Research on the Control Cover against *Solenopsis invicta* and Rapid Extinguishment of Its Epidemic

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Abstract Based on the biological characteristics of *Solenopsis invicta* and the structural characteristics of its ant nest, a fast and efficient closed treatment device was developed. Compared with the simple chemical treatment commonly used at present, the developed treatment device (the ant nest control cover) is a fast and efficient method to exterminate *S. invicta* in 7 d, featured by short course, quick results and good effect.

Key words Alien invasive species; *Solenopsis invicta*; Control cover; Epidemic extinguishment technology

1 Introduction

Solenopsis invicta, a subject of quarantine in China, is one of the 100 most important invasive species in the world and a universally recognized alien pest that poses a major hazard to public safety, such as agricultural production, ecological environment and human health. In addition to harming agricultural production, it destroys power supply, telecommunications, farmland, dams and other facilities, but also harms other organisms in the ecological environment and destroys biodiversity. More importantly, when it is disturbed, it will also sting people and animals in groups, threatening people's health and safety. *S. invicta* originally distributed in some countries in South America, and after continuous spread and diffusion, it has now occurred in more than 10 countries and regions and caused serious harm. *S. invicta* first invaded Taiwan in 2004 and now have spread to Hong Kong, Macao, Guangdong, Guangxi, Hunan, Fujian, Hainan, Jiangxi, Sichuan and other provinces of China. Due to the lack of natural predators and other constraints, coupled with its amazing reproduction rate and strong population competitive advantages, as well as preference of nesting in the lawn and spread with the lawn, *S. invicta* is now breaking out in China and causes general damage[1]. In 2009, it was found in Xiamen City, and now has spread across urban and rural areas, restricting the city's economic and tourism development.

The prevention and control of alien species such as *S. invicta* has become an important task for the relevant competent departments, including the garden department, and strengthening scientific and technological research and development to accelerate the extinguishment technology against *S. invicta* is a major task. China has carried out a lot of research on the prevention and control of invasive *S. invicta*, forming some control methods. The prevention control method of poisoning without accessory treatment is the most commonly used, however, the most fatal shortcoming of this method is that it is carried out in an open environment with the problems such as escape, diffusion and establishment of new ant colonies during the control process, and the prevention and control work has not been effectively carried out, resulting in the continuous spread of the epidemic. Therefore, it is urgent to develop a fast, efficient, environmentally friendly and compatible universal method for exterminating *S. invicta*[2].

2 Materials and methods

2.1 Fast and efficient treatment device According to the biological characteristics of *S. invicta* and the structural characteristics of its ant nest, a fast and efficient closed treatment device was developed.

2.2 Evaluation of the efficacy of treatment by means of treatment device and conventional methods

2.2.1 Agent. The most commonly used agent 'Huoyijing' (insecticide powder containing 0.1% high-efficiency cypermethrin) was selected, and ham sausage was used as bait.

2.2.2 Field test method. The rapid and efficient treatment device developed was compared with the conventional method, and its treatment effect was evaluated. The experiment consisted of 3 application treatments and 1 control.

(i) Treatment method. Treatment 1: 'Huoyijing' was evenly spread once on the surface of ant nest, 15 g per nest; the number of insects per nest and the active ant nests in each plot were checked at 7 d post application; three ant nests were arranged as total of 3 replicates. Treatment 2: 'Huoyijing' was spread twice on the surface of ant nest with an interval of 7 d, 15 g per time per nest; the number of insects per nest and the active ant nests in each plot were checked at 7 and 14 d post application; three ant nests were arranged as total of 3 replicates. Treatment 3: 'Huoyijing' was spread once on the surface of ant nest, 15 g per nest, and a control cover device was settled simultaneously; the number of insects per nest and the active ant nests in each plot were checked at 7 d post application; three ant nests were arranged as total of 3 replicates. Control: no treatment, two replicates were

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(ii) Implementation of treatment methods. In the plots seriously damaged by *S. invicta* with more than 10 active ant nests, 3 ant nests were randomly selected as a group, with a total of 3 groups corresponding to 3 treatments. The other ant nests were used as control. Each active ant nest participating in the test was marked with a small flag to record nest number, treatment method and test date.

2.2.3 Data acquisition. (i) Before application, the 10 mm long ham sausages as bait were placed on each test ant nest marked, and after 60 s, the number of insects attracted by each bait on each test ant nest was calculated. (ii) At 7 and 14 d post application, each test ant nest was dug up and bait was placed inside, and after 60 s, the number of *S. invicta* attracted by each bait in each test ant nest at 7 and 14 d was calculated.

2.2.4 Criteria for determining ant nest activity. At 7 and 14 d post application, the tested ant nests were checked. When 3 or more than 3 insects of *S. invicta* were attracted, the nests were judged as active, and less than 3 was considered as inactivated.

2.2.5 Data processing. According to the data collected, the active ant nest decline rate, population decline rate and control effect of each treatment at 7 and 14 d were calculated according to the following calculation formulae:

(i) Population decline rate (%) = (Number of insects in bait before application − Number of insects in bait after application)/ Number of insects in bait before application × 100;

(ii) Ant nest decline rate (%) = (Number of active ant nests judged before application − Number of active ant nests judged after application)/Number of active ant nests judged before application × 100;

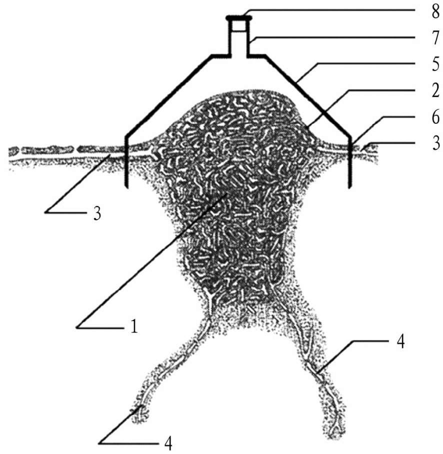
(iii) Treatment effect (%) = (Ant nest decline rate in treatment − Ant nest decline rate in control)/ (100 − Ant nest decline rate in control) × 100.

3 Results and analysis

3.1 Development of fast and efficient control cover

3.1.1 Principle. *S. invicta* is a kind of social insect, and usually nests in the park green space, near trees or rocks. The nest of *S. invicta* is a cylindrical honeycomb structure composed of fiber and soil particles, generally with a diameter of 200 − 400 mm. An anthill with a diameter no larger than that of the nest and a height of 100 − 150 mm are formed on the ground, and the bottom depth is generally 1.5 times the diameter, with the deepest depth of 600 − 700 mm underground. The ant nest is less than 30 mm near the surface, and a number of foraging tunnels are extended around to connect with the outside world. At the bottom of the nest, there are several water intake paths extending deep underground, with the deepest of 950 mm. According to the structural characteristics of *S. invicta* ant nest, an ant nest control cover can be installed to cut off the passageway connecting the nest through the foraging tunnel and the space spreading outward through the anthill, forming a relatively closed environment isolated from the outside world. When chemical agents are applied to this environment, *S. invicta* is prevented from escaping and spreading outwards in the control, and all ants in the entire ant nest can be completely extinguished[3-4].

3.1.2 Structure design. The treatment device is equipped with an ant nest control cover, which is composed of cone part, isolation belt part, application tube and application tube cover. The chemical agent against *S. invicta* is injected into the cone part of outer cover: the top of the isolation belt part is connected with the bottom of the cone part; the outlet of the application tube is connected with the top of the cone part; the outlet of the application tube is connected with the cone part; and the application tube cover is located at the entrance of the applicator tube (Fig. 1).



Note: 1. Ant nest; 2. Anthill; 3. Foraging tunnel; 4. Water intake path; 5. Cone part of outer cover; 6. Isolation belt part of outer cover; 7. Application tube of outer cover; 8. Application tube cover of outer cover.

Fig. 1 Structure and control diagram of the treatment device

3.1.3 Operation procedure. When discovering an ant nest of *S. invicta* (a), the ant nest outer cover invented is fastened above the ant nest, and pressing the isolation belt into the soil (b). Chemical agents are applied through application tube of outer cover (c). The agent applied can be a variety of fumigation agents, or liquid agents, powders and fumigation agents, and killing powder was used in this test. After application, the application tube cover of outer cover (d) should be covered without delay to prevent the leakage of the agent and prevent the escape of *S. invicta* (Fig. 2).

3.2 Field treatment effect with the treatment device

3.2.1 Population decline effect. Treatment 3 was able to extinguish all the pests 7 d after single application, while treatment 2 could only extinguish most of the pests 14 d after secondary application. Treatment 1 could not completely eradicate the pests after single application, and a small number of pests suppressed were extinguished at 14 d post application (Table 1).

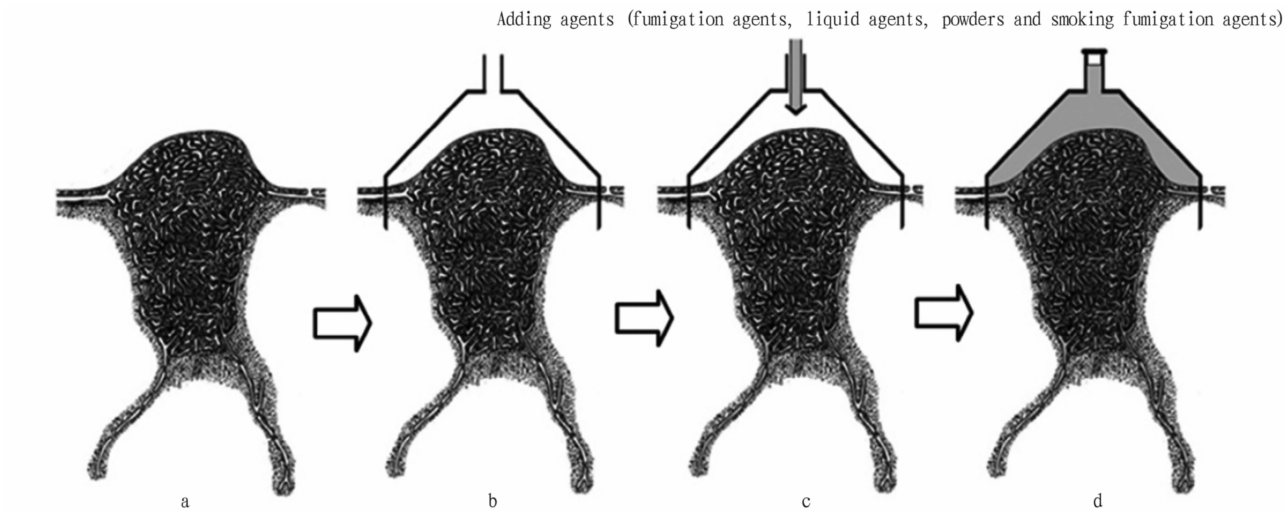


Fig. 2 Process of controlling *Solenopsis invicta* with treatment device

Table 1 Population decline rate at 7 and 14 d post application

Treatment	Repetition	Initial number of insects	Number of insects after application		Population decline rate after application//%	
			7 d	14 d	7 d	14 d
1	I	31	12	9	/	/
	II	19	7	2	/	/
	III	26	10	12	/	/
	Average	25.3	9.7	7.7	62.0	71.4
2	I	24	9	0	/	/
	II	35	13	1	/	/
	III	29	11	0	/	/
	Average	29.3	11.0	0.3	62.5	99.0
3	I	14	0	0	/	/
	II	37	0	0	/	/
	III	31	0	0	/	/
	Average	27.3	0.0	0.0	100.0	100.0
Control	I	26	24	29	/	/
	II	32	36	30	/	/
	Average	29.0	30.0	29.5	-2.4	-2.6

3.2.2 Ant nest decline effect. Treatment 3 could destroy all ant nests 7 d after single application, while treatment 2 could destroy all ant nests only 14 d after secondary application. Treatment 1 could not destroy ant nests 7 d after single application, and a few ant nests were destroyed at 14 d post application (Table 2).

3.2.3 Control effect. Treatment 3 achieved a treatment effect of 100% 7 d after single application, while treatment 2 only achieved a control effect of 100% 14 d after secondary application, and treatment 1 only achieved a control effect of 33.3% 14 d after single application (Table 3).

The above test results show that compared with the current common simple chemical control, the developed treatment device for chemical control is a fast and efficient method featured by short course, quick results and good effect.

Table 2 Ant nest decline rate at 7 and 14 d post application

Treatment	Repetition	Situation before application	Situation after application		Decline rate after application//%	
			7 d	14 d	7 d	14 d
1	I	+	+	+	/	/
	II	+	+	-	/	/
	III	+	+	+	/	/
	Number of active ant nest	3	3	2	0	33.3
2	I	+	+	-	/	/
	II	+	+	-	/	/
	III	+	+	-	/	/
	Number of active ant nest	3	3	0	0	100
3	I	+	-	-	/	/
	II	+	-	-	/	/
	III	+	-	-	/	/
	Number of active ant nest	3	0	0	100	100
Control	I	+	+	+	/	/
	II	+	+	+	/	/
	Number of active ant nest	2	2	2	0	0

Note: '+' indicates the ant colony is active, and '-' indicates the ant colony has been inactivated.

Table 3 Control effect at 7 and 14 d post application %

Treatment	7 d	14 d
1	0	33.3
2	0	100
3	100	/

4 Conclusions and discussion

According to the biological characteristics of *S. invicta* and the structural characteristics of its ant nest, the control cover developed can cut off the channel through which the nest is connected to the surrounding by foraging tunnel to form a relatively closed space environment isolated from the outside world, so as to prevent *S. invicta* from escaping and spreading when chemical agents are applied to this environment, thus achieving the effect of completely exterminating all the ants in the entire ant nest.

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The test results also showed when an ant nest control cover was installed in the treatment of *S. invicta*, the population decline rate was 100%, the nest decline rate was 100% and the control effect was 100% at 7 d post application. Compared with the control status without control cover, the population decline rate, the nest decline rate and the control effect at 14 d post application were 71.4%, 33.3% and 33.3%, respectively, when chemical agents were applied once, and 99%, 100% and 100%, respectively, when chemical agents were applied twice. The control duration without control cover was twice as long as that with control cover, and the dose used to achieve the control effect was also twice as much. At the same time, *S. invicta* would escape and establish new nests during the control process. This indicates that the control of *S. invicta* by adding control cover can not only shorten the control time and use less medicine, but also effectively solve the problem of escape, which significantly improves the actual control effect and is economical and environmental protection compared with traditional simple application of medicine without control cover[5-7].

The results show that the control cover of *S. invicta* is a fast and effective exterminating tool to deal with *S. invicta* epidemic. Although it is not possible to use the control cover in some places because of the terrain restrictions, the vast majority of *S. invicta* nests are built in parks, green spaces, nurseries, orchards and other flat open fields[8]. The control cover is basically applicable to broad lawns and fields, and thus has broad application prospect. With the popularization and the installation tool developed subsequently, the use of control cover made from plastic is more convenient, the cost will be further reduced, so it has the value of popularization.

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