TROPICAL HOUSEHOLD ANTS: PEST STATUS, SPECIES DIVERSITY, FORAGING BEHAVIOR, and BAITING STUDIES

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Abstract Questionnaire-based surveys of homeowners revealed that ants were the most economically important and abundant household pest after mosquitoes and cockroaches in Malaysia. Twenty-five species of ants were found indoors and outside buildings; all species nest outdoors except *Monomorium pharaonis, Monomorium floricola*, *Tapinoma melanocephalum* , and *Solenopsis molesta* . Surveys of houses and food stores indicated the most common species were *Pheidole* sp., *T. melanocephalum*, *Monomorium destructor,* and *Paratrechina longicornis*. A survey of homeowners' attitudes and knowledge of ants showed that 62% found ants daily in their homes. Most respondents tolerated < 50 ants indoors; 65% used aerosol sprays for control, 6% used ant baits. Homeowners were not aware that ants can mechanically vector pathogenic organisms. Bacteria, fungi, and yeasts were isolated from ants collected from food outlets. Most ant species responded to peanut butter attractant, except *P. longicornis* and *T. melanocephalum*, which preferred honey. Attractancy to peanut butter and honey changed in an 18-month study of *M. pharaonis*. All species, except *Pheidole* sp. preferred liquid bait. Foraging of *P. longicornis*, *M. pharaonis,* and *Solenopsis geminata* was negatively correlated with temperature; their peak activity was 2-4 hours after sunset. Most baits gave >75% reduction after one week post-treatment.

Key Words household ants, Malaysia, pest status, food preference, foraging, baits

INTRODUCTION

Household ants are an important group of insect pests in the urban environment because of their close association with mankind (Holldobler and Wilson, 1990) and foraging activity in mass numbers (Chong, 1997; Robinson, 1996; Lee et al., 1999). Of the 10,000 ant species that have been described, less than 0.5% are pests in the human environment, particularly in structures and buildings in south Asia (Lee and Robinson, 2001). Prior to the 1990s, household ants were considered a less important group of household pests than cockroaches and mosquitoes in Asia, but their status has risen in many Asian developed countries, such as South Korea and Singapore. In tropical Malaysia, ant control accounted for about 10% of the business of the pest control industry in 1995 (Yap and Lee, 1996), while in other developed countries in Asia, it has a market share of between 15-30%.

The species of household ants that have been studied extensively include Pharaoh ant, *Monomorium pharaonis*, (Edwards, 1986), carpenter ants, *Camponotus* spp., (Hansen and Akre, 1993), Argentine ant, *Linepithema humile*, (Vega and Rust, 2001), and fire ant, *Solenopsis* spp. (Taber, 2000; Williams et al., 2001). Information is limited on important biological aspects and behaviour of many tropical species of household ants such as ghost ant, *Tapinoma melanocephalum*, crazy ant, *Paratrechina longicornis*, and big-headed ant, *Pheidole megacephala*. The objective of this paper is to summarize some of the published and unpublished findings of research projects on tropical household ants conducted in Malaysia. Presented here will be pest status and human perception, and some important biological aspects, such as species composition, distribution, seasonal food preference, and foraging patterns of household ants in the tropics.

Household Pest Status

Several questionnaire-based surveys on the status of household pests were done between 1983-2001 among homeowners and the pest control industry in Malaysia (Table 1). The survey conducted in 1983 (Yap and Foo, 1984) revealed that ants were the most important group of household pests after mosquitoes and cockroaches. A similar finding was obtained in 1995. In the survey conducted in 1998 (Yap et al., 1999) ants were still at the same position as before, but cockroaches have become the most important household pests, rather than mosquitoes. Currently, improved household insecticide products are available for mosquitoes compared to products for other household insect pests in Malaysia. Products for cockroach and ant control are primarily limited to aerosols, and only three cockroach baits and one ant bait are available. Estimated figures show that Malaysian households spent US$48 million annually on household insecticide products in 1997/1998 (Yap, 1999) and US$57 million in 2000/2001 (I. Ridzuan, personal communication), compared to about US$25 million in 1986/1987 (Yap, 1988). Only 5-10% of these figures were spent on products for cockroach and ant control.

A survey in 2001 of the importance of pest groups to the Malaysian pest control industry showed that household ant control ranked third after termite and cockroach control (C.Y. Lee, unpublished), compared to its fourth position in a 1995 survey (Yap and Lee, 1996) (Table 2). Currently, it accounts for 10% of an estimated total business volume of US$18-20 million (Lee et al., 1999). The demand for household ant control in Malaysia, especially in food preparative outlets has increased since the introduction of cockroach gel baits for German cockroach control in 1997. In many countries around the world, including the United States, ants have become the number one household pest in terms of control revenue (Gooch, 1999; Kaminski, 2000; Jenkins, 2001), and rated the most difficult pests to control (Gooch, 1999).

Structure-Invading Ants

Yap and Lee (1994) reported on household ants in residential premises in Penang, Malaysia. They recorded *M. pharaonis* as the predominant species, followed by *Tapinoma sessile* and *P. longicornis*. Between June 2000 and December 2001, 479 households were sampled in Penang, Malaysia; these sites ranged from houses to apartments in rural, suburban, and urban areas. Ants were collected from baited cards (6.2 by7.5 cm) placed in the living room, dining area and kitchen, along the perimeter or corridor of the house, and outside the house. Twenty-five ant species from four subfamilies – Myrmicinae, Formicinae, Dolichoderinae, and Ponerinae – were collected (Table 3). With the exception of *M. pharaonis*, *M. floricola*, *T. melanocephalum*, and *S. molesta*,

Table 1. Household pest status in Penang, Malaysia (1983 – 1998)

Household pest	Year of survey 1983[1]	1995[2]	1998[3]
Cockroaches	2	2	1
Ants	3	3	3
Mosquitoes	1	1	2
Rodents	4	4	4
House flies	5	5	5
Others[4]	6	6	6

[1]Based on Yap and Foo (1984) (n = 395 houses).
[2]H.H. Yap and C.Y. Lee, unpublished data (n = 814 houses).
[3]Yap et al. (1999) (n = 245 houses).
[4]Others = geckos, spiders, wasps, fleas, begbugs, etc.

Table 2. Rank of targeted pests of the pest control industry in Malaysia (based on total business volume)

Pest	Year of survey 1995[1]	2001[2]
Termites	1	1
Cockroaches	2	2
Ants	4	3
Rodents	3	4
Mosquitoes	4	5
Flies & other incidental pests	6	6

[1]Yap and Lee (1996) (n = 42 companies)
[2]C.Y. Lee, unpublished data. (n = 55 companies).

Table 3. Household ants of Malaysia – locations of collection (Na & Lee, 2001)

Subfamily Species	Common name	Location where ants were found within a structure/building		
		Indoors	Perimeter	Outdoors
Subfamily Myrmicinae				
Monomorium pharaonis	Pharaoh ant	x	x	-
Monomorium destructor	Singapore ant	x	x	-
Monomorium orientale	—	x	x	-
Monomorium minimum	—	x	x	-
Monomorium floricola	—	-	x	-
Crematogaster sp.	Acrobat ant	-	x	-
Pheidole sp.	Big-headed ant	x	-	-
Tetramorium sp.	Pavement ant	-	x	-
Solenopsis geminata	Tropical fire ant	x	x	x
Solenopsis invicta	Imported fire ant	x	x	x
Solenopsis molesta	Thief ant	x	-	-
Subfamily Formicinae				
Anoplolepis longipes	Red crazy ant	-	x	-
Paratrechina longicornis	Crazy ant	x	x	x
Paratrechina sp.	Crazy ant	-	x	x
Camponotus sp.	Carpenter ant	-	x	x
Prenolepis imparis	Small honey ant	-	x	-
Formica sp.	Field ant	-	x	x
Subfamily Dolichoderinae				
Tapinoma sessile	Odorous house ant	x	x	x
Tapinoma melanocephalum	Ghost ant	x	x	-
Tapinoma indicum	Ghost ant	x	x	-
Linepithema humile	Argentine ant	x	x	-
Oecophylla smaragdina	Weaver ant	-	-	x
Technomyrmex albipes	White-footed ant	-	x	-
Dolichoderus bituberculata	Rambutan ant	x	x	x
Subfamily Ponerinae				
Odontoponera sp.	—	-	x	x

which nest indoors, the majority of the ants collected were outdoor-nesting species, but forage indoors for food.

The most dominant species trapped in the residential premises was the big-headed ant, *Pheidole* sp., followed by the ghost ant, *T. melanocephalum*, the Singapore ant, *Monomorium destructor*, and the crazy ant, *P. longicornis* (Table 4). The big-headed ant, which is also an important insect pest in agriculture (Reimer et al., 1990), was often found nesting outdoors under flower pots. The ghost ant primarily occurs outdoors, but many nests were reported in kitchens. Nesting habitats for *M. destructor* are generally outdoors, especially in soil with vegetation and shrubs, while *M. pharaonis* and *M. floricola* prefer to nest indoors.

Surveys were conducted on ants in food outlets, including university cafeterias, coffee shops, residential kitchens, and hotel kitchens (Lee et al. 2001a), and university dormitory pantries (Loke, 2002). In both studies, *M. destructor* was the dominant species (Table 4). Other species found in large numbers were *P. longicornis*, *Pheidole* sp., and *T. melanocephalum*. The university cafeterias showed the highest diversity of ant species; species trapped were: *P. longicornis*, *T. melanocephalum*, and *Monomorium* spp. They are cosmopolitan in distribution and considered

Table 4. Survey on household ants in residential premises and food-handling outlets

Species	% of total ants collected		
	Residential[1] (n = 479)	Food outlets[2] (n = 31)	Dormitory pantries[3] (n = 124)
Anoplolepis longipes	0.4	1.7	6.8
Camponotus sp.	< 0.1	0.1	< 0.1
Dolichoderus bituberculata	0.1	1.2	—
Formica	—	—	0.2
Monomorium destructor	9.1	27.8	25.1
Monomorium floricola	3.0	10.8	0.6
Monomorium minimum	2.0	—	—
Monomorium pharaonis	6.2	3.4	7.4
Odontoponera sp.	< 0.1	—	—
Paratrechina longicornis	4.9	9.0	21.2
Pheidole sp.	32.4	16.4	21.7
Prenolepis imparis	0.2	0.3	0.9
Solenopsis geminata	0.1	3.7	—
Solenopsis invicta	1.9	—	3.6
Tapinoma melanocephalum	27.7	19.5	12.3
Tapinoma indicum	8.9	4.2	0.2
Tetramorium sp.	0.1	1.9	—
Others	2.9	—	—

[1]Based on Na (2001) and Lee, unpublished data (n = 52,389 ants).
[2]Based on Lee et al. (2001) (n = 5531 ants).
[3]Based on Loke (2002) (n = 19,083 ants).

to be tramp ants. Tramp ants are polygynous, unicolonial, reproduce by budding, largely dispersed worldwide through human commerce, and live in close association with humans (Holldobler and Wilson, 1990; Passera, 1994). Although a number of ant species demonstrate anthropophilic tendencies (Pisarski, 1982; Prins et al., 1990; Thompson, 1990), only tramp species are truly domestic with great ability for nest changes. Nesting in an unstable habitat such as the human environment requires frequent migration, and migration has become a unique characteristic of tramp ant species (Passera, 1994). The crazy ant, *P. longicornis*, is often observed to be the first species to succeed in a disturbed habitat or a new building or structure (C.Y. Lee, unpublished). Tramp ant species often displace other ant species once they become established. Wetterer et al. (1999) reported the displacement of several species and other insects by *P. longicornis* in a greenhouse structure.

Homeowner Attitude and Knowledge Concerning Household Ants

Wood et al. (1981) reported that an understanding of the attitude and knowledge of homeowners toward pests is important to the success of a pest management program, especially in terms of their appreciation of the value of sanitation and pesticide application. To have a better understanding of the perception of the Malaysia homeowners towards ant problems, a questionnaire-based survey was conducted in Penang, Malaysia. Penang has a population of about 1 million and is located in northern Malaysia. Face-to-face interviews with 256 residents of single-story, double-story, link houses, and apartments in urban, suburban, and rural areas were conducted between May and September 2000.

A total of 159 homeowners reported ants and ant problems in their houses (Table 5); there was no significant difference between (c^2 = 2.44, $P > 0.05$, df = 3) between these two responses. When asked about the cause(s) of ants in their home, 70% reported food and beverages as the

Table 5. Survey on attitude and knowledge of homeowners toward ant problems in Penang Island, Malaysia (n = 256) (Na 2001)

1. Location of survey?	
Urban	47%
Suburban	41%
Rural	12%
2. Age of respondents?	
<20	6%
20 – 29	20%
30 – 39	20%
40 – 49	29%
50 – 59	16%
60 – 69	6%
70 and above	3%
3. Gender of respondents?	
Male	41%
Female	59%
4. Problem with pest ants?	
Yes	62%
No	38%
5. Do you find ants daily in your house?	
Yes	62%
No	38%
6. What causes ants in your house?	
Food/beverages	70%
Rubbish	5%
other sources	14%
do not know	11%
7. Level of tolerance (# ants per sight)?	
1 – 10	30%
10 – 20	16%
20 – 50	17%
50 – 100	23%
>100	14%
8. How do you get rid of the ants?	
Crush them with finger	5%
Aerosol spray	65%
Hot water	2%
Sweep with a broom	10%
Ant bait	6%
Not bothered at all	3%
Other methods (eg., miracle chalk)	9%
9. Best way to control ants?	
Aerosol spray	55%
Sanitation	13%
Ant bait	8%
Cooperation from neighbours	0%
Do not know	11%
Others (eg., miracle chalk)	13%
10. Main reason for ant control?	
Embarrassed in presence of guest	1%
Ants transmit germs	4%
Ants in food/drinks	38%
Aesthetical nuisance	11%
Others	27%
Not bothered	19%
11. Which is the most important?	
Ant problem	3%
Rat problem	11%
Leaking pipe	22%
A crying baby	59%
Unwashed clothes	5%
12. Can ants be eliminated?	
Yes	29%
No	65%
Not sure	6%

most likely reason. Sixty-three percent of the respondents had a tolerance of < 50 ants per sighting, while only 36 respondents out of 256 tolerated >100 ants per sighting. A low tolerance of homeowners to ants did not cause them to regard ants as a problem in their houses (χ^2 = 62.72, P < 0.05, df = 3). However, if ants were found daily in the home, residents tolerated seeing more than 20 ants before initiating a control program (χ^2 = 7.51, P > 0.05, df = 3).

Most homeowners (65%) used aerosol sprays for ant control; 6% used ant baits. Responses to another question, on the best way to control ants, indicated that only 55% chose aerosol sprays, indicating that many have experienced control failure using aerosols. Only 13% and 8%, respectively, of the respondents felt that sanitation and ant bait, respectively, were the best methods for ant control, while 55% commented that ant bait products were expensive when compared to aerosol. The majority (>80%) were not aware of the importance of sanitation in preventing ant problems in their houses.

Thirty-eight percent reported the main reason for ant control was the presence of ants in their food and beverages, while 11% initiated control when ants became an aesthetical nuisance. Only 4% of the respondents controlled ants because they were potential mechanical vectors of pathogenic organisms. Surprisingly, 19% of the respondents were not bothered by the presence of ants. The importance of the ant problem in relation to several other negative situations was also investigated. Results indicated that ant problems received the lowest ranking when compared to other situations such as a crying baby, rat problems, leaking pipes, and unwashed clothes. Most homeowners (65%) felt that it would be impossible to eliminate pest ants from their premises.

Microorganisms From Ants in Food Outlets

Problems associated with ant infestations include food contamination (Lee et al., 2001b), stings, bites, and allergies (Goddard, 1993; Williams et al., 2001), contamination of surgical instruments in hospitals (Beatson, 1972), as well as serving as mechanical vectors of human diseases (Aleksev et al., 1972; Beatson, 1972; Edwards and Baker, 1981; Eichler, 1990; Bueno and Fowler, 1994). Most of the above studies concentrated on ants infesting hospital buildings, or on fire ants. There is limited information on microorganisms isolated from household ants found in food outlets, such as restaurants, cafeterias, and household kitchens. This study was initiated to provide information in this area.

Ants were collected on index cards (6.2 x 7.5 cm) and brought back to the laboratory in sterile petri dishes. In the laboratory, live ants were randomly selected and introduced into agar nutrient and Sabourand dextrose agar plates, and incubated at 37^{o} C for 24-48 hours, and for 1-7 days, respectively. Colonies found growing on the agars were isolated and subcultured. Preliminary identification of bacteria was done according to the Gram's method. Gram negative bacteria were identified using *in vitro* API 20E and API 20NE diagnostic kits. Isolates of yeasts and fungi were stained with lactophenol cotton blue, and identified manually using a light microscope.

Table 6. Microorganisms isolated from pest ants collected in food-outlets and food preparation areas in Penang, Malaysia (Lim 2001)

Pathogen group and Species	Isolation frequency
Bacteria	
Gram positive, bacilli	+ + + + + +
Gram positive, cocci	+ + + + +
Gram positive, streptococci	+ +
Gram positive, staphylococci	+ +
Gram negative, bacilli	+ + + +
Gram negative, cocci	+ + +
Gram negative, coccobacilli	+
Acinetobacter baumannii	+
Aeromonas hydrophila	+ + + +
Aeromonas salmonicida	+ +
Agrobacterium radiobacter	+ + + +
Alcaligenes faecalis	+
Bordetella bronchiseptica	+
Burkholderia cepacia	+ +
Burkholderia pseudomallei	+
Chryseobacterium meningo-septicum	+ +
Chryseomonas luteola	+
Erwinia sp.	+
Enterobacter sakazakii	+
Pantoea spp.	+
Pasteurella multocida	+
Bacteria, continued	
Pseudomonas aeruginosa	+
Serratia liquefaciens	+
Serratia plymuthica	+
Sphingomonas paucimobilis	+ +
Stenotrophomonas maltophila	+ +
Vibrio alginolyticus	+
Vibrio parahaemolyticus	+ +
Vibrio fluvialis	+
Yersinia pseudotuberculosis	+ +
Fungi	
Aspergillus flavus	+ + + +
Aspergillus fumigatus	+ +
Aspergillus niger	+ + + + +
Cladosporium wernickii	+
Fusarium oxysporum	+
Penicillium spp.	+
Scopulariopsis spp.	+ +
Syncephalastrum spp.	+
Yeast	
Geotrichum candidum	+ + +
Trichosporon cutaneum	+ +

A total of 193 bacterial isolates were obtained; 55.4% of them were gram positive, and most of these were bacilli and cocci. Among the 23 species of bacteria identified, *Aeromonas hydrophila* and *Agrobacterium radiobacter* were the most frequently isolated (Table 6). Of the eight species of fungi isolated, *Aspergillus flavus* and *Aspergillus niger* were the most common. Two species of yeast were identified. This study provided an insight into various microorganisms found on the external body surface of household ants collected in food preparation premises.

Foraging Behavior

Food baits used on index cards were different in attractiveness towards common species of household ants. Field studies revealed that peanut butter was more attractive than honey to *M. pharoanis*, *M. destructor*, *Pheidole* sp., and *Solenopis geminata*, while *T. melanocephalum* and *P. longicornis* preferred the latter (Table 7). Further studies conducted on a field population of *M. pharaonis* showed a seasonal preference to peanut butter and honey baits. In an 18-month study (February 1999 to August 2000), the attractancy to peanut butter and honey was found to vary. Granovsky and Howell (1983) also reported changes in bait preference. This behavior can be caused by changes in colony development (Erpenbeck, 1981), or food satiation (Edwards and Abraham, 1990). Regulation of nutrient intake is important to the foraging workers because queens and larvae have different nutritional requirements (Chong, 1997).

In the process of baiting household ants, it was regularly observed that different bait bases have varying attractiveness to foraging ants. The time for ants to become attracted to the bait can

Table 7. Food preference of several species of household ants as baited using ruled index cards

Species	Peanut butter*	Honey*
Monomorium pharaonis	+ + + +	+
Monomorium destructor	+ + + +	+
T*apinoma melanocephalum*	++	+ + +
Pheidole sp.	++++	+
Paratrechina longicornis	+	+ + + +
Solenopsis geminata	+ + + + +	

*A '+' represents 20% of total ants feeding on the food attractant.

Table 8. Changes in food preference of a *Monomorium pharaonis* population in the field[1]

Date	Peanut butter[2]	Honey[2]
Feb '99	+++++	
Jun '99	++++	+
Aug '99	+ ++++	
Dec '99	+++++	
Feb '00	++++	+
May '00	++++	+
Aug '00	+ ++++	

[1]Experiment was conducted on one field population of *M. pharaonis* with three replicates (one replicate was done every alternate day).
[2]One '+' represents 20% of total ants feeding on the food attractant.

also vary with different formulations. Experiments were conducted using laboratory colonies of household ants. Depending on ant species and availability, all colonies have between 2-10 queens, 500-1000 workers, and 1-3 gm of brood. Blank bait bases containing 30% sucrose were formulated in the laboratory. It was previously determined that a 20-30% sucrose solution was the most attractive concentration for the majority of Malaysian household ant species (Lee, unpublished data). Choice experiments were done by presenting different bait bases simultaneously to foraging ants.

Results indicated that a liquid base was the most attractive base to all species tested. *Pheidole* spp. showed a relatively low response to all three bait bases, followed by gel base (Table 9). It was observed that granular toxicant bait gave better control against *Pheidole* sp. when compared to other toxicant bait bases (Lee, unpublished data). Paste base, which is widely used in commercial bait, received little or no response from the foraging ants. However, unlike the 30% sucrose used in this study, most commercial bait formulations contained one to several food attractants.

Studies were done to determine the speed of response of different species of household ants to liquid bait base. Using laboratory colonies in test arenas (40 x 25 cm), it was observed that *P. longicornis* registered the shortest time,10 min, to achieve peak foraging activity, followed by *T. melanocephalum*, 20 min, when compared to other ant species (Table 10). The erratic and ran-

Table 9. Preference of laboratory colonies of several household ant species to different blank bait bases (at 30 minutes after introduction) (Beh, 2002)

	bait base		
Species	Liquid	Gel	Paste
Monomorium pharaonis	+ + +	+	-
Monomorium floricola	+ + +	+	+
Monomorium destructor	+ + +	+	-
Paratrechina longicornis	+ + +	+ +	-
Pheidole sp.	+	-	-
Solenopsis molesta	+ + +	+ +	-
Formica sp.	+ + +	+	+
Tapinoma melanocephalum	+ + +	+ +	-

A '+' represents 20% of total ants feeding on the bait formulation (or carrying the granular formulation).

Table 10. Differential response of laboratory colonies of several household ant species to liquid bait formulation (Beh, 2002)

Species	Time taken to achieve peak foraging activity (min)
Monomorium pharaonis	60
Monomorium floricola	100
Monomorium destructor	110
Paratrechina longicornis	10
Solenopsis molesta	80
Formica sp.	40
Tapinoma melanocephalum	20

dom foraging activity of both species could be a factor that increased the chance of the foraging ants finding the food source.

When screening residential premises to determine suitable houses to conduct the ant bait trials, inconsistent sampling results were often recorded when sampling time varied. Household ants may have a daily foraging activity pattern, especially those species that nest outdoors, but forage indoors for food. In this study, three ant species were chosen: *P. longicornis*, *M. pharaonis,* and *S. geminata*. These were infesting a large building, and samples were taken along the exposed outside corridor. Baited index cards were placed at locations where the ants were seen trailing every 2 hours and continuously up to 48 hours. The number of foraging workers on the index cards was counted at about 30 min after placement. Experiments were replicated three times and each replicate was done every alternate week. Results indicated that all three species have relatively similar foraging pattern (Figure 1). Foraging activity peaked 2-4 h after sunset (22:00), and the activity gradually ceased at about 15:00 in the afternoon. The findings suggested that foraging activity patterns of *M. pharaonis*, *P. longicornis,* and *S. geminata* were negatively correlated with ambient temperature. In Malaysia, the outdoor temperature averages 25°C at night, while day temperature averages 33°C, but can reach as high as 35°C. Hooper and Rust (1997) reported that foraging activity of *Solenopsis xyloni* began approximately 4 h before sunset and maximal activity occurred 2-7 h after sunset. They found that foraging workers avoid the times of the day when ground surface temperatures were relatively higher (Hooper and Rust, 1997).

Baiting Tropical Household Ants

Residual insecticide sprays are used for household ant control by Malaysian pest control operators (Chong et al., 1998; Lee et al., 1997). Because the number foraging accounts for only about 10% of total nest population (Adams et al., 1999), colony elimination using this method is not

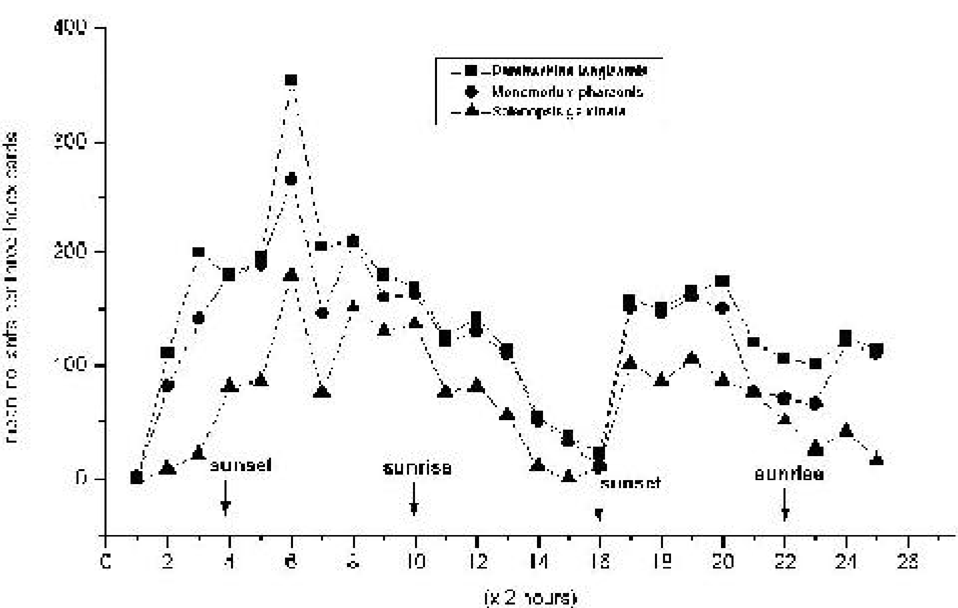

Figure 1. Foraging activity patterns of Paratrechina longicornis, Monomorium pharaonis, *and* Solenopsis geminata

possible unless the nest is located and directly treated (Lee and Robinson, 2001). Residual spraying with pyrethroid insecticides has limitations in control, including unpredictable efficacy due to heterogeneity of treatment surface (Knight and Rust, 1990), insecticide repellency (Chong and Lee, 1999; Lee et al., 2002), and inability to eliminate the colony (Forschler and Evans, 1994a). Numerous bait toxicants evaluated have shown efficacy against several ant species such as the Argentine ant, odorous house ant, carpenter ant, Pharaoh ant, and fire ant. These toxicants are generally neurotoxic insecticides (Newton and Coombes, 1987; Oi et al., 1996; Lee, 2000), stomach poisons (Klotz et al., 1996, 1997a, 1997b, 2000a), metabolic inhibitors (Williams and Whelan, 1992; Forschler and Evans, 1994a, 1994b; Oi et al., 1994; Blachly and Forschler, 1996; Klotz et al., 2000b; Lee, 2000), and insect growth regulators (Edward and Clarke, 1978; Rupes et al., 1978; Newton, 1980; Oi et al., 1996, 2000; Reimer et al., 1991; Vail and Williams, 1995; Vail et al., 1996; Williams, 1990; Williams and Whelan, 1992; Williams and Vail, 1993, 1994; Williams et al., 1999).

Field studies were conducted to evaluate the performance of bait formulations against major household ant species: *M. pharaonis*, *T. melanocephalum*, *P. longicornis*, and *Pheidole* sp. All bait formulations containing fipronil and imidacloprid, hydramethylnon and boric acid, and sodium borate showed efficacy, with >75% reduction within a week post-treatment, with the exception of the borate-based bait against *Pheidole* sp. (Table 11). Bait containing methoprene eliminated the colonies by 8 weeks post-treatment. Horwood (1988) reported control of a field population of *Pheidole megacephala* using 0.5% methoprene in peanut butter.

Although a substantial reduction of household ants was recorded by most bait toxicants, limited success was registered when baiting crazy ants and ghost ants with paste and granular bait formulations. Hedges (1998) also reported that *P. longicornis* and *T. melanocephalum* were difficult to control with bait.

The effects of sanitation on field performance of toxic bait against household ants was also studied. Houses chosen for the trial were rated for their sanitary condition as follow: 1 = poor, 2 = moderate, and 3 = good. Two bait formulations were used: containerized bait and gel bait. Three containerized baits, each containing 1.65 g bait, were placed in houses, while 55 dabs of 0.09 g gel bait were applied in the other houses chosen for gel bait treatment. There was a positive correla-

Table 11. Summary of field studies on the performance of bait formulations against several species of Malaysian household ants

Bait active ingredient	Targetted species[1]	% reduction after n$^{th.}$ week			
		1-week	4-week	8-week	12-week
hydramethylnon (1%)[2]	Mp, Tm, Pl	82.0	83.7	54.9	-
fipronil (0.01%)[2]	Mp, Tm, Pl	92.7	90.4	79.3	-
methoprene (0.5%)[3]	Mp	51.9	87.6	100	100
hydramethylnon (1%)[4]	Mp	89.1	89.9	100	100
boric acid (5.3%), sodium borate (4.3%)[4]	Mp	76.2	74.5	78.2	-
boric acid (5.3%), sodium borate (4.3%)[5]	Ph.	39.1	65.2	98.9	-
methoprene (0.5%)[6]	Ph	6.5	94.3	100	100
imidacloprid (2.15%)[6]	Mo	92.1	93.2	84.8	-
hydramethylnon (1%)[6]	Mo	83.7	98.7	82.8	-

[1]Mp = *Monomorium pharaonis*, Tm = *Tapinoma melanocephalum*, Pl = *Paratrechina longicornis*, Ph = *Pheidole* sp., Mo = *Monomorium* spp. (*destructor, floricola*, and *pharaonis*).
[2]Based on Lee (2000).
[3]Based on Lee et al. (2001).
[4]Based on Lee and Lee (2001).
[5]Based on Loke (2002).
[6]Lee, unpublished data.

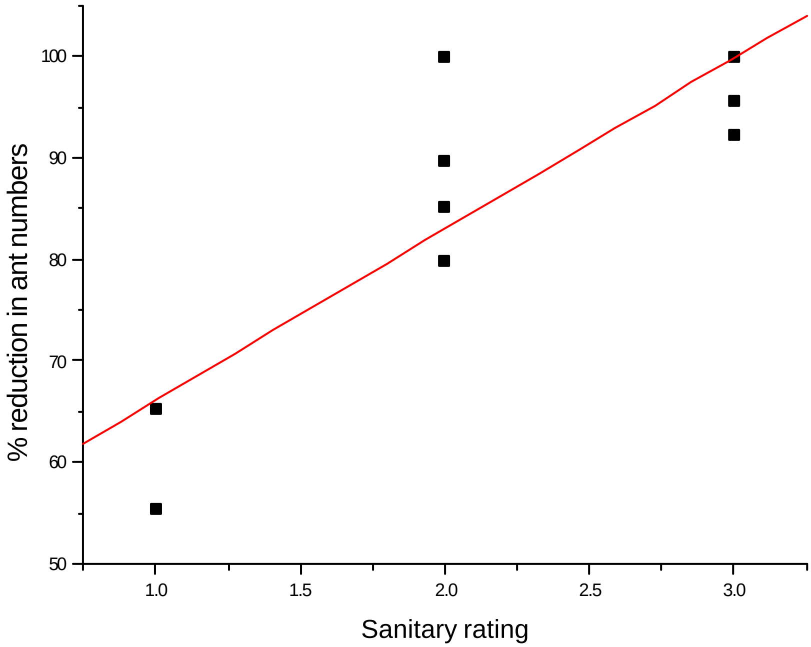

Figure 2. Relationship between containerized bait performance and sanitary condition in baited premises.

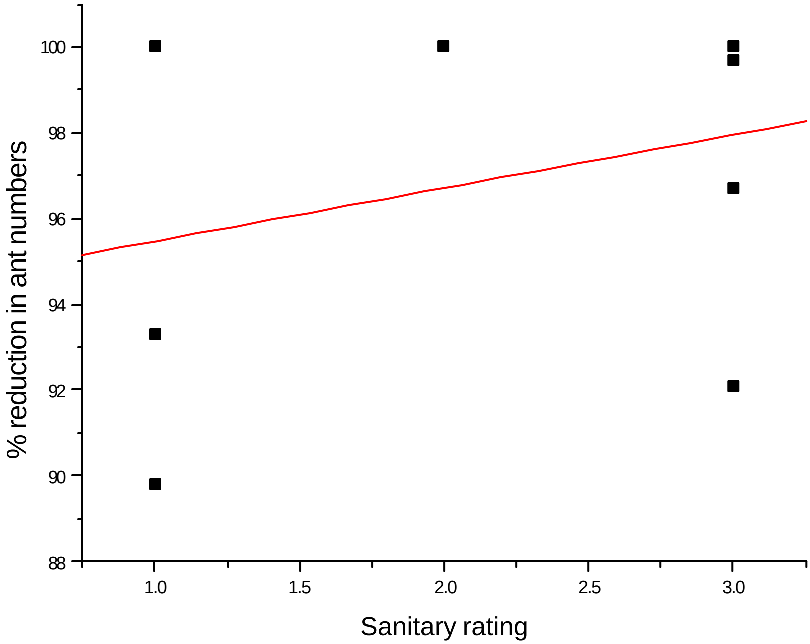

Figure 3. Relationship between gel bait performance and sanitary condition in baited premises.

tion (y = 49.2 $\pm$ 16.9x; x $\geq$ 1, r^2 = 0.849, P = 0.0038) between sanitation and the performance of containerized bait (Figure 2). However, no correlation (r^2 = 0.2659, P = 0.4589) was found between sanitary condition and the performance of gel bait (Figure 3). This result suggests that sanitation did not play a significant role when baiting ants using gel bait, perhaps because of the higher number of placements in gel treatment when compared to containerized bait that had only three placements. Therefore, by increasing bait placements, it may be possible to overcome efficacy problems due to bad sanitary conditions. A similar finding was also observed earlier when baiting American cockroaches in urban slums (Lee, unpublished data).

In the tropics several ant species of ants may occur within a living unit at the same time. One species may be predominant and be more aggressive, and have a wider foraging territory than others. One bait may show good performance against one species, but may not be effective against other household ant species. When baiting *Monomorium pharaonis*, *M. destructor*, and *M. floricola* using imidacloprid gel bait, a significant reduction (>90%) in the numbers of *Monomorium* spp. was recorded at 1-2 weeks post-treatment (Figure 4). However, following a reduction of *Monomorium* spp., an increase in *T. melanocephalum* and *P. longicornis* counts occurred on index cards. It is speculated that upon reduction or elimination of the more dominant *Monomorium* spp., other tramp ant species, such as *T. melanocephalum* and *P. longicornis*, were now able to forage at a wider area for food and thus were found in larger numbers on index cards. What long term effects the imidacloprid gel bait has on these species is still unknown. However, it is likely that the effect would be minimal, because it was observed that the two species were not receptive to the freshly applied gel bait.

SUMMARY and CONCLUSION

Ants are an increasingly important group of household pests in the human environment in Malaysia. This was evident from the various household pest surveys that had been conducted on

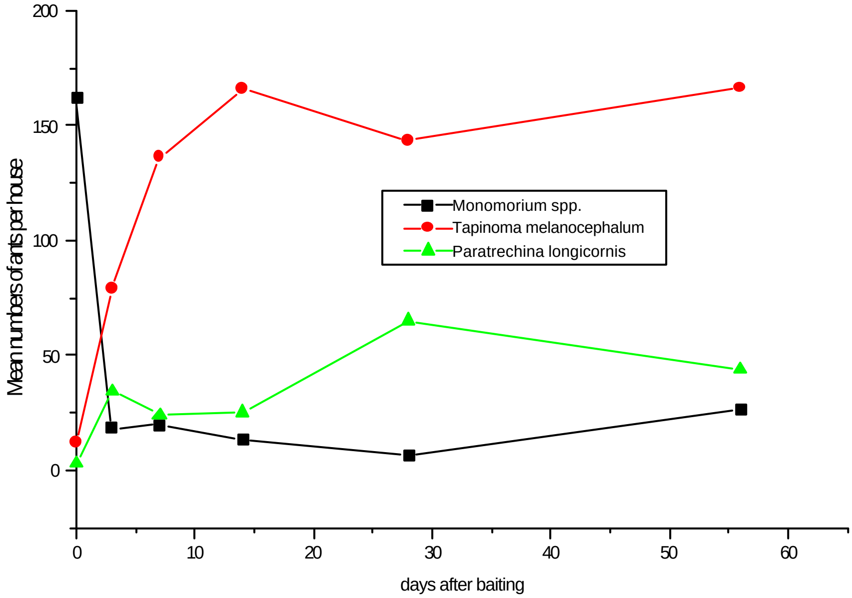

Figure 4. Changes in number of foraging ants upon baiting Monomorium *spp. with 2.15% imidacloprid gel bait.*

homeowners in Penang, Malaysia. Twenty-five species were found in and around buildings and structures. Most of these were tramp ants, such as *Monomorium* spp., *P. longicornis*, *T. melanocephalum*, and *Pheidole* sp. Most tropical household ants prefer a liquid bait base over gel and paste base. However, a liquid bait is susceptible to spillage and dessication. Despite a liquid bait being the preferred base choice, all granular, paste, and gel baits tested showed efficacy against field colonies of household ants. Most formulations showed >70% reduction in ant numbers after 4 weeks post-baiting. It was also noted that the effect of sanitation on bait performance in the premises baited can be reduced if a higher bait placement was done. More studies, especially on foraging biology of important tropical household ants such as *M. destructor*, *Pheidole* sp., *T. melanocephalum*, and *P. longicornis*, are warranted, so that a reliable pest management program can be effectively constructed.

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