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A New Way to Control Invasive Ants

Figure 1. An Argentine ant feeds from an alginate hydrogel bead filled with toxic liquid bait.

Harnessing Hydrogels in the Battle Against Invasive Ants

Could a hydrogel baiting system solve Argentine ant problems in southern California citrus?

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Project Summary

Despite the substantial economic threat Argentine ants (AA) pose to California's citrus industry, control options that are effective, low-maintenance, target-specific and environmentally sustainable are lacking. This report describes progress made in the development and field evaluation of a hydrogel baiting system that eliminates the negative features associated with standard industry treatments for ant control while rivaling them in efficacy.

Why is Argentine Ant Control Necessary?

The southern California citrus agroecosystem provides a climatically optimal environment for the invasive[1] AA, replete with resources and devoid of natural enemies or encroaching competitor ants. Consequently, the vast majority of commercial citrus in southern California sustain heavy, persistent AA infestations (**Figure 2**).

AA cause damage by forming beneficial relationships with honeydew-producing hemipterans (HPHs – i.e., sap-sucking insects such as aphids, psyllids, mealybugs, whiteflies and scales), many of which are invasive, economically-damaging pests. Ant workers tend HPHs for the sweet, energy-rich waste they produce (honeydew) and guard their highly valued "livestock" from the natural enemy "wolves" we depend on for biological control[2] (biocontrol) (**Figure 3**; Schall and Hoddle 2017).

Figure 2. Argentine ants tend an Asian citrus psyllid colony to collect sugary honeydew.

Figure 3. An Argentine ant captures and kills a parasitoid (*Tamarixia radiata*) of the Asian citrus psyllid colony she is tending for honeydew, disrupting biocontrol.

In addition to disrupting natural enemy efficacy, ants disperse tended pests throughout groves (expanding the territory they infest), reduce pathogen incidence and spread within HPH populations by removing HPH waste and promote more rapid HPH feeding, which can increase HPH development rate, reproductive output and longevity. As a result, ants can facilitate pest HPH outbreaks, transforming groves into HPH refuges (Holway et al. 2002). The consequence is greater HPH-associated pathogen transmission, plant damage, yield loss and control costs. Consequently, ant control is a critical component of integrated pest management programs for HPH pests in citrus.

"The low (application) rate provides comparable long-term ant control with half the material, translating to significant cost savings."

The Scenario in California Citrus

Given the considerable biocontrol efforts targeting the Asian citrus psyllid (ACP), AA control should be a priority. Previously completed projects by the Hoddle lab at the University of California, Riverside (UCR) have shown that short-term AA control can improve biocontrol of ACP by its parasitoid, *Tamarixia radiata* (Milosavljević et al. 2017). Further, preliminary data from ongoing projects strongly suggest long-term ant control in commercial citrus drastically decreases infestation by ACP and other HPH pests.

Current Status of Commercial Ant Control

Despite the robust evidence that AA control improves biocontrol of several economically important citrus pests, tools to implement an ant control program and reap the associated benefits are limited. Chlorpyrifos, the industry standard insecticide for AA control, is highly toxic to natural enemies needed for HPH control. Further, contact insecticide barrier sprays repel or kill surface foragers, but have no impact on the subterranean colony. As a result, ant activity quickly rebounds (Tollerup et al. 2004). Liquid baiting programs are excellent alternative strategies that provide long-term suppression of entire AA colonies while preserving natural enemies and minimizing environmental contamination. However, the standard bait and dispenser design may not be practical for large-scale commercial operations as it is expensive and labor-intensive to maintain.

A Superior Treatment Option

Our approach to ant control capitalizes upon the proven effectiveness of liquid baiting programs while eliminating bait station set-up and maintenance, drastically improving ease of application and reducing costs. At UCR, the Mulchandani lab (Department of Chemical Engineering) and the Choe lab (Department of Entomology) have developed alginate (seaweed-based) hydrogels (**Figure 4**) that act as dispersible, biodegradable bait stations. These porous beads, each about the size of a plain M&M candy, absorb the liquid bait they are soaked in (i.e., 0.0001 percent thiamethoxam in 25 percent sucrose solution). Workers readily drink from hydrogels and transfer toxic bait to nestmates (**Figure 1**), killing entire

Figure 4. A handful of biodegradable alginate hydrogels loaded with a sugar water and low-toxicity insecticide-laced liquid bait for Argentine ant control.

colonies in laboratory experiments. Furthermore, field trials in urban residential settings indicated a reduction in AA activity by nearly 80 percent in eight weeks following two hydrogel applications (Tay et al. 2017). We conducted a preliminary field trial to determine if comparable control could be achieved in an AA-infested citrus grove and to examine hydrogel water loss and biodegradation under field conditions.

Figure 5. Monitoring techniques for Argentine ants: visual counts (top) and monitoring vials loaded with liquid sugar bait (bottom).

Field Trial Design

From July through September 2017, we conducted a small-scale field study in three citrus plots, which consisted of a 16 tree square plot (four by four trees) located within UCR's Biological Control Grove. Plots were randomly assigned one of three hydrogel application rates: high (500 grams per tree), low (250 grams per tree) or untreated control.

In the four days prior to hydrogel application, we monitored AA activity in all plots to provide a baseline of ant densities. Activity was monitored through one-minute visual counts of workers traversing tree trunks and sugar-water filled monitoring vials deployed under trees for a 24-hour period (**Figure 5**). The number of worker visits to vials was calculated from the quantity of liquid removed after correcting for evaporative loss.

After baseline monitoring, hydrogels were hand-distributed on damp soil around the base of each trunk (**Figure 6**). All 16 trees in each treated plot received an initial application and an identical follow-up application one week later. Following hydrogel application, the four innermost trees of each plot were monitored for AA activity daily over a four-week period and once per week for four weeks thereafter to determine treatment efficacy and AA rebound rate. To estimate hydrogel water loss under field conditions, subsamples of ten hydrogel beads were collected daily from all monitored trees, cleaned of debris and weighed in the lab.

Figure 6. Hydrogels were tossed in a circular transect around tree trunks, where worker ants heavily trail and forage.

Results: Water Loss and Biodegradability

Hydrogels were highly attractive to AAs, which recruited within minutes of deployment (**Figure 7**). Due to a combination of worker feeding and evaporation, hydrogels lost, on average, 86 percent of their weight one day after field deployment and 95 percent after four days (**Figure 8**). Rehydration following irrigation was limited, with hydrogels increasing in weight by 37 percent from the previous day immediately following shut-off, but losing this gain about 15 hours later. Hydrogels visually dissipated into the soil five days after treatment application, confirming their biodegradability.

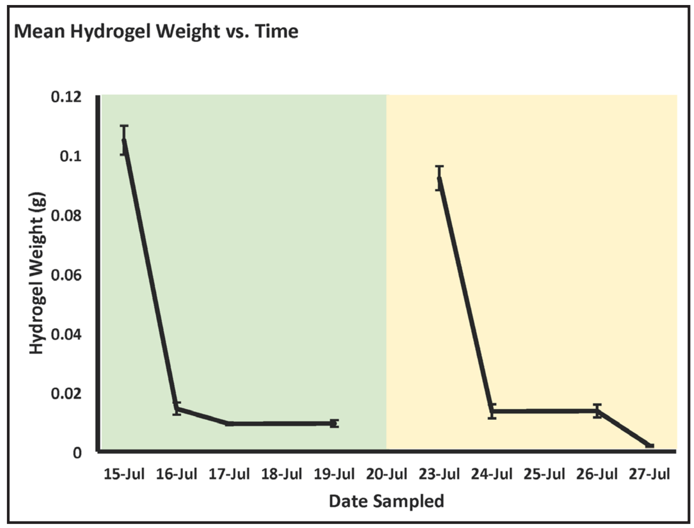
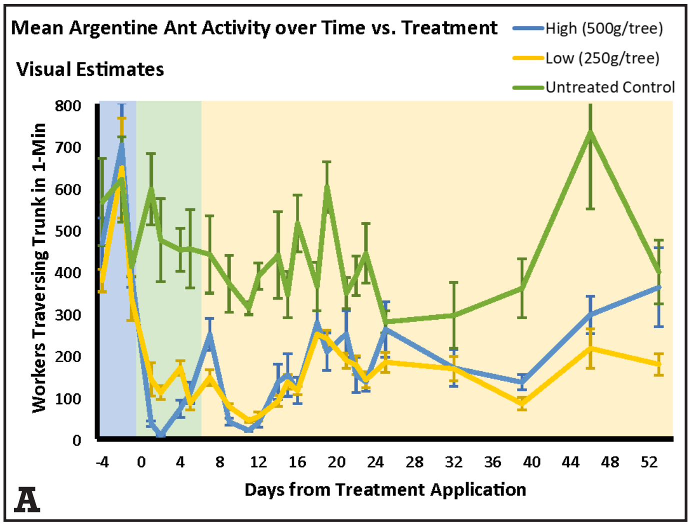


Figure 8. Average weight loss of hydrogel samples collected prior to and following each field deployment (July 15 for first application [green] and July 23 for second application [yellow]). Hydrogels lost weight (water) rapidly under summer field conditions.

Figure 7. Argentine ants swarm and begin feeding upon hydrogels soon after deployment.



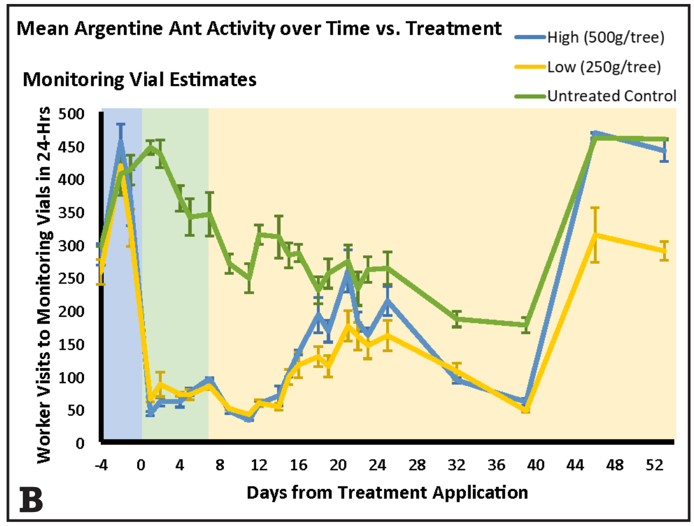


Figure 9. Average Argentine ant activity over the two-month sampling period as determined from visual (A) and monitoring vial (B) estimations. Comparisons can be made across the three treatments: high hydrogel application rate (500 grams per tree), low hydrogel application rate (250 grams per tree) and an untreated control. Background colors represent timing of various treatments and sampling periods: pre-treatment monitoring (blue), first treatment (applied on day 0; green) and second treatment (applied on day 7; yellow).

Results: Control Efficacy

Overall, visual estimates (V; Figure 9A) and monitoring vial estimates (M; Figure 9B) of foraging ant densities followed a similar pattern with a rapid and drastic reduction in activity observed for all treated plots after hydrogel deployment. Forty-eight hours after the first hydrogel application, average AA activity reduction from baseline was 98 percent (V) and 84 percent (M) in the high application rate plot and 76 percent (V) and 74 percent (M) in the low application rate plot while rising in the untreated control plot by 12 percent (V) and 20 percent (M). Ant activity evened out in both treated plots 72 hours after the second treatment, with a reduction of 96 percent (V) and 91 percent (M) in the high application rate plot and 90 percent (V) and 88 percent (M) in the low application rate plot. The minor reduction in AA activity observed in the control plot likely was related to concurrent low soil temperatures, not hydrogel treatment spill-over, as all plots were spaced apart by 260 feet, further than the maximum recorded AA foraging distance. These similarities in treatment efficacy were maintained for weeks.

Extended monitoring indicated that both application rates could provide residual control for more than four weeks after the second application. Though this hydrogel baiting strategy was highly effective at both application rates tested, these data suggest the low rate provides comparable long-term ant control with half the material, translating to significant cost savings.

Despite heavy AA reinvasion pressure into treated plots (as a result of being surrounded by heavily infested areas), hydrogel applications provided a level of control similar to that achieved in other studies utilizing commercially available treatment options (i.e., chlorpyrifos barrier sprays and liquid baiting programs) (Tollerup et al. 2004). With realistic grove-wide applications, a further reduction in AA activity and rebound rate are likely.

Take-away

Results from this preliminary field trial informed our choice of application rate for a second study conducted in three commercial citrus groves. A similar level of AA control was achieved in the large-scale trial, confirming our tested application rate is effective even for greatly infested commercial operations.

We conclude this baiting system has significant benefits compared to current AA treatment options in citrus, as hydrogels require relatively low labor inputs, preserve natural enemies that attack HPH pests and may provide a level of control that is highly competitive with commercially available products.

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Glossary

[1]**Invasive:** A non-native insect that causes significant ecological or economic damage. Invasive species typically spread and establish rapidly and widely.

[2]**Biological control (biocontrol):** Suppression of a target pest population to less damaging levels by natural enemies such as predators or parasitoids.

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Acknowledgments

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