EMIGRATION AND COLONY BUDDING BEHAVIOUR OF THE BLACK CRAZY ANT, *Paratrechina longicornis* LATREILLE (HYMENOPTERA: FORMICIDAE)

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ABSTRACT

The existence of the house infesting ants not only brings nuisance to humans, but they could also infest foodstuffs which can lead to food poisoning. They may emigrate and even split from the main colony into two or more colonies when disturbed. To produce highly effective control products, it is essential to understand how fast the ant colonies emigrate and how they divide their colonies when after disturbed. The aims of our study were to determine the emigration time and to identify the number of new nests emerging from a single colony. In the first experiment, one artificial nest was placed in front of the old nest at 40 cm distance for emigration method. In the second experiment, three new nests were provided 40 cm in front of the old nest to investigate the budding behaviour. Results revealed that the Black Crazy Ant, *Paratrechina longicornis* colonies completed emigration time in about one hour and small colonies with minimum as 38 workers can split into two new nests after destruction of the old nest. This study provides new information and understanding of the household ant behaviour which is essential in pest management.

Keywords: Infestation, Black Crazy Ant, emigration, budding behaviour

ABSTRAK

Kewujudan semut perosak isi rumah bukan sahaja membawa masalah kepada manusia, malah ia menyerang makanan dan boleh menyebabkan keracunan. Semut boleh berhijrah (emigrasi) dan berpecah dari koloni utama ke dua atau lebih koloni apabila diganggu. Untuk menghasilkan produk kawalan yang sangat berkesan, adalah penting untuk memahami seberapa cepat koloni semut berhijrah dan bagaimana mereka membahagikan koloni mereka selepas sarang diganggu. Tujuan utama kajian ini adalah untuk menentukan masa emigrasi dan mengenal pasti jumlah sarang baru yang muncul dari koloni asal. Dalam eksperimen pertama satu sarang buatan diletakkan di hadapan sarang asal pada jarak 40 cm dalam kajian emigrasi. Dalam eksperimen kedua, tiga sarang baru diletakkan pada jarak 40 cm di hadapan sarang asal bagi menyiasat pemecahan koloni semut. Kajian ini mendapati bahawa Semut Hitam Gila, *Paratrechina longicornis* mengambil masa sekitar satu jam untuk berhijrah sepenuhnya ke sarang yang baharu dan koloni kecil dengan jumlah pekerja seminimum 38 individu mampu berpecah membentuk dua sarang baharu selepas kemusnahan sarang lama. Kajian ini memberikan maklumat dan pemahaman baru mengenai tingkah laku semut perosak isi rumah yang sangat penting dalam pengawalan perosak.

Kata kunci: Serangan, Semut Hitam Gila, penghijrahan, tingkah laku pemecahan

INTRODUCTION

House-infesting ants are considered important in urban environments because they interact with the human daily life. House-infesting ants also influence the local populations of many organisms, from decomposers to animal groups higher up the food chain (Wills & Landis 2018). They easily establish well in human association as they have a colonization mechanism (Stukalyuk & Goncharenko 2020; Rizali et al. 2010). There are many species of ants that commonly invade homes for finding food and nesting sites (Buczkowski & Bennet 2009). According to Ab Majid et al. (2016) the most common species of household ants found based on the surveyed residence in Pulau Pinang, Malaysia are *Tapinoma indicum* (17.74%), *Paratrechina longicornis* (22.09%), *Tapinoma melanocephalum* (17.0%), *Pheidole* sp. (5.22%). and *Monomorium pharaonis* (10.61%).

In this study, the *P. longicornis* Latreille (Hymenoptera: Formicidae) colonies were chosen to be investigated on the emigration behaviour of the house-infesting ants. The *P. longicornis* known as a black crazy ant, commonly in greyish-black colour (Na & Lee 2001). According to Wetterer (2008) black crazy ant occurs primarily in highly disturbed coastal and urban environments which also come in massive numbers in residence or indoors. Their flexibility in colony size and caste number gives pharaoh ants the ability to establish a new colony rapidly with a small number of individuals (Eow et al. 2004).

Emigration of ant colonies is fundamental for their social behaviour, but in certain cases colonies of ants will not emigrate when there is low disruption of nesting sites (Mitrus 2016). However, earlier study by Dornhaus and Franks (2006) on *Temnothorax albipennis* ant found out that this species may emigrate to a new site even though the current nest site is still undamaged, because the ant compare the quality of its original nest with the newly discovered nest.

Some factors that contribute to the ant's decision to emigrate are such aspects like the availability of food, influence to parasites, exposes to predators, reproduction and competition with other social insects' species (Hölldobler & Wilson 1990). If ants have multiple options of new nest sites condition, they may decide based on the best quality of each nest. They may emigrate to a new nest site which is further away from their original nest site if the nearest nest is in risk condition for their colonies (Syoji & Eguchi 2017)

Emigration involves the cooperation of a large number of workers which the first scouts must locate possible nests, exchange information with nest mates, assess area features and finally agree making choice to initiate the movement (Visscher 2007). This was further supported by Avargues-weber and Monnin (2009) colonies of *Aphaenogaster senilis* move in systematic order. The outside workers locate the potential nest site, initiating colony emigration and leading the colony members to the new nest site (Visscher 2007). During the emigration process, a new colony of ants can form or emerge by splitting into another and searching the new best quality site. Nest movement is a challenging and risky technique that requires considering the possible risks and consequences of moving (Bouchet et al. 2013). The energy spent on finding and building a new nest site, wasted foraging time, competition with native species and resources for food supplies (McGlynn et al. 2004) and predation during emigration are all possible costs of nest relocation (Pezon et al. 2005). Colony disruption and budding can be affected by a variety of the environmental changes such as physical disruption, natural climate changes as well as chemical interference (Buczkowski et al. 2005).

Newly emerge nests usually interact with the original colony nest, resulting in large polydomous colonies with several nests (Heller & Gordon 2006). It is suspected that budding may benefit reproductive strategy, where the physical disruption by humans stimulate factor budding to enable the spread of the pest ant (Buczkowski & Bennett 2009).

Studies on the emigration behaviour of ants had been mostly done by using *T. albipennis* ant which is the outdoor species of ants (Dornhaus et al. 2008). No study, to our knowledge, has been conducted on the emigration behaviour on the house-infesting ants. House- infesting ants bring nuisance to humans and become an important pest especially in tropical countries (Ab Majid et al. 2016). Some of them are known to carry pathogens such as *Salmonella* (Alharbi et al. 2019; Simothy et al., 2018). Control of house-infesting ants are challenging because of their robust behaviour (Suiter et al. 2021). New colonies often return inside premises after treatment was conducted. This could be because part of the colonies had moved to new nest sites and divided their colonies during the treatment period.

However, it is unknown how quick house infesting ant colonies can emigrate from original nest to new nest sites. To produce new and highly effective control products, it is essential to understand how fast the ant colonies emigrate and how they divide their colonies when being disturbed. Thus, it is important to understand the ant behaviour, which is essential to develop effective pest control products to suppress the ant colonies and to have better understanding of the pests' problem that Malaysia faced.

MATERIALS AND METHODS

Ant Colonies

A total of 15 colonies of *P. longicornis* (black crazy ant) were collected from different locations around the campus and student residential areas in the Universiti Malaysia Terengganu (5.406020 N, 103.086918 E) between January to August 2019.

To find the ant's nest, food baits were placed on the index papers (7.5 cm x 7.5 cm) and randomly setup near the building cracks and crevices (Kenne et al. 2005). Ants that visited the bait were traced to their nest as they returned back to nest site. A mixture of lemon with water (1:1) was injected into the nest through the entrance using a syringe. A mixture of lemon with water was used to force the ants to evacuate their colony (Chaudhari et al. 2013). As the ants moved out from their nest, they were collected using an aspirator and fine brush. Ants were then put into vials and transferred into a plastic container with fluon coated the upper inner walls to prevent ants from escaping. The ants were collected ranging from queens, workers, and broods. To confirm all individuals were collected, the colony entrance was observed for 10 minutes after ants were collected. If there were no ants came out from the entrance within 10 minutes after the collection, the whole ants in the colony were assumed had been moved out. However, in some cases the queen ant from the colony cannot be collected even after 10 minutes. In this case, each of the colony is ensured to contain the broods.

In the laboratory, the ants were transferred into an artificial nest (Figure 1) that was constructed by using glasses of microscope slides (7.5cm x 5 cm) sandwiching between two cardboards (Franks et al. 2008). Ants were fed with honey, small pieces of mealworm and water. The colonies were allowed to settle in the artificial nest for a week before any experiment was performed.

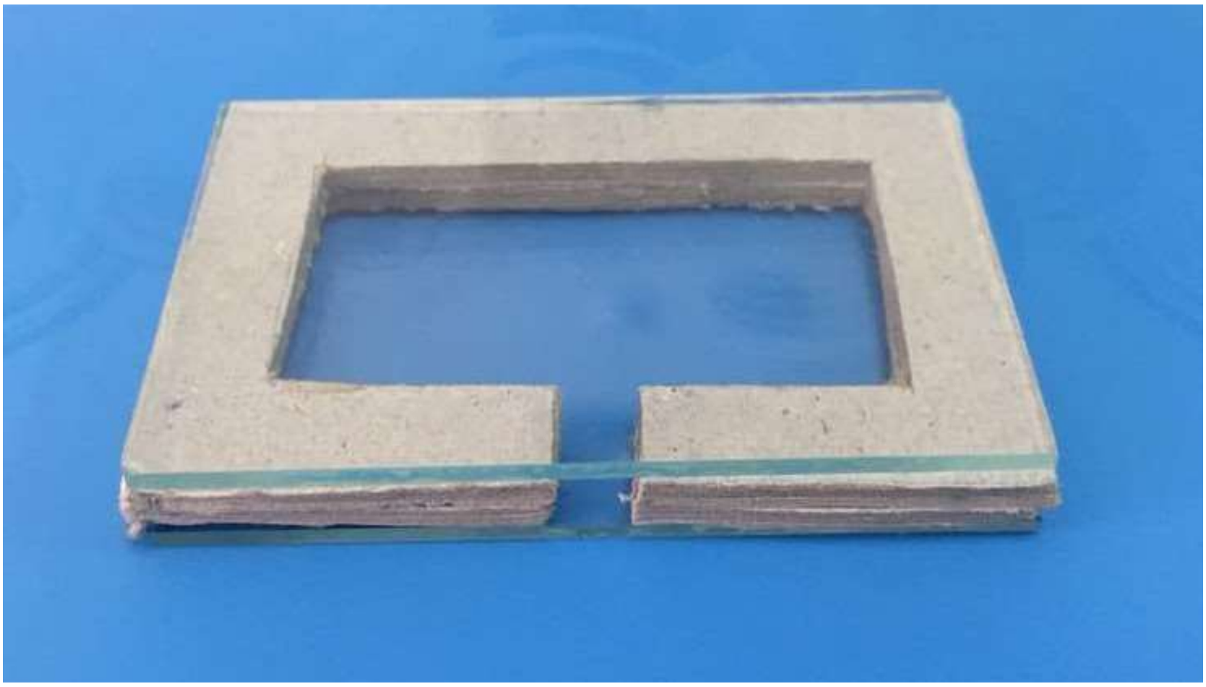

Figure 1. The structure of artificial nest

Each ant colony was used repeatedly throughout the experiment until enough data were collected. Most of the colony were used two times with a week gap before the same colony was used again in the next trial. This was done to reduce the ants' previous emigration experience memory (Langridge et al. 2004). In the experiment, a total of 30 colonies of *P. longicornis* were used in which thirteen colonies with 16 to 130 workers (58±37.130) were queenless and seventeen colonies with 20 to 210 workers (79.59±50.551) have a queen. All experiments were carried out within a large rectangular arena (50cm x 40cm) where the upper inner walls were coated with fluon.

Experimental Procedures

Experiment 1: Emigration period

For the emigration period experiment, a new nest (NN) that has the same quality as the old nest was placed in front of the old nest (ON) at 40 cm distance (Figure 2). To force the ants to emigrate, the old nest was destroyed by removing the top glass of the microscope slides. During the emigration, we recorded the time of discovery of the new nest (the first worker ant entered the new nest), the first brood transfer into the new nest (this indicates that the ants have decided to move into the new nest) and complete emigration time.

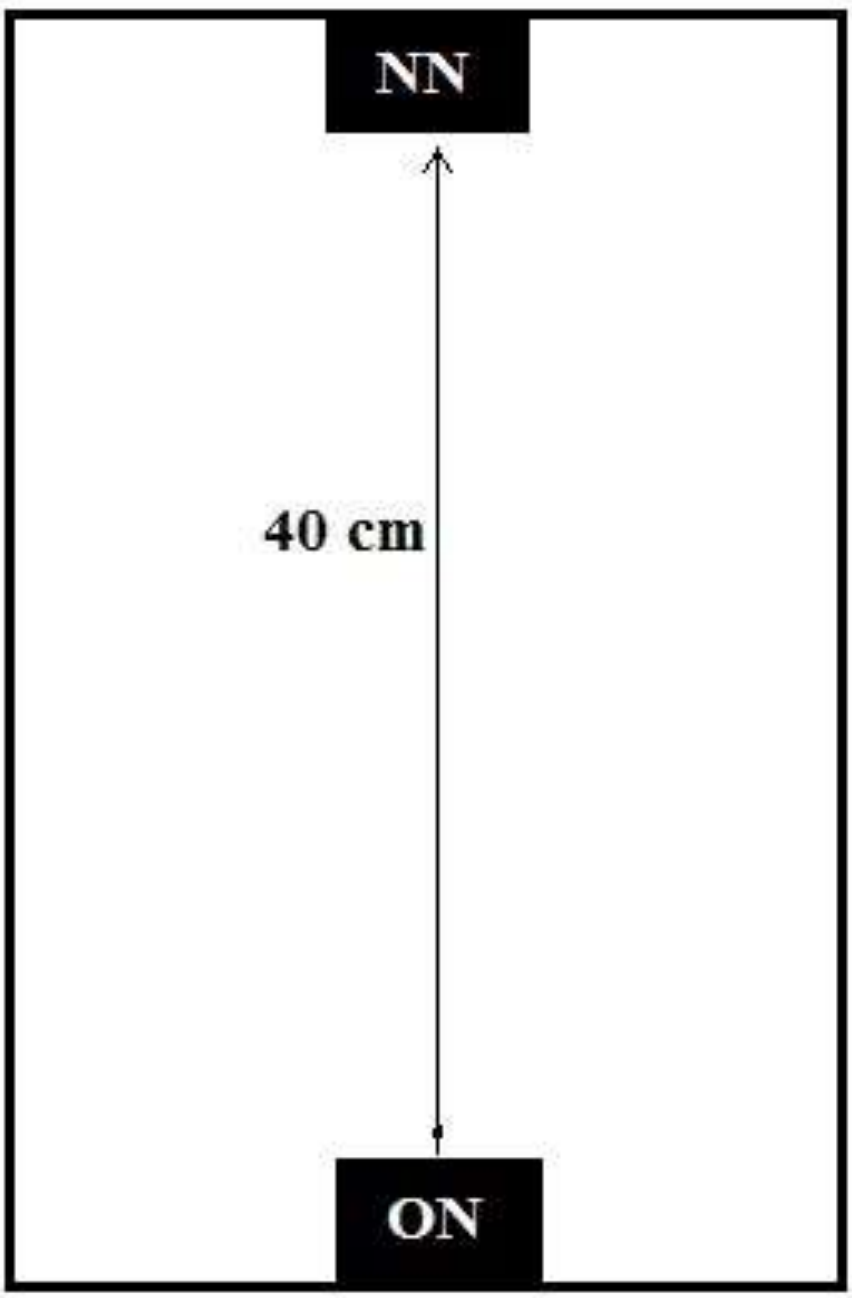

Figure 2. The experimental set up for the emigration period of house-infesting ants. ON: original nest; NN: new nest

Experiment 2: Colony budding behaviour

Before starting this experiment, the ant's colonies used in Experiment 1 were left for seven days in their emigrated nest, now become an old nest (ON). A colony of ants in the old nest (ON) was placed in the arena and three new nests (NN) of the same quality were presented in front of the old nest (ON) (Figure 3). To induce emigration, the old nest (ON) was destroyed by removing the upper glass of the microscope slides. The ants were left to choose their new nest for 24 hours. If ants and the broods were found in multiple new nests after 24 hours, the colony was assumed to have split (budding) from their original nest (Dornhaus et al. 2004).

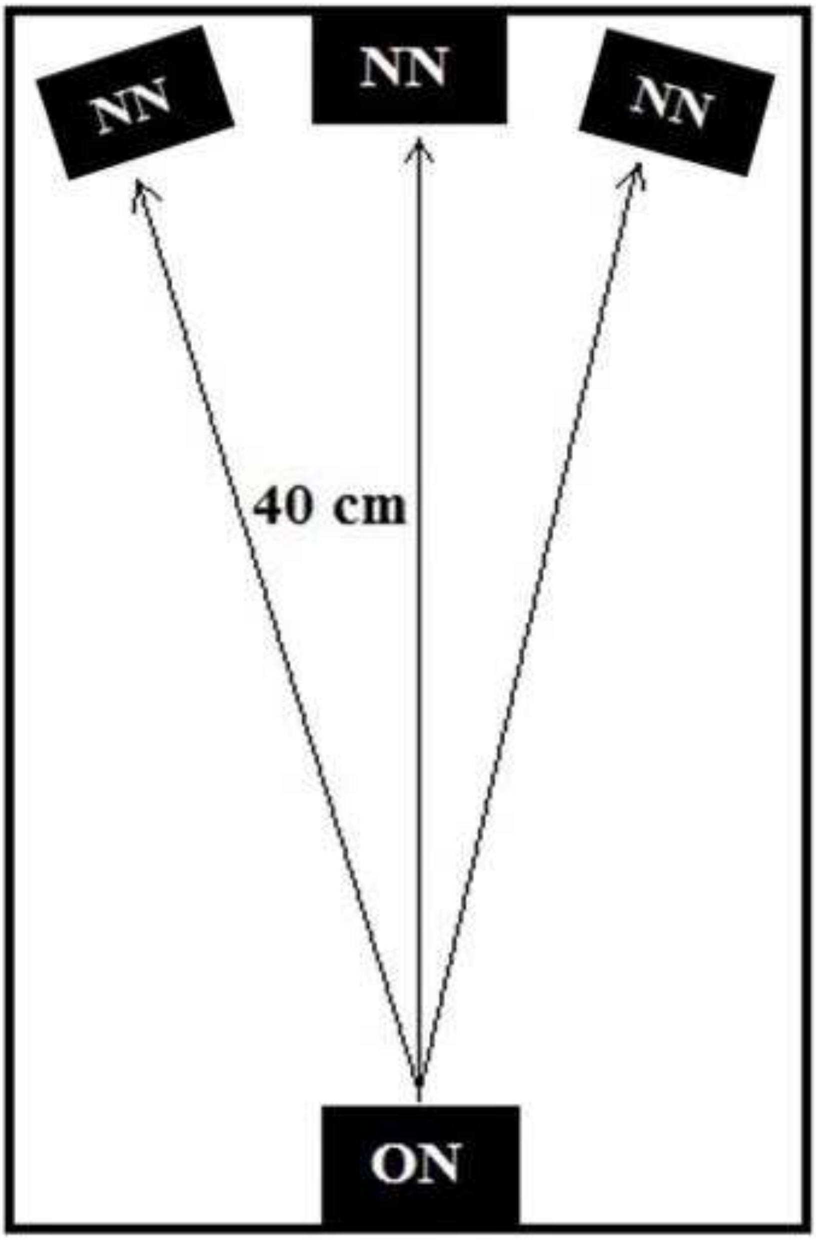

Figure 3. The experimental set up for colony budding behaviour of house-infesting ants. The distances between the new nest and the old nest were measured from entrance to entrance. ON: original nest; NN: new nest

Statistical Analysis

All analyses were conducted using IBM SPSS Statistic 22 software. The data was transformed into log base 10 and the normality test was performed. Our data was found to be normally distributed based on the Shapiro-Wilk test (*P>0.05*). We then performed a two-way ANOVA to determine the difference between the ant activities (time of new nest discovery, brood transfer and complete emigration) versus colony conditions (queen or queenless) and colony types (large or small colony) and the interaction between the ant activities (time of new nest discovery, brood transfer and complete emigration) and the colony types (large or small colony). The colony types were determined from the middle of the size range of the number of workers which details based on Franks et al. (2007). The median size of the *P. longicornis* colonies used here was approximately 63 workers (interquartile range 94-33.5) Colonies that above the median size were considered as large colonies (L) while colonies below median were considered as small colonies (S).

RESULTS

Emigration Period

The colonies were divided into small and large types; colonies that have 63 workers and below (35.87 ± 14.446) considered as small (S) and the colonies that have 63 above workers (104.60 ± 40.098) were considered as large (L) colonies. Out of 30 colonies, there were 15 small and 15 large colonies. The colony with 30 workers (small colony) discovered the nest slowly in about 26 mins but took only 10 mins after the first brood transfer to complete emigration and the large colony (130 workers) discovered the nest faster. Overall, the ants took two minutes to find the new nest and 35 mins after the first brood transfer to fully emigrate after the first brood was transferred (Figure 4). In this experiment, our result shows that there is no significant interaction between all the activities with or without the presence of queen in the colony and the colony types (Two-way ANOVA, $F_{2,84}$=0.042, *P>0.05*).

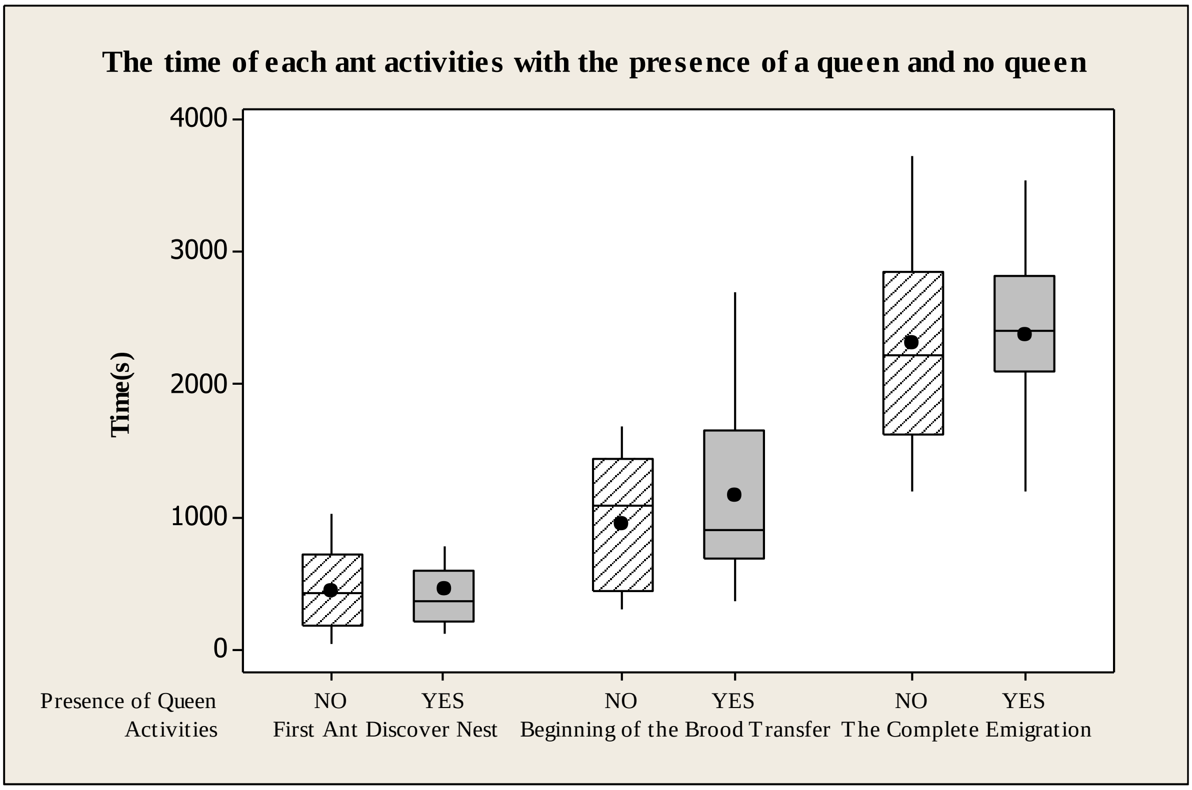

Figure 4. Emigration period colonies of *P. longicornis* with each type of activities that have queen and no queen. Solid circles indicate means; boxes indicate the interquartile range; horizontal lines within boxes indicate the median value of the data. Two-way ANOVA shows that there was no significant different time for all activities for colonies with or without queen (Two-way ANOVA; *P>0.05*)

The results showed that the larger colonies discovered the new nests quickly but took longer time to complete emigration while the small colonies took longer time to discover the new nest but they completed the emigration processes faster than larger colonies (Figure 5). There was a significant interaction between all the ant activities, first ant discovery, during the brood transfer and fully emigrate versus the colony types and colony conditions (Two-way ANOVA, $F_{5,78}$=3.071, $P<0.05$).

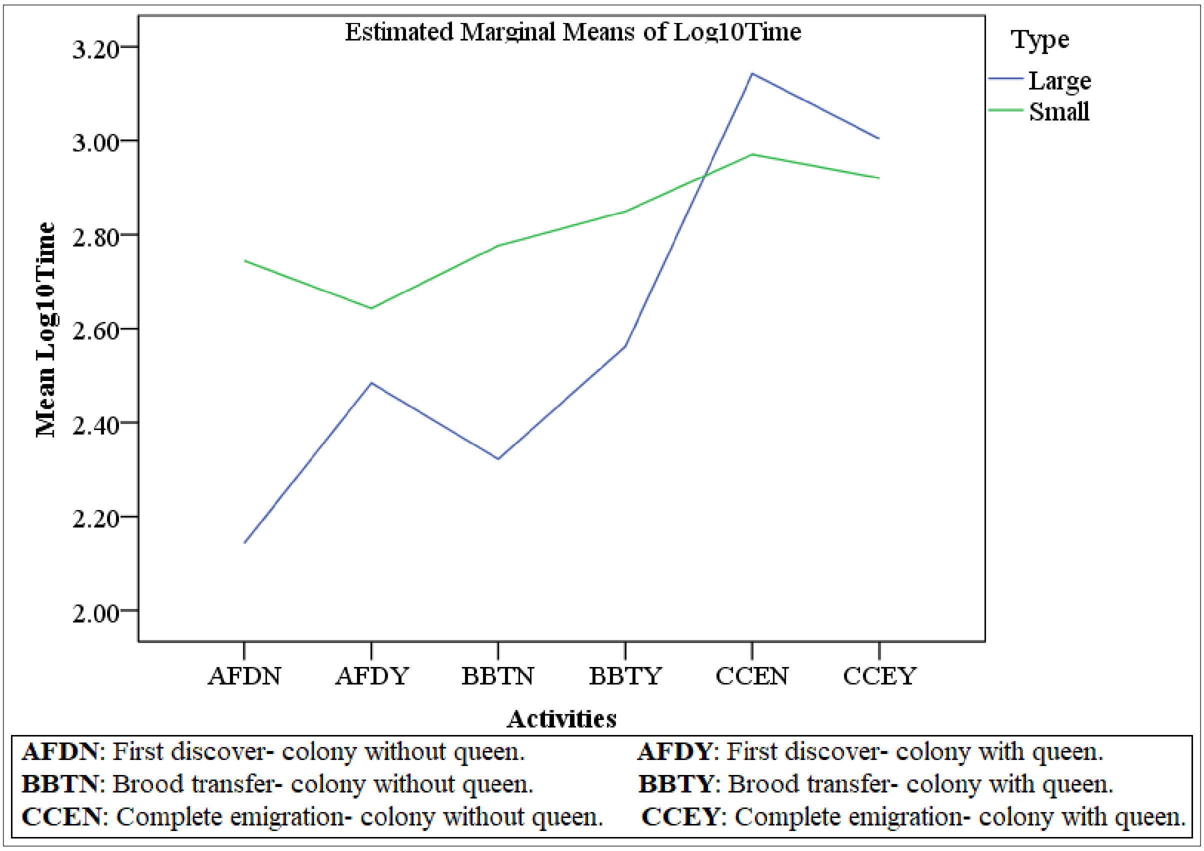

Figure 5. Interaction between ant activities during emigration versus the colony types of *P. longicornis*. L: Large colonies; S: Small colonies

Colony Budding

Among 30 colonies of *P. longicornis* only 12 colonies split forming two new nests (Table 1). The ants only occupied two out of the three presented new nests. Colonies with about 38 workers and above can split into two new nests after destruction. Out of the 12 colonies that split into two nests, six of the colonies have queen and all of the queen chose to enter the new nest with the highest number of workers and broods ($\chi^2_{11,1234}$=572.421, $P<0.001$) (Table 1).

Table 1. The number of workers entered the new nests after budding from the 12 budding colonies of *P. longicornis*

Number of workers	**Number of New Nest Occupied**	
	Nest 1	**Nest 2**
38	28	10
43	24*	19
52	23	29
64	41	23
65	34*	31
72	26	46*
80	32	48*
87	50	37
108	78*	30
184	101*	83
196	58	138
245	98	147

The asterisk (*) indicated the presence of the queen in the colony.

DISCUSSION

Colonies of *P. longicornis* not only proficient in invading houses and food exploitation (Witte et al. 2007), but based on our results, we found that these ants also quick in choosing new nest sites when their original nests were being destroyed. *Paratrechina longicornis* tooks about 45 minutes to one hour to complete emigration. The finding of this study displays quite similar with the result reported by Dahbi et al. (2008) where the emigration of *Cataglyphis iberica* lasted between one and two hours when the nest was attacked by another ant species.

After the destruction of the original nest, only a few workers of *P. longicornis* went out searching for a new nest. These ants then left a pheromone trail on their way back from the new nest to the old nest. When some of the workers start to search for a potential new nest site, the others remain close to the nest protecting the brood and queen until the returning worker ants start sharing information by leaving a pheromone trails. The emigration of *P. longicornis* became much faster after they start to transfer the first brood. The emigration divides into two phases, first recruiting nest mates, then once the quorum threshold reaches the limit, they change to emigrate faster (Sasaki et al. 2015).

The results in this study revealed that larger colonies discover the new nest quicker than the small colonies. However, the larger colonies took longer time to complete emigration and vice versa. Large colonies were faster than small ones at discovering the new nest possibly since they are able to organize more workers (Franks et al. 2003). However, larger colonies took more precise decisions than small colonies, and in most instances they did so more quickly. Although the decision-making accuracy of small groups was comparable to that of large groups in favorable environments, decision-making in small colonies was generally ineffective under more demanding conditions (Cronin 2016).

The time consumed during emigration between small and larger colonies might not be the same because they are faced with different obstacles during emigration (Dornhaus & Franks 2006). As a result, large colonies in nature most likely are able to find more available nests quickly than small colonies (Frank et al. 2006). This is due to the task specialization that is different depending on the size of the colony (Holbrook et al. 2013). One worker may be assigned for two tasks. However, it is different with the larger colonies which have advantage in distribution of task management (Thomas & Elgar 2003).

Colonies use a quorum-based decisions in which individuals gather information on available actions then select the options they decide until the number of quorum individuals is reached, a phase shift occurs and decisions are taken at the group level (Cronin 2015).The likelihood of a person performing an action increases rapidly once a critical number of individuals quorum decisions help to filter out individual errors and can achieve cohesive option of the best selection (Sumpter & Pratt 2009).

In this study the queen ants emigrate into the new nest in the middle of emigration on their own without being carried by the workers. It is interesting because this behaviour is the same as reported earlier by Franks & Sendova-Franks (2000) from their study using *T. albipennis* ant. It has been reported that the reason for the queen to move in the middle of emigration is perhaps to reduce risks as the queen was transported from the defense of half of the colony in the old nest to protect the other half in the new nest. Late emigration of the queen could give chances for predators to attack due to direct exposure and allowing the queen with the least number of workers (Franks & Sendova-Franks 2000). According to Robinson (1992) higher numbers of workers affect communication flexibility which contributes to the success reproduction of a colony by allowing it to continue to grow, develop, and produce a new generation of males and females which can change colony conditions.

In this study, the queen does not affect the activities during emigration. However, the presence of the queen in the colony can maintain condition to the colony. Based on what has been observed, the colonies that have queens performed better and were easy to rear compared to the colony without queen. Possibly, this is because the queen can produce the odor that can be recognized by their workers (Crosland 1990). This probably explains the workers behaviour where they tend to stay near the queen and remain in the artificial nest. Compared to the nests that did not have a queen, workers usually move around and were a bit chaotic. However, further studies should be done to clarify this behaviour.

In colony splitting experiment, three new artificial nests were provided. However, most of the colonies that split occupied only two nests. Possibly this is because the colony size was not large enough to split into three new nests. In nature colonies of *P. longicornis* could have up to 10000 workers and hence, would probably split into more than two new nests (Vittum 2020).

Based on the result, a small colony of less than 38 workers in *P. longicornis* remained in the same colony and did not perform budding. Smaller colonies might well be at a disadvantage because of their smaller number of scouts which they adjust their decision making and recruitment mechanisms such that they eventually achieve the same accuracy as large colonies, but at the cost of taking longer to complete an emigration (Frank et al. 2006). Based on observation, the queen emigrates to the new colony that has a high number of workers and brood.

CONCLUSION

Many ant pest control products are made of chemicals with low concentrations to reduce harm especially to human beings. These products could take long time to fully eliminate ant colonies. We revealed that *P. longicornis* only took about one hour to emigrate and they can multiply their colonies rapidly since colonies with just 38 workers can split into two. This study provides important information on the household ants behaviour for future and better production of ant control products. The control products should be environmentally friendly and able to act faster to suppress ant colonies before they could emigrate or split their colonies and continue to infest households.

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