Impacts of Red Imported Fire Ants (Hymenoptera: Formicidae) on Striped Pine Scale (Homoptera: Coccidae) Populations[1]

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ABSTRACT Loblolly pines, *Pinus taeda* L., were banded in three seed orchards in Georgia to prevent the red imported fire ant, *Solenopsis invicta* (Buren), from tending infestations of striped pine scales, *Toumeyella pini* (King). Ant activity had no effect on female scale insect survival as numbers per shoot were never significantly different between check and banded trees in any of the orchards. Parasitism of females rarely differed between treatments, with higher rates twice in one orchard on unbanded trees and once in another orchard on banded trees. There also appeared to be no treatment effects on predator numbers. Coincident populations of the mealybug *Oracella acuta* (Lobdell) and the woolly pine scale, *Pseudophilippia quaintancii* Cockerell, on the shoots also were unaffected by the presence of fire ants.

KEY WORDS *Toumeyella pini, Solenopsis invicta*, scale insect/ant association

Scale insect outbreaks in southern pine seed orchards have become more frequent in recent years. Secondary population resurgences of these pests have been related to the application of insecticides for seed and cone insect control, particularly pyrethroids (DeBarr et al. 1982, Nord et al. 1985). The lower toxicity of pyrethroids to scale insects (Clarke et al. 1988), coupled with their adverse effects on natural enemies (Clarke et al. 1990a) appears largely responsible for the onset and continuation of outbreaks. The four species commonly found infesting shoots and needles are the striped pine scale, *Toumeyella pini* (King), the pine tortoise scale, *T. parvicornis* (Cockerell), the wooly pine scale, *Pseudophilippia quaintancii* Cockerell, and a mealybug, *Oracella acuta* (Lobdell).

Imported fire ants, *Solenopsis invicta* (Buren) and *S. richteri* Forel, have also invaded many southern pine plantations and seed orchards. *Solenopsis* spp. have been reported tending homopteran pests (Hays and Hays 1959, Lyle and Fortune 1948, Travis 1941), including *T. parvicornis* (U. S. Department of Agriculture 1958, Wilinson and Chellman 1979) and *T. pini* (Clarke et al. 1989). They feed on the extruded honeydew and may erect shelters over their attendees (Green 1952, Clarke et al. 1989).

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The benefits of ant-scale insect relationships have been well documented (Smith 1942, Nixon 1951, Way 1963, Beattie 1985, Buckley 1987). Ants may protect the scale insects through interference with natural enemies or the construction of shelters. The removal of honeydew by ants may prevent the entrapment of crawlers, speed scale development, and inhibit the growth of sooty molds which may smother the scales. Ants may also move scale insects either to plants where conditions are more favorable or to their nests, enabling the scales to avoid natural enemies or to survive periods of environmental duress. Ants may regulate populations by utilizing some scales as prey and keeping numbers at advantageous levels. In return, the ants are provided with a food source, honeydew. The excretion of honeydew also attracts other insects, which the ants capture for prey.

Ant-scale insect relationships have been evaluated for two species of *Toumeyella*. Bradley (1973) found that a major predator of *T. parvicornis*, the coccinellid *Hyperaspis congressis* Watson, was more numerous on trees banded to exclude the ant, *Formica obscuripes* Forel, than on unbanded trees. The coccinellid was unable to eliminate scale insect populations when the ants were present. Tending by the ant *Dolichoderus taschenbergi* (Mayr) increased survival of the tuliptree scale, *T. liriodendri* (Gmelin), from 8.2 to 46.8 percent (Burns 1973).

As ant associations proved beneficial for these species of Toumeyella, a study was undertaken to examine the effects of tending by *S. invicta* on *T. pini* populations to determine if fire ant eradication could be a control strategy in a pest management program for scale insects in southern pine seed orchards, and to check if *P. quaintancii* and *O. acuta* received incidental protection from ant activity on the shoots.

Materials and Methods

Exclusion Study 1. The first fire ant exclusion study was conducted at a loblolly pine, *Pinus taeda* L., seed orchard established in Toombs Co., GA in 1978. An outbreak of striped pine scale began in 1982, the result of an aerial application of fenvalerate (Pydrin®; Shell Chemical Company, Modesto, CA). The orchard continued to receive operational aerial applications of azinphosmethyl (Guthion®; Mobay Chemical Company, Kansas City, MO), and the infestation was still active in 1985. In October, five susceptible clones were identified and two ramets of these clones with visibly heavy scale insect infestations and active fire ant mounds were selected. Mounds were located at the south base of the trees, with additional mounds occasionally between trees. One ramet per clone was randomly designated for ant exclusion, with the other ramet as a control. On 24 October, the mounds by exclusion trees were treated with the fire ant bait Amdro® (hydramethylnon, 0.88% [AI]; American Cyanamid, Princeton, NJ) and one week later a band of stickem approximately 15 cm wide was applied around the trunk approximately 1 m above the ground. The stickem provided a barrier which the ants could not cross. In this and the following studies, the selected trees had no overlapping branches with adjacent trees, to prevent possible ant immigration from neighboring trees. Trees also were checked periodically to insure that the sticky barriers were intact.

Shoot samples were collected on 26 November 1985 and 24 January, 24 March, 11 April, 16 May, 2 June, and 23 June 1986. The trees were visually divided into directional quadrants and into two crown levels: lower and middle to upper crown. One shoot from each quadrant-crown level section was randomly selected and clipped on each sampling date except the first and last, when two shoots per section were taken. A sample shoot was defined as the current growth cycle plus approximately 10 cm of old growth. This orchard continued to receive operational aerial applications of azinphosmethyl in spring and summer of 1986.

Exclusion Study 2. A second study was established in 1987 at a loblolly pine seed orchard in Bulloch Co., GA. A striped pine scale outbreak had begun in 1982 in sections receiving aerial applications of fenvalerate and azinphosmethyl. The infestation persisted in 1987 and had spread to adjacent sections which had never been aerially sprayed. The study was conducted in two of these sections, one established in 1981 and the other in 1982. As in the previous study, two infested ramets of five susceptible clones were selected per section, with one ramet randomly selected for fire ant exclusion. Fire ant mounds were treated with hydramethylnon on 11 November, with stickem bands applied 1 wk later.

Shoot samples (as previously defined) were collected on 9 December 1987 and 24 March 1988. The trees were visually divided into directional quadrants, with one shoot randomly chosen and clipped per date. Crown level separation was not done due to the smaller tree size. Sampling at this orchard had to be discontinued when the orchard was offered for sale and management practices were suspended.

Exclusion Study 3. The third study was conducted at a loblolly pine seed orchard established in 1984 in Putnam Co., GA. A striped pine scale infestation began in 1988 following aerial applications of esfenvalerate (Asana®; Shell Chemical Company, Modesto, CA). Some pine tortoise scales (needle form) and woolly pine scales also were present. No insecticides were applied in 1989 during the experiment. Ten susceptible clones were identified, and two infested ramets per clone with adjacent active fire ant mounds were selected, with one ramet designated for ant exclusion. Mounds were treated with the fire ant bait Affirm® (avermectin B_1, 0.011% (AI); Merck & Co., Rahway, NJ) on 24 April 1989, and stickem bands were applied 1 wk later.

Shoot samples from the study trees were collected on 24 August. The trees were visually divided into directional quadrants and two crown levels, and one shoot from each section was randomly selected and clipped.

Predator collections were made 14 July. One lower crown shoot from the north and south side of each study tree was beaten by hand over a $27 \times 40 \times 9$ cm cardboard beverage case in which a 5.5×2.5 cm glass vial had been inserted in the bottom near a corner. The fallen arthropods were herded into the vial, which was then removed, filled with 75% ethanol, capped, and labeled. The shoot was then clipped, bagged and labeled.

All sample shoots in each study were examined under a microscope and the numbers of live, dead, and parasitized female striped pine scales recorded. Numbers of female *O. acuta* and *P. quaintancii* also were recorded, if present. Possible predators on the shoots were identified and counted, as were those collected from the shoot beatings.

Mean numbers of live females per shoot and percent parasitism per treatment were analyzed for each sampling date using analysis of variance (SAS 1985), with mean separation by LSD tests. Tree means were used in the analyses for live females per shoot. Percent parasitism was calculated using sums per tree, and an arcsine transformation was used prior to analysis.

Results

Exclusion Study 1. Significant differences in numbers of live females per shoot per treatment were not found on any sampling date (Table 1). Percent parasitism differed significantly between treatments in March and May, with rates close to 25% and 6% on control and exclusion trees, respectively. First generation crawlers emerged in May and a considerable number settled on shoots on both banded and unbanded trees (Table 1). The population showed no indications of collapsing in either treatment.

The only significant crown level differences between treatments in numbers of live females occurred in the upper crown on 24 January. Control trees had a mean (± SEM) of 6.9 ± 1.5 live females per shoot, versus 1.4 ± 0.9 females on banded trees.

Laetilia coccidivora (Comstock), *Leucopis* sp., and lacewings (Chrysopidae and Hemerobiidae), known predators of *T. pini* (Clarke et al. 1989), as well as spiders, were observed on the collected shoots. Most of these potential predators were collected on the first sampling date (Table 2). Numbers were lower in the spring and summer when operational aerial spraying occurred and *T. pini* numbers declined. No trends between treatments appeared evident.

A small *O. acuta* infestation began in June, with treatment means of 1.5 ± 1.2 and 0.6 ± 0.4 females per shoot for check and banded trees, respectively. These means were not significantly different.

Exclusion Study 2. Treatment differences in numbers of live *T. pini* per shoot and percent parasitism were not significant at the Bulloch Co. orchard (Table 3). Predators were scarce, with three *Leucopis* sp. and one *L. coccidivora* collected from shoots of control trees, and one *Leucopis* sp. and one lacewing larva collected from banded trees.

Oracella acuta and *P. quaintancii* also were present, and treatment differences were also non-significant (Table 3). Parasitism was abundant for *O. acuta*, reaching over 30% in March, but was not observed on *P. quaintancii*. *Coccidomyia* sp. and *Dicrodiplosis* sp., cecidomyiid predators of *O. acuta*, were active, with 27 collected on banded trees and 24 on control trees.

Exclusion Study 3. The *T. pini* population collapsed at the Putnam Co. orchard during the summer, decreasing from 2.1 ± 1.0 and 3.9 ± 1.2 live first-generation females per shoot on banded and unbanded trees, respectively, in July to less than 0.3 second generation females/shoot for both treatments in late August. Differences in live females per shoot were not significant on either sampling date. Percent parasitism was significantly higher on first generation females on banded trees (19.1 ± 6.5) than on unbanded trees (5.1 ± 2.1) in August, but not in July or for second generation females in August, when parasitism was ≤ 10%. Treatment differences within crown levels were all non-significant.

Table 1. Mean numbers (± SEM) of live *T. pini* females and percent parasitism on banded and unbanded loblolly pines at the Toombs Co., GA seed orchard in 1985 and 1986.

Generation	Treatment	26 Nov.	24 Jan.	24 March	11 April	16 May	2 June	23 June
				Females per shoot*				
Over-wintering	Banded	4.0 ± 1.9 a	3.3 ± 1.7 a	0.7 ± 0.2 a	0.9 ± 0.8 a	0.9 ± 0.5 a	0.4 ± 0.2 a	0.4 ± 0.4 a
	Unbanded	13.1 ± 7.0 a	8.4 ± 2.2 a	1.5 ± 0.8 a	2.2 ± 1.3 a	1.1 ± 0.2 a	0.1 ± 0.1 a	0.1 ± 0.1 a
				Percent parasitism*				
	Banded	1.5 ± 1.0 a	8.5 ± 3.9 a	6.0 ± 2.2 a	19.4 ± 5.2 a	6.4 ± 4.0 b	2.2 ± 2.2 a	0 a
	Unbanded	1.3 ± 0.8 a	6.4 ± 2.2 a	24.7 ± 6.2 a	14.0 ± 5.0 a	24.8 ± 2.6 a	0 a	6.2 ± 6.2 a
				Females per shoot*				
First	Banded	–	–	–	–	7.1 ± 2.3 a	7.6 ± 1.6 a	6.6 ± 1.9 a
	Unbanded	–	–	–	–	9.3 ± 2.6 a	5.7 ± 1.0 a	7.6 ± 1.4 a
				Percent parasitism*				
	Banded	–	–	–	–	0.2 ± 0.2 a	2.8 ± 1.2 a	2.9 ± 0.3 a
	Unbanded	–	–	–	–	1.2 ± 0.8 a	3.8 ± 3.1 a	4.8 ± 3.0 a

* Means in columns followed by the same letter are not significantly different, ($P = 0.05$)., LSD (SAS Institute 1985).

Table 2. Numbers of potential *T. pini* predators collected on loblolly pine shoots from banded and unbanded trees at the Toombs Co., GA seed orchard in 1985 and 1986.

Date	Treatment	Araneae	Chrysopidae and Hemerobiidae	*Laetilia coccidivora*	*Leucopis* sp.
26 Nov.	Banded	8	3	4	7
1985	Unbanded	18	0	1	6
24 Jan.	Banded	3	0	0	0
1986	Unbanded	7	0	0	1
24 March	Banded	2	3	0	0
1986	Unbanded	2	8	1	0
Other	Banded	1	3	2	1
1986*	Unbanded	0	2	3	4

* Combined data from 11 April, 16 May, 2 June, and 23 June.

A small population of *P. quaintancii* was recorded, with means of 0.01 ± 0.01 and 0.19 ± 0.19 live females per shoot on banded and control trees, respectively.

A large number of spiders were collected, with higher numbers on banded trees in August (Table 4). *Laetilia coccidivora*, green lacewings, and coccinellids were collected in July, but not in August following the population collapse. The adult coccinelldis identified from the study area were *Cycloneda munda* (Say), *Hippodamia convergens* Guerin-Meneville, *Chilocorus stigma* (Say), *Coccinella septempunctata* L., and *Hyperaspis* spp.

Discussion

The results indicate that tending by fire ants has little effect on striped pine scale survival and the actions of their natural enemies in loblolly pine seed orchards and that fire ant eradication would have little influence on controlling outbreaks. Population maintenance and collapses could still occur despite the presence or absence of ants. The use of insecticides for seed and cone insect control appeared to be a more important regulator of *T. pini* populations, as the outbreak at the Toombs Co. orchard persisted as operational spraying was continued in 1986, while the population at the Putnam Co. orchard collapsed when spraying was discontinued.

The major reasons for the failure of the ants to play a more significant role in the population dynamics of *T. pini* appeared to be the inconstant tending of the scale insects and defensive strategies of the predators. Observations of the

Table 3. Mean numbers (± SEM) of live *T. pini, O acuta,* and *P. quaintancii* females per shoot and percent parasitism on banded and unbanded loblolly pines at the Bulloch Co., GA seed orchard in 1987 and 1988.

Treatment	*T. pini*		*O. acuta*		*P. quaintancii*
	Females per shoot	Percent parasitism	Females per shoot	Percent parasitism	Females per shoot
9 December, 1987					
Banded	1.5 ± 0.4 a	16.5 ± 3.6 a	1.3 ± 0.3 a	22.2 ± 5.9 a	1.4 ± 0.7 a
Unbanded	3.4 ± 1.0 a	10.4 ± 1.9 a	1.2 ± 0.3 a	17.8 ± 4.0 a	1.3 ± 0.7 a
24 March, 1988					
Banded	0.6 ± 0.2 a	3.9 ± 2.1 a	1.1 ± 0.3 a	43.5 ± 8.1 a	0.2 ± 0.1 a
Unbanded	0.6 ± 0.2 a	13.3 ± 5.7 a	1.6 ± 0.1 a	31.9 ± 6.4 a	0.1 ± 0.1 a

Means followed by the same letter are not significantly different, (P = 0.05), LSD (SAS Institute 1985).

Table 4. Numbers of potential *T. pini* predators collected on loblolly pine shoots from banded and unbanded trees at the Putnam Co., GA seed orchard in 1989.

Treatment	Araneae	Chrysopidae and Hemerobiidae	*Laetilia coccidivora*	Coccinellidae
		14 July*		
Banded	83	2	1	2
Unbanded	80	4	1	8
		24 August		
Banded	49	0	0	0
Unbanded	28	0	0	0

* Includes numbers counted on shoots and those collected in vials from beating the shoots prior to clipping.

female scale insects during the day indicated that individuals were not tended by fire ants a majority of the time. Ants were always active on the trunks during inspections, but the ants tended only a small proportion of *T. pini* on the shoots at a time. This lack of constant tending was probably the major factor in their failure to reduce parasitism. Parasitism was occasionally higher on trees with ants than those with ants excluded. Though Bartlett (1961) reported that some parasites are affected by the Argentine ant despite short ovipositional times, it appeared that parasites would have ample opportunity to oviposit on *T. pini* at most times.

The only striped pine scales constantly tended were the few beneath ant-constructed shelters at the Toombs Co. orchard. These shelters were observed only at low population levels, which may relate to the assertion of Way (1963) that protection is better when honeydew is in short supply.

Several factors may limit *T. pini* tending activity by the fire ants. Horton (1918) stated that ant interference is more likely when the scales are in groups. Female striped pine scales generally do not settle near the mother, thus large clumps of females are not present except when populations numbers are high (Clarke et al. 1989). Perhaps species such as the shoot form of *T. parvicornis,* which is often grouped as many females settle near the mother on southern pines (personal observation), may benefit more from ant attendance, as reported by Bradley (1973).

Tree size may also affect the extent of ant attendance. Large pines may have numerous and widespread honeydew sources, and constant tending of all individuals would be difficult. Scale insects on seedlings however could receive continuous tending, leading to infestations in plantations described by Wilkinson and Chellman (1979). Fire ants are also primarily nocturnal foragers, and activity is limited during periods of high temperatures (Claborn and Phillips 1986, Claborn et al. 1988).

Defense mechanisms of predators may have increased their survival in the presence of fire ants. *Laetilia coccidivora* was enclosed in a tubular web which Horton (1918) and Burns (1973) reported could not be penetrated by ants when intact. Horton also described the secretion of an ant-repellent fluid by lacewing larvae, though Tedders et al. (1989) found that the fire ant was an important predator of the eggs, larvae, and pupae of the chrysopid *Chrysoperla rufilabris* (Burmeister). Bartlett (1961) reported that Argentine ants were very aggressive against *Leucopis bella* Loew and were very successful in capturing adults and larvae. The *Leucopis* sp. larvae found in our samples were beneath the female scales and were not accessible to the fire ants. Coccinellids, though not generally associated with *T. pini* infestations (Clarke et. al. 1989), were apparently present in response to *T. parvicornis* on the needles at the Putnam Co. orchard and appeared to have aided in the speedy population collapse. Though the cottony or spiny coverings of the larvae may have provided some protection, the larvae appeared relatively unattractive to the ants, as larvae and pupae often were observed on the trunks near ant trails. Horton (1918) and Bartlett (1961) found a similar response to coccinellids for Argentine ants.

Another important factor in the *T. pini*-fire ant relationship is the alternate honeydew sources provided by the scale insect *Toumeyella virginiana* Williams and the mealybug, *Dysmicoccus obesus* (Lobdell) on the bole. These species were located deep in the bark crevices, generally along ant trails. Both were tended by fire ants which often built protective runways up the side of the bole and over the settled individuals. These species were observed at the Bulloch and Putnam Co. seed orchards. The trees at the Toombs Co. orchard were not checked because we were unaware of the pervasiveness of these two species at the time. These species would provide a closer and more convenient honeydew source than *T. pini,* and they would have the advantage of the added protection afforded by the the bark scales. It does appear likely that fire ants are important in maintaining populations of *T. virginiana* and *D. obesus* on the boles of pines in seed orchards. Thompson and Colvin (1990) reported a close association between *D. obsesus* and two species of *Crematogaster* ants on loblolly pines, and Tedders et al. (1989) found a mutualistic relationship between fire ants and the mealybug (*Dysmicoccus morrisoni* (Hollinger), on the boles of pecan, *Carya illinoensis* (Wangenh) K. Koch. However, the destructive nature of the required sampling and the high value of the pines in seed orchards would make evaluation difficult.

There also appeared to be no incidental protection afforded other Coccoidea on the shoots. *Oracella acuta* adults live underneath a protective resin cell and were not observed being tended by *S. invicta*. Parasitism of the mealybugs, an important factor in their population dynamics (Clarke et al. 1990b), was unaffected by the presence of ants on the shoots.

Despite the removal of some honeydew production of *T. pini* by fire ants, as well as by numerous wasps and bees, heavy infestations produced more honeydew than could be removed, providing a growth medium for sooty mold. Sooty mold buildup could affect scale insect survival and tree vigor. Crawlers were occasionally observed trapped in the honeydew, though their numbers appeared minute when compared to overall crawler production.

In conclusion, it is apparent that insecticide applications have a much greater effect on *T. pini* populations and their natural enemies than do fire ants. The beneficial effects of fire ants may be increased on small trees or by the construction of shelters. However, the conditions precipitating the construction of shelters over *T. pini* females by *S. invicta* are not known. Any increase in the survival at low population levels could increase the rapidity and severity of outbreaks following insecticide applications.

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