Bait Distribution Among Multiple Colonies of Pharaoh Ants (Hymenoptera: Formicidae)

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ABSTRACT Pharaoh ant, *Monomorium pharaonis* (L.), infestations often consist of several colonies located at different nest sites. To achieve control, it is desirable to suppress or eliminate the populations of a majority of these colonies. We compared the trophallactic distribution and efficacy of two ant baits, with different modes of action, among groups of four colonies of Pharaoh ants. Baits contained either the metabolic-inhibiting active ingredient hydramethylnon or the insect growth regulator (IGR) pyriproxyfen. Within 3 wk, the hydramethylnon bait reduced worker and brood populations by at least 80%, and queen reductions ranged between 73 and 100%, when nests were in proximity (within 132 cm) to the bait source. However, these nest sites were reoccupied by ants from other colonies located further from the bait source. The pyriproxyfen bait was distributed more thoroughly to all nest locations with worker populations gradually declining by 73% at all nest sites after 8 wk. Average queen reductions ranged from 31 to 49% for all nest sites throughout the study. Even though some queens survived, brood reductions were rapid in the pyriproxyfen treatment, with reductions of 95% at all locations by week 3. Unlike the metabolic inhibitor, the IGR did not kill adult worker ants quickly, thus, more surviving worker ants were available to distribute the bait to all colonies located at different nest sites. Thus, from a single bait source, the slow-acting bait toxicant provided gradual, but long-term control, whereas the fast-acting bait toxicant provided rapid, localized control for a shorter duration.

KEY WORDS *Monomorium pharaonis*, foraging, hydramethylnon, pyriproxyfen, insect growth regulator, ant control

THE CONTROL OF Pharaoh ants, *Monomorium pharaonis* (L.), with toxic baits has been documented in several studies, including Edwards and Clarke (1978), Oi et al. (1994, 1996), Vail et al. (1996), and Williams and Vail (1994). Success of toxic baits may be attributed largely to the acceptance of the baits by the ants and the delayed toxicity of the active ingredients used. This delay permits the trophallactic distribution of the toxic bait throughout the colony before the ants begin to die. The onset of mortality is contingent upon the type of active ingredient. In general, ant baits that contain active ingredients that are metabolic inhibitors, for example hydramethylnon or sulfluramid, have a 2- to 3-d delay before extensive mortality occurs throughout the colony. This delay was documented in red imported fire ants, *Solenopsis invicta* Buren, by Williams et al. (1980) and Vander Meer et al. (1985) and also was observed in Pharaoh ants (unpublished data). Baits containing insect growth regulators (IGRs), such as methoprene, fenoxycarb, or pyriproxyfen, take several weeks before colony populations are reduced substantially or killed. In Pharaoh ants this reduction is attributed to the disruption of brood development. In addition, reduced oviposition and minor amounts of adult worker caste mortality have been reported (Edwards 1975, Williams and Vail 1993, Vail and Williams 1995).

Pharaoh ants are a polygynous and polydomous species, and structural infestations often contain multiple colonies. Anecdotal reports from pest control operators indicate rapid reinfestations after treatments with bait containing a metabolic inhibitor. We speculated that colonies killed by this type of active ingredient are quickly replaced by other colonies in the vicinity because the nest site represents a favorable habitat. Because IGR effects are manifested more slowly, we hypothesized that baits containing IGRs would be distributed more extensively among multiple colonies of Pharaoh ants than metabolic inhibitor baits. Thus, the two objectives of this study were as follows: (1) to compare the populations among multiple colonies of Pharaoh ants that had access to either a metabolic inhibiting or insect growth-regulating bait; and (2) to compare the extent of bait distribution between these two types of bait among multiple Pharaoh ant colonies.

Materials and Methods

Pharaoh ants were obtained from colonies maintained at the United States Department of Agriculture,

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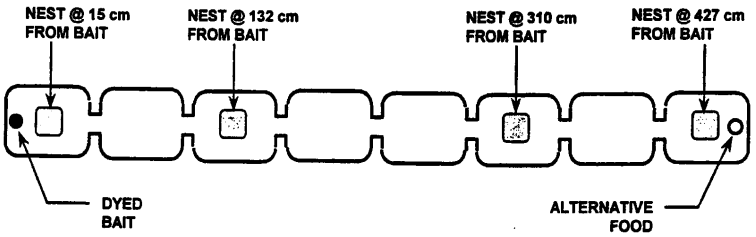

Fig. 1. Pharaoh ant nest locations and the placement of dyed bait and nondyed alternative food within a series of eight connected trays.

Agricultural Research Service, Center for Medical, Agricultural and Veterinary Entomology in Gainesville, FL. For each treatment and replicate, a portion of a Pharaoh ant colony was divided into four subcolonies consisting of 15 queens, 1 g of brood (eggs, all larval stages, and pupae), and 0.5 g of workers (≈2,100 workers). Each subcolony was placed in a nest cell (10 by 10 by 1.5 cm) (Williams 1990) and then placed in separate sections of a foraging arena. The foraging arena consisted of eight trays (56.8 by 44.5 by 12.7 cm) connected by PVC pipe and vinyl tubing, which resulted in a 4.7-m-long arena (Fig. 1). Nest cells were placed in alternate trays starting with the trays at each end. Bait (2 g) was place in one end tray and an alternative source of food (2 g) was placed in the other end tray. As a result, colonies were located at distances of 15, 132, 310, and 427 cm from the bait, and at reciprocal distances from the alternative food source (Fig. 1). The alternative food source was included to reflect field conditions, where access to nonbait food sources are generally available. To increase foraging activity, colonies were starved for 5–7 d before baits and alternative food were provided. Only water was available during the starvation period. Baits consisted of a pregel defatted corn grit (Illinois Cereal Mills, Paris, IL) carrier containing 30% (wt:wt) unprocessed peanut oil dyed with calco blue (1% wt:wt in oil) and either the metabolic inhibitor hydramethylnon (0.9% wt:wt in dyed oil) or the IGR pyriproxyfen (0.5% wt:wt in dyed oil). The 0.9% hydramethylnon concentration has been used in commercial ant bait preparations, and the 0.5% pyriproxyfen concentration was an effective concentration for Pharaoh ant control in studies by Vail and Williams (1995). The alternative food source consisted of pregel defatted corn grit carrier mixed with 30% (wt:wt) nondyed, unprocessed peanut oil. After 7–9 d, frozen crickets and honey-water were added next to the baits and alternative food source. The experiment was replicated six times.

The number of live adult Pharaoh ant workers and queens was counted within each nest cell and tray. Dead ants were removed from trays to facilitate counting. The amount of brood in each nest cell was estimated by comparing it with photographs of visually distinguishable amounts of brood (Williams and Vail 1993). The photographs corresponded to brood quantities of the following weights: 0.0, 0.0048, 0.012, 0.099, 0.187, 0.273, 1.317, 2.358, 3.410, or 3.647 g. These weights represented points on a continuous scale.

The extent of the trophallactic distribution of the baits among the colonies was based on the percentage of adult workers and larvae that contained blue dye as perceived visually under 3.5× binocular magnification (Optivisor model DA-10, Doengan Optical, Lenexa, KS). The percentage of workers with dye was determined by inspecting 20 individuals, from four arbitrarily selected areas on the outer edge and 20 individuals from four areas toward the inner portion of each nest cell, and counting the number of dyed ants out of five ants in each area. The percentage of workers with dye from the inner and outer portions of the nest cell were then averaged together to provide the percentage of workers with dye for the entire nest. The percentage of larvae with dye was based on a total of 20 larvae that contained food boluses. Five larvae, from four arbitrarily selected sites along the periphery of the brood pile of each colony were examined for dye. The percentages of dyed workers and larvae at each sample site within a nest were averaged to obtain an estimate of the percentage of the colony that was dyed. Observations for the presence of dye were made on the first 3 d after bait introduction and then weekly for 8 wk.

The number of live workers, the number of live queens, and the brood levels were determined for each tray containing a nest cell at weekly intervals after baits were provided for a total of 8 wk. The number of live workers was transformed $[\sqrt{(x + 0.5)}]$ to provide more homogeneous variances. Analyses of variance (ANOVA) (PROC GLM, SAS Institute 1996) for a split-split plot design with subunits in strips (Cochran and Cox 1957, Steel and Torrie 1980) were used to compare the number of live workers, grams of brood, and the number of live queens among active ingredients used in the baits, nest locations, and time (weeks). Main plot treatments were the active ingredients, the subplots were the nest location distances from the baits, and the sub-subplots were the weeks when counts were obtained. Significant main plot treatments were compared among each other with orthogonal contrasts. Simple linear, quadratic, and cubic regression models also were tested for significance among nest locations and time (weeks) after bait introductions.

Table 1. Mean ± SE number of live workers per nest cell among active ingredients and nest locations over the 8-wk study period

Nest Location, cm from bait	Active Ingredient			
	Control	Hydramethylnon	Pyriproxyfen	Mean ± SE
15	1,626.8 ± 215.7	564.3 ± 134.0	1,134.0 ± 150.8	1,108.3 ± 140.1
132	1,769.7 ± 182.7	728.6 ± 175.7	1,166.7 ± 100.1	1,221.7 ± 134.1
310	1,782.0 ± 223.3	1,116.2 ± 177.2	1,240.3 ± 123.3	1,379.5 ± 119.9
427	1,774.3 ± 235.8	1,779.6 ± 300.0	1,359.5 ± 160.4	1,637.8 ± 138.1
Mean ± SE	1,738.2 ± 101.3	1,047.2 ± 137.0	1,225.1 ± 65.8	

Note that active ingredient × nest location × week interaction was significant.

Results

Adult Worker Ants. When compared over all nest locations and weeks with orthogonal contrasts, there were significantly fewer live worker ants in the hydramethylnon and pyriproxyfen bait treatments than in the control bait ($F = 30.82$; df = 1, 10; $P < 0.001$). No signficant differences were observed between the two insecticide treatments ($F = 3.40$; df = 1, 10; $P = 0.0950$; Table 1). The regression analysis indicated a significant linear increase in worker ant populations at each nest site as nest distances increased from the treated bait source ($F = 36.70$, df = 1, 15; $P < 0.001$), when compared over all treatments and weeks (Table 1). However, when ant populations from each bait treatment were examined by ANOVA among nest locations, or weeks, or locations and weeks, there were significant interactions of treatment × location ($F = 5.86$; df = 6, 30; $P < 0.001$), treatment × week ($F = 13.80$; df = 16, 80; $P < 0.001$), location × week ($F = 2.13$; df = 24, 120; $P = 0.004$), and treatment × location × week ($F = 2.49$; df = 48, 240; $P < 0.001$). Regression analysis of these interactions partitioned into first through third order regressions on weeks showed that worker populations had significant curvilinear responses (Table 2). These responses are depicted in Fig. 2 where there were varying patterns in the number of live workers for each treatment and nest location over time. For colonies exposed to the hydramethylnon bait, the nests located closest to the bait at 15 and 132 cm had 99.4 and 89.8% reductions in workers, respectively, by the second week after bait exposure. Populations at these nest sites slowly rebounded, probably from ants moving from the nests located at 310 and 427 cm. Maximum worker reductions of 71.8 and 36.4% were recorded at the 310- and 427-cm nest locations, respectively (Fig. 2B). For the pyriproxyfen treatment, there was a gradual decline in worker populations at all nest locations. Percentage of reductions from initial nest populations after 8 wk was 88.7, 86.4, 82.2, and 72.9% for nests located at 15, 132, 310, and 427 cm from the bait, respectively (Fig. 2C). In the controls, average percentage of reductions in worker populations was between 18.7 and 25.1% per nest location (Fig. 2A).

Brood. Orthogonal contrasts showed that brood quantity (g) was reduced significantly in the treatments containing hydramethylnon and pyriproxyfen versus the control ($F = 47.2$; df = 1, 10; $P < 0.001$) when compared across all nest locations and weeks. Similarly, significantly less brood was observed in the pyriproxyfen treatment compared with the hydramethylnon treatment ($F = 9.6$; df = 1, 10; $P = 0.011$; Table 3). Analyses of the regression models revealed that when brood was combined over treatments and weeks, there was a significant linear increase in brood as nest distances increased from the treated baits ($F = 12.52$, df = 1, 15; $0.01 > P > 0.001$; Table 3). However, when brood from each bait treatment were examined among nest locations, weeks, or locations and weeks, there were significant interactions of treatment × location ($F = 5.07$; df = 6, 30; $P = 0.0011$), treatment × week ($F = 5.56$; df = 16, 80; $P < 0.001$), location × week ($F = 1.61$; df = 24, 120; $P = 0.05$), and treatment × location × week ($F = 1.82$, df = 48, 240,

Table 2. Regression analysis results of simple curvlinear models (first to third order) of Pharaoh ant adult worker populations, grams of brood, and live queens on weeks and treatment or nest location interactions

Source	df	Workers F value	Brood F value	Queens F value
Week	1, 40	71.34***	25.26***	344.35***
Week^2	1, 40	25.10***	7.30**	41.31***
Week^3	1, 40	11.60**	3.60 NS	1.07 NS
Week × Treat.	2, 80	68.47***	19.74***	70.94***
Week^2 × Treat.	2, 80	23.52***	20.53***	9.35***
Week^3 × Treat.	2, 80	12.60***	0.35 NS	11.61***
Week × Location	3, 120	1.92 NS	1.14 NS	0.58 NS
Week^2 × Location	3, 120	9.03***	4.32**	4.01**
Week^3 × Location	3, 120	2.75*	2.27 NS	4.07**
Week × Treat. × Loc.	6, 240	1.83 NS	1.62 NS	4.84***
Week^2 × Treat. × Loc.	6, 240	6.07***	7.07***	1.80 NS
Week^3 × Treat. × Loc.	6, 240	6.42***	3.17**	2.80**

Treat., treatment; Loc., location. NS, $P > 0.05$; *, $0.05 \geq P > 0.01$; **, $0.01 \geq P > 0.001$; ***, $P < 0.001$.

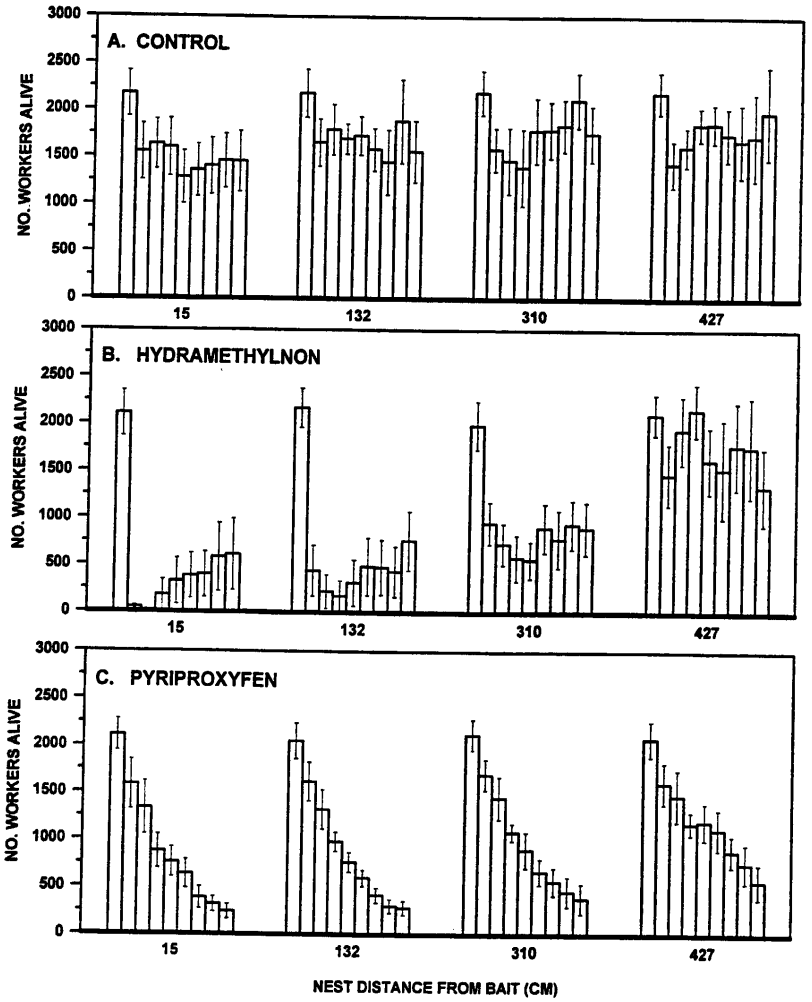

Fig. 2. Mean ± SE (n = 6) number of live adult worker ants per nest located at 15, 132, 310, and 427 cm from the dyed bait containing. (A) No active ingredient (control). (B) Hydramethylnon. (C) Pyriproxyfen. Each column per nest location represents a weekly sample obtained at 0–8 wk after baits were introduced.

P = 0.002). Regression analysis of these interactions partitioned into first- through third-order regressions on weeks showed various significant curvilinear responses in the grams of brood per nest (Table 2). These responses are shown in Fig. 3 where brood weights vary among each treatment, nest location, and weekly sample. For colonies exposed to the hydramethylnon bait, the nests located 15, 132, and 310 cm from the bait had maximum reductions of 99.6% at 2 wk, 83.3% at 3 wk, and 73.0% at 4 wk, respectively. By week 8, average brood weights had increased from the lowest levels during the 8-wk period. At the 427-cm nest location, average brood weight was greater than the initial brood level on all samples dates except at 7

Table 3. Mean ± SE grams of brood per nest cell among active ingredients and nest locations over the 8-wk study period

Nest Location, cm from bait	Active ingredient			
	Control	Hydramethylnon	Pyriproxyfen	Mean ± SE
15	1.265 ± 0.240	0.388 ± 0.096	0.463 ± 0.045	0.706 ± 0.127
132	1.532 ± 0.153	0.613 ± 0.121	0.568 ± 0.053	0.904 ± 0.125
310	1.400 ± 0.190	0.843 ± 0.156	0.600 ± 0.044	0.948 ± 0.113
427	1.372 ± 0.223	1.570 ± 0.264	0.587 ± 0.053	1.176 ± 0.150
Mean ± SE	1.392 ± 0.097	0.854 ± 0.122	0.555 ± 0.025	

Note that active ingredient × nest location × week interaction was significant.

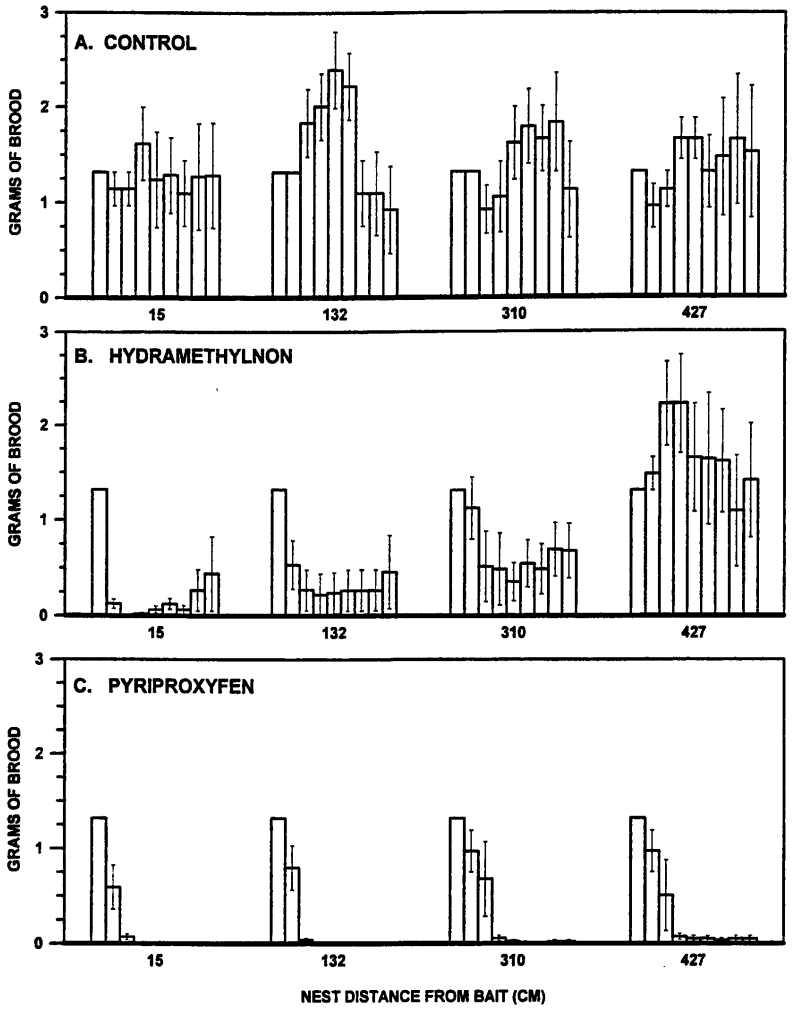

Fig. 3. Mean ± SE ($n = 6$) grams of brood per nest located at 15, 132, 310, and 427 cm from the dyed bait containing. (A) No active ingredient (control). (B) Hydramethylnon. (C) Pyriproxyfen. Each column per nest location represents a weekly sample obtained at 0–8 wk after baits were introduced.

wk (Fig. 3B). In the pyriproxyfen treatment, there was a rapid decline in brood at all nest locations where percentage of reductions were >94.8% after 3 wk. These low brood levels declined further through the end of the study (Fig. 3C). Average brood levels in the control generally were maintained or increased from initial levels at all nest locations (Fig. 3A).

Queens. Orthogonal contrast comparisons of the number of live queens revealed significant reductions in the hydramethylnon and pyriproxyfen treatments compared with the control ($F = 66.69$; df = 1, 10; $P < 0.001$) when examined over all nest locations and weeks. However, the queen numbers did not differ significantly ($F = 3.51$; df = 1, 10; $P = 0.0905$) between the pyriproxyfen and hydramethylnon treatments (Table 4). Regression analyses showed a significant linear increase in queens as nest distances increased from the treated baits ($F = 26.15$; df = 1, 15; $P < 0.001$) when examined over all treatments and time (Table 4). However, there were significant interactions when the numbers of live queens from each bait treatment were examined among nest locations, weeks, or location and weeks. These interactions included treatment × week ($F = 12.29$; df = 16, 80; $P < 0.001$), location × week ($F = 1.86$; df = 24, 120; $P = 0.0156$), and treatment × location × week ($F = 1.46$; df = 48, 240; $P = 0.0344$). Partitioning these interactions into first- through third-order regression models on weeks revealed various significant curvilinear responses in the number of live queens per nest (Table 2). Fig. 4 illustrates these responses among treatments, nest locations, and weekly sample dates. For colonies exposed to the hydramethylnon bait, queen reductions ranged from 73.3 to 100%, within 2 wk, at nests located 132 and 15 cm from the bait, respectively. At the 310- and 427-cm nest locations, queen reductions were

Table 4. Mean ± SE number of queens per nest cell among active ingredients and nest locations over the 8-wk study period

Nest location, cm from bait	Active ingredient			Mean ± SE
	Control	Hydramethylnon	Pyriproxyfen	
15	11.4 ± 1.6	4.7 ± 0.7	7.6 ± 1.3	7.9 ± 0.94
132	12.4 ± 1.2	5.2 ± 1.2	7.6 ± 1.0	8.4 ± 0.95
310	12.7 ± 0.9	8.2 ± 1.2	8.8 ± 0.7	9.9 ± 0.70
427	13.6 ± 1.9	11.3 ± 1.4	10.3 ± 0.8	11.7 ± 0.86
Mean ± SE	12.5 ± 0.69	7.3 ± 0.77	8.6 ± 0.51	

Note that active ingredient × nest location × week interaction was significant.

more gradual, reaching 93.3 and 80.0% after 8 wk, respectively (Fig. 4B). In the pyriproxyfen treatment, the number of queens generally decreased over time with some fluctuations (Fig. 4C). Percentage of reductions averaged over all sample dates were 49.3, 48.8, 41.3, and 31.3% for nests located at 15, 132, 310, and 427 cm from the bait, respectively. In the control, the average number of live queens fluctuated between 5.3 and 17 (Fig. 4A) with an overall reduction of 16.4% for all nest locations and sample dates.

Dye Distribution. The presence of dye in the workers and brood among nest locations and sample dates

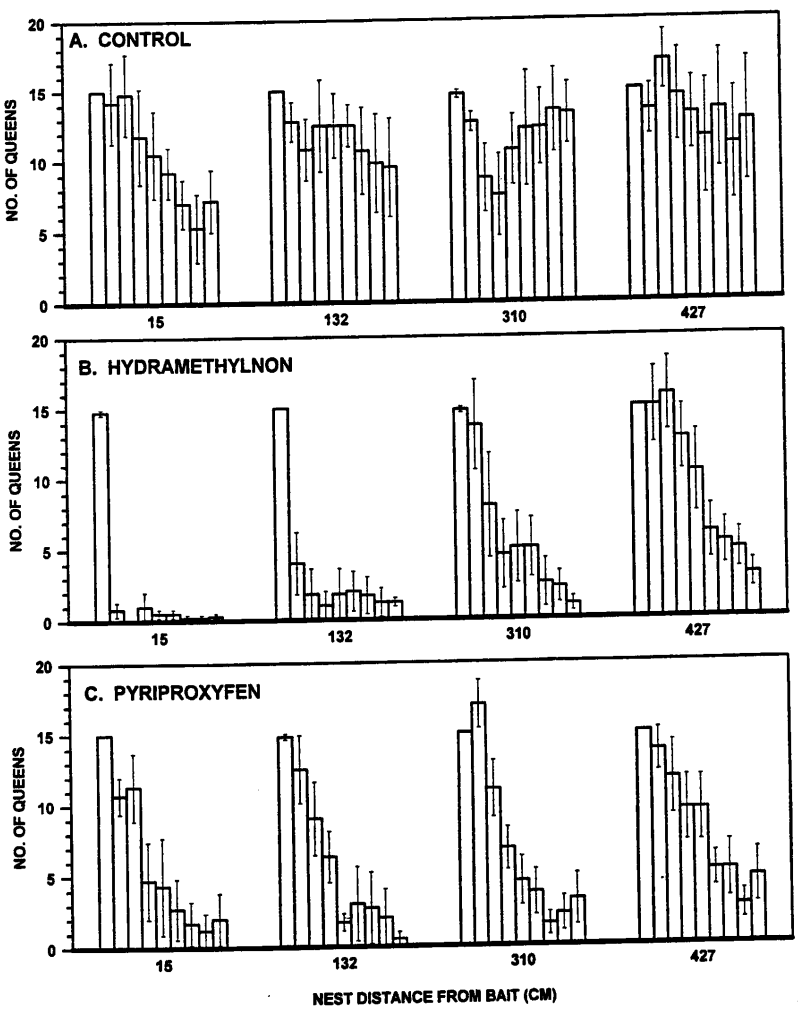

Fig. 4. Mean ± SE ($n = 6$) number of live queens per nest located at 15, 132, 310, and 427 cm from the dyed bait containing. (A) No active ingredient (control). (B) Hydramethylnon. (C) Pyriproxyfen. Each column per nest location represents a weekly sample obtained at 0–8 wk after baits were introduced.

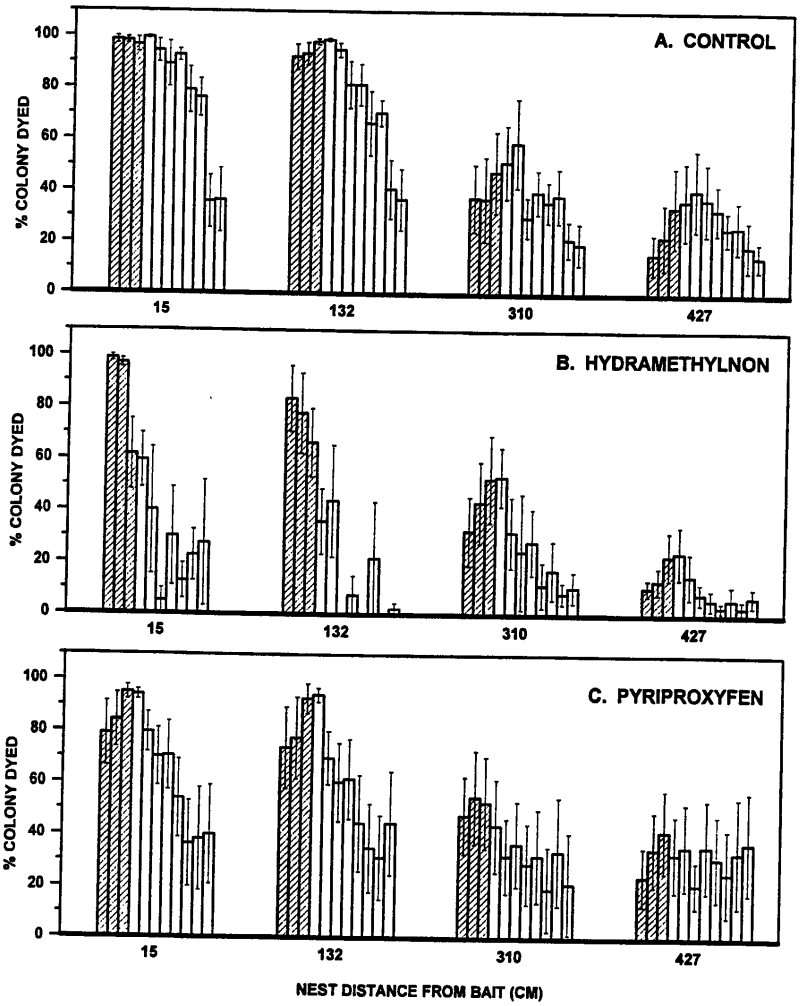

Fig. 5. Mean ± SE (n = 6) percentage of the colony dyed per nest located at 15, 132, 310, and 427 cm from the dyed bait containing: (A) No active ingredient (control). (B) Hydramethylnon. (C) Pyriproxyfen. Each clear column per nest location represents a weekly observation obtained at 1–8 wk after baits were introduced. Shaded columns represent observations obtained at 1, 2, and 3 d after baits were introduced.

provided an indication of how efficiently bait was distributed. In the hydramethylnon treatment, dye was observed in at least 78% of the colony members in nests located at 15 and 132 cm for the first 2 d after bait introduction. Fig. 5B indicates that after day 2 there was a rapid decrease in dye presence, which corresponded to the reduction in colony populations at these locations. After the fourth week, when these nest locations began to be repopulated, dye presence fluctuated between 0 and 30%. At the 310- and 427-cm nest locations, maximum dye presence was 53 and 24%, respectively, both at the 1-wk sampling (Fig. 5B).

From Fig. 5C, dye distribution in the pyriproxyfen treatment was between 74 and 94% at the 15- and 132-cm nest locations during the first week of bait access. Dye presence was always >30% for the remainder of the study at these locations. At nests located at 310 and 427 cm, the average dye presence was more uniform throughout the 8-wk study, with a maximum of 55% and a minimum of 19% (Fig. 5C). Dye presence after week 3 was restricted mainly to workers at all nest locations because of the absence of brood (Fig. 3C).

In the controls, dye was distributed from 67 to 100% of the colony populations for the first 6 wk and then declined to a minimum of 36% at the 15- and 132-cm nests sites. At the 310- and 427-cm locations, dye presence was between 15 and 59% of the colonies for the duration of the study (Fig. 5A).

Discussion

The study was terminated after 8 wk because time and space constraints made it logistically difficult to

continue the study for all replicates. However, observations of colonies at varying times beyond 8 wk (10 to 25 wk) revealed a continuing pattern of effects for each treatment that was observed at the end of the 8-wk study. In the hydramethylnon treatment, brood and worker populations increased or remained the same despite the decrease in queens. In the pyriproxyfen treatment, brood and workers continued to decrease, and in the controls, populations generally increased.

The significant interactions in colony populations among the treatments, nest locations, and sampling dates may be attributed to the different modes of action of the active ingredients used in the baits and their effect on bait distribution among nest locations. Hydramethylnon is a metabolic inhibitor (Hollingshaus 1987) that can cause substantial mortality in Pharaoh ants 2–3 d after ingestion (unpublished data). This was evident in this study by the rapid decline in populations at nest sites nearest the hydramethylnon bait (15 and 132 cm). However, by week 4 these sites were being reinfested with workers and brood from the nest site at 310 cm, and with queens from both the 310- and 427-cm sites. The average dye level observed in the 427-cm nest sites was 11% (±2 SE), whereas average worker and brood levels at this location, over the 8-wk study, were 84 and 119% of the initial populations, respectively (Figs. 2B and 3B), with an average of 11 queens (Table 4). This suggested that hydramethylnon was not being thoroughly distributed to all nest sites.

In contrast to hydramethylnon, pyriproxyfen is a juvenile hormone analog that does not cause rapid mortality of adult, worker-caste ants (Glancey et al. 1990, Banks and Lofgren 1991, Reimer et al. 1991). Its major effect at the concentrations used in this study was brood reduction. Thus, more workers were available to distribute bait among all colonies. This was evident by the absence or very low levels of brood after 2 wk, and the gradual decline in workers and queens at all nest locations (Figs. 2C, 3C, and 4C). In addition, substantial bait distribution was indicated by average dye levels that ranged from 65 (±5 SE) to 31% (±4 SE) at nests located nearest and furthest from the pyriproxyfen bait introduction site, respectively.

The presence of a food source near the 427-cm nest sites, and the addition of food near the toxic baits and the food source after 7–9 d, provided workers alternatives to foraging on only the toxic baits. Because Pharaoh ants have been reported to forage >16 m (Vail and Williams 1994), access to baits by workers from colonies located furthest from the baits (427 cm) was not limited by distance. Although dye was observed in colonies at the 310- and 427-cm nest sites, it was less prevalent among these colonies than among colonies at the 15- and 132-cm locations (Fig. 5 A–C). This dye distribution pattern included the control where it was not confounded by the effects of the active ingredients. Thus, the alternative food sources probably had some effect on reducing the distribution of active ingredients to colonies located further away from a bait source. In the absence of alternative food near the 427-cm nest, it is probable that mortality at the 310- and 427-cm nest sites would have been higher because of increased foraging on the baits or starvation. However, the lack of alternative food represents a more artificial scenario.

The distribution of the bait to the more distant nest sites also may have been affected by the amount of intercolony trophallaxis by workers from colonies located closest to the dyed bait. The hydramethylnon treatment had the least dye presence at nest sites located 310 and 427 cm from the dyed bait and had rapid and substantial worker ant mortality at nest sites located at 15 and 132 cm from the bait. This suggested that rapid worker ant mortality from the hydramethylnon in colonies located closest to the bait, reduced bait distribution to the colonies located furthest from the bait because workers from the 15- and 132-cm nest sites were no longer available to distribute bait to the more distantly located colonies. In contrast, the more extensive dye distribution to all nest locations in the control and pyriproxyfen treatments was probably facilitated by the longer survivorship of worker ants from colonies nearest these bait treatments.

The findings of this study suggest that the rate of adult, worker-caste mortality from the ingestion of toxic baits can affect bait distribution among polydomous ant species. This may be an important factor in the control of pest ant species such as Pharaoh, Argentine [*Linepithema humile* (Mayer)], and polygynous imported fire ants, which can have extremely large, mobile populations located within a network of multiple nest sites. Because agonism between colonies is minimal in these species, slow-acting IGR-based toxicants, which may take several weeks to reduce adult worker-caste populations (Banks 1986), will be spread more thoroughly between colonies than fast-acting metabolic-inhibiting toxicants, which can cause substantial adult worker mortality within a week (Williams et al. 1980, Vander Meer et al. 1985). In polygynous, red imported fire ant populations, Drees et al. (1992) detected the effects of the IGR fenoxycarb in colonies located several meters from treated nest sites. The thorough distribution of toxicant among colonies located both near and far from a bait source reduces the probability of reinfestation by causing a gradual population decline in colonies at all locations. A thorough toxicant distribution among all colonies is in contrast to toxicant distribution to colonies that are only in proximity to a bait source. Such localized toxic bait distribution can permit unaffected, distant colonies to move into nest sites that were previously occupied by colonies that were killed by proximally located bait. Vail (1996) reported that 57% of the nest sites used by Pharaoh ants in small structures had been previously occupied by Pharaoh ants. Although ants that reinfest a nest site of a killed colony may have moved closer to a bait, that bait may no longer be attractive to foragers because it is too old or the bait is possibly associated with causing death. Toxic baits that cause immediate mortality are sometimes covered with debris by surviving workers, and apparently are no longer an accepted food source (unpublished

data). Williams and Vail (1994) reported the reappearance of Pharaoh ants in a large building that was treated with a metabolic-inhibiting ant bait. They attributed the reappearance to insufficient bait distribution as a result of the active ingredient killing workers too fast, relative to the speed of adult worker death by an IGR bait. Thus, to compensate for the less efficient toxicant spread among colonies, fast-acting bait toxicants may require more bait placements to improve the probability that all colonies will encounter the bait.

Given the difficulty in locating and baiting individual nest sites in polydomous pest ant species, the mode and speed of action of the bait toxicant should be considered in the selection of ant baits. In this study, a slow-acting toxicant provided gradual, pervasive, and long-term control from a single bait source, whereas the fast-acting bait toxicant from a single bait source, provided more rapid, localized control.

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