Anthraquinone as a Vole Repellent: Not Just for the Birds?

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ABSTRACT: California voles cause extensive damage to tree crops through girdling of young stems. Recent laboratory trials have indicated substantial repellency (up to 84%) of anthraquinone (a post-ingestive repellent) to voles on treated grain. Given these lab results, we established a field study to test the efficacy of anthraquinone applications to tree stems to reduce girdling damage from voles. We also assessed the impact of vegetation around the base of trees to determine the impact of cover on girdling activity. In Fresno County, CA, during summer 2016 and spring 2017, we established twenty 3.35 × 2.44-m bins (hereafter mesocosms) where we evenly spaced eight 1-yr-old clementine orange trees. Cover crops including various grasses and forbs were planted on randomly-selected halves of each mesocosm. All trees were treated with anthraquinone in half of the mesocosms; trees were left untreated in the remaining half. We captured 40 voles and released two individuals into each mesocosm and tracked girdling damage once weekly for five weeks during summer and six weeks during spring. We observed a significant reduction in girdling damage on anthraquinone-treated trees. The removal of vegetation around the base of trees completely eliminated girdling damage for anthraquinone-treated trees during summer, although vegetation did not significantly impact damage for untreated trees during summer, nor for either anthraquinone-treated or untreated trees during spring. We did not observe an increase in damage over time in anthraquinone-treated mesocosms, indicating that anthraquinone maintained its repellency during the duration of this study. Anthraquinone appears to be highly repellent to voles, and it is worthy of field study in other mammalian species as well.

KEY WORDS: anthraquinone, girdling, *Microtus californicus*, repellent, vegetation management, vole

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INTRODUCTION

Voles cause extensive damage to a variety of tree (4.2-4.4% loss in revenue) and vine crops (2.9% loss in revenue) through girdling activities (Baldwin et al. 2014). Generally, an integrated pest management (IPM) approach is recommended for minimizing vole damage in these cropping systems. A variety of tools could be incorporated into such an IPM approach including exclusion, habitat modification, and rodenticide application. The use of plastic tree protectors is considered one tool for reducing girdling damage from voles, but their effective use generally requires burying the base of the protector to reduce the likelihood of voles burrowing underneath and around the protector (Davies and Pepper 1989, Marsh et al. 1990). The cost of the protectors, combined with the extensive labor required to cover all the stems in a given area, often renders this approach too costly unless vole damage is quite substantial. The removal of vegetation for 0.6-1.2 m from around the base of stems is another tool used to minimize vole damage (Holm et al. 1959, Davies and Pepper 1989, Sullivan et al. 1998, Merwin et al. 1999). These denuded areas leave voles susceptible to predation if they linger, ultimately lowering vole damage in some settings (Witmer et al. 2009). Rodenticide applications are often used when vole populations reach high densities; they are often considered the most effective management tool in these situations (Baldwin et al. 2014). However, rodenticides can only be applied during the dormant season in tree and vine crops. This eliminates their use for the entire growing season. Furthermore, for citrus crops, there is no dormant season; fruit is present on the tree for the entire year. This leaves few effective management options in citrus crops when vole numbers surge.

Chemical repellents are another potential tool that could be considered for inclusion into a vole IPM program. Historically, repellents have not proven overly effective for field application against voles (Merwin et al. 1999, Hansen et al. 2016). However, recent laboratory testing of anthraquinone indicated that even low concentrations of this chemical were effective at reducing grain consumption by California voles (*Microtus californicus*; Werner et al. 2016). Furthermore, anthraquinone has proven effective as a bird repellent (e.g., Dolbeer et al. 1998, Werner et al. 2014, Werner et al. 2015). Anthraquinone is a post-ingestive product that causes animals that consume the product to become ill, thereby making it less likely that the animal will consume the product again during a subsequent feeding event. This kind of repellent is ideally suited for stem application given that the repellent can easily be applied to the portion likely to be consumed by the vole. If effective, minimal girdling damage should be observed. A repellent application also has the added advantage in that it can easily be paired with vegetation management to hopefully further reduce girdling damage when compared to using either one of these approaches alone. Therefore, we set up a study to test the potential impact that a combination of vegetation management and anthraquinone applications would have on girdling damage by voles to young citrus trees. We also tested the longevity of anthraquinone to determine if long-term repellency following field application was likely. We tested this impact during both spring (characterized by a cool-wet weather pattern) and summer (characterized by a hot-dry weather pattern) seasons to determine if weather impacted potential girdling damage. This publication serves as an extended abstract for a more comprehensive journal article found in the Journal of Pest Science. Please see (Baldwin et al. 2018) for greater detail on this study.

METHODS

For this study, we used a mesocosm approach, where trees and voles were housed within 20 3.3 m × 2.1 m tubs that were 1.2 m deep. A sandy substrate filled approximately half of each tub (i.e., 0.6 m in depth). The tubs were located at the Kearney Agricultural Research and Extension Center near Parlier, CA. During summer 2016, eight clementine citrus trees were planted per tub, with trees spaced approximately 0.46 m apart. A cover crop was planted on one half of each tub to provide cover and food for voles. The cover crop was allowed to establish before voles were released into the mesocosms. All trees in half of the mesocosms were treated with anthraquinone along the bottom 15 to 20 cm of the trunks. Trees in the other mesocosms were left untreated. Voles were captured in several locations throughout California, with two released per mesocosm. Vole girdling damage was monitored weekly for five weeks. This same process was then repeated during spring 2017, although voles were monitored for six weeks instead of five during this season, and anthraquinone applications were extended to 30 cm up the stem of the tree. Please see Baldwin et al. (2018) for additional details on study design.

RESULTS

Anthraquinone proved highly effective as a repellent during both seasons (>90% reduction in girdling damage). When combined with anthraquinone treatments, the removal of vegetation completely eliminated all girdling damage during summer, but vegetation removal in the absence of an anthraquinone application had less effect on girdling damage (31% reduction). During spring, we observed no impact of vegetation management regardless of the presence (1% more girdling damage for sites without vegetation) or absence (14% more girdling damage for sites without vegetation) of anthraquinone. We observed substantial longevity associated with anthraquinone treatments, with no increase in girdling damage observed after five and six weeks during summer and spring, respectively. Please see Baldwin et al. (2018) for additional details on the results of this study.

DISCUSSION

This study collectively illustrated substantial vole repellency for anthraquinone applications to stems, with this repellency likely to last for at least two months and potentially much longer. The impact of vegetation management is less clear, although we did observe some added benefit of pairing vegetation management with anthraquinone treatments during summer. The inclusion of vegetation management with anthraquinone applications is likely warranted given our understanding of the need for multiple management strategies to maintain the long-term effectiveness of rodent management programs (Engeman and Witmer 2000, Baldwin et al. 2014). We recommend further investigation into the potential utility of anthraquinone as a repellent for other mammalian species given our findings and those of Werner et al. (2016).

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