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Evaluation of a Hydrogel Matrix for Baiting Western Yellowjacket (Vespidae: Hymenoptera)

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Abstract

Baiting is an effective method to manage *Vespula* spp. yellowjacket (Hymenoptera: Vespidae) populations without having to locate and treat nests. Here, we assessed the utility of a commercially available polyacrylamide hydrogel as an alternative bait material for yellowjacket baiting. The experimental bait (hereafter referred to as 'hydrogel bait') consisted of diluted chicken juice (from canned chicken meat) and fipronil (0.025%, wt/wt) absorbed into granular polyacrylamide hydrogel particles. Three separate 24-h baiting trials were conducted at two different field sites with the western yellowjacket, *Vespula pensylvanica* (Saussare), as the target species. The monitoring data from pre- and posttreatment periods indicated that baiting with polyacrylamide hydrogel baits provided ≈74–96% reduction in the foraging activity of *V. pensylvanica* during its active season. In addition to their ability to absorb large quantities of aqueous bait containing phagostimulants and toxicants, the hydrogels' tactile resemblance to fresh meat upon hydration makes them a promising option as a non-meat material for delivering small amounts of insecticides to yellowjacket populations in a highly targeted manner.

Key words: polyacrylamide, *Vespula pensylvanica*, fipronil, monitoring

Adult yellowjackets, *Vespula* spp. (Hymenoptera: Vespidae), rely on carbohydrate sources such as sugary liquid materials (e.g., honeydew, fruit juice, and soda) for energy, but they also forage on proteinaceous items such as soft-bodied insects (e.g., caterpillars, flies) or fresh animal carrion to feed developing larvae in nests (Akre et al. 1980). In contrast to yellowjacket species in the *V. rufa* group, which have strictly predatory habits, members of the *Vespula alascensis* subgroup (formerly *Vespula vulgaris*) actively scavenge at various locations where human outdoor activity occurs (MacDonald et al. 1976). In addition to the nuisance and human health concerns, high levels of yellowjacket activity also indirectly impact the tourism and entertainment industries by reducing recreation values of the sites (MacIntyre and Hellstrom 2015). High-density yellowjacket populations that are maintained with human foods could also magnify their impacts on other local insect populations through direct predation or exploitative competition (Wilson and Holway 2010).

Control options of pest yellowjacket populations may include insecticide injections directly into their subterranean nests (Mussen and Rust 2012). As an alternative approach, baiting with insecticide-laced foods has been demonstrated as an effective method for area-wide control of yellowjacket populations. Several kinds of processed or fresh meats have been tested as a bait material for yellowjacket control. For example, canned chicken or fish, freeze-dried chicken, fish, beef, or kangaroo meat have been tested as bait materials for several species of yellowjackets (Chang 1988; Spurr 1991, 1995; Harris and Etheridge 2001; Sackmann et al. 2001; Wood et al. 2006; Sackmann and Corley 2007; Rust et al. 2010; Hanna et al. 2012; Rust et al. 2017). Overall, the results of these studies suggest that: 1) foragers typically chew and condition proteinaceous baits prior to carrying them back to the nest to feed larvae, 2) foragers prefer some types of meats over others and hence take more loads back to the nest, and 3) the preferred meats impregnated with some insecticides (e.g., fipronil, hydramethylnon) can be used to bait the yellowjacket populations for an area-wide suppression.

However, no 'ready-to-use' products are yet available for baiting yellowjackets in the United States. Onslaught Microencapsulted Insecticide (esfenvalerate 6.4%, wt/wt) is currently the only pesticide registered for the yellowjacket baiting in the United States, but it does not include a bait material/food attractant that is needed to make foraging yellowjackets bring the toxicant to their nest. Thus, users need to prepare their own bait material (e.g., raw chicken pieces, raw fish, canned tuna, or cat food) and mix it with the insecticide. A lack of detailed information on proper concentration of the insecticidal active ingredient in the final bait further complicates its preparation. Besides these technical issues, the use of meats in yellowjacket baiting has several other challenges. For example, Ross et al. (1984) pointed out 'fresh meats are messy to handle and have a short-lived attractiveness, possibly due to oxidation, dehydration, and associated crusting-over which may trap attractive meat volatiles inside'. The short-livedness and rapid moisture loss of the meat-based bait have been also recognized by Harris and Etheridge (2001) and Wood et al. (2006). The rapid water loss from the bait surface is particularly problematic if baits are contained in cup-type containers (i.e., only the top surface is available for foraging yellowjackets), or if they are not quickly discovered by foragers, especially when summer temperatures are high (>30°C) for prolonged periods.

Ross et al. (1984) explored the idea of using chemical compounds extracted from meats to develop a novel bait system. Ross et al. (1984) experimentally demonstrated that solvent extracts of some meats were highly attractive to foraging *V. germanica* (F.) workers when they were presented on the filter paper, making them land on the treated filter paper. When copresented with meat that is inherently not very attractive, the extracts also increased the yellowjacket visitation toward the meat. Ross et al. (1984) discussed that some of these extractable compounds could be incorporated into an inert matrix, which does not spoil but is readily collected by foraging yellowjackets, along with a small amount of toxicants. However, Ross et al. (1984) pointed out that other cues (i.e., tactile) might be important to make the foraging yellowjackets collect the inert bait matrix and return it to the colony. Indeed, several previous observations suggested that physical or tactile cues of the bait materials are critical to elicit yellowjacket wasp's normal foraging behavior. For example, Reid and MacDonald (1986) reported that finely ground meat paste was collected by *V. germanica* foragers far less frequently compared with the same meat that was intact or coarsely ground. Spurr (1995) and Ross et al. (1984) also reported that *Vespula* spp. foragers did not collect some bait materials even though their volatiles were highly attractive to them. These results suggest that yellowjackets rely on olfactory cues to locate food items, but they will subsequently require other cues, such as proper texture (tactile) and taste (gustatory), to initiate normal collection and retrieval behaviors.

Recently, a synthetic hydrogel material, polyacrylamide, was tested as a matrix to retain and deliver toxic liquid baits to pest ant populations (Boser et al. 2014, Buczkowski et al. 2014, Rust et al. 2015). Hydrogels are polymeric compounds with three-dimensional hydrophilic macromolecular networks that facilitate the absorption of large quantities of water resulting in a significant expansion in volume (Kopećek 2007). Due to their high absorbency for water, inertness to normal biological processes, and permeability to water-soluble compounds (Wichterle and Lim 1960), the hydrogels appeared to be possible candidates as an effective matrix for yellowjacket baiting. For example, aqueous liquid bait containing necessary phagostimulants and toxicants might be readily absorbed by hydrogels. Fully hydrated hydrogels might provide mechanical properties and consistencies that might be similar to those of meats, possibly allowing yellowjackets' natural foraging behaviors. Due to their excellent water retention properties (Johnson 1984, Montesano et al. 2015), the hydrogels might also retain and distribute moisture within the bait materials more effectively compared to meat-based bait materials, maximizing longevity and consumption of the bait when deployed in outdoor environments.

As a first step to explore the hydrogels' potential as a bait matrix for yellowjacket baiting, Rust et al. (2017) preliminarily tested if foraging *V. pensylvanica* would accept polyacrylamide hydrogel crystals when they are hydrated in chicken juice containing a toxicant (hereafter referred to as 'hydrogel bait'). Yellowjackets exhibited normal foraging behavior toward the hydrated hydrogel particles by cutting them into small pieces and carrying them back to the nest. However, Rust et al. (2017) did not formally determine the efficacy of the hydrogel bait for yellowjacket control due to low yellowjacket activity at the study site. In this report, we examined the efficacy of the hydrogel baiting using field populations of *V. pensylvanica* in outdoor recreational areas.

Materials and Methods

Study Sites

Two different sites (Fig. 1A) were chosen for study based on their accessibility and sufficient levels of yellowjacket activity. Both sites were located in Southern California. Site A (34.3556°N, 117.6323°W) was a private country club (≈0.06 km^2) with a small artificial lake for swimming (≈6,070 m^2), and supporting recreational infrastructure (e.g., picnic tables, barbecue facilities, children's playgrounds, etc.) (Fig. 1B). The site was surrounded by mixed conifer and oak forest. Site B (33.7963°N, 117.7526°W) was a multiple-use regional park (≈0.65 km^2) surrounded by undeveloped wilderness areas composed primarily of a riparian, coastal sage scrub, and oak woodland plant community (Fig. 1C). In 2014, site A was used. In 2016, sites A and B were used.

Monitoring

The activity level of yellowjackets was measured using an active monitoring trap with a chemical lure, heptyl butyrate (Davis et al. 1967, Reierson and Wagner 1975, Landolt et al. 2003). This volatile compound is highly attractive to western yellowjacket workers and queens (Simmons 1991). Modified wet traps (Reierson et al. 2008) provisioned with an 8-ml vial (glass, 10-mm opening) containing about 7 ml heptyl butyrate were used. The heptyl butyrate volatile was released through a piece of absorbent surgical wadding material (6 cm in length, Absorbal dental absorbent, Absorbal, Inc., Wheat Ridge, CO) plugged into the vial. Wasps that entered the trap through five side ports were funneled into a bottom jar containing a solution of antifreeze coolant (propylene glycol, Sierra Antifreeze/Coolant, Old World Industries, Inc., Northbrook, IL) diluted with water (70:30, vol:vol). The coolant solution was effective in killing and preserving the insects. The monitoring traps were hung under trees and bushes about 0.5–1.5 m off the ground.

For site A (2014 and 2016), a total of seven monitoring traps (Fig. 1B) were used. For site B (2016), a total of 55 monitoring traps were set up throughout the entire site (Fig. 1C), but a subset of those locations with high yellowjacket activity levels (i.e., 10 locations, see Results) were selected for the baiting study. For both sites, the number of wasps collected was divided by the number of days in the monitoring session to obtain the number of yellowjackets trapped per day. The number data were used for subsequent statistical analyses. Although these values did not provide absolute figures for total population per unit area, they provided a useful index for overall flight/foraging activity of yellowjackets in the area. Also, since only a small fraction of the total yellowjackets flying nearby will be attracted to the monitoring traps, and only a part of the attracted will be caught in the traps, the removal of the foraging yellowjackets through the monitoring did not cause any dramatic reduction during the active season of the yellowjacket (i.e., in the untreated plots, the trap catches continue to increase over the active season even with the continuous trapping) (Wagner and Reierson 1969, Rust et al. 2010).

At site A (2014 only), wasp traffic at nest entrances was also used to estimate individual colony's overall activity level. Two live

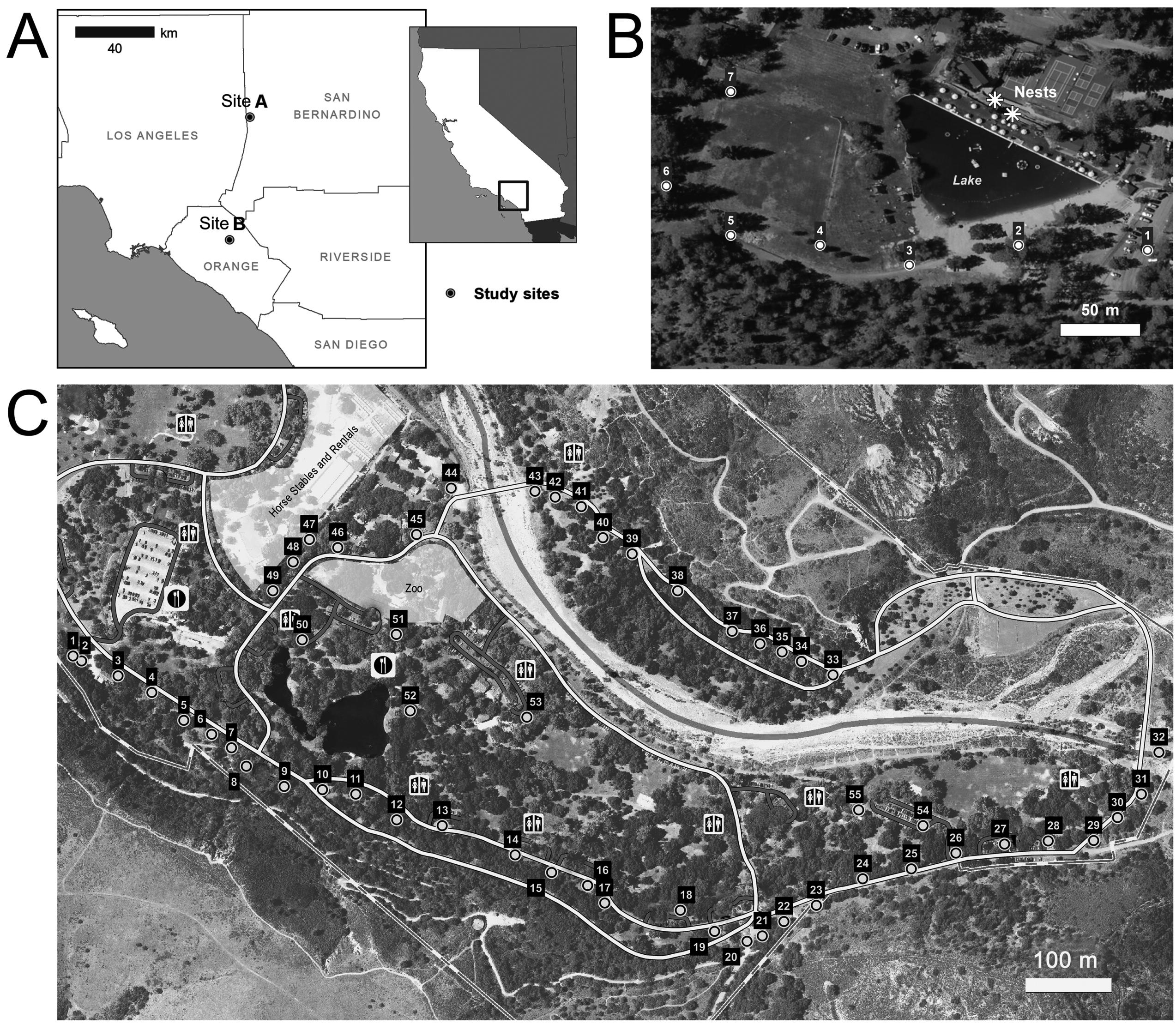

Fig. 1. Study sites. (A) Location map for two study sites. (B) Site A. Circles indicate the locations of seven monitoring traps. Two asterisks show the locations of yellowjacket nests observed in the study during 2014 (see text for details). (C) Site B. Circles indicate the locations of 55 monitoring traps. The numbers within the black squares are the numbers assigned to the monitoring traps.

yellowjacket nests were located about 100 m away from the closest monitoring trap (Fig. 1B, asterisks). The yellowjacket traffic at the nest entrances was quantified by counting the number of wasp leaving the nest entrance for 5 min in the morning (09:00–11:00). Three observations were made per nest with 5-min interval between two consecutive measurements. The data were collected at three different time points: 1) immediately before setting up the baits (on the day of baiting), 2) day 1 posttreatment, and 3) week 1 posttreatment.

Baiting

Hydrogel bait with 0.025% (wt/wt) fipronil was prepared using the following steps. Chicken juice was obtained from canned chicken meat (Swanson Premium Chunk Chicken Breast, Campbell Soup Co., Camden, NJ). About 150 ml of chicken juice was obtained from each can. Chicken juice was filtered to remove large particles. Filtered chicken juice was diluted with deionized water of same volume (150 ml), resulting in a 50% dilution.

The liquid bait with 0.025% (wt/wt) fipronil was prepared by mixing 0.8 ml of Termidor SC (9.1% fipronil, density 1.06 g/ml, BASF, Research Triangle Park, NC) with 300 g of diluted chicken juice. After mixing the liquid bait thoroughly, 15 g (≈13 ml) of granular polyacrylamide hydrogel (Water Storing Crystals, Miracle-Gro Lawn Products, Inc., Marysville, OH) was introduced into the liquid bait (total weight of mixture was 315 g). This preparation was mixed thoroughly with a spatula and left to condition at room temperature for 6 h to ensure complete absorption of liquid bait into the hydrogel particles. By the end of this conditioning process, the hydrogel particles absorbed ≈20 times their own weight of the liquid bait. The bait portions were measured out (either 20 or 30 g, see below) into 59-ml plastic cups (Amerifoods Trading Co., Los Angeles, CA), and the bait cups were capped and weighed. The bait cups were stored in a refrigerator (8°C) until used. They were used within 24 or 48 h postproduction.

The bait cups with hydrogel bait were deployed within bait stations (20 cm by 20 cm by 15 cm) that were constructed from two pieces of pine board and metal wire mesh (2.54-cm mesh) (Fig. 2A). The wire mesh was to preclude removal of bait by other larger nontarget organisms such as vertebrates, while allowing the yellowjacket

Fig. 2. Western yellowjacket baiting with the hydrogel bait. (A) Foraging yellowjackets at a bait station with hydrogel bait cups. (B) After leaving the bait station with a small piece of the hydrogel bait, yellowjackets often continued their 'food-handling' behavior by landing on nearby vegetation before taking off again.

workers to freely forage on the bait. The pine boards formed the top and bottom of the bait station, and the metal wire mesh formed the sides. The bait station was constructed by stapling a long rectangular metal wire mesh around three sides of the boards. In one side of the bait stations, the metal wire mesh was not stapled to the boards, forming a door to load the bait station with the bait cups. Twist ties were used to close the metal wire mesh door after bait cups were placed inside the bait station. Each bait station received three bait cups.

To ensure the sufficient bait take by the foraging wasps, a substantially high yellowjacket activity level (i.e., 10 yellowjackets per trap per day) was used as an action threshold for baiting at a location (Rust et al. 2010). Site A in 2014 was baited with 21 bait stations deployed along the monitoring trap line (three bait stations for each monitoring trap location). Thirty grams of bait was used per bait cup. One bait station was hung on a tree close to an adjacent monitoring trap (within 1 m), and the other two were placed on both sides of the monitoring trap along the perimeter line of monitoring traps within ≈15 m of the central bait station. For site A in 2016, the locations and arrangement of the seven monitoring traps were identical to those used for the 2014 study. However, in 2016, site A was baited with seven bait stations deployed along the monitoring trap line (one bait station for each monitoring trap location). Twenty grams of bait was used per bait cup. For site B in 2016, each trap location was baited with two or three bait stations. The distance between two adjacent bait stations was about 25–30 m. Twenty grams of bait was used per bait cup.

The baiting was conducted for 24 h. To prevent potential competition between monitoring traps and bait stations, the heptyl butyrate lure vials and collection jars were removed from monitoring traps at the baited locations during the 24-h baiting period. To determine the amount of water loss from the hydrogel bait, 3–5 bait cups were set up within bait stations covered with fine (0.16-cm mesh) metal wire mesh, which completely prevented removal of the bait by foraging yellowjackets (evaporation check). The evaporation check bait stations were set up with the regular bait stations at similar locations.

After 24-h baiting, all of the bait cups were capped, placed in a cooler, returned to the laboratory, and weighed. Weight loss of the bait was determined by subtracting the final weight from the initial weight for the bait cup. The approximate amount of gel bait taken per cup (g) was estimated in two different methods. In the first method, the average amount of bait take was estimated by subtracting the average weight loss of the evaporative checks from the average weight loss of the bait cups. This is a conservative estimate because it corrects for consumption by subtracting the total possible loss of water for 24 h from the entire bait amount. Because bait cups with partial consumption do not have the original amount of water to be lost via evaporation, this first method tended to underestimate the amount of consumption. In the second method, the average amount of bait take was estimated by multiplying the first estimate with [initial bait weight/average final weight evaporation checks]. The second method assumes that most of bait take occurs at the early stage of baiting when the hydrogel baits are fully hydrated (i.e., within a couple of hours after setting up the bait cups). Since the exact timing of the bait take is unknown, the ranges between two estimates are reported for the bait consumption.

Statistical Analyses

Based on the trap catch data, Wagner and Reierson (1969) and Rust et al. (2010) showed that significant drops (i.e., >50% reduction) in western yellowjacket activity do not occur until early to mid-October in Southern California sites. In the current study, all of the baiting trials were conducted between late August and mid-September, and all of the monitoring trials were completed by late September at the latest. These time lines are well within the active season of western yellowjacket, during which a significant drop in the trap catches cannot be seen as a result of natural decline of the yellowjacket populations. Thus, efficacy of baiting was determined by directly comparing the numbers of yellowjackets trapped per trap per day between pre- and posttreatment monitoring sessions with a Wilcoxon signed rank test with the normal approximation at the 0.05 level of significance (Analytical Software 2008). For the wasp traffic data, the data from each nest entrance were compared among three different time points with Kruskal–Wallis one-way ANOVA, followed by Dunn's all-pairwise comparison test at the 0.05 level of significance (Analytical Software 2008).

Results

Site A in 2014

Pretreatment monitoring traps were set up on 26 August 2014 and removed on 28 August 2014 (2-d collection). Before baiting, the average number of yellowjackets captured per trap per day was 211.8 ± 17.7 (mean ± SEM, $n = 7$).

On 30 August 2014, site A was baited with 21 bait stations. Foraging wasps were readily attracted to the cups containing bait, landed on the cups, and showed the typical foraging behaviors toward the hydrogel bait (e.g., manipulating the hydrogel bait with mandibles and flying away with a small piece of hydrogel bait)

(Fig. 2A and B). After 24-h baiting, the average weight loss of the bait cup was 22.7 ± 0.4 g (mean ± SEM, n = 60) (three bait cups were missing and not included in the calculation). Average amount of water loss from the evaporation checks was 14.4 ± 0.2 g (mean ± SEM, n = 3). Estimated amount of bait take per cup was 8.3–16.0 g or about 27–53% of the bait placed out. Overall, it was estimated that yellowjackets removed a total of about 523–1,008 g of bait at site A.

Posttreatment monitoring traps were set up on 5 September 2014 and the collection jars were removed on 7 September 2014 (2-d collection). The average number of yellowjackets captured per trap per day was 54.6 ± 6.6. When compared to the pretreatment levels, this represented a ≈74% reduction in the yellowjacket activity (Wilcoxon signed rank test; z = 2.3, P = 0.02) (Fig. 3A).

Traffic counts observed at two nearby nest entrances also significantly decreased after the baiting (Kruskal–Wallis one-way ANOVA; H = 7.8, P < 0.001 and H = 7.7, P < 0.001). Immediately before setting up the baits (on the day of baiting), the traffic counts at the two nest entrances were 66.7 ± 8.7 and 49.0 ± 10.3 foragers (means ± SEM, n = 3 for each). These values were reduced to 2.3 ± 0.7 and 11.0 ± 3.5 foragers on day 1 posttreatment (31 August 2014). Observations indicated that many of the surviving foragers around the nest entrances were disoriented and engaged in localized 'wandering' or extended periods of inactivity. By day 7 posttreatment (6 September 2014), forager traffic activity at both nest entrances was not observed, suggesting that the two colonies had been significantly impacted as a result of the baiting program. Based on the Dunn's multiple comparison tests (α = 0.05), the traffic counts at day 7 posttreatment were significantly lower than the pretreatment values for both nest entrances.

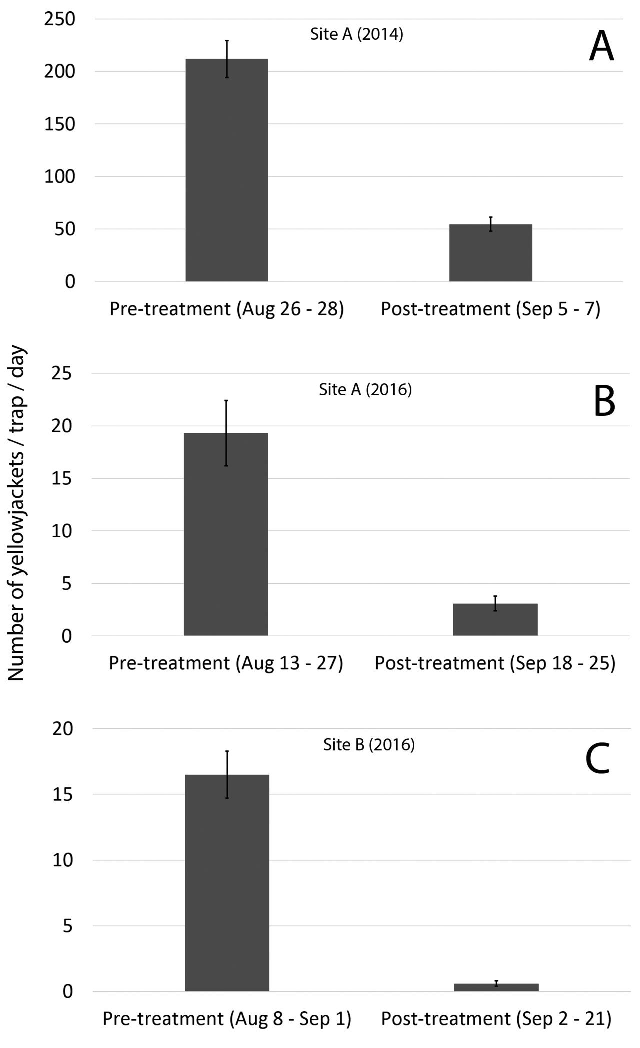

Fig. 3. Yellowjacket foraging activity level comparisons between pre- and posttreatment monitoring periods. The hydrogel baits were deployed on 30 August 2014 (site A, 2014), 17 September 2016 (site A, 2016), or 1 September 2016 (site B, 2016). For all three trials, numbers of yellowjackets per trap per day were significantly different between pre- and posttreatment monitoring periods (Wilcoxon signed rank test: α = 0.05). Error bar indicates SEM.

Site A in 2016

Pretreatment monitoring traps were set up on 13 August 2016 and the collection jars were removed on 27 August 2016 (14-d collection). Before baiting, the average number of yellowjackets captured per trap per day was 19.3 ± 3.1 (mean ± SEM, n = 7).

On 17 September 2016, site A was baited with seven bait stations deployed along the monitoring trap line. After 24-h baiting, the average weight loss of the bait cup was 18.3 ± 0.2 g (mean ± SEM, n = 21). Average amount of water loss from the evaporation checks was 10.0 ± 0.1 g (mean ± SEM, n = 3). Estimated amount of bait take per cup was 8.3–16.5 g or about 42–83% of the bait placed out. Overall, it was estimated that yellowjackets removed a total of about 174–346 g of bait at site A.

Posttreatment monitoring traps were set up on 18 September 2016 and collection jars were removed on 25 September 2016 (7-d collection). The average number of yellowjackets captured per trap per day was 3.1 ± 0.7. When compared to the pretreatment level, this represented a ≈84% reduction in the yellowjacket activity (Wilcoxon signed rank test; z = 2.3, P = 0.02) (Fig. 3B).

Site B in 2016

For site B, foraging activity levels of yellowjackets were monitored throughout the entire park starting 16 May 2016. Starting from the third monitoring session (conducted between 13 June 2016 and 27 June 2016), some monitoring traps exceeded the treatment threshold of 10 yellowjackets per trap per day. Pretreatment monitoring traps were set up on 8 August 2016 and the collection jars were removed on 1 September 2016 (24-d collection). The average number of yellowjackets caught per trap per day for these baited locations was 16.5 ± 1.8 (mean ± SEM, n = 10). Based on the data and trend of catch increase, 10 monitoring trap locations (monitoring traps 1, 28, 30–32, 33, 42–43, 53, and 54) with above-threshold yellowjacket activity levels (i.e., ≥10 yellowjackets per trap per day) were chosen for baiting.

On 1 September 2016, these 10 locations were baited with 26 bait stations. After 24-h baiting, the average weight loss for the bait cup was 11.3 ± 0.4 g (mean ± SEM, n = 78). Average amount of water loss from the evaporation checks was 5.5 ± 0.1 g (mean ± SEM, n = 5). Estimated amount of bait take per cup was 5.8–8.0 g or 29–40% of the bait placed out. Overall, it was estimated that yellowjackets removed a total of about 452–624 g of bait at site B.

Posttreatment monitoring traps were set up on 2 September 2016 and the collection jars were removed on 21 September 2016 for baited locations (19-d collection). For these locations, each trap collected an average of 0.6 ± 0.2 (n = 10) yellowjackets per trap per day. This indicated that the foraging activity of yellowjackets was reduced by ≈96% in the posttreatment monitoring period when compared to that of pretreatment monitoring (Wilcoxon signed rank test; z = 2.8, P = 0.006) (Fig. 3C).

Discussion

This study clearly demonstrated that polyacrylamide hydrogel could be used as an effective matrix for yellowjacket baiting. Polyacrylamide hydrogel particles effectively absorbed the diluted chicken juice containing 0.025% (wt/wt) fipronil. Based on our pre- and posttreatment monitoring data, the level of yellowjacket foraging activity in the baited areas dramatically decreased (≈74–96% reduction) immediately after the baiting. Direct observations of yellowjacket activity at two nest entrances within the study site (site A in 2014) also indicated that baiting provided complete suppression of the foragers by 7 d posttreatment. These nests were located ≈100 m away from the closest bait station. Since *V. pensylvanica* can fly up to 400 m to forage (Akre et al. 1975), bait stations at site A were probably within the potential foraging range of these nests.

Yellowjackets showed normal foraging behaviors toward hydrogel baits; they chewed and cut them into small pieces and carried them away. In addition to the meat-like physical texture provided by the hydrated polyacrylamide hydrogel, its ability to absorb and maintain large amounts of aqueous liquids, and chemical inertness may also explain its acceptance by foraging yellowjackets. The synthetic hydrogel bait might be also highly effective in keeping the surface of the bait hydrated. Within a single hydrogel particle, moisture from the inner portion will migrate to moisten the surface. Further, desiccating hydrogel particles that are in contact with neighboring hydrogels can acquire water if the neighboring hydrogels have higher moisture contents (D.-H. Choe, unpublished data). These mechanisms may help keep the surface of hydrogel bait moist, thereby increasing the longevity of bait attractiveness to yellowjackets.

Polyacrylamide hydrogel is nontoxic as a polymer. However, light and heat can decompose polyacrylamide to its monomer, acrylamide, a chemical that can be potentially toxic (WHO 1985, Slayne and Lineback 2005, Zovko et al. 2015). In the current study, the total amount of polyacrylamide hydrogel (in its dehydrated form) used for three separate outdoor baiting trials was relatively small (i.e., <200 g). Also, it is likely that most of the hydrogel bait was moved into the subterranean nests where it was fed to developing larvae. In this underground environment, hydrogels would be protected from long-term exposure to direct sunlight and heat that could cause the polymer to break down into monomers. Nonetheless, it would be worthwhile to explore alternative hydrogel materials, in particular biodegradable hydrogels made from natural compounds (Tay et al. 2017). Further research is warranted to assess the utility of these alternative hydrogel materials in developing yellowjacket baits.

The use of hydrogel as a bait material might facilitate the pesticide or pest control product manufacturers to develop a commercial ready-to-use bait product for yellowjacket control. Hydrated or dry hydrogel baits can be packaged in bait containers. The dehydrated form would need to be hydrated with a prescribed amount of water before using. The bait containers can be housed in a separate bait stations for further protection of nontarget organisms. The current study employed the juice from canned chicken meat as an attractant and/or phagostimulant. However, this component of the bait could be also possibly replaced with chemical extracts of meat (Ross et al. 1984) or other synthetic attractants or phagostimulants as long as they elicit normal foraging behavior when incorporated into the hydrogel matrix. The use of artificial attractants and phagostimulants with the hydrogel baits warrants further investigation.

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