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Integrated control strategies of invasive land snails

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The land's snail Theba Pisana (Helicidae) is a very harmful snail that is found on some crops and lives on attacking fruits and ornamental plants. It has another name, which is the white garden snail. Theba Pisana is native to the western Palearctic but it became invasive in many parts of the world. It negatively affects agriculture industries. In this review, we will report the results of some studies about the biology-ecology of the white snail and some other snails. Control strategies using trapping, essential oil plants, natural enemies and chemical pesticides, will be presented as a part of an integrated pest management against snails in order to evaluate their effectiveness, sustainability, and feasibility in fields.

Keywords: White snail, *Theba Pisana,* crops, pest management, biocontrol

INTRODUCTION

Mollusca is the second-largest phylum of invertebrate animals. The words mollusc and mollusk are both derived from the French "mollusque", which originated from the Latin "molluscus", from mollis "soft". The study of molluscs is called malacology. The gastropods are the class that represents the most species. Snails and slugs belong to gastropods (Gastropoda, from ancient Greek γαστήρ/ gastḗr and πούς/ poús: gastros (stomach) and podos (foot)), characterized by the twisting of their visceral mass. Their characteristic univalve and twisted dorsal shell when present can generally recognize them. Most gastropods are aquatic and breathe with gills. Only a minority is terrestrial that is why they have gradually abandoned the gills to replace them with a pulmonary cavity. Slugs and terrestrial snails form the order of the Pulmonata.

The family of helicidaes includes several terrestrial snails such as Helix Aspersa, Theba Pisana , Eobania Vermiculata, the helicidaes are native to the western Palearctic but became invasive in many parts around the world. Most of the species that belong to this family are pests of several crops around the world, many studies attempted to find solutions in order to reduce the damage caused by these pests.

TAXONOMY AND DESCRIPTION

Taxonomy

Kingdom: Animalia; Phylum: Mollusca; Class: Gastropoda; Order: Stylommatophora; Family: Helicidae; Genus: Theba; Species: T. pisana, Binomial name: Theba pisana (Müller, 1774)

Morphology

Theba Pisana exhibits distinctive morphological features, including a towering shell and small size. Typically, it displays a light yellow to white hue adorned with delicate, dark brown fragmented spiral bands, often arranged in chevron patterns. In juveniles, the whorls appear angular, gradually transitioning to rounded forms in adults. The species is further distinguished by a moderately sized, rounded aperture and a narrow umbilicus. In addition, internally the shell lip is thicker and turns pink but remains externally unthickened and non-reflective. The juvenile shells have a sharp keel along (part of) the periphery (Blacket, 2016; Gittenberger and Ripken, 1987). Concerning the genitalia, there is no or only one rudimentary flagellum on the epiphallus (Gittenberger and Ripken, 1987).

Geographical distribution

The geographic range of Theba Pisana (which is determined by the range of its subspecies) includes almost the entire Mediterranean coastline, extending from the Atlantic coast of Europe to the extreme south of the Netherlands, south-west England and Wales and eastern Ireland, to the Madeira islands. Moreover the species: T. Pisana, T. Andalusica, T. Solimae, T. Sacchii and T. Shudeaui are present in Southern Spain and Western Morocco (Gittenberger and Ripken, 1987). It extends along the Atlantic coasts of North Africa and was accidentally introduced into Australia, South Africa and California (Cowie, 1990).

Biology and Ecology

In order to understand the life cycle of the snail Theba Pisana, researchers used different methods such as the census of individuals in a specific area during the cycle (Heller, 2009) and the collection of individuals during different periods of the year (Cowie, 1984, 1990).

Snails enter quiescence periods when it is too hot or too dry and winter when it is too cold, such in areas characterized by a cold winter and autumn and hot and dry summers. The snails have about the same life cycle characterized by wintering in winters and autumn and an estivation in summer and a period favorable to growth in spring. The duration of the two phases (wintering/estivation), depends on the climate of each zone (Cowie, 1984; Heller, 1982). The life cycle duration (1 or 2 years) is most likely determined by the duration of the estivation or hibernation, which can show considerable local variations. For example,in Morocco, T. pisana has an annual cycle (Johnson, 1988, 2011). In France, it has a two-year cycle in some localities (Däumer et al., 2012) while in others, the life cycles are annual (Cowie, 1984).

T. Pisana is a hermaphrodite, developing sperm and ova in the same gonad. However, each egg is wrapped in several non-germinal follicular cells that isolate female germ cells from male germ cells (Luchtel, 1972), the germ line compartment is isolated from the male line. The ovotestis consists of several lobes; each is composed of many acini (Avivi and Arad, 2013). Regarding copulation and oviposition, it have been observed in the field throughout October, copulation occurs in the early hours of the evening (6 pm to 10 pm), whereas oviposition occurs mainly at night when many snails descend from the vegetation and dig into the sand. In the laboratory, where temperatures fluctuated between 12 and 22°C, eggs were laid 9 to 14 days after copulation, 60 to 107 eggs per clutch (mean of nine clutches). Up to five clutches are laid in pairs and each snail lays an average of 120 eggs throughout the season. Egg diameters range from 1.8 to 2.3 mm (Heller, 1982). These results are consistent with those established by Cowie (1984) where the average number (with 95% confidence limits) of clutches produced per potentially producing pair (twenty-five pairs) was 4.8 and 5.2 for those actually producing (twenty-three pairs), with a maximum of 15, the average number of eggs per clutch was 76.7 (Cowie, 1984, 1990).

Host plants (Host preference)

It has been shown that snail localization capabilities are limited to already known foods and are not dependent on their hunger status (Teyke, 1995). Another view says that these result from the fact that snails are usually tested while they are in a moderate state of hunger, so that they benefit from feeding on known foods, but not from taking the risk of feeding on unknown foods. The results obtained by Rodríguez et al. (2019) show that, under certain conditions of food deprivation (i.e. 45 days), Theba pisana can find a new food source and when saturated with a given food, 24 hours of deprivation are not enough for the body to show an attraction to its smell. Thus, by manipulating the level of hunger, they have shown that Theba pisana is not "blind" to the new food's odors and that they are not always attracted to the food that has been conditioned (Rodríguez et al., 2019).

Description of damages

T. Pisana was considered as the worst and harmful snails in the holy land where it feeds on ornamental and vegetable gardens, on the fruit and young foliage of citrus trees and on grapevine leaves, exposing the grapes to excessive solar radiation (Abd El Rahman and Al Akra, 2012; Benfradj et al., 2018; EL-Wakil, 1999). Damage is usually described as holes in the fruit and foliage (Barker, 2002).

EFFECT OF PESTICIDES ON THE PEST

Metaldehyde

Metaldehyde (40% aqueous emulsion) showed good molluscicide and anti-climbing activity against Oncomelania hupensis snails in laboratory and field experiments with an LC50 of 0.78 g/m2 (24 hours), 0.44 g/m2 (48 hours), and 0.46 g/m2 (72 hours) in spraying experiments, respectively. Mortality of Oncomelania hupensis snails exceeded 90% after 7 days at 2 g/m2 in spraying experiments (Zheng et al., 2021). In another study about the contact toxicity and biochemical impact of metaldehyde against Theba pisana snail; the LD50 values obtained were 11.3, 8.53 and 6.87 µg/g BW, after 24, 48 and 72 hours of treatment, respectively. LT 50 values were 88.2, 55.8, and 25.7 h for doses of 6, 8, and 12 µg/g BW, respectively (Abobakr et al., 2021). The reduction after application of metaldehyde bait 2% was 76.7% of the population for theba pisana, while the population reduction of M.cartusiana and E. vermiculata after the same product was applied, was 72% and 74.2% for each application, respectively (Amal et al., 2019a; Rizk et al., 2017).

Niclosamide

Niclosamide showed strong molluscicidal activity against different types of snails, and its LC50 values for B. glabrata, B. straminea, and B. pfeifferi were 0.070 ppm, 0.049 ppm, and 0.076 ppm, respectively (He et al., 2017). The LC50 for the 24, 48 and 72 h SCN (Niclosamide Concentrated Suspension) was 0.051, 0.050 and 0.047 mg/l, respectively, and the LC50 for the 24, 48 and 72 h WPN (Wet Niclosamide Powder) was 0.103, 0.096 and 0.087 mg/l, respectively. Mortality rates in all groups of snails sprayed with SCN at 0.5 g/(l m2). When sprayed with WPN at 1.0 g/(l m2), snail mortality rates ranged from 60% to 100% (Amjad, 2007; Dai et al., 2008; Singh et al., 2021).

Methomyl

Tests at the laboratory on methomyl have shown its effectiveness against snails. The mortality rate reached 85.0% for E. vermiculata after 48 h of testing and 95.0% after 72 h. For the toxic effect on T. pisana, the mortality rate reached up to 80% in the first period and 100% in the second period of testing (Abdallah et al., 2015; Amal et al., 2019b; Eshra, 2014).

Copper products

E. vermiculata and T. pisana treated with copper hydroxide at concentrations of 2500, 5000, 10 000 and 15 000 ppm yielded mortality percentages of 45.0, 55.0, 75.0 and 90.0 after 72 h of testing against E. vermiculata, respectively. While these values were 20.0, 35.0, 60.0 and 80.0 in the 1st period and 33.3, 50.0, 67.0 and 85.0 in the 2nd one against the snail T. pisana (Eshra, 2014; Hoffman and Zakhary, 1953). In another study, several copper-based fungicides were tested against theba pisana snails and the inferred mortality values were 60,0, 56.7 and 33.3% after 6 days after snails feed on leaves treated with copper oxychloride fungicide at 0.5%, 0.25% and 0.125%, respectively. The corresponding LT50 values were 4.67, 5.18 and 8.41 respectively. For copper hydroxide, the values were 46.7, 26.7 and 20.0, respectively. These values corresponded to LT50 values of 5.62, 6.39 and 7.54 days at its tested concentrations of 0.5%, 0.25% and 0.125%, respectively. The same concentrations of galbine copper fungicide (0.5, 0.25 and 0.125%) yielded mortality values of 55.0, 53.2 and 20.0, corresponding to the calculated LT50 values of 5.47%, 5.59% and 9.40%, respectively (Sadany et al., 2009). Copper sulphate was also evaluated as a molluscicide for controlling B. alexandrine snails in Egypt. Mortality of B. alexandrine snails could reach 100% in 2 weeks at 0.25 ppm (Hoffman and Zakhary, 1953; Wise et al., 2006).

EFFECT OF MOLLUSCICIDES ON THE ENVIRONMENT

Niclosamide is the only molluscicide recommended by the World Health Organization (WHO) because of its high efficacy, low mammalian toxicity and low risk of pesticide residues (WHO (World Health Organization), 1993). Copper sulphate is an inexpensive inorganic salt. However, the toxicity of molluscicides to non-target organisms and secondary environmental pollution problems are not negligible (Hoffman and Zakhary, 1953; Wise et al., 2006; Zheng et al., 2021). Metaldehyde has been shown to be toxic to terrestrial mammals and birds. The lethal dose for dogs and probably other mammals is 10 g 228 metaldehyde bait per kilogram of body weight (100-1000 mg metaldehyde per kilogram of body weight). In rats, the LD50 is 283 mg of metaldehyde per kilogram of body weight, the minimum lethal dose of metaldehyde is 500 mg of metaldehyde per kilogram of body weight for birds. Arthropods and earthworms do not appear to be affected by metaldehyde (Abobakr et al., 2021; Autin et al., 2013; Castle et al., 2018a; 2018b). There is conflicting information on the toxicity of metaldehyde to aquatic organisms. Reports indicate that the 96-hr LC50 for bluegill fish is 10 ppb and for trout is 62 ppb. Other reports indicate that aquatic organisms are not affected by metaldehyde. Humans can be poisoned by metaldehyde if swallowed. After a few hours, the following symptoms will appear: abdominal pain, nausea, vomiting, diarrhea, fever, convulsions, coma and persistent memory loss, exposure may also lead to tachycardia, respiratory breath, acute, asthmatic reaction, depression, drowsiness, high blood pressure, excessive urination and defecation, muscle tremors, sweating, excessive salivation, tearing, cyanosis, acidosis, stupor and unconsciousness. Some symptoms may persist for months after acute poisoning (Macar et al., 2023; Rumbeiha, 2014; Saito et al., 2008).

AVAILABLE BIOCONTROL METHODS

Natural enemies

The larvae of Lampyridae

Larvae of Pyrocoelia pectoralis appear to feed primarily on two species of terrestrial snails, Bradybaena similaris and Bradybaena ravida, and have been observed only on live, fresh terrestrial snails in the wild and in the laboratory. It often attacks snails by climbing on them with their pygopods, clinging firmly to their shells and biting exposed snail heads, when snail heads are sucked into the shells. Firefly larvae use their elongated heads to insert their mouthparts under the shell and continue to bite and chew the snails bodies (Wang et al., 2007). In other breeding experiments of Pyrocoelia pectoralis (Coleoptera: Lampyridae), as many biological agents as possible to control the terrestrial snail Bradybaena ravida in the field, 33 out of 50 larvae survived and pupated. The period spent as larvae were 114.3, 16.7 days (mean standard deviation), similar to laboratory development at 30°C with a L:D of 12:12; feeding capacity reached 1.76 -0.19 g (mean standard deviation), a value close to that observed in laboratory-bred subjects at 25°C and an L:D of 16:8 (Fu ad Benno Meyer-Rochow, 2013).

The predator snail

The Rumina decollate snail (L.) has been used as a biological control agent against Cornu aspersum (Müller) in California for nearly a half century, despite little evidence of its effectiveness in the laboratory and the field. It has been shown that R. decollata can only successfully kill C. aspersum which is <13 mm (shell diameter) and if given the choice between a known food plant (carrot roots) and C. aspersum in this vulnerable size range, the majority of R. decollata (93%) chose carrots. R. decollata adults feed on C. aspersum eggs and the average total consumption per individual was 3 eggs over 7 days (Donnell et al., 2016).

The parasitic nematode Phasmarhabditis sp

The snail's parasite, Phasmarhabditis sp (Nematode: Rhabditidae), could infect all species (L. flavus, E. vermiculata, A. fulica) and all exposed stages, killing 100% of E. vermiculata eggs and all individuals of other species and stages. Approximately 50% of A. fulica eggs and 100% of other species and stages were released into the infectious stage of the nematode. The results indicated that all species were suitable hosts for the parasitic nematode and, therefore, that the isolated nematode was suitable to control these pests at their various stages (Azzam and El-Abd, 2021).

The parasitic diptera Megaselia scalaris

Megaselia scalaris (Diptera: Phoridae) has the potential for biological control of terrestrial snail Bradybaena similaris (Ferussac). The results of a study show an extrusive relationship between the diffusion of M. Scalaris in plots and mortality rates of juvenile or mature snails and the time required for total mortality was reported much longer period in mature snails as juvenile snails. It could be concluded that M. scalaris can play an important role in controlling terrestrial gastropods (Daif et al., 2023; Quintero Santos et al., 2022; South, 1992).

Attractive Trap

The results of the snail trap experiments highlighted that attractive traps, containing wheat straw covered with a box equipped with an alert alarm and mixed with about ¼ kg of a lure (2½ l of water + ½ kg of molasses + 5 kg of bran), were installed in every 5 trees. As a result, the decrease in the number of terrestrial snails was respectively 48.9%, 51.3% and 55% for M. cartusiana, T. pisana, and E. vermiculata. When traps were set at intervals of 10 trees, the population reduction for each species was 29.3%, 33.3%, and 32%. Additionally, E. vermiculata exhibited a higher level of attractiveness compared to T. pisana and M. cartusiana when the traps were set every 5 trees, but the attraction rate was consistent with all species when all 10 trees were laid (Rizk et al., 2017). Eshra (2004) notes that blue buckets are more attractive than other coloured buckets and T. pisana was the highly attracted one followed by E. vermiculata, H. vestalis and M. obtracta. Snails of the same order are attracted by the bait of bran + sugar + cane honey then lettuce and water. In another study, four commercial traps were tested: Snailer Snail and Slug Trap™ (American Organic Products, Ventura), Snail Buster (Environmental Services, Tallahassee,) and Universal Yellow and White Nocturnal Traps (Great Lakes IPM, Inc., Vestaburg) and slug mats (Liphatech, Milwaukee, WI) were baited with 100 ml Snail Buster bait placed in a petri dish at the bottom of the trap. Snails were caught in all types of traps and there was no difference in the total number of snails trapped but snails managed to escape from all traps. Apparently, the snail had learned to lift the swing door mechanism after feeding on the bait (Roda et al., 2018). In the same context, a study that tested the effect of using synthetic lures as attractive has shown that snail traps baited with synthetic emulsion lure with metaldehyde have captured significantly more GAS (Giant African snail) than traps baited with metaldehyde alone. There was no significant difference in the number of GAS traps when the lure was formulated in mineral oil or canola oil emulsions. Bait-emulsified traps had 74-81% more P. martensi than traps containing only metaldehyde, but the difference was not significant. The addition of flavored papaya oil decoy or synthetic decoy has increased the number of GAS found in 34% and 50% respectively compared to the number of control plots 12 h after application (Roda et al., 2019).

Plowing soil

The actions carried out at the field level of the orange orchard, on which Rizk and his collaborators carried out the trial, were to turn and plow the soil, cut, paint, and spray the trees using Bordeaux mixture and fertilize the soils. These actions were implemented until November (Rizk et al., 2017).

The data showed that after the actions already mentioned were car rid out, the number of E. Vermiculata, M. Cartusiana and T. Pisana decreased to 118, 84 and 111 snails against 140, 102, and 123 in the untreated area and the reduction of snail population for each species was 11.3% 13.4%, and 14.6% in treated area, respectively (Rizk et al., 2017). Furthermore, it has been reported that tillage decreased the population of M. cartusiana and E. vermiculata to 52.3 and 43.3% for six weeks after tillage (Bashandy and Awwad, 2023; Rizk et al., 2017).

Essential oils

Among the active plants, interest is given in particular to the oils of the fruit Citrus aurantium L. var. Valencia late and aerial parts of Origanum compactum Benth. These oils showed a strong reversal effect on Bulinus truncalus at less than 24 hours and lowest concentrations (LC50=O.28 / LC90= 0.37 µg/mL (0.21-0.38) ppm and 0.44/0.69 (0.32-0.60) ppm, respectively). They were followed by Ruta chalepensis L. (LC50 =0.52 (0.39-0.68 ppm), Atlantic Cedrus needles (LC90= 0.69 µg/mL), Chenopodium ambrosioides aerial parts (LC50=0.54/ LC90= 0.74 µg/mL (0.38-0.76) pp) and Anthemis nobilis L. (LC50 = 0.56 (0.42-0.74) ppm) (Lahlou and Berrada, 2001, 2003). The essential oil extracted from lemon seeds C. limon also has a molluscicide effect with LC50 13.5 mg L-1. The lethal concentration for 90% mortality is 130.6 mg L-1 in 24 h (Gomes et al., 2019). A study of the essential oil of the barks of the species Citrus sinensis showed that the toxicity of this oil was considered non-toxic with CL 50 of 511.6 µg/ml. This essential oil showed lethal LC 50 and LC90 results of 83.3 µg/mL and 168.7 µg/mL (Júnior, 2018).

Nerium oleander contains a large amount of cardiac glycosides, which can inhibit the growth and development of many parasites such as Oncomelania snails at lethal doses of 50 and 90 (LD 50, LD 90) respectively 4.05 mg/L and 22.2 mg/L. With increased treatment concentration, mortality rates for Oncomelania snails are increasing (Xue et al., 2017).

Ferula asafoetida, Syzygium aromaticum and Carum carvi have also a molluscicide effect with LC 50 after 24 h of 175.0, 172.7, 270.0 mg/l and of 96 h 82.7, 52.0, 140.6 mg/l, respectively. Ethanol extraction from the three spices was the most toxic against snails. The 24-hour LC50 of ethanol extracts of F. asafoetida dried latex powder, S. aromaticum bud powder and C. carvi seeds against L. acuminata snail respectively was 132.3, 83.5 and 130.6 mg/l. The column-purified fraction of the three spices was highly toxic (Kumar and Singh, 2006).

CONCLUSION

The snail Theba Pisana is a very harmful pest that causes significant damage to ornamental plants and citrus leaves. Its damage affects vine leaves and many other agricultural products.

Numerous control strategies have been explored to manage this pest, ranging from implementing sound agricultural practices and employing biocontrol methods utilizing natural enemies, to utilizing essential oils and resorting to chemical interventions. While various active ingredients of chemical controls have demonstrated efficacy as molluscicides, it is imperative to adopt an integrated approach to pest management. This entails identifying and testing biological alternatives under conditions where they are both effective and economically viable.

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