Repellent Effects of Five Plant Essential Oils on the Red Imported Fire Ant, *Solenopsis invcita*

by

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ABSTRACT

The aim of this experiment was to search for the essential oils which have repellent effects on red imported fire ants. Effect of five kinds of essential oils in four concentrations on fire ant workers was evaluated using a Y-tube olfactometer bioassay. Our results indicate that *C. annuum* oil showed a strong repellent effect on fire ant workers in the four concentrations ($P < 0.01$), and the repellent effect on fire ants is enhanced with increasing concentration. The repellency rate of the concentration of 1000μl/ml was 91.2%, indicating that the essential oils had a significant repellent effect. *C. nardus*, *C. cassia*, *I. purpurea* were also considered as effective repellent substances for fire ants, especially at high concentrations, while *S. sclarea* was not suggested for use as fire ant repellent.

Key words: *Solenopsis invicta,* Plant essential oil, Olfaction.

INTRODUCTION

The Red Imported Fire Ant, *Solenopsis invicta* Buren, is one of the most important 100 invasive species in the world, and causes severe damage to humans, animals and the environment. White pustules form after people are attacked by the fire ant and cause further bacterial infection. Bites can also bring about chills, fever, dizziness, headache, swollen lymph nodes and other symptoms (Zeng *et al.* 2005). Fire ants diminish the utilization of parks and recreation, and affect the tourism industry greatly (Vinson 1997).

S. invicta disperses by means of flight, budding (radial expansion of colonies) (Tschinkel 1998) and so on (Xu *et al.* 2009; Xu *et al.* 2006), which poses a great obstacle to the control of fire ants. Currently many urban zones in South China with great population and housing density are likely to be affected by

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fire ants. Meanwhile the high toxicity of chemicals applied is undoubtedly a threat to human health and the environment. Therefore, research and development of alternative control tactics, such as fire ant repellents, is necessary to reduce the use of the synthetic contact insecticides (Chen 2005; Blum *et al.* 1991; Chen *et al.* 2008).

To search for the essential oils which had efficient repellence to red fire ant, the olfactory behavioral responses of fire ants to five essential oils were tested with a Y-tube olfactometer in this study. Our results should facilitate the search for plant-source repellence to fire ants, and provide a scientific basis for the sustainable management of fire ants.

MATERIALS AND METHODS

Insects

S. invcta colonies were collected from the suburb of Guangzhou and maintained in the laboratory for bioassays. The collected ants were fed with a mixture of 10% honey and live insects (*Tenebrio molitor* L.). A test tube (25 mm×200 mm), which was filled partially with water and plugged with cotton, was used as a water source. Ants were maintained in the laboratory at 25 ± 2°C.

Olfactometer

The Olfactometer mainly consisted of the following accessories which were connected with the odorless silicone tube: circulating water pumps, Y-tube tube boom, distilled water bottles, and odor source bottles. The length and diameter of the main and side arms were 19cm and 2.5cm respectively, with 75° as the angle of two sides. Gauze was fixed in the side arms to block the path to the odor bottles (Fig. 1).

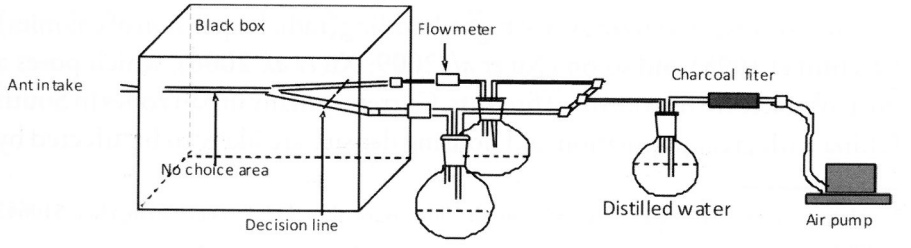

Fig. 1 Sketch map of Y-tube olfactometer

Reagents

Plant essential oils of *Cymbopogon nardus*, *Cinnamomum cassia*, *Ilex purpurea*, *Salvia sclarea* and *Capsicum annuum* were provided by DaMo Chemical Co. Ltd. Hexane and ethanol used in the bioassay were the AR and produced by Sinopharm Chemical Reagent Co. Ltd. and DaMao Tianjin Reagent Factory.

Olfactory response test

All of the plant essential oils were diluted to 10%, 1%, 0.1% and 0.01% with hexane for the bioassay. The Y-tube olfactometer was ventilated with air pump for 15min prior to the test.

100μL test solution was instilled into the filter paper strip (15 mm × 40 mm). Then the tested filter paper strip was put into one of the odor source bottles, and filter paper strip with hexane was put into the other one as a control. One fire ant worker was induced to the main arm, and the number of workers which went through one or the other of the side arms and stayed for 30 seconds (regarded as reaction to the odor) was recorded for ten minutes after the beginning of the test. 30 replicates were used for each treatment. Ethanol was used to clean the olfactometer after each replicate, and then it was cleaned with distilled water, and then dried. The two side arms were exchanged in turn for treatments and control.

The oils were tested from low to high concentration. We washed and dried the Y-tube olfactometer after the test for each concentration with industrial alcohol.

Statistical analysis

Chi-Square Test was used to compare the worker numbers between the treatment and control arm. All the statistical analyses were conducted using the SPSS13.0 software package.

Repellency rate of the essential oils to the fire ant was calculated according to the following formula:

Repellency Rate (%) = Number of ants selected control / (Number of ants selected treatment odor + Number of ants selected control) × 100%

RESULTS

Our results showed that all of the plant oils tested have repellent effects on fire ant workers, and the dose effect was obvious. For *C. nardus* oil, the

repellent effect was not significant at the concentration of 1ul/ml (χ^2=1.524, p=0.217), with 59.5% as the repellency rate, but as the concentration increased, the repellent effect significantly increased (P<0.01) (Table 1). For the concentrations of 10ul/ml and 100ul/ml, the repellency rate was 74.5%, and 83.6%, respectively. As for the concentration of 1000ul/ml, the repellency rate to fire ants was 95.1%, indicating that a high concentration of citronella oil repelled the fire ants with good results (Fig. 2).

C. cassia oil showed no significant repellent effect (χ^2=8.02, P=0.05) on the fire ants at the concentration of 1μl/ml (Table 1), but the repellent effect was significantly (P<0.01) enhanced as the concentration increased. The repellency rate was 85.1% when the concentration increased to 10μl/ml, and 95.3% at 100μl/ml. That *C. cassia* oil at high concentrations has a good repellent effect on fire ants (Fig. 2).

The results showed that repellent effect of *I. purpurea* oil on fire ants at four concentrations were obvious (p <0.01), and all of the repellency rates at different concentrations were nearly 70% (Fig. 2).

Compared with the other essential oils, repellency rates of *S. sclarea* oil are relatively low (Fig. 2). The results indicated that repellence of the *S. sclarea* oil to the fire ant was not significant at the concentrations of 1,10 and 1000 μl/ml(p>0.05). While the repellent effect is substantial at the concentration of 100μl/ml (P <0.05), with a 67.65% repellency rate (Table 1).

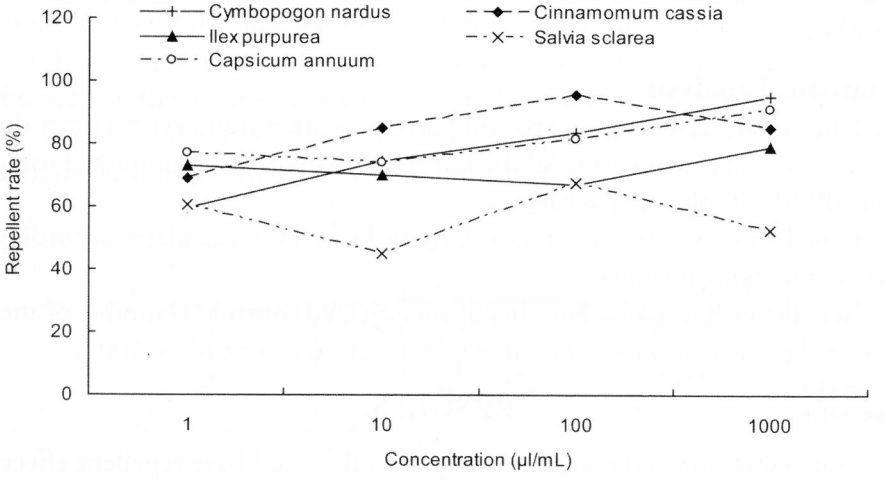

Fig. 2 Repellency Rate of plant oils to fire ant workers

Table 1 Repellence of five plants oils to *S. invicta* workers.

Plant oils	Concentration (μl/ml)	Worker numbers		χ^2
		Treatment	Control	
Cymbopogon nardus	1	5.67±0.70	8.34±1.45	1.52^{ns}
	10	4.3±0.88	12.70±0.90	12.26**
	100	3.67±1.67	18.67±0.90	30.24**
	1000	1.00±0.58	19.30±0.90	49.59**
Cinnamomum cassia	1	5.67±0.70	12.67±0.30	8.02^{ns}
	10	3.31±0.30	19.00±1.20	32.97**
	100	1.33±0.30	27.33±0.70	70.74**
	1000	4.00±1.00	22.67±0.90	39.20**
Ilex purpurea	1	6.67±0.30	18.00±1.00	15.62**
	10	8.00±2.00	17.67±0.90	10.92**
	100	7.00±21.50	14.33±2.80	7.56**
	1000	5.00±1.00	19.00±1.50	24.50**
Salvia sclarea	1	5.67±0.30	8.67±0.30	1.88^{ns}
	10	7.67±0.70	6.33±1.80	0.38^{ns}
	100	3.67±0.30	7.67±0.30	4.24*
	1000	6.00±0.60	6.67±1.20	0.11^{ns}
Capsicum annuum	1	4.00±1.70	13.30±0.70	15.08**
	10	2.34±0.30	6.67±1.80	6.26**
	100	1.67±0.30	7.33±0.90	10.74**
	1000	1.00±0.00	10.30±1.70	23.06**

Note: ns, * and ** on the table indicates no significant difference at 0.05 and 0.01 level between the treatment and control in the same row.

Our results showed that *C. annuum* oil showed strong repellent effect son fire ant workers in all four concentrations ($P < 0.01$), and its repellent effect was enhanced at higher concentrations. The repellency rate of the concentration of 1000μl/ml was 91.2%, indicating that the essential oil had a significant repellent effect (Table 1, Fig. 2).

DISCUSSION

According to our bioassay, *C. annuum* oil had the most effective repellence among the five plant oils, which could interfere with the olfactory behavior of fire ants. *C. nardus*, *C. cassia*, *I. purpurea* could also be considered as effectively repellent for the fire ants, especially at high concentrations. *S. sclarea* was

not as effective. All of the oils tested in this study were plant-source, which makes them less harmful to humans and the environment. *C. annuum* an important crop vegetable consumed by people of many countries, and its oil showed great repellent effects on fire ants, which indicates its potential for application in the management of fire ants.

Dose effect also appeared in the test, and the concentration of the oils applied should be taken into consideration. Repellence effect of essential oils could be enhanced when mixed with chemical pesticides (Fuhremann & Chtenstein 1979). To avoid environmental pollution, people should make efforts to seek mixed use of essential oils and other botanical pesticides, microbial pesticides and insect pheromones, which could produce a synergistic effect to improve the control effects on fire ants.

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