Developing and Implementing an Effective Management Plan for Roof Rats in Citrus Orchards

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ABSTRACT: Roof rats are an invasive rodent that can cause substantial damage in citrus orchards. Their populations appear to be expanding throughout California, yet little is known about efficacious, cost-effective strategies to manage this invasive pest while minimizing pesticide use. Therefore, we developed two Integrated Pest Management (IPM) programs based on results of recent studies that incorporated observations of roof rat movement patterns, compared monitoring tools, and tested trapping and baiting options. Both IPM programs utilized elevated bait stations containing 0.005% diphacinone-treated oats and trapping, and we compared those programs to a bait-station only approach to determine which strategies were most practical. Initial IPM plots included a combination of elevated bait stations followed by a brief snap-trapping program and a longer-duration trapping program with Goodnature® A24 traps to hopefully keep rat numbers at low levels (Trial 1). Although initial bait applications were effective at reducing rat numbers, populations quickly rebounded within both the bait station only and IPM treatment areas within two-months following the completion of the baiting programs. Additionally, costs for this initial IPM approach were almost five times as much as a bait station approach. Our second IPM strategy (Trial 2) again incorporated an initial bait application period to knock down roof rat populations, followed by the use of trapping tunnels that contained two snap traps to further reduce/maintain rat numbers longer-term. We again observed effective knockdown with bait applications. However, in contrast to Trial 1, we observed substantial success with trapping tunnels at maintaining, and even increasing, overall efficacy within IPM plots, and IPM plots were always more efficacious than bait station only plots. Although the bait station only approach was less costly than the IPM approach used in Trial 2, the cost disparity was substantially less than that for Trial 1, and the cost difference disappeared during subsequent years, indicating long-term cost-effectiveness of this IPM approach. Collectively, the relatively low cost and high efficacy of a management program that incorporates initial bait applications to knock down roof rat populations, followed by a long-term snap-trapping program to maintain low densities, should provide an effective strategy for managing roof rats in citrus orchards.

KEY WORDS: bait station, citrus, diphacinone, Goodnature A24 trap, home range, Integrated Pest Management, population index, *Rattus rattus*, roof rat, snap trap

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INTRODUCTION

Citrus is an important commodity in California, with revenues >$2.2 billion in 2022–2023 (CDFA 2023). A common vertebrate pest in citrus is the roof rat (*Rattus rattus*), where they can cause substantial losses through girdling damage, consumption of fruit, damage to irrigation infrastructure, and by posing as a food safety risk (Worth 1950, Tobin 1992, White et al. 1998, Yabe 1998, Dongol et al. 2021). Since 2020, we have been researching how to effectively manage roof rats in citrus. In the following sections, we highlight some of the findings of these research projects, and we provide a strategy that should provide efficacious and cost-effective management solutions for this invasive vertebrate pest in citrus.

MONITORING

Effective management of rodent pests requires practical monitoring tools to detect increases in rodent numbers over time, as well as to determine how effective applied management actions are. We tested a strategy that used systematically placed tracking tunnels (Black Trakka, Gotcha Traps, Warkworth, NZ; and Pest Control Research LP, Christchurch, NZ) that contained a tracking card and ink pad to detect roof rat presence throughout orchards (tunnels tied to a board placed 0.7-1.6 m up in tree). Tracking tunnels were baited with a soft bait packet (Liphatech Rat and Mouse Attractant™, Liphatech, Inc., Milwaukee, WI). When a rat visits the tunnel, it leaves ink footprints on the tracking card. We also used remote-triggered cameras (Bushnell NatureView HD Max cameras, Bushnell Outdoor Products, Overland Park, KS) to detect visitations by roof rats to an attractant (Liphatech Rat and Mouse Attractant™), with the cameras and attractants placed 0.7-1.6 m up in the trees. We determined that one tracking tunnel approximately every 70 m yielded an accurate estimate of current roof rat activity (as determined by comparisons of index values to both minimum number known alive and mark-recapture estimates). Please see Baldwin and Meinerz (2022) for additional details.

As noted, a lure helps to draw rats into the tracking tunnel. We tested several options including peanut butter, Liphatech Rat and Mouse Attractant™, and Liphatech NoTox™ wax blocks and found that all were equally effective. Given the ready availability and cheaper cost associated with peanut butter, it may be preferred by some, although the pre-packaged nature of the other attractants could make them desirable by users as well. Further details on this study can be found in Wales et al. (2021).

ACTIVITY PATTERNS

Prior to our studies, little was known about roof rat movements in citrus orchards. Such knowledge is important to determine where to target management strategies, to understand ideal spacing between traps, bait stations, and monitoring devices, and to assess when roof rats were active in the orchards (Whisson et al. 2004, Baldwin et al. 2014a). To understand movement patterns in roof rats, we deployed a unique tracking system that used cellular technology to identify locations every few seconds (Cellular Tracking Technologies [CTT], Rio Grande, NJ). This allowed us to determine areas utilized by rats, as well as how far they moved throughout the landscape. We determined that roof rats exclusively used orchards, indicating that management efforts should be targeted within orchards rather than in adjacent habitats. We also determined that roof rats had large home ranges that averaged 2.36 ha; minimum home range size was 0.72 ha. This equated to a radius of approximately 87 m and 48 m for average and minimum-sized home ranges, respectively. This information is valuable in determining ideal spacing between traps and bait stations to guarantee rat access to at least one of these management tools within their home range.

We also used remote-triggered cameras to determine when roof rats were active within orchards. Based on photo data, roof rats were active exclusively at night, with activity often peaking around midnight. If necessary, roof rat removal efforts could be targeted exclusively at night to eliminate nontarget effects to diurnal species (i.e., those active only during the daytime), although such actions would likely be cost prohibitive. See Baldwin et al. (2024b) for additional details on activity patterns of roof rats in citrus.

TEST OF POTENTIAL MANAGEMENT TOOLS

We focused our control efforts on the use of rodenticides and trapping as the only two techniques currently available that were likely to have a substantial impact on roof rat populations within citrus orchards. Previous research indicated that the use of a 0.005% diphacinone-treated oat bait was effective at reducing roof rat populations when used in elevated bait stations within almond orchards (Baldwin et al. 2014a). However, almond and citrus orchards are very different both in the cover provided by the trees, as well as in the food sources available. As such, we needed to test this product in citrus to determine its utility.

Effective IPM programs rely on more than one technique to safely and effectively manage pests (Baldwin et al. 2014b, Witmer 2018, Taggart et al. 2024). As such, we were also interested in using trapping as an additional tool to manage roof rats. Historically, trapping in tree crops has relied on snap trapping, but snap traps are often viewed as too labor intensive for broad-scale use over large areas (Carter et al. 2016). The recent advent of the Goodnature® A24 trap had the potential to substantially reduce the amount of labor required to operate a trapping grid due to the long-lasting lure and use of a CO_2 cartridge that would allow for use for four to six months without having to relure or reset the traps (Carter et al. 2016, Shiels et al. 2022).

Regardless of the tool used, spacing between each subsequent bait station or trap was important to ensure success while minimizing cost. We originally established trapping and baiting grids where individual units were separated by approximately 76 m, which was meant to approximate the radius of an average home range size for a roof rat. However, initial testing across three separate orchards indicated that this spacing was not effective for bait stations ($\bar{x}$ efficacy = 12%), so we reduced the spacing to 50 m for the final orchard to mimic the minimum size of a roof rat home range (Baldwin et al. 2024b). This spacing resulted in much higher efficacy (77%), and we used that spacing moving forward. Likewise, we did not find the A24 trap to be effective at reducing roof rat activity across our first three study sites; in fact, we observed an increase in rat activity at these sites ($\bar{x}$ efficacy = –70%). After consultation with staff from Goodnature®, we placed a platform underneath each trap to assist the rats in pushing far enough up into the trap to activate it. This modification increased efficacy for our final site (50%), so we added this adjustment in subsequent trials. Additional details on this study can be found in Baldwin et al. (2022).

DEVELOP AND TEST IPM STRATEGIES

Taking information already learned, we developed an IPM strategy that used elevated bait stations at 50-m spacing that contained 0.005% diphacinone-treated oats to initially knock down populations. Baiting typically lasted four weeks. We followed this up with two weeks of snap trapping using trapping tunnels tied to boards and placed in trees (Tomcat® Tunnel™ Trapping System, Motomco, Windsor, WI). The trapping tunnels were targeted in areas with remaining rat activity to further reduce the population. Following completion of snap trapping, we deployed A24 traps for the remainder of a six-month period in an attempt to maintain low rat densities. We compared these results to that of a bait station-only approach (hereafter bait station) to determine which was most effective. Initial bait applications substantially reduced roof rat activity ($\bar{x}$ efficacy = 73%), but neither the IPM nor bait station approaches adequately slowed reinvasion of the study sites (two-month post bait application efficacy: bait station $\bar{x}$ = -5%, IPM $\bar{x}$ = 13%; five-month post bait application efficacy: bait station $\bar{x}$ = 24%, IPM $\bar{x}$ = 43%). As such, we developed a second IPM approach that again incorporated bait stations to knock down populations. We followed this up with a snap-trapping program, again using trapping tunnels. For this approach, we spaced the trapping tunnels in a grid pattern with the traps 75 m apart. These trapping tunnels were operated for the remainder of a six-month period. This approach was very effective, with rat activity decreasing over time (two-month post bait application efficacy: bait station $\bar{x}$ = 34%, IPM $\bar{x}$ = 88%; five-month post bait application efficacy: bait station $\bar{x}$ = 85%, IPM $\bar{x}$ = 93%). In total, we removed 97 rats via snap trapping in IPM plots (n = 4 plots) during this part of the trial, again indicating the effectiveness of this approach. For bait station plots, rats quickly rebounded two months after the completion of the baiting program, indicating that the IPM approach was more effective. Interestingly, rat populations again declined in the bait station plot for unknown reasons

(no additional bait was used for the remainder of the study), although the IPM plots were always more effective. From an efficacy perspective, the IPM program was the better approach given the importance of using multiple tools to maintain long-term efficacy of management programs (Baldwin et al. 2014b, Witmer 2018, Taggart et al. 2024). Additional details on this study can be found in Baldwin et al. (2024a).

We also collected information on the cost of these management programs to better inform which were most practical. The IPM plots that used A24 traps were by far the most expensive ($484/ha), primarily given the substantial cost associated with each trap (a minimum of $152 /trap). Given this high cost and the limited efficacy of this approach, management programs using A24 traps were deemed impractical for use in citrus orchards.

As expected, the bait station plots were the least expensive ($98/ha), but they were also less effective. Conversely, the IPM plots that relied on bait stations and trapping tunnels were more efficacious but were more expensive to operate ($171/ha). However, this cost was far more reasonable when compared to trapping programs that included A24 traps. Furthermore, the primary difference in cost between bait station plots and IPM plots that used bait stations plus snap trapping was due to the cost of the trapping tunnels. Assuming trapping tunnels could be used for several years, the cost for all subsequent years of this IPM program would essentially be the same as the bait station approach ($37-$40/ha for both). Although we have no direct quantifiable data on crop losses associated with roof rats, this IPM cost may be justifiable depending on damage. For example, assuming a price of $12 for a box of fancy lemons (115 lemons per box) or navel oranges (72 per box), then around 14 boxes of fruit would have to be saved per ha per year to justify management costs for the first year, but only around 3 boxes of fruit would need to be saved to justify expenditures for subsequent years. This price does not account for infrastructure damage associated with rats nor the potential food safety risks associated with their presence in orchards, further increasing the value of this management approach. Please see Baldwin et al. (2024a) for additional details on this project.

MANAGEMENT RECOMMENDATIONS

We recommend the following IPM strategy for managing roof rats in citrus.

1. Conduct initial monitoring using tracking tunnels to determine background roof rat activity (e.g., rat management effort could be motivated by times where rat damage is noted). A recommended tracking tunnel design for a 16-ha block of citrus is 36 tracking tunnels spaced 70 m apart in a grid. Tracking tunnels should be active for three to four consecutive nights (either will work; keep the same throughout to maintain consistency as additional nights will lead to greater tunnel visitation), and they can be baited with peanut butter or a commercial attractant (e.g., Liphatech Rat and Mouse Attractant™).
2. When roof rat management is desired (e.g., when rat damage or activity seems high based on grower-defined thresholds; no official threshold yet established), implement a baiting program (0.005% diphacinone-treated oats) using elevated bait stations. A recommended bait station design for a 16-ha block of citrus is 64 bait stations spaced 50 m apart in a grid. Check and refresh bait monthly, and operate bait stations until bait consumption is minimal.
3. Next, place trapping tunnels containing rat snap traps 75 m apart within the established grid; this will equate to 36 trapping tunnels assuming a treatment area of 16 ha. Check traps approximately every three weeks to rebait and reset as needed.
4. Lastly, to determine the effectiveness of these rat control efforts and to determine when and if retreatment with bait is required, use tracking tunnels like described in #1. We suggest operating tracking tunnels every three months to determine the status of the roof rat population. It is important to remember that extirpation of rats is not likely. As such, we recommend continuous operation of trapping tunnels. However, at a minimum, roof rats should be reduced by ≥90%, at which point snap trapping could be halted and replaced by long-term monitoring. Additional snap trapping or bait applications could then be incorporated when rat numbers begin to rebound, although, again, we recommend continuous trapping to maintain long-term suppression of roof rats given the relatively low cost of such management actions.

Following this strategy should provide efficacious, cost-effective control for this invasive rodent, while also reducing non-target exposure to diphacinone by limiting rodenticide applications only to situations where trapping is not sufficient to keep rat numbers at acceptable levels.

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