Comparison of Foraging Ability Between *Solenopsis invicta* and *Tapinoma melanocephalum* (Hymenoptera: Formicidae)

by

Lu Yong-Yue*, Wu Bi-Qiu, Zeng Ling & Xu Yi-Juan

ABSTRACT

In this study, we investigated the foraging ability of the invasive ant *Solenopsis invicta* and native ant *Tapinoma melanocephalum* (Hymenoptera: Formicidae) by measuring their searching and recruitment time for 5 types of food (sausage, sausage & honey, honey, mealworm and peanut oil) in infested wasteland and litchi orchards in south China. The searching time was determined by measuring the time required for the first ant to find the food. The recruitment time was determined by measuring the time to recruit 10 ants to the food which was placed on petri dish 30 cm away from nest entrances. 30 colonies each of *T. melanocephalum* and *S. invicta* were tested. In the infested wasteland, the searching time of *S. invicta* for sausage & honey, sausage, mealworm and honey and the recruitment time of *S. invicta* for sausage & honey, mealworm and honey were significantly longer than those of *T. melanocephalum*, but the searching time of these two species of ants for peanut oil was not significantly different. In the infested litchi orchard, the recruitment time of *S. invicta* for sausage was significantly longer than that of *T. melanocephalum*, while the recruitment time for the other four types of food was not significantly different between the two species of ants. The searching time for all the five types of food was not significantly different between the two species of ants in the infested litchi orchard.

Key words: *Solenopsis invicta*, *Tapinoma melanocephalum*, searching time, recruitment time

INTRODUCTION

Interspecific competition refers to interference or suppression between two or more species. The consequences of interspecific competition are often

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Red Imported Fire Ant Research Center, South China Agricultural University, Guangzhou 510642, P.R.China

*Corresponding author, email:luyongyue@scau.edu.cn, insectlu@163.com

a reduction of efficiency in reproduction, growth and survival of one species due to the utilization or interference of common resources by another species. Competition for scarce resources by two species leads to an adverse effect on both species. Resource competition can be divided into exploitation competition and interference competition (Reitz & Trumble 2002). In exploitation competition, the ability of acquiring resources in one species is greater than that in another species. The mechanisms of exploitation competition include differential resource acquisition, differential female fecundity, differential searching ability, resource preemption, differential strategies and reactions to bad resources (Reitz & Trumble 2002, Xu & Cheng 2005).

Solenopsis invicta Buren is a dangerous pest originally discovered in South America, Brazil, Argentina, Paraguay and the Panama Canal (Vinson 1997). It is currently distributed all over the 19 southern states and regions of the US, an area of 128 million hectares (Callott & Collin 1996, Callott 2002, Alfredo & Jim 2004). On Sep., 28, 2004, *S. invicta* was first identified in Wuchuan, Guangdong in China, and subsequently it was found in other areas of Guangdong, Guangxi, Fujian, Hunan, and Hongkong (Zeng *et al.* 2005a). This alien ant can reduce the diversity of the native ants and cause effects on other organisms directly or indirectly (Holway *et al.* 2002). During the competition with native ants, the invasive ants can extend their searching and recruitment time due to their large popualtions, which enhances the exploitation competition (Johnson *et al.* 1987). In invaded areas, compared to the native ants, *S. invicta* normally has stronger exploitation competition, which allows them to rapidly find food, discover more food resources, recruit more ants and extend the recruitment time (Jones & Phillips 1990, Porter & Saignano 1990, Morrison 1999, Calcaterra *et al.* 2008). Previous studies have shown that invasion by *S. invicta* has already reduced the diversity and abundance of native ants in south China (Sheng *et al.* 2007, Wu *et al.* 2008, Lu *et al.* 2012). However, further studies on the exploitation competition between *S. invicta* and native ants in south China are needed.

While investigating the ant diversity in the areas with *S. invicta* in South China, we found that a small and fast-moving native ant (*Tapinoma melanocephalum* Fabricius) can co-exist with *S. invicta*, and is still the one of dominant species in the areas infected by *S. invicta* (Lu *et al.* 2012). *T. melanocephalum* and *S. invicta* have similar reactions to the soil surface temperature: with the increases of soil surface temperature, the percentage of ants appearing and controlling the food was decreased (Zheng *et al.* 2007). However, the heat resistance of *T. melanocephalum* is slightly higher than that of *S. invicta* (Zheng *et al.* 2007). How about the competition between these two species of ants? Which is stronger? These questions need to be answered. To avoid the interference of other species of ants and reveal the foraging ability of *T. melanocephalum* and *S. invicta*, we investigated the foraging capabilities and recruitment dynamics of both ants at a short distance (30 cm to the ant nest) in different habitats. By comparing the exploitation competition between *T. melanocephalum* and *S. invicta*, we expected to provide potential mechanisms by which *T. melanocephalum* co-exists with *S. invicta* and remains a dominant species in the areas with *S. invicta* in south China.

MATERIALS AND METHODS

Experimental environment

This study was conducted in Longgang, Shenzhen in 2007. *S. invicta* colonies in this district were polygyne. Based on the density and distribution of active *S. invicta* colonies (Zeng *et al.* 2005b), *S. invicta* was considered to be introduced for more than two years at the infested wasteland and litchi orchard. The general information of the two regions is summarized in Table 1.

Table.1 General information of infested wasteland and litchi orchard areas

Area type	Infested wasteland	Infested litchi orchard
Altitude(m)	46.5	40.7
Longitude and latitude	N22°44''.260'' E114°22'.340''	N22°44'.227'' E114°22'.303''
Area (m^2)	1826	2241
Agrotype	yellow-red soil	yellow lato soil
Grass coverage degree(%)	90	60
Defoliation thickness (cm)	-	2-3cm
Shade density(%)	-	92
Active *S. invicta* nests/100m^2	0.93	0.18

Experimental design

Three fan-shaped side wall with equal areas (≈ 0.023 cm^2) were removed from the bottom side of plastic petri dishes (diameter = 9 cm) and then wet filter paper (diameter = 9 cm) was placed on the bottom of the petri dishes. Subsequently, five types of food including sausage (representing artificial food with abundant protein), sausage & three drops of honey (representing artificial food with abundant protein and carbohydrates), mealworms (representing natural food with abundant protein), peanut oil (representing artificial food with abundant oils) and honey (representing artificial food with abundant carbohydrates) were placed on the center of the petri dishes as baits. Peanut oil and honey were dropped in the cotton wool at the center of the petri dishes with a plastic head dropper. Five types of baits were placed (at a distance of 30 cm) around the nest of *T. melanocephalum* and *S. invicta*.

The time from food placement in petri dishes to the first ant appearing on the food was the searching time, and the time required to recruit 10 ants to the food was recruitment time, and both of them were recorded by stopwatch. A total of 30 nests for *T. melanocephalum* and *S. invicta* respectively were tested in the wasteland and litchi orchard. Because of the hot weather in August in Shenzhen, we performed the experiments at the time of the relatively low temperature, from 8 AM to 10 AM in the morning or from3 PM to 6 PM. in the afternoon. During the experiment, the soil surface temperature in the wasteland was between 30.0°C and 42.4°C, and the relative atmospheric humidity was between 49% and 81%. The soil surface temperature in the litchi orchard was between 30.8°C and 36.9°C, and the relative atmospheric humidity was between 61% and 92%.

Statistical analysis

Each nest in wasteland and litchi orchard was regarded as one replicate and Duncan's new multiple range method was used to compare the foraging ability between different types of food. Non-paired student *t* test was used to compare the foraging ability between *T. melanocephalum* and *S. invicta*. All statistical analyses were conducted using SPSS, version 14.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Foraging ability of *S. invicta* for different types of food

In the wasteland, the shortest searching time (2.98 min) for *S. invicta* was observed for peanut oil, which was significantly shorter than the longest searching time (7.84 min) for sausage (n=30, $P<0.05$). Searching time of *S. invicta* for sausage & honey, honey and mealworms was not significantly different. The longest recruitment time for *S. invicta* was 9.87 min, recorded for honey, which was significantly longer than that for sausage & honey, sausage and mealworms (n=30, $P<0.05$). *S. invicta*'s recruitment time for honey and peanut oil was not significantly different.

In the litchi orchard, *S. invicta*'s shortest searching time was observed for peanut oil (2.1 min), while the longest searching time was observed for sausage (3.5 min) (n=30, $P<0.05$). The longest recruitment time was observed for honey (12 min), which was significantly longer than that for sausage & honey, sausage and peanut oil (n=30, $P<0.05$). The recruitment time for honey and mealworms was not significantly different (Table 2).

Foraging ability of *T. melanocephalum* for different types of food

In the wasteland, the longest searching time of *T. melanocephalum* was observed for peanut oil (3.02 min), while the shortest searching time was observed for honey (1.07 min). The searching time for peanut oil was significantly longer than that for sausage & honey (1.37 min) and honey (1.07 min) (n=30, $P<0.05$), but was not significantly different from that for sausage and mealworms. The longest recruitment time was observed for peanut oil (12.55 min), which was significantly longer than that for the other four types of food (n=30, $P<0.05$).

In the litchi orchard, the longest searching time of *T. melanocephalum* was observed for mealworms (2.84 min), while the shortest searching time was observed for peanut oil (1.54 min). The searching time for mealworms was significantly longer than that for sausage & honey (1.85 min), honey (1.82 min) and peanut oil (2.84 min) (n=30, $P<0.05$), but was not significantly different from that for sausage. The longest recruitment time for peanut oil was observed for peanut oil (8.42 min), which was significantly longer than that for the other four types of food (n=30, $P<0.05$, Table 2) .

Comparison of foraging ability between *T. melanocephalum* and *S. invicta*

The results for the comparison of the foraging ability between *T. melanocephalum* and *S. invicta* are summarized in Table 2. In the wasteland, the searching time of *S. invicta* for sausage & honey, sausage, honey and mealworms was significantly longer than that of *T. melanocephalum* (n=30, $P<0.05$). The searching time of *S. invicta* for peanut oil was not significantly different from that of *T. melanocephalum*. The recruitment time of *S. invicta* for sausage & honey, sausage, honey and mealworms was longer than that of *T. melanocephalum* (n=30, $P<0.05$).

In the litchi orchard, all searching timse for five types of food between *S. invicta* and *T. melanocephalum* were not significantly different. The recruitment time of *S. invicta* for sausage, honey and mealworms was significantly longer than that of *T. melanocephalum*.

DISCUSSION

In the wasteland and litchi orchard, the shortest searching time of *S. invicta* was observed for peanut oil, while the longest searching time was observed for sausage. This is possibly due to the rapid attraction of *S. invicta* to the food by the evaporated peanut smell. When they discover food, *S. invicta* can recruit their companions rapidly to the sausage or sausage & honey, then cut and move the sausage back to the nests. The longest recruitment time of *S. invicta* was observed for the honey. These results suggest that *S. invicta* favors high-protein food, while high-carbohydrate food is least attractive for *S. invicta,* which is in agreement with previous studies (Xu *et al*. 2006). *T. melanocephalum* prefers honey to the other food sources according to the shortest searching and recruitment time both in the wasteland and lithci orchard. In contrast, in the litchi orchard, the smell of the peanut oil attracts *T. melanocephalum* early, but the recruitment time of sausage & honey, sausage, honey and mealworms was significantly shorter than that of the peanut oil, suggesting that *T. melanocephalum* favors artificial or natural food with high levels of carbohydrate and protein. The litchi orchard has higher diversity of vegetation and provides more honey than wasteland. This may explain why *T. melanocephalum* in the litchi orchard does not search for honey or recruit as rapidly as in the wasteland. The results suggest that *T. melanocephalum*

Table 2. Searching time and recruitment time of S. invicta and T. melanocephalum for 5 foods in infested areas (min).

Food type	Searching time				Recruitment time			
	Wasteland		Litchi orchard		Wasteland		Lichi orchard	
	S. invicta	*T. melanocephalum*	*S. invicta*	*T. melanocephalum*	*S. invicta*	*T. melanocephalum*	*S. invicta*	*T. melanocephalum*
Sausage & honey	4.61±0.68bc	1.37±0.23bc**	3.13±0.66ab	1.85±0.37b	4.86±0.96b	1.87±0.40b**	3.69±0.54b	2.42±0.24b
Sausage	7.84±1.10a	2.44±0.83ab**	3.50±0.57a	2.18±0.49ab	4.88±0.70b	2.76±0.85b	4.86±0.70b	2.07±0.33b**
Honey	5.09±1.27bc	1.07±0.09c**	2.41±0.33ab	1.82±0.37b	9.87±2.82a	1.85±0.57b**	12.00±3.17a	4.09±0.82b**
Mealworm	5.99±1.01ab	2.11±0.45abc**	2.48±0.40ab	2.84±0.57a	5.02±1.02b	1.92±0.33b**	9.24±3.30ab	3.21±1.11b**
Peanut oil	2.98±0.34c	3.02±0.72a	2.10±0.28b	1.54±0.33b	8.09±2.11ab	12.55±2.74a	5.75±1.92b	8.42±2.34a

Means within a column followed by the same letter are not significantly different ($P > 0.05$) using the Duncan method of multiple comparisons, following a one-way ANOVA. "*", "**" represent significant differences at $P < 0.05$ and $P < 0.01$ respectively, between means using the unpaired small swatches *t*-test.

searches for high-carbohydrate or high-protein food more rapidly than *S. invicta*. In addition, the recruitment of *T. melanocephalum* is faster than that of *S. invicta*.

Ants belonging to *Dolichoderinae* and *Formicinae* favor sweet foods (Li *et al.* 2000). The honeydew secreted by aphids, scale insects, and angle cicadas, etc. is the favorite food of ants belonging to Formicinae (Wu & Wang 1995). In this study, we found that *T. melanocephalum* favors high-carbohydrate foods, e.g., honey. We also found that food proficient in protein is the favorite food of both *T. melanocephalum* and *S. invicta*, which is one of the reasons leading to the competition between these two species of ants. However, *T. melanocephalum* also favors high-carbohydrate foods, but *S. invicta* does not, which provides a good condition for the survival and proliferation of *T. melanocephalum* when it lives in the areas with *S. invicta*. Furthermore, for the high-carbohydrate food and high-protein food, the searching and recruitment ability of *T. melanocephalum* is stronger than that of *S. invicta*, indicating that the exploitation competition of *T. melanocephalum* is stronger than that of *S. invicta*. In addition, *T. melanocephalum* has a smaller size and moves more rapidly than *S. invicta* (Li *et al.* 2008). Therefore, *T. melanocephalum* can find and transport sufficient food before *S. invicta* arrives. We also found that *T. melanocephalum* lived in many *S. invicta*-abandoned nests (naturally abandoned or abandoned due to human activities), and sometimes the nests of these two speices were very close. The exploitative nesting habit and wide range of favorite food allows *T. melanocephalum* to survive in various areas (Smith 1965). Rapid food searching and recruitment of *T. melanocephalum* can explain why *T. melanocephalum* can co-exist with the alien ant *S. invicta* and continue to be one of the dominant species in areas invaded by *S. invicta*. This is also in agreement with the hypothesis that resource division (e.g., food, time and space) can result in ecological segregation between species.

The areas with long-term (several years) invasion of *S. invicta* were chosen as experimental sites in this study. Therefore, the effect of short-term invasion of *S. invicta* on the foraging ability of *T. melanocephalum* needs to be further studied.

ACKNOWLEDGMENTS

We would like to thank Zhendong Song and Haiquan Wu for their observations and records. Our study was supported by the National Basic Research

Program of China (Award# 2009CB119200) and National Natural Science Foundation of China (Award# 305712427).

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