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Red Imported Fire Ant Invasion Reduced the Populations of Two Banana Insect Pests in South China

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Abstract

As a severe invasive pest, red imported fire ant (*Solenopsis invicta* Buren) had important effects on ecosystem of its infected areas. Here, we surveyed the impact of *S. invicta* on populations of two banana insect pests, banana skipper (*Erionota torus* Evans) and banana lacebug (*Stephanitis typical* Distant). The results showed that influences of *S. invicta* on the populations of *E. torus* and *S. typical* depend on weed coverage degree of banana plantations. Comparing to the areas without *S. invicta*, banana skipper population was reduced by 39.2%, 41.4% and 23.4% respectively, in high, moderate and low weed coverage of banana plantations with *S. invicta* invasion. Banana lace bug population was reduced by 17.8%, 43.0% and 39.2% respectively, in high, moderate and low weed coverage of banana plantations with *S. invicta* invasion.

Introduction

As a famous invasive pest, red imported fire ant *Solenopsis invicta* preyed on many different kinds of invertebrates at different developmental stages including egg, larvae, pupae and adults (Stiles & Jones, 2001), and caused a sharply decline on populations and diversity of invertebrates and some epigeous vertebrates in its introduced areas (Cook, 2003; Morrison, 2002; Wojcik et al., 2001). However, *S. invicta* also is an active and efficient predator of pests. 58%-85% cotton boll weevil (Fillman & Sterling, 1983) and 85% tobacco budworm (McDaniel et al., 1981) were consumed by *S .invicta* in investigated fields. Vogt et al. (2001) showed that *S. invicta* preyed on about seven times more pest arthropods than beneficial arthropods in peanut field. In Florida, *S. invicta* preyed on eggs and larvae of soybean armyworm (*Anticarsia gemmatalis*). *S. invicta* also reduced population of diamondback moth and leaf beetles in collards (Harvey & Eubanks, 2004). Accordingly, Harvey and Eubanks (2004) believed that *S.*

invicta may be particularly important biological control agent in agroecosystems.

Banana is an important economically crop in south China. In China, the most economically damaging pests of banana are *Odoiporus longicollis* Olivier, *Pentalonia nigronervosa* van der Goot, *Erionota torus* Evans, and *Stephanitis typical* (Lu et al., 2002). *E. torus* is a phytophagous lepidopteran that feeds on banana plants leaves. *E. torus* curled up banana leaves and took them as pupation sites (Lu et al., 2002). Nymphs and adults of *S. typical* feed on phloem sap of banana plant and also are vectors of banana rosette dwarf disease which causes serious damage of banana production (Zhou et al., 1993).

In South China, 10-50% banana plants were infected by *S. typical* and *E. torus* in banana garden (Lin et al., 2009; Guo et al., 2012). Although conventional pesticides still are the primarily method for these pests control, integrated pest management (IPM) and biological control are essential for the control of banana pests because many people are concerned about the pollution of the environment and food security issues.

Since it was detected in mainland China at 2004 (Zeng et al., 2005), *S. invicta* has been found in many habitats including banana plantation. Harvey and Eubanks (2004) indicated that increasing habitat complexity can enhance *S. invicta* efficacy and herbivore control. So, *S. invicta* may be a potential effective predator of banana pests because banana plants are often grown in complex, intercropping systems in China (Liu et al., 2015; Ke et al., 2012; Chen et al., 2008). The goal of our study is to assess the effect of *S. invicta* on population of *S. typical* and *E. torus*. Meanwhile how habitat complexity affects *S. invicta* predation of *S. typical* and *E. torus* was also evaluated.

Materials and Methods

Experimental plot and habitat conditions

The experimental plots located in the banana plantation of South China Agricultural University Ningxi teaching and study training center, Guangzhou, China. The banana plantation (total area of 3.5 acres, and 1.3 acres selected for experiment) was newly established and was in good ventilation and less external disturbance. In this study, dwarf banana was planted which is a hybrids cultivated variety of genus *Musa* planted widely in south China.

Based on weed coverage, experimental plots were divided into high weed coverage plots, moderate weed coverage plots, and low weed coverage plots. Depend on our investigations (Fig 1), the *S. invicta* infestation level of all three types of experimental plot are high degree due to the density of fire ant mounds was 7-10 per 100m², and 100-200 workers in each bait trap in each experimental plot before experiment was conducted (Wang et al., 2009). Plots with high weed coverage and without *S. invicta* were taken as control. Each type of plots was consisted of 6 small plots (2m width × 70m length), and they are separated by water drain way (Fig 1).

In this study, high weed coverage was defined as weed was allowed freely growth and more than 70% of plot area was covered. Moderate coverage was defined as weed

was partially removed periodically and 30-70% of plot area was covered. Low coverage was defined as weed was rooted out often and less than 30% of plot area was covered. The microclimate, soil condition and ecological environment in all plots were basically similar, and main weed species in our study sites are *Cynodon dactylon*, *Cyperus exaltatus* and *Cirsium setosum*.

Experimental methods

S. invicta colonies in our study sites were polygyne. The abundance of *S. invicta* in experimental plots was surveyed once in the middle of each month during May to October in 2008 by bait traps (Lu et al., 2012). Meanwhile, the number of *S. invicta* nests was also counted in experimental plots. The survey was conducted at 10:00 am in the sunny day.

The larvae and pupae of banana skipper *E. torus* and the living nymphs and adults of banana lace bug *S. typica* on all leaves of a banana plant were counted. Five banana plants in each small plot were surveyed, and three of six small plots were chosen randomly in every time of investigation. The survey was conducted once in the middle of each month from May to October, 2006. The study was conducted from May to October because it is the major occurring period of both pests. It also is the period that banana grow from the later seedling stage to young fruit stage.

Data analyses

All data were tested for normal distribution and homogeneity of variances by the Shapiro-Wilk test and Levene's test, respectively. Since all data were normal distribution, the analysis of variance followed by LSD mean comparison at α = 0.05 was used to compare the number of fire ant mounds, trapped fire ant workers and populations of *E. torus* and *S. typica* among different plots and among different months using generalized linear model (GLM). All statistical analyses were conducted using SPSS, version 18.0 (SPSS Inc., Chicago, IL, USA).
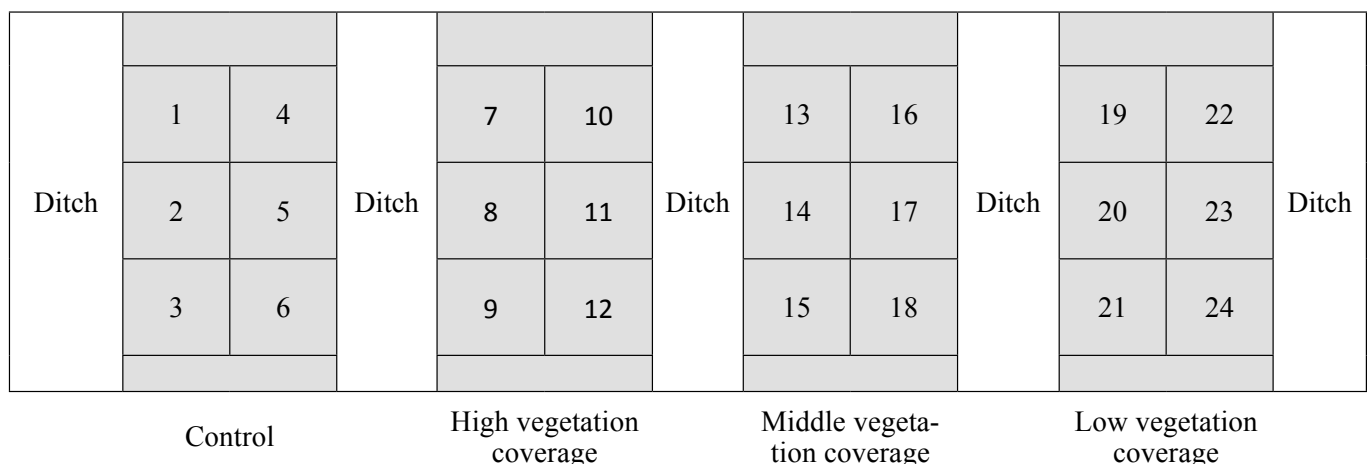

Fig 1. Schematic diagram about experimental site.

Results

Dynamic of S. invicta in banana plantation

The numbers of *S. invicta* workers varied from May to October in high, moderate and low weed coverage experimental plots (Table 1, F = 184.0, df = 17, P < 0.001). The numbers of trapped workers increased after May and reach a peak in July. In July, 252 ants/trap, 275 ants/trap and 290 ants/ trap were collected in high, moderate and low weed coverage experimental plots, respectively. The numbers of trapped ants decreased in August and September and significantly increased again in October. The density of *S. invicta* nests also changed with time in different types of coverage experimental plots. The density of ant nests reached a peak in August in high weed coverage plots and reached the peak in June in moderate and low weed coverage plots (F = 148.2, df = 17, P < 0.001).

Effect of S. invicta on banana skipper population E. torus

In our investigation, *E. torus* populations in *S. invicta* infected plots were less than those in control from May to October (Table 2, F = 150.07, df = 8, P < 0.0001). *E. torus* population reduction in high and moderate weed coverage plots were significantly higher than that in low weed coverage plot, but there was no significant difference between the high and moderate weed coverage plots from May to October (F = 150.07, df = 8, P < 0.0001). The population of *E. torus* reduced by 21.6% - 53.4%, with an average 39.2% in high weed coverage plots. In moderate weed coverage plots, it was reduced by 13.4% - 52.9%, with an average 41.4%. The population of *E. torus* also was reduced from -5.4% to 33.5% in low weed coverage plots, with an average 19.2%.

Table 1. Dynamics of *S. invicta* population in the three types of banana plantations.

Date (mm-yy)	Area of high vegetation coverage		Area of moderate vegetation coverage		Area of low vegetation coverage	
	worker (ind./trap)	mound (ind./cell)	worker (ind./trap)	mound (ind./cell)	worker (ind./trap)	mound (ind./cell)
05-2008	49.7±10.2	8.0±1.7	87.8±16.8	8.7±0.7	54.5±11.9	10.3±1.3
06-2008	110.1±25.3	17.0±1.5	119.9±23.9	17.3±1.9	74.0±24.2	17.0±0.6
07-2008	252.4±25.8	19.0±1.5	274.5±33.3	14.7±0.7	289.8±32.7	8.7±0.9
08-2008	182.6±25.8	20.3±2.2	169.2±14.3	11.0±1.5	201.3±36.0	9.3±0.9
09-2008	167.8±22.6	16.3±0.7	103.1±23.0	11.0±1.2	147.0±45.4	8.0±1.0
10-2008	378.2±27.4	15.3±1.2	219.8±48.1	16.1±1.8	361.0±32.4	13.0±0.4

Effect of S. invicta on banana lacebug S. typica populatione

Population of *S. typica* in experimental plots was significantly lower than that in control plots from May to October (Table 3, F = 257.29, df = 8, P < 0.0001), and reduction rate varied from 20.8% to 67.9%. Reduction of *S. typica* population in the higher weed coverage plots was significantly lower than that in either moderate or lower weed coverage plots, and there are no significant difference in reduction of *S. typica* population between moderate and low weed coverage plots from May to October (F = 257.29, df = 8, P < 0.0001). The population of *S. typica* reduced significantly in May and September in high weed coverage plots. In July, population reduction rate of *S. typica* in moderate and low weed coverage plots reached the peak with 50.9% and 67.9%, respectively.

Table 2. Effects of *S. invicta* invasion on population of banana skipper *E. torus*.

Date (mm-yy)	Banana skipper density (ind./trunk)				Reduction of banana skipper (%)		
	Control area	High vegetation coverage	Moderate vegetation coverage	Low vegetation coverage	High vegetation coverage	Moderate vegetation coverage	Low vegetation coverage
05-2008	8.6±1.3a	6.2±0.8b	6.9±1.2ab	7.1±1.4b	27.9	19.8	20.9
06-2008	11.9±0.4a	6.8±0.5c	10.3±0.4b	9.9±0.5b	42.9	13.4	16.8
07-2008	16.1±1.0a	7.5±0.4c	6.6±0.5c	10.7±0.6b	53.4	59.0	33.5
08-2008	3.7±0.3ab	2.9±0.2b	1.8±0.2c	3.9±0.3a	21.6	51.4	-5.4
09-2008	3.4±0.2a	1.9±0.1c	1.6±0.2c	2.6±0.2b	44.1	52.9	23.5
10-2008	3.1±0.1a	1.7±0.2c	1.5±0.2c	2.3±0.1b	45.2	51.6	25.8
Average					39.2± 5.3	41.4± 8.7	19.2±5.4

Note: Same letters indicated there is no significant difference in the same line (P<0.05).

Table 3. Effects of *S. invicta* invasion on the population of banana lacebug *S. typica*.

Date (mm-yy)	Banana lacebug (ind./trunk)				Reduction of banana lacebug (%)		
	Control area	High vegetation coverage	Moderate vegetation coverage	Low vegetation coverage	High vegetation coverage	Moderate vegetation coverage	Low vegetation coverage
05-2008	79.0±5.3a	62.6±3.1b	62.5±3.4b	57.0±4.5b	20.8	20.9	27.8
06-2008	43.2±3.6a	36.6±3.2a	22.7±2.4b	20.7±2.2b	15.3	47.5	52.1
07-2008	5.3±0.4a	3.8±0.5b	2.6±0.3bc	1.7±0.3c	28.3	50.9	67.9
08-2008	5.7±0.6a	5.4±0.8a	2.9±0.4b	4.5±0.5ab	5.3	49.1	21.1
09-2008	15.5±1.6a	8.0±1.3b	8.1±1.0b	9.8±1.0b	48.4	47.7	36.8
10-2008	14.6±1.3a	16.3±0.9a	8.6±0.8b	10.3±1.1b	-11.6	41.1	29.3
Average					17.8±8.3	43.0±4.6	39.2±7.2

Note: Same letters indicated there is no significant difference in the same line (P<0.05).

Discussion

Ants are important predators in agroecosystems (Risch & Carroll, 1982; Way & Khoo, 1992) and have been used in pest management (Huang & Yang, 1987; Olotu et al., 2013), including the combination of ants in banana pest management programs banana (Sirjusingh et al., 1992; Gold et al., 2001). Our study provides evidence that *S. invicta* also can be an important biological control agent in banana plantation. 19.2% – 41.4% of *E. torus* population and 17.8%-43.0% of *S. typical* population decreased when *S. invicta* appeared in three types of weed coverage banana plantations. Our results are consistent with previous studies indicating that *S. invicta* are particularly effective predators in agroecosystems (Ali et al., 1984; Bessin & Reagan, 1989; Eubanks, 2001; Harvey & Eubanks, 2004). Our investigation also gives support to the suggestion that *S. invicta* can play beneficial role in pests control although it was considered a serious pest in human health and crops (Vinson, 1997).

It showed the efficacy of *S. invicta* as biological control agent on *E. torus* was greater in the more complex habitat, it consistent with Harvey and Eubanks (2004)'s study. Harvey and Eubanks (2004) speculated that complex habitat resulted simpler plant architecture which can increase predator efficiency. It may be the same result to explain our result. However, controlling efficacy of *S. invicta* on *S. typical* is negative with the habitat complex. *S. typical* adults have wings and can fly, and nymphs are more actives than *E. torus* larvae and pupae. Complex habitant provides more hidden places for *S. typical* when they are attacked by *S. invicta*. Our results suggested that efficacy of *S. invicta* as a biological control agent was related to not only complexity degree of habitat, but also target pests.

Our results partially that *S. invicta* can be important and effective biological control agents. Although this study found that increasing habitat complexity only enhanced the efficacy of *S. invicta* on some target pests, intercropping may give more shelters to native species and reduce the negative effects of *S. invicta* on arthropod community. Future work should focus on the impact of *S. invicta* on banana plantation ecosystem and production since more data are needed to fully understand the ecological effects of the fire ant invasion, and the action of an effective biological control agent must result in decreased crop damage and increased yield (Symondson et al., 2002).

References

Ali, A.D., Reagan, T.E. & Flynn, J.L. (1984). Influence of selected weedy and weed-free sugarcane habitants on diet composition and foraging activity of the imported fire ant (Hymenoptera: Formicidae). Environmental Entomology, 13: 1037-1041.

Bessin, R.T. & Reagan, T.E. (1989). Cultivar resistance and arthropod predation of sugarcane borer (Lepidoptera: Pyralidae) affects incidence of deadhearts in Louisiana sugarcane. Journal of Economic Entomology, 86: 929-932.

Chen, L., Chen, Z., Chen, Z., Wang, C., Lu, H., Lu, R. & Zhou, J. (2008). The interplanting technology of banana and mushroom. Edible Fungi, 30: 13-15.

Cook, J. (2003). Conservation of biodiversity in an area impacted by the red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae). Biodiversity and Conservation, 12: 187-195.

Eubanks, M.D. (2001). Estimates of the direct and indirect effects of red imported fire ants on biological control in field crops. Biological Control, 21: 35-43.

Fillman, D.A. & Sterling, W.L. (1983). Killing power of the red imported fire ant [Hym.: Formicidae]: a key predator of the boll weevil [Col.: Curculionidae]. Biocontrol, 28: 339-344.

Gold, C.S., Pena, J.E. & Karamura, E.B., (2001). Biology and integrated pest management for the banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae). Integrated Pest Management Reviews, 6: 79-155.

Guo, Z., Zeng, L., Fan, H., Yang, P., Tang, Z., Shi, Z., Bai, J., Guo, B. & Duan C. (2012). Investigation on the species of banana insect pest and their damages in Yunan Province.

Chinese Journal of Tropical Agriculture, 32: 42-45.

Harvey C.T. & Eubanks, M.D. (2004). Effect of habitant complexity on biological control by the red imported fire ant (Hymenoptera: Formicidae) in collards. Biological Control, 29: 348-358.

Huang, H. & Yang, P. (1987). The ancient cultured citrus ant. BioScience, 37: 665-671.

Ke, K., Li, R., Lin, W., Zeng, W., Xie, S., Zhou, J., Liang, J. & Ye, C. (2012). Benefit evaluation of banana and pepper interplanting model. China Tropical Agriculture, 3: 50-52.

Lin, M., Liu, F., Peng, Z., Li, W., Xu, W. & Wang, X. (2009). Survey and identification of pest insects on banana crop in Hainan. Southwest China Journal of Agricultural Sciences, 22: 1619-1622.

Liu, Y., Ding, W., Ca, Q., Liu, X., Li, W., Liang, Y. & Li, H. (2015). Effects of *Allium tuberosum* interplanting and bio-organic fertilizer application on banana wilt disease and soil microorganisms. Journal of Agro-Environment Science, 34: 303-309.

Lu, Y.Y., Wang, L., Xu, Y., Zeng, L. & Li, N. (2012). Correlation of the nest density and the number of workers in bait traps for fire ants (*Solenopsis invicta*) in southern China. Sociobiology, 59: 1197-1204.

Lu, Y.Y., Zeng, L. & Liang, G. (2002). Advances in integrated management of major pests of banana in China. Wuyi Science Journal, 18: 276-279.

McDaniel, S.G., Sterling, W.L. & Dean, D.A. (1981). Predators of tobacco budworm larvae in Texas cotton. Southwestern Entomologist, 6: 102-108.

Morrison, L.W. (2002). Long-term impacts of an arthropod-community invasion by the imported fire ant, *Solenopsis invicta*. Ecology, 83: 2337-2345.

Olotu, M.I., Du Plessis, H., Seguni, Z.S. & Maniania, N.K., (2013). Efficacy of the African weaver ant *Oecophylla longinoda* (Hymenoptera: Formicidae) in the control of *Helopeltis* spp. (Hemiptera: Miridae) and *Pseudotheraptus wayi* (Hemiptera: Coreidae) in cashew crop in Tanzania. Pest Management Science, 69: 911-918.

Risch, S.J. & Carroll, C.R. (1982). The ecological role of ants in two Mexican agroecosystems. Oecologia, 55: 114-119.

Sirjusingh, C., Kermarrec, A., Mauleon, H., Lavis, C. and Etienne, J., (1992). Biological control of weevils and whitegrubs on bananas and sugarcane in the Caribbean. Florida Entomologist, 75: 548-562.

Stiles, J.H. & Jones, R.H. (2001). Top down control by the red mi ported fire ant (*Solenopsis invicta*). American Mid land Naturalist, 146: 171-185.

Symondson, W.O.C., Sunderland K.D. & Greenstone, M.H. (2002). Can generalist predators be effective biocontrol agents? Annual Review of Entomology, 47: 561-594.

Vinson, S.B. (1997). Insect life: invasion of the red imported fire ant (Hymenoptera: Formicidae). American Entomologist, 43: 23-39.

Vogt, J.T., Grantham, R.A., Smith, W.A. & Arnold, D.C. (2001). Prey of the red imported fire ant (Hymenoptera: Formicidae) in Oklahoma peanuts. Environmental Entomology, 30: 123-128.

Wang, F.X., Wang, L., Li, X.N., Zeng, L., Lu, Y.Y., Wu, S.H. & Zhu, J.Q. (2009). National standard: Guidelines for quarantine surveillance of *Solenopsis invicta* Buren. Beijing: Standards Press of China.

Way, M.J. & Khoo, K.C. (1992). Role of ants in pest management. Annual Review of Entomology, 37: 479-503.

Wojcik, D.P., Allen, C.R., Brenner, R.J., Forys, E.A., Jouvenaz, D.P. & Lutz, R.S. (2001). Red imported fire ants: impact on biodiversity. American Entomologist, 47: 16-23.

Zeng, L., Lu, Y.Y., He, X.F., Zhang, W.Q. & Liang, G.W. (2005). Identification of red imported fire ant *Solenopsis invicta* to invade mainland China and infestation in Wuchuan, Guangdong. Chinese Bulletin of Entomology, 42: 144-148.

Zhou, S., Chen, Z., Zhang, Q., Kong, X., Zhong, Y., Lai, B., Chen, S. & Wei M. (1993). The study on the transmission of banana rosette dwarf disease by *Stephanitis typicus* Distant. Journal of Chinese Electron Microscopy Society, 3: 238-241.