IMPACT OF RED IMPORTED FIRE ANT[1] ON FOLIAR HERBIVORES AND NATURAL ENEMIES

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ABSTRACT

The impact of red imported fire ant, *Solenopsis invicta* Buren (Hymenoptera: Formicidae), on foliar herbivores was examined in a commercial 'Cheyenne' pecan orchard for two seasons by establishing a methoprene bait treatment, a chlorpyrifos trunk treatment and an untreated control. Ants were monitored by periodic mound counts. Herbivores and their natural enemies were monitored by inspecting foliage and deployment and recovery of corrugated cardboard refuge strips. Methoprene bait treatment significantly reduced red imported fire ant mounds compared to the other treatments. Blackmargined pecan aphid, *Monellia caryella* (Fitch) (Homoptera: Aphididae), was the primary herbivore present during both seasons, with peak densities occurring in June, but not exceeding economic thresholds. Natural enemies, particularly lacewings, lady beetles and spiders, fluctuated in density in concert with aphids. The red imported fire ant was not shown to affect aphid densities, but lacewing larvae and pupae and lady beetle adults were significantly greater on some sampling dates in treatments where fire ants were reduced. Fire ants may have a limited impact on natural enemies. The pecan IPM program for managing herbivores in the canopy does not require adjustment to accommodate red imported fire ant at this location. Generalization to remaining sites in Texas awaits completion of other studies underway.

INTRODUCTION

The red imported fire ant, *Solenopsis invicta* Buren, was originally introduced into Alabama in the 1930's and now occurs throughout the southern United States. Invasion of new areas is ongoing and is expected to continue until climatic barriers are encountered that prevent further range expansion (Camilo and Phillips 1990, Lofgren 1986, Sanford et al. 1988). Locations where soil temperatures of 10°F, or lower, are encountered represent the northern limits of anticipated spread, indicating coastal states are the primary locations at risk. Current estimates indicate about 56 million acres are infested in Texas, and the economic impact is estimated to exceed $300 million annually. About $90 million of this impact is associated with agricultural activities (Lard et al. 2001).

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The red imported fire ant (RIFA) is an aggressive invader and readily establishes 100 mounds inhabited by monogyne colonies/ha, or up to 1000 polygyne inhabited mounds/ha. The mounds become conspicuous as the colonies mature and can reach heights and diameters of about 50 cm. Each colony can contain as many as 100,000 ants. This is in contrast to most native ant species whose mounds and colonies are smaller, peaking at about 10,000 ants/colony (Macon and Porter 1996). RIFA readily invades disturbed areas and rapidly becomes the dominant species in the region, suppressing other ant species and associated fauna. Management with contact insecticides applied to the mounds readily kills workers; but, unless the queen is also killed, resurgence occurs quickly. Insecticidal baits, whose toxicological effects are sufficiently delayed to allow treatment of the queen through prophylaxis, prevent resurgence. Insect growth and reproductive regulator baits primarily target the queen(s) and ultimately the colony dies out even if existing workers are relatively unaffected by the treatment.

RIFA is a serious pest for many reasons. The mounds they produce physically alter the landscape to prevent its use or enjoyment. The worker ants bite and sting. Their high densities result in routine contact with other fauna in the region. RIFA recruits thousands of ants to subdue prey, scavenge resources and repulse interlopers. Humans are repelled by bites and stings and some are plagued by allergic reactions to ant toxins that can result in fatalities due to anaphylactic shock. RIFA also form mounds around equipment, irrigation lines, pumps, and electrical switch boxes, disabling magnetos, plugging up irrigation emitters, and shorting out circuits due to their activities (Drees et al. 1990). We are investigating the impact of RIFA in the pecan orchards of Texas and obtaining a database to use in pursuing management strategies to reduce or prevent economic losses (Calixto et al. 2001). The work reported here emphasizes the effects of RIFA on pecan pests and natural enemies in the pecan canopy.

MATERIALS AND METHODS

The study was conducted in a commercial pecan orchard of 'Cheyenne' variety (Robertson County, Texas) receiving standard management determined by the producer. We established three treatments replicated four times by randomly assigning each replication to an 8 by 9 tree block (trees spaced 45 ft by 45 ft). Treatments were: 1, untreated control; 2, chlorpyrifos (Lorsban 4E TM) trunk treatment. [Chlorpyrifos (1 pint/100 gallons water) was applied to runoff from soil level to a height of 3 ft on each tree trunk using a hand gun powered by a pump attached to a nurse tank. Trunk sprays were applied 12 May, 24 July and 12 October 2000 and 25 June 2001]; and 3, broadcast methoprene (Extinguish TM) bait treatment. [Methoprene (1.5 lbs/acre) was applied using a Herd spreader from an all-terrain 4 wheeler delivering a 30 ft swath at 10 MPH. Treatments applied 19 May and 12 October 2000 and 12 June 2001].

Several methods were used to monitor RIFA and associated fauna in each treatment. Initial pretreatment RIFA density was determined by counting mounds in the randomized plots on 26 March 2000, prior to the chlorpyrifos trunk treatment (12 May 2000) and initial methoprene bait application (19 May 2000). Mound counts were made by inspecting a 3.7 by 68.6 M transect bisecting five trees in each of the four replicated plots (totaling 0.1 Ha/treatment) to estimate density, distribution and abundance of all ant species detectable by this method. Inspections were conducted 26 March, 27 June, 25 July and 7 December 2000, and 12 April and 4 October 2001. Weekly inspections of pecan leaves were made to monitor herbivores, natural enemies and ants inhabiting the leaves during the 2000 and 2001 growing seasons. Pecan leaf inspections were made by visually examining and recording arthropods found on 640 leaves in situ in each treatment each week (four terminals of ten leaves/tree, four trees/plot, replicated four times/treatment). Corrugated cardboard strips (13 cm long by 6 cm wide were folded over a terminal twig and held by a clothespin) were deployed weekly (ten strips/tree, five trees/plot, replicated four times/treatment = 200 strips/treatment/week) during the 2000 and 2001 growing seasons. Strips were collected weekly, with the ten strips from each tree placed in a ziploc plastic bag and returned to a freezer (-10° F) in the laboratory and then inspected within a few days. Strips primarily captured lacewings, lady beetles and spiders that used the sites as refuges. The periodic sampling of the tree canopies using leaf inspections and refuge strips to monitor herbivore and natural enemy densities were conducted to reflect any impact that occurred from the reduction in RIFA mound density on fauna in the canopy.

Additional sampling methods were used including pitfall trapping, bait vials, visual inspections, etc., but will not be discussed further in this paper. Data was analyzed using X^2 analysis to compare means.

RESULTS AND DISCUSSION

RIFA mound density averaged 642 (16.3 ± SE1.3 per 255M^2. Plot mounds/hectare (26 March 2000), and the areas designated for later treatment application did not differ in RIFA mound density. This density was consistent with the polygyne form of RIFA, which occurs at densities three or more times higher than the monogyne form (Porter et al 1991). Subsequent inspection of mounds in the orchard has shown presence of occasional monogyne colonies in what appears to be primarily a polygyne infestation. RIFA mound densities in the methoprene treatment were lower and significantly differed from other treatments (P> .05, 2df) at each of the five inspection periods subsequent to application of the initial treatment on 19 May 2000 (Fig. 1). The chlorpyrifos trunk treatment significantly differed from the control,

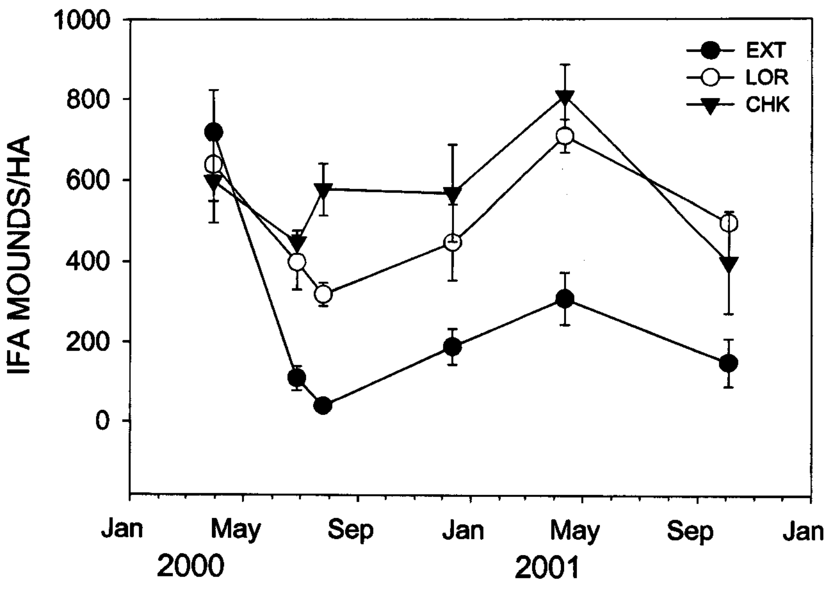

FIG. 1. Mound densities of *Solenopsis invicta* determined by visual inspection of 4 replications of 0.025 Ha in each treatment. EXT = methoprene bait treatment; LOR= chlorpyrifos trunk spray; CHK= control. Bars show standard deviation.

which was higher, and the methoprene bait, which was lower, on 25 July 2000, but did not significantly differ from the control at other times. The methoprene bait treatments significantly and consistently reduced RIFA mound densities throughout the 2000 and 2001 growing seasons.

The blackmargined pecan aphid, *Monellia caryella* (Homoptera: Aphididae), was the primary herbivore found infesting pecan leaves during the 2000 season (Fig. 2). Minor leaf tattering was observed by the pecan sawfly, *Periclista sp.* (Hymenoptera: Tenthredinidae), and minor feeding symptoms were observed from unknown organisms that together never affected more than 2% of the foliage. Natural enemies, particularly lacewing (Neuroptera: Chrysopidae) eggs, larvae, pupae and adults, lady beetle (Coleoptera: Coccinellidae) larvae, pupae and adults, and spider (Araneae) immatures and adults, were routinely recorded on the inspected leaves. These proved to be the most commonly encountered macroscopic arthropods and, together with blackmargined pecan aphid, represent the most abundant taxa found on foliage. Ants (Hymenoptera: Formicidae) were not routinely encountered in the foliage. Other taxa were noted in low densities and will not be discussed in this paper.

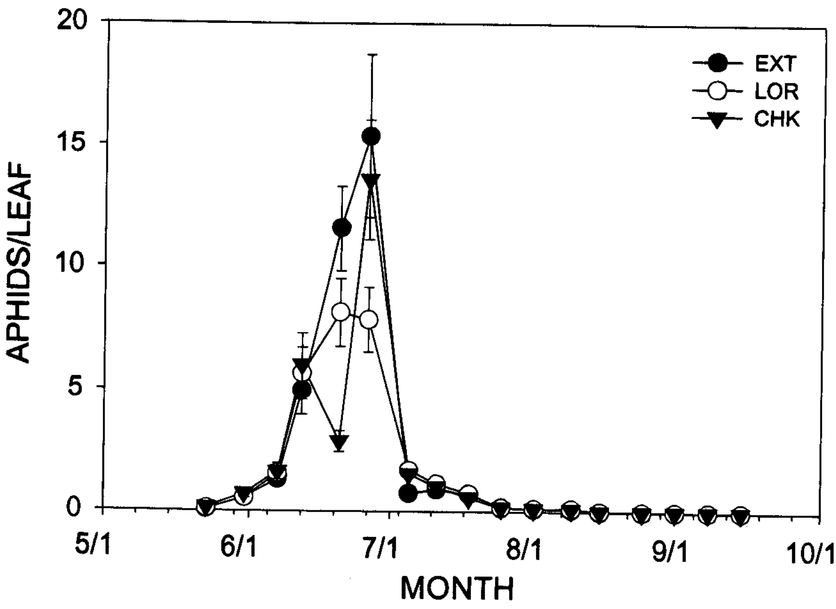

FIG. 2. Densities of nymph and adult *Monellia caryella* determined by visual inspections of 640 pecan leaves (4 terminals of 10 leaves/tree, 4 trees/plot, replicated 4 times/treatment) during the 2000 season. EXT= methoprene bait treatment; LOR= chlorpyrifos trunk spray; CHK= control.

Blackmargined pecan aphid (BMA) were at low densities when monitoring began in May and increased to highest densities in late June 2000. Densities subsequently declined among all treatments to less than one aphid per compound leaf in early July and remained there until leaf dehiscence in the fall (Fig. 2). Densities never exceeded the economic threshold of 25 aphids/compound leaf established for the region (Harris et al. 1998). Significant differences (X^2, P> .05 level 1df) were observed among treatments from 23 May to 26 June, with only the 20 and 26 June sample dates possibly having any biological significance. Natural enemy densities were examined to determine their role in aphid density fluctuations that could be affected by RIFA predation.

Chrysopids were the most abundant of the natural enemies on foliage (Fig. 3). Adults were encountered in May (about 1/300 leaves at highest density observed), and eggs (1/14 leaves), larvae (1/60 leaves) and pupae (1/200 leaves) were found at highest densities in late June-early July, coinciding with the BMA outbreak and decline. Chrysopid data were consolidated for the various life forms. No significant differences in chrysopid densities were observed among treatments.

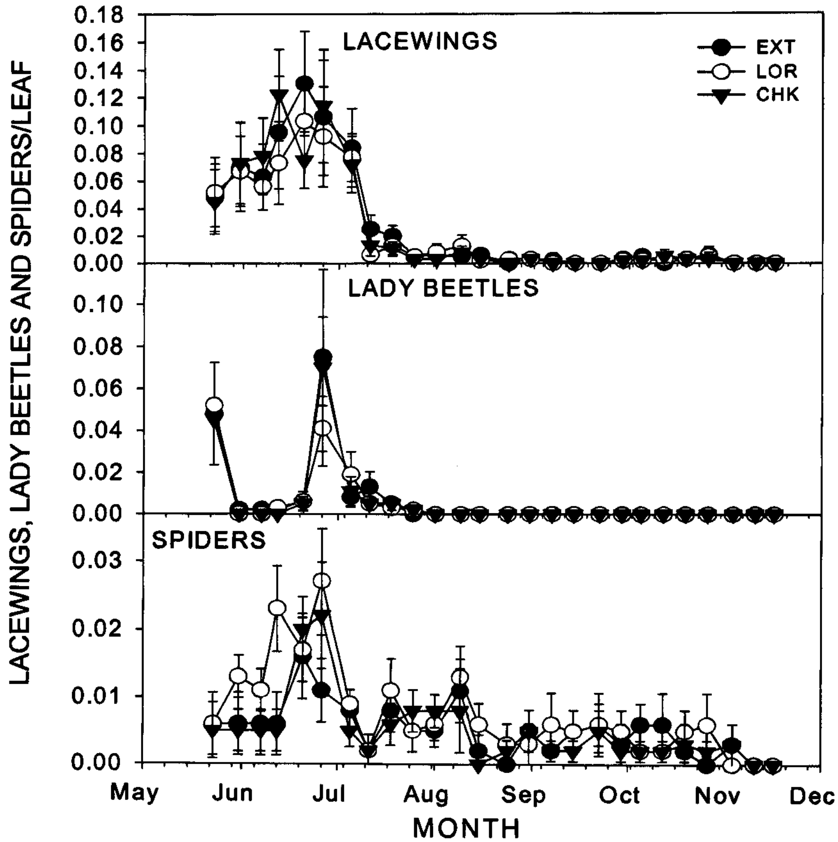

FIG. 3. Densities of chrysopids (eggs, larvae, pupae and adults combined), coccinellids (larvae and pupae combined), and Araneae (immatures and adults combined), determined by visual inspections of 640 pecan leaves (4 terminals of 10 leaves/tree, 4 trees/plot, replicated 4 times/treatment) during the 2000 season. EXT= methoprene bait treatment; LOR= chlorpyrifos trunk spray; CHK= control.

Lady beetles were initially found in May and then following a decline were observed to reach their highest density in late June (Fig. 3), coincident with BMA (Fig. 2). The highest density observed briefly approximated 1/15 leaves, but rapidly declined to less than 1/100 leaves.

Spiders were routinely encountered on the foliage throughout the 2000 growing season (Fig. 3). Densities more than doubled coincident with the peak in BMA density (Fig. 2), and then dèclined from about 1/50 leaves to about 1/150 leaves.

Blackmargined pecan aphid (BMA) were at low densities when monitoring began in early April and increased to highest densities of about three/leaf in late June 2001. Densities subsequently declined among all treatments to less than one/leaf by late July and remained there until leaf dehiscence in the fall (Fig. 4). Densities were less than those observed in the 2000 growing season. Significant differences (X^2, P> .05, 1df) were not observed among treatments. Natural enemy densities were again examined to determine their role in aphid density fluctuations that could be affected by RIFA predation.

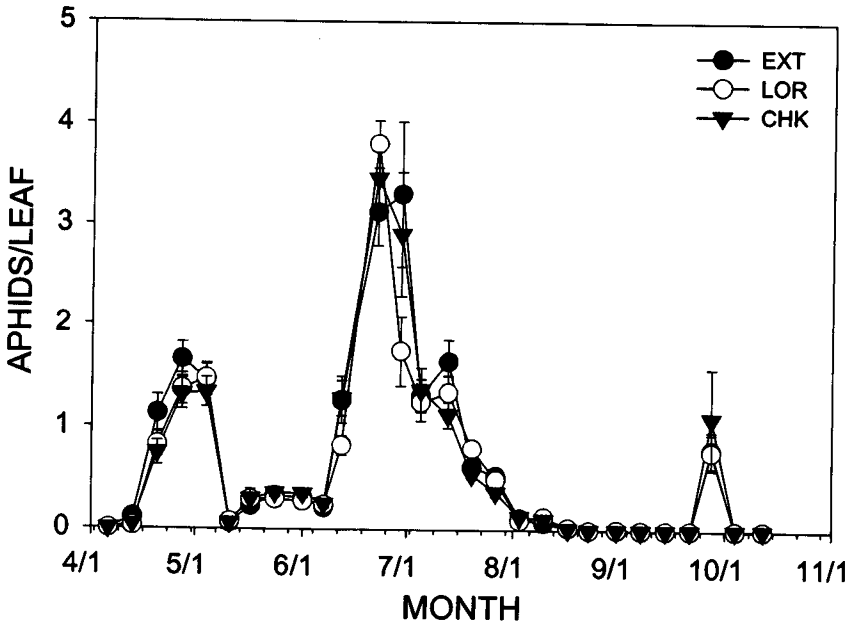

FIG. 4. Densities of *Monellia caryella* determined by visual inspections of 640 pecan leaves (4 terminals of 10 leaves/tree, 4 trees/plot, replicated 4 times/treatment) during the 2001 season. EXT= methoprene bait treatment; LOR= chlorpyrifos trunk spray; CHK= control.

Chrysopids were the most abundant of the natural enemies on foliage in 2001 (Fig. 5). Adults were encountered in late May (about one/45 leaves at highest density observed), and eggs (one/four leaves), larvae (one/80 leaves) and pupae (one/160 leaves) were found at high densities in late June-early July. A distinct late season peak for all chrysopid life stages was also observed on 27 September 2001. Chrysopid data were consolidated for the various life forms. Chrysopid densities increase and decline coincident with BMA densities, which peak in late June, with another small peak in September. No significant differences in chrysopid densities were observed among treatments.

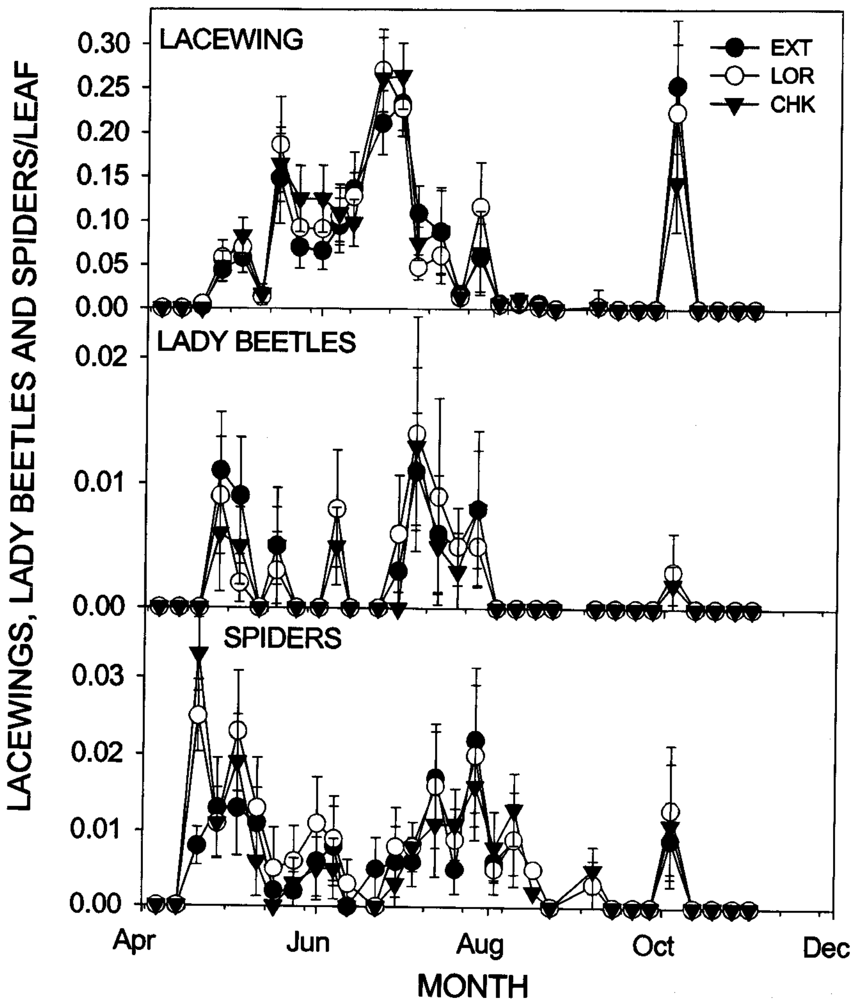

FIG. 5. Densities of chrysopids (eggs, larvae, pupae and adults combined), coccinellids (larvae and pupae combined), and Araneae (immatures and adults combined), determined by visual inspections of 640 pecan leaves (4 terminals of 10 leaves/tree, 4 trees/plot, replicated 4 times/treatment) during the 2001 season. EXT= methoprene bait treatment; LOR= chlorpyrifos trunk spray; CHK= control.

Lady beetles were initially found in April and then following a decline were observed to reach their highest density in late June (Fig. 5), coincident with BMA (Fig. 4). The highest density observed briefly approximated one/70 leaves, but rapidly declined to less than one/100 leaves.

Spiders were routinely encountered on the foliage throughout the 2001 growing season (Fig. 5). Densities increased coincident with the tri-modal activity periods observed in BMA density (Fig. 4), reaching densities of 1/35 leaves in April, 1/50 in July and 1/100 in September, interspersed with levels of about 1/150 leaves.

The refuge strips harbored high numbers of lacewings, lady beetles and spiders throughout both growing seasons (Table 1). Spider density was significantly higher in the control than in other treatments in 2000 (X^2, P> .05, 2df), and chrysopid larvae and pupae and lady beetles were higher in the methoprene bait treatment than in the control, and lady beetles were higher in the chlorpyrifos trunk treatment than in the control in 2001 (X^2, P>.05, 2df). Visual inspection of the phenologies of these natural enemies shows densities fluctuate in rough concordance with BMA densities (Figs. 6 and 7, compared to Figs. 2 and 4). Chrysopids appear most sensitive to BMA densities throughout each season with coccinellids best associated in the early season and spiders best associated in 2000 and less so in 2001.

TABLE 1. Natural Enemy Densities Found in Refuge Strips Attached to Pecan Twigs during the 2000 and 2001 Growing Seasons by Examining 200 Bands/Treatment at Weekly Intervals from 30 May to 12 September 2000 and from 19 April to 19 October 2001. Data are Mean Number/Treatment ± STD/sample date.

YEAR	TREATMENT[a]	LACEWINGS LARVAE	LACEWINGS PUPAE	LADY BEETLES	SPIDERS
2000	EXT	11.5 ± 12.1	17.1 ± 25.9	10.8 ± 20.8	39.1 ± 8.3
2000	LOR	10.1 ± 11.0	17.6 ± 28.8	8.3 ± 13.9	41.0 ± 12.6
2000	CHK	12.9 ± 14.2	18.1 ± 25.4	9.1 ± 16.5	50.3 ± 10.6
2001	EXT	29.0 ± 31.3	29.4 ± 29.2	1.8 ± 3.2	77.5 ± 58.8
2001	LOR	26.1 ± 29.0	23.1 ± 25.5	3.4 ± 5.7	83.4 ± 65.8
2001	CHK	24.3 ± 26.0	19.2 ± 18.5	0.9 ± 1.3	80.3 ± 58.5

[a] EXT = Methoprene bait treatment; LOR = chlorpyrifos trunk treatment; CHK = control

GENERAL DISCUSSION

RIFA mound densities were significantly reduced in the methoprene bait treatment throughout the 2000 and 2001 growing seasons and significantly reduced on one inspection date in the chlorpyrifos trunk treatment in mid-season 2000 (Fig. 1). RIFA activity was readily evident on the ground in the control and chlorpyrifos trunk treatments and minimal in the methoprene bait treatment throughout this study based on observations and other sampling methods (bait vials, pitfall trapping, and visual inspections of ant activity on the ground adjacent to trees not presented here). The foliage inspections and refuge strips did not census RIFA in the canopy sufficiently to reflect the differences observed on the ground.

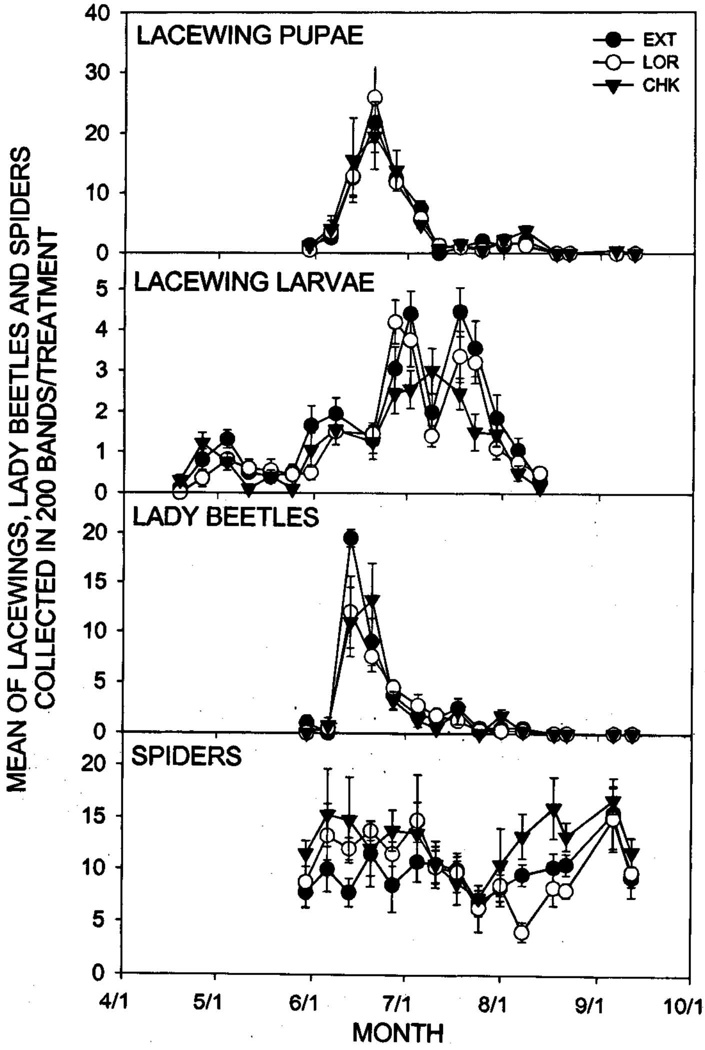

FIG. 6. Densities of chrysopid larvae and pupae, coccinellids (larvae and pupae combined), and Araneae (immatures and adults combined), determined from cardboard refuge strips deployed and collected weekly (10/tree, 5 trees/plot, replicated 4 times/treatment) during the 2000 season. EXT= methoprene bait treatment; LOR= chlorpyrifos trunk spray; CHK= control.

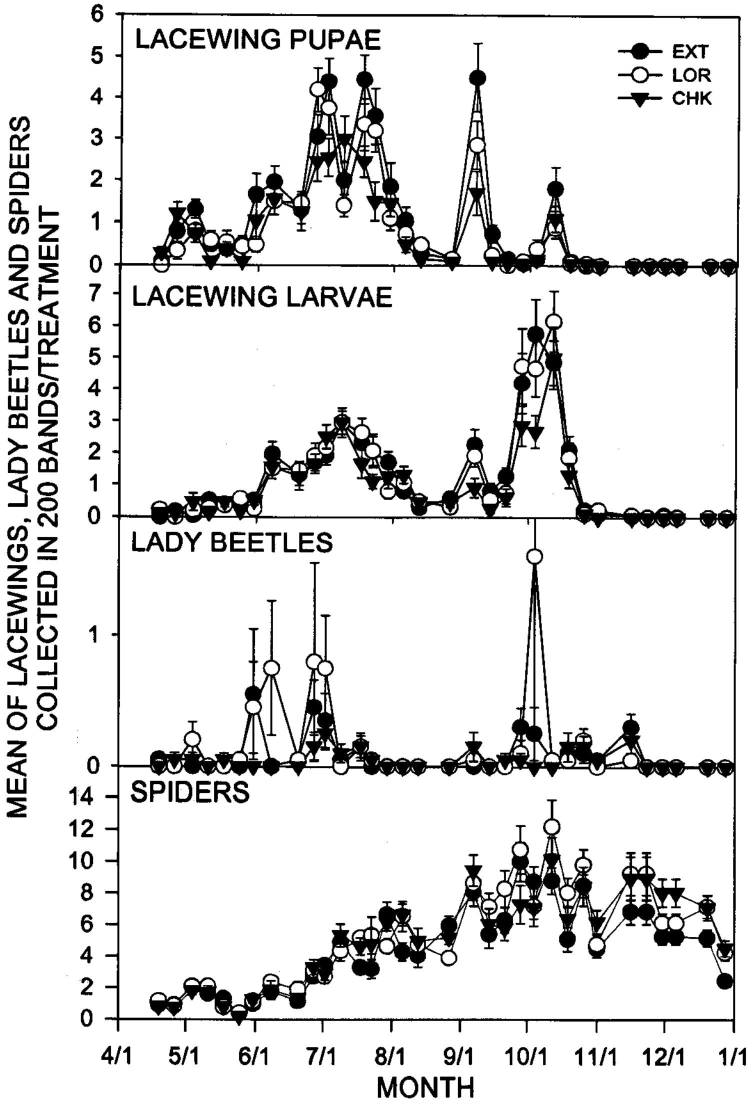

FIG. 7. Densities of chrysopid larvae and pupae, coccinellids (larvae and pupae combined), and Araneae (immatures and adults combined), determined from cardboard refuge strips deployed and collected weekly (10/tree, 5 trees/plot, replicated 4 times/treatment) during the 2001 season. EXT= methoprene bait treatment; LOR= chlorpyrifos trunk spray; CHK= control.

BMA densities were about twice as high in 2000 as in 2001 (Fig. 2, Fig. 4). The significant differences in BMA densities observed in 2000 occurred primarily during the outbreak phase of BMA increase typically observed in this area of Texas (Harris and Li 1996, Liao et al. 1984, 1985). We attribute this to natural variation in rapid density increase and note densities were comparable on earlier and later inspection dates (Fig. 2). RIFA will take aphids as prey (Dutcher et al. 1999) and use honeydew as a sugar resource (Scarborough 1984, Tedders et al. 1990), but are not known to tend pecan aphids. RIFA did not appear to affect the population dynamics of the typical pecan aphid outbreaks observed in either year.

Lacewings, lady beetles and spiders capture and consume a wide range of prey, including aphids (Bumroongsook et al. 1992; Liao et al. 1984, 1985). Each of these categories of natural enemies clearly increase and decline with the outbreaks of pecan aphids observed in these studies. The foliar inspections did not show significant differences in these natural enemy densities among treatments. However, examination of refuge strips placed in the canopies did show consistent differences among treatments for spiders, which were significantly higher in refuge strips in the control compared to other treatments in the 2000 growing season (Fig. 5). The strips primarily harbored hunting spiders and the reason for this treatment difference does not appear related to RIFA density or densities of aphids, or other natural enemies found in the canopy. We note spiders were abundant, fluctuating among all treatments during 2000, and the slightly higher numbers observed in the control is best ascribed to natural variation. Chrysopid larvae and pupae and lady beetles in refuge strips were significantly higher in the methoprene treatment than in the control in 2001, and lady beetle densities in refuge strips were higher in the chlorpyrifos treatment than in the control in 2001. RIFA will prey upon larvae and pupae of chrysopids and coccinellids, and may account for reductions of these predator densities in the control. However, if true, the effects could not be shown to be associated with aphid densities.

RIFA density reduction using methoprene baits or chlorpyrifos trunk treatments do not appear to have had any large, consistent effects on the distribution and abundance of fauna in pecan tree canopies based on foliar inspection and refuge strip sampling methods. The high RIFA mound densities found in this orchard reflect about 30 million ants/ha (600 mounds/ha times 50,000 ants/mound) in the control and trunk treatments and far fewer in the bait treatment. We expect the impact of this difference among treatments will be reflected in other studies underway. Based on current findings, the pecan integrated pest management program in Texas (Harris et al 1998) does not need modification to address RIFA impact on pests in the canopy.

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LITERATURE CITED

Bumroongsook, S., M. K. Harris, and D. A. Dean. 1992. Predation on blackmargined aphids (Homoptera: Aphididae) by spiders on pecan. Biological Control 2: 15-18.

Calixto, A., A. Knutson, M. K. Harris, B. Ree, and A. Dean. 2001. Interspecific interactions of *Solenopsis invicta* with other ants, aphids, predatory insects and spiders in pecan. pp. 162-170. *In* S. B. Vinson and S. Ellison [eds.]. Proc of the 2001 Annual Imported Fire Ant Research Conference. San Antonio, Texas.

Camilo, G. R., and S. A. Phillips. 1990. Evolution of ant communities in response to invasion by the fire ant *Solenopsis invicta*. pp. 190-198. *In* R. K. Van der Meer, K. Jaffe, and A. Cedeno [eds.]. Applied Myrmecology, a world perspective. Westview Press, Boulder, Colorado.

Drees, B., C. Barr, W. Ree, D. Reue, and S. B. Vinson. 1990. Effect of insecticides applied to pecan tree trunks and the floor for the suppression of the red imported fire ant (Hymenoptera: Formicidae). "http://fireant.tamu.edu/"

Dutcher, J. D., P. M. Estes, and M. J. Dutcher. 1999. Interactions in entomology: aphids, aphidophaga and ants in pecan orchards. J. Entomol. Sci. 34: 40-56.

Harris, M. K. and T. Li. 1996. The blackmargined aphid as keystone species: a predator attractor redressing natural enemy imbalances in pecan systems. pp. 112-116. *In* W. J. Mattson, P. Niemela, and M. Roussi [eds.]. Dynamics of forest herbivores: quest for pattern and principle. USDA For. Serv. Gen. Tech. Rep. NC-183.

Harris, M., B. Ree, J. Cooper, J. Jackman, J. Young, R. Lacewell, and A. Knutson. 1998. Economic impact of pecan integrated pest management implementation in Texas. J. Econ. Entomol. 91: 1011-1020.

Lard, C., V. Salin, D. Willis, S. Robinson, J. Hadley, and K. Schroeder. 2001. The Statewide Economic Impact of Red Imported Fire Ants in Texas: A part of the Texas Fire Ant Initiative 1999-2001. Fire Ant Economic Research Report #01-08.

Liao, H-.t., M. K. Harris, F. E. Gilstrap, D. A. Dean, C. W. Agnew, G. J. Michels, and F. Mansour. 1984. Natural enemies and other factors affecting seasonal abundance of the blackmargined aphid on pecan. Southwest. Entomol. 9: 404-420.

Liao, H-.t., M. Harris, F. Gilstrap and F. Mansour. 1985. Impact of natural enemies on the pecan aphid *Monellia caryella* (Homoptera: Aphididae). Environ. Entomol. 14: 122-126.

Lofgren, C. S. 1986. History of imported fire ants in the United States. pp. 36-47 *In* C. C. Lofgren and R. K. Van der Meer [eds.]. Fire ants & leaf-cutting ants; biology and management. Westview Press, Boulder, Colorado.

Macon, J. E., and S. D. Porter. 1996. Comparison of polygyne and monogyne red imported fire ants (Hymenoptera: Formicidae) population densities. Ann. Entomol. Soc. Amer. 89: 535-593.

Porter, S.D., A. Bhatkar, R. Mulder, S. B. Vinson, and D. Clair. 1991. Distribution and density of polygyne fire ants (Hymenoptera: Formicidae) in Texas. J. Econ. Entomol. 84: 866-874.

Sanford, D. P., B. V. Eimeren, and L. W. Gilbert. 1988. Invasion of red imported fire ants (Hymenoptera: Formicidae): Microgeography of competitive replacement. Ann. Entomol. Soc. Amer. 81: 913-918.

Scarborough, T. W. 1984. Mutualism of the red imported fire ant with honeydew producing Homoptera. Ph. D. Diss. Texas A&M Univ. College Station. 110pp.

Tedders, W., C. Reilly, B. Wood, R. Morrison, and C. Lofgren. 1990. Behavior of *Solenopsis invicta* (Hymenoptera: Formicidae) in pecan orchards. Environ. Entomol. 19: 44-53.