

TRAPS AND PROTEIN BAIT TO SUPPRESS POPULATIONS OF YELLOWJACKETS (HYMENOPTERA: VESPIDAE)

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Abstract Seasonal and annual intensity of foraging pestiferous yellowjackets in California (USA) was determined with wet capture traps using heptyl butyrate (HB) lure. Although 3 species were sympatric at every test site, the most abundant at > 85 to 90% of total was *V. pensylvanica* (Saussure). There was a nearly 40-fold annual variation in the total number captured at some sites, the ultimate number of foragers apparently related to spring weather episodes. Independent of total number caught, traps indicated typical summer-fall seasonality, with the peak occurring in the warmest months. Queens and workers were attracted to HB. Early-season queen trapping and season-long trapping of foragers did not reduce the number of daily foragers nor reduce the number of reported sting episodes. In the short-term a ring of strategically placed interceptive traps reduced the number of yellowjackets foraging at a picnic food pavilion. Longer-term control was achieved one year with proprietary baits. Longer-term control one year was achieved with bait. Using minced chicken or one specific commercial fish-flavored pet food as the matrix, 0.05% chlorfenapyr or indoxacarb provided >90% non-resurgent control within 7 days. Results with bifenthrin, imidacloprid, and others were less spectacular, probably because of being repellent or having too rapid KD effects. Confirmation trials indicated that bait efficacy depends upon a minimum number of foragers/day. Trap catch is a good indicator of that minimum, there generally needing to be about 25 wasps/trap/day for baiting to be effective. Control may be achieved with toxicants such as fipronil or indoxacarb as they are transferred from the cuticle of foragers to other wasps in the colony. This transfer was substantiated by placing a wire-mesh cage soaked with 0.05% fipronil over a nest entrance for 15 min. The few caged exiting wasps were released and allowed to return to the colony, whereupon the colony was eliminated within 1 day.

Key Words *Vespula*, wasp, baiting, trapping, attractant, lure

INTRODUCTION

Yellowjackets are predators (Gambino and Loope, 1992), some species of which resort to scavenging when the quantity of their prey declines. In the U.S., most serious scavenging species occur in the west (Miller, 1961), and yellowjackets represent serious regional public health problems during summer and fall (Akre et al., 1981). Colonies begin in the spring from overwintering mated queens. As colonies develop and prey declines, some species become annoying and aggressive, competitively foraging on proteins and sweet liquids. Pest species nest underground, often with several nests per hectare. Nest entrances are usually well camouflaged, and may be encountered accidentally. Envenomization may be painful, and incapacitating or fatal for hypersensitive individuals. Campgrounds, schools and other outdoor recreational facilities may be affected to the extent they must close or face litigation. Identified colonies may be eliminated by directing toxicant into the nest opening. However, because they are well concealed it is nearly impossible to locate most yellowjacket nests. Except for incidental nests, individual nest treatment is not an option.

Traps have been promoted for years as effective devices for monitoring or controlling yellowjackets (Wagner and Reierson, 1969; Reierson and Wagner, 1978). Although other lures have been reported (Davis et al. 1967; Landolt et al. 1999), most commercial wasp traps rely on heptyl butyrate or a similar substance as a lure. There are dry traps and wet traps, the advantage of wet traps being that captured wasps are killed more quickly.

Baiting incorporates a toxicant into an acceptable protein food base which is fed upon by foraging yellowjackets and presumably disseminated to brood in the nest. There is currently no yellowjacket

bait product registered in the USA. The objective of this study was to determine the utility of trapping yellowjackets and to develop an effective bait to control pest yellowjackets.

MATERIALS AND METHODS

Test Sites

The studies were made during 2006 and 2007. Several sites where cooperators expressed interest in the project were surveyed with traps. The 3 selected for study included 1.) 3 multi-use public regional parks in central coastal CA, ranging in size from 61 to 658 ha, 2.) a 4.9-ha outdoor health spa near Corona, CA (Riverside Co.), and 3.) a 223-ha private recreational vehicle park near Idyllwild, CA (Riverside Co.). The two former sites were at ~250 to 300 m elevation, while the later was at ~1100 m. These locations were used because they had documented histories of significant numbers of yellowjackets in previous years, represented a spectrum of representative geographical locations, and we had assurance of cooperation and security at each.

Monitoring

Traps were used to determine population abundance. Traps for the study were custom 2-part plastic traps made of 0.9 L bottles connected to 0.45L wide-mouth jars (Figure 1). About 150 ml collecting liquid such as 70% ethyl alcohol in the lower jar killed captured specimens. Liquid HB lure (Sigma-Aldrich, St. Louis, MO) was dispensed from rolled dental wick protruding from the bottom to about 5 mm beyond the opening of an 11 ml glass vial screwed into a hole cut in the handle of the larger bottle. Wasps entered the trap through 5 side ports and were funneled into the liquid. Traps were suspended approx. 30 m (100 ft) or more apart by wire hangers from tree branches or other supports ca. 1.5 to 2 m from the ground. Species presence was verified by periodic net collection. Captured wasps from each trap were counted, identified and recorded weekly. This was often facilitated by replacing jars with new collecting jars and fluid. HB was replenished about every 2 or 3 wks and collecting fluid approximately monthly. Traps were installed at the same locations both years in order to make annual and seasonal comparisons. Additional traps were used to monitor the effect of baiting.

Queen Trapping and Trap Efficacy

Sixty traps were installed approx 45 m apart along a service road around a health spa in Corona, CA. There were > 100 documented stings of patrons every year, resulting in economic loss and threat of litigation. Queen yellowjackets establish their colonies in early spring and are nestbound by June. Traps were installed around the spa in March and were maintained weekly through October. Records were kept of the number and stage of yellowjackets caught and the number of stings reported.

Interceptive Trapping

Four monitor traps were hung from the corners of the roof of an open air 45.7 by 45.7-m outdoor picnic pavilion in Santa Clara, CA. The pavilion had ten 2.4 m-long wooden tables and 2 barbeques, and was used daily. Picnics and cooking foods attracted yellowjackets. We encircled the pavilion with 54 metal fence posts inserted in the ground approx. equidistant from one another ca. 60 m from the pavilion. Traps were suspended on a post at each of 4 quadrants. The eight traps were maintained as baseline traps from May to July. The 50 peripheral traps were hung from the posts 15 July. Effectiveness was determined as the difference in catch at the pavilion (i.e. inside the outer ring) compared to the catch in the quadrant traps.

Bait Acceptance and Baiting

During the summer in CA, pest yellowjackets prefer protein-based foods. They maintain energy by consuming sweets, but their primary food is meat. Because of convenience and low cost, we evaluated canned pet food as a protein-based-bait matrix. Those reported to be effective as bait bases (Wagner and Reiersen, 1971) are no longer available. Because pilot acceptance trials in 2005 suggested Swanson's® brand canned white chicken was the most foraged canned food besides fresh ground chicken, foraging acceptance studies were made with a series of pet foods. We evaluated 18 canned cat foods comprising a variety of flavors and

Horizontal Transfer of Insecticide

To investigate the potential for novel trap-and-release control methods, we exposed yellowjackets to a fipronil-treated surface and determined nest effects later. Investigators report that fipronil is readily transferred among termites and ants, other social insects. A 5-sided wire mesh cage measuring 15.2-cm per side was soaked in a 0.05% Termidor 80 WP (fipronil) suspension and then air-dried on a lab bench. The treated cage was set over the entrance of nests discovered in our test sites. We antagonized the colony to get as many wasps to fly into the cage as we could. The cage was removed at 15 to 30 min and the wasps released. The wasps returned to the nest within minutes. We observed the nest site the following day.

RESULTS AND DISCUSSION

Traps

Traps were sensitive indicators of the presence of yellowjackets. The predominant species by nearly 85 to 90% was *V. pensylvanica* (Saussure) with noticeable numbers of *V. atropilosa* (Sladen) and *V. sulphurea* (Saussure) also being present. As in previous years (Vetter et al., 1995), we detected a few *V. germanica* (Fabricius) in southern CA in 2006, but none at these test sites. The later species are also scavenging species, so we had little concern that their presence would affect results. There were noticeably fewer yellowjackets in 2007 than in 2006. Whereas week-long trapping in 2006 often yielded up to 400 wasps/trap, fewer were caught or seen in the field in 2007. Daily trap catch in 2007 was often < 5. Although far fewer were caught in 2007, the seasonal pattern of catch was remarkably similar, queens first appearing and the number of workers peaking at about the same date both years. This pattern is remarkably similar to that reported by Wagner and Reiersen (1971a, b) and others for other locations in CA. As reported by Wagner and Reiersen (1969), heptyl butyrate was effective and continued to be effective if liquid remained in the dispenser, usually 2 to 3 weeks. Remnant HB on dental wick had virtually no attraction. Some recently developed polymer formulations of HB and other lures are also effective. To enable counting and identification, captured specimens in our studies needed to be dead and intact. We avoided using dry traps because captured wasps live too long and dismember previously captured ones. Cooperators needed a fluid with which they could capture and preserve specimens for identification. Specimens rotted and discolored within days in soap water. Although denatured isopropyl alcohol (IPA) is readily available, it was repellent, generally reducing trap catch by > 70%. Ethyl alcohol was not repellent and it was a good preservative, but it was unavailable except by research permit. Commercial antifreeze has been used for pitfall trapping ants, spiders as well as for other flying insects (Uchida et al., 2006) and was an excellent collecting fluid for our traps. After initial tests in 2006, we used 70% ethylene glycol exclusively.

Queen Trapping and Trap Efficacy

HB attracted yellowjacket queens, probably in similar proportion as workers. Total *V. pensylvanica* queen catch at the spa was nearly equal, 55 in 2006 and 59 in 2006 but worker catch decreased 97.5%, from 46,991 in 2006 to 1196 in 2007. A dramatic decrease in 2007 compared to past years was characteristic of most of CA. Apparently, the timing of severe climatic condition (e.g. drought, rain or severe frost) in late spring affects queens or early brood. Spa workers initially reported fewer stings in 2006 than 2005, but records indicate some stings may be from honeybees or other wasps. That some were reported as early as February and 37% of stings for the year were reported before April, it is likely other insects such as honeybees were involved. That we ultimately trapped so many in 2006 indicates that queen trapping had no effect on resultant numbers of workers. This confirmed the same results in a study we conducted at Lake Almandor, Shasta Co., CA in 2005. Low worker numbers are likely the result of severe climate.

Interceptive Trapping

The peripheral ring of traps around the food pavilion reduced the number of foraging yellowjackets, presumably by intercepting them (Figure 3). No nests were found or reported between the ring and the pavilion, indicating that foragers in the pavilion were coming from nests beyond the ring. Between 26 July to 23 August, <10 yellowjackets/trap/day were caught in monitor traps at the pavilion (avg. = 5.4/trap/day), whereas >30 to 70/trap/day were caught in the ring traps (avg. = 44.9/trap/day). Nearly 6,000 foragers were

caught in the ring compared to only 208 at the pavilion. We presume fewer foragers translates to fewer stings. Maintenance is crucial. Foragers at the pavilion increased one week when the lure dried. Interceptive trapping may be more effective if traps are hung closer together.

Bait Acceptance and Baiting

Yellowjackets shunned nearly all pet foods presented to them. They sometimes landed on the food for 1 or 2 sec, but did not forage any. They did, however, forage Swanson's® canned chicken and Friskies® Ocean Whitefish Dinner at the same rate and significantly more than the others (ANOVA, $P < 0.001$). If foraging was intense, 30 to 60 cc was depleted within 2 h. All other pet foods were neglected or only marginally foraged. This was confirmed in volumetric and weight-loss determinations where no more than 10% of any pet food presented was foraged. We used the Swanson's and Friskies interchangeably in bait trials in 2006, but we standardized on Swanson's in 2007 trials.

Regardless of site, foraging tended to be reduced or extinguished as toxicant was added. Pyrethroids such as bifenthrin exhibited dose-dependent repellency. Of the toxicants evaluated, the most foraged was indoxacarb 0.05% (wt/wt Indoxacarb 150 SC). Indoxacarb is unique in that it is metabolically activated in insects from a low-toxicity 'pro-insecticide' to an active form. Activation does not occur in mammals. Similarly, chlorfenapyr is a unique, slow-acting metabolic toxicant which appeared to be a promising bait ingredient. We used Phantom SC. We used these 2 materials in preliminary bait control trials in 2006. Other toxicants tested at the 0.05% rate in 2007 included acetamiprid, es-fenvalerate (Archer), fipronil (Termidor), imidacloprid (Merit 75WP), and spinosad (Tracer).

As shown in Table 1, excellent control was achieved in 2006 with 0.05% chlorfenapyr or indoxacarb bait, there being > 90% reduction in the number of yellowjackets within 2 weeks. Control persisted for more than a month, and would likely persist longer if baiting had been done earlier in the season.

Figure 3. Number of yellowjackets captured/trap/day in interceptive peripheral traps position in a ring around a food pavilion compared to the number caught at the pavilion.

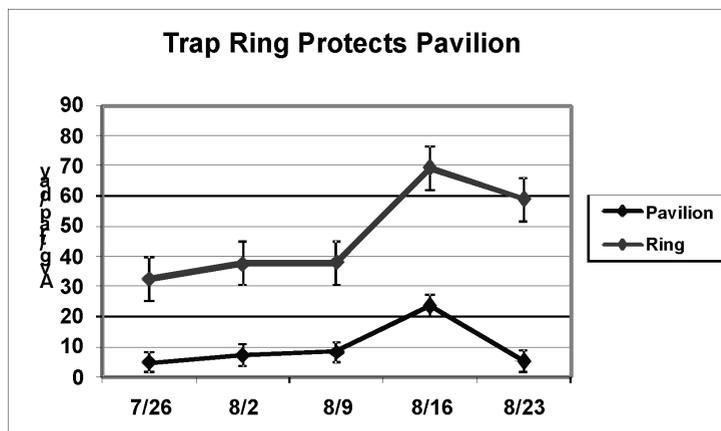


Table 1. Effectiveness of chlorfenapyr and indoxacarb in cat food^a as bait to control the western yellowjacket, *Vespula pensylvanica*, 2006.

| Bait AI (0.05%) | Avg. before No./trap/day ^c (total) | % Reduction ^b at week | | |
|-----------------|--|----------------------------------|------|------|
| | | 1 | 2 | 4 |
| Chlorfenapyr | 45.2 (1898) | 90.7 | 90.0 | 99.7 |
| Indoxacarb | 54.1 (2273) | 95.4 | 93.6 | 99.7 |
| Untreated | 32.2 (1354) | 0.0 | 0.0 | 24.7 |

^a Toxicant 0.05% AI formulated SC in Friskies Ocean Whitefish Dinner.

^b Baiting begun 15 September; Silent Valley Club, Idyllwild, CA.

^c Six traps /location left for 7 days; bait and control sites ca. 0.5 mile apart.

2006 Versus 2007. Surprisingly, bait control trials in 2007 did not confirm 2006 results. The > 95% control obtained with 0.05% Indoxacarb SC and Phantom SC in 2006, was not confirmed in 2007 trials. This lower level of performance summarized in Table 2. In this trial there was 0% reduction with indoxacarb bait. We attribute this discrepancy to there being an insufficient number of foraging yellowjackets in 2007. There were not enough foragers to take adequate amounts of bait to the nests. Monitoring with traps apparently accurately reflected population density and foraging. For baiting, the threshold indicator level in monitor traps appears to be >15 to 20/trap/day. Catch at our trap sites in 2007 were <10/trap/day when we initiated bait trials. Foraging bait was too inefficient to be effectual when such lower numbers were caught.

Table 2. Baiting for yellowjacket control in 2007.

| Bait (% wt/wt) ^a | Precount | Avg no. per trap/day (\pm % change) ^b | | |
|-----------------------------|----------|---|---------------|---------------|
| | | 1 week | 2 weeks | 3 weeks |
| 0.05% indoxacarb | 5.5 | 11.5 (+ 109) | 5.3 (3.6) | 5.0 (9.1) |
| 0.05% Onslaught | 5.7 | 18.5 (+ 224.6) | 8.8 (+ 54.4) | 6.8 (+ 19.3) |
| Untreated control | 10.3 | 19.8 (+ 92.2) | 12.0 (+ 16.5) | 12.0 (+ 16.5) |
| | | | | |

^a Avg of 4 traps per area; precount 1 August 2007; bait matrix Swanson's minced chicken.

^b In parentheses, + is % increase compared to precount; no + is % reduction.

Although nest kill was not attained, behavioral response could be determined from just a few wasps. In one instance where there was only 1 or 2 wasps/h foraging at one of our test sites in 2007, we could observe avoidance and handling behaviors, return time from bait to nest, and speed of action of the toxicant. For instance, we found that dinotefuran is extremely somewhat repellent and fast-acting, 0.1% in bait interfering with homing and literally killing wasps in flight. Lower rates had less dramatic effects and are probably more effective in bait. As indicated with traps, a minimum number of yellowjackets per area is apparently necessary for baiting to be effective. Less than 10 yellowjackets/trap/day indicated an insufficient number of foragers and that the population was likely below a problem threshold level. Such low levels do not constitute a problem. Only incidental nests need be treated in such circumstances.

Horizontal Transfer

We discovered 4 nests on which we placed the fipronil-treated mesh cage. Although antagonized, relatively few wasps emerged into the cage, usually < 50. Surprisingly, the nests were dead in 24 to 48h. Skunks or other mammals unearthed two during the night. In the other instances we unearthed the nests and determined their contents had succumbed. These observations suggest that some form of catch-and-release "virtual bait trap" containing a surface treated with fipronil may be effective in providing control by lethal transfer to the colony. Fipronil is unique in having exceptional biological activity and good transfer characteristics. Although less biologically active, indoxacarb also transfers readily among insects, and may be a candidate for this technique.

CONCLUSIONS

Yellowjackets are serious public health pests. Encounters with incidental nests or wasps often result in painful dangerous stings. Trapping with synthetic lure provided a reliable way to indicate relative numbers of foragers and revealed dramatic annual population fluctuation. We have observed fluctuations in previous years, but differences in population levels were exceptional between 2004-2007. Exceptionally harsh springtime climate conditions in the western USA correlated with subsequent unprecedented low numbers of yellowjackets in summer 2007. Excessive rain or untimely freezes in the spring as overwintering queens emerge or during foraging of early brood apparently reduce survival of individuals and nests.

Intensive interceptive trapping reduced the number of yellowjacket foragers around a food pavilion. This was the first documented instance of traps protecting and specific area. This showed that strategically-placed traps may have utility by intercepting or diverting yellowjackets from a target site.

Baiting success is dependent on the intensity of the foraging population, and this intensity may be determined with traps. This was shown by our study in which >95% control was achieved with chlorfenapyr, fipronil or indoxacarb in a trial where baiting was started after catching > 20 wasps/trap/day whereas insignificant control was attained at the same sites the next year when baiting was started after catching just < 5/trap/day. A substantial foraging population is needed for baiting to be effective. The treatment as well as the problem threshold level appears to be near 5 to 10/trap/day.

For baiting, slurried fresh and canned minced chicken and one particular canned fish-flavored pet food were the most foraged foods tested. Effective AIs were relatively slow-acting, enabling yellowjackets to make multiple trips between bait and their nest. Most AIs were repellent at biologically relevant concentrations or acted too quickly to allow foragers to disseminate sufficient AI from the bait to the nest. This was especially true of pyrethroids such as bifenthrin, cypermethrin and deltamethrin. Dinotefuran was a notable exception, being so biologically active that foragers died and their colonies succumbed from miniscule amounts in bait. As shown in the cage-horizontal transfer trial, fipronil is also biologically active. In addition, it and indoxacarb are readily transferred from surfaces and among insects. Both are good candidates as ingredients in yellowjacket bait.

These studies showed that traps should be an integral part of a yellowjacket management strategy. Traps may be used strategically to divert foragers in certain situations, but should be used primarily as monitoring devices to detect presence and intensity, and to help determine if and when baiting is to be undertaken. A few insecticides, especially some with good horizontal transfer characteristics, show promise as yellowjacket bait actives.

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