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Effects of Habitat Diversity on the Population Distribution of *Solenopsis invicta* and Efficacy of Chemical Control

Hongdan HUANG[1], Yingning WEN[2], Wenjing ZHAI[3], Yiyan ZHU[1], Zhihui CHEN[2], Jianyou ZHANG[1], Feng ZHANG[1*]

1. Huizhou Jianhe Ecological Agriculture Co., Ltd., Huizhou 516057, China; 2. Huizhou Agricultural Science Research Institute, Huizhou 516003, China; 3. Guangdong Haichuan Biotechnology Co., Ltd., Huizhou 516343, China

Abstract The prevalence of *Solenopsis invicta* is associated with habitat diversity, with a preference for various habitats ranked in the following order: ponds, wastelands, green belts, roads, parks, farmlands, and villages. Consequently, management strategies should be tailored to each habitat. There are two occurrence peaks of *S. invicta* throughout the year, specifically from March to April and from September to October. It is essential to emphasize prevention and control measures during the active periods of *S. invicta*. To enhance the effectiveness of these measures, supplementary control should be implemented within 10-15 d following the initial prevention and control efforts. Furthermore, the efficacy of prevention and control is notably higher on the second to third day immediately following rainfall. This study aimed to evaluate the efficacy of various agents in controlling *S. invicta*. A comparative analysis was conducted on the efficacy of three different brands of agents against *S. invicta*. The findings indicated that a concentration of 0.08% -0.10% indoxacarb exhibited a comparable extermination effect on *S. invicta* worker ants. However, agents with larger particle sizes demonstrated a reduced efficacy in exterminating *S. invicta* nests.

Key words *Solenopsis invicta*, Habitat, Monitoring, Occurrence regularity, Prevention and control

1 Introduction

Solenopsis invicta Buren, native to South America, is a highly aggressive social insect and is recognized as one of the most destructive invasive alien species by the International Union for Conservation of Nature (IUCN). This species frequently causes significant damage to agricultural production, ecological environments, and public infrastructure, while also posing risks to human health[1-5]. In the 1930s, *S. invicta* was introduced to the United States, Australia, New Zealand, and several other countries, significantly endangering the lives and livelihoods of local populations while posing a substantial threat to agriculture and forestry in the affected regions[3]. Between September and October 2003, *S. invicta* was introduced to Taiwan, China, from the United States as a result of the loading of container boxes and the transfer of turf[6]. The infestation was first identified in 2004 in Wuchuan, Guangdong Province, and subsequently proliferated rapidly throughout China, disseminating to various regions across the country.

The presence of *S. invicta* was first identified in Huizhou in early 2005. Historical survey data from the agricultural department indicated that the incidence of *S. invicta* across various counties and districts at the beginning of the year was generally classified at level 3. Following preventive measures and control efforts, this level was reduced to level 1, but it subsequently increased to level 3 in certain habitats in the following year. This observation suggests a potential correlation between the reproduction and proliferation of *S. invicta* and the type of habitats. Li Yan *et al.* [7] found that the occurrence and distribution of *S. invicta* were influenced by temperature, rainfall, and light, while various modes of transmission, including water flow and transport vehicle transmission, also impacted the occurrence and distribution of *S. invicta*. Lu Yongyue *et al.* [8-9] identified a correlation between the spatial distribution patterns of *S. invicta* nests and habitat heterogeneity. Specifically, they observed that in more homogeneous environments, the distribution of nests tended to be random to uniform, whereas in non-heterogeneous environments, the distribution shifted from random to aggregated patterns. This study thoroughly investigated the occurrence regularity of *S. invicta* in Huizhou over recent years, and examined the relationship between the distribution of *S. invicta* and the habitat preferences across various environments, as well as the diversity of these habitats. Additionally, the research employed three different agents to assess their efficacy in controlling *S. invicta* populations, in order to offer valuable insights for the development of targeted prevention and control strategies for *S. invicta*.

2 Materials and methods

2.1 Materials The materials utilized in the study comprised trap bottles, ham sausages, alcohol, logo flags, magnifying glasses, plastic buckets, and test tubes.

Preventive and control agents included Brand I, which contained 0.1% indoxacarb and exhibited coarse granularity, with a passing rate of 70% through a 10 mesh sieve; Brand II, which contained 0.08% indoxacarb and demonstrated fine granularity, with a passing rate of 95% or greater through a 10 mesh sieve; and Brand III, which also contained 0.1% indoxacarb, exhibited fine granularity, and had a passing rate of 95% or greater through a 10 mesh sieve.

2.2 Setting of monitoring points The survey was conducted from April to December 2024 and continued from January to March 2025. Monitoring sites for the survey were established in five villa-

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ges across five counties and districts within Huizhou City, including Daliang Village in Huicheng District (23°22′ N, 114°47′ E), Aiguang Village in Huiyang District (22°57′ N, 114°55′ E), Baishabu Village in Huidong County (23°03′ N, 114°68′ E), Huangxi Village in Boluo County (23°53′ N, 113°89′ E), and Wucun Village in Longmen County (23°78′ N, 114°78′ E). It is noteworthy that most of these villages had implemented effective control measures for *S. invicta* in the preceding year.

2.3 Investigation of occurrence regularity In Baishabu Village, located in Huidong County, three segments of green belts, each approximately 500 m in length and characterized by minimal human interference, were selected along transportation routes. Additionally, three areas of wastelands, totaling approximately 667 m^2, were designated for the population dynamics survey of *S. invicta*. Monitoring of the population dynamics was conducted biweekly, at intervals of 15 d.

The on-site survey was conducted to assess the number of live ant nests. During the survey, the monitors recorded the presence of ant mounds or sand-heap-like nests exhibiting activity of *S. invicta* and quantified the number of nests identified.

The population of worker ants was assessed using a trapping method. A specialized trapping bottle, containing ham sausages with a thickness of approximately 0.5 cm and a diameter of 2 cm, was securely positioned on the ground in a shaded area within the habitat of *S. invicta* from 8:00 to 11:00 on a sunny morning. After 30 min, the bottles were promptly collected and filled with anhydrous ethanol. Subsequently, the bottles were transported to an indoor facility for the identification and counting of worker ants based on the morphological characteristics of *S. invicta*. A total of 50 bottles were systematically distributed at each site, ensuring a minimum distance of 10 m between each bottle.

2.4 Effects of habitat diversity on the occurrence of *S. invicta* The distribution of *S. invicta* was examined across five villages, each encompassing an area of approximately 133.33 hm^2. The complexity of habitats varied among the villages. Daliang, Baishabu, and Wucun villages exhibited a high degree of habitat diversity, comprising over ten distinct habitat types, including rivers, farmlands, vegetable fields, wastelands, forests, residential areas, parks, roads, and traffic green belts. In contrast, Aiguang and Huangxi villages presented relatively simpler habitats, primarily consisting of farmlands, vegetable fields, residential areas, and roads. Five survey areas were established in each village, with four monitoring points designated within each area to encompass a variety of habitats. Each monitoring point covered an area of approximately 6 666.67 m^2. A consistent survey method was employed to assess both the number of live ant nests and the population of worker ants.

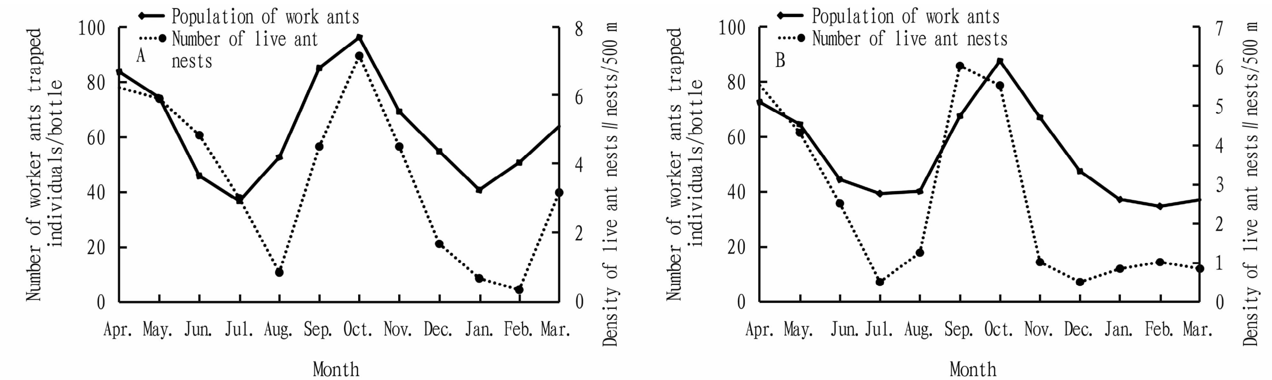
2.5 Preference of *S. invicta* for different habitats The test were conducted in Baishabu Village, Huidong County, and Daliang Village, Huicheng District. Multiple survey points were established within each village to comprehensively cover various habitats, including rivers, farmlands, wastelands, transportation roads, green belts, and residential areas. Each habitat encompassed approximately 6 666.67 m^2. The survey was also conducted to equally assess the number of live ant nests and the population of worker ants.

2.6 Drug efficacy test The efficacy test of three brands of agents was conducted in July 2024, during which the fatality rate and extermination rate of each agent against *S. invicta* were assessed. Specimens of *S. invicta* were collected from the field and placed in plastic buckets, where they were maintained for one week to establish stable nests. Fifty worker ants were cultured in test tubes, to which 1 g of agent was added. The mortality rate of the worker ants was recorded every 12 h, with 50 replicates established for each agent. Concurrently, 50 ant nests, each with a diameter of approximately 20 – 30 cm, were selected in the field to serve as a control group for the three agents. A dosage of 50 g of agents was administered to each nest, and the agents were reapplied after 15 d. The extermination rate of the ant nests was subsequently assessed approximately every 7 d.

3 Results and analysis

3.1 Dynamic occurrence regularity of *S. invicta* The monitoring results from both habitats (Fig. 1) indicated that the population of *S. invicta* workers or the number of ant nests exhibited two distinct peaks between April and December 2024, occurring in April and October. The population reached its maximum in April, subsequently declining to its lowest levels in July and August. A resurgence was observed in September, culminating in a second peak in October, followed by another decline. In 2025, the incidence of the population was low during January and February, with a subsequent increase observed beginning in March. According to this study, *S. invicta* exhibited year-round activity, which was influenced by temperature fluctuations. During January and February, the low temperatures restricted their activity levels. However, as temperatures began to rise in March, the ant colonies became increasingly active. Conversely, the excessively high temperatures experienced in July and August adversely impacted the activity of *S. invicta* population, leading to a decline in their population.

3.2 Occurrence of *S. invicta* in different habitats with varying degrees of complexity The survey results indicated significant variability in the *S. invicta* epidemic across different villages during the same period (Fig. 2). The average number of live nests and the average population of worker ants were ranked as follows: Baishabu Village > Daliang Village > Wucun Village > Aiguang Village > Huangxi Village. This ranking suggests that Baishabu Village exhibited the most complex habitat and the most severe infestation, with an average of 9.515 nests per 667 m^2 and an average of 131.947 worker ants per bottle. The simplest habitat in Huangxi Village exhibited the lowest degree of occurrence, characterized by an average of 8.67 nests per 667 m^2 and an average of 119.754 worker ants per bottle. The difference in the average number of nests between the two villages was 0.845, while the difference in the population of worker ants was 12.193. These findings support the hypothesis that the occurrence of *S. invicta* is positively correlated with habitat complexity. Specifically, more complex habitats are associated with a higher degree of occurrence of this species.



NOTE A. 500 m of green belt; B. 667 m^2 of wasteland.

Fig. 1 Dynamic change trends of *Solenopsis invicta* epidemics in different habitats

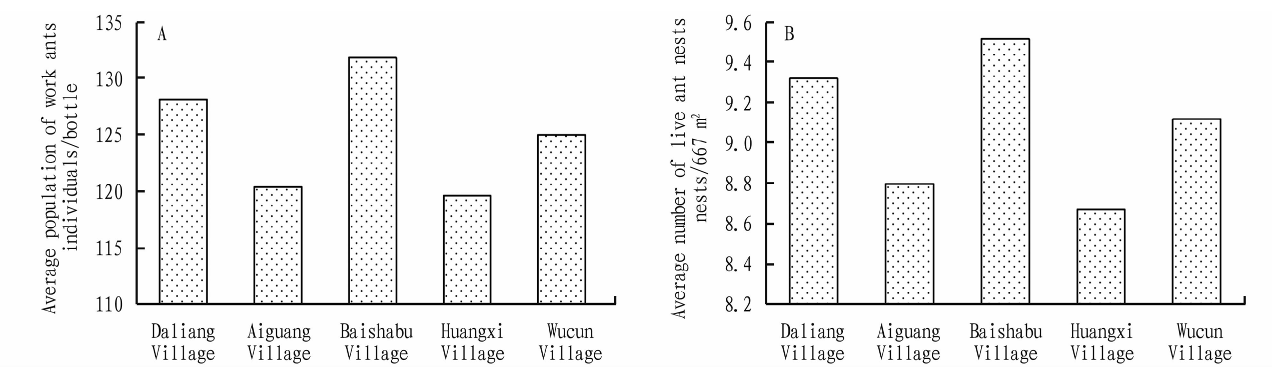


Fig. 2 Occurrence degree of *Solenopsis invicta* epidemic at survey sites across various counties and districts

3.3 Occurrence of *S. invicta* in different habitats Table 1 illustrates the significant variation in the occurrence of *S. invicta* across different habitats. The three habitats with the highest occurrences of *S. invicta* in the two villages were identified as ponds, wastelands, and green belts, each contributing more than 15% to the total occurrence. The highest density of worker ants in Wucun Village was recorded in the pond, with an average of 130.51 individuals per bottle, representing 15.92% of the total. Conversely, the lowest density was observed in the village, with an average of 98.52 individuals per bottle, accounting for 12.02% of the total. The highest density of live ant nests was observed in the pond, with a measurement of 10.25 nests per 667 m^2, representing 15.82% of the total. Conversely, the lowest density was recorded in the farmland, at 7.79 nests per 667 m^2, which accounted for 7.97% of the total. In Huangxi Village, the highest number of worker ants was also found in the pond, with an average of 146.96 individuals per bottle, constituting 16.88% of the total. In contrast, the lowest number of worker ants was observed in the park, with 103.92 individuals per bottle, accounting for 11.93% of the total. Additionally, the highest density of live ant nests in the pond was recorded at 11.50 nests per 667 m^2, representing 16.88%, while the lowest density in the farmland was 8.05 nests per 667 m^2, accounting for 12.31%. It can be concluded that ponds exhibit the highest frequency of occurrence among the various habitats, followed by wastelands or green belts, while farmlands, parks, and villages demonstrate the lowest frequency of occurrence.

Table 1 Monitoring data on the occurrence degree of *Solenopsis invicta* in different habitats

Habitat type	Wucun Village				Huangxi Village			
	Population of worker ants trapped individuals/bottle	Proportion %	Density of live ant nests nests/667 m^2	Proportion %	Poplation of worker ants trapped individuals/bottle	Proportion %	Density of live ant nests nests/667 m^2	Proportion %
Park	108.04	13.18	8.95	13.80	103.92	11.93	8.20	12.54
Road	121.23	14.79	9.16	14.12	128.01	14.70	9.26	14.16
Wasteland	127.82	15.59	9.85	15.18	141.32	16.23	10.03	15.34
Green belt	128.3	15.65	9.80	15.11	134.25	15.42	9.82	15.02
Village	98.52	12.02	8.90	13.72	107.66	12.36	8.53	13.04
Farmland	105.24	12.84	7.97	12.28	108.75	12.49	8.05	12.31
Pond	130.51	15.92	10.25	15.80	146.96	16.88	11.50	17.59

3.4 Efficacy analysis of agents against *S. invicta* According to the results presented in Fig. 3, all three agents demonstrated a significant effect on the mortality of *S. invicta*. The mortality rates observed within 12 h were 41.35% for Brand I, 42.12% for Brand II, and 42.89% for Brand III. Furthermore, the mortality rates at 120 h were 99.18% for Brand I, 98.99% for Brand II, and 98.76% for Brand III. Notably, there were no significant differences in the lethal time of worker ants across the various time intervals. The efficacy of the three agents in exterminating ant nests was observed to follow the order of Brand II > Brand III > Brand I. Notably, Brand I exhibited the largest particle size among the three brands, while Brands II and III displayed similar particle sizes. This suggests that an excessively large particle size may negatively impact the extermination efficiency of the ant colony within the nest. There was minimal variation in the extermination rate of *S. invicta* nests on the 7th and 15th day following the application of the agents. However, the extermination rate exhibited a rapid increase, surpassing 95% by the 15th day after the implementation of supplemental control measures, thereby indicating the effectiveness of the supplemental control.

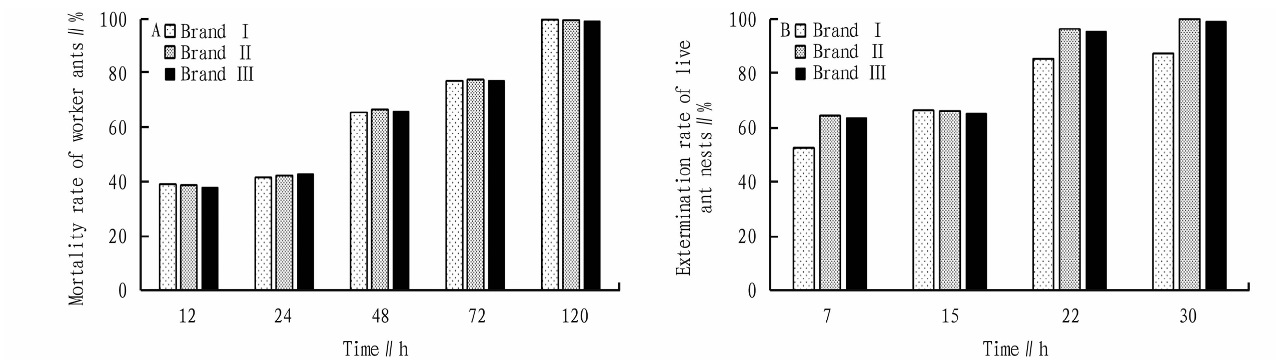


Fig. 3 Fatality rate of worker ants and extermination rate of live ant nests by different brands of agents

4 Conclusions and discussion

S. invicta is a complex social insect characterized by its remarkable survival capabilities. In southern China, there are a diverse array of habitats susceptible to invasion, and *S. invicta* has the capacity to invade and establish populations in all areas, with the exception of those regions exhibiting high forest coverage[10]. The study revealed that increased habitat diversity correlated with a more severe epidemic of *S. invicta*. This relationship suggests that complex habitats offer greater opportunities for the survival of this species. Furthermore, it was observed that more intricate habitats were conducive to the recovery of the *S. invicta* population following control measures, thereby complicating efforts to manage this species effectively.

S. invicta exhibits phobotaxis, which is primarily characterized by its attraction to fertilizers, shaded areas, and greenery, while simultaneously avoiding water and potential threats. This species demonstrates a preference for nesting in elevated ridges and dry, shaded environments, such as wastelands, green belts, and roadsides. The occurrence of *S. invicta* is particularly pronounced at the edges of watersheds, including ponds and riverbanks, and is less prevalent in residential areas with frequent human activity or in farmlands characterized by a homogeneous ecological structure. The primary reason may be the favorable conditions present in water source areas that enhance their survival. Additionally, the presence of mobile water sources facilitates the dispersal and aggregation of *S. invicta* populations. Human intervention plays a significant role in influencing the occurrence of *S. invicta* as well. Prolonged and active measures for prevention and control, along with the destruction of nests, have a direct impact on the population size of *S. invicta*.

The effect of agents containing varying concentrations of indoxacarb on the extermination of worker ants demonstrates minimal differences, but particle size exerts a significant influence. Attractants with smaller particle sizes facilitate the transportation of bait by worker ants to the interior of the ant nest, thereby enabling the colony to engage in contact trapping, which results in improved control efficacy. It was observed that in the outbreak area, the effectiveness of prevention and control measures improved following the mowing measures. This action not only disrupted the living environment of the ants but also made their nests more visible. Consequently, some of the alarmed *S. invicta* relocated to construct new nests and actively transported bait, thereby enhancing the trapping efficiency of the ant colony. In the process prevention and control, it has been observed that the management of *S. invicta* is most effective when implemented within 2 – 3 d following heavy rainfall. This heightened efficacy is attributed to the rapid construction of nests by *S. invicta* post-rainfall, during which the worker ants exhibit increased activity in the upper soil layers, actively foraging to facilitate the trapping effect. Furthermore, the prevalence of *S. invicta* in the root systems of newly planted trees approaches 100%, underscoring the critical need to enhance prevention and control strategies for *S. invicta* in newly established orchards during the reclamation of wasteland. *S. invicta* exhibits the highest migration rates and demonstrates increased activity in the southern region during the months of April and May[11], followed by the period from September to November, which coincides with both the rainy season and the peak of agricultural activities. Factors such as human interference, coverage, high shade, and the application of chemicals may facilitate their migration and nesting behaviors[12]. These activities are more likely to occur in aquatic environments, including riversides, ditches, and ponds. Therefore, it is imperative to capitalize on this critical period to enhance the prevention and control measures for *S. invicta*.

To further consolidate and expand the outcomes of *S. invicta* prevention and control, the following strategies may be employed in the future to optimize and enhance these efforts, thereby continuously broadening the scope of prevention and control measures. Firstly, it is necessary to enhance scientific research and continuously improve the standards of prevention and control technologies. Secondly, it is important to increase research efforts focused on *S. invicta* and explore innovative means and methods for its prevention and control. Thirdly, it is essential to promote and demonstrate the application of these technologies, disseminating advanced prevention and control techniques and experiences through technical training and the establishment of demonstration sites. Fourthly, there is a need to strengthen the monitoring and early warning systems for *S. invicta*, establishing a robust monitoring network and system to effectively capture the dynamic information regarding this species. Fifthly, it is imperative to enhance public awareness and education, thereby increasing community support and participation in the prevention and control of *S. invicta* through various publicity and educational initiatives. Lastly, it is crucial to reinforce organizational leadership and coordination, clearly delineating the responsibilities and tasks of each department, fostering collaboration among departments, and establishing a scientific and efficient operational mechanism.

References

[1] ZHANG SQ, CHEN HM, GOU J, *et al.* Activity ability of red imported fire ant workers after nest disturbed in different habitats of Southern China [J]. Journal of Environmental Entomology, 2025, 47(2): 586 – 592. (in Chinese).

[2] HUANG J, LU YY, ZENG L, *et al.* Attraction effect comparison of different setting forms of bait for *Solenopsis invicta*[J]. Journal of South China Agricultural University, 2007, 28(4): 23 – 25. (in Chinese).

[3] JIANG SH, LIU D, LI GJ. A review: The biology of red imported fire ant (*Solenopsis invicta* buren)[J]. Journal of Southwest Agricultural University (Natural Science), 2005, 3: 312 – 315. (in Chinese).

[4] LI ND, ZENG L, LIANG GW, *et al.* Dynamics of red imported fire ant *Solenopsis invicta* in Wuhan, Guangdong[J]. Chinese Bulletin of Entomology, 2008, 45(1): 54 – 57. (in Chinese).

[5] LI ND, ZENG L, LIANG GW, *et al.* Dynamics of red imported fire ant *Solenopsis invicta* in Wuchuan, Guangdong[J]. Entomological Knowledge, 2008, 45(1): 54 – 57. (in Chinese).

[6] ZENG L, LU YY, HE XF, *et al.* Identification of red imported fire ant *Solenopsis invicta* to invade China's Mainland and infestation in Wuchuan, Guangdong[J]. Entomological Knowledge, 2005, 42(2): 144 – 148. (in Chinese).

[7] LI Y, LIU P, TAI YM, *et al.* Dynamics of red imported fire ant worker and its optimum control period in Chenggong, Kunming, China[J]. Journal of Environmental Entomology, 2021, 43(6): 1552 – 1556. (in Chinese).

[8] LI ND, LU YY, ZENG L, *et al.* Study on types of environment, spatial distribution and sampling of red imported fire ant *Solenopsis invicta* buren active mounds in Wuchuan, Guangdong province[J]. Journal of Huazhong Agricultural University, 2006, 25(1): 31 – 36. (in Chinese).

[9] LU YY, LI ND, LIANG GW, *et al.* Spatial distribution of *Solenopsis invicta* new founded mounds by nuptial flight[J]. Journal of South China Agricultural University, 2007, 28(4): 1 – 5. (in Chinese).

[10] XU YJ, LU YY, ZENG L. Spatial distribution characteristics of *Solenopsis invicta* nests in newly invaded areas[J]. Guangdong Agricultural Sciences, 2010, 37(8): 16 – 19. (in Chinese).

[11] WANG L, ZENG L, LU YY, *et al.* Effect of destructing mounds on the colony migration of red imported fire ant *Solenopsis invicta*[J]. Entomological Knowledge, 2010, 47(5): 941 – 944. (in Chinese).

[12] WANG L, LU YY, ZENG L, *et al.* Nest distribution and dynamics of colony movement of red imported fire ant in lawn[J]. Journal of South China Agricultural University, 2012, 33(2): 149 – 153. (in Chinese).