

Feeding and foraging behaviour of tropical urban pest ants

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References

- Appel AG, JPS Na & CY Lee. 2004. Temperature and humidity tolerances of the ghost ant, *Tapinoma melanocephalum* (Hymenoptera: Formicidae). *Sociobiology* 44: 89 – 100.
- Beh SW. 2002. Studies on bait matrices and formulations for development of ant baits against eight species of household ants (Hymenoptera: Formicidae). B. Appl. Sci. dissertation. School of Biological Sciences, Universiti Sains Malaysia, Penang. 66 pp.
- Borgesen LW. 1989. A new aspect of the role of larvae in the Pharaoh's ant society (*Monomorium pharaonis* [L.] Formicidae, Myrmicinae): producer of fecundity-increasing substances to the queen. *Insect. Soc.* 36: 313 – 327.
- Borgesen LW. 2000. Nutritional function of replete workers in the Pharaoh's ant, *Monomorium pharaonis* (L.). *Insect. Soc.* 47: 141 – 146.
- Chong ASC, HH Yap, NL Chong & CY Lee. 2002. Effects of starvation on nutrient distribution in the Pharaoh ant, *Monomorium pharaonis* (L.) (Hymenoptera: Formicidae) workers and various larval stages. pp. 121 – 128. In: *Proceedings of the Fourth International Conference on Urban Pests* (SC Jones, J Zhai & WH Robinson, eds.). Pochahantas Press, Blacksburg, VA.
- Chong KF & CY Lee. 2006. Food preference and foraging activity of field populations of a pest ant, *Tapinoma indicum* (Hymenoptera: Formicidae). *Sociobiology* 48: 875 – 883.
- Edwards JP & L. Abraham. 1990. Changes in food selection by workers of the pharaoh's ant, *Monomorium pharaonis*. *Med. Vet. Entomol.* 4: 205 – 211.
- Eow AGH & CY Lee. 2007. Comparative nutritional preferences of tropical pest ants, *Monomorium pharaonis*, *Monomorium floricola* and *Monomorium destructor* (Hymenoptera: Formicidae). *Sociobiology* 49: 165 – 186.
- Eow AGH, ASC Chong & CY Lee. 2004b. Behavioural plasticity in polyethism of *Monomorium* spp. (Hymenoptera: Formicidae). *Sociobiology* 43: 557 – 564.
- Eow AGH, ASC Chong & CY Lee. 2005. Effects of nutritional starvation and satiation on feeding responses of tropical pest ants, *Monomorium* spp. (Hymenoptera: Formicidae). *Sociobiology* 45: 15 – 29.
- Franks NR & AB Sendova-Franks. 1992. Brood sorting by ants: distributing the workload over the work-surface. *Behav. Ecol. Sociobiol.* 30: 109 – 123.
- Granovsky TA & HH Howell. 1983. Texas A&M research team develops new Pharaoh's ant control technique. *Pest Control Technol.* 11: 30 – 34.
- Hooper LM & MK Rust. 1997. Food preference and patterns of foraging activity of the Southern fire ant (Hymenoptera: Formicidae). *Ann. Entomol. Soc. Am.* 90: 246 – 253.
- Lee CY. 2002. Tropical household ants – pest status, species diversity, foraging behaviour and baiting studies. pp. 3 – 18. In: *Proceedings of the 4th International Conference on Urban Pests* (SC Jones, J Zhai & WH Robinson, eds.). Pochahantas Press Inc, Blacksburg, Virginia.
- Lee CY. 2008. Sucrose bait base preference of selected urban pest ants (Hymenoptera: Formicidae). pp. 59 – 63. In: *Proceedings of the 6th International Conference on Urban Pests* (WH Robinson & D. Bajomi, eds.). OOK-Press Kft., Hungary.
- Lim SP & CY Lee. 2005b. Brood arrangement and food distribution among larvae under different colony conditions in the Pharaoh's ant, *Monomorium pharaonis* (Hymenoptera: Formicidae). *Sociobiology* 46: 491 – 503.
- Lim SP, KKK Chong, ASC Chong & CY Lee. 2005. Dietary influence on larval storage proteins of the Pharaoh's ant, *Monomorium pharaonis* (Hymenoptera: Formicidae). *Sociobiology* 46: 505 – 514.
- Loke PY & CY Lee. 2004. Foraging behavior of field populations of the big-headed ant, *Pheidole megacephala* (Hymenoptera: Formicidae). *Sociobiology* 43: 211 – 219.
- Loke PY & CY Lee. 2005. Effects of colony compositions and food type on foraging behavior of *Monomorium orientale* (Hymenoptera: Formicidae). *Sociobiology* 46: 595 – 602.
- Loke PY & CY Lee. 2006a. Influence of colony caste composition, food nutritional content and satiation on the food preference of a tropical pest ant, *Monomorium orientale* (Hymenoptera: Formicidae). *Sociobiology* 47: 5 – 18.
- Loke PY & CY Lee. 2006b. Effects of colony composition and food type on nutrient distribution in colonies of *Monomorium orientale* (Hymenoptera: Formicidae). *J. Econ. Entomol.* 99: 129 – 133.
- Norasmah B, A Abu Hassan, MR Che Salmah & H Nur Aida. 2006. Daily foraging pattern and proteinaceous food preferences of *Solenopsis geminata* (Fabricius) (Hymenoptera: Formicidae). *Trop. Biomed.* 23: 134 – 139.
- Sorensen AA & SB Vinson. 1981. Quantitative food distribution studies within laboratory colonies of the imported fire ant, *Solenopsis invicta* (Buren). *Insect Soc.* 28: 129 – 160.
- Wheeler DE. 1994. Nourishment in ants: patterns in individuals and societies. pp. 245 – 278. In: *Nourishment and Evolution in Insect Societies* (J Hunt & CA Nalepa, eds.). Westview Press, Boulder, CO.
- Wilson EO. 1971. *The Insect Societies*. Harvard University Press, Cambridge, Massachusetts. 548 pp.
- Wilson EO. 1976. Behavioral discretization and number of castes in an ant species. *Behav. Ecol. Sociobiol.* 1: 141 – 154.
- Vander Meer RK & L Morel. 1995. Ant queens deposit pheromones and antimicrobial agents on eggs. *Naturwissenschaften* 82: 93 – 95.

The study of feeding and foraging behavior of pest ants in South East Asia is vital to the creation of an effective pest management program in the region. In the tropics, after termites and cockroaches, pest ants are important to the pest management industry. Common species of pest ants found in and around buildings and structures in South East Asia include the ghost ants (*Tapinoma melanocephalum* and *Tapinoma indicum*), crazy ant (*Paratrechina longicornis*), Pharaoh ant (*Monomorium pharaonis*), Singapore ant (*Monomorium destructor*) and big-headed ant (*Pheidole* sp). Despite their importance, information available on their biological aspects and behaviour is limited. Knowledge on foraging and feeding behaviour is essential to the planning and execution of a suitable and effective pest management programme. This paper summarizes some of the published works on the foraging and feeding behaviour of tropical pest ant species in Malaysia such as *T. melanocephalum*, *T. indicum*, *P. longicornis*, *M. pharaonis*, *M. destructor*, *Monomorium orientale* and *Anoplolepis gracilipes*.

Different ant species often exhibit varying behavioural responses and foraging activities to food. It was found that different food bait used on index cards was different in its attractiveness for common species of household ants. Field studies on foraging ant populations revealed that peanut butter was more attractive than honey to *M. pharaonis*, *M. destructor*, *Pheidole* sp. and *Solenopsis geminata*, while *T. melanocephalum* and *P. longicornis* preferred the latter. Further studies conducted on a field population of *M. pharaonis* showed a seasonal preference to peanut butter or honey bait. In an 18-month study (February 1999 – August 2000), the attractiveness to peanut butter and honey was found to vary over time (Lee 2002).

Loke & Lee (2004) carried out an evaluation of 19 field populations of *P. megacephala* and found that they prefer to feed on proteinaceous and lipid-based foods to carbohydrate foods (Table 1). Their food preference, however fluctuated over the 30-week study period. The same authors also reported their studies on *M. orientale* (Table 1). This species prefers to feed on carbohydrate foods rather than on foods with other nutrients. All colony types (normal, broodless or queenless) preferred to feed on sucrose, saccharose, tuna and olive oil (Loke & Lee 2006a). Loke & Lee (2006b) found that carbohydrates were rapidly distributed (>60% colony in 24-h) when compared to other nutrients. Protein distribution was delayed, while lipids were hardly distributed. Queens in all colony conditions did not feed on protein, while only queens in broodless colonies showed signs of lipid feeding (<10% in 24-h).

Eow & Lee (2007) compared the nutritional preference of three species of *Monomorium* (*M. pharaonis*, *M. floricola* and *M. destructor*). They found that *M. pharaonis* preferred to feed on both proteinaceous and lipid foods, *M. floricola* preferred lipid, and *M. destructor* preferred to feed on carbohydrate foods (Table 1). Periodic alternation and interval fluctuation in response to different nutrients were observed in long-term preference studies. Irrespective of whether the colony was lacking of brood or queen, the authors did not find any such effects on their nutrient preference. Nevertheless, Chong & Lee (2006) reported nutritional preferences in field populations of the ghost ant (*T. indicum*) and found that this species preferred carbohydrate and proteinaceous food (especially tuna fish). The *T. indicum* populations were not responsive to lipid food.

One major challenge in ant baiting is the bait switching behaviour (Granovsky & Howell 1983) where ants alternated their feeding among different food types. Edward & Abraham (1990) reported that this could be due to food satiation. They found that when a colony is satiated with a particular type of food, their workers will not respond to new food from the same nutrient group, but instead forage for

foods from other nutrient groups. Eow et al. (2005) studied the effects of starvation and satiation on three species of *Monomorium*. They found that feeding preferences of *M. floricola* workers correlated to nutrients they were deprived of. When they were starved of all nutrients, lipid food was the most favoured choice. Satiation caused *M. floricola* to forage for either lipid or proteinaceous food. *M. pharaonis* consistently showed preference towards proteinaceous food, irrespective of what they were starved of, or satiated with. On the other hand, *M. destructor* workers would forage primarily for carbohydrate and proteinaceous food when starved or satiated. Another study by Loke & Lee (2006a) found that satiation effects on *M. orientale* were not observed for carbohydrate feeding, but were revealed for protein and lipid feeding within a week.

Nutrient distribution from worker ants to larvae is essential for the survival of a colony. Because workers are incapable of digesting solid food, larvae play an important role in this aspect and serve to regurgitate the liquidated food to the worker ants (Wilson 1971). Generally, workers sort brood (immature stages) according to their ages. Eggs and first instar larvae are separated from older ones within the same brood chamber while the pupae are kept in a different and drier brood chamber (Vander Meer & Morel 1995). Proteinaceous foods are given primarily to larvae and queens while sugars are fed mainly to other workers. These observations prompt researchers to suggest that larvae communicate either directly or indirectly to make their nutritional requirements known to the workers (Sorensen & Vinson 1981; Wheeler 1994).

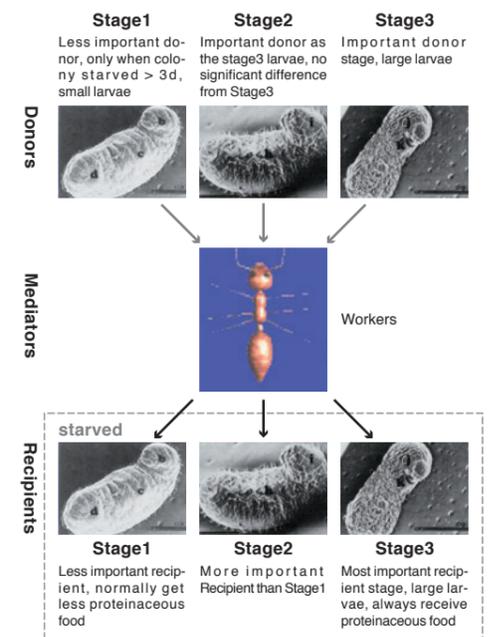
Chong et al. (2002) reported that worker ants of *M. pharaonis* actively donate carbohydrate and proteinaceous food to larvae at all stages, while lipids were transferred only during a prolonged period of starvation, especially to larvae at stage III. Food was more actively transferred to the latter stages when compared to the youngest larval stage (eg. larval stage I). In addition, the older stages were also found to be preferred donors, when compared to the younger ones (Fig. 1).

Lim & Lee (2005) explored the brood arrangement in the Pharaoh ant colonies. By using dye markers, they found that there were three distinct rings in the arrangement of brood piles of the *M. pharaonis* colonies. The outermost layer contained older broods (L2 and L3), while the centre pile consisted of the eggs and L1. The pupae and pre-pupae were placed in the intermediate ring between the two. This study supported Franks & Sendova-Franks (1992) hypothesis that different brood members are sorted in such a way to alleviate the particular type of care they beseech. Since the older (or largest) larvae require the most nutrients, they are placed in the boundary. This positioning will make them highly accessible to the worker ants. Franks & Sendova-Franks (1992) suggested that the creation of such a spatial pattern helps the worker ants to organise the work of brood care and ease the specialised care of certain brood types.

Larvae are involved in regulating colony nutrient flow and distribution (Wilson 1976; Borgesen 1989). Colony fecundity of *M. pharaonis* was found to be dependent on nutrient transfer from larvae to queens (Borgesen 2000). Important storage proteins required for colony development and metamorphosis have been isolated and identified from the larvae of several ant species. However, under field conditions, the protein resources and availability may change with time (or seasons) and location. Lim et al. (2005) initiated a study to determine how dietary protein levels changed the larval storage protein of different larval stages. They found that larval storage protein profiles changed with dietary protein levels as well as the larval stages. The findings also indirectly suggested that different larval stages have different roles and responsibilities within a colony.

Table 1. Nutritional preference of common Malaysian urban pest ants.

Species	Nutrient			Reference
	Carbohydrate	Protein	Lipid	
<i>M. pharaonis</i>	Moderate	High	High	Eow & Lee (2007)
<i>M. floricola</i>	Moderate	Moderate	High	Eow & Lee (2007)
<i>M. destructor</i>	High	Moderate	Moderate	Eow & Lee (2007)
<i>M. orientale</i>	High	Moderate	Low	Loke & Lee (2006a)
<i>T. indicum</i>	High	Moderate	No	Chong & Lee (2006)
<i>T. melanocephalum</i>	High	Moderate	No	Wong & Lee, unpubl.
<i>A. gracilipes</i>	High	Moderate	Low	Chong & Lee, unpubl.
<i>P. longicornis</i>	High	Moderate	No	Lee, unpubl.
<i>P. megacephala</i>	Low	High	Moderate	Loke & Lee (2004)
<i>S. geminata</i>	No	High	High	Lee (2002c)
<i>Tetraponera rufonigra</i>	Moderate	High	Moderate	Sumino & Lee, unpubl.



Note
Stage1:1-5d after hatching, anus at posteroventral end, body covered with hairs in parallel rows.
Stage2:6-10d after hatching, presence of hooked body hair, developed head and mouthpart.
Stage3:11-15d after hatching, extended head with mouthpart, food basket at anteroventral body region.

Fig. 1. Food movement from donor to recipient larvae as mediated by workers of the Pharaoh ant.

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Table 2. Bait base preference of the common Malaysian urban pest ants.

Species	Bait formulation			
	Liquid	Gel	Paste	Granule (solid)
<i>M. pharaonis</i>	High	High	Moderate	Moderate
<i>M. floricola</i>	High	High	Poor	Poor
<i>M. destructor</i>	High	Moderate	Moderate	Moderate
<i>M. orientale</i>	High	High	Poor	Poor
<i>T. indicum</i>	High	High	Poor	Poor
<i>T. melanocephalum</i>	High	High	Poor	Poor
<i>A. gracilipes</i>	High	High	Poor	Moderate
<i>P. longicornis</i>	High	High	Poor	Poor
<i>P. megacephala</i>	Poor	Poor	Poor	High
<i>S. geminata</i>	Poor	Poor	Poor	High

Table 3. The speed of response of different ant species to 4 sucrose bait bases (Lee 2008).

Species	No. replicates	Mean % foraging ants \pm SEM* at 60 min post-treatment			
		Liquid	Gel	Paste	Granule
<i>M. pharaonis</i>	5	70.0 \pm 1.9 a	22.0 \pm 2.9 ab	6.6 \pm 2.1 b	1.4 \pm 1.0 b
<i>M. floricola</i>	5	59.8 \pm 8.1 a	27.4 \pm 10.7 ab	12.0 \pm 3.3 ab	0.8 \pm 0.4 b
<i>M. destructor</i>	5	62.2 \pm 3.4 a	25.8 \pm 3.3 ab	1.6 \pm 1.0 b	7.4 \pm 3.1 b
<i>M. orientale</i>	5	67.6 \pm 3.8 a	26.6 \pm 4.6 ab	4.8 \pm 2.2 b	1.0 \pm 1.0 b
<i>T. indicum</i>	5	83.4 \pm 2.4 a	13.6 \pm 1.9 ab	1.0 \pm 1.0 b	2.0 \pm 0.9 b
<i>T. melanocephalum</i>	5	76.8 \pm 1.9 a	19.8 \pm 1.4 ab	2.6 \pm 1.9 b	0.8 \pm 0.8 b
<i>P. longicornis</i>	5	76.2 \pm 4.5 a	19.0 \pm 3.5 ab	3.0 \pm 2.0 b	1.8 \pm 1.1 b
<i>A. gracilipes</i>	5	58.2 \pm 3.3 a	21.4 \pm 2.2 ab	2.6 \pm 0.9 b	17.8 \pm 2.4 ab
<i>Pheidole</i> sp.	5	11.4 \pm 4.9 ab	4.6 \pm 2.7 b	16.4 \pm 5.6 ab	67.6 \pm 5.7 b
<i>S. geminata</i>	5	3.2 \pm 2.1 a	3.6 \pm 2.2 a	11.0 \pm 3.6 ab	82.2 \pm 6.6 a

*Means followed by different letters within the same row are significantly different ($P < 0.05$, Kruskal-Wallis multiple range test).

Table 4. Field performance of 0.001% fipronil bait against field populations of *T. melanocephalum* (Lee, unpublished).

Bait base	Mean % reduction at n th week after treatment			
	1-w	2-w	4-w	8-w
liquid	95.7	99.0	100	100
gel	83.2	96.1	100	100
paste	43.2	59.0	67.3	23.6
granule	-10.3	-25.8	11.3	17.2

Being social insects, ants practise polyethism (division of labour) where different castes perform different tasks within a colony. In experiments with *M. floricola* and *M. pharaonis*, however, when brood number increased, it was found that more *M. floricola* foragers were retained in the nest as nurses, but this was not found in *M. pharaonis*. In a situation without foragers or nurses, *M. floricola* and *M. pharaonis* showed behavioural plasticity in task switching within the colony (Eow et al. 2004b).

In the process of baiting pest ants, it was regularly observed that different bait bases have varying attractiveness to foraging ants (Table 2). An acceptable bait base is extremely important to ensure sufficient intake of toxicants by foraging individuals to achieve effective management. The speed of ants attracted to the bait can also vary with different bases. Experiments were conducted using laboratory colonies of pest ants. Depending on ant species and availability, all colonies had a 2 - 10 queens, 500 - 1000 workers and 1 - 3 gm of brood. Blank bait bases containing 30% sucrose were formulated in the laboratory, since it was found earlier that a 20 - 30% sucrose solution was the most attractive concentration for the majority of Malaysian household ant species (Lee 2002). Choice experiments were done where different bait bases were presented simultaneously to the foraging ants. Results indicated that a liquid base was the most attractive base to all species tested (with the exception of *Pheidole* sp. which showed a high preference for solid bait), followed by a gel base. Granular toxicant bait provided better management against *Pheidole* sp. when compared to other toxicant bait bases (Beh 2002; Lee 2002c). It is interesting to note that the paste base, which is widely used in containerized bait, received little or no response from the foraging ants. This finding, however, must be interpreted with caution, because unlike the 30% sucrose solution used in this study, most commercial bait formulations contained one to several food attractants.

Further studies were done to determine the speed of response of different ant species to arrive first at four sucrose bait bases (Lee 2008). It was found that *T. indicum*, *T. melanocephalum*, *A. gracilipes* and *P. longicornis* were the quickest in foraging at all the bait bases in comparison to other species. On average, they took between 5.4 and 20.3 min, compared to other species, which required a minimum of 29 min. Most foraging ants (with the exception of *M. orientale*, *A. gracilipes*, *Pheidole* sp. and *S. geminata*) showed significantly quicker response times to the liquid and gel baits than the other two bait bases.

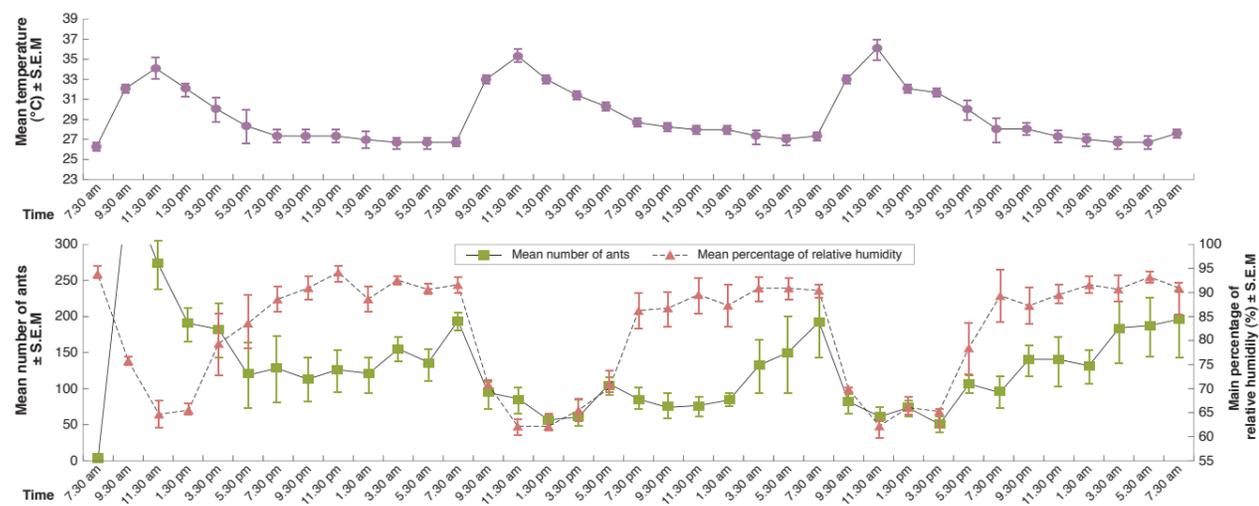


Fig. 2. Foraging activity of the ghost ant (*T. indicum*) over a period of 72 hours in relation to temperature and humidity (Chong & Lee 2006).

The correct choice of ant bait base will ensure the success of an ant management programme. Studies using different bait bases containing 0.001% fipronil against field populations of the ghost ants (*T. melanocephalum*) on the university campus revealed varying results. Liquid bait showed the best performance against ghost ants with >95% reduction within a week of post-baiting. The high attraction to liquid bait could likely be due to high susceptibility of this species to desiccation (Appel et al. 2004), and thus showed a higher preference for baits with higher moisture content.

When screening residential premises to determine suitable houses for conducting the ant bait trials, inconsistent sampling results were often recorded when sampling time varied. It was hypothesized that pest ants demonstrated a daily pattern of foraging activity, especially those species that nest outdoors but forage indoors for food. In this study, three ant species were chosen, namely *P. longicornis*, *M. pharaonis* and *S. geminata*, which were infesting a departmental building. Samplings were carried out along the corridors of the building which were directly exposed to the outdoor environment. Baited index cards were placed at locations where the ants were seen trailing every two hours and continuously up to 48 hours. The number of foraging workers on the index cards was counted approximately 30 minutes after placement. The experiment was replicated three times every other week. Results indicated that all three species demonstrated a relatively similar foraging pattern. Foraging activity peaked at 2 - 4 hours after sunset (20:00), 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 about 25°C at night, while the daytime temperature (especially in early afternoon) averages about 33°C, but can reach as high as 35°C (Lee 2002).

A relatively similar finding was observed by Chong & Lee (2006) on field populations of *T. indicum*. Over a period of continuous observation for 72 hours, they also found that *T. indicum* activity was negatively correlated with environmental temperature, but positively correlated with relative humidity (Fig. 2). Loke & Lee (2005) reported the daily foraging rhythm of *M. orientale*. The normal colony showed peak activity between 00:00 and 04:00. Norasmah et al. (2006) also recorded similar observations in their studies on tropical fire ant (*S. geminata*), where peak foraging activity was recorded between 23:00 and 00:00. Earlier, Hooper and Rust (1997) reported that foraging activity of *Solenopsis xyloni* began approximately four hours before sunset and maximal activity occurred between 2 and 7 hours after sunset. They found that foraging workers avoided foraging at the times of the day when ground surface temperature were relatively higher.

In summary, ant foraging and feeding behaviour are influenced by a variety of factors as shown in Fig. 3. In an ant colony, larger larvae play an important role in regulating the storage and distribution of nutrients, especially protein. The foraging activity of worker ants are determined by several factors such as colony development, environmental conditions and starvation. Feeding is affected by four factors namely food preference, colony development, starvation/satiation effects, and inter- and intra-species competition. Some species prefer to feed on liquid and semi-solid foods, while solid food will be brought back to the nest to be given to the larvae, since workers are incapable of ingesting solid food. When baiting pest ants, three factors influence the feeding of bait, namely bait base (matrix), food attractant, and the active ingredient used. Ants may be killed via direct feeding of the bait; necrophoresis (carrying and dumping of the poisoned dead ants); or other forms of horizontal transmission. Once the ant colony is suppressed or eliminated, another species or population may take over the existing territory.

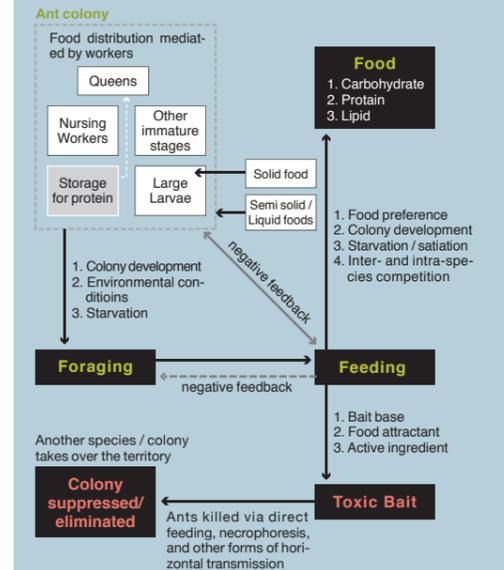


Fig. 3. Hypothetical pathway of foraging and feeding behaviour of pest ants.

Profile

Dr Chow-Yang Lee is internationally recognized for his research in biology and the management of urban pest cockroaches, ants and termites in South East Asia. He received his Ph.D. in Insect Toxicology/Urban Entomology in 1996 from Universiti Sains Malaysia/University of Science, Malaysia (USM) before joining USM as a lecturer. He was appointed associate professor in 2002, and finally as Professor of Entomology in 2006. He has authored and co-authored 96 peer-reviewed papers; 7 books and 36 other publications; and delivered more than 100 talks including keynotes and plenary and symposium speeches in numerous international conferences and seminars. Dr Lee received many accolades at international and national levels including the Outstanding Young Malaysian Awards 2008, Kyoto University Visiting Professorship (2007), HH Yap Award (2003), MSPTM Medal (2003), Fulbright Scholarship (2002) and the National Young Scientist Award (2000).

