

Colonial Growth Dynamics of Tropical Urban Pest Ants, *Monomorium pharaonis*, *M. floricola* and *M. destructor* (Hymenoptera: Formicidae)

by

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ABSTRACT

Experiments on the colonial growth dynamics of normal, broodless and queenless colonies of three tropical urban pest ants, namely the Pharaoh's ant, *Monomorium pharaonis* (L), *M. floricola* (Jerdon) and the Singapore ant, *M. destructor* (Jerdon) were executed in the laboratory. The growth dynamics of *M. pharaonis* and *M. floricola* colonies were high, even in the absence of queen or brood. Intrinsic rate of increase (r_m) calculated for normal colonies were 0.0233 ± 0.002 and 0.0249 ± 0.001 for *M. pharaonis* and *M. floricola*, respectively. In contrast, colonies of *M. destructor* showed poor growth dynamics in the laboratory, even under normal colony conditions. A further experiment was conducted to determine the minimum egg number required to produce queen(s) in a simulated queenless colony of *M. pharaonis* and *M. floricola*. Results indicated that a minimum of 1000 eggs with 100 workers were needed to successfully produce new queens in all replicates for both species. Percentage of queen production was recorded at 0.69 and 0.65% for *M. pharaonis* and *M. floricola*, respectively. The numbers of queens produced ranged between 1 and 6 for *M. pharaonis*, and between 1 and 18 for *M. floricola*. The mechanism of caste regulation in these tropical household ant species is discussed.

Keywords: ants, *Monomorium pharaonis*, *Monomorium floricola*, *Monomorium destructor*, colony growth, intrinsic rate of increase, caste regulation.

INTRODUCTION

Urban pest ants are an important group of insect pests in the urban environment. In the tropical region, the Pharaoh ant, *Monomorium pharaonis* along with *Monomorium floricola* and the Singapore ant, *Monomorium destructor* are common pest ants in residential premises

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and food preparative outlets (Na & Lee 2001, Lee 2002, Lee *et al.* 2002). With exception of *M. pharaonis*, little is known about the colonial growth dynamics of *M. floricola* and *M. destructor*. The life cycles of *M. pharaonis* was earlier reported by Peacock *et al.* (1950) who recorded the following developmental periods for the worker caste: egg, 7.3 days; larva, 17 days; prepupae, 3.1 days, pupa, 9 days, for a total of 36.4 days. Both sexual forms (male and queen) take slightly longer to reach adulthood (41.25 days).

All three *Monomorium* species are polygynous (Passera 1994). For *M. pharaonis* and *M. floricola*, dissemination of nests is likely by sociotomy (budding), in which part of an existing colony migrates carrying brood to a new nesting site (Edward 1986, Hedges 1998). However, new colonies of *M. destructor* are formed by nuptial flight although budding is likely to occur (Hedges 1998). Although *M. floricola* and *M. destructor* are also recognized as 'tramp species' (Passera 1994), it remain unknown whether colonies of these species also exhibit polydomic and unicolonial characteristics as *M. pharaonis* does.

The colony growth dynamics and colony life cycle of social insects have been well studied by Brian (1965), Wilson (1971) and Oster & Wilson (1978). These studies mainly dealt with insects which found colonies through nuptial flight of either haplometrosis, or pleometrosis. *Monomorium pharaonis* and *M. floricola* are examples of ant species that have abandoned the nuptial flight and territorial boundaries among colonies and adopted budding as the mode of colony dissemination (Wilson 1971). As it is almost impossible to study the colonial growth dynamics of these species empirically due to the difficulty in locating their nests in the natural environment and their nests are also highly sensitive to disturbance, this laboratory study was therefore initiated to determine and compare the colonial growth dynamics of these three species of *Monomorium*.

MATERIALS AND METHODS

Colony dynamics of the three *Monomorium* species

Insects: The three *Monomorium* species used in this study were obtained from stock cultures maintained at the Urban Entomology Laboratory, Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia. They were reared in wooden boxes measuring 15 x 9 x 2 cm with folded papers which were placed in rectangular plastic trays (50 x 37 x 9 cm). The inner-upper surfaces of the trays were smeared with a thin layer of fluon (polytetrafluoroethylene suspension) to prevent the ants from escaping. Moisture was supplied

through an inverted plastic cup over the lid of a petri dish. Food was provided *ad libitum* consisting of 10% (w/w) sucrose solution soaked in cotton wool ball, boiled egg yolk, canned tuna fish, segments of freshly-killed late nymphs of lobster cockroach (*Nauphoeta cinerea*) and peanut oil on filter paper. The cultures were maintained under 12-hour photoperiod, $26 \pm 2^\circ\text{C}$ and $60 \pm 5\%$ r.h. Each colony consisted of 100 – 150 queens and 5000 – 10,000 workers for *M. pharaonis*, 400 – 500 queens and 15,000 – 20,000 workers for *M. floricola*, and 40 – 50 queens and 10,000 – 15,000 workers of *M. destructor* respectively.

Colonial growth dynamics:

A total of 15 colonies (five each of normal, queenless and broodless colonies) were isolated for each *Monomorium* species and were placed in aluminum pans (38 x 22 x 8cm) to establish experimental colonies. A translucent plastic petri dish (d = 9 cm) with holes drilled along its side was used as their nest cell. A normal colony consisted of 300 workers, 5 mature queens, 0.1 g brood (approx. 2070 individuals of mixed immature stages of *M. floricola*, 1290 for *M. pharaonis*, and 1570 for *M. destructor*), while a queenless colony was established with 300 workers and 0.1 g brood only. A broodless colony only consisted of 300 workers and 5 queens. Food and water were given *ad libitum*. All the colonies were kept in 12-hour photoperiod.

Colony sizes were estimated at 4th, 8th, 12th, 16th and 24th week by capturing digital pictures of the colony and the number of workers and queens were counted later on a computer. The brood was weighed using an analytical balance. Intrinsic rate of increase (r_n) of each species at different experimental condition was calculated based on formula in Grothaus *et al.* (1981) and Lee *et al.* (1996): $r_n = [\log_e(n_{t+1}) - \log_e(n_t)] / \text{time}$, where r_n = daily rate of population increase, n_t = population at t , n_{t+1} = population at $t+1$, and time = difference between $t+1$ and t . Data were subjected to analysis of variance (ANOVA) and means were separated using Scheffe test.

Egg numbers for queen formation:

In this experiment, the effects of egg numbers on queen formation in *M. pharaonis* and *M. floricola* were studied. A hundred small colonies, each containing 200 workers and varying number of healthy queens (between 10 and 50 queens) were initially set-up in polyethylene containers (18 x 7 x 2.5 cm). The queens were allowed to lay eggs for a period of up to 10 days, upon which the number of eggs was counted under a dissecting scope. Colonies containing 100, 500, 1000, 1500 and 2000 eggs were established, and each was replicated 6 times. Caution was taken to avoid mechanical injury to the eggs by allowing

only worker ants to carry the required number of eggs into the experimental container. Whenever more eggs than the required number were recorded in any container prior to the experiment, they were removed using a pair of soft forceps. The eggs in each container were left to acclimatize with 100 workers for 24 hours before another count was made. Colonies which excessive eggs were cannibalized by worker ants were replaced. The experiment lasted for 80 days. This period was needed to ensure the eggs had fully hatched.

RESULTS AND DISCUSSIONS

Colonial growth dynamics

Under controlled conditions, normal colonies with complete castes (worker, queen and brood) generally grow better than in natural

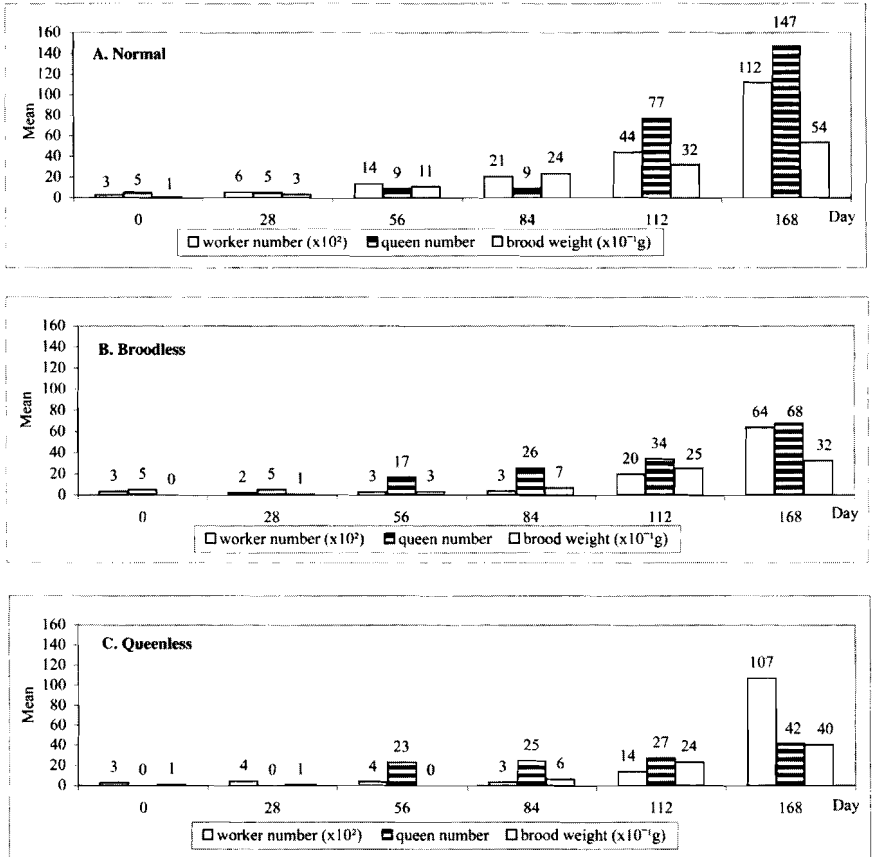


Fig.1: Caste individual numbers in different colony types of *M. pharaonis* over 24 weeks experimental period.

environment. However, this hypothesis is only true for *M. pharaonis* (Fig. 1) and *M. floricola* (Fig. 2). The colonies of *M. destructor* were found to have impeded growth even under the presence of complete caste composition of a normal colony (Fig. 3). Mortality of queens was observed along with workers and brood in all replicates over the experimental period. The gradual decrease of individuals in the colonies implied that the natality was slower than mortality, which was either due to their inability to form new reproductives, or because limited new queens were formed. Although the queens were laying eggs in broodless colonies (Fig. 3), the fecundity rate was slower than the reduction rate in colony members. The broodless colonies were gradually diminished as the queens aged. In the queenless colonies (Fig. 3),

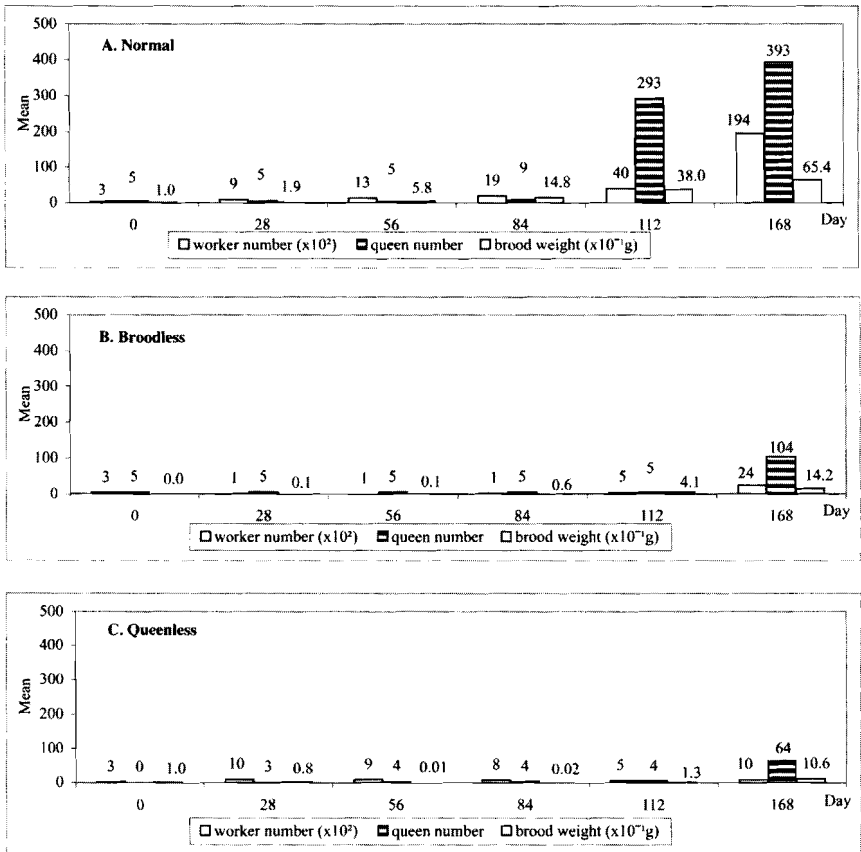


Fig. 2: Caste individual numbers in different colony types of *M. floricola* over 24 weeks experimental period.

the emergence of workers from initial brood increased the number of workers, but failure to develop sexual larvae from the brood eventually resulted in gradual attenuation of the colonies. The poor survivorship of all the colonies was suspected to be due to inadequate population size of the experimental colonies. Colonies of *M. destructor* appeared to be healthy and flourishing in stock cultures with large populations (40 – 50 queens and 10,000 – 15,000 workers) where both male and female sexual forms were found once a year in the laboratory (A.G.H.E., unpublished). This possibly suggested that this species is not well-adapted for laboratory culture, unless they are being maintained in large colonies. This peridomestic species is primarily found nesting

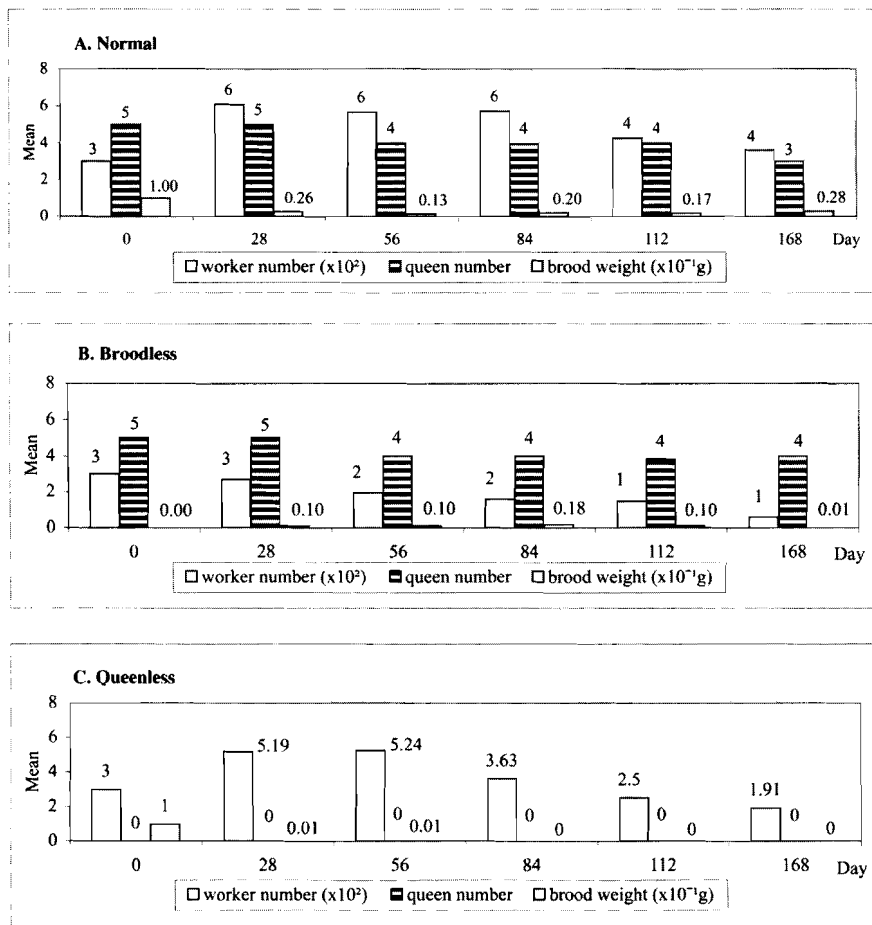


Fig.3: Caste individual numbers in different colony types of *M. destructor* over 24 weeks experimental period.

outdoors in the soil, at the base of trees, or under items that were in contact with the soil (Hedges 1998, Lee *et al.* 2002).

Among normal, broodless and queenless colonies, it was noticeable that the growth dynamics of *M. floricola* were high, even when the queen or brood were absent. The positive growth of the queenless colonies (Fig. 2) confirmed the ability of the *M. floricola* colonies to produce new reproductives (both queen and male) from existing brood. The capability of the new queens to produce female castes (workers and queens) suggested that the production of new queens is via intranidal mating. In all the colony types, continuous increments of queen numbers were observed. This was even distinctly found in normal colonies where the production of queens was up to an average of 393 from 5 queens initially within a period of 6 months (Fig. 2). In all types of colonies, there was not much increment of queen numbers observed in the first few months before the colonies achieved a level in which a required amount of all caste compositions were attained. This may possibly indicate that production of new reproductives was suppressed before that level of the colony was achieved. The ratios of workers to brood stages attained at the particular point before drastic increment of the queen numbers varied (1.06 [Day 84] for a normal colony, 0.60 [Day 112] for a queenless colony and 2.17 [Day 112] for a broodless colony).

A similar growth pattern was also observed in *M. pharaonis* colonies (Fig. 1). Their ability to produce newly-fertilized queens through intranidal mating has been previously reported (Peacock *et al.* 1950, Petersen-Braun & Buschinger 1971, Edwards 1986, Berndt & Eichler 1987). Hence, it is not surprising to find that the workers were capable of producing reproductives from existing brood in queenless colonies since the queen is not essential for successful colonization (Peacock *et al.* 1955, Wilson 1971, Edwards 1986). In addition, the successful

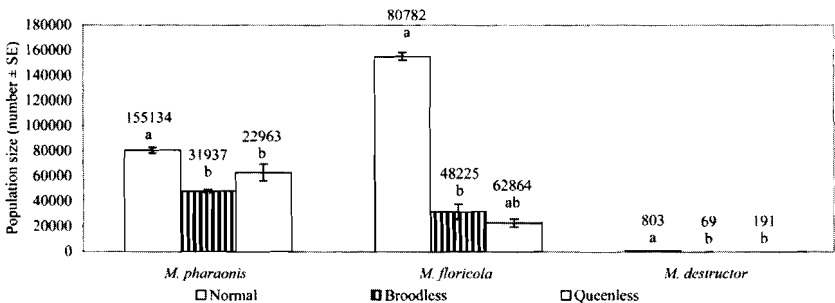


Fig. 4: Population sizes of *M. pharaonis*, *M. floricola* and *M. destructor* in different colony types after 24 weeks experimental period.

survivorship of a broodless colony and subsequent proliferation also confirmed that colonization is possible without the presence of brood. This is in contrast to Wilson's (1971) statement that colonization attempts would fail without the presence of brood. Under normal conditions, sociotomy usually occurs when the colony outgrows the resources in its home range (Edwards 1987). However, it can also happen under special circumstances such as attack by predators, repellence by insecticides, etc. Thus, the ability to continue to be prolific in a broodless situation would increase the survivorship of the colony.

The caste regulation of *M. pharaonis* has been well studied by Edwards (1987). It appears that the caste of female larvae is determined in the egg or at a very early stage in larval development, and that the potential to form both males and queens exists within the colony at all times. Edwards (1987) had emphasized that the presence of fertile queens in a Pharaoh's ant nest would prevent the rearing of new reproductive forms in which the inhibitory action is linked directly to the reproductive capability of the present queen(s). The only way to prevent the production of queens is to cannibalize all queen-determined larvae (Edwards & Abraham 1991) and workers primarily effect this regulation. However, the results of this study suggest that the inhibitory or suppression effect of the queens is only present for the earlier development of the colony. The number of queens increased exponentially as the population grew and before the fecundity of extant queens dropped. This implies that the 'egg-signal' hypothesis may not exclusively conclude the caste regulation in colony growth patterns. One possibility that fits the hypothesis of Edwards (1987) and yet explains the phenomenon observed in this study is that the caste regulation of *M. pharaonis* may be determined by the number of eggs present relative to the number of workers in which both egg and worker numbers are the two variables. Egg number reduction (due to declining queen fecundity) relative to constant workers number, or otherwise (due to emergence of new workers), would signal the rearing of reproductives. While there is no evidence that either quantitative or qualitative food differences (Edwards 1984), or the ratio of worker to brood stages are responsible for the determination of castes in *M. pharaonis*, we speculate that in the absence of an 'egg-signal', the workers are still able to respond to the stimulus of 'worker-signal' consequent to colony expansion. Thus, the workers are likely to determine the final size and composition of the colony. The ways that workers recognize and respond to the stimulus of the 'egg-signal' and 'worker-signal' are likely by monitoring the number of egg-contacts per

Table 1: Growth dynamics of *M. pharaonis*, *M. floricola* and *M. destructor* under different colony conditions.

Colony type	Mean intrinsic rate of increase ($r_n \pm \text{SEM}^{1,2}$)		
	<i>M. pharaonis</i>	<i>M. floricola</i>	<i>M. destructor</i>
Normal	0.0233 \pm 0.0002 b (a)	0.0249 \pm 0.0001 a (a)	-0.0053 \pm 0.0009 a (b)
Broodless	0.0299 \pm 0.0009 a (a)	0.0277 \pm 0.0002 a (a)	-0.0099 \pm 0.0019 a (b)
Queenless	0.0219 \pm 0.0003 b (a)	0.0077 \pm 0.0069 a (a)	-0.0137 \pm 0.0005 b (b)

¹Means followed by the different letters (not in bracket) within the same column are significantly different (Scheffe test; $p < 0.01$).

²Means followed by the different letters (in bracket) within the same column are significantly different (Scheffe test; $p < 0.01$).

worker per unit time. The same regulation mechanism could be applied on *M. floricola* as well since an almost similar growth pattern was found.

The r_n values of the laboratory colonies of the three *Monomorium* species under consistent extrinsic factors (without resources limitation and disturbance) were shown in Table 1. The r_n s of all colony types of *M. destructor* registered negative values, implying that all experimental colonies were decreasing with time. By contrast, the r_n s of all colonies of *M. floricola* and *M. pharaonis* recorded positive values, implying that the populations were increasing with time. There appeared to be no significant difference in terms of r_n values among simulated normal, broodless and queenless colonies of *M. floricola*. Similar findings were demonstrated by *M. pharaonis* except that the r_n of broodless colony showed significantly greater value. This may possibly indicate that both broodless and queenless colonies of *M. floricola* and *M. pharaonis* were able to compensate the absence of brood or queen, respectively, by exponentially increasing their growth rates toward the normal rate of colony development. The greater r_n values of broodless colonies suggested a better survivorship than the queenless colonies, despite that the queenless condition is always documented as basic composition in natural colony founding and dissemination (Peacock *et al.* 1955, Wilson 1971, Edwards 1987).

The use of r_n provided more comprehensive information on overall growth dynamics. In broodless colony of *M. pharaonis* for instance, the r_n value was significantly greater than normal colony. However, its final population size was significantly smaller than a normal colony (Fig. 4). Thus, if only population size is considered as a parameter in colony studies, the actual growth rate may be neglected. In addition, the r_n value would be suitable to be used for comparative purposes, especially

either among ant species or among studies that were conducted under different conditions or at different places. However, the r_n obtained in this laboratory study may not be a good representation of the actual field situation because any changes or disturbances occurred in the natural environment could alter the overall growth dynamics of the ant colony.

Egg numbers for queen formation

Peacock *et al.* (1950) have documented the longevity of queens (up to 39 weeks) and males (3 – 8 weeks) of *M. pharaonis*. On the other hand, Edwards (1986) observed that some queens could survive for more than

52 weeks in the laboratory. This is still relatively short when compared to other ant species (Hölldobler & Wilson 1990). The short queen's life of *M. pharaonis* is compensated by its ability to produce new queens (Passera 1994), as well as the need for relatively few workers and brood to perpetuate a new colony. Peacock *et al.* (1955) had reported that only 100 workers and 50 brood individuals was sufficient to initiate a successful colony.

The survivorship of immature stages of social insects is low as mortality occurs from stage to stage before achieving adulthood (Wilson 1971). For example, the survivorship for bumble bees, *Bombus agrorum* (egg to adult stage) is 47% (Brian 1951a, 1952), while it is only 33% for that in ants, *Myrmica ruginodis* (Brian 1951b). Thus based on the above fact, it is predicted that the survivorship of sexual brood is low (as queens only comprised ~1-5% of the total adult individuals for *M. pharaonis* and *M. floricola*), the results obtained from earlier experiments demonstrated that the queenless colonies of *M. pharaonis* and *M. floricola* could essentially produce queens from existing 0.1 g brood (approx. 1290 and 2070 individuals of mixed immature stages of *M. pharaonis* and *M. floricola*, respectively. A subsequent study was car-

Table 2: Effects of egg numbers on queen formation in *M. pharaonis* and *M. floricola*.

Egg number	n	<i>M. floricola</i>			<i>M. pharaonis</i>		
		No. queens produced (mean ± SEM)	% queens per egg	% success in replicates	No. queens produced (mean ± SEM)	% queens per egg	% success in replicates
100	6	0.50 ± 0.22	0.50	50.0	0	0	0
500	6	2.17 ± 0.60	0.43	83.3	2.33 ± 0.88	0.47	83.3
1000	6	7.67 ± 1.74	0.77	100.0	8.33 ± 2.16	0.83	100.0
1500	6	8.50 ± 1.69	0.57	100.0	9.17 ± 1.49	0.61	100.0
2000	6	12.33 ± 1.33	0.62	100.0	12.33 ± 1.56	0.62	100.0

ried out to determine the minimum egg numbers needed to produce queens in a simulated queenless colony. Because there was no evidence that worker to larvae ratio would affect the production of queens of *M. pharaonis* (Edwards 1984), only 100 workers were given to each simulated colony of both species.

Results obtained indicated that in simulated queenless colonies of *M. floricola*, only 50% of the six replicates of colonies with 100 eggs successfully produced queens (Table 2). Meanwhile, in colonies with 500 eggs, the success rate in queen production was 83.3% among the six replicates. All replicates in colonies with ≥ 1000 eggs produced queen(s), with a mean percentage of queen production of 0.65% per egg. The lowest number of queens produced in a colony of ≥ 1000 eggs was 1, while the highest was 18.

As for *M. pharaonis*, no queen was developed in colonies with 100 eggs (Table 3). A total of 5 out of 6 replicates with 500 eggs successfully produced queens. The number of queens produced ranged from 1 to 6. However, all simulated colonies with ≥ 1000 eggs recorded queen production, with a mean queen production per egg of 0.69%. Further observation indicated that all queens produced in this experiments were fertile. Colonies which failed to produce queens were gradually diminished soon after complete emergence of larvae from eggs.

The finding obtained above showed that in order to successfully produce new queens in a queenless colony with 100 workers in all replicates for both *M. pharaonis* and *M. floricola*, a minimum of 1000 eggs is needed.

In conclusion, both *M. pharaonis* and *M. floricola* are likely a more successful tramp ant species than *M. destructor*, judging from their higher colonial growth dynamics, and their ability to quickly produce queens and brood under queenless and broodless conditions, respectively.

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