College of Tropical Agriculture and Human Resources
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Hydrogel Baits for Ant Control and the Combined Use of Hydrogel Baits and Tanglefoot for Citrus Sooty Mold Control

Introduction

Ants are known to tend honeydew-producing pests such as aphids, whiteflies, mealybugs, and scales, and consequently negatively impact natural biocontrol by protecting these pests from their natural enemies (McCalla et al., 2020). The attendance of ants can result in outbreaks of honeydew-producing pests, which can promote the growth of problematic sooty mold fungi on the honeydew (Figure 1). Some of the common genera of fungi associated with sooty mold are *Cladosporium, Aureobasidium, Antennariella, Limacinula, Scorias,* and *Capnodium*. Although sooty mold does not infect plant tissues, it reduces plant photosynthesis (Nelson, 2008). Citrus sooty mold is of concern because it affects not only crop growth but also postharvest quality. Ant control is a critical component of sooty mold integrated pest management (IPM) programs. Common invasive ants such as the big-headed ant, *Pheidole megacephala*, and yellow crazy ants, *Anoplolepis gracilipes* (Figure 2), form mutualistic relationships with phloem-feeding insect pests such as aphids, whiteflies, mealybugs, and scales, thereby increasing the probability of sooty mold disease on a wide range of crops (Nelson, 2008).

Pesticide (e.g., fungicide and insecticide) sprays are among the most common control options against sooty mold. However, broad-spectrum pesticide treatments are ineffective for long-term control and are hazardous to both the environment and the natural enemies of honeydew-producing insects. One alternative is by controlling ants

Figure 1. A citrus tree stunted by sooty mold.

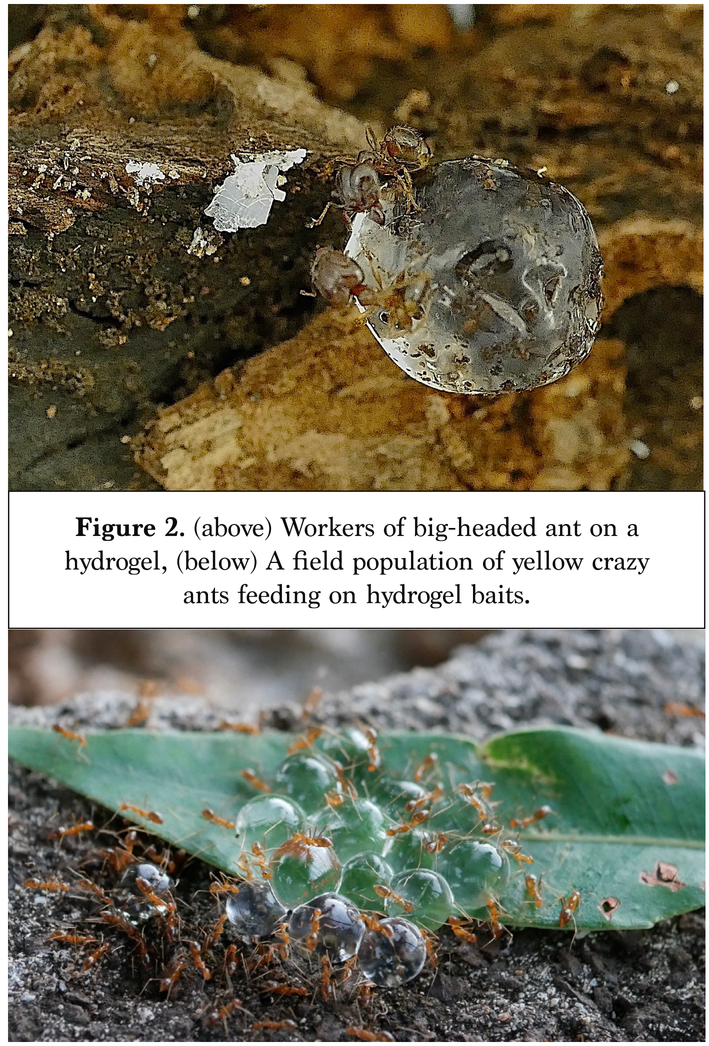

Figure 2. (above) Workers of big-headed ant on a hydrogel, (below) A field population of yellow crazy ants feeding on hydrogel baits.

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using liquid sucrose bait, infused with a low concentration of insecticide. Controlling the ants will allow the natural enemies of the honeydew-producing insects to protect the plants and prevent sooty mold. However, in order to perform effectively in open fields, liquid baits need to be contained and dispensed via bait stations.

Alginate hydrogel beads derived from seaweed can deliver liquid bait without the bait stations (Figure 3). These hydrogel beads made from alginate, a naturally-occurring polysaccharides, can be engineered via a cross-linking process and can be mass-produced using shower head nozzles in the laboratory (Tay et al., 2017, 2020). The resultant hydrogels are a polymer with the ability to absorb a large amount of liquid. After producing the hydrogels, they are conditioned in 25% sucrose bait laced with a small amount of active ingredient against ants, such as boric acid.

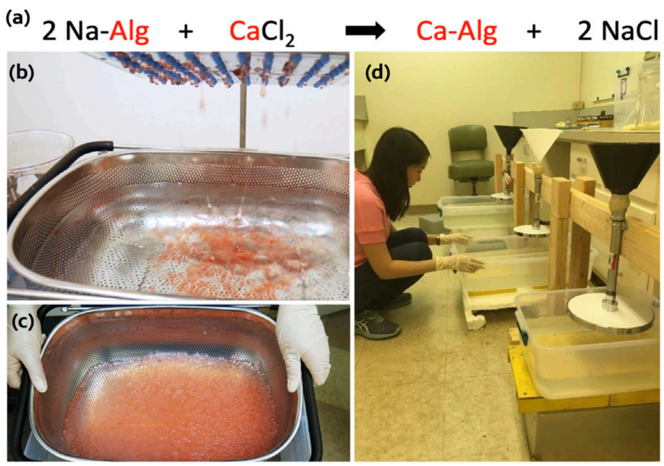

Figure 3. (a) Chemical reaction for ionically cross-linked hydrogel: calcium ions from a $CaCl_2$ solution replace the sodium ions in a sodium alginate solution, forming solid calcium alginate hydrogel beads; (b-d) sodium alginate droplets pass through shower head nozzles and drop into a $CaCl_2$ solution to form hydrogel beads.

Boric acid is practically nontoxic to birds, fish, and aquatic invertebrates and relatively nontoxic to beneficial insects (EPA, 1993). According to the EPA toxicity rating standard (acute oral toxicity), boric acid is rated in the "toxicity category III," indicating it is only slightly toxic for vertebrates (2006). Boric acid has sufficient solubility in water to be prepared in a 10-25% sucrose solution, which are preferred by many ant species (Choe et al., 2021). Another reduced risk IPM approach against sooty-mold complex is painting Tanglefoot to the tree trunk to block ants from crawling up the tree foliage. Integrating the application of boric acid hydrogels on the ground with Tanglefoot on the tree trunk can offer greater ant control and sooty mold reduction.

The objective of this project was to examine the efficacy of boric acid hydrogel bait treatment as an "attract and kill" system, by itself and with a combination of Tanglefoot painted on the tree trunk, in an IPM approach to manage big-headed ants and sooty mold on citrus. Big-headed ants are common agricultural pests in Hawai'i. They are omnivorous, soil-nesting ants and responsive to hydrogel baiting.

Materials and Methods

Alginate Hydrogel Bait Production

Biodegradable hydrogels were made from alginate, a naturally occurring polysaccharide derived from brown seaweed, as described by Tay et al. (2017) (Figure 3). Hydrogels were then incorporated with phagostimulant (25% sucrose solution) and 2% technical-grade boric acid. Boric acid hydrogel baits were stored in the refrigerator until use in the field trials.

Field Trials

Two field trials were conducted on citrus farms: 1) lime trees at the Poamoho Experiment Station, University of Hawai'i on O'ahu, and 2) lime and lemon trees at a commercial fruit farm in Lihue on Kaua'i. For the O'ahu trial, three treatments were applied: a) boric acid hydrogel baits, b) boric acid hydrogel baits in combination with TangleFoot insect barrier, and c) control. Each treatment was replicated on 10 trees. TangleFoot (Contech Enterprises Inc., Victoria, British Columbia, Canada) is a sticky physical barrier painted on the tree trunk, approximately 5 cm wide band at 10 cm above the base of the tree (Figure 4). For the boric acid hydrogel baits treatment, approximately 150 g of hydrogel baits were deployed on the ground once, close to each tree trunk. Applications under tree canopies could potentially extend the life of hydrogel baits by reducing the water loss rate. For the Kaua'i trial, only two treatments were applied: a) boric acid hydrogel baits and b) control, and each treatment was replicated on 4 trees.

Figure 4. (left) A citrus tree treated with boric acid hydrogel baits in combination with Tanglefoot on the tree trunk. Hydrogel baits may be deployed in a bait station on the ground; (right) Hydrogel baits may also be directly deployed on the ground, as our preliminary data showed they have similar efficacy.

Ant Number Monitoring

Ant monitoring was conducted in both citrus plots on Kaua'i and O'ahu, where the ant foraging activity level was quantified using visual assessments and monitoring with index cards from four citrus trees. Below each tree, one drop of honey was put at the center of a laminated index card (Scotch's self-laminating cover, Scotch Brand, MN, USA) placed on the ground near ant foraging trails. Ant foraging activities were monitored on index cards on day-1 pre-treatment and every week after treatments were installed for up to five weeks after treatment.

Sooty Mold Monitoring

Incidence of sooty mold was not monitored in the Kaua'i trial. Incidence of sooty mold was monitored in the O'ahu trial at 2-week intervals for up to 10 weeks post treatment. Each tree was rated for severity of sooty mold in a scale of 0-5, where 5 is severely covered by sooty mold (Figure 1). Data for percent leaves with sooty mold were taken on four trees per treatment at 2-week intervals up to 10 weeks post treatment, where 1-3 branches per tree were marked and repeatedly being recorded for the branches' percent leaves with sooty mold.

Results and Discussions

Effects on ants: The numbers of ants were significantly reduced at the 1st and 3rd week post-treatment using 2% boric acid hydrogel baits in the Kaua'i trial (Figure 5). On the O'ahu trial, the numbers of ant were reduced at the 1st, 2nd and 3rd week post-treatment, with a slight rebound at the 4th and 5th week with boric acid hydrogel baits only, and in combination with Tanglefoot (Figure 6).

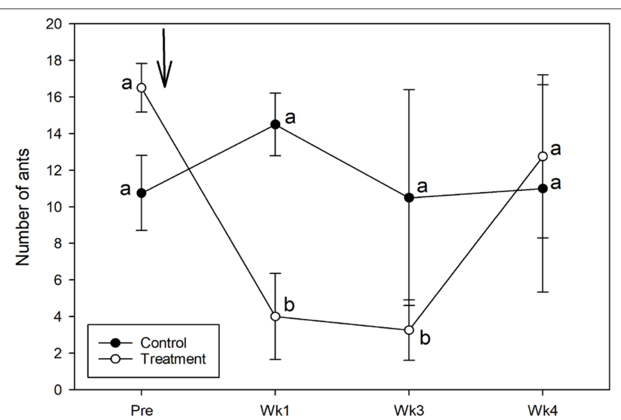

Figure 5. Number of ants (mean ± SE) recorded in the control and treatment plots on the Kaua'i citrus plot over 4 weeks. Data with different letters within a treatment are significantly different (Repeated-measures one-way ANOVA followed by Bonferroni test, $P < 0.05$, n=4). Arrow indicates the time of boric acid hydrogel treatment application.

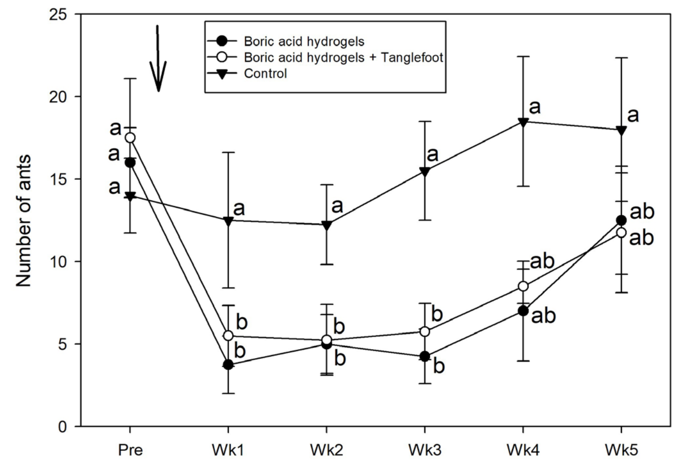

Figure 6. Number of ants (mean ± SE) recorded in the control and treatment plots on the O'ahu citrus plot over 5 weeks. Data with different letters within a treatment are significantly different (n=4). Arrow indicates the time of treatment application.

Effects on sooty mold: Integration of boric acid hydrogel bait and Tanglefoot was more effective than boric acid hydrogel bait alone in reducing the sooty mold rating on the leaves and the percent of leaves with sooty mold (Figure 7A, B). The use of boric acid hydrogel bait alone did not significantly reduce the overall sooty mold rating or the percent of leaves with sooty mold on the O'ahu trial ($P \leq 0.05$).

Overall, this study showed that boric acid hydrogel treatment, alone and in combination with Tanglefoot, is effective in reducing the big-headed ant population on the ground around citrus trees. Reduction in ant population density was apparent during the first three weeks post-treatment in both trials. However, the ant activity rebounded at the fourth week post-treatment. Thus, it might be necessary to recommend monthly retreatment of hydrogel baits for ant control in the areas where ant pressures are high. Although boric acid hydrogel alone was effective in reducing ant activities on the ground, it was not sufficient to reduce sooty mold on the trees through a three-tier effect (i.e., reduction of ants reduce honeydew-producing insects, and reduction of honeydew-producing insects reduce sooty mold) during our relatively short study period.

The effect of boric acid hydrogel bait alone on the sooty mold may become more obvious if we prolong the study period with monthly retreatment of hydrogel baits. Severe sooty mold from pre-treatment is difficult to disappear but they will slowly weather away when there is no development of new sooty mold from the reduction of ants and honeydew-producing insects. With its relatively low toxicity

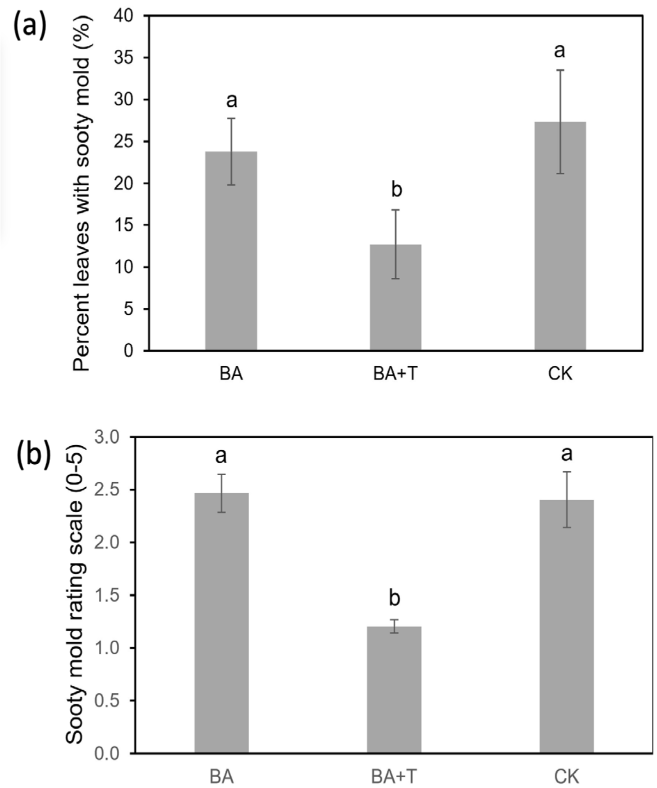

Figure 7. (A) Sooty mold rating scale (0-5) and (B) percent of leaves with sooty mold monitored by repeated measures over 10 weeks at 2-week intervals. Means (n=44) are average from four trees (one branch per tree in readings 1 and 2; three branches per tree in readings 3 to 5). Means followed by different letter are significantly different based on log10 (x+1) or $\sqrt{x}$ transformation for rating scale and percent sooty mold, respectively. Mean separation is based on Waller-Duncan k-ratio (k=100) t-test ($P \leq 0.05$).

BA = boric acid hydrogel; BA+T = boric acid hydrogel + Tanglefoot; CK = control.

to non-target organisms and humans, use of hydrogels containing a sucrose solution and boric acid is a targeted and sustainable approach. Both strategies tested here are more environmentally friendly ways in controlling ants, and subsequently, sooty mold than the repeated use of broad-spectrum pesticide sprays.

Note to Farmers: Since the alginate natural hydrogels from this study are not commercially available as of now, please keep an eye on our follow-up Extension publication about a commercially available synthetic hydrogel used alternatively to deliver liquid baits to manage ants, and information on preparation of the liquid ant bait for this ant control system on your orchards.

Conclusion

In this study, the IPM approach using both boric acid hydrogel baits and Tanglefoot was found to provide an optimum solution for sooty mold control. Sooty mold incidence was significantly reduced in the IPM approach when treated with both hydrogel bait and Tanglefoot, as compared to boric acid hydrogel bait alone. Nonetheless, boric acid hydrogel bait treatment alone was effective in reducing ant numbers. In addition to using hydrogel bait alone, future study should examine the use of the Tanglefoot alone to further understand its efficacy in reducing sooty mold. The results warrant future studies on the two methods for managing other ant species.

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