Evaluation of Control Measures for Black Carpenter Ant (Hymenoptera: Formicidae)

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ABSTRACT Current control methods for the black carpenter ant, *Camponotus pennsylvanicus* (De Geer), include the use of remedial and preventative residual sprays as well as toxic baits. We evaluated the acceptance of three baits (Maxforce, Niban, and Baygon) to field colonies of the black carpenter ant in the spring and fall. Maxforce bait granules were more readily accepted than either Niban or Baygon bait granules in the spring. A change in food preference from protein to sugar by the black carpenter ant appeared to reduce the number of Maxforce bait granules removed in the fall, resulting in no differences in bait acceptability. The longevity of Dursban 50W and Tempo 20WP were evaluated in the summer and fall on painted wood panels. Panels aged outside for 15 d under prevailing weather conditions exhibited increased LT50 values. For each sampling period, panels aged on the south face (in the sun) exhibited less insecticidal activity (i.e., large LT50 values) than panels on the north face (shaded; small LT50 values). At each sampling period, Tempo 20WP provided smaller LT50 values than Dursban 50W. Because of changing dietary preferences, our data highlight the importance of using various bait types for carpenter ant control. Moreover, the application of residual spays should be made to locations protected from direct sunlight.

KEY WORDS black carpenter ant, *Camponotus pennsylvanicus,* bait, residual spray, control

CHEMICALLY BASED CARPENTER ant, *Camponotus pennsylvanicus* (DeGeer), control consists largely of remedial measures in infested voids and the application of a protective insecticidal barrier to the outside perimeter of the structure (Akre and Hansen 1988, 1990; Hedges 1998). Placement of insecticidal aerosols or dusts into voids eliminates existing infestations, whereas a continuous program of residual sprays around the outside perimeter of the structure is often necessary to prevent ants from entering. Gibson and Scott (1989) evaluated 14 insecticides for use against *C. pennsylvanicus* and found this species to be highly susceptible to diazinon, chlorpyrifos, and deltamethrin, among other active ingredients.

In theory, baits are ideal for use against ant pests because the ants transport the toxicant back to the nest and share it with other members of the colony. Baits replace the difficult and laborious task of finding and treating a nest site that may be located in an inaccessible area. Anecdotally, the acceptance, and thus efficacy, of available carpenter ant baits is variable at best. In addition, there exists little data regarding the longevity of residual sprays exposed to field conditions. The purpose of our study was to determine, under field conditions, the acceptability of three baits to black carpenter ants and to evaluate the residual longevity of two sprays exposed to outdoor weather conditions.

Materials and Methods

Bait Acceptance Assays. The qualitative factor bait was evaluated at three levels (i.e., Maxforce [1% hydramethylnon, Clorox, Pleasanton, CA,]; Niban [5% ortho boric acid, Nisus, Rockford, TN]; Baygon [2% propoxur, Bayer, Kansas City, MO]) and the qualitative factor season was simultaneously evaluated at two levels (i.e., spring and fall). For each bait, each of four or five colonies were provided bait granules from a small plastic dish (4 by 0.5 cm) placed 1–2 m from the tree housing the colony. Each dish containing 100 bait granules was placed next to a foraging trail at 2000 hours (EST). After 30 min, remaining granules were collected, returned to the laboratory, and the number removed was determined. This procedure was repeated in August with the same colonies used during June.

Food Preference Assays. Food selection studies were performed intermittently on 26 evenings be-

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tween 11 June and 24 August according to the method of Reid and Klotz (1992). On each evening that selection studies were performed, foraging ants from two, three, or four colonies were provided a choice of protein (i.e., diced mealworms) or carbohydrate (i.e., clover honey), and the quantity collected overnight measured gravimetrically; the same colonies were used throughout. Bait consumption was calculated as the difference in temperature cabinet-acclimated (24 h at 25°C and 50% RH) weights measured before and after testing, and corrected for weight change in unexposed controls. All experiments were initiated between 2000 and 2400 hours.

Longevity of Residual Sprays. During both June and September, the residual longevity of Tempo 20WP (Bayer) was evaluated against worker carpenter ants, whereas Dursban 50W (Dow AgroSciences) was evaluated only during September. Painted wood panels (232 cm^2) were treated with an automated spray tower. Each Tempo-treated panel was sprayed with 0.95 ml of a 0.10% suspension (i.e., 0.10% at 4.1 liters/100 m^2 [= 1 gal/1,000 $feet^2$]). Each Dursban-treated panel was sprayed with 4.73 ml of a 0.24% suspension (i.e., 0.12% at 41 liters/100 m^2 [= 10 gal/1,000 $feet^2$]). The spray volume was halved and the concentration doubled for Dursban to avoid suspension runoff during treatment.

A wall (1.6 by 1.2-m plywood boards with a north and a south face) was constructed outdoors, and 10 (i.e., five replicate panels per treatment) insecticide-treated panels hung in a checkerboard pattern (i.e., alternating treatments) to two rows on each face of the wall. A third plywood board (1.6 by 0.9 m) was placed on the top of the wall to simulate the eaves of a home.

After 0, 10, and 15 d of aging, panels were returned to the laboratory, and 10 worker ants were confined to each panel, and the number dead recorded at 1-min intervals until all ants were dead. Field-collected ants from five colonies were collected the night before testing and confined in plastic buckets, the interior wall was coated with a thin film of mineral oil and petroleum jelly (mixed 2:3) to prevent escape. Cotton wicks soaked in a 10% sucrose solution and a harborage were provided after ants were returned to the laboratory.

Statistical Methods. SAS software was used for all statistical analyses (SAS Institute 1985, Schlotzhauer and Littell 1987). The mean number of granules removed during the 30-min period was analyzed by two-way analysis of variance (ANOVA). After two-way ANOVA, one-way ANOVAs were performed among baits for each season, and between seasons for each bait. Means were separated with the Tukey honestly significant difference test.

Because row marginal totals were not fixed, food consumption data were analyzed by a chi-square test for independence with a 2 × 2 contingency table to test for independence between the variables time of year (fall or spring) and food type (carbohydrate or protein). Each cell in the 2 × 2 table consisted of the total quantity of food (either honey or mealworms) collected by the same three colonies on five different nights between 11 and 18 June (representing spring) and 18 and 24 August (representing fall).

Toxicity data were analyzed with SAS Probit (SAS Institute 1985). Each analysis yielded sample size (n), chi-square (with P value), slope (±SE), and 50% lethal time values (with 95% fiducial limits). For each factor level combination (i.e., panel age/treatment/face), each of the five replicates tested was composed of 10 ants collected from one of five colonies. Ants from the same five colonies were used during both seasons.

Table 1. Two-way ANOVA of seasonal bait acceptance (spring versus fall) by black carpenter ant

Source	df	SS	MS	F	P
Bait	2	3,396.3	1,698.1	14.3	0.0001
Season	1	1,227.8	1,227.8	10.4	0.0038
Bait × Season	2	2,616.0	1,308.0	11.0	0.0004
Error	23	2,728.8	118.6		
Total	28	9,968.8			

Results

Bait Acceptance. Two-way ANOVA indicated a highly significant interaction (P = 0.0004) between bait and season (Table 1). One-way ANOVA among the three baits indicated a preference for Maxforce in the spring (F = 20.70; df = 2, 11; P = 0.0002), but no preference in the fall (F = 0.74; df = 2, 12; P = 0.4969; Table 2). Furthermore, Maxforce granules were more acceptable in spring than in the fall (F = 12.15; df = 1, 7; P = 0.0102). There was no difference in the acceptance of Niban (F = 0.43; df = 1, 8; P = 0.5309) or Baygon (F = 2.45; df = 1, 8; P = 0.1559) granules between the spring and the fall.

Food Preference. The chi-square test indicated that a strong dependency exists between food type and time of year (χ^2 = 8,773.9, df = 1, P = 0.001). The resulting contingency coefficient of 0.396 indicated a moderately strong association between food type and time of year. Contingency coefficients (0 = no association to 1 = strong association) indicate the degree of association between two related variables.

Carpenter ant workers shifted food preference from proteins in early June to carbohydrates in late August; the shift appeared to occur sometime during the 18-d

Table 2. Mean ± SE number of ant bait granules removed by foraging black carpenter ants during a 30-min period

Bait	n^a	Season	
		Spring[b]	Fall[c]
Maxforce	5	52.3 ± 11.0ay	11.0 ± 6.1az
Niban	5	4.8 ± 1.7by	7.8 ± 4.3ay
Baygon	5	7.6 ± 2.4by	3.6 ± 0.8ay

Means within (a or b) or across (y or z) a column followed by the same letter are not significantly different.

[a] For each bait the same five colonies were bioassayed during each season. Exception: n = four colonies tested for Maxforce in the spring.

[b] Assays conducted between 4 and 24 June 1997.

[c] Assays conducted between 24 and 26 August 1997.

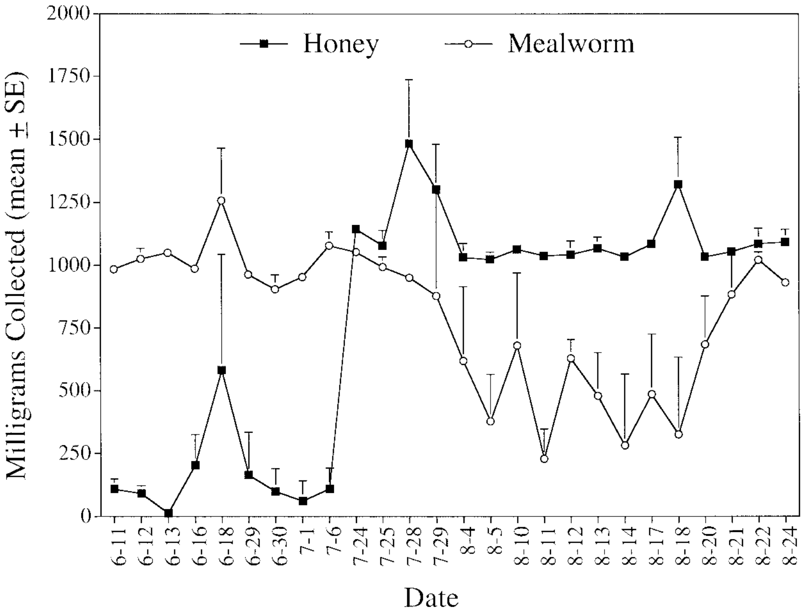

Fig. 1. Collection of clover honey and diced mealworms by colonies of black carpenter ants from 11 June to 24 August. Each value represents the mean ± SE consumption by n = two, three, or four colonies.

period from 6 to 24 July (Fig. 1). During the nine dates tested from 11 June to 6 July, the mean ratio of protein-to-carbohydrate consumption was 16.5 ± 8.1 (median ratio = 9.1); and carpenter ant colonies removed a mean of 905–1,258 mg of protein per night compared with 13–582 mg of carbohydrate. On the subsequent 17 dates (between 24 July to 24 August) the mean consumption ratio had dropped to 0.61 ± 0.06 (median = 0.64), and colonies removed a mean of 229–1,054 mg of protein per night compared with 1,024–1,483 mg of carbohydrate.

Residuals. Residual toxicity data are presented in Table 3. During June, regardless of the face on which panels were aged, the insecticidal activity of Tempo decreased with aging. The LT50 of panels aged on either the north or south face showed an increase of 13 and 20 min from day 10–15, respectively; the insecticidal activity of Tempo-treated panels aged on the south face was less (i.e., larger LT50) than the insecticidal activity of panels aged on the north face. After 10 and 15 d aging, the LT50 of ants exposed to panels aged on the south face was 10 and 17 min longer, respectively, than the LT50 of ants exposed to panels aged on the north face.

During September, regardless of the face on which panels were aged, the activity of both insecticides decreased with age. Fresh (i.e., day 0) deposits of Tempo provided an LT50 of 15.9 min. The activity of

Table 3. Probit analysis of black carpenter ant worker mortality on painted-wood panels aged outdoors

Month	Day	Face	Product	n^a	Slope ± SE	LT_{50}, min	95% CI	$(\chi^2)^b$
June[c]	0	—	Tempo	50	12.4 ± 1.1	22.3	21.8–22.8	1.8
	10	North	Tempo	50	1.9 ± 0.1	17.5	15.3–19.5	63.6
		South	Tempo	50	5.2 ± 0.3	27.3	26.3–28.2	14.4
	15	North	Tempo	50	2.6 ± 0.1	30.1	28.3–31.8	63.6
		South	Tempo	50	8.4 ± 0.5	47.8	46.9–48.7	22.7
September[d]	0	—	Tempo	100	8.4 ± 0.8	15.9	15.5–16.3	1.5
		—	Dursban	100	8.4 ± 0.3	45.7	45.1–46.3	3.6
	10	North	Tempo	50	6.0 ± 0.4	20.3	19.6–20.9	8.0
		North	Dursban	50	7.7 ± 1.4	125.5	115.8–146.8	0.2
		South	Tempo	50	6.8 ± 0.7	29.0	27.7–30.8	45.7
		South	Dursban	50	—	>2 h	—	—
	15	North	Tempo	50	6.6 ± 0.3	26.4	25.7–27.1	13.0
		North	Dursban	50	3.0 ± 0.6	160.6	131.1–252.6	1.1
		South	Tempo	50	5.4 ± 0.2	40.0	39.1–41.0	21.5

[a] Number of insects used in the probit analysis.
[b] Pearsons chi-square-goodness-of-fit test. Excluding "Fall/Tempo 20WP/Day 10/South face (P = 0.0005)", all P values are >0.100, indicating goodness-of-fit.
[c] From 9 June to 23 June.
[d] From 10 September to 24 September.

panels treated with Tempo and exposed on the north or south face was reduced 10.5 and 24.1 min, respectively, after 15 d of aging (15.9 to 26.4 min from day 0–15 on the north face and 15.9 to 40 min on the south face). Fresh deposits of Dursban provided an LT50 of 45.7 min; the activity of panels exposed for 10 d on either the north or south face was reduced to >2 h. Regardless of the chemical tested, the insecticidal activity of panels aged on the south face was less than that of panels aged on the north face. After 10 and 15 d aging, the LT50 of ants exposed to Tempo-treated panels aged on the south face was 8.7 and 13.6 min longer, respectively, than the LT50 of ants exposed to panels aged on the north face. A similar trend was noted for Dursban after 10 d of aging (Table 3), although Tempo (LT50 of 15.9 min at day 0) was significantly more toxic to *C. pennsylvanicus* than Dursban (LT50 of 45.7 min at day 0). Regardless of face, after 0, 10, and 15 d aging, the LT50 of ants exposed to Tempo was less than the LT50 of ants exposed to Dursban.

Discussion

The seasonal variability in collection of a solid protein-based bait such as Maxforce by foraging carpenter ants may be related to a change in the colony's food requirements because of differences in larval and adult diet. This is reflected in the distinct shift in the ants' collection from mealworms to honey from June to August.

With the onset of egg production and larval growth in spring and early summer (Hansen and Akre 1993), an ant colony requires a high level of protein to feed its developing larvae (Abbott 1978). Cornelius and Grace (1997) demonstrated that protein uptake by laboratory colonies of *Ochetellus glaber* (Mayr) was directly related to the amount of brood present. Protein-based solid foods are fed to the larvae by workers who are unable to consume solids and lack the necessary endopeptidases in their foregut to digest them (Stradling 1987). The quantity and quality of nitrogen in the proteins and amino acids ingested are the key factors for growth and development (Hagen et al. 1984). Later in the summer, as newly eclosed ants add to the worker force (Fowler 1986), the colony's dietary needs shift predominantly to carbohydrates, the primary energy source of adults (Abbott 1978).

Dietary changes occur on a yearly basis in Argentine ants, *Linepithema humile* (Mayr). Markin (1970) found that the amount of prey fluctuated with 0.8 ants per 1,000 carrying prey in November to 8.6 ants per 1,000 in May. M. K. Rust (personal communication) found that acceptance of sucrose or honey by Argentine ants dropped off slightly from December through February. Partitioning of a colony's nutrients also has been documented within the nest by red imported fire ants, *Solenopsis invicta* Buren, where workers feed solid protein to larvae as soon as it is collected and retain honey longer for themselves (Sorenson and Vinson 1981).

The higher contact toxicity of cyfluthrin (as 0.5% Tempo 10WP) to *C. pennsylvanicus* compared with chlorpyrifos (as 0.5% Dursban LO) was reported by Klotz and Reid (1994) in a field test of residual insecticides. Twenty-eight days after treatment, cyfluthrin was still killing 50% of exposed workers, whereas chlorpyrifos was ineffective even on fresh deposits. In addition, Klotz and Reid (1994) reported an increase of cyfluthrin's toxicity over time. The increased efficacy of cyfluthrin over time may be the result of tests being performed at lower temperatures (negative temperature-activity coefficient). Klotz and Reid (1994) conducted bioassays in the field where ambient temperature fluctuated widely from one test to the next.

In laboratory bioassays, Gibson and Scott (1989) exposed *C. pennsylvanicus* to chlorpyrifos and 13 other contact insecticides. Ants were exposed to the insecticides in jars coated with the active ingredient dissolved in acetone. Gibson and Scott (1989) reported that chlorpyrifos was highly toxic (LC50 = 0.29) to the carpenter ants. The contrast in toxicity of chlorpyrifos in our tests and those reported by Gibson and Scott (1989) may be caused by differences in experimental design, formulation of insecticide, and substrate. Tests by Gibson and Scott (1989) were conducted indoors with technical grade insecticide applied to glass.

Our results indicate that exposure to outdoor weather conditions rapidly degrades residual sprays. Akre and Hansen (1990) stated that residual sprays should be applied under the eaves of a home and thus out of direct sunlight. We strongly support this advice based on results of our tests. Currently, residual perimeter sprays are a preferred means of carpenter ant control. They are simple and quick to apply, but as these experiments indicate, they are only effective for a short period of time.

A review of weather data collected at the Purdue University airport indicated that there were 4 and 6 d of precipitation during the spring and fall aging periods, respectively. The most significant precipitation during the spring aging period occurred on the fourth and fifth day, when 0.66 and 3.51 cm of rain fell, respectively. No other day during either season had >0.5 cm of rainfall. Panels were arranged in a checkerboard pattern to ensure that the influence of rain or other weather factors might be minimized. Because the panels on each face showed similar rates of insecticide degradation during both seasons, rain does not appear to have influenced the results.

Ultra-violet light is generally considered a strong factor influencing insecticide degradation (Zepp and Cline 1977, Tanaka et al. 1985, Torrents et al. 1997). Katagi (1993) studied the photodegradation of esfenvalerate in clay suspensions and found it to have a half-life of 4 d when exposed to UV light. Although Tempo appeared to have a greater half-life than 4 d, it was still measurably degraded after 10 d of outside exposure, as indicated by the increased LT50 values. In this study, the south face received more direct sunlight and thus a greater exposure to UV light than the north face. This supports the results in Table 3 that show a more rapid degradation on the south face.

Control of carpenter ants includes the application of baits and residual chemical barriers (Hansen 1996). Unfortunately, baits have shown only marginal efficacy. Therefore, residual insecticides continue to be used extensively until more effective carpenter ant baits become available. Proper application of residual insecticides will maximize their efficacy and longevity, while minimizing human exposure and environmental damage (Rust 1995). Specific sites, such as the lower edge of siding and around window and door frames, can be treated so that carpenter ants encounter the deposits while foraging. Insecticide application in these cryptic areas where carpenter ants tend to trail protects the active ingredient from direct sunlight and rain (Hansen and Akre 1993), and reduces the negative impact of wide-scale barrier treatments, which kill many of the beneficial insects and may result in secondary pest outbreaks (Smith et al. 1996).

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