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Comparison of recruitment and competition behavior between *Solenopsis geminata* and two resident ant species in Cameroon

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Abstract
In Cameroon, we compared recruitment and competition behavior between *Solenopsis geminata* and two resident ant species i.e. *Paratrechina longicornis* and *Pheidole megacephala*. For the recruitment essays, a 35 cm long and 30 cm wide plywood were placed in contact with three nest and fried fish was deposited at 15 cm from the nest. The mean number of *Solenopsis geminata* foragers collected on the fish was compared with that of the two resident ants. On the other hand, individual and group aggression assays were used to competition evaluation between *Solenopsis geminata* and the two resident ants. In individual aggression essays, one medium-sized of *Solenopsis geminata* worker and one medium-sized worker of each resident ant species were separately placed in a Petri dish. Aggression between the two competitor ants was recorded and a comparison was done between ant species on the attacks initiation by the competitors. In the group essay, 150 workers of each resident ant species were separately allowed to competition with 150 workers of *Solenopsis geminata* and a comparison was done between the two groups of competitors on the mean number of ant species found on the baits and the mean mortality. Our result showed that the mean number of *Pheidole megacephala* recruited on the fish (156.47±16.05) was the highest, follow by *Paratrechina longicornis* (140.53±9.21) and *Solenopsis geminata* (127.54±8.54). During individual aggression essays, *Solenopsis geminata* workers initiated more attacks (67.33%) than those of *Paratrechina longicornis* (32.67%), while *Pheidole megacephala* workers initiated more attacks (62.38%) than those of *Solenopsis geminata* (37.62%). In the group essay for the species pair, the mean number of *Solenopis geminata* workers on the bait (30.30±0.60) was higher than that of *Paratrechina longicornis* (12.16±1.10), while the mean number of *Pheidole megacephala* workers on the bait (22.50±1.50) was higher than that of *Solenopsis geminata* (18.60±2.00). Moreover, the mean mortality of *Paratrechina longicornis* (61.94±0.48) was higher than that of *Solenopsis geminata* (38.06±0.48), while the mean mortality of *Solenopsis geminata* (58.64±1.25) was higher than that of *Pheidole megacephala* (41.36±1.25). The data led us to conclude that *Pheidole megacephala* is more competitive than *Solenopsis geminata* and can then be used to his control.

Keywords: *Solenopsis geminata*, predatory behavior, competition, recruitment, resident ants

1. Introduction

Recruitment and competition are two complementary phenomenon of invasive success. The success of most invasive species is associated with the monopolization of resources due to recruitment of nest mates and a high level of aggressiveness towards native species that are either displaced or eliminated through competition. Indeed, any species in its new living environment interacts with conspecifics and must also exercise strong competition allowing it to settle and expand its invasion area. This competition involves a strong recruitment in which the members of each species established a system of communication allowing them to collect the large food resources. Thus, social insect usually defend their nest and their territory against foreign conspecifics, and their workers are able to distinguish between friend and enemies with a simple antenna contact between workers [1]. In consequent, aggressive behavior occur when antenna contact take place between two different species. In interspecific encounters, a strong aggressive behavior frequently occur between invasive and native species. Furthermore, the most aggressive species often have competitive advantages [2]. Among invasive species in the world, ants are highly successful invaders. They can be ecologically and economically devastating and often outcompete native ant species [3, 4, 5].

Among these invader ants, the tropical fire ant *Solenopsis geminata* is considered one of the most damaging and widespread introduced species [6]. *Solenopsis geminata* is native of Central and South America, but has spread through human commerce to many parts of the world [7]. In it introduced area, this tropical fire ant has often become one of the dominant pest decreasing biodiversity and displacing other ants and arthropods via competition behavior [8, 9]. Moreover, this competition usually occur on food, as well as direct collision between species at the foraging moment [10], and can be individual between two ant species or in group. However, like most other invasive ants, this species is especially difficult to eradicate. In countries where *Solenopsis geminata* has been introduced, the absence of natural enemies allow it to reach higher density than that of the native range. So, in many part of the word where this fire ant has been introduced, the use of chemical method has been carried as better solution for their control. In the Spit Island, Midway Atoll, Hawaii, the control of this ant was carried using the formicide Maxforce^{R} (active ingredient: hydramethylnon) which better reduced *Solenopsis geminata* abundance until more than 12 months post-treatment [11]. In Cameroon, farmers usually used cypercal insecticide to reduced *Solenopsis geminata* density. However, because of the dramatic impact causing by chemical control on biodiversity and particularly on public health [12], biological methods have been carried for the better control of *Solenopsis geminata* without great consequence on biodiversity and public health. This method use natural enemies to strong competition against pest, such as *Solenopsis geminata* [13]. However, although this method is used in Cameroon to protect many plants [14], biological control of *Solenopsis geminata* in Cameroon is not yet documented. Here, we report the result of experiments designed to study recruitment behavior and competition between the tropical fire ant, *Solenopsis geminata* and two resident ants in littoral Cameroon. Our specific objective is to control, and possibly eradicate the tropical fire ant, *Solenopsis geminata*, using a biological method.

2. Material and Methods

2.1. Study sites

The study was carried out in the littoral part of Cameroon, particularly in Douala city. This town has several neighbourhoods from which we selected two as sampling sites: Mboppi (04°02.709'N; 009°42.958'E) and Ndog-bong (04°02.714'N; 009°42.947'E). Douala's climate is hot and humid with temperature ranges between 24.8 °C (February) and 27.6° (July), and annual precipitation are 3, 600 mm [15].

2.2. Animal Material

The tropical fire ant, *Solenopsis geminata*, and two other ant species ie *Pheidole magacephala* and *Paratrechina longicornis* were collected in Mboppi and Ndog-bong. The species of ants were confirmed using a key [16]. Two of these species are resident from Cameroon, while *Solenopsis geminata* is introduced.

2.3. Recruitment essays

Recruitment essays took place in the field where three nest of each studied ant species were selected as sampling. The protocol used was that described by Dejean *et al.* [17], with modifications. Indeed, a 35cm long and 30cm wide plywood was placed in contact with each nest to serve as a hunting area. The trials began seven days after installation of the hunting areas to allow foragers of each ant species to integrate these experimental hunting areas into their natural hunting areas. During these seven days, honey and small prey were deposited on the plywood. The trials took place during the day, from 6 am to 11 am and from 1 pm to 6 pm. Each trial lasted 60 minutes and started by depositing 100g of fried fish 15 cm from the nest, which was stabilized on the plywood with a fine needle. The number of ants present around the fish was counted every three minutes during 60mn. After 60mn observation, the hunting area was quickly transported and immersed in hot water and all the ants coming from it were collected and preserved in alcohol diluted at 70%. These ants were then transported to the laboratory where they were counted. The time interval between two trials was 60 minutes and the number of trials per day was set at 06. The experiment took place in 06 seasons (03 dry seasons and 03 raining seasons), at the frequency of 90 trials per season for each ant species. The mean number of ants recorded in the dry and raining seasons for each of the resident ant species was compared to that of the *S. geminata* species, recorded at the same periods.

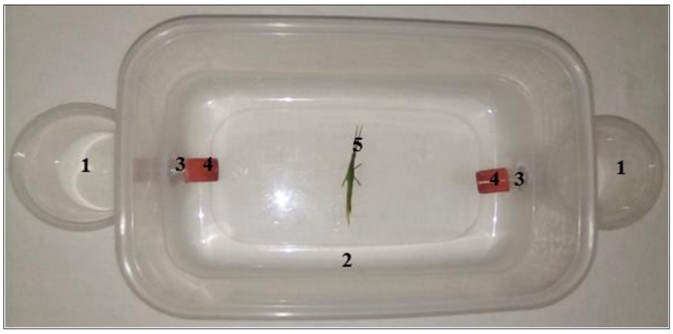
2.4. Competition essays

2.4.1. Individual aggression essays

To evaluated individual aggression between *Solenopsis geminata* and the three resident ants, we used the following behavioral assay [18, 19, 20, 21]. One medium-sized of *Solenopsis geminata* worker and one medium-sized worker of each resident ant species were separately placed in a Petri dish (diameter= 4.0cm, height= 1.5cm). To prevent the ants from climbing out, the petri dish was coated with Fluon. The first competitor ant was introduced in the petri dish one minute before the second one. Aggression between the two competitor ants was scored using four behavioral indices: 1= touch including prolonged antennation, 2= avoid and retreat in opposite directions immediately upon contact, 3= aggression which includes lunging, biting, pulling legs/antenna or stinging and 4= prolonged fight including death [18]. Furthermore, interaction between the two competitors was recorded for five minutes and a comparison was done between ant species on the attacks initiation by the competitors. Forty trials were perform with different workers.

2.4.2. Group aggression essays

Two groups of 150 ant workers were separately placed in two opposite artificial nests. One of these nests contained *Solenopsis geminata* species, while the other contained one of the two resident ants. Each group contained 110 medium-sized of workers and 40 soldiers. The artificial nests were plastic dishes (diameter= 5cm, height= 4cm), coated at 3cm height with Fluon. Each of these Artificial nests were connected via a covered plastic tube to a common foraging arena 11 x 19cm coated at 3cm height with Fluon, with a bait (grasshopper) located at the center. The cover of the plastic tubes were then opened to allow workers of each ant species moving from the artificial nest to the arena, and the total number of workers found on the bait was recorded every 3 minutes for 30 minutes. During the 30 minutes observations, the aggressive behavior of each ant specie was recorded. Forty trials were perform with different group of workers. A comparison was then made between *Solenopsis geminata* species and each of the resident ant species on three parameters i.e. the time taken by different ant species to discover the bait, the mean number of each ant species found on the bait at the end of the experimental period and the mean mortality. Ant species which was the most found on the bait at the end of the experimental period, and which has the less mortality was recorded as the dominant species.



1= Artificial nests; 2= Common foraging arena; 3= Plastic tubes; 4= Plastic tube covers; 5= Bait (grasshopper).

Fig 1: Experimental device used to group aggression between *Solenopsis geminata* and resident ant species.

3. Result

3.1. Recruitment essays

In each of the three ant species, recruitment phenomenon took place when foragers detected food resources. Indeed, after detected food source, the discover ant tried to carry it individually in the nest. However, when the food resource size didn't permit this hunter ant to carry it individually, it gets back quickly in the nest direction, and return on the food resources without arriving in the nest. After this hunter act, we observed many ants moving from the nest to the food resource, following a line. On the other hand, some of the foragers were recruited in the foraging area before the discoverer ants went back in the nest. In addition, ant number coming from the nest varied among species. Thus, at the end of the essays, the mean number of *P. megacephala* workers collected on the food resources was significantly higher than that of *S. geminata* and *P. longicornis* ($p \leq 0.0001$), both in the dry and the raining season. On the other hand, the mean number of *S. geminata* workers was significantly low than that of *P. longicornis* and *P. megacephala* ($p \leq 0.0001$) (Table 1).

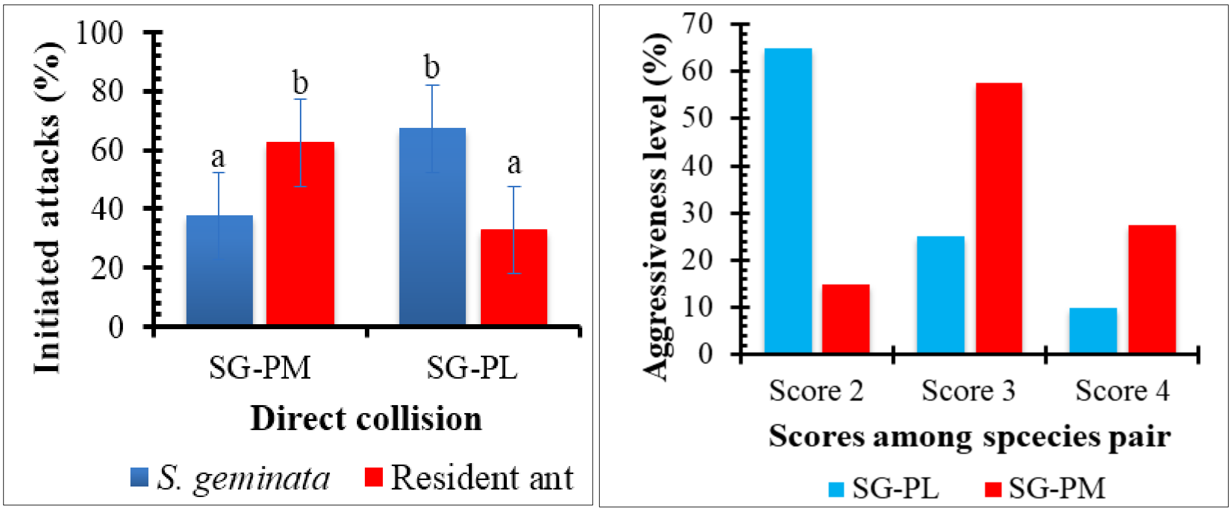
Table 1: Mean number of workers recruited, related with ant species and season

	Mean number of workers	
Species	**Dry season**	**Raining season**
P. megacephala	$156{,}47 \pm 16{,}05^{b}$	$214{,}73 \pm 17{,}70^{b}$
P. longicornis	$140{,}53 \pm 9{,}21^{ab}$	$189{,}33 \pm 12{,}81^{b}$
S. geminata	$127{,}54 \pm 8{,}54^{a}$	$161{,}67 \pm 8{,}13^{a}$

a, b, c, for the number of *ant species recruited*, means affected with the same letter are not significantly different at $p \leq 0.0001$.

3.2. Individual aggression essays

During all individual aggression assays between species pairs, we didn't observed the score 1 behavior. So, the aggressive behavior occurred between species pairs on the food resource, and can also occurred during direct collision between ant species at the foraging moment. In the individual aggression assays, attacks initiation varied among species pairs. Indeed, *S. geminata* workers initiated more attacks (67.33%) than those of *P. longicornis* (32.67%) ($p \leq 0.0001$), while *P. megacephala* workers initiated more attacks (62.38%) than those of *S. geminata* (37.62%) ($p \leq 0.0001$). Aggressive acts in avoidance occurred more frequently in *S. geminata-P. longiconis* interaction, while aggression which includes lunging, biting, pulling legs/antenna or stinging, and prolonged fight including death occurred more frequently in *S. geminata-P. megacephala* interaction (Figure 2).



A B

Fig 2: Agressiveness behavior between ant species during competition (A: attacks initiated, B: behavioral indices).
SG = *Solenopsis geminata*, PM = *Pheidole megacephala*, PL = *Paratrechina longicornis*.

3.3. Group aggression essays

Group competition between *S. geminata* and resident ant species revealed important differences during contests (Figure 3 and 4). Interactions between *S. geminata* and *P. megacephala* showed that *P. megacephala* first discovered the bait ($p \leq 0.0001$). Furthermore, it was able to rapidly recruit workers to bait during the experiment and dominated the majority of baits by the end of the experiment ($p \leq 0.0001$). However, the interactions between *S. geminata* and *P. longicornis* did not show the same result. Indeed, during the competition between *P. longicornis* and *S. geminata*, *p. longicornis* first discover the baits ($p \leq 0.0001$), and was able to rapidly recruit workers to bait during the first 12 minutes of the experiment. After this time, *S. geminata* took over and dominated the majority of baits by the end of the experiment ($p \leq 0.0001$). After domination of bait by *S. geminata*, *P. longicornis* moved rapidly around the arena and avoided confrontation with *S. geminata*.

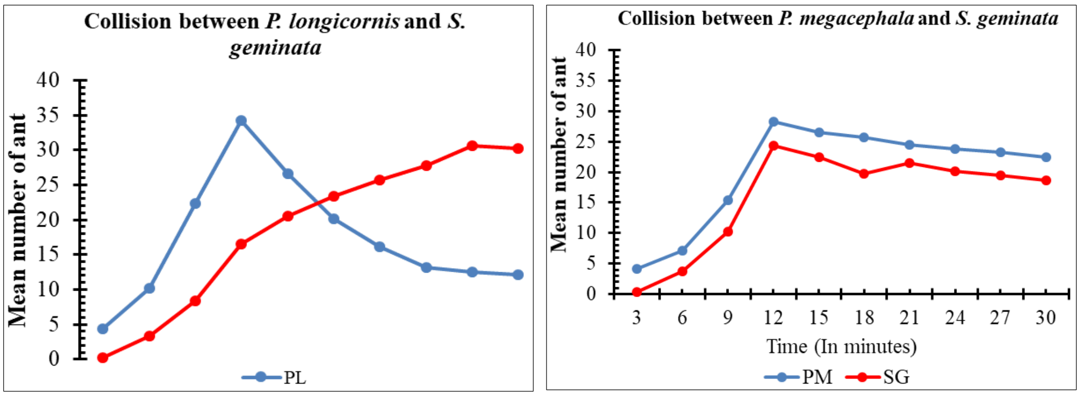
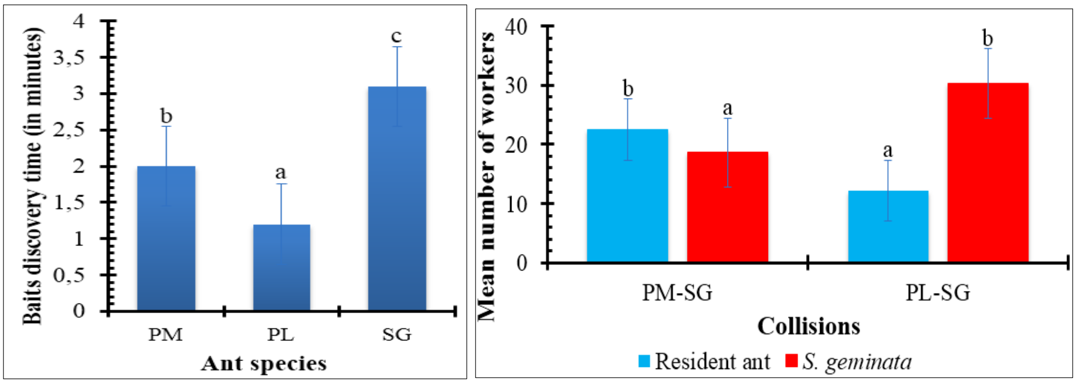


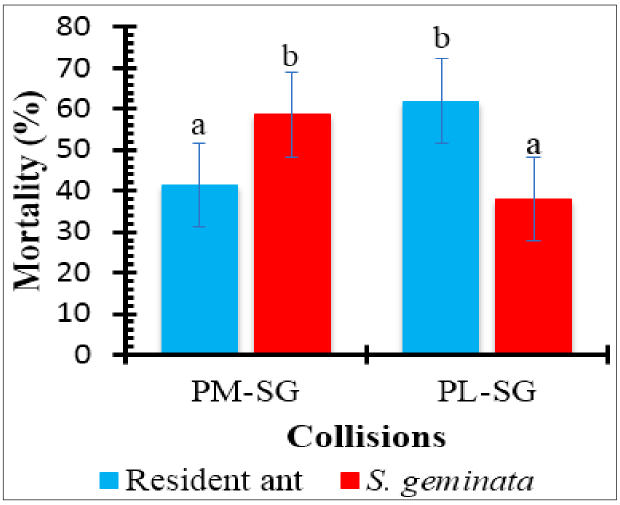
Fig 3: Mean number of ant species on the baits during competition.



A B

Fig 4: Time taken by different ant species to discover a bait (A), and the mean number of ants on the baits by the end of experiment (B).

In the group aggression assays, mortality varied among species pairs. Workers of *P. megacephala* were aggressive towards *S. geminata* and higher mortality of *S. geminata* was observed in this pair ($p \leq 0.0001$). However, during group aggression between *P. longicornis* and *S. geminata*, higher mortality of *P. longicornis* was observed than that of *S. geminata* ($p \leq 0.0001$) (Figure 5).



a, b, c, for the mean mortality of *ant species*, means affected with the same letter are not significantly different at $p \leq 0.0001$.

Fig 5: Mean mortality of ant species during group aggression.

4. Discussion

Our data showed that each forager for these three ant species that has discovered a food resource cannot move alone hence recruited nest mates to help in transport. These ant species exhibit an important communication system between a discoverer ant and nest mates. So, this communication system orientates and recruits other members of the colony towards food resources. Indeed, after discovering a large food resource, a discoverer ant emits pheromones to recruit nest mates towards food resource. These three ant species recruit at short range those nest mates situated at the foraging area, and can also use a long-range recruitment based on food resource size. Firstly, the discover ant can emits volatile attractant pheromones into the air to recruit nest mates. On the other hand, the discover ant returns to the nest depositing a pheromone trail which is follow by the recruit ants from the nest to the food resources. This cooperative transport of large food resources has been described by several studies in many ant species including *Pheidole megacephala*, *Paratrechina longicornis*, and *Solenopsis geminata*. For still larger prey, *Pheidole megacephala* recruit at short range those nest mates situated within reach of an alarm pheromone and together spread-eagle the insect. These behaviors are complimented by a long-range recruitment based on prey size [22]. As well as long-term recruitment to stable food resources, *Paratrechina longicornis* uses short-term recruitment pheromones to recruit nest mates to assist in the exploitation of large food resources.

Recruitment to large food resources is via a pheromone trail laid by the discoverer ant. This trail is initially followed by recruits from the nest to the food resources [23]. In addition, food-discover ants can recruit nearby nest mates to a large food resources without returning to the nest, using volatile pheromones [23]. According to *Solenopsis geminata* foragers, they also uses recruitment pheromones to organize the retrieval of large food resources back to the colony [24]. In addition**,** medium workers of *S. geminata* exhibited a high trail-following behavior as well as a high antennal response to pheromones, comparing with large and small workers [25]. Our data also showed that *Pheidole megacephala* and *Paratrechina longicorgis* recruited nest mates more than *Solenopsis geminata*. Indeed, the mean number of *Pheidole megacephala* foragers collected on the food resources was significantly higher than that of *Paratrechina longicornis* and *Solenopsis geminata*, while the mean number of *Solenopsis geminata* collected was significantly low than that of *Paratrechina longicornis*. The difference in the mean number of these ant species may be due to the difference in communication system among nest mates, related with the difference in concentration of pheromone released by the discover ant and that received by recruiting ant, the difference in volatility of these pheromones and the difference in sensibility of nest mates which received them. Previous studies also revealed relationship between pheromone quantity and ant behavior, suggesting that animal reactions in pheromone may vary depending on the concentration of pheromone released and the possible previous experience of the recipient individual [26]. Therefore, the number of recruited ants to a certain resource may vary according to the strength of the chemical signal [27]. In addition, the difference in the volatility of pheromones and the sensibility of the recipients can influence the behavior of a colony individuals [28]. Our data also indicated that during the individual aggression essay, *Pheidole megacephala* initiated more attacks than *Solenopsis geminata*. These data suggest that in individual confrontation, *Pheidole megacephala* is more competitive than *Solenopsis geminata*. On the other hand, *Pheidole megacephala* rapid discover the bait and monopolized it against *Solenopsis geminata* during group aggression essays. Furthermore, the mean number of *Solenopsis geminata* mortality was significantly higher than that of *Pheidole megacephala* at the end of group experiments. This domination of *Pheidole megacephala* workers may firstly be due to their powerful mandible which allow them to cut *Solenopsis geminata* workers during competition, and their great aggressiveness toward *Solenopsis geminata*. On the other hand, *pheidole megacephala* domination may be due to their higher possibility to recruit workers during competition. Our results are similar with those revealed by previous studies. Indeed, it was revealed that the success of most invasive ants is associated with the monopolization of resources in part due to mass recruitment and a high level of aggressiveness towards native ants that are either displaced or eliminated through competition [29, 30, 31]. In addition, it was also reported that *Solenopsis geminata* was poor at discovering resources against *Pheidole* species [32] and was out complete with some ant species such as *Solenopsis invicta* and *Pheidole megacephala*, mostly through direct conflict for food and habitat [9]. Our data also showed that *Paratrechina longicornis* located the food faster than *Solenopsis geminata* and this may be due to it long legs which allow it to be faster than *Solenopsis geminata*, which moves slowly. Faster-moving foragers have been hypothesized to be better discoverers of food [33]. Previous studies also revealed that longer legs allow faster movement [34, 35]. So, *Paratrechina longicornis* workers have distinctly long legs compared to *Solenopsis* species which may account for their faster movement [36]. However, although *Solenopsis geminata* came later on the bait during competition, it was able to defend and monopolize the bait by not allowing Paratrechina *longicornis* near the bait. Similar behavior has been observed in Paratrechina *longicornis* and *Solenopsis geminata* in the field [37]. This domination of *Solenopsis geminata* may be due to their competitive ability, their aggressive behavior both in individual and group encounters with *Paratrechina longicornis*. Previous studies reported that competitive ability and aggressive behavior contribute to successful invasion of *Solenopsis* species, particularly *Solenopsis invicta* [38]. It was also documented that *Solenopsis geminata* achieves a competitive advantage through aggression by workers, and reducing the access of other ants to food [39, 40].

Our data also showed that *Paratrechina longicornis* were found to explore the bait area quickly and were able to avoid direct collision with *Solenopsis geminata*. Similar behavior has been reported in *Anoplolepis gracilipes* in interactions with several ant species [41], and may be due to the panic and intimidating of this resident ant specie by *Solenopsis geminata*, via it higher aggressiveness. However, in group aggression essay, *Paratrechina longicornis* mortality was higher than that of *Solenopsis geminata*. This may be due to their tendency to avoid confrontation during individual assays, while direct collision possibilities with *Solenopsis geminata* are higher in group essay. Furthermore, *Solenopsis geminata* workers use toxic venomous which allow them to kill a higher number of *Paratrechina longicornis* workers. Previous studies reported that *Solenopsis geminata* workers have a venomous sting that allows them to subdue vertebrate and large invertebrate prey [6].

5. Conclusion

Our specific objective in this study was to control, and possibly eradicate the tropical fire ant, *Solenopsis geminata*, using a biological method. Our study clearly indicated that *Solenopsis geminata* is a very hostile and dominant species, which displaced *Paratrechina longicornis* from food resources via it aggressive behavior. However, the bigheaded ant, *Pheidole megacephala* appear to be more hostile than *Solenopsis geminata*. This species rapid recruit workers and it powerful mandible allow it to kill a great number of *Solenopsis geminata* workers by cutting them during competition. Therefore, *Pheidole megacephala* can be used as natural enemy to *Solenopsis geminata* control.

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7. References

1. Ellen VW, Johanna C, Tsutsui ND. Experience influences aggressive behavior in the Argentine ant. Biol. Lett. 2010 6:152-155.
2. Obin MS, Meer RKV. Between-and within-species

recognition among imported fire ants and their hybrids (Hymenoptera: Formicidae): application to hybrid zone dynamics. Annals of the Entomological Society of America. 1989;82:649-652.
3. Byeon Dh, Jung JM, Park Y, Lee HS, Lee JH, Jung S, *et al*. Model-based assessment of changes in the potential distribution of *Solenopsis geminata* (Hymenoptera: Formicidae) according to climate change scenarios. J Asia Pac. Biodivers. 2020;13:331-338.
4. Suarez AV, Tsutsui ND. The evolutionary consequences of biological invasions. Molecular Ecology. 2008;17:351-360.
5. LeBrun EG, Abbott J, Gilbert LE. Imported crazy ant displaces imported fire ant, reduces and homogenizes grassland ant and arthropod assemblages. Biological Invasions. 2013;15:2429-2442.
6. Holway DA, Lach L, Suarez AV, Tsutsui ND, Case TJ. The causes and consequences of ant invasions. Annual Review of Ecology and Systematics. 2002a;33:181-233.
7. Wetterer JK. Worldwide spread of the tropical fire ant, Solenopsis geminata (Hymenoptera: Formicidae). Myrmecol. News. 2011;14:21-35.
8. Geetha V, Ajay N. The effect of urbanization on the biodiversity of ant fauna in and around Bangalore. Journal of Ecobiology. 2000;12(2):115-122.
9. Taber SW. Fire ants. College Station, Texas, Texas A and M University Press. 2000; 308p.
10. Moloney S, Vanderwoude C. Red Imported Fire Ants: A threat to eastern Australia’s wildlife? Ecological Management and Restoration. 2002;3(3):167-175.
11. Plentovich S, Swenson C, Reimer N, Richardson M, Garon N. The effects of hydramethylnon on the tropical fire ant, Solenopsis geminata (Hymenoptera: Formicidae), and non-target arthropods on Spit Island, Midway Atoll, Hawaii. J Insect Conserv. 2010, 7p.
12. Aktar WMD, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture: their benefits and hazards. Interdisc Toxicol. 2009;2(1):1-12.
13. Van Lenteren JC. The state of commercial augmentative biological control: plenty of natural enemies, but a frustrating lack of uptake. BioControl. 2012;57(1):1-20.
14. Hoopen GMT, George A, Martinez A, Stirrup T, Flood J, Krauss U. Compatibility between Clonostachys isolates with a view to mixed inocula for biocontrol. Mycologia. 2014;102(5):1204-1215.
15. Feumba R, Ngounou Ngatcha B, Tabué Youmbi JG, Ekodeck GE. Relationship between Climate and Groundwater Recharge in the Besseke Watershed (Douala-Cameroon). Journal of Water Resource and Protection. 2011;10:607-619.
16. Zeng L, Lu Y, He X, Zhang W, Liang G. Identification of red imported fire ant, Solenopsis invicta, to invade mainland China and infestation in Wuchuan, Guangdong. Chinese Bulletin of Entomology. 2005;42:144-148.
17. Dejean A, Moreau CS, Uzac P, Le Breton J, Kenne M. The predatory behavior of Pheidole megacephala. C. R. Biologies. 2007;330:701-709.
18. Thomas ML, Payne-Makris CM, Suarez AV, Tsutsui ND, Holway DA. Contact between supercolonies elevates aggression in Argentine ants. Insect. Soc. 2007;54:225–233.
19. Tsutsui ND, Suarez AV, Grosberg RK. Genetic diversity, asymmetrical aggression, and recognition in a widespread invasive species. Proc. Natl. Acad. Sci. USA. 2003;100:1078-1083.
20. Rice ES, Silverman J. Submissive behavior and habituation facilitate entry into habitat occupied by an invasive ant. Animal Behavior. 2013;86:497-506.
21. Lei N, Meihong N, Dongdong N, Hao R, Babar H, Yijuan X. Comparing mechanisms of competition among introduced and resident ants in China: from behavior to trophic position (Hymenoptera: Formicidae). Myrmecol. News. 2019;29:125-133.
22. Dejean A, Moreau CS, Uzac P, Le Breton J, Kenne M. The predatory behavior of Pheidole megacephala. C. R. Biologies. 2007;330:701–709.
23. Czaczkes TJ, Vollet-Neto A, Ratnieks FLW. Prey escorting behavior and possible convergent evolution of foraging recruitment mechanisms in an invasive ant. Behavioral Ecology. 2013;24(5):1177–1184.
24. Igwe OU, Offiong SP. Chemistry of Semiochemicals Used as Trail Pheromones in Tropical Fire Ant (*Solenopsis geminata*). IJCBS. 2015;(7):35-40.
25. Brindis Y, Lachaud JP, Gómez BGY, Rojas JC, Malo EA, Cruz-lópez L. Behavioral and Olfactory Antennal Responses of Solenopsis geminata (Fabricius) (Hymenoptera: Formicidae) Workers to their Dufour Gland Secretion. Neotropical Entomology. 2008;37(2):131-136.
26. Howse PE. Pheromones and Behaviour. In P.E. Howse, I. Stevens, O. Jones (Ed.), Insect pheromones and their use in pest management, Chapman and Hall; c1998. p. 1-130.
27. Traniello JFA. Foraging strategies of ants. Ann Rev Entomol. 1989;(34):191-210.
28. Verheggen FJ, Haubruge E. Les phéromones d'alarme dans le règne animal. Faunistic Entomology. 2011;63(4):259-274.
29. Le Breton J, Chazeau J, Jourdan H. Immediate impacts of invasion by Wasmannia auropunctata (Hymenoptera: Formicidae) on native litter ant fauna in a New Caledonian rainforest. Austral Ecology. 2003;28:204-209.
30. Le Breton J, Jourdan H, Chazeau J, Orivel J, Dejean A. Niche opportunity and ant invasion: The case of *Wasmannia auropunctata* (Roger) in a New Caledonian rainforest. Journal of Tropical Ecology. 2005;21:93-98.
31. Rowles AD, O’Dowd DJ. Interference competition by Argentine ants displaces native ants: implications for biotic resistance to invasion. Biol. Invas. 2007;9:73-85.
32. Perfecto I and Vander Meer J. Ant Assemblage on a Coffee Farm: Spatial Mosaic Versus Shifting Patchwork. Environmental Entomology. 2013;42:38-48.
33. Dussutour A and Simpson SJ. Communal nutrition in ants. Current Biology. 2009;19:740-744.
34. Zollikofer C. Stepping patterns in ants – influence of body morphology. Journal of Experimental Biology. 1994;192:107-118.
35. Pearce-Duvet JM, Elemans CP, Feener DH. Walking the line: search behavior and foraging success in ant species. Behavioral Ecology. 2011;22:501-509.
36. Espadaler X, Gómez C. Formicine ants comply with the size-grain hypothesis. Functional Ecology. 2001;15:136-138.
37. Johnson LK, Hubbell SP, Feener DH. Defense of food supply by eusocial colonies. American Zoology. 1987;27:347-358.

38. Lai LC, Hua KH, Wu WJ. Intraspecific and interspecific aggressive interactions between two species of fire ants, Solenopsis geminata and S. invicta (Hymenoptera: Formicidae), in Taiwan. Journal of Asia-Pacific Entomology. 2015;18:93-98.
39. Torres JA. Niches and coexistence of ant communities in Puerto Rico: repeated patterns. Biotropica. 1984;16:284-295.
40. Morrison LW. Community organization in a recently assembled fauna: the case of Polynesian ants. Oecologia. 1996;107:243-256.
41. Chong KF, Lee CY. Inter and Intraspecific Aggression in the Invasive Long legged Ant (Hymenoptera: Formicidae). Journal of Economic Entomology. 2010;103:1775-1783.