Correlation of the Nest Density and the Number of Workers in Bait Traps for Fire Ants (*Solenopsis invicta*) in Southern China

by

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ABSTRACT

The relationship between *Solenopsis invicta* nest density and the number of fire ant workers in bait traps and percentages of traps capturing ants were investigated in the waste land of Wuchuan, Guangdong, South China. The results showed that fire ant nest density is positively correlated with the number of workers captured in traps, and could be described by N=60.53LnD +348.0D+421.1. The workers exceeded 200 and 300 in bait traps while the density of fire ant nests was over 0.023 and 0.084 ind./m^2, respectively. The percentages of traps capturing ants were also positively correlated with fire ant nest density and fit by $Pe=1/(1+e^{0.9694-309.85D})$. When the nest density was over 0.018 ind./m^2, over 99% of traps captured fire ant workers. $N=8.8796e^{0.0346Pe}$ was the fitting line for worker amount and trap percentage. The workers per trap were about 50, 100, and 200 when the trap percentages were 50%, 70% and 90%, respectively.

Key words: fire ants, *Solenopsis invicta*, nest density, bait traps

INTRODUCTION

The red imported fire ant, *Solenopsis invicta*, is a serious economic pest. Since its introduction into the U.S., the ant has infested most of the southern states (Williams *et al.* 2003). To date, *Solenopsis invicta* is also seen in Australia, New Zealand, mainland China and Taiwan (McCubbin & Weiner 2002, Pascoe 2002, Zeng *et al.* 2005). Red imported fire ants can cause many problems to

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human health, agriculture and native animals. It can cause 12.2-26.1% potato loss, and numbers of the fire ants are negatively correlated with potato and soybean seed yields (Adams *et al.* 1988, Apperson & Powell 1983). The red imported fire ant can also feed on flowers and developing fruits of citrus, and destroy young citrus trees (Banks *et al.* 1991). Because of its painful and allergenic stings, fire ants are a serious health threat to some people. High density of fire ant populations may make lawns lose their value (Lofgren *et al.* 1975). However, sometimes the fire ant is also considered as a beneficial insect in many crops. Fire ants can prey on boll weevils in cotton (Sterling 1978), and citrus leafminers in citrus trees (Zappalà *et al.* 2007).

Although pesticides may harm nontarget animals, chemicals are effective control methods reducing the population of fire ants. Chemicals are formulation as drenches and baits (Kemp *et al.* 2000), and baiting is an effective control measure for fire ants (Lofgren & Weidhass 1972). Before bait application, the amount and density of fire ant nests and workers must be surveyed and obtained accurately. This work takes much time and manpower, especially in large areas with high fire ant density. Oi *et al.* (2004) utilized a GIS system to map the bait stations in fish farms, and the map can indicate the locations of fire ant nests. That method can save 43% of time compared to walking surveys. The objective of our study is to reveal the relationships among nest density, the amount of worker ants captured by bait trap, and the percentage of bait traps capturing ants. A calculation method is then designed to calculate the percentage of bait traps capturing ants to estimate the density of fire ant nests and workers in the surveyed area. This will allow more efficient surveying of fire ants.

MATERIALS AND METHODS

Study sites and sampling

We conducted this study during April and June, 2005 in Wuchuan, Guangdong, China. The habitat surveyed was wasteland. We chose five sites for the experiment, where densities of fire ant mound were different covering in total 2.4 hm^2. The experimental sites were divided into 16 blocks with one block of about 1500 m^2. Nest densities were recorded by visual observation. No. of fire ant workers were sampled by using bait traps. The sampling method is similar to Huang *et al.* (2011). At each block, 25ml plastic vials containing a 5 mm thick piece of sausage was placed on the ground surface for 30 min. The number of bait traps depended on the area of site. More than 15 bait traps were put in each block. The ants captured in traps were dipped into soapy water and counted later. The amount of traps which did not trap any ants was recorded. At the same time, the number of *Solenopsis invicta* active nests was counted in each block. Inspections were performed twice each month, and five times in total.

Statistical analysis

Nest density was calculated through the nest number divided by the acreage of one block. No. of fire ant workers per bait trap was the mean of the workers captured by all traps in each block. Percentage of bait traps capturing fire ants in each block was presented by the ratio of the trap numbers with and without fire ants. All statistical analyses were conducted using SPSS, version 14.0 (SPSS Inc., Chicago, IL, USA).

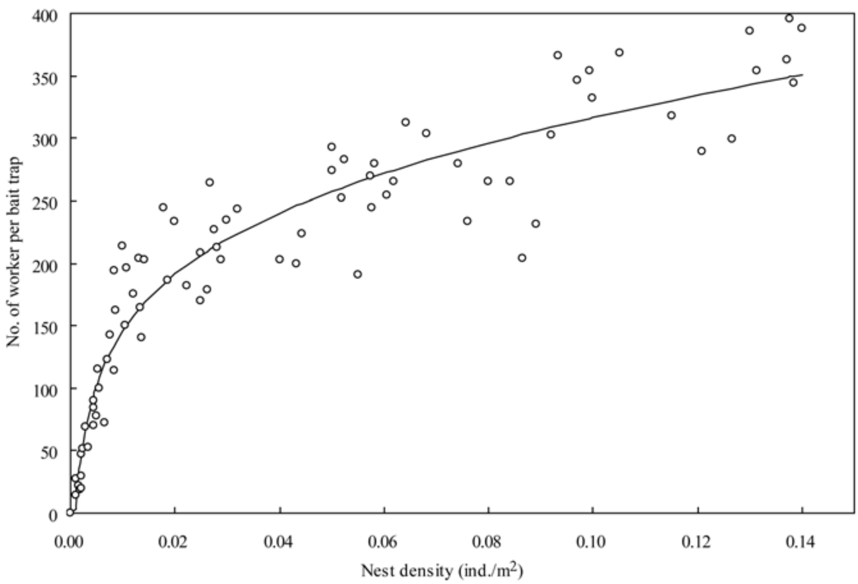

Fig. 1. Correlation of nest density with number of worker captured by bait traps. N=60.5257LnD +348.0473D+421.1183, R=0.9454, n=80, df=79, F=319.8, P<0.01. N means no. of workers captured by bait traps, and D means nest density in this function

Table 1. Nest density, worker amount per bait trap, and percentage of bait traps capturing workers at wasteland, southern China.

Nest density ind./m^2 D	No. of workers per bait trap N	Percent of baits capturing workers Pe	Nest density ind./m^2 D	No. of workers per bait trap N	Percent of baits capturing workers Pe
0	0	0	0.02800	212.7	100
0.00099	13.8	15.0	0.02889	202.5	94.4
0.00105	27.0	21.1	0.03000	234.5	100
0.00167	21.4	33.3	0.03188	243.2	93.8
0.00182	18.3	31.3	0.04000	202.4	100
0.00200	20.1	50.0	0.04333	199.5	100
0.00214	29.5	57.1	0.04420	223.2	94.4
0.00222	47.2	40.7	0.05000	292.5	91.7
0.00227	51.7	45.5	0.05000	274.4	100
0.00286	68.9	61.9	0.05195	252.3	93.3
0.00333	52.9	73.3	0.05250	282.8	100
0.00441	90.2	84.6	0.05500	190.8	91.7
0.00446	84.7	65.0	0.05733	269.5	100
0.00452	70.2	66.7	0.05778	244.3	92.3
0.00500	78.3	81.3	0.05810	279.3	100
0.00519	115.2	53.8	0.06063	254.1	100
0.00556	100.1	71.4	0.06200	265.3	100
0.00667	72.3	57.1	0.06417	312.4	91.7
0.00706	122.3	76.5	0.06815	303.4	92.3
0.00752	142.4	84.6	0.07417	279.3	100.0
0.00830	113.5	76.9	0.07600	233.3	100
0.00833	194.4	58.3	0.08000	265.6	100
0.00859	162.3	75.0	0.08417	265.5	91.7
0.01000	214.2	84.6	0.08667	204.3	100.0
0.01048	150.5	90.5	0.08917	231.5	91.7
0.01064	195.8	94.4	0.09200	302.1	100
0.01200	175.3	90.9	0.09333	365.8	100
0.01311	203.6	100	0.09714	346.7	100
0.01350	164.1	93.8	0.09926	354.4	84.6
0.01364	140.5	86.7	0.10000	332.0	100
0.01417	203.2	100	0.10519	367.8	92.3
0.01773	244.6	95.0	0.11500	318.4	91.7
0.01852	186.3	80.0	0.12100	289.2	100
0.02000	233.2	100	0.12667	299.6	100
0.02229	182.2	93.8	0.13000	386.3	91.7
0.02500	208.3	84.6	0.13143	353.6	100
0.02500	169.5	100	0.13704	362.3	92.3
0.02620	178.4	94.4	0.13778	395.6	100
0.02679	264.6	100	0.13833	344.2	100
0.02750	226.9	91.7	0.14000	388.4	100

RESULTS

80 groups of data were obtained over 3 months and listed in Table 1. Fire ant nest density is presented from low to high.

Fig.1 shows that the interdependence of density of *Solenopsis invicta* nests and mean number of ants in traps. The best fit line, a natural logarithm function, N=60.53LnD +348.1D+421.1(R=0.9454, N=80, df=79, F=319.8, P<0.01), predicted the amount of workers were captured in traps as the fire ant nest density increased. The relationship suggested that growth speed of amount of ants was the fastest when the nest density varied from 0 to 0.005 ind./m^2, and ant amount was over 100 ind. per trap. The growth rate decreased fewer than 2% when density of nests was over 0.017 ind./m^2. A bait trap can capture more than 200 and 300 workers on average when the nest densities were over 0.023 and 0.084 ind./m^2, respectively.

Fig. 2 shows that the higher percentages of bait traps capturing ants were associated with higher fire ant nest density. More than 50% of the traps of the captured ants occurred in mounds with a density of 0.0032 mounds/m^2. The growth percentage of the trap capturing ants was very fast. When the

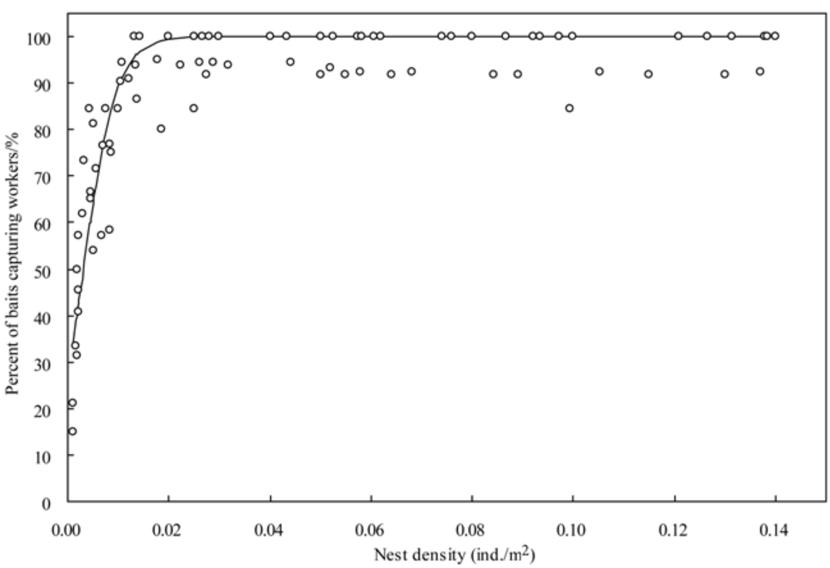

Fig. 2. Correlation of nest density with baits capturing workers. Pe=1/(1+exp(0.9694-309.85D)), R=0.9124, n=80, df=79, F=387.5, P<0.01. Pe means percent of baits capturing workers, and D means nest density in this function.

density was over 0.018 nest/m^2, the lowest percent of traps capturing ants was nearly 90%. In other words, nearly all traps can capture fire ants. And the best fit line was $Pe=1/(1+\exp(0.9694-309.85D))$ ($R=0.9124$, $N=80$, $df=79$, $F=387.5$, $P<0.01$).

The dynamics of worker number captured by bait trap with percent of baits capturing workers varied (Fig.3). The function, $N=8.8796e^{0.0346Pe}$ ($R=0.8974$, $n=80$, $df=79$, $F=137.8$, $P<0.01$) could describe the relationship between the two variables. First, the number of worker ants per trap increased gradually with trap percent progressing under 50% by which they increased sharply with trap percent over 70~80%. The worker amounts were about 50, 100, and 200 ants per trap when the trap percent were 50%, 70% and 90%, respectively.

DISCUSSION

The results indicate a correlation between the density of fire ant nests, amount of foraging workers per trap, and percentage of bait traps capturing ants. We can estimate the amount of fire ant nests, and workers in surveyed area by bait trap sampling according to the functions described. The results

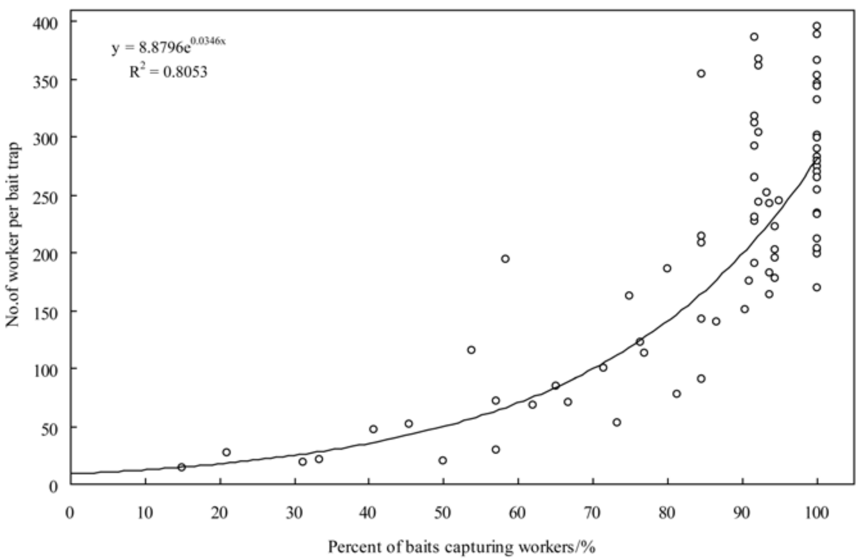

Fig. 3 Correlation of worker number captured by bait trap with baits capturing workers. $N=8.8796e^{0.0346Pe}$, $R=0.8974$, $n=80$, $df=79$, $F=137.8$, $P<0.01$. N means no. of workers captured by bait traps, and Pe means percent of baits capturing workers in this function.

can be not only be used in monitoring fire ants, but also in controlling them. Estimating fire ant density can guide how much pesticide bait should be used, and promote the efficiency of pesticide utilization.

Bait trap sampling is an important method in ant sampling (Briano *et al.* 2002), and it can be utilized to determine whether an area contains active fire ant mounds (Oi *et al.* 2004). Currently, pesticide bait is still an effective control method for fire ants (Williams *et al.* 2001), especially in countries and regions newly invaded by fire ants. Before baits are spread, the population of fire ants must be surveyed and located. The time required to perform a walking survey to marked nests was 2.8 person-h (Oi *et al.* 2004). In comparison, the bait trap sampling method only required 1 person-h. Significant time can be saved by using the bait trap sampling method when controlling a large fire ant population. This method is faster than that decribed by Oi *et al* (2004).

In sampling, advanced technologies are needed. Bao *et al.* (2011) designed a new hotdog-baited trap (B-trap) to detect red imported fire ants under field conditions in Taiwan and demonstrated the B-trap was more efficientthan other methods. There needs to be a simple index to assess the occurrence and severity of fire ants, especially for pest management enterprises. Adams *et al.* (1986) reported that the economically significant threshold of fire ants is 80 fire ant workers per trap in average. In our investigation, about 50% and 100% of traps could capture ants when the mean density exceeded 0.0032, and 0.02 ind. per m^2, respectively. This observation suggests that the percentage and density are key data in evaluating whether fire ants are widespread or severe. Our research could aid development of a standard in classifying hazard rating of *Solenopsis invicta*.

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REFERENCES

Adams, C.T., W.A. Banks & C.S. Lofgren. 1988. Red imported fire ant (Hymenoptera: Formicidae): correlation of ant density with damage to two cultivars of potatoes (*Solanum tuberosum* L.). J. Eco. Ent. 81(3):905-909.

Apperson, C.S., E.E. Powell.1983. Correlation of the red imported fire ant (Hymenoptera: Formicidae) with reduced soybean yields in North Carolina. J. Eco. Ent. 76(2):259-263.

Banks, W.A., C.T. Adams & C.S. Lofgren. 1991. Damage to young citrus trees by the red imported fire ant (Hymenoptera: Formicidae). J. Eco. Ent. 84(1):241-246.

Briano, J.A., D.F. Williams, D.H. Oi & L.R. Davis Jr. 2002. Field host range of the fire ant pathogens *Thelohania solenopsae* (Microsporida: Thelohaniidae) and *Vairimorpha invictae* (Microsporida: Burenellidae) in South America. Bio. Control. 24(2002):98-102.

Huang, J., Y.J. Xu, Y.Y. Lu & G.W. Liang. 2011. Changes to the spatial distribution of *Ageratum conyzoides* (Asterales:Asteraceae) due to red imported fire ant *Solenopsis invicta* (Hymenoptera: Formicidae) in China. J. Insect Behav. 24(4):307-316.

Kemp, S.F., R.D. deShazo, J.E. Moffitt, D.F. Williams & W.A. Buhner 2nd. 2000. Expanding habitat of the imported fire ant (*Solenopsis invicta*): a public health concern. J. Allergy Clin. Immunol. 105(4):683-91.

Lofgren, C.S., W.A. Banks & B.M. Glancey. 1975. Biology and control of imported fire ants. Ann. Re. Ent. 20:1-30.

Lofgren, C.S., D.E. Weidhaas. 1972. On the eradication of imported fire ant: a theoretical appraisal. Bul. Ent. Soc. Am. 18:17-20.

McCubbin, K.I., J.M. Weiner. 2002. Fire ant in Australia: a new medical and ecological hazard. Med. J. Aust. 176(11):518-519.

Oi, D.H., C.A. Watson & D.F. Williams. 2004. Monitoring and management of red imported fire ants in a tropical fish farm. Flo. Ent. 87(4):522-527.

Pascoe, A. 2002. Strategies for managing incursions of exotic animals to New Zealand. Micronesia. 6:129-135.

Sterling, W.L. 1978. Fortuitous biological suppression of the boll weevil by the red imported fire ant. Env. Ent. 7:564-568.

Williams, D.F., D.H. Oi, S.D. Porter, R.M. Pereira & J.A. Briano. 2003. Biological control of imported fire ants (Hymenoptera: Formicidae). Am. Ent. 49(3):150-163.

Williams, D.F., H.L. Collins & D.H. Oi. 2001. The red imported fire ant (Hymenoptera: Formicidae): an historical perspective of treatment programs and the development of chemical baits for control. Am. Entomol. 46:146-159.

Zappalà , L., M.A. Hoy & R.D. Cave. 2007. Interactions between the red imported fire ant, the citrus leafminer, and its parasitoid *Ageniaspis citricola* (Hymenoptera: Encyrtidae): laboratory and field evaluations. Biocontrol Sci. Techn. 17: 353-363.

Zeng, L., Y.Y. Lu, X.F. He, W.Q. Zhang & G.W. Liang. 2005. Identification of red imported fire ant *Solenopsis invicta* to invade mainland China and infestation in Wuchuan, Guangdong. Chin. Bul. Ent. 42(2):144-148.

Bao, S.Z., L. Kafle & C.J. Shih. 2011. A new baited trap for monitoring Solenopsis invicta (Formicidae: Hymenoptera) in Taiwan. Appl. Entomol. Zool. 46:165-169.