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TRAPPING YELLOWJACKETS (HYMENOPTERA: VESPIDAE) WITH HEPTYL BUTYRATE EMITTED FROM CONTROLLED-RELEASE DISPENSERS

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ABSTRACT

Numbers of workers of *Vespula pensylvanica* (Saussure) (western yellowjacket) and *V. atropilosa* (Sladen) trapped with heptyl butyrate in Washington increased with greater release of the attractant from vial dispensers, up to an estimated 2.3 milligrams heptyl butyrate per hour. *Vespula germanica* (F.) (German yellowjacket) workers were also captured in significant numbers, and numbers of workers captured increased with increased release of heptyl butyrate, up to an estimated 1.4 milligrams per hour. Numbers of workers of *Vespula squamosa* (Drury) trapped with heptyl butyrate in Oklahoma increased with increased release of heptyl butyrate from dispensers, up to an estimated 3.3 milligrams per hour. Vial dispensers, with holes of 6, 12, 22, and 33 mm diameter in the vial lid, lost 0.42, 1.4, 2.3, and 3.3 milligrams of heptyl butyrate per hour in the laboratory and these rates changed little over a period of 4 weeks, indicating close to a zero order rate of release pattern. Rates of loss of 2 ml heptyl butyrate applied to a cotton ball decreased with exposure time, from an initial rate of 6.0 milligrams per hour to near zero at 16 days post-treatment. Captures of wasps in traps sold commercially might be improved with the use of a controlled-release dispenser.

Key Words: Wasp, yellowjacket, trap, attractant, lure, heptyl butyrate

RESUMEN

El número de trabajadores de *Vespula pensylvanica* (Saussure), la avispa "chaqueta amarilla" occidental, y los de *V. atropilosa* (Sladen) atrapados con el butirato heptílico en el estado de Washington aumentó con una mayor liberación del atrayente en frascos dispensadores, hasta un estimado de 2.3 miligramos de butirato heptílico por hora, los trabajadores de *Vespula germanica* (F.), la avispa "chaqueta amarilla" alemán, tambien fueron capturados en números significantes, y el número de trabajadores capturados aumentó con la mayor liberación de butirato heptílico, hasta un estimado de 1.4 miligramos por hora. El número de los trabajadores de *Vespula squamosa* (Drury) atrapados con butirato heptílico en Oklahoma aumentó con el aumento de la liberación de butirato heptílico de los dispensadores, hasta un estimado 3.3 miligramos por hora. Los frascos dispensadores, con hoyos de 6, 12, 22 y 33 mm de diametro en el tapón del frasco, perdieron 0.42, 1.37, 2.3, y 3.3 miligramos de butirato heptílico por hora en el laboratorio y estas proporciones cambiaron poco sobre un período de 4 semanas, indicando una proporción del orden cerca del cero del patrón de liberación. La proporción de perdida de 2 ml de butirato heptílico aplicado a una pelota de algodón bajó con el tiempo de exposición, desde una proporción inicial de 6.0 miligramos por hora hasta cerca de cero a los 16 dias después del tratamiento. La recolección de avispas en trampas para venta comercial puede ser mejorada con el uso de un dispensador de liberación controlada.

Heptyl butyrate is attractive to some species of yellowjackets, and is sold commercially as a lure for traps. Workers of the western yellowjacket, *Vespula pensylvanica* (Saussure), and both queens and workers of *Vespula atropilosa* (Sladen), are captured in large numbers in traps baited with heptyl butyrate (Davis et al. 1969; MacDonald et al. 1973; Landolt 1998). Workers of *Vespula acadica* (Sladen), *Vespula consobrina* (Saussure) (blackjacket), *Vespula germanica* (F.) (German yellowjacket), *Vespula maculifrons* (Buysson) (eastern yellowjacket), *Vespula squamosa* (Drury), *Vespula sulphurea* (Saussure), *Vespula vidua* (Saussure), *Vespula vulgaris* (L.), and other wasps have also been captured in traps baited with heptyl butyrate (Grothaus et al. 1973; Landolt 1998; MacDonald et al. 1974; Reed & Landolt 2003; Reierson & Wagner 1975, 1978). These trapping studies indicate a broad-based but variable response of a taxonomic range of yellowjacket species to heptyl butyrate. However, it has been concluded that the chemical is effective primarily in attracting *V. pensylvanica* and *V. atropilosa* and is weak or ineffective as a lure for other species of social wasps (Akre et al. 1981).

The use of heptyl butyrate as a trap lure might be improved by providing a controlled release system for optimizing the amount of the chemical

evaporated from traps. In studies evaluating wasp responses to this chemical in traps, heptyl butyrate has been applied directly to the bottom of the trap (0.25 ml) (Davis et al. 1968, 1969), to cotton swabs (0.4 ml) (Howell et al. 1974), to cotton balls (one to 5 ml) (Davis et al. 1973; MacDonald et al. 1973, 1974; Sharp & James 1979), rubber stoppers (Chang 1988), and in polyethylene caps (Landolt 1998). Currently, measured amounts of heptyl butyrate are applied to cotton balls as a means of baiting traps sold commercially for yellowjackets (Rescue Trap®, Sterling International, Inc., Veradale, WA). Although a dose of one to several ml on cotton has been effective as a lure for the yellowjackets *V. pensylvanica* and *V. atropilosa* (Davis et al. 1973, MacDonald et al. 1973, 1974), there are no published determinations of the relationship between dosage or release rate of heptyl butyrate and captures of wasps in traps. Thus, we do not know how to provide optimum amounts of heptyl butyrate for maximum attraction or capture of wasps in traps.

We report here the trapping of several species of *Vespula* with heptyl butyrate emitted at varied release rates, and the first documentation of worker *V. germanica* and *V. squamosa* response to heptyl butyrate in controlled experiments. This study was designed to test for trapping of *V. pensylvanica* in Washington and *V. squamosa* in Oklahoma as primary pest species. Our long term objective is to improve the efficacy of trapping systems for these pest wasps.

Materials and Methods

The Dome trap (yellowjacket trap of Gempler's, Bellevue, WI), was used in all field experiments. This plastic trap is opaque yellow below and clear above, with a bottom entrance through which wasps enter the trap. Traps contained about 200 ml of a drowning solution made of 0.01% unscented dishwashing detergent (Palmolive Concentrated Dishwashing Liquid, Colgate-Palmolive, New York, NY) in water. Polypropylene vials (Nalge Nunc International, Rochester, NY, 15 ml 2118-9050 and 30 ml 2118-0001) were used as a means of dispensing heptyl butyrate (Aldrich Chemical Co., Milwaukee, WI). Ten ml of heptyl butyrate were pipetted onto three balls (ca 2.5 cm diam) of cotton wedged into the bottom half of the vial. Chemical release was through a hole in the lid of the vial. Vials were suspended in the top center of the inside of traps by wire.

A range of release rates of heptyl butyrate was provided by varying the diameter of the hole in the lid of vial dispensers. Comparisons of captures of wasps in traps with varying heptyl butyrate release rates were conducted in both the Yakima, Washington and Tulsa, Oklahoma areas, in order to obtain data for *V. pensylvanica* and *V. squamosa* respectively. The same chemical, lures, traps, and methods were used for the experiments in both Yakima and Tulsa. A randomized complete block design was used for each test, with each of a series of vial hole sizes (providing a different release rate) represented within each of the five replicate blocks. Holes of different sizes were made using sets of drill bits. The first test compared heptyl butyrate in 15 ml vials with holes of 0, 1.0, 1.5, 3.0, 6.0, and 12 mm diameter. The vial with no hole (0 mm hole diameter) was presumed to not release heptyl butyrate. This test was followed by another experiment comparing heptyl butyrate in 30 ml vials with holes of 1.5, 3.0, 6.0, 12, 22, and 33 mm diameter.

In Yakima, the first test was conducted from 19 to 31 July 2000. Traps were hung on fences, shrubbery, and low branches of trees at a golf course, at a height of 2 m, with 30 m spacing between traps. The second test in Yakima was conducted from 4 to 21 August 2000. Traps were positioned as described above, with some blocks at a golf course and others at a commercial tree nursery.

In Tulsa, Oklahoma, the first test was conducted from 12 September to 6 October 2000, with traps on vegetation on and adjacent to the campus of Oral Roberts University. The second test in Tulsa was conducted from 6 October to 3 November 2000, with traps again on vegetation on and near the campus of Oral Roberts University. At both locations, traps were checked twice per week, and the drowning solution of traps was changed weekly. In Tulsa, heptyl butyrate dispensers were replaced after two weeks. In both locations, trap positions were randomized initially and each time that traps were checked.

Release rates of heptyl butyrate from vials were determined by weighing vials that contained heptyl butyrate at intervals to determine weight loss with time. Weight loss was determined for four replicates of 30 ml vials loaded with 10 ml of heptyl butyrate on cotton balls, and with vial hole diameters of 0, 6, 12, 22, and 33 mm. These vial hole sizes were selected because we sought to determine the range of release rates of heptyl butyrate that are effective in attracting wasps to traps. Weight loss was also determined for cotton balls placed on aluminum foil weighing dishes, with an initial application of two ml of heptyl butyrate to the cotton. Vials and cotton balls were weighed every two or three days over the 3-week period of time following the initial loading of the vials with heptyl butyrate. Vials and cotton balls on weighing dishes were held in a fume hood inside the USDA-ARS Yakima Agricultural Research Laboratory, for the 21 day duration of the experiment. Temperature inside of the fume hood was 22.5 ± 1°C, with the temperature variance likely due to changes in building air handling rates and heating/cooling which could alter both the air flow rate through the fume hood and the ambient temperature.

For each of the four trapping experiments, trap catch data were subjected to a regression analysis (DataMost 1995) to determine if there was a significant positive relationship between numbers of wasps captured and vial hole diameter. Also, data from the first experiment for *V. germanica* in Yakima, Washington, and for *V. squamosa* in Tulsa, Oklahoma were subjected to an ANOVA, with treatment means compared using a paired t test (DataMost 1995), to determine if workers of these two species were captured in significant numbers in traps baited with heptyl butyrate. Weight loss data for heptyl butyrate from cotton balls and from vials were subjected to a regression analysis (DataMost 1995) to determine if there was a significant negative relationship between dispenser age and rate of loss.

Results

In the first field test conducted in Yakima, there was a significant positive regression of numbers of wasps trapped in relation to vial hole diameter, and the greatest numbers of *V. pensylvanica* were captured in traps baited with vials with the largest hole size (12 mm diam) (Table 1). Although numbers of *V. atropilosa* and *V. germanica* captured in this test were small, there was a significant positive relationship between vial hole diameter and numbers of workers trapped for both species (Table 1). Numbers of *V. germanica* workers in traps with vials releasing heptyl butyrate were statistically significant compared to traps with vials that did not release heptyl butyrate (0 mm hole), for the 1.5 mm ($t = 2.33$, $p = 0.02$), 3 mm ($t = 1.79$, $p = 0.05$), 6 mm ($t = 1.92$, $p = 0.04$), and 12 mm ($t = 3.87$, $p = 0.001$) diameter holes in vial lids. In this test, totals of 695 *V. pensylvanica*, 58 *V. atropilosa*, and 106 *V. germanica* workers were captured.

In the second field test conducted in Yakima, there was a significant linear regression of numbers of *V. pensylvanica* trapped with all vial hole diameters tested (Table 1). Greatest numbers of *V. pensylvanica* and *V. atropilosa* were captured in traps baited with vials with 22 mm diameter holes, with no increase in catches of these wasps with the largest diameter hole in vials, 33 mm (Table 1). The regression of wasps captured versus hole diameter was more significant for vial hole diameters of 1.5 to 22 mm ($r^2 = 0.98$, $p = 0.002$, $df = 5$), compared to 1.5 to 33 mm. Similarly, there was a significant regression of numbers of *V. atropilosa* trapped with all vial hole diameters tested (Table 1), which was stronger for 1.5 to 22 mm ($r^2 = 0.98$, $p = 0.0015$, $df = 5$), compared to 1.5 to 33 mm. There was not a significant linear relationship between vial hole diameter and numbers of *V. germanica* captured in this test (Table 1). Totals of 5075 *V. pensylvanica*, 172 *V. atropilosa*, 114 *V. germanica*, 18 *Dolichovespula maculata* (L.), 4 *Dolichovespula arenaria* (F.), 2 *Polistes aurifer* Saussure, and 1 *Polistes dominulus* (Christ) were captured in this second test in Yakima.

In the first dose-response test conducted in Tulsa, Oklahoma, there was a significant relationship between vial hole diameter and numbers of wasps trapped and greatest numbers of *V. squamosa* workers were captured in traps baited with vials with the largest hole size (12 mm diam) (Table 2). Also, in this test, numbers of *V. squamosa* workers captured in traps with vials releasing heptyl butyrate were significantly greater than numbers of workers in traps with vials that did not release heptyl butyrate, for vial hole diameters of 1.5 mm ($t = 2.03$, $p = 0.02$, $df = 29$), 3 mm ($t = 2.95$, $p = 0.003$), 6 mm ($t = 4.90$, $p = 1.7 \times 10^{-5}$), and 12 mm ($t = 6.2$, $p = 4.4 \times 10^{-7}$). No other vespine wasps, but six female *Polistes perplexus* (Cresson) and nine female *Polistes fuscatus* (F.) were captured in traps in this test. These numbers were not sufficient for statistical analyses.

Table 1. Mean (±SE) numbers of wasps captured per trap per trap-check. Traps baited with heptyl butyrate in polypropylene vials with varied hole diameters. Yakima, Washington, 2000.

Test 1, July 19-31	Vial hole diameter (mm)						Regression statistics	
Wasp species	0	1	1.5	3	6	12	r^2	p
V. atropilosa	0.0 ± 0.0	0.1 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.5 ± 0.1	1.9 ± 0.4	0.93	0.002
V. germanica	0.0 ± 0.0	0.2 ± 0.2	0.4 ± 0.2	0.6 ± 0.3	1.2 ± 0.6	1.6 ± 0.4	0.94	0.001
V. pensylvanica	0.0 ± 0.0	1.3 ± 0.3	2.4 ± 0.7	2.5 ± 0.7	6.8 ± 2.4	22.0 ± 7.1	0.95	0.001
Test 2, August 4-21	**Vial hole diameter (mm)**						**Regression statistics**	
Wasp species	1.5	3	6	12	22	33	r^2	p
V. atropilosa	0.1 ± 0.1	0.3 ± 0.1	0.6 ± 0.2	1.0 ± 0.3	2.6 ± 0.5	2.3 ± 0.4	0.84	0.01
V. germanica	0.3 ± 0.2	0.9 ± 0.3	0.4 ± 0.1	1.2 ± 0.4	1.1 ± 0.4	1.0 ± 0.3	0.37	0.20
V. pensylvanica	5.3 ± 1.4	12.7 ± 2.3	27.8 ± 5.5	34.9 ± 4.0	63.2 ± 5.1	58.3 ± 8.2	0.84	0.01

TABLE 2. MEAN (±SE) NUMBERS OF WASPS CAPTURED PER TRAP PER TRAP-CHECK. TRAPS BAITED WITH HEPTYL BUTYRATE IN POLYPROPYLENE VIALS WITH VARIED HOLE DIAMETERS. TULSA, OKLAHOMA, 2000.

Test 1, September 12-October 6	Vial hole diameter (mm)						Regression statistics	
Wasp species	0	1.0	1.5	3	6	12	r^2	p
V. squamosa	0.2 ± 0.2	0.3 ± 0.1	0.9 ± 0.3	1.3 ± 0.3	5.5 ± 1.0	11.2 ± 1.7	0.99	<0.001
Test 2. October 6-November 3	Vial hole diameter (mm)						Regression statistics	
Wasp species	1.5	3	6	12	22	33	r^2	p
V. squamosa	0.4 ± 0.1	1.1 ± 0.2	3.1 ± 0.7	6.3 ± 1.3	12.3 ± 2.1	17.8 ± 3.0	0.99	<0.001

In the second dose-response test conducted in Tulsa, there was a significant positive regression of numbers of wasps trapped with vial hole diameter, up through the largest hole tested, 33 mm, and the greatest numbers of *V. squamosa* captured were in traps baited with vials with 33 mm diameter holes (Table 2). A total of 582 *V. squamosa* workers were captured in the first test in Tulsa, while 1641 *V. squamosa* workers were captured in the second test in Tulsa. No other vespines, but six female *P. fuscatus*, were captured in these traps; not numerous enough for a statistical analysis.

For all vial hole diameters, weight losses from vials were steady over the 28 day duration of the study (Fig. 1). Y-intercepts of best fit line equations indicated initial release rates (weight losses) of 0, 0.42, 1.37, 2.30, and 3.30 milligrams per hour for vials with holes of 0, 6, 12, 22, and 33 mm in diameter. For vials with holes of 6, 12, 22, and 33 mm in diameter, there was no significant slope (for 6 mm diam holes, $r^2 = 0.05$, df = 10, p = 0.49; for 12 mm diam holes, $r^2 = 0.02$, df = 10, p = 0.65; for 22 mm diam holes, $r^2 = 0.00$, df = 10, p = 0.89; for 33 mm diam holes, $r^2 = 0.25$, df = 10, p = 0.12), indicating a near zero order release rate function. Heptyl butyrate on cotton balls was released at a higher rate initially, but decreased over time (Fig. 2). Initial weight losses were near 6 milligrams per hour, decreasing to 5 mg/hr by day 9 and near

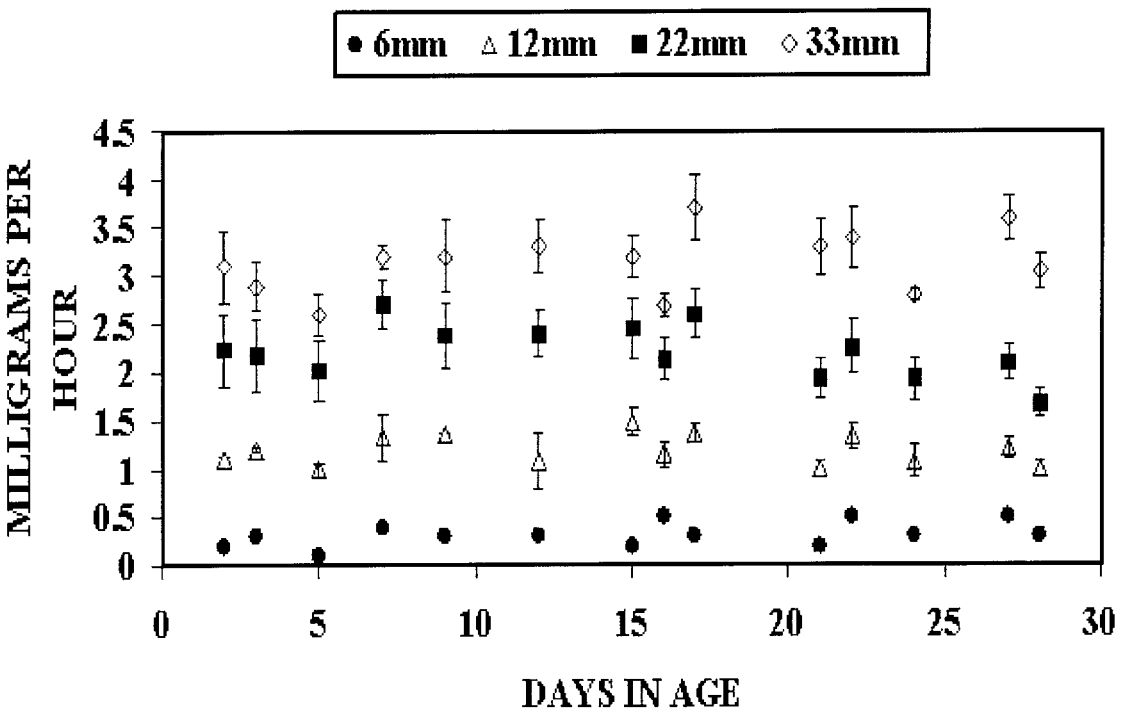

Fig. 1. Mean (±SE) milligrams of heptyl butyrate lost per hour from 30 ml polypropylene vials in a laboratory fume hood. Vials had lid holes with diameters of 6, 12, 22, and 33 mm.

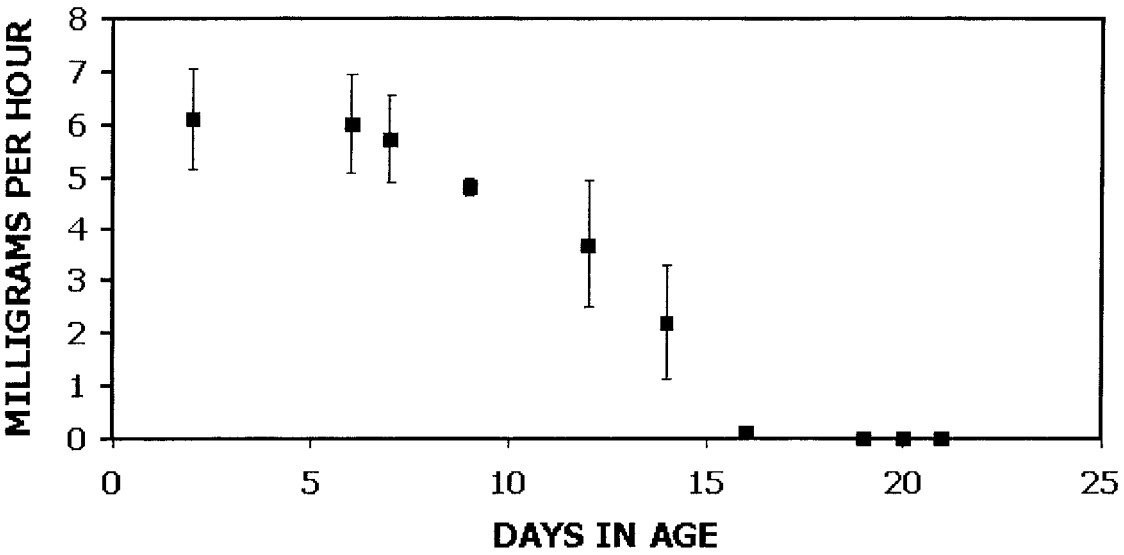

Fig. 2. Mean (±SE) milligrams of heptyl butyrate lost per hour from cotton balls in a laboratory fume hood. Cotton balls were soaked with 2 ml heptyl butyrate, and then were placed on aluminum foil weighing dishes.

zero mg/hr by day 16. Rate of loss of heptyl butyrate from exposed cotton balls was related to dispenser age ($r^2 = 0.93$, df = 9, $p < 0.01$).

Discussion

These results provide conclusive experimental evidence of worker response to heptyl butyrate for the southern yellowjacket *V. squamosa* and the German yellowjacket *V. germanica*. *Vespula squamosa* is widely distributed in eastern and central North America from the mid Atlantic states to the Gulf of Mexico (Akre et al 1981), and in areas of Central America as far south as Honduras (Hunt et al. 2001). *Vespula germanica* is native to Eurasia, and has become widely distributed and abundant throughout much of temperate North America (MacDonald & Akre 1984; Akre et al. 1989; Vetter et al. 1995). Both species are significant pests. Consistent and significant numbers of *V. squamosa* were captured in this study in traps baited with heptyl butyrate, demonstrating attraction to this chemical. The studies of Grothaus et al. (1973) suggested attractiveness of heptyl butyrate and other chemicals to *V. squamosa*, but did not include unbaited traps or traps that did not release heptyl butyrate as experimental controls, leaving open the question of whether or not *V. squamosa* workers are attracted. Sharp and James (1979) used a mixture of heptyl butyrate and octyl butyrate in their studies of *V. squamosa*, which did not include control traps for comparison. They did not address the question of *V. squamosa* worker attraction to heptyl butyrate, but rather sought to evaluate the attractiveness of trap colors.

A response of *V. germanica* workers to heptyl butyrate was also undocumented prior to this study. Small numbers of *V. germanica* workers were previously captured in traps baited with heptyl butyrate dispensed from a polyethylene cap (Landolt 1998), but unbaited traps were not included in that study as a control. Thus, conclusions could not be drawn regarding the attractiveness of the chemical to *V. germanica*. The experimental demonstration of attractiveness of these wasps to heptyl butyrate with their capture in baited traps does not address the question of the utility of the chemical as a practical means of trapping either species. However, comparisons of heptyl butyrate with lures that release acetic acid and isobutanol indicate a much stronger response by *V. germanica* to the latter attractant (Landolt 1998).

It is of interest, but not known, why numbers of *V. germanica* workers captured in traps in the first test in Yakima increased with vial hole diameter, and yet did not increase with vial hole diameter in the second test in Yakima. Possible variables to consider in future studies are the temperature effects on heptyl butyrate release rates in the field, competitive interactions with other social wasps at or in traps, and changes in responsiveness of *V. germanica* wasps to heptyl butyrate with the advance of the season, or variance in the availability of competing odor sources and food materials.

Greatest numbers of *V. squamosa* workers were captured in traps with heptyl butyrate in vials with the largest hole size tested (33 mm), which gave an estimated rate of loss of about 3.3 milligrams of heptyl butyrate per hour at 22.5°C in the laboratory. It is possible that more *V. squa-*

mosa wasps might be caught at even higher heptyl butyrate release rates.

It has been thoroughly established that very large numbers of *V. pensylvanica* workers can be captured in traps baited with heptyl butyrate (Davis et al. 1969; MacDonald et al. 1973), and results of this work are consistent with those reports. Significant numbers of *V. atropilosa* and *V. germanica* workers were captured in heptyl butyrate-baited traps here, indicating attraction to the chemical. *Vespula atropilosa* has been trapped extensively with heptyl butyrate (Davis et al. 1969; MacDonald et al. 1973). The numbers of both *V. atropilosa* and *V. germanica* captured were dramatically less than the numbers of *V. pensylvanica* captured. The relative differences in numbers of workers captured for different species may reflect both differences in population density at trapping sites and differences in responsiveness to the attractant (MacDonald et al. 1973).

These results provide information that can be used to optimize captures of yellowjackets in traps baited with heptyl butyrate and to provide a means of long-term sustained release of heptyl butyrate at an optimized release rate. An optimum release rate was determined for heptyl butyrate as an attractant for trapping *V. pensylvanica* as well as *V. atropilosa*. Laboratory data indicated release rates (weight losses) of 2.3 and 3.3 milligrams per hour respectively from vials with those hole diameters at laboratory temperatures. The amounts of heptyl butyrate emitted from these vials in the field will change with temperature, wind, and other variable environmental parameters, but these results provide a benchmark for comparison to other types of controlled release technologies and materials. The weight losses of vial dispensers loaded with heptyl butyrate were steady for 30 days for all hole sizes evaluated. Application of heptyl butyrate to a cotton ball (a presently-used commercial application) provided a release rate that was high and likely to be a strong attractant for 6 to 9 days, but changed with time and was reduced to near zero after two weeks, suggesting a relatively short period of attractiveness. The dispensing of heptyl butyrate from a suitable device has the potential of increasing both the attractiveness of the lure to wasps by stabilizing the release rate at a targeted amount and the longevity of the lure at that desired release rate.

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