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Pest Management

Suitability of containerized toxicant to control *Solenopsis invicta* (Hymenoptera: Formicidae) threatening cave species in Bexar County, Texas

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Several protected troglobitic invertebrate species are known to occur in caves on Joint Base San Antonio—Camp Bullis, Bexar County, Texas, United States. The United States Fish and Wildlife Service (USFWS) identified red-imported fire ant *Solenopsis invicta* (hereafter RIFA) (Buren 1972) as the primary threat to cave species' nutrient sources, cave crickets, *Ceuthophilus secretus* (Scudder 1894). Per the service's recommendations, Joint Base San Antonio—Camp Bullis currently implements boiling water mound injections with digging for RIFA control. However, treatment effectiveness is highly variable and largely dependent on the time of day, weather, and personnel diligence. Toxicants have been used for RIFA treatment throughout the world, but concerns exist that traditional applications of toxicant bait around caves might be accessible and inadvertently affect nontarget arthropods, including cricket populations. To mitigate this accessibility, physically limiting access to the toxicant from crickets may be an option. Our objectives were to (i) compare and evaluate the effectiveness of Amdro (Hydramethylnon) and Advion (Indoxacarb) granular baits housed in Ants-No-More Bait Stations (Kness MFG. Inc., Albia, IA) and (ii) evaluate the distance of effectiveness of each bait within a bait station. Ultimately, we observed a 98% reduction in RIFA mound abundance from both baits. Additionally, RIFA mounds within 10 m of the containerized toxicant were reduced by 70%. Our pilot study suggested that Ants-No-More Bait Stations are an effective way to reduce RIFA mounds by 70% if placed 10 m from each other. In practice, this could include bait stations completely covering a particular distance to a cave entrance or fewer bait stations in a ring barrier at a single radial distance to a cave entrance. Containerized toxicants may be a cost-effective and safe RIFA control option around protected cave environments, but further studies are needed to determine potential effects on nontarget arthropods, optimal bait station configuration, and potential effects of biomagnification.

Key words: Joint Base San Antonio, red-imported fire ant, cave cricket, toxicant, bait station

Introduction

Red-imported fire ants (RIFA) are an exotic invasive species that can affect native wildlife either through direct predation or indirectly by reducing critical food sources. On JBSA-BUL, RIFA poses a risk to the 32 caves and karst features with federally-listed endangered cave-obligate species, *Rhadine exilis* (Reddell 1966), *Rhadine infernalis* (Barr and Lawrence 1960), and *Cicurina madla* (Gertsch 1992). These cave-obligate species rely on cave crickets (*Ceuthophilus* sp.) to provide crucial nutrients to the oligotrophic cave ecosystem both directly (e.g., consumption of the cricket, their eggs, or feces) and indirectly (e.g., feeding on species) that consume bacteria and fungi decomposing cave cricket guano (Taylor et al. 2007). Cave crickets can provide these additional nutrients because they leave the cave to forage, where they must both compete for resources and are vulnerable to attacks from RIFA. Studies have found that the success of listed cave invertebrates and other nonlisted invertebrates correlates with cave cricket density and minimizing RIFA near cave entrances (Lavoie et al. 2007).

Previously, the United States Fish and Wildlife Service (USFWS) identified RIFA as the primary threat to cave species' nutrient sources and after informal consultation with USFWS (Consultation No: 02ETAU00-2015-I-0216), JBSA-BUL conducts semiannual inspections for RIFA. This includes counts of all mounds within 50 m (~164 feet) of each cave entrance to ensure RIFA mound density is below the recommended threshold (80 mounds within 50 m). Per USFWS recommendations, mounds are treated with boiling water and soap to kill ants if RIFA mound density is above the recommended threshold. Mounds are also treated anytime they are found within 10 m of the cave entrance.

Previous studies estimated that boiling water injection (which includes adding soap as a desiccant) is approximately 60% effective for killing a mound by destroying the reproductive queen (Drees et al. 2016). However, treatment effectiveness is highly variable and largely dependent on the time of day, weather, and personnel diligence. While hot water injection is a means of selectively treating RIFA without the potential negative side effects of toxicants, there are also key disadvantages. This management technique is labor-intensive, an occupational hazard (e.g., employing boiling water), destroys surrounding vegetation, and may promote multi-queen colony fragmentation (Drees et al. 2016). Multi-queen (polygyne) colonies are socially connected to other colonies in the area, and due to this nonaggressive behavior with neighboring colonies, the number of multi-queen colonies can exceed 500 mounds per hectare and pose significantly greater control, safety, and health concerns than single queen (monogyne) variants (Vinson and Sorenson 1986, Macom and Porter 1996).

An alternative management technique for RIFA control includes the use of toxicant baits. These are typically protein- or soy-based granules that use pheromones and other semiochemicals to encourage worker RIFA to locate the bait and return it to the colony for mound eradication. However, concerns exist about the labeled directions for broadcast applications around caves. It is unknown if loose bait might inadvertently affect cave cricket populations as bait would be readily accessible when they leave the cave to forage. Containerized bait could selectively be placed in target areas, therefore, maximizing exposure to ants while minimizing access to nontarget species (e.g., cave crickets) and habitats. The containment system would also limit bait exposure to ultraviolet (UV) light, allowing for ongoing RIFA management while only requiring infrequent checks to ensure proper installation and bait availability. Precision-based containerized bait release and dispersal technology have been demonstrated to provide effective big-headed ant, *Pheidole megacephala* (Fabricius 1793) eradication (Taniguchi et al. 2003, Gaigher et al. 2012) but literature testing the effectiveness with RIFA is lacking.

The goal of this pilot study was to test if containerized bait-based ant toxicants could provide effective RIFA management near sensitive cave habitats on JBSA-BUL. Specifically, our objectives were to compare the effectiveness of Amdro (Hydramethylnon) and Advion (Indoxacarb) granular baits using the Ants-No-More Bait Stations (Kness MFG. Inc., Albia, IA; Fig. 1); determine the distance of effectiveness of bait stations; and consider how this setup could most safely and effectively be incorporated for more efficient RIFA management near caves on JBSA-BUL.

Study Site

This study was conducted at JBSA-BUL (29°37′19″N, −98°34;20″W; 11,286 ha), just north of San Antonio at the cross-section of the Edward's Plateau, South Texas Plains, and the Blackland Prairie ecoregions of Texas (Gould 1975). This site has a limestone and karst geology that includes areas of both plains and rolling hills. Typical vegetation includes pockets of mixed-grass prairie, mowed landscapes, and dense stands of Ashe juniper, *Juniperus ashei* (Buchholz 1930), live oak, *Quercus virginiana* [and Texas oak (*Quercus fusiformis*)]. The normal mean temperature ranges from 10 °C in January to a high of 29 °C in July. Annual rainfall averages 84.6 cm (U.S. Climate Data 2016).

Fig. 1. Ants-No-More Bait Station includes a covered cup to hold bait and a porous stalk where the bait is available to foraging RIFA.

Methods

Toxicant Effectiveness

To first study toxicant effectiveness, we established a testing area (72 m × 40 m) with known RIFA activity but away from any cave entrances and karst features. The test area was divided into a randomized block design to include 45 adjacent 8 m × 8 m plots. Each plot was randomly assigned to 1 of 3 treatments, totaling 15 replicates each: containerized Amdro, containerized Advion, or a control plot with no toxicant (Fig. 2). For plots with toxicants, we filled the central vertical tube of Ants-No-More Bait Stations with the assigned toxicant (approximately 28 g) and embedded the spike at the center of the assigned plot. We inspected all plots weekly for active mound abundance and refilled bait as needed. Mounds were defined as active if RIFA could be seen on or near the mound after gentle stomping next to the mound. If no ants were seen, the mound was defined as inactive. After 3 weeks of inactivity, the mound was excavated with a shovel to ensure inactivity and to officially declare the colony dead. Differences in live mound abundance in the Amdro, Advion, and control plots were described using simple statistics and tested using the Kruskal–Wallis test with a χ^2 approximation at 1, 9, and 16 wk.

Range of Effectiveness

To determine the range of effectiveness for Ants-No-More Bait Stations, 5 circular plots (10 m radius) were established in an

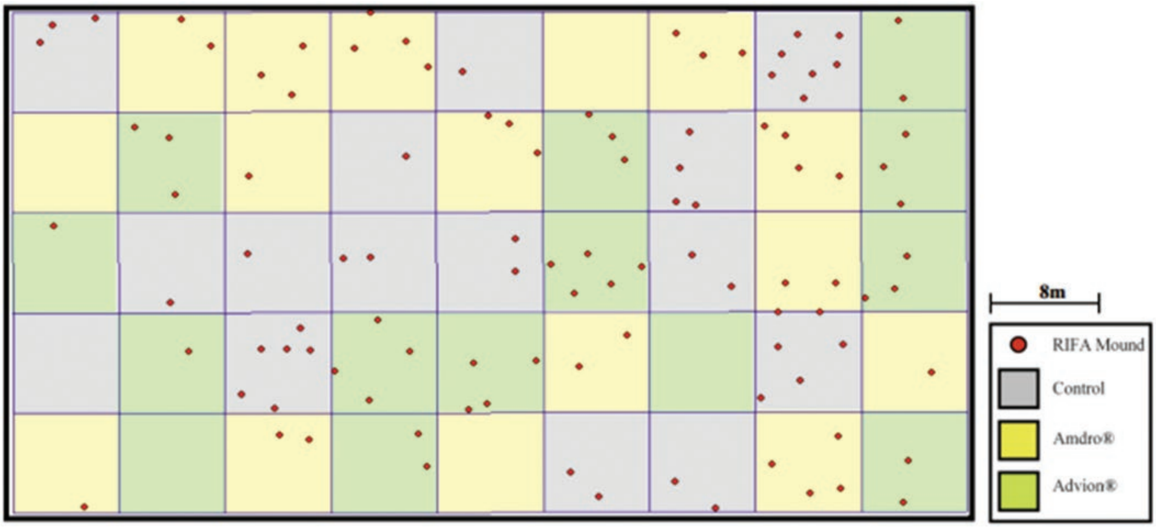

Fig. 2. Grid showing the distribution of 8 m × 8 m plots displaying assignment (i.e., Amdro, Advion, Control) and distribution of RIFA mounds at week 0.

adjacent area with RIFA away from any cave entrances and karst features. Two circular plots had Ants-No-More Bait Stations with Amdro, 2 circular plots had bait stations with Advion, and 1 circular plot was a control (Fig. 3). For plots with toxicants, we filled the central vertical tube of Ants-No-More Bait Stations with the assigned toxicant (approximately 28 g) and embedded the spike at the center of the assigned plot. Similarly, plots were inspected weekly for mound abundance using the same perturbation methodology, we measured mound distance to the bait station, and bait was refilled, as needed. Similarly, differences in live mound abundance in the Amdro, Advion, and control plots were described using simple statistics and tested using the Kruskal–Wallis test with a χ^2 approximation at 1, 4, and 6 wk.

Results

Toxicant Effectiveness

We studied toxicant effectiveness for 16 wk from 6 April 2021 to 29 July 2021. There were noticeable decreases in the number of RIFA mounds within the first 3 wk with a steady increase in the percentage of mounds declared dead in both treatments and control plots. Mounds within the treated zones were declared dead at a higher percentage than in the control zones with over 90% of mounds within the treated areas declared dead by week 7 (Fig. 4). There was a resurgence of live mound abundance following hard rains on week 7 (Fig. 4). The number of live mounds at the 2 treatments and control plots were not statistically different at zero wk (χ^2 = 0.310; P = 0.856), 8 wk (χ^2 = 4.397; P = 0.111), or 16 wk (χ^2 = 0.728; P = 0.695).

Range of Effectiveness

We studied the range of bait effectiveness over 6 wk from 6 September 2021 to 2 November 2021. There was a visible decrease in mounds within 10 m from the containerized bait for both toxicants (Table 1). The number of active mounds at the 2 treatments and control circles was not statistically different at 0 wk (χ^2 = 2.4; P = 0.301), 4 wk (χ^2 = 3.0; P = 0.223), or 6 wk (χ^2 = 2.0; P = 0.368). Caution should be used when interpreting these statistical results due to the small sample size. Within 6 m from the bait station, both treatments decreased the number of RIFA colonies by 80% or higher. From 6 to 10 m, both treatments showed an approximately 60% reduction. Control saw a maximum of 27% reduction throughout the trial period at any distance (Table 2).

Discussion

The goal of this project was to determine the viability of containerized bait toxicants for RIFA control near sensitive caves. This method has the potential to streamline management compared to the more labor-intensive and potentially dangerous hot water injection. While there are limits to the conclusions we can draw based on our pilot study design, our results showed that containerized Amdro and Advion in Ants-No-More Bait Stations, rather than the standard broadcast method, both decreased the number of active RIFA mounds with plots. This suggests that RIFA were able to find the containerized toxicant and successfully transport it back to their colonies before it was rendered ineffective by rain, UV light exposure, or heat.

In the toxicant effectiveness portion of this study, the total number of RIFA mounds similarly decreased in both Amdro and Advion plots. This suggests that either toxicant could be considered for further studies without sacrificing effectiveness. The control plots also experienced a large decline in mound abundance despite not having a toxicant within the plot. This is likely a result of mounds in control plots foraging in adjacent toxicant plots. Utilizing larger treatment blocks should be considered when performing another similar study.

Based on our results in the range of effectiveness portion of this study, full coverage of the 50 m radius management area around a cave with bait stations no more than 10 m apart (e.g., therefore maintaining the 70% reduction of RIFA mounds), we would need to place 18 stations around the cave (Fig. 5). Full coverage may not be ideal as bait would be nearer to caves and we still need to study the effects of bait exposure to nontarget species (e.g., native arthropods, raccoons, white-tailed deer) and water sources near caves. Additionally, holes in the station are large enough that some arthropods, beyond RIFA, can still access the toxicant (e.g., cave cricket nymphs). Modifications to the bait stations (e.g., smaller holes) may be useful in further limiting the direct contact with nontarget arthropods. The effects to nontarget species were not explored in this study.

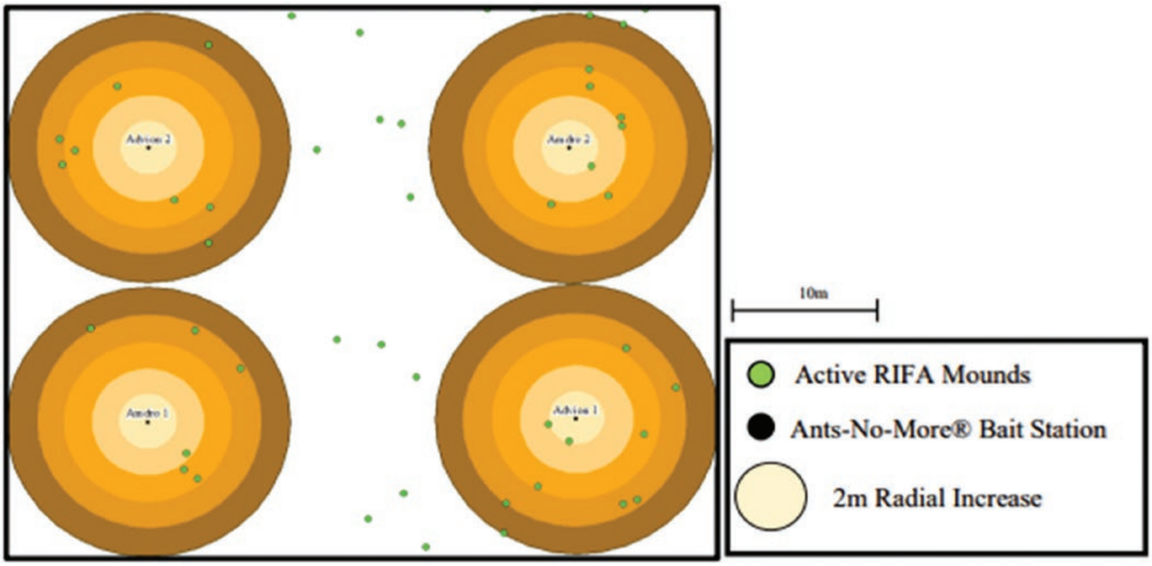

Fig. 3. Distribution of 10 m radius circular plots displaying 2 m radial increase and distribution of RIFA mounds at week 0.

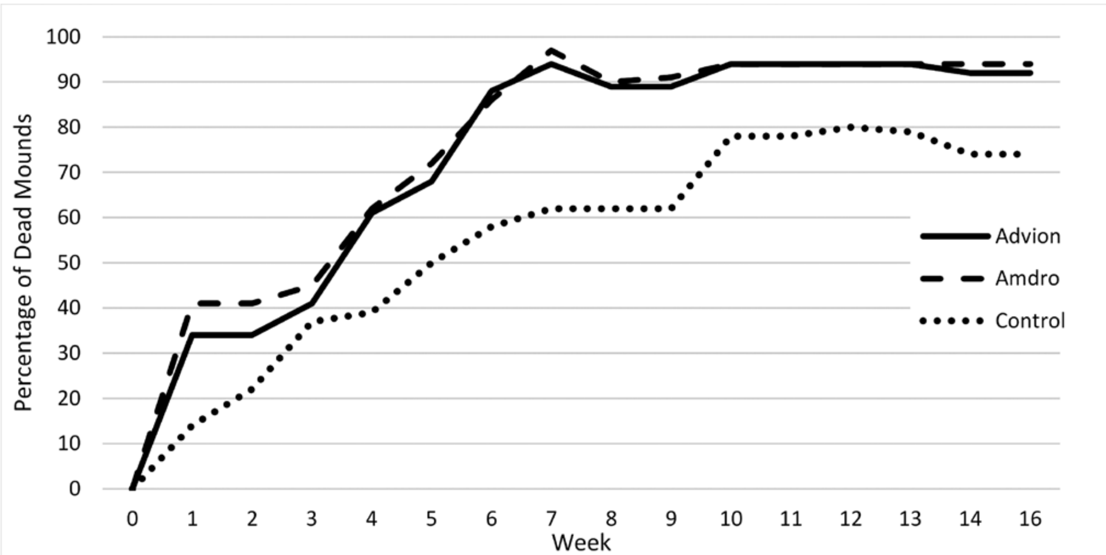

Fig. 4. Changes in the percentage of dead RIFA mounds for Advion, Amdro, and control 8 m × 8 m square plots.

Table 1. Percent mound decrease in 10 m circular plots treated with either Amdro, Advion, or control on Joint Base San Antonio—Camp Bullis, 2021

	Week 1 (%)	Week 4 (%)	Week 6 (%)
Amdro	42	75	67
Advion	40	71	71
Control	25	10	27

To reduce the number of stations deployed and the risk to nontarget species, a 'barrier' of the containerized toxicant that circles around the cave could be created to guard against encroaching RIFA mounds (Fig. 5). Circling bait stations in a 40 m radius from the cave would still control 70% of RIFA mounds within 10 m of each station. This distance between a cave entrance and containerized bait would also limit cave cricket nymph exposure to the bait as 75% of a cave's cave cricket nymphs do not forage beyond 40 m of a cave entrance (Taylor et al. 2005). This would also likely inhibit new RIFA populations from encroaching the managed 50 m radius from the cave entrance. Additionally, this barrier method (toxicants at a 40 m radius) with hot water injection (within a 50 m radius) around a cave entrance would represent a two-step management approach. Adding diversity to management will likely increase and prolong overall RIFA management effectiveness while increasing overall applicator efficiency and safety.

While this pilot study's results suggest there are ways to incorporate containerized bait for RIFA control, there are additional questions that need to be answered before this method is widely employed near caves or any other sensitive habitat. As discussed above, more detailed surveys are needed to test the effectiveness and efficiency of the proposed barrier method and quantify exposure to nontarget species, including cave crickets. Additionally, studies are also needed to better understand the potential for toxicant biomagnification through the consumption of baited animals.

Table 2. Percent dead or inactive mounds in 10 m circular plots treated with either Amdro, Advion, or control on Joint Base San Antonio—Camp Bullis, 2021

	Week								
	0	1	2	3	4	5	6	7[a]	8
Advion <6 m	0%	67%	66%	66%	75%	80%	83%	–	83%
Amdro <6 m	0%	29%	29%	71%	86%	67%	80%	–	80%
Advion 6–10 m	0%	29%	29%	25%	70%	72%	58%	–	67%
Amdro 6–10 m	0%	40%	20%	40%	60%	60%	60%	–	40%
Control <10 m	0%	25%	25%	25%	10%	21%	27%	–	27%

[a]Data was not collected.

Fig. 5. Full coverage (left) and barrier method (right) for distribution of containerized bait stations with 10 m treatment extent around a central cave.

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Author Contributions

Mathew Kramm (Conceptualization [Lead], Investigation [Lead], Project administration [Lead], Supervision [Lead], Writing – original draft [Lead], Writing – review & editing [Equal]), Jacob Lampman (Conceptualization [Equal], Investigation [Equal], Project administration [Equal], Supervision [Equal], Writing – review & editing [Equal]), Daniel Jackson (Data curation [Equal], Investigation [Equal], Methodology [Equal], Writing – review & editing [Equal]), Andrea Montalvo (Project administration [Equal], Validation [Equal], Writing – review & editing [Equal]), and Roel Lopez (Conceptualization [Lead], Methodology [Lead], Project administration [Lead], Resources [Lead], Supervision [Lead])

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