneoctamethyl	$C_8H_{24}O_4Si_4$	296.07	2.41	9.38
8	Benzene, 1,4-Bis(trimethylsilyl)	$C_{12}H_{22}Si_2$	222.13	3.87	10.22
9	Thiosulfuric acid, *S*-(2-aminoethyl) ester	$C_2H_7NO_3S_2$	156.99	2.74	20.18
10	1,2,4-trichloroacetophenone	$C_8H_5Cl_{30}$	221.94	1.36	26.45
11	Total			100.00	

Table 4. Chemical composition of mucus from *T. pisana* (cited from Sallam et al., 2009).

Also, data in Table 5 show that the chemical constituents of mucus from *M. obstructa*. Seven compounds were identified in this mucus, bothoxime, methoxy-phenyl, and diethyl phthalate were mainly characterized by a high concentration of total compounds (57.95 and 14.20%, respectively), while pentadecane and hexatriacontane were characterized by a low concentration (3.55 and 2.22%), respectively.

Peak No.	Name of compounds	Chemical formula	Molecular weight (MW)	Area %	Retention time (RT)
1	Oxime-, methoxy-phenyl	$C_8H_9NO_2$	151.06	57.95	3.97
2	Cyclotrisiloxane, hexamethyl	$C_6H_{18}O_3Si_3$	222.06	12.88	6.62
3	Pentadecane	$C_{15}H_{32}$	212.25	3.55	13.19
4	Diethyl phthalate	$C_{12}H_{14}O_4$	222.09	14.20	15.04
5	10-Methylnonadecane	C_2OH_{42}	282.33	4.51	16.62
6	Hexatriacontane	$C_{36}H_{74}$	506.58	2.22	18.04
7	1,2-Benzene dicarboxylic acid, dibutyl ester	$C_{16}H_{22}O_4$	278.15	4.70	20.23
8	Total			100.00	

Table 5. Chemical composition of mucus from *M. obstructa* (cited from Sallam et al., 2009).

It is obvious that the different composition of mucus from different species of land snails, oxime, methoxy-phenyl, and cyclotrisiloxane, hexamethyl were major components found in all species. This difference in composition of mucus may be due to differences from one species to another, different mechanical properties (function) and are influenced by external factors such as temperature, humidity, light intensity, soil conditions and food supply. These data agreement with Meikle et al. (1988) found substantial differences between the mucus of six coral species. It should not be surprising that different forms of mucus have different compositions and different mechanical properties. There is wide variation in the gross composition of mucus secretions (Davies & Hawkins, 1998) and in their function (Denny, 1989). As Davies & Hawkins (1998) point out, relatively little is known about the structure of invertebrate mucus secretions. In the study by Smith & Morin (2002), the composition of the adhesive form of march periwinkle mucus was compared to the trail mucus used during locomotion. They found that the trail mucus consists primarily of large, carbohydrate-rich molecules with some relatively small proteins. In contrast, the adhesive mucus has 2.7 times as much protein with no significant difference in carbohydrate concentration. This change in composition corresponds to an order of magnitude increase in tenacity with little clear change in overall concentration.

Previous research on marine mucus secretion found that roughly 50% of the dry weight was inorganic residue (Connor, 1986; Davies et al., 1990). This value can also be estimated from the percentage of inorganic salts in seawater (3.56%) (Schmidt-Nielsen 1990); for typical marine mucus containing 96 – 98% water, we would predict that inorganic material would make up 46 – 64% of the dry weight (Sallam et al., 2009).

7. Damage and feeding behaviour of land snails

Land mollusca pests are serious problem, every year; damage involving considerable financial losses is inflicted on cereal, potatoes, vegetables, lettuce, carrots, cabbage, maize, clover as well as other agricultural and horticultural crops. They eat leaves, root and tuber of nearly all vegetables, field crops, ornamental plants as well as fruits in field, garden and green house. Land snails cause heavy damage, especially to seeds and seedlings of cereals and seeds of oil plants. Damage was manifested in chewing soft vegetative growth, flowers and fruits, beside eating seeds, roots and tubers after sowing or during repining. On the other hand, land molluses left viscous liquids upon the plant on which they had been fed giving bright trace films. Moreover, unpleasant garlic odour was smelt on Egyptian clover which infested with *M. abstracta*, making farm animals refuse it. (El-Okda, 1980; Imevore & Ajayi, 1993; Ismail et al., 2003; Ramzy, 2009).

El-Okda (1980) mentioned that land mollusca attacked raw Succulent vegetables and proffered soggy parts. These pests attacked seeds, seedlings, roots and tuber crops. The more succulent raw leaf vegetables, fruits and buds were extra ordinarily attacked in addition to flower damage when land mollusca become abundant. Also, these land mollusca leave unpleasant slimy tracks on the injured parts.

Imevbore & Ajayi (1993) reported that when mature snails fed once daily at 2 % of body weight on diet containing 20 different feeds categorized as leaves, fruits, and household waste. Feed intake data indicated that the African giant snail a definite preference for fresh fruits and low preference for household waste.

The food preference and consumption of certain vegetable plants and field crops leaves for three land snails: *M. Cantiana, Succina Putris* and *T. pisana* was studied by El- Deeb et al. (2001). Results showed that Egyptian clover was the most preferred crop for *M. contiana* followed by lettuce, cucumber, carrot, cabbage and squash, while carrot fruits were the most preferable for *S. putris* followed by Egyptian clover, lettuce, cabbage, cucumber and squash. On the other hand, the lettuce was the most preferable for *T. pisana* followed by cabbage, carrot, cucumber, clover and squash, see Fig (8). In the same time, the results indicated that the bran was the most preferred bait for the three snails species followed by crushed wheat, crushed bread, crushed rice and crushed maize. The relative susceptibility of five fruits species (apple, orange, pear, plum trees and banana plants) to the four land snail species infestation was studied under laboratory conditions by identification of fruit leaf cells in their excrement. Results indicated that *T. pisana, H. vestalis* and *C. acuta* highly prefer pear, while *E. vermiculata* prefers banana. Orange ranks second in their favorability. On the contrary, plum, and apple are not preferred for the snail species, beside banana for *C. acuta*

Moreover, pear and orange are mostly attacked by *T. pisana* and banana by *E. vermiculata* (Shahawy et al., 2008; Tadros et al., 2001).

Fig. 8. Feeding damage by terrestrial snails on different plants (cited from Ramzy 2009).

8. Control of terrestrial mollusca

Molluscan pests can be destroyed in several different ways: by chemical means (Molluscicides), through the use of biotechnical measures, by mechanical methods and by interference with the environment. These different methods can, and sometimes have to be used simultaneously.

The control of pulmonates by whatever method is not simple, and each of the above-mentioned methods has its associated problems. A prerequisite from species to species is even in the same area.

8.1 Legislative control

Different ways of dispersal of economic pest mollusca may occur by man, plants, seeds, soil, ships, trains, airplane, cars, cargo, baggage, postal packages and food stuffs (Herzberg & Herzberg, 1962). For example, most of gastropds entering the USA with baggage come from Europe, Asia, Africa, Hawaii and the Philippines (Godan, 1983). Most Countries have now established quarantine regulations allowing important of plant and baggage under certain strictly specified conditions. Land mollusca among the economic pest species are listed in the rules and regulations of plant pest control in USA, the plant quarantine treatments contains dosages for fumigation of containers and ships to control gastropods.

Several investigators used the fumigants to combat the quarantinable snails. Richardson & Roth (1963) used ethyleue oxide 10 %, carbondioxide 90 % mixture (carboxide) instead of methyl bromide for fumigation against the very resistant aestivated *C. barbara* (L.) and *T. pisana* on military cargo from Mediterranean areas, and it showed good efficiency, penetration, and stability as a suitable substitute for methyl bromide.

Ittah & Zisman (1992) evaluated the volatile allylalcohol derivatives for control of *T. pisana* snails on cut roses for export. They found that allyl alcohol esters (propionate, formate, acetate) to be very effective in the fumigation of snails infesting flowers of roses. Concentration of allyl acetate of 0.022 mM at 25°C for 3 hrs was found to cause 100 % snail mortality without any fear of phytotoxicity towards roses.

8.2 Mechanical control

1. Hand collection with subsequent squashing of the slugs and snails is the oldest mechanical methods and was the only control measure used up to the middle ages (Carman, 1965; Mahrous et al., 2002; Shah, 1992). Common salt was then employed this causes an over reproduction of mucus by snails. Later, traps and protective barriers were used. The flower pots tiles, cabbage leaves, flat stones towels and also drain pipes, these hand to be searched for snails in early morning such dark shelters are especially effective as traps when they are baited with raw fresh potato slices of fresh lettuce leaves. It is necessary, however, to collect the snails daily and to kill them with a strong solution of common salt or in boiling water.
2. Burning –over- burning vegetation on which aestivating snails attach will reduce throwers or commercial weed- burners is effective in reducing snail populations along fence rows and in areas where other measures may not be practical. (Joubert & walters, 1951)
3. Protective barriers of dehydrating substance such as cattle salt, caustic soda, kainite or completely dry quick lime can act as barrier. Nakhla (1995) studied a mechanical method to protect orchard trees from land snails by using a band of metal sheets around the tree trunk. The rings tested were in the shape of cornea and were made of copper sheet, aluminum sheet, wire screen gauze (14 mesh) and a fiber cord, (Rape). The results revealed that wire screen rings gave the highest percentage of production against the different snails, i.e. *E. vermiculota*, *C. acuta, H. vestalis* and *T. pisana* followed by the copper sheet rings. Aluminum sheet rings gave intermediate protection while the rape rings gave poor protection

8.3 Agricultural control

Plough of the soil before sowing seeds of wheat, in early spring, is the most effective means of ecological control, that protect wheat from damage caused by slugs. This way results in exposure of the slugs and their eggs to predators and the weather (Wouters, 1970). Slugs need moist soil for egg-laying and cool shelter for protection during the day opening up the garden to more light and air movement will reduce the amount of favorable habitat (Mahrous et al., 2002; Shetlar, 1995). There are many methods which are effective in the agricultural practices:

1. Plowing-In open fields, adjacent to outside storage and on base housing areas, plowing the soil twice a year has been found to reduce both snails and slugs populations. Cultivating the soil in late autumn destroys many of the immature and adult snails, as well as eggs that have been deposited in the soil.
2. Disking and culti-packing. This is helpful in reducing land snail populations in areas where plowing may be not practical because of thin top soil or where erosion may be a serious problem. The mechanical action of the disc and culti-packr will eliminate many adult snails, while stirring the soil will destroy many eggs.
3. Improvement of soil structure, results in exposure of the sensitive egg and juvenile slugs to direct sunlight and they die of desiccation.
4. Clearing of the edges of fields and irrigation ditches after the harvest can reduce the level of infestation, but does not eliminate it altogether.

8.4 Biological control

In the following section the possibilities are discussed of using such environmentally harmless methods of control of molluscs, whether by diseases, parasites, predators or biotechnical procedures (Baker, 1989; Godan, 1983).

A. Fungi

Fungi attack mainly eggs of gastropods, for examples those, of *Deroceras reticulatum* by *verticullium chlamydosorium*. This fungus is not suitable for use in biological control, despite a high infection rat of the eggs (Mead, 1961). While fungal infections are important when rearing molluscs in the laboratory, since the may destroy the whole stock, in the field, fungi seldom cause total elimination or even a reduction in gastropod number.

B. Bacteria

Bacteria of the genera Escherichia, Alcaligenes and Bacillius, in France an aerobacter infection occurred on a *Helix fram* (Mead, 1961).

The combination between "victoback12" as (*Bacillus thuringiensis*) and the parasitic nematoda *Rhabditis* sp. can play an effective role in controlling *E. vermiculuta* as well as the other terrestrial snail and slugs in Egypt (Azzam & Belal, 2002)

C. Viruses

Very little is known about the effect of viruses on molluscs. This is a most neglected area of research.

D. Nematodes

The nematodes are the third large group of worms which parasitize molluscs; they are mostly of interest to veterinary medicine, but in a few cases also affect man. A comprehensive review of snails considered them as intermediate hosts of nematodes (Azzam, 1999; Azzam & Hegab, 2000; Wilson et al., 1996).

The slug nematodae *Phasmarhabditis hermaphrodita* (Schiender) has been successfully used control slugs in field experiments (Wilson et al., 1996). The snail parasitic nematode *Rhabditis* sp. was recorded for the first time in Egypt and showed high infectivity different snails, slugs and insects in laboratory (Azzam, 1998). Production of this nematode from different pests was investigated and it was found that *L. flavus* slug and *E. vermiculata* snail was the most adequate host producing high numbers of this nematode, as shown in Table (6) (Azzam, 1999).

Azzam & Hegab (2000) exposed the terrestrial snail, *E. vermiculata* to different concentrations (10-300 I.S/ Snail) of the snail parasitic nematode, *Rhabditis* sp. under laboratory conditions. They are found that the period needed for snail death decreased by increasing concentration.

E. Parasites and predators

E.1. Parasites

The most important of these parasitic include protozoa, flat worms, lung worms, carabid beetles, the glowworm larvae of lampyrid bettles as well as the larvae of Sciomyzidae (Diptera), as shown in tables (6 and 7). Protozoa associated with molluscs both parasitically and symbiotically (Baker, 1989; Godan, 1983). The sprrozoan *klossia* sp. has been found in the kidney in various slugs and snails, and an amoeba is found as on endo-parasite in *Arion rufus*

Tetrhymena rostrata (Kahl) was isolated from the soil in which the slugs live, showing that contamination occurs through the soil. Slug is probably infected by contact with cysts in the soil during the winter. It is also possible that the parasites are transferred by way of the eggs; the some eggs laid by *Deroceras reticulatum* were found to be infested with ciliates.

Field slugs infested with *T. rostrata* show the following symptoms: mantle shield swollen, posterior end of the body some what elongated and laterally compressed; after death the body shortened, and a tumor-like swelling of the mantle shield.

E. 2. Predators

Attempts have understandably been made to use predators for control of pest gastropods, especially for the biological control of land snails. For example *Byfo melanosticus*, *Rantigran tigrian* used in control *Lavicaulis alte* (Muthumani et al., 1992). Insects from order diptera, family sciomyzidae including 84 species as predators of Molluscs (Knutson, 1966; Neff, 1964; Verbeke, 1964). Beetles from order coleoptera, family carabidae, species, i.e. *Thermophilum hexaasticum* (Gerstaeker), *Carabus violaceus* (L.), and *Scophinorus striatopunctatus* (Choudoir) were used as biological control agents for *Achatina fulica*.

Fouad et al. (2000) illustrated the predation potential of some vertebrates, i.e. rodents, (*Rattus rattus rattus, Rattus norvegicus*, *Arvicanthes niloticus* and *Acomys cahirinus*) and birds (*Ardola ibis ibis* and *Bubulcus ibis*) for the different stages of three land snail species, *M. abstructa, T. pisana* and *E. vermiculata* under laboratory conditions.

It is concluded that the predation potential for the vertebrate animals markedly differed according to predator species and size of the prey or tested snail species as the rodent *R. norvegicus* exhibited a comparatively high potential for all stages of the tested gastropod species followed by *R. rattus* when compared with the *A. niloticus*, while *A. cahirinus* showed the lowest effect against all tested gastropod species. On the other hand, *A. ibis ibis* occupied the first order between bird species when compared with *B. ibis* birds. In the same time, the obtained data revealed that all tested predators exhibited a high predacious effect against all land snails particularly their juvenile stages as animals characterized by soft shell were more vulnerable for predator attacking, while the adults of snails were enable to protect themselves either by disappearing inside the hard shell or by releasing extensive mucus, as *M. obstructa* more acceptance to both vertebrate species which have small size than *T. pisana* and *E. vermiculata*.

Species	Host	
	Snail	Slug
Plathelmiuthes		
Trematoda		
Brachycoelium obesum (Nicolli)		*Deroceras agreslo* (L.)
Brachylaema helices (Pomaliae)	*Cepaea hortensis* ((Müller)	
Brachyiaema nicolli (Witenberg)		*Deroceras agreslo* (L.)
Brachyiaema obesum (Nicolli)		*Deroceras agreslo* (L.)
Dicrocoelium dendriticum (Rudolphi)	*Helicella obvia* (Hartmann)	*Arion fasciatus* (Nilsson)
(D. lanceolatum (Rudolphi)	*Helicella itala* (L.)	*Arion subfuscus* (Draparneud)
(Lancet liver fluke)(Grazing stock)	Monacha cartisicne (Müller)	*Deroceras reticulatum* (Müller)
	Cochlicelle acuta (Müller)	*Limax tenellus* (Müller)
	Cochlicopa lubrica (Müller)	
Leucochloridlum paradoxum	*Succinea putris* (L.)	
Monocerus Sp.		*Arion* spp.
Cestods		
Anomotaenia arionis (Siebold)		*Arion ater* (L.)
Aporina delafondi Railliet		*Arion rufus* (L.)
Choanotaenia crassiscolex (Linstow)	*Oxychilus cellarius* (Müller)	*Deroceras* spp., *Arion* spp.
Cyslicercoidos dukae (Holland)	*Succinea Putris* (L.)	
Davainea proglottina (Davaine)	*Helicella itala* (L.)	*Arion hortensis* (Ferussac)
	Helicella obvia (Hartmann)	*Arion intermedius* (Normand)
	Succinnea putris (L.)	*Deroceras caruanae* (Pollonera)
	Succineidae	*Deroceras leave, D. reticulatum* (Müller)
		Lehmannia marginata (Müller)
		Limax flaves (L.), *Limax maximus* (L.)
Hemenolepis multiformis (Creplin)		*Arion* spp.
Raillietina bonini (Megnin)	*Cepaea hortensis* (Müller)	*Arion* sp., *D. reticulatum* (L.)
		Marginata
Teania bothrioplitis (Filippi)	*Monacha cartusiane* (Müller)	
Nemathelminthes		
Nematoda		
Aelurostrongytus abstrusus (Railliet) (Lungworm of catts)	*Helix* spp.	*Arion circumscri* *Deroceras agreste., D. reticulatum*
Alloionema appendiculatum (Schneider)		*Arionater* (L.) *A. tufus* (L.) *D. agreste*
		D. agreste
Angiostoma helices (Conte & Bonnet)	*Helix asperea* (Müller)	
Angiostoma limacis (Dujardin) *Leptodera angiostoma* (Oujardin)		*Arion* spp., *Limax* spp.
Angiostrongylus cntonensis (Chen)	*Achatina fulica*	*Deroceras leave* (Müller), *Limax* spp.
Crenosoma vulpis (Dujardin) (Cat, Dog, Fox)	*Cepaea* spp., *Helix* spp., *Succinea* spp.	*Arion* spp., *D. reticulatum*
Cystocaulus ocreatus (Davtian)	*Cochilicella acuta* -Helicidae	*D. reticulatum* (Müller)
Hexamermis albicans (Siebold)	*Succinea patrus* (L.)	*D. agreste., D. reticulatum*
Mermis nigrescens (Dujardin)	*S. patrus* (L.)	*D. agreste., D. reticulatum*
Mullerius capillaries (Müller) (Lungworm of Sheep & Cattle)	*Cepaea vindobonensis, C. acuta* *H. obvia, H. Pomatia, M. cartusiane, T. pisana*	*A. ater, A.hortensis, D. laeve* *D. reticulatum, Limax* sp.
Protostrongylux nufescens (Longworm of Sheep)	*Cepaea* sp., *Helicella* sp.,*Helix* sp., *Monacha* spp.	

Table 6. Terrestrial gastropods intermediate hosts of worm parasites.

Molluscan predators have two ways of seizing their prey. If the prey is a snail, it is reached through the mouth of the shell, the predator penetrating deeper and devouring its prey as it does so: Ganaxis feed on terrestrial snails in this way. *Edentuline ovoidea* (Brugier) predatory snails used for control of *Achatina fulica* (Bowdied). Other predators on terrestrial gastropods, *Edentulina affiris*, and *Haplotrema minimum* (Ancey) are used to control the *H.*

aspersa (Müller). The latter species reduced the population and succeeds in keeping is number down. (Godan, 1983; Zeidan, 2001).

Species	Host	
	Snail	**Slug**
Amoeba		
Acanehamoebe sp		*Arion fasciatus* (Nilsson)
Amoeba sp		*Arion rufus* (L.)
Ryplobia hellcis (Trypanoplasma)	*Cepaea hortensis* (Müller), *C. nemorallis* (L.) *Helix pomatia* (L.) (in Receptaculum semnis)	
Trichomonas liracis	*Cernuella Virgata* (Dacosta)	*Limax* sp.
Sporozoa		
Isopora incerta (Schneider)		*Limex cinereoniger* (Wolf)
Isopora rera Aime (Schneider)		*Limax* sp.
Klossia loosi (Nabin)	*Helix, Cepaea and Succinea* sp.	*Arion* spp., *Limax* sp.
Pfeiffercirclla impudica (Leger & Hollande)		*Lehmannia marginata* (Müller)
Plistiphora husseyi (Michaud)	*Achating zobra* (Sganzin)	
Trichodina echauinae	*Achatina zebra* (Sganzin)	
Ciliata		
Colpoda aspersa (Kahl)		Deroceras agreste (L.)
Colopoda steini (Maupas)		*Deroceras agreste* (L.) *Deroceras reticulatum* (Müller) *Lehmannia marainata* (Müller)
Concophthirus steenstrupi (Stein)	*Helix* spp.	*Arion ater* (L.) *Deroceras agreste* (L.)
Semitricholina sphaeronuclea	Zonitidae	-------------------------------
Tetrahymena limacis (Warren)	*Trichia lubomirskii* (Slosarski)	*Arion hortensis* (Ferussac), *Deroceras reticulatum* (Müller), *D. leave* (Müller), *Lehmannia marginata* (Müller), *Limax flavusl, L. maximus* (L.) *Milax gagates* (Dr.)
Tetrahymena rostrata	*Zonitoides nitidus* (Müller)	*Arion intermedius* (Normand) *Deroceras reticulatum* (Müller)

Table 7. Parasitic protozoan in terrestrial gastropods (cited from Zeidan, 2001).

Predation by the carnivorous snail, *oxychilis* sp. on the newly hatched and youngsters of *Monacha* sp. snails was observed by El-Okda (1984). Another predatory decollates snails (*Rumina decolata*). These snails are used very successfully in commercial citrus groves in California and provide excellent control to the brown garden snails (Fisher & Orth, 1985) and to slugs (Allikas, 1997).

8.5 Chemical control

Chemical control of exotic snails typically employs metaldehyde, methiocarb (Mesurol), salt, or combinations of these chemicals with other molluscicides in a myriad of bait formulations or foliar sprays.

8.5.1 Methods of application

Spraying, Dusting and use of pellet bait. Today the use of bait is the most common method of gastropod control in both agriculture and horticulture, where as spraying and dusting are less frequently used. El-Massry (1997) studied the effectiveness of certain pesticides namely, i.e. methomyl (Lannate); paraquate (Garamoxone); oxyfluorfen (Goal); Glyphosate (Lansar) and pendimethalin (Stomp) against adult stage of three species of land snails (*H. vestalis, M. contiana* and *E. vermiculata*) under laboratory conditions using three methods for testing, i.e. direct spray, dipping and poisonous bait technique. He found that toxicity of any tested compound was varied according to the method of application. Mothomyl was the most effective toxicant against adults of the three tested species (Gabr et al., 2006).

8.5.2 Chemical components as snailcides

A. Metaldehyde treatments

They are applied during dry climatic conditions are usually more successful than the degree of control achieved during damp, high humidity conditions, at which time snails are likely to be more active (Dax1, 1970; Moens, 1970). The principal toxic effect of metaldehyde is through stimulation of the mucous gland which cause excessive sliming, leading to death by dehydration. Metaldehyde is broken down into acetaldehyde by sunlight, so where possible the pellet should be put in shady places, particularly under the leaves of the affected plants (Henderson, 1970; Henderson & Triebskorn, 2002).

B. The pesticidal properties of methiocarb

They are similar to the toxic action of other carbamates which prevent effective nerve transmission by inhibiting the enzyme acetyl cholinesterase. The methyl carbamate most widely used as amolluscicide is methiocarb. This compound is more poisonous than metaldehyde pellets and less active as a contact killer, acting more as stomach poison when ingestion the baits for controlling slugs *D. reticulatum* (Getzin & Cole, 1964). The effectiveness of methiocarb is compromised less by low temperatures and high humidity than that of metaldehyde which is amagor advantage (Mallet & Bougran, 1971).

C. Differences in the symptoms of poisoning by metaldehyde and methiocarb

The symptoms shown by gastropods poisoned with metaldehyde differ markedly from those following carbamate poisoning (Godan, 1965). The metaldehyde can affect molluscs either by contact, with absorption through the skin, or through the gut when eaten. The main effect is that of an irritant, causing the molluscs to produce masses of mucus, leading to dehydration and sometimes death. Loss of mucus also means that the animals can no longer move around, so that death and dying animals are found close to the baiting site. Molluscs that have been poisoned by methiocarb can however, move around for a while, but then swell up with fluid and become immobile dying shortly afterwards. In dry conditions this swelling can be reduced, and some animals may recover, although generally recovery rates are lower than with metaldehyde (Abd El-Wakeil, 2005).

D. In addition to these molluscicides, sodium chloride (common table salt)

It is an effective dehydrating agent. It may be applied as ainch barrier application on the perimeter of known/ suspected snail infested area. During periods of rain or high relative humidity, salt are aestivating.

E. Further chemical compounds

They are being tested for their possible molluscicidal effects, even substance with other uses, such as fertilizer, fungicides, insecticides and herbicides (Van der Gulk & Springett, 1980). Fox (1964) used herbicides among the substance used for plant protection in agriculture and horticultural plants. The results indicated that herbicides were effective against land snails. Mode of action was in contact over long period of time with snail or as direct feeding on treated plants.

El-Massry et al. (1998) tested fertilizers, urea, ferrous sulfate and calcium super phosphate against many species of land snails; *H. vestalis, M. Contiana* and *E. vermiculata* in the laboratory. He found that urea the highest toxic effect against the three species of land snails, respectively, followed by ferrous sulfate, while calcium super phosphate showed the last toxic.

The evaluation of a molluscicide is based on testes of its toxicity, persistence of effectiveness, attractiveness to gastropods and also the chances of recovery of affected slugs or snails studies by many researchers (i.e. Arafa, 1997; El-Okda et al., 1989; El-Sebae et al., 1982; Ghamry et al., 1994; Mahrous et al., 2002; Radwan & El-Zemity, 2001).

El-Sebae et al. (1982) tested locally formulated bran baits containing aldicarb, methomyl or Dupont- 1642 against land snails, *H. vestalis, E. vermiculata* and *T. pisana*. Different wheat and rice brains are containing 0.5% aldicarb or methomyl showed high attractant action and toxicity for land snails, represented by their high mortality percentages.

El-Okda et al. (1989) evaluated the efficacy of the formulated local 0.5 %, aldicarb, oxamyl, methiocarb, Lannat and metaldhyde in controlling the land molluscs ; *H. aspersa, Eobania sp., Theba sp., Rumina* sp. and *oxychilus* sp. The results indicated that, aldicarb, oxamyl and Lannat gave the highest toxicity against the most snails and slugs species, while methiocarb and metaldehyde were less toxic.

Ghamry et al. (1994) evaluated fourteen insecticides against tow land snails; *M. contiana and E. vermiculata*. Results from bait testes revealed that, methomyl, dithiocarb, carbaryl, chlorpyrifos and dimethoate were effective for killing snails after 12 days under laboratory conditions. On the other hand, the same trend was observed with those insecticides under field conditions.

Arafa (1997) tested sucmate- granules, Mesural and Nuvacron against the land snail *E. vermiculata* under field conditions. The results revealed that sucmate- granules gave the highest mortality (100%) when used as poison baits while Novacron gave 46% mortality when it used as direct spray after two weeks. Mesural gave 48.5 % mortality percentage when it used as poison baits.

Radwan & El-Zemity (2001) synthesized a new series of 1,2,4- triazol derivatives and screened for their molluscicidal activity against two type of terrestrial snail, *H. aspersa* and *T. pisana*, by two methods of application, either as contact or as bran baits. Several of the tested compounds exhibited good molluscicidal activity, and *T. pisana* was more sensitive than *H. aspersa*. Substitution at the 0 and or P- positions of the phenyl ring with chlorine or bromine gave higher molluscicidal activity than unsubstituted compound, with O, P- dichloro substitution being optimum. In addition compounds containing two triazole moieties showed higher molluscicidal activity, particulary as stomach poisons, that the contact toxic effect of the corresponding compound with one triazole ring. In general, carbamate derivatives were more active than their corresponding 1,2,4- triazol derivatives.

Mahrous et al. (2002) tested seven pesticides to evaluate their molluscicidal activity as poisonous baits against *M. Cartusiana* in Sharkia Governorate, Egypt. The obtained results that the molluscicidal efficiency of the tested pesticides after 15 day- treatment could be arranged as follows: fenamiphos> sethoxydim> oxamyl> monocrotophos> butachlor> biofly and seed grad. On the other hand, carrier or attractive materials usually used in poisonous baits showed insignificant effect on the molluscicidal activity of fenamiphos in controlling *M. cartusiana*.

8.6 Botanical pesticides against molluscan pests

Plant products known to possess molluscicidal activity against the snails of agricultural importance are presented in Table (8) along with details of their forgeneric names, plant parts tested to possess biological activity and their formulations (Prakash & Rao, 1997). Azardirachtin, and active component isolated from neem kernel extract, was also reported to show mulluscicidal activity against *Lymnea luteda* (Ramesh, 1983). The molluscicidal activity of saponins isolated from saponaria roots was investigated (Kadey et al., 1982). Also, Kady et al. (1986) attributed the molluscicidal action of the wild herb, *Peganum harmala* (L.) (seeds) to its alkaloidal constituents which affect the respiration and/ or the nervous sytem of the snails. Kishor & Sati (1990) reported "spirostanol glycoside" from an ornamental plant, *yacca aloifolia* to be 100 % toxic at 10 ppm when tested against the snails like *Biumphalaria glabrata*. El- Hwashy et al. (1996) showed that the ethanolic leave extracts of Cauliflower, Oshar and pergularia were most effective against *E. vermiculata* snails when tested as residue film technique with mortality percentage of 88.8, 88.8 and 77.7 respectively. Molluscicidal activity and repellent properties of thirteen monoterpenoidal compounds were studied against the snail, *H. aspersa*. Camphor, thymol, (R)-carvone and carvacrol proved to be potent molluscicides of the compounds tested only citronellol, geraniol, (±) methanol and thymol were highly effective as repellents (El-Zemity et al., 2001). Repellency effect of 28 plant extracts obtained from different parts of 13 indigenous plants, i.e. Damsisa, Halfa barr, Colocynth, khella, Harmala, Datura, Santonica, Sucalyptus (L.), Eucalyptus (S), Enab eddhib, Calotropis, Alocasia, Halouk and Geranium, was investigated against *M. cantiana* land snails, using one and two choice feeding methods (Abd El- All et al., 2002). All plant materials either extracted with hexane and/ or ethanol showed a considerable snail repellency effect, when their crude extracts were tested using one choice feeding methods. In contrast results of two choice feeding test method Indicated that all the tested plant extracts showed snail repellant effect except Damsisa, Enabeddip, Calotropis and Geranium hexane crude extracts, which failed to achieve 50 % or more repellency level.

Generic name	**Part of plant and its formulations**	**Biological activity**	**Reference**
Azardirachta indica A. Juss. (Meliaceae)	Kernel extract of neem and neem cake extract	Toxicity to *Lymnaea matalensis* and *L.auricularea*.	Reynaud, 1986; Sasmal, 1991
Balantisa egyptica (L.) Delite (Simaroubaceae)	Nut and leaf powders	Toxicity to the snails	Belen, 1982
Citrus mitis (Linn.) Macf. (Rutaceae)	Dried fruit powder and its aqueous extract	Toxicity to the snails	Belen, 1982
Coryzadenia balsamifera Griff. (Hernandiaceae)	Fruit and leaf aqueous extracts	Toxicity to the snails	Belen, 1982
Croton figluim (L.) (Euphorbiaceae)	Leaf extract in water	Toxicity to the snails	Belen, 1982
Entade gigas(L.) Fawc and Rendle (Mimosaceae)	Leaf seed and bark extracts in water	Toxicity to the snails	Belen, 1982
Jatropha curcas (L.) (Euphorbiaceae)	Fruit and seed aqueous extract	Toxicity to the snails	Belen, 1982
Menispermum coculus (L.) (Menispermaceae)	Leaf, branch, fruit and seed extracts in water	Toxicity to the snails	Belen, 1982
Prago pabularia Hybrid (Cactaceae)	Aqueous leaf extract	Toxicity to the snails	Belen, 1982
T*hevetia nerifolia* Juss.ex Steud (Apocynaceae)	Alcoholic fruit extract	Toxicity to the garden snail	Johri et al., 1993

Table 8. Molluscicidal properties of plant products (Cited from Parakash & Rao, 1997).

8.7 Integrated mollusca control

Integrated pest management (IPM) is an economic necessity, and is vital for our modern agriculture, this approach requires a good understanding of all biological and ecological aspects of the mollusca in question (Snails or slugs). These methods include using all control procedures to suppress molusca populations to non-damaging levels as follows:

1. Plough of the soil before sowing seeds, results in exposure of the sensitive egg and Juvenile slugs and snails to direct sunlight and they die of desiccation.
2. Hand collection of the snails and slugs daily and to kill them with a strong solution of common salt or in boiling water (Mahrous et al., 2002)

3. Burning over is a quick method of clearing land of pests before sowing crops.
4. Beer – baited traps have been used to trap and down slugs and snails, and scrape off the accumulated snails and slugs daily and destroy them by crushing (Olhendorf, 1996)
5. Protective barriers of dehydrating substance, will keep snails and slugs out of planting beds.
6. The use of poisonous bait is the most common method of gastropod control.

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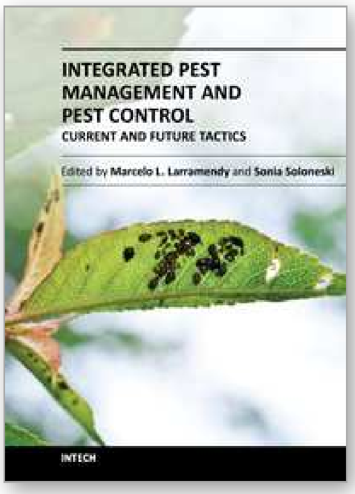

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