Effects of Honeydew-Producing Hemipteran Denial on Local Argentine Ant Distribution and Boric Acid Bait Performance

R. J. BRIGHTWELL AND J. SILVERMAN[1]

Department of Entomology, North Carolina State University, Raleigh, NC 27695

J. Econ. Entomol. 102(3): 1170–1174 (2009)

ABSTRACT The Argentine ant is well known for its affinity for honeydew and is often associated with hemipteran outbreaks in agricultural and urban environments. It has been suggested that Argentine ants may be controlled by restricting access to honeydew, thereby forcing the ants to move or by encouraging increased liquid toxicant intake. We tested this possible control strategy by restricting Argentine ant access to the honeydew-producing terrapin scale within the canopy of red maple trees and monitoring ant numbers with pitfall traps and nest counts in the mulch around the tree base. Argentine ant nest numbers fell dramatically in the mulch around ant-excluded trees; however, there was no reduction in Argentine ant numbers caught in pitfalls around trees with or without canopy access. We added 0.5% boric acid bait stations at the base of the red maples and monitored bait consumption. Pitfall and nest counts were not affected by the addition of boric acid, although bait consumption was lower around ant-excluded trees, suggesting that restricting access to honeydew-producing Hemiptera did not enhance bait performance. We attribute this result to the increased distance Argentine ant workers had to trail from nest to bait station when not tending nearby terrapin scale. We suggest an alternative management strategy concentrating direct insecticidal control of Argentine ants around a few host plants infested with honeydew-producing Hemiptera by controlling Hemiptera in nearby host plants.

KEY WORDS *Linepithema humile*, *Mesolecanium fasciatum*, foraging activity, pest management

The Argentine ant, *Linepithema humile* (Mayr), is a significant worldwide urban and agricultural pest (Silverman and Brightwell 2008). One feature of Argentine ant biology, in common with many invasive ant species, is their predilection for the honeydew produced by phloem-feeding Hemiptera (Holway et al. 2002). It is thought that honeydew is the fuel that allows some ant species to achieve and maintain extraordinary densities (Davidson et al. 2003). Honeydew is an important source of carbohydrate for the Argentine ant (Flanders 1951, Holway et al. 2002, Ness and Bronstein 2004). It has been suggested that controlling honeydew-producing Hemiptera may indirectly reduce Argentine ant infestations (Rust et al. 2003).

Although Rust et al. (2003) saw some reductions in Argentine ant foragers after treating hemipterans with systemic insecticides, this treatment provided poor Argentine ant control. One problem the authors considered was that the Argentine ant foragers counted at their monitoring stations had traveled from nests located at a distance. Argentine ant workers may forage up to 60 m (Vega and Rust 2003), and therefore, any effects on local Argentine ant numbers may have been masked by individuals from distant nests. Another possible problem involved measuring Argentine ant foraging activity through the removal of sugar water from monitoring stations (described in Reierson et al. 1998). Argentine ants are polydomous and may shift nests toward food sources (Newell and Barber 1913, Holway and Case 2000, Silverman and Nsimba 2000). The addition of monitoring stations containing sugar water may have had the effect of substituting one carbohydrate resource for another. The Argentine ant foragers and nests that may have moved away after collapse of the honeydew producing Hemiptera may have been attracted back into the treatment area by the monitoring stations. The Argentine ant prefers sugary liquids over other food types (Newell and Barber 1913, Baker et al. 1985). A bait that mimics honeydew seems to be the most acceptable to the Argentine ant worker (Silverman and Roulston 2001). This raises the possibility that pest ants, such as the Argentine ant, may be encouraged to consume more aqueous carbohydrate based toxicant if the foraging workers are excluded from alternate or competing sources of carbohydrate, such as honeydew (Silverman and Brightwell 2008).

A commercial park in Raleigh, NC, has a large infestation of Argentine ants with workers commonly seen foraging up into the canopy of many trees and bushes planted within the park. Red maple trees, *Acer rubrum,* infested with the native terrapin scale, *Me-*

[1] Corresponding author, e-mail: jules_silverman@ncsu.edu.

solecanium nigrofasciatum (Pergande), are common within the Argentine ant–infested areas of the park (R.J.B., personal observation). The terrapin scale has a univoltine life history and is known to produce copious amounts of honeydew (Simanton 1916). Restricting the access of Argentine ant foragers to terrapin scale resulted in a population collapse of the Coccid within the park (unpublished data). Herein we report on the effect that limiting access to terrapin scale populations has on the local abundance of Argentine ant populations. We also report on the consumption and efficacy of aqueous boric acid bait when Argentine ant workers were denied access to the red maple canopy.

Materials and Methods

Effect of Excluding Ants From Scales on Ant Numbers. Mature red maple trees are used extensively in ornamental plantings within the park. Rows of trees (four of more trees per row) were selected for experiments that were separated by at least 39 m to limit worker movement between rows (Vega and Rust 2003). The trees within each row were spaced ≈7 m apart. In 2006, eight rows of red maple trees were selected for an Argentine ant exclusion experiment. Six of the rows contained five trees, and two rows contained four trees. Four rows each were assigned to the exclusion and control treatments, 19 trees being used for each treatment. The exclusion treatment consisted of a 80-mm-wide band of Tanglefoot (Tanglefoot Company, Grand Rapids, MI) applied directly to each tree trunk. Trees were inspected, and Tanglefoot was reapplied weekly until mid-November 2006, when applications were halted.

Argentine ant worker numbers were assessed with pitfall traps. Four PVC collars (31 mm ID by 120 mm) were dug into the mulch around each tree and orientated north, south, east, and west. The top of the collar was situated ≈40 mm under the mulch surface and ≈300 mm from the tree. These collars allowed the placement and removal of the pitfall traps with minimum disturbance to the pine straw mulch. The pitfalls were a 50-ml centrifuge tube (Evergreen Scientific, Los Angeles, CA) containing 30 ml of a 99:1 ethanol: glycol mixture. Pitfall traps were deployed 3 August (13 d before the exclusion treatment was applied) and again 17, 44, and 74 d after the application of Tanglefoot. The 2006 pitfall data were analyzed with PROC MIXED repeated measures analysis of variance (ANOVA) with exclusion treatment as the between-subject variable and time as the within-subject variable (SAS). Data were log transformed to stabilize variances.

Insecticidal Bait Efficacy. In 2007, we added a row of trees to both the exclusion and control treatments that were used in our 2006 experiment. In addition, we provided ants with 0.5% boric acid bait (in 25% sugar water) 36 d after Tanglefoot application. All trees within a treatment row were banded with Tanglefoot as described above until mid-November 2007 when the experiment ended. Four pitfalls were arranged as described previously but only around those trees at the end of each row. This arrangement ensured that the distance between the end trees was at least 40 m for every row. As with 2006, all trees within an exclusion treatment row were banded. Pitfall samples were started 2 August (5 d before Tanglefoot banding) and repeated every 2 wk. Each week we also counted Argentine ant nests in the mulch around the experimental trees. The mulch layer was carefully peeled back by hand, and nests (defined as a concentration of brood) were counted. We found that ants remained in the inspected area with this procedure, similar to Silverman et al. (2006).

Increased bait efficacy with Tanglefoot banding was considered effective if we observed a decrease in pitfall counts of Argentine ants and numbers of Argentine ant nests in the mulch surrounding the tree. Boric acid bait stations were added to one of the end trees in each row (five exclusion + bait and five control + bait replicates), placed into the mulch ≈300 mm from the trunk and offset 45° from being in line with other trees in its row. Two PVC collars, described above, were sunk into the mulch with the top 10 mm protruding above the mulch around the trees at the ends of each row. One end of each row was randomly assigned to receive a boric acid bait station with the other left unbaited. The bait stations were 50-ml centrifuge tubes filled with 40 ml of 0.5% boric acid (Klotz et al. 1998). The lid had a 3 mm hole through its center and a scintillation vial lid floating on the boric acid solution to prevent the mass drowning of Argentine ants in the bait solution. A control bait station with fine mesh glued over the hole in the cap served as a water evaporation control and was paired with each treatment bait station. Bait stations were changed every 1–2 d until the trial was completed. Bait consumption was determined by the difference in bait volume after placement in the field, adjusted for any water evaporation.

There were three rows that had trees banded in both 2006 and 2007 and two rows that had been banded in 2007 only. This allowed us to examine pitfall results for trees banded for 1 versus 2 years well as any interaction between banding length of time and boric acid bait. These data along with 2007 pitfall data and nest count data and were tested using PROC MIXED repeated-measures ANOVA with exclusion treatment and bait station presence as the between-subject variables and time as the within-subject variable. The boric acid consumption data were analyzed with PROC MIXED repeated-measures ANOVA with exclusion treatment as the between-subject variable and time as the within-subject variable (SAS). Data for pitfall counts and bait volume consumption were log transformed to stabilize variances, whereas nest count data were square root transformed for the same purpose.

Results and Discussion

In this study, we investigated the effect of honeydew denial on the foraging of nearby Argentine ants. We found no difference in pitfall capture rates of Argentine ants around exclusion and control trees in 2006 ($F_{1,10.8} = 3.30$, $P = 0.0970$) or in 2007 ($F_{1,8.16} = 2.41$, $P = 0.1582$). Furthermore, there was no differ-

Table 1. Repeated-measures ANOVA table for mean Argentine ant nest numbers in Tanglefoot banding and 0.5% boric acid bait trials

Effect	df	F	P
Banding	1,31.7	122.66	<0.0001
Bait	1,31.7	0.32	0.5728
Week	10,122	7.62	<0.0001
Banding × bait	1,31.7	2.44	0.1279
Banded × week	10,122	7.64	<0.0001
Bait × week	10,122	0.57	0.8343
Banded × bait × period	10,122	1.04	0.4125

Period has three variables: (1) pre-Tanglefoot banding; (2) post-Tanglefoot banding but pre-boric acid bait introduction; and (3) post-Tanglefoot banding and boric acid bait consumption.

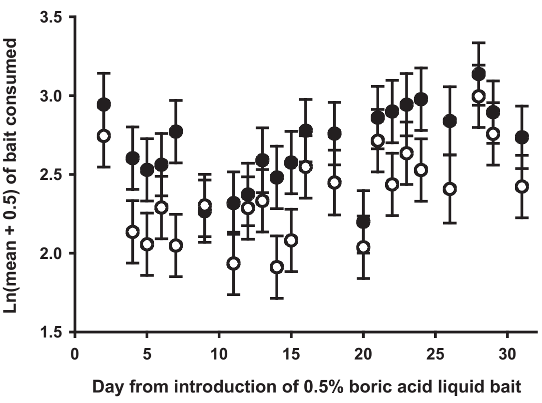

Fig. 2. Mean (± S.E.) milliliters of 0.5% boric acid solution removed from bait stations located in the pine needle mulch around red maple trees in 2007. (●), bait stations around unbanded trees; (○), bait stations around Tanglefoot banded trees.

ence in the number of Argentine ants found in pitfalls around exclusion trees Tanglefoot banded for both years compared with those trees banded for 1 yr only ($F_{1,3.33}$ = 0.02, P = 0.8985). Alder and Silverman (2004) found that pitfall sampling produces large daily sampling variation compared with other methods such as worker counts at baits, and this large variation may have masked any reduction in the numbers of foraging Argentine ant workers. We did find evidence that denying access to honeydew-producing hemipterans alters local Argentine ant densities. Argentine ants shifted nearly all of their nests away from the exclusion treatment trees, presumably to suitable nesting sites in ornamental hedges and trees situated a few meters away (Table 1; Fig. 1). The Argentine ant is noted for its propensity to move nests close to food resources and away when that resource is depleted (Newell and Barber 1913, Holway and Case 2000, Silverman and Nsimba 2000). Honeydew is one carbohydrate resource that allows a dominant ant species, including invasive ant species, to maintain the large worker numbers required for community dominance (Davidson 1997, Holway et al. 2002, Davidson et al. 2003).

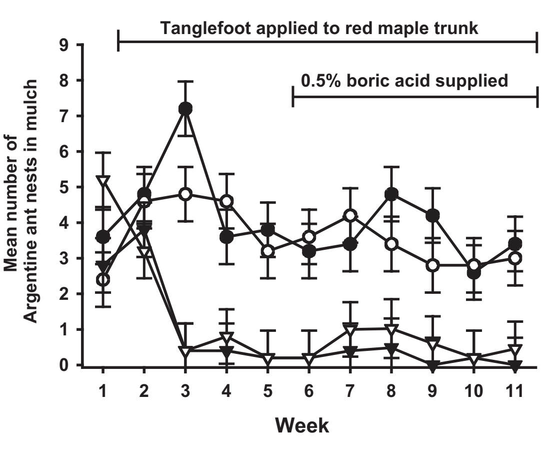

Fig. 1. Mean (± S.E.) numbers of Argentine ant nests located in the pine needle mulch around red maple trees in 2007. (●), unbanded trees without boric acid treatment; (○), unbanded trees with boric acid treatment; (▼), Tanglefoot banded trees without boric acid bait treatment; (▽), Tanglefoot banded trees with boric acid treatment. Boric acid bait treatment was begun 36 days after Tanglefoot banding applied.

Argentine ants rely on a mass recruitment foraging strategy, keeping a proportion of workers at the nest ready to be recruited to exploit newly discovered resources, thereby limiting the number of workers that may be committed to resource exploration (Roulston and Silverman 2002). Those Argentine ant nests situated at the base of the control trees seem to dedicate most of their workers to honeydew retrieval from the red maple canopy. These nests may not, therefore, commit many more foragers to searching the mulch at the base of these trees than Argentine ant nests situated further away. A large number of ornamental plantings were well within the Argentine ant foraging distance previously noted. Previous studies investigating the effect on Argentine ant foraging numbers after insecticidal treatment of honeydew-producing Hemiptera returned equivocal results (Rust et al. 2003). Given the proximity of surrounding nests, it is reasonable to expect that any decrease in foraging activity around exclusion trees would be modest at best.

The addition of 0.5% boric acid bait in 2007 had no effect on the numbers of Argentine ant workers caught in the pitfalls, regardless of whether the tree was Tanglefoot banded or not ($F_{1,8.15}$ = 0.72, P = 0.4193). Nor did the addition of the 0.5% boric acid bait have any effect on Argentine ant nest numbers (Table 1; Fig. 1). There was no interaction between years of Tanglefoot banding and the addition of boric acid ($F_{1,3.43}$ = 0.35; P = 0.5916). We did find that boric acid bait consumption was lower around exclusion treatment trees than around control trees ($F_{1,10.7}$ = 5.41; P = 0.0409; Fig. 2). We assume that this was because of fewer foragers at the bait station. Klotz et al. (1998) also reported a reduction in Argentine ants recruiting to boric acid bait stations compared with control stations filled with 25% sucrose water only. Low concentrations of boric acid are not repellent to a variety of ant species including *Camponotus floridanus, Monomorium pharaonis,* and *Tapinoma melanocephalum,* as well as the Argentine ant (Klotz and Moss 1996, Klotz et al. 1996) The Argentine ant nests at the base of the control trees were probably contributing the majority of foragers visiting the boric acid bait stations at these trees. In contrast, the Argentine ant workers visiting bait stations at the base of exclusion treatment trees were likely traveling from nearby ornamental plantings.

Ant foraging effort has been shown to lessen over distance in *Formica* species, an ant that uses a central place foraging strategy (Karhu 1998, Wimp and Whitham 2001). The Argentine ant, with its dispersed central place foraging strategy and polydomous colony structure, will rapidly establish nests near a food source (Newell and Barber 1913, Holway and Case 2000). It is, therefore, surprising that Argentine ant nests did not relocate close to our boric acid bait stations. It is unclear why our bait stations did not attract Argentine ants to locate close by. Our bait stations held a maximum of 40 ml of boric acid bait, with access limiting the number of Argentine ant workers that could feed simultaneously. It may be that limiting the number of simultaneously feeding workers may not have allowed foraging trails to grow sufficiently large to trigger nest movement. An alternative explanation is that there were alternative carbohydrate resources within the environment plentiful enough to preclude nest movement to our bait stations. The extended distances from nests to bait stations at the base of exclusion treatment trees probably limited foraging effort to the bait stations as distance increased from nest to bait.

Argentine ants will move nests away when food resources have been exhausted (Newell and Barber 1913, Holway and Case 2000). We did not see a reduction in Argentine ant numbers or nests around canopy-accessible red maples after 0.5% boric acid bait was introduced. Denying access to terrapin scale, which resulted in Argentine ant nests moving away, suggests an alternate management strategy derived from trap-mulching (Silverman et al. 2006). Treating the majority of honeydew-producing Hemiptera but leaving some plants infested should encourage Argentine ants to nest closer to those infested plants. This should concentrate Argentine ant nests for targeted, cost effective, treatment of the infestation. Daane et al. (2006) suggested that initial deployment of liquid baits in spring should encourage bait consumption when honeydew is still limited and when winter aggregations are breaking up (Newell and Barber 1913). Our proposed strategy may be most effective under these conditions, but we have shown nests can be encouraged to move in the height of summer and, therefore, may prove to be a useful strategy from early spring through late summer.

Acknowledgments

We thank R. R. Dunn, F. Gould, and G. G. Kennedy for providing valuable comments on the manuscript; A. Carper and K. Brightwell for technical assistance; and C. Brownie and C. Arellano for statistical advice. The Blanton J. Whitmire Endowment at North Carolina State University and USDA Grant SRIPM 2008-34103-19001 supported this study.

References Cited

Alder, P., and J. Silverman. 2004. A comparison of monitoring methods used to detect changes in Argentine ant (Hymenoptera: Formicidae) populations. J. Agric. Urban Entomol. 21: 142–149.

Baker, T. C., S. E. Van Vorhis Key, and L. K. Gaston. 1985. Bait-preference tests for the Argentine ant (Hymenoptera: Formicidae). J. Econ. Entomol. 78: 1083–1088.

Daane, K. M., K. R. Sime, B. N. Hogg, M. L. Bianchi, M. L. Cooper, M. K. Rust, and J. H. Klotz. 2006. Effects of liquid insecticide baits on Argentine ants in California's coastal vineyards. Crop Protect. 25: 592–603.

Davidson, D. W. 1997. The role of resource imbalances in the evolutionary ecology of tropical arboreal ants. Biol. J. Linn. Soc. 61: 153–181.

Davidson, D. W., S. C. Cook, R. R. Snelling, and T. H. Chua. 2003. Explaining the abundance of ants in lowland tropical rainforest canopies. Science 300: 969–972.

Flanders, S. E. 1951. The role of the ant in the biological control of homopterous insects. Can. Entomol. 83: 93–98.

Holway, D., and T. Case. 2000. Mechanisms of dispersed central-place foraging in polydomous colonies of the Argentine ant. Anim. Behav. 59: 433–441.

Holway, D. A., L. Lach, A. V. Suarez, N. D. Tsutsui, and T. J. Case. 2002. The causes and consequences of ant invasions. Annu. Rev. Ecol. Syst. 33: 181–233.

Karhu, K. J. 1998. Effects of ant exclusion during outbreaks of a defoliator and a sap-sucker on birch. Ecol. Entomol. 23: 185–194.

Klotz, J. H., and J. I. Moss. 1996. Oral toxicity of a boric acid-sucrose water bait to Florida carpenter ants (Hymenoptera: Formicidae). J. Entomol. Sci. 31: 9–12.

Klotz, J. H., L. Greenburg, and E. C. Venn. 1998. Liquid boric acid bait for control of the Argentine ant (Hymenoptera: Formicidae). J. Econ. Entomol. 91: 910–914.

Klotz, J. H., D. H. Oi, K. M. Vail, and D. F. Williams. 1996. Laboratory evaluation of a boric acid liquid bait on colonies of *Tapinoma melanocephalum* Argentine ants and Pharaoh ants (Hymenoptera: Formicidae). J. Econ. Entomol. 89: 673–677.

Ness, J. H., and J. L. Bronstein. 2004. The effects of invasive ants on prospective ant mutualists. Biol. Invas. 6: 445–461.

Newell, W., and T. C. Barber. 1913. The Argentine ant. U.S. Dep. Agric. Bur. Entomol. Bull. 122: 1–98.

Reierson, D. A., M. K. Rust, and J. Hampton-Beesley. 1998. Monitoring with sugar water to determine the efficacy of treatments to control Argentine ants, *Linepithema humile* (Mayr). *In* Proceedings of the National Conference on Urban Entomology, 26–28 April 1998, San Diego, CA.

Roulston, T. H., and J. Silverman. 2002. The effect of food size and dispersion pattern on the retrieval rate by the Argentine ant, *Linepithema humile* (Hymenoptera: Formicidae). J. Insect Behav. 15: 633–648.

Rust, M. K., D. A. Reierson, and J. H. Klotz. 2003. Pest management of Argentine ants (Hymenoptera: Formicidae). J. Entomol. Sci. 38: 159–169.

SAS Institute. 2000–2004. SAS 9.1.3 help and documentation. SAS Institute, Cary, NC.

Silverman, J., and B. Nsimba. 2000. Soil-free collection of Argentine ants (Hymenoptera: Formicidae) based on food-directed brood and queen movement. Fla. Entomol. 83: 10–16.

Silverman, J., and T. H. Roulston. 2001. Acceptance and intake of gel and liquid sucrose compositions by the Argentine ant (Hymenoptera: Formicidae). J. Econ. Entomol. 94: 511–515.

Silverman, J., and R. J. Brightwell. 2008. The Argentine ant: challenges in managing an invasive unicolonial pest. Annu. Rev. Entomol. 53: 231–252.

Silverman, J., C. E. Sorenson, and M. G. Waldvogel. 2006. Trap-mulching Argentine ants. J. Econ. Entomol. 99: 1757–1760.

Simanton, F. L. 1916. The terrapin scale: an important insect enemy of peach orchards. U.S. Dep. Agric. Tech. Bull. 351: 1–96.

Vega, S. Y., and M. K. Rust. 2003. Determining the foraging range and origin of resurgance after treatment of Argentine ant (Hymenoptera: Formicidae) in urban areas. J. Econ. Entomol. 96: 844–849.

Wimp, G. M., and T. G. Whitham. 2001. Biodiversity consequences of predation and host plant hybridization on an aphid-ant mutualism. Ecology 82: 440–452.

Received 28 October 2008; accepted 21 January 2009.