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An Evaluation of Snail Immobilization and Mortality Effects Using Selected Chemical Treatments for Potential Trapping Apparatuses

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Abstract

This study evaluated the immobilization and mortality effects of selected wet and dry chemical treatments on the giant African snail. The chemical treatments used were 5 g and 10 g respectively of sodium chloride, calcium hydroxide and copper sulphate. Distilled water was used as a control in the wet phase evaluation of the study. In the first phase, each treatment was dissolved in 1000 ml of water. A total of ten (10) snails were submerged into each treatment and this was replicated ten (10) times. In the second phase of the study, 5 g and 10 g respectively of each dry treatment was evenly sprinkled over ten (10) snails within a confined area. This was replicated ten (10) times. It was concluded that the submergence effects of the wet treatment resulted in 100 percent immobilization and mortality for both the calcium hydroxide and copper sulphate treatment at six (6) hours post submergence. The dry treatments had no effect on immobilization and mortality up to six (6) hours post treatment. There was no treatment effect of sodium chloride for both the wet and dry treatments. The study concludes that low cost solutions such as calcium hydroxide can have an effect on the immobilization of the giant African snail. This finding can enable the development of trap designs which could eliminate the one-way door design and enable multiple entrances. Although both calcium hydroxide and copper sulphate solutions were effective for the immobilization and death of the snails, calcium hydroxide is the recommended option given its low toxicological profile when compared to copper sulphate.

Keywords: chemical treatments, drowning, giant African snail, immobilization, mortality, traps

1. Introduction

The giant African snail, *Achatina* (*Lissachatina*) *fulica* Bowdich is a highly invasive terrestrial snail native to East Africa (Sarma, Munsi, & Ananthram, 2015; Raut & Barker, 2002). As a consequence of the destructive ecological characteristic of this pest, the Global Invasive Species Database has ranked it among the "100 Worst Alien Invasive Species" (Lowe, Brown, Boudjelas & Poorter, 2000). This snail is of significant importance to tropical agricultural productivity (Raut & Barker, 2002). Furthermore, the snail is a threat to human health since it is known to be a vector of the rat lungworm, *Angiostrongylus cantonensis*, which causes eosinophilic meningoencephalitis in humans (Provciv, Spratt, & Carlisle, 2000; Alicata, 1991).

The high invasion potential of the giant African snail (Teles et al., 2004), its ployphytophagous feeding habit on over 500 plant species (Raut & Barker, 2002; Capinera, 2011), its ability to reproduce rapidly under optimal field conditions and attains high densities and biomass in a very short time (Raut & Barker, 2002; Tiller, 1982; Raut & Ghose, 1984) aggravates the management of this pest. Environmental conditions such as high humidity, moderate temperature and abundant rainfall favours the reproduction of *A. fulica* (Berry & Chan, 1968; Lai, Funasaky & Higa, 1982; Raut & Barker, 2002). Conversely, unfavourable environmental conditions triggers the giant African snail to aestivate (Rahman & Raut, 2010). The generalist feeding habit, its ability to aestivate and epipghram formation to withstand adverse environmental, limited predation, hermaphroditic nature and its high reproductive capacity (Roda, Nachman, Weihman, Yong Cong, & Zimmerman, 2016; Tomiyama, 1993) are significant features contributing to the pestiferous nature of *A. fulica* Bowdich.

In 1984, *A. fulica* was established on the Caribbean island of Guadeloupe, by 1988 on Martinique, and subsequently in Barbados and Saint Lucia (Raut & Barker, 2002). In October 2008, the Giant African Snail was discovered in the Republic of Trinidad and Tobago in one specific location in Trinidad only and currently numerous areas of infestations within Trinidad has been discovered both in agricultural and non-agricultural districts. It is likely given the current trend that new infestations will continue to emerge within Trinidad. Currently, in the island of Tobago the snail has not been reported, however, the risk of invasion is high given the movement of agricultural produce, commercial goods and people on a regular basis.

Metaldehyde is a popular pesticide used for the control of the giant African snail in Trinidad and world-wide. It has been reported that the extensive use of metaldehyde to combat agriculture pest creates environmental problems (Keighley et al., 2021; Saad et al., 2017; Castle et al., 2017; Kay & Grayson, 2014). The environmental problems mentioned relate to water pollution and adverse impacts to non-target organisms. Globally, many countries are concerned about the overall use of metaldehyde against pests and its inclusion into the environment which can contribute to pollution and other unfavourable conditions for habitats. The agricultural society of the United Kingdom reported that metaldehyde residues remained in the soil and polluted the ground water thereby reducing water quality and impacting consumption (Balashova, Hiscock, Reid, & Reynolds, 2021). At the end of March 2022, the UK ambassadors have taken the initiative to prohibit the use of metaldehyde in the environment as it has been determined that it is one of the major factors affecting ecological stability in the ecosystem and natural biome (Balashova et al., 2021). The containment of metaldehyde or other potential chemicals to control the giant African snail would prevent contamination to the environment.

Drowning slugs or snails for several days in a covered bucket filled with soapy water or a 15% solution of salt water is a convenient and safe way to kill slugs and snails (Hollingsworth, Howe, & Jarvi, 2013). The Ministry of Agriculture in Trinidad and Tobago recommends the dissolving 546 g sodium chloride in 4 liters of water for effectively drowning the snail which would have been collected using the hand picking method of population management. As a result of the environmental risk posed by the use of metaldehyde, the use traps can provide an effective approach for the management of the giant African snails in an infested area. The use of traps with suitable liquids can be used with attractive food lures to immobilize the snail within a containment vessel.

The current study investigates the use of several treatments: sodium chloride, copper sulphate, calcium hydroxide on the immobilization effectiveness and drowning as an approach to effectively contain and exterminate the giant African snail. The study also examined the dry treatment application on the snails to determined immobilization and mortality effectiveness. It is envisaged from the current study that the most effective solution can be incorporated into a design element for an effective trap for the management of the giant African snail. Additionally, the retention of the liquid within a trap will enable the environmentally safe disposal of the liquid contained in the trap which was used to manage the snail population.

2. Methods

A total of fourteen hundred (1400) snails with an average weight of fourteen (14) grams and measuring approximately 4.5 cm in length were collected from a farming community in Orange Grove (10°37′25″ N 61°21′11″ W), Trinidad, West Indies. This is a flat, agricultural area, with a lot of weed vegetation as well as active crop production. Active snails were collected during the rainy season but not during rainfall events. The environment from which the snails were collected had no recent treatments with any mollusicide to ensure that the snails were not impaired. The treatments used in the study were 5 g sodium chloride, 10 g sodium chloride, 5 g copper sulphate, 10 g copper sulphate, 5 g calcium hydroxide, 10 g calcium hydroxide and distilled water at room temperature.

In the first phase (wet treatments) of this study, a total of seven hundred (700) snails were investigated in solution submergence. As such, each treatment was dissolved in 1000 ml of distilled water at room temperature using a transparent glass vessel with a capacity of 2000 ml. The vessel was open at the top to enable the snails to escape. The treatment with only distilled water was used as a control. A total of ten (10) snails were submerged into each treatment and this was replicated ten (10) times. Once the snails were introduced into each treatment, the vessel was placed into a well-ventilated covered plastic container measuring 55 cm long × 40 cm wide × 25 cm high to contain any escaped snails from the submersion vessel. The behaviour and immobilization effect of the snails for each solution was observed and recorded during and after submersion.

In the second phase (dry treatments) of this study, a total of seven hundred (700) snails were investigated using dry treatment applications of 5 g sodium chloride, 10 g sodium chloride, 5 g copper sulphate, 10 g copper sulphate, 5 g calcium hydroxide and 10 g calcium hydroxide. A total of ten (10) snails was placed on a ceramic plate with an area of approximately 530 cm^2 and each plate was then placed into the ventilated plastic container. Each treatment was evenly sprinkled over the snails contained within the area and observed. Each dry treatment was replicated ten (10) times. A control of "no treatment" was included and comprised of ten (10) snails replicated ten (10) times. The behaviour and immobility of the snails was determined by their movement out of the treatment area as defined by the area of the ceramic plate.

The mortality of all the snails in both the wet and dry treatment phases of this study was determined after 6 hours. The mortality was determined by holding the snail and prodding the foot with a dissecting probe for approximately 15 seconds, a lack of motor response was considered evidence of mortality (Ciomperlik et al., 2013). The moribund snails or those showing minor motor response reactions, were not considered dead. The percent immobilization and mortality was calculated as the number of snails immobilized or killed divided by 100, then multiplied by 100. Contemporary research in crop protection involves experimentation on live organisms. While most countries have ethical standards regarding the use of animals for scientific purposes, experiments involving insects are not included in these standards (Freelance, 2019). There were no ethical standards for the use of the giant African snail in pesticide studies.

3. Results

3.1 Wet Treatment Immobilization and Mortality Effects

The snails upon submersion into all solutions except the sodium chloride solution and the control treatment responded initially by immediately retracting tightly into their shells coupled with the secretion of copious amounts of thick mucus. The snails remained immobilized and tightly retracted into their shells while in submersion for six (6) hours under observation. The body of the snails in the sodium chloride solution treatment within one (1) minute of submersion were all complete extended out of their shells and were beginning to energetically climb out of the solution. A similar response was observed for the distilled water. It is noted that submersion into the sodium chloride treatments and the water did not stimulate mucus secretion and the snails actively climbed out of the solution. Calcium hydroxide and copper sulphate at 5 g and 10 g respectively were highly effective at immobilizing the snails in solution. Table 1 summaries the percentage of immobilization and mortality for each treatment effect.

Table 1. Percentage snail immobilization and mortality for each wet treatment

Wet Treatment (1000 ml distilled water)	Percentage Immobilization	Percentage Mortality
Sodium Chloride (5 g)	0	0
Sodium Chloride (10 g)	0	0
Copper Sulphate (5 g)	100	100
Copper Sulphate (10 g)	100	100
Calcium Hydroxide (5 g)	100	100
Calcium Hydroxide (10 g)	100	100
Distilled Water	0	0

3.2 Dry Treatment Immobilization and Mortality Effects

There was no effect of treatment on the immobilization of the snails or on mortality effects for each dry treatment application. The snails in each replicate treatment group moved from within the treatment area and was observed to be active after six (6) hours post-treatment. There were no visible indications of stress on the snails attributed to the dry treatment applications.

4. Discussion and Conclusion

The study presented the immobilisation and mortality effects of wet and dry selected chemical treatments on the giant African snail. The use of calcium hydroxide and copper sulphate in quantities as low as 5 g and 10 g respectively in 1000 ml immobilized and eliminated the snail after six (6) hours in the respective solutions. Comparatively, the dry treatment application on all replicate groups did not have an effect on the snails. The solution was effective since there was direct contact through the aperture of the shell. In the dry application, there was little contact exposure through the aperture to elicit an immobilization and mortality effect for the quantities used. In essence, there was greater contact effectiveness for the wet treatment compared to the dry treatment for the same effective quantities that caused immobilization and mortality. The snails' mortality responsiveness to calcium hydroxide and copper sulphate in solution may be attributed to the secretion of copious amounts of thick mucus from the body of the snail and also from asphyxiation attributed to drowning. It should be noted that copper sulphate has been used as a regulated molluscicide in Australian rice crops (Stevens, Doran, & Mo, 2014). Additionally, the use of calcium hydroxide as a molluscicide was reported by Clearwater, Hickey, and Martin (2008), and Noatch and Whitledge (2011) for aquatic snails. In both these scenarios, the environment was exposed to these chemicals.

Several studies (Coleman, Dreyer, & MacDonald, 2011; Roda et al., 2018; Minnot, Jagroo, & Ramdwar, 2018) have demonstrated the use of traps for the control of the giant African snail. Albeit, concentrated sodium chloride solution has been used as an effective method for controlling snails by dehydration effects and drowning, the current study demonstrated the effectiveness of low quantities of calcium hydroxide and copper sulphate which can be used in potential snail traps. Although, both calcium hydroxide and copper sulphate was effective for the immobilization and mortality effects of the snails, calcium hydroxide would be the recommended solution given its low toxicological profile compared to copper sulphate.

The use of metaldehyde as a bait and in other pesticide formulations has significant negative consequences to the environment (Castle et al., 2017). As such, there is a need for safer approaches to control the giant African snail. The use of safer chemical alternatives which can be contained within a trap design to prevent environmental issues can be useful. The inclusion of low cost solutions like calcium hydroxide could support the development of trap designs that would eliminate the one-way door design and permit multiple entry routes into the trap. The trap design would also require the use of food baits or synthetic attractants since it is envisaged that calcium hydroxide alone would not attract the snails into the traps.

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