THE IMPACT OF THE RED IMPORTED FIRE ANT, *SOLENOPSIS INVICTA* BUREN (HYMENOPTERA: FORMICIDAE), ON SOYBEAN ARTHROPOD PESTS AND THEIR ASSOCIATED NATURAL ENEMIES IN GEORGIA

by

MICHAEL PAUL SEAGRAVES

(Under the direction of Dr. Robert M. McPherson)

ABSTRACT

A two year study was undertaken to examine the impact of *Solenopsis invicta* Buren (Hymenoptera: Formicidae) suppression on soybean pests, beneficial predators, and crop yield. Three treatments were examined an untreated control, Amdro (hydramethylnon) bait, and chlorpyriphos in combination with Amdro. The treatments were successful in suppressing fire ant foraging and abundance in the treated plots. This led to decreased predation on lepidopteran eggs and pupae. An increase was seen in the threecornered alfalfa hopper, *Spissistilus festinus* (Say) and lady beetles in the treated plots. In 2000, pitfall monitoring revealed ground-dwelling spiders were more abundant in the untreated control. Earwigs were more abundant in both years in the chlorpriphos + Amdro treatment and at times the Amdro alone treatment. The residual toxicity of acephate, chlorpyriphos, methomyl, and l-cyhalothrin on fire ant workers was investigated and dose-mortality curves were developed for each chemical.

INDEX WORDS: Red imported fire ant, *Solenopsis invicta*, *Glycine max*, biological control, pesticide selectivity

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MICHAEL PAUL SEAGRAVES

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MICHAEL PAUL SEAGRAVES

Approved:

Major Professor: Robert M. McPherson

Committee: S. Kristine Braman
John R. Ruberson

Electronic Version Approved:

Gordhan L. Patel
Dean of the Graduate School
The University of Georgia
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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Soybeans were planted on 180,000 acres in Georgia in 2000 with a value of 17 million dollars (United Soybean Board 2001). In Georgia and other southeastern states, soybeans are attacked by numerous pest arthropods throughout the entire growing season. Stink bugs and foliage feeding lepidopterans such as the velvetbean caterpillar, soybean looper, and corn earworm are serious pests that cause annual economic losses in soybean. Lesser cornstalk borer, bean leaf beetle, and threecornered alfalfa hopper are also serious pests in some years. Occasional pests include green cloverworm, whiteflies, armyworms, grasshoppers, spider mites, wireworms, and grubs but rarely cause economic damage on their own (Funderburk et al. 1999). In 1996 losses due to insects (damage and control) in Georgia soybean totaled $5,084,000 (McPherson et al. 1997).

American agriculture over the last half century has relied heavily on chemical pesticides as pest management tools. Concerns over public health, environmental risk, economic constraints, and development of insecticide resistance have led to a push for the adoption of integrated pest management (IPM). IPM is an ecologically, economically, and socially guided decision support system for growers that seeks to prevent economic loss of crops from pest damage while reducing the dependence on chemical use. Increased regulatory limitations on broad-spectrum pesticides plus the emergence of resistance to some chemical classes by key pests has made IPM a necessity to growers.

Biological control, particularly the conservation of natural enemies, is a key strategy for maintaining pest populations below damaging levels. The impact of natural enemies on target pests needs to be evaluated and characterized to place biological control on a more predictive footing. The red imported fire ant, *Solenopsis invicta* Buren, is rarely thought of as a beneficial organism, but this predaceous arthropod has many characteristics that make it potentially useful as a natural enemy of soybean pests. It is highly abundant, consumes mainly other arthropods, is capable of subduing prey larger than itself, and is an efficient forager.

S. invicta was introduced into Mobile, AL. between 1933 and 1945, probably in ballast from South American ships (Taber 2000). It has been considered a pest ever since. Its close relative *Solenopsis richteri* Forel, the black imported fire ant, was imported into the same location around 1918 (Taber 2000). Since it's introduction *S. invicta* has displaced *S. richteri* and spread throughout the entire southeastern United States and isolated spots in the western states as well.

Fire ant stings are mainly a painful nuisance but pose a serious medical risk to hypersensitive individuals, possibly resulting in death (Taber 2000, Apperson & Adams 1983). *S. invicta* is also a pest of livestock, particularly newborn calves that are vulnerable to attack. Roadways and other structures are damaged by the red imported fire ant. This species also has been reported to damage electrical boxes, air-conditioners, telephone cables, and irrigation outlets (Taber 2000, Lofgren 1986). Of particular concern to biologists is the impact that this introduced species might have on the native fauna of the southeast. Fire ants have been implicated in the decline of many invertebrates, mammals, birds, and reptiles (Taber 2000, Lofgren 1986, Vinson 1994).

The status of *S. invicta* in agriculture is unsettled. A great deal of literature has been published on its negative impact on both crop plants and arthropod pests. There is considerable confusion about the diet of *S. invicta.* Early researchers reported that the red imported fire ant was completely carnivorous. It is now considered to be an omnivore that consumes a great variety of animal, plant, fungal, and bacterial food (Taber

2000). Wilson and Oliver (1969) examined the material collected from returning foragers in Louisiana pastures and pine forests. They determined that *S. invicta* was an aggressive generalist predator and scavenger not seeking specific prey but being opportunistic. The majority of the ants' diet was other arthropods, particularly smaller insects and immature stages. Since it has been demonstrated that the red imported fire ant is largely a predator of other arthropods and given its wide distribution and abundance, investigation into possible beneficial aspects in pest management is warranted.

Soybeans in the southeastern United States are infested with *S. invicta*. An investigation in six states showed that the number of active mounds present per ha of soybeans ranged from 22.2-207.5 (Banks et al. 1990). Tillage has been shown to impact red imported fire ant populations. Morrill and Greene (1975) demonstrated that discing and plowing in seedbed preparation drastically reduced the number of active mounds in a soybean field. This seemed to be only a temporary effect as the number of active mounds between untilled and tilled were similar at the end of the season. With the widespread adoption of conservation tillage, reduction of pesticide sprays, and use of more selective insecticides that is occurring in agriculture, the role of *S. invicta* as a beneficial predator may increase.

Although ants are not always considered biological control agents, taking advantage of their predaceous habits is not a new idea. In perhaps the first recorded example of applied biological control, Chinese growers as early as 900 AD encouraged the nesting of *Oecophylla smaragdina* F. in orange trees to suppress pest insects (Ehler 1998). Way and Khoo (1992) review the use of all ants in pest management. They discuss positive qualities of predaceous ants, and suggest that since eradication is improbable, then beneficial aspects of *Solenopsis* spp. should be investigated and encouraged.

Investigations into the impact of the red imported fire ant on key pest arthropods and their associated predators have taken place in a variety of crop systems. In Texas cotton, the boll weevil, *Anthonomus grandis* Boheman, did not reach economically damaging levels in eleven years in fields infested with *S. invicta* (Sterling et al. 1984). It was found that 58-85% of boll weevil pupae were preyed on by fire ants (Fillman and Sterling 1983, Sterling 1978, Strum and Sterling 1990). When infested fields of early-planted cotton were treated with the chlorinated hydrocarbon insecticide Mirex, a semi-selective chemical targeting *S. invicta*, the percentage of boll weevil damaged flower buds was 39% compared to 17% in an untreated control where ants were abundant (Jones and Sterling 1979). In a similar experiment in a Mirex-treated field, as the number of ants per plant dropped the percentage of damaged buds rose to over 90%; whereas in a check plot, the number of ants per plant remained constant and the percentage of damaged buds never exceeded 10% (Sterling et al. 1984). It was found that the critical fire ant density needed to prevent economic damage by the boll weevil was 0.4 ants/10 plant terminals (Fillman and Sterling 1985). This ant density prevented boll weevil populations from reaching damaging levels 90% of the time. The impact of *S. invicta* on the boll weevil is the most dramatic demonstrated experimentally. This may be due to the fact that the boll weevil is also a foreign species that has no other biotic mortality factors present in North America other than *S. invicta*. Sterling (1978) stated that if *S. invicta* had not been accidentally introduced serious consideration would have to be given to importing this species as a biological control agent for the boll weevil. Of course with what is now known about the would be non-target effects of *S. invicta* Sterling's statement seems nonsensical.

Another key pest of cotton is the tobacco budworm, *Heliothus virescens* F. In radiotracer studies where ^{32}P labeled *H. virescens* eggs were exposed in a cotton field, fire ants accounted for 85.3% of radioactive predators collected (McDaniel and Sterling 1979). Radiotracer studies may skew the importance of fire ants as predators, since foragers may become radioactive through trophaplaxis instead of actual predation. Still it is clear that fire ants prey heavily on the egg stage of heliothine species (McDaniel and Sterling 1982).

S. invicta is often considered an indiscriminate predator, which raises a concern for its use in biological control if it attacks other control agents. Sterling et al. (1979) reported that even when very abundant fire ants failed to reduce 47 taxa of predaceous arthropods associated with cotton fields. Aphids and predaceous hemipterans were found to be positively associated with *S. invicta* in east Texas cotton (Reilly and Sterling 1983a,b). This suggests that hemipterans have effective defenses against ant attack, likely secreted aromatic compounds. This conflicts with early work that suggested that entomophagous organisms were reduced and the ecosystem simplified and destabilized by the presence of *S. invicta* (Lofgren 1975, Whitcomb 1972).

The presence of fire ants reduced the predatory effectiveness of coccinellids, syrphid fly larvae, and lacewing larvae on laboratory cotton aphid, *Aphis gossypii* Glover, populations (Vinson and Scarborough 1989). In this study it was observed that it took more than one ant to kill any of the predators; however, the authors hypothesized that these predators would prefer locations of low ant density, possibly increasing cotton aphid numbers. Cocoons of the braconid parasitoid *Cardiochiles nigriceps* Viereck which are placed in the soil, were preyed on heavily by *S. invicta* foragers (Lopez 1982). When fire ant foragers were within a few millimeters of the parasitoid *Lysiphlebus testaceipes* Cresson, the parasitoid would cease attacking the aphid *Rhopalosiphum maidis* Fitch thereby increasing the searching time and reducing the efficacy of the parasitoid (Vinson and Scarborough 1991). Of a larger concern to biological control is the impact on the parasitoid population; nearly 100% of parasitized aphids were destroyed six days after parasitation by ants, dramatically reducing parasitoid numbers.

Eubanks (2001) reported that *S. invicta* was negatively associated with all herbivore taxa in Alabama cotton and provided substantial economic benefits in suppressing cotton pests. Natural enemies also were affected by the presence of *S. invicta* and 22 out of 24 natural enemy taxa were negatively associated with *S. invicta*. Despite being a prolific intraguild predator, *S. invicta* can still negatively impact pest populations.

The red imported fire ant has long been recognized as an important component of the predator assemblage attacking the sugarcane borer, *Diatraea saccharalis* Fabricus. Negm and Hensley (1969) observed ants preying on the egg, larval, and pupal stages of this pest. In Mirex-treated plots of Louisana sugarcane, infestation levels of *D. saccharalis* increased by 53% and damage by 69% (Reagan et al. 1972). The increase in borer numbers and damage was attributed to the decrease of *S. invicta* in the treated plots, since the treatment did not affect spider numbers. In an ant removal experiment with Mirex in Florida, *S. invicta* was positively correlated with *D. saccharalis* numbers, leading the researchers to conclude that *S. invicta* was less important than the native ant *Pheidole dentate* Mayr in the predator assemblage that suppresses the borer (Adams et al. 1981).

The red imported fire ant was the second most abundant arthropod predator in Alabama peanut fields (Kharboutli and Mack 1991). On certain sampling dates fire ants were significantly more abundant in irrigated fields compared to nonirrigated. In Oklahoma peanut fields, fire ants recovered from foraging tunnels were found to be collecting seven times more pest arthropods than beneficials, although the largest percentage of fragments were unidentifiable (Vogt et al. 2001).

Pecan orchards in Georgia are often heavily infested with *S. invicta.* Survival of pecan weevil larvae was 15% greater in areas where fire ant mounds were drenched with the insecticide acephate compared to untreated areas (Dutcher and Sheppard 1981). Acephate drastically reduced fire ant numbers leading to the conclusion that *S. invicta* often attacked this important pest. Ants have been observed foraging as high as 9m in pecan trees, and do not seem correlated to aphid outbreaks (Tedders et al. 1990). *S. invicta* was a major predator of the eggs, larvae, and pupae of the green lacewing and of pupal syrphids, yet had little effect on coccinellid eggs (Tedders et al. 1990).

Within a greenhouse heavily infested with the whitefly *Trialeurodes vaporariorum* Westwood, *S. invicta* removed over 15,000 immatures and 2,588 adults from plants in one day (Morrill 1977). However, this predation had no apparent effect on the whitefly population.

Work conducted specifically in soybean has demonstrated that *S. invicta* may suppress key lepidopterans and stink bugs. Buschman et al. (1977) observed that ants, along with earwigs, were responsible for most of the predation on velvetbean caterpillar eggs. Test plots of soybeans where ground predators had been eliminated contained the highest numbers of velvetbean caterpillar and green cloverworm (Brown and Goyer 1982). Plots where fire ant populations decreased showed a significant increase in certain carabid species, and ants were observed attacking carabid larvae in the control plots. The authors of the study concluded that *S. invicta* was the dominant ground predator and preyed on other beneficials as well as lepidopteran pests (Brown and Goyer 1982). Lee et al. (1990) demonstrated that *S. invicta* accounted for nearly all predation on velvetbean caterpillar pupae. Additionally, Lee et al. (1990) reported that *S. invicta* reduced other ground-dwelling predators. In certain locations, *S. invicta* is the most prolific consumer of small and medium sized velvetbean caterpillar larvae (Elvin et al. 1983). Whereas in other locations, nabids were the major consumer demonstrating that often fire ant predation may be simply replacing other biotic mortality factors. Interestingly, in a study of the predators of velvetbean caterpillar eggs and larvae Godfrey et al. (1989) made no mention of *S. invicta*. Eubanks (2001) in Alabama soybeans found no positive or negative association between *S. invicta* and populations of lepidpopteran larvae.

In Georgia soybeans, fire ants were excluded from row segments using mesh cages and aluminum edging driven into the ground around the cage along with dursban around the edge. In these fire ant-excluded cages seven times as many *Nezara viridula* L. individuals were collected as opposed to cages where ant colonies had been placed (Krispyn and Todd 1982). It was noted that early nymphs (1st and 2nd instar) were especially vulnerable to fire ant foragers due to their aggregation in clumps. Using path analysis it was demonstrated that *S. invicta* had a substantial negative impact on stinkbugs in Alabama (Eubanks 2001). In Louisiana soybean, *S. invicta* was found to be responsible for most predation on southern green stink bug eggs during the vegetative stages of growth (Stam et al. 1987). However, predation of stink bugs during vegetative stages of soybean growth may not be very important, since stink bug survival is very low even in the absence of predation. Ants were not observed preying on stink bug eggs during the R5-R6 stage of soybean development (Stam et al. 1987). It should be noted that it is unclear how often *S. invicta* forages in the soybean canopy. Kidd and Apperson (1984) concluded that fire ants mainly foraged on the soil surface and were rarely seen foraging more than 20 cm high on the soybean plant.

As noted before, *S. invicta* is an omnivore and consumes some plant material. *S. invicta* has been reported to be a plant pest of several crops, particularly soybeans (Apperson and Adams 1983). The presence of *S. invicta* was shown to cause indirect loss of yield in soybeans due to interference with harvesting combines leading to some beans being left unharvested (Adams et al. 1976). Fire ants also have been reported to directly impact soybean yields leading to a reduction of 400 to 575kg per ha in infested plots compared to noninfested plots (Adams et al. 1983, Lofgren and Adams 1981). Reduced soybean yields also were correlated with fire ants in North Carolina (Apperson and Powell 1983). The mechanism of yield reduction was likely the destruction of seeds and seedlings by fire ants leading to significantly fewer plants per meter than noninfested plots. In infested plots, there was a greater number of pods per plant but fewer pods per meter. Radioactive ants were collected around radiotracer injected plants indicating they also feed on growing plants and not just seeds and seedlings, and this seemed to impact plant height. The feeding on larger plants is probably on the root system and hard to detect. Adams et al. (1983) concluded that cultural practices were largely responsible for fire ant damage to soybeans, since this crop is planted at the time of greatest food stress on a fire ant colony.

Other radiotracer studies have reported that *S. invicta* also feeds on okra and corn to a small degree, in addition to soybeans (Smittle et al. 1983). It was assumed that since very few other radioactive arthropods were found the positive result was due to actual plant feeding and not due to consuming arthropod herbivores. Soybean seeds/seedlings that emerged in association with *S. invicta* had decreased vigor (Shatters and VanderMeer 2000). Time to seedling emergence was doubled, three times as many malformed seedlings occurred, and visible damage was seen to cotyledons in comparison to seedlings not associated with fire ants. In addition, plants that emerged in association with RIFA produced 28% less root dry matter and contained 81% fewer root nodules than control plants (Shatters and VanderMeer 2000).

Sorghum and corn seeds were damaged by *S. invicta* in a laboratory study (Drees et al. 1991). Foragers rasped open the pericarp of seeds and removed the embryo. Dry seeds were attacked but water soaked or germinating seeds were attacked at a higher rate. In another laboratory experiment, dry seeds of wheat, corn, and sorghum were heavily damaged by *S. invicta* and to a lesser extent cotton and soybean seeds (Morrison et al. 1997). These laboratory feeding experiments need to be confirmed by field work before strong conclusions can be made about reduction of stands in crops due to ant predation.

Banks et al. (1991) reported that *S. invicta* often fed on new growth of young citrus trees and girdled the bark to obtain sap. Trees in fire ant-infested areas had mortality rates 5-6 times higher than treated areas.

In the literature tremendous positive and negative agricultural impacts are assigned to *S. invicta*. Further investigation is needed into the status of fire ants in all cropping systems throughout its range. No study to date has examined the impact of *S. invicta* on pests, beneficials, and crop yield simultaneously. Therefore, research was initiated to:

1. Investigate the impact of fire ant removal on soybean pest insects and their associated natural enemies in the soybean canopy and the soil surface.
2. Evaluate the effect of fire ant removal on the survival of eggs and pupae of lepidopteran pests.
3. Examine the impact of fire ant removal on soybean yield
4. Determine baseline residual toxicity of chemicals regularly used in Georgia row crop agriculture to *S. invicta* using a coated glass vial bioassay.

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CHAPTER 2

THE IMPACT OF *SOLENOPSIS INVICTA* BUREN ON SOYBEAN FOLIAGE ARTHROPODS AND CROP YIELD[1]

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Abstract

The red imported fire ant, *Solenopsis invicta* Buren, is a voracious consumer of arthropod species and occurs in high abundance in crop fields. *S. invicta* has been reported to be an effective natural enemy of key agricultural pests; however, it has also been implicated as a major intraguild predator and disrupter of biological control. Additionally, fire ants have been reported to be pests of soybean, reducing stands and yield. Information on the role of *S. invicta* in agroecosystems is very relevant to the design of biologically-based IPM programs throughout the fire ant's range. A fire ant exclusion experiment, using insecticides, was conducted in 2000 and 2001 to investigate the impact of *S. invicta* on soybean arthropod insects and their natural enemies. The treatments were: (1) untreated check, (2) Amdro (hydramethylnon) fire ant bait, and (3) chlorpyriphos plus Amdro bait. Reduced fire ant density, due to the fire ant suppression treatments, led to decreased predation on lepidopteran eggs and pupae. Few changes occurred in the soybean arthropod fauna due to the suppressed ant foraging. In 2000, threecornered alfalfa hoppers, *Spissistilus festinus* (Say), were more abundant in the ant suppressed plots. No other treatment effects were observed for pest species. Coccinellids, when present, were more abundant in the Amdro treated plots, suggesting fire ants have a detrimental impact on lady beetle populations. The fire ant suppression treatments had no impact on soybean yield despite reduced ant populations in the treated plots throughout the entire season

Key words: Red imported fire ant, *Solenopsis invicta*, *Glycine max*, biological control

The red imported fire ant, *Solenopsis invicta* Buren, is considered a serious pest of man, wildlife, and structures throughout its range (Vinson 1994, Taber 2000). Its status in row crops is unsettled. Fire ants have been widely reported to be predators of pest insects as well as being themselves serious crop pests. *S. invicta* is a key biological control agent of the boll weevil in east Texas (Sterling 1978, Jones & Sterling 1979). Sugarcane borer damage and abundance was increased in Louisiana sugarcane when fire ants were suppressed with Mirex (Reagan 1972). Often, *S. invicta* is the most abundant predaceous arthropod in row crop systems and this species is considered beneficial by many growers in the Southeastern United States.

S. invicta is considered by most researchers to be indiscriminate in the arthropods it chooses to attack and consume. Wilson & Oliver (1969) determined that *S. invicta* was an aggressive generalist predator not seeking specific prey. This may have implications for other natural enemies of crop pests. Sterling et al. (1979) reported that even at high population densities, fire ants failed to reduce 47 taxa of predaceous arthropods in cotton fields. However, fire ants have been shown to reduce the predatory effectiveness of coccinellids, syrphid fly larvae, and lacewing larvae on cotton aphid populations reared in the laboratory (Vinson & Scarborough 1989). Direct predation by *S. invicta,* or even their mere presence, may negatively impact some parasitoids (Lopez 1982, Vinson & Scarborough 1991). *S. invicta* was negatively associated with 22 out of 24 natural enemy taxa monitored in Alabama cotton fields (Eubanks 2001). Similarly, 14 of 16 natural enemy taxa in soybean were negatively associated with *S. invicta* (Eubanks 2001).

Soybean is an excellent candidate for the expansion of biologically based IPM programs due to the crop's ability to compensate for considerable insect damage. *S. invicta* may be a useful natural enemy of soybean pests in the southern United States. Buschman et al. (1977) observed that ants and earwigs were responsible for most of the predation on velvetbean caterpillar, *Anticarsia gemmatalis* Hubner, eggs. Soybeans that had the ground predator complex eliminated, of which *S. invicta* was dominant, contained the highest numbers of velvetbean caterpillar and green cloverworm, *Hypena scabra* (F.) (Brown & Goyer 1982). In some locations, *S. invicta* is the largest consumer of small and medium sized velvetbean caterpillar larvae (Elvin et al. 1983). However, Godfrey et al. (1989) made no mention of *S. invicta* in their study of the predators of velvetbean caterpillar eggs and larvae in Florida. In Alabama soybean, no positive or negative association between *S. invicta* and populations of lepidopteran larvae was found (Eubanks 2001).

In Georgia soybean, *S. invicta* severely depressed field caged populations of the southern green stink bug, *Nezara viridula* (Krispyn & Todd 1982). Using path analysis, Eubanks (2001) showed that *S. invicta* had a substantial negative effect on stink bugs in an open-field study. In Louisiana soybean, *S. invicta* preyed heavily on *N. viridula* eggs during soybean vegetative stages, but were not observed attacking stink bug eggs during the soybean reproductive stages (Stam et al. 1987).

S. invicta has been reported as a serious pest of soybeans. Fire ant mounds may reduce yield indirectly by interfering with harvesting machinery, leaving some beans unharvested (Adams et al. 1976). Direct loss of yield has also been correlated with *S. invicta* (Adams et al. 1983, Lofgren &Adams 1981, Apperson & Powell 1983). Most researchers believe that seed and seedling destruction by ants leading to stand reduction is the mechanism of yield loss. Adams et al. (1983) concluded that this was due to cultural practices, because soybeans are often planted at the time of greatest food stress on *S. invicta* colonies. Radiotracer studies indicate that *S. invicta* feed on growing plants as well (Adams et al.1983). Soybean seeds/seedlings that emerged in direct association with *S. invicta* had decreased vigor, longer time to emergence, more malformed seedlings, less root dry matter, and fewer root nodules in comparison to seedlings not associated with *S. invicta* (Shatters & VanderMeer 2000).

The increased adoption of conservation tillage and reduction of pesticide use may increase the role of *S. invicta* in the agricultural production. The impact of *S. invicta* on pests, natural enemies, and plants needs to be better understood to allow the design of more effective integrated pest management strategies in fire ant infested areas. This study was undertaken to document the impact of fire ant removal on the abundance of soybean pests and natural enemies and to assess any effects fire ants may have on crop yield and quality.

Materials and Methods

Tests were conducted at two cooperator farm sites (Bradford and Shannon) in Tift, Co. Georgia in 2000 and 2001. These locations were chosen due to their history of crop production using minimal tillage practices, as tillage is reported to suppress the number of active red imported fire ant colonies (Morrill and Greene 1975).

Soybeans (Deltapine 6200 RR) were planted into wheat stubble with a no-till drill planter with 7 in. row spacing at the Bradford farm on 7 June 2000. At the Shannon farm soybeans (Northern King RR) were planted on 14 June 2000 in 6 ft. beds with 36 in. row spacing with a strip-till planter into rye stubble. Glyphosate (Roundup ultra, Monsanto Corp.) was applied to both locations approximately two weeks after planting for weed control. Soybeans were planted on the same two farms during the 2001 growing season (Shannon on 4 June 2001 and Bradford on 11 June 2001) with identical cultural practices, except the Shannon farm was planted into a fallow field after glyphosate herbicide burndown instead of into rye stubble as the year before. The test sites were partitioned into plots that averaged 0.8 acres, and plots were assigned to one of three treatments: Untreated/control, Amdro (hydramethylnon, BASF Corp.) broadcast at 1.5lbs/acre, or broadcast applications of Lorsban (chlorpyriphos, Dow Agro Sciences) (1 qt/acre) + Amdro (1.5 lbs./acre). Amdro was applied with a hand spreader over the entire Amdro-treated plot; however, a 15 ft. untreated border was left on all four edges to try and eliminate effects on foraging ant populations from adjacent plots. Chlorpyriphos (Lorsban 4E) was applied at 1qt./acre over the entire Lorsban-treated plots. Treatments were arranged in a randomized block design with three replications at each farm in 2000 and four replications in 2001.

Fire ant foraging rates were monitored weekly in each experimental plot using a hotdog bait. Two sections of hotdog were placed in each plot at around 7:45 AM and checked for ants approximately 45 min. later. The number of ants was estimated and given a rating from 0 to 5 (0: 0 ants, 1: 1-10 ants, 2: 11-50 ants, 3: 51-100 ants, 4: 101-150, 5: >150 ants). Whenever ants were detected in treated plots, then Amdro was reapplied. Amdro was applied five days after planting in both fields in 2000 and again in early July. Lorsban applications were made with a tractor mounted sprayer in appropriate plots two days after the Amdro applications. In 2001 initial treatments of Amdro and

Lorsban were made just after planting. The Shannon farm received another application of Amdro on 28 June since fire ants were detected in treated plots. Both farms were retreated with Amdro on 20 July and chlorpyriphos on 23 July to assure fire ant suppression in the treated plots. A late season (mid-September) application of Dimilin (diflubenzuron, Uniroyal Chemical) and boron was applied to the Shannon farm in 2000 for control of velvetbean caterpillars. In 2001, late season applications of Karate (l-cyhalothrin, Syngenta Crop Protection) (Shannon farm) and Scout Xtra (tralomethrin, Aventis Crop Science) (Bradford farm) were made to control pests. No other pesticides were applied on either farm either year.

Soybean looper moths from an existing laboratory colony in Tifton, GA, were allowed to oviposit on butcher paper. Sections of paper with a known number of same-day-old eggs (100 for each plot) were placed on soybean foliage on the upper fully expanded trifolioates in the experimental plots by clipping the paper to the leaves with a paper clip. Eggs were left in the field for 24 hours, then they were retrieved and the number of remaining eggs were counted. Concerns of psuedoreplication led to a change of technique in the 2001 season. Corn earworm eggs obtained from a laboratory colony were individually placed on soybean leaves using Bovine Serum Album (BSA) solution as an adhesive. Fifty eggs were placed in each plot on selected dates and the number remaining after 24 hours was recorded. Egg predation observations were done in both 2000 and 2001. The percent recovery (eggs recovered/initial number) of eggs remaining after 24 hours was transformed using arcsine transformation then analyzed using Proc GLM (SAS Institute 1990).

The impact of fire ant suppression treatments on the mortality of lepidopteran pupae was investigated by placing soybean looper pupae in the experimental plots and measuring recovery. Pupae from an existing colony were placed either in the soybean canopy or on the soil surface. Diet cup lids with pupae naturally attached by their webbing were secured to the underside of the upper soybean trifoliolates with a paper clip, 5 to 20 pupae were placed in each plot depending on availability. Pupae attached to diet cup lids or pupae removed from the webbing also were placed on the soil surface underneath the soybean canopy. This direct soil technique also utilized 5-20 pupae per plot. Pupal location was marked in each plot with a field flag. After 24 hours had elapsed the pupae were checked to see if they were still alive, absent, or damaged by predatory feeding. Pupal recovery was measured on three dates at each test site for both foliage and ground placement. Data was pooled for all dates and analyzed using Proc GLM (SAS Institute 1990).

Soybean arthropods were sampled weekly beginning when the soybeans were in the V1 stage and the first trifoliolate leaves were present (Fehr et al. 1971) around mid to late June, and sampling continued through maturity. Two random 25-sweep samples were taken down a single row of each plot with a 15-inch sweep net (Kogan and Pitre 1980). Samples were then bagged, labeled, and frozen until pest and predator species could be identified and counted at a later date. The insect count data were analyzed using Proc GLM (SAS Institute 1990) for each date and for the entire season.

Samples were harvested from each plot in both years with a combine. A random section measuring 50 feet long and 6 feet wide was combined in each plot. The beans were cleaned and percent moisture and weight were recorded. Proc ANOVA was used to compare yield between treatments (SAS Institute 1990).

Results

Fire ant foraging. From the average rating of fire ant abundance on hotdog baits, the amount of fire ant foraging on the soil in the experimental plots can be inferred. The bait ratings are summarized in Table 2-1 for 2000 and Table 2-2 for 2001. The fire ant suppression treatments appear to have caused the desired effect because fire ant activity was much higher in the untreated control compared to the treated plots. The averages ranged from 2.5 (~75 ants) to 4.83 (200+ ants) in the untreated plots while the treated plots on average had no ants or very few ants attracted to the hotdog bait (Table 2-1 and 2-2).

Survival of sessile lepidopteran stages. In 2000, a strong treatment effect was observed for the recovery of artificially-placed soybean looper eggs. The untreated plots had significantly fewer ($P<0.0001$, Table 2-3) eggs 24 hrs. after placement than either of the fire ant suppression treatments. This overall pattern was seen on three of the four dates with only 6 July not being significant (although the mean recovery in the untreated plots was lowest even on this date).

In 2001, the same pattern of treatment effects was seen with corn earworm eggs, which were not placed in clumps as with looper eggs. The effects of treatments were more varied between specific dates. On 18 June egg recovery in the Amdro treated plots was significantly higher than recovery in the untreated or the Lorsban + Amdro plots. Significantly fewer eggs were recovered in the untreated plots had significantly lower recovery than in the Lorsban + Amdro treated plots on 7 August. Across all dates in

2001, the untreated plots had lower recovery of corn earworm eggs than either of the treated plots.

Percent recovery of soybean looper pupae was significantly lower in the untreated plots in comparison to the two fire ant suppression treatments (on foliage: F=14.67, P<0.0001, df=2,27; on ground: F=11.21, P=0.0007, df=2, 18, Table 2-5). Recovery of pupae was lower in all treatments for pupae placed on the ground (4.6-49.3%) when compared to pupae placed on the foliage (57.8-91.9%)(Table 2-5). Fire ants were directly observed on several occasions preying on pupae that had been left in the field.

Threecornered alfalfa hopper. In 2000, threecornered alfalfa hopper, *Spissistilus festinus* (Say), (TCAH) was significantly more abundant (F=3.15, P=0.0447, df=2, 218)(Table 2-6) in the Lorsban + Amdro treatment in comparison to the untreated which had the fewest. A similar trend was observed on most of the sampling dates but was not significant (Table 2-6). On 16 August significantly more TCAH were found in the Lorsban + Amdro plots than in the Amdro alone or the untreated plots (Table 2-6). On 13 September the Lorsban + Amdro treatment had significantly more TCAH than the plots with Amdro alone. TCAH populations peeked in late August at nearly 6 per 25 sweeps and again in late September to mid-October at 4.2-4.5 per 25 sweeps (Table 2-6). Table 2-7 records the means of TCAH captured in our samples for 2001. No treatment effects were seen for the entire season. On 21 August a significant treatment effect (P=0.0424) was seen but the Tukey's test failed to separate the means. It appears that the difference between the number of TCAH in the untreated plots versus the Amdro plots was very close to significant on this date. Similarly, on 28 August the Lorsban + Amdro plot harbored the highest counts of TCAH in comparison to the other treatments but was not separated by Tukey's (Table 2-7). Significantly higher numbers of TCAH were observed in the Amdro alone plots compared to the Lorsban + Amdro plots on 21 September (F=3.80, P=0.0527, 2,12). The untreated check appeared to be approaching significantly higher numbers of TCAH on the last sampling date, 25 September, in comparison to the other two treatments (Table 2-7). In 2001, TCAH numbers began rising in mid-August and peaked in mid-September at over 23 hoppers per 25 sweeps. No clear pattern was observed in the impact of the fire ant suppressive treatments when all the data was combined.

Whitefringed beetles. Whitefringed beetles, *Graphognathus spp.*, were rather uniformly abundant throughout the 2000 season and no discernible peak was observed (Table 2-8). No treatment effects were seen on the abundance of whitefringed beetles for the overall season. Additionally, the only statistically significant difference was observed on 27 July when the Lorsban + Amdro treatment had fewer beetles than the other treatments (Table 2-8). Whitefringed beetles were less abundant in 2001 and again no treatment effects were apparent when dates were combined for analysis. However, on the later sampling dates (12 September and after) when beetle numbers were declining, significantly more beetles were present in the Lorsban + Amdro plots (Table 2-9).

Grasshoppers. Grasshoppers were present in low numbers throughout the 2000 season. On 27 July, significantly fewer grasshoppers were collected in the Lorsban + Amdro treatment compared to the untreated plots (Table 2-10). No other date had a significant treatment effect. Grasshoppers were more abundant in the early season of 2001. Over all the dates, significantly fewer (F=13.31, P<0.0001, df=2, 285) grasshoppers were collected in the Lorsban + Amdro treated plots than the other two treatments.

Significantly lower numbers of grasshoppers also were present on five of the first six sampling dates (Table 2-11).

Stink bugs. Stink bugs were absent or present at very low population densities in all plots until mid-September 2000 and mid-August 2001. The southern green stink bug, *Nezara viridula* (L.), was the most common species when stink bugs were collected; however, some brown stink bugs, *Euschistus servus* (Say), and green stink bugs, *Acrosternum hilare* (Say), also were present. No overall treatment effects were observed for seasonal means either year (Tables 2-12 and 2-13), and only one sampling date (4 September 2001, Table 2-13) had significantly more stink bugs in the untreated plots than in the Lorsban + Amdro plots.

Green cloverworms. Green cloverworm, *Hypena scabra* (F.), numbers peaked in 2000 during early August, but larvae were present throughout the entire season (Table 2-14). When dates were combined for analysis, the untreated plots had more green cloverworms than the Lorsban + Amdro treatement ($F=3.21$, $P=0.0423$, $df=2, 218$) and the untreated plots tended to have more cloverworms than the Amdro alone treatment. This same pattern of treatment effects was seen on 10 August and 16 August when cloverworm abundance was highest (Table 2-14). In 2001, green cloverworms had a slight peak in numbers in early August and another higher peak in mid-September (Table 2-15). The Lorsban + Amdro treatment had significantly fewer cloverworms than the untreated plots on 9 August 2001, and on 4 September significantly more green cloverworms were collected in the Amdro treatment in comparison to the others (Table 2-15). The seasonal mean number of green cloverworms across all dates combined was not different between treatments in 2001 (Table 2-15).

Soybean loopers. Soybean loopers, *Pseudoplusia includens* Walker, were collected at our test sites beginning in mid-August and were present throughout the rest of the season in 2000. No treatment effects on the number of soybean loopers collected was apparent in 2000 by sampling date or pooled for the season (Table 2-16). In 2001, soybean loopers again were present from mid-August until crop maturity. On 21 August the Lorsban + Amdro treatment had significantly more loopers than the Amdro alone treatment (Table 2-17), but no other differences between treatments were noted.

Velvetbean caterpillars. Velvetbean caterpillars, *Anticarsia gemmatalis* Hubner, (VBC) peaked in late September in 2000 and again in early October (Table 2-18). The fire ant suppression treatments had no apparent effect on the number of VBCs captured in our sampling on any specific date or over all dates combined. In 2001 a much higher population of VBC colonized our test sites. Numbers of approximately 50 VBCs per 25 sweeps were collected on 12 September necessitating insecticidal intervention by the growers. As in 2000, no differences in treatments were apparent in our 2001 sampling (Table 2-19) even at economic threshold levels.

Spiders. Spiders, mainly *Peucetia viridans* Hentz, the green striped lynx spider, were found in the sweep samples from the beginning of sampling to the end of the season at relatively constant levels (Tables 2-20 and 2-21). In 2000, no difference in the number of spiders sampled was seen for any date or overall (Table 2-20). In 2001 when all dates were combined, the Lorsban + Amdro treatment had significantly lower spider populations ($F=4.22$, $P= 0.0156$, $df=2, 285$)(Table 2-21) than the other two treatments. This same trend was seen on most sampling dates but was significant only on 19 July ($F=3.94$, $P=0.0484$, $df=2, 12$)(Table 2-21).

Bigeyed bugs. The most commonly collected predaceous heteropteran by far was *Geocoris punctipes* (Say). In 2000, bigeyed bugs were most abundant on the first sampling date (5 July) then declined until late August and then peaked again on 21 September (Table 2-22), when the population of lepidopteran defoliators was present. No treatment effects on the number of bigeyed bugs were apparent in 2000 for specific dates or all dates combined. Bigeyed bugs also were present throughout the sampling period in 2001(Table 2-23) but were less abundant than in 2000. No treatment effects on bigeyed bugs were detected in 2001.

Damsel bugs. Damsel bug, *Nabis* spp., populations peaked twice at our test sites in 2000, an increase in August followed by a decline and a peak in mid-September (Table 2-24). This peak on 21 September coincides with the peak numbers of bigeyed bugs and lepidopteran defoliators. When dates were analyzed individually and combined, no treatment effects on damsel bugs were apparent in 2000. Damsel bugs peaked in late August in 2001 (Table 2-25) at the same time as soybean loopers. As was the case in 2000 no treatment effects were demonstrated in 2001, except on 26 July when more damsel bugs were present in the untreated control than in the treated plots (Table 2-25).

Lady beetles. Lady beetles were present at our test sites throughout the 2000 season and were most abundant in late August and late September (Table 2-26). When all dates were combined, the number of lady beetles collected from the untreated plots was significantly lower than the number collected from the Amdro treated plots ($F=3.69$, $P=0.0266$, $df=2, 218$). This trend was observed on most sampling dates and was significant on 19 July and 27 July (Table 2-26). Lady beetles were rare at our test sites in 2001 with only 25 individuals collected throughout the entire season.

Other Arthropods. Our sampling also captured various other arthropods throughout both years. Corn earworm, beet armyworm, various mirids were collected on occasion as well as two different cucumber beetles. Assasin bugs, pirate bugs, lacewings, and long legged flies were occasionally collected. None of these organisms occurred in sufficient numbers to analyze for treatment effects.

Soybean yield. In both years the Shannon farm outyielded the Bradford farm (Table 2-27). Soybean yield was low (12.7-19.3 bu/acre) in 2000. A better crop was produced in the wetter 2001 season with yields ranging from 20.3 bu/acre to 41.5 bu/acre (Table 27). In neither year were treatment effects on yield apparent (Table 2-27). Additionally, no differences in soybean stand density (# plants/meter) were detected among treatments in 2001 (not shown).

Discussion

The fire ant suppression treatments seemed to be effective in that fire ant foraging was decreased greatly in the treated areas. Differences between the untreated control and the treated plots, particularly the Amdro alone treatment, are most likely due to the difference in the abundance of foraging fire ant workers. The results of this study suggest that suppressing *S. invicta* foragers leads to increased survival of the sessile life stages of key lepidopteran pests of soybean. The impact of treatments on egg survival was more dramatic in the 2000 season when clumps of soybean looper eggs were placed in the field in comparison to the effect seen when individual eggs of the corn earworm were exposed in the different treatments in 2001. This suggests that prey items that are clumped together in close proximity are more susceptible to fire ant predation due to the nature of fire ant foraging and recruitment. Soybean looper pupae also were more frequently fed upon in the untreated plots where ant densities were higher. Pupal survival was dramatically lower when placed on the ground as opposed to on the soybean foliage, although a strong treatment effect was seen for each location. Soybean loopers do not pupate on the soil surface, but our results emphasize the importance of fire ants and other ground predators in the predation of ground pupating pests (e.g. velvetbean caterpillar and corn earworm). *S. invicta* may prove to be a useful natural enemy in managing pest populations that are regulated at the egg or pupal stage. Despite the decrease in egg and pupal predation in our treated plots there was no overall beneficial effect on the abundance of key soybean pests. Eubanks (2001) also reported that fire ants had no overall effect on lepidopteran larvae populations and discussed the cancellation of direct and indirect effects. Lepidopteran defense mechanisms such as falling off plants and flailing violently may be more successful in escaping ant predation within the architectural complexity of a crop field than previously thought. Stink bugs have been reported to have a defensive semiochemical that is particularly repellent to *Solenopsis* spp. (Pavis et. al 1994). Defense mechanisms evolved by insect herbivores to repel native predaceous ants are likely effective tactics against the introduced *S. invicta*.

It may be, as reported by Kidd and Apperson (1984), that fire ants rarely forage high in the soybean canopy. This coincides well with our observations in that rarely were ants observed in the upper plant foliage or collected in our sweep samples. It should be pointed out that fire ants may be more active in the late evening or at night within the plant canopy and temporally escaped our sampling method. Other factors such as intraguild predation cannot be overlooked in the apparent failure of fire ants to suppress key soybean arthropod pests as thoroughly discussed by Eubanks (2001). However, no differences were seen between treatments in the numbers of the predaceous bugs. Reilly and Sterling (1983) speculated that specific aromatic excretions of predaceous heteropterans proved effective in deterring ant attack. Lady beetles in 2000 were found in higher numbers in the fire ant-suppressed Amdro treatment. Our findings support the conclusion of Vinson and Scarborough (1991) that coccinellids may preferentially seek spaces with lower ant density.

The three cornered alfalfa hopper was the only pest sampled that had higher numbers in the fire ant suppressed plots, indicating *S. invicta* may be an important natural enemy of this species. However, this was seen only in 2000 and not in 2001 when hoppers were more abundant.

Our study demonstrates that season-long fire ant reduction did not impact soybean yield. This does not agree with literature that reported a dramatic negative impact on soybean yield in fire ant-infested areas. This should prompt closer investigation into the root-feeding and seed predation activities of ants in the crop and their ultimate impact of crop yield. At our test sites fire ants failed to build up large mounds never reaching a height greater than 6 in. This may have been a result of the sandy soil. Also, fire ant mounds caused no interference with harvesting machinery as reported by Adams et al. (1976).

Information gained through this study should prove useful to research and extension personnel trying to implement a biologically intensive IPM program for soybean and other crops in *S. invicta* infested areas.

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Table 2-1. Average rating of fire ant abundance on hot dog baits in soybeans containing three different treatments, Tift Co., GA, 2000.

	Untreated	Amdro 1.5lb/acre	Lorsban (1qt/acre) + Amdro 1.5lb/acre
6/23/00	3.11	0.39	0.00
6/29/00	3.11	0.22	0.00
7/6/00	3.86	0.57	0.11
7/12/00	3.27	0.00	0.22
7/19/00	3.83	0.39	0.72
7/27/00	2.78	0.28	0.00
8/3/00	2.78	0.33	0.00
8/10/00	2.39	0.28	0.61
8/16/00	3.33	1.00	0.83
8/24/00	4.83	1.67	0.17
9/7/00	2.92	0.58	0.25
9/25/00	2.50	1.00	0.58
All dates	3.22	0.56	0.29

Baits consisted of a ¼ inch slice of hot dog that was placed in the field at two sites per plot at approx. 7:45 AM and checked at 8:30 AM. The number of ants present at each bait was rated from 0 to 5 using the following scale: 0: 0 ants, 1: 1-10 ants, 2: 11-50 ants, 3: 51-100 ants; 4: 101-150 ants, and 5: >150 ants.

Table 2-2. Average rating of fire ant abundance on hot dog baits in soybeans containing three different treatments, Tift Co. GA, 2001.

	Untreated	Amdro 1.5lb/acre	Lorsban (1qt/acre) + Amdro 1.5 lb/acre
6/27/01	3.06	0.94	0.81
7/5/01	3.56	0.25	0.00
7/12/01	3.81	0.50	0.19
7/19/01	3.75	0.87	1.81
7/26/01	3.06	0.00	0.00
8/2/01	3.69	0.00	0.00
8/9/01	3.31	0.81	0.00
8/16/01	4.44	0.31	0.00
8/22/01	4.19	0.81	0.00
8/29/01	4.48	1.31	0.44
9/12/01	3.50	0.75	0.75
9/21/01	2.31	1.06	0.88
9/25/01	4.37	1.06	0.88
All dates	3.65	0.61	0.39

Baits consisted of a ¼ inch slice of hot dog that was placed in the field at two sites per plot at approx. 7:45 AM and checked at 8:30 AM. The number of ants present at each bait was rated from 0 to 5 using the following scale: 0: 0 ants, 1: 1-10 ants, 2: 11-50 ants, 3: 51-100 ants, 4: 101-150 ants, and 5: >150 ants.

Table 2-3. Mean percent recovery (± standard errors) of soybean looper eggs placed on soybean foliage for a 24 hour exposure in plots containing three different fire ant suppression treatments, Tift Co., GA. 2000.

Sampling date	Untreated	Amdro 1.5lb/acre	Lorsban 1qt/acre + Amdro 1.5lb/acre	F	P	df
6/28/00	16.5±6.3b	55.4±11.1a	61.0±8.9a	23.06	0.0005	2, 8
7/6/00	10.5±6.4a	16.7±7.4a	30.1±9.5a	2.09	0.1859	2, 8
7/12/00	28.2±7.8b	63.1±8.3a	56.0±6.9a	9.99	0.0067	2, 8
7/25/00	24.0±10.1b	40.7±12.0a	48.1±16.0a	14.39	0.0022	2, 8
All dates	19.9±3.9b	44.8±6.1a	49.2±5.8a	21.56	<.0001	2, 53

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test). Soybean looper eggs were placed in the soybean canopy 100 per plot in groups of ten. Ten eggs on paper were clipped to the soybean plant using a paper clip.

Table 2-4. Mean percent recovery (± standard errors) of corn earworm eggs placed on soybean foliage for a 24 hour exposure in plots containing three different fire ant suppression treatments, Tift Co., GA. 2001.

Sampling date	Untreated	Amdro 1.5lb/acre	Lorsban 1qt/acre + Amdro 1.5lb/acre	F	P	df
7/9/01	13.3±5.1a	22.1±6.2a	36.4±9.6a	2.81	0.1124	2, 9
7/18/01	3.5±0.5b	42.5±9.1a	15.8±4.0b	13.02	0.0022	2, 9
8/2/01	45.4±3.0a	43.5±7.1a	39.4±10.4a	0.20	0.8210	2, 6
8/7/01	7.5±2.9b	13.0±2.5ab	18.5±2.2a	4.66	0.0408	2, 9
All dates	15.8±4.5b	29.7±4.7a	26.9±4.2a	5.44	0.0091	2, 33

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test). Corn earworm eggs were placed in the soybean canopy 50 per plot using a bovine serum albumin solution as an adhesive.

Table 2-5. Mean percent recovery (± standard error) of soybean looper pupae after a 24 hour exposure in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000 and 2001.

Pupal location	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
On foliage*	57.8±10.5b	83.2±12.9a	91.9±9.9a	14.67	<.0001	2, 27
On ground**	4.6±4.6b	30.2±12.9a	49.3±18.0a	11.21	0.0007	2, 18

Treatment means for each location followed by the same letter are not significantly different (P<0.05, Tukey's studentized range test).

*pupae attached to diet cup lid by cocoon were placed on soybean foliage by attaching lid with paper clip to the underside of a leaf.

** exposed pupae or pupae in webbing on diet cup lid were placed on soil surface.

Table2-6. Mean number (± standard error) of threecornered alfalfa hoppers per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
12 July	0.2±0.1a	0.2±0.2a	0.2±0.2a	0.00	1.000	2,8
19 July	0.9±0.4a	0.6±0.2a	0.6±0.8a	0.43	0.6632	2, 8
27 July	0.3±0.2a	1.1±0.6a	1.0±0.4a	1.54	0.2724	2, 8
3 August	0.4±0.2a	0.7±0.2a	0.2±0.2a	1.46	0.2877	2,8
10 August	0.8±0.2a	0.4±0.1a	0.9±0.3a	0.91	0.4398	2, 8
16 August	2.9±0.6b	3.3±0.8b	5.9±0.7a	8.04	0.0122	2, 8
23 August	4.2±1.00a	3.2±0.8a	5.9±1.2a	2.91	0.1123	2, 8
29 August	3.1±0.8a	4.2±0.9a	5.2±0.5a	1.72	0.2389	2, 8
5 September	0.3±0.2a	1.2±0.7a	1.2±0.5a	1.61	0.2579	2, 8
13 September	1.1±0.4ab	0.5±0.2b	1.8±0.5a	4.83	0.0422	2, 8
21 September	3.4±1.0a	3.9±1.3a	4.2±1.1a	0.14	0.8677	2, 8
27 September	2.8±0.6a	3.1±0.8a	3.3±0.8a	0.15	0.8599	2, 8
3 October	3.3±1.0a	4.2±1.7a	3.1±1.3a	0.19	0.8267	2, 8
12 October	1.7±0.5a	4.6±2.5a	2.1±0.5a	1.31	0.3227	2, 8
Dates combined	1.7±0.2b	2.1±0.3ab	2.4±0.3a	3.15	0.0447	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-7. Mean number (± standard error) of threecornered alfalfa hoppers per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.1±0.1a	0.1±0.1a	0.2±0.3a	1.29	0.3119	2, 12
5 July	0.1±0.1a	0.2±0.1a	0.0±0.0a	2.63	0.1133	2, 12
12 July	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.30	0.7462	2, 12
19 July	0.1±0.1a	0.2±0.1a	0.1±0.1a	1.17	0.3444	2, 12
26 July	0.4±0.1a	0.3±0.2a	0.6±0.3a	0.90	0.4305	2, 12
2 August	0.9±0.3a	0.9±0.3a	0.8±0.3a	0.06	0.9452	2, 12
9 August	0.4±0.2a	0.3±0.2a	0.3±0.1a	0.15	0.8623	2, 12
14 August	2.4±0.6a	2.4±0.5a	2.4±0.6a	0.01	0.9914	2, 12
21 August	2.5±0.4a	1.6±0.4a	2.4±0.5a	4.16	0.0424	2, 12
28 August	6.2±1.8a	6.2±1.9a	9.6±4.1a	3.89	0.0498	2, 12
4 September	12.6±7.1a	23.4±14.6a	15.5±8.1a	1.63	0.2361	2, 12
12 September	18.0±7.6a	21.3±7.1a	23.2±7.6a	1.43	0.2765	2, 12
21 September	0.9±0.3a	1.5±0.5a	0.3±0.2a	3.80	0.0527	2, 12
25 September	4.4±1.5a	2.2±0.5a	2.2±0.8a	4.00	0.0467	2, 12
Dates combined	3.5±0.9a	4.3±1.3a	4.1±1.0a	0.23	0.7909	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-8. Mean number (± standard error) of whitefringed beetles per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	1.8±0.8a	1.4±0.6a	4.7±2.9a	1.45	0.2896	2, 8
12 July	0.9±0.4a	1.3±0.6a	0.8±0.3a	0.81	0.4802	2,8
19 July	2.1±0.8a	2.1±0.3a	1.2±0.4a	0.74	0.5052	2, 8
27 July	1.9±0.6ab	2.0±0.5a	0.1±0.1b	5.45	0.0321	2, 8
3 August	0.9±0.5a	2.5±1.4a	0.2±0.3a	3.28	0.0912	2,8
10 August	1.3±0.4a	0.7±0.4a	0.9±0.5a	0.72	0.5177	2, 8
16 August	1.8±0.8a	1.5±0.4a	2.5±0.9a	0.58	0.5839	2, 8
23 August	1.2±0.5a	1.0±0.9a	1.2±0.8a	0.28	0.7629	2, 8
29 August	1.2±0.6a	1.3±0.7a	0.4±0.2a	4.12	0.0589	2, 8
5 September	1.2±1.9a	3.1±2.1a	2.7±1.8a	1.31	0.3219	2, 8
13 September	0.8±0.3a	0.6±0.3a	1.2±0.5a	0.80	0.4809	2, 8
21 September	1.5±0.5a	2.5±0.5a	3.3±0.6a	3.81	0.0688	2, 8
27 September	1.5±0.6a	1.2±0.4a	1.4±0.6a	0.05	0.9501	2, 8
3 October	1.6±0.9a	2.5±1.00a	1.2±0.5a	3.09	0.1012	2, 8
12 October	0.8±0.3a	0.3±0.2a	0.2±0.1a	1.95	0.2036	2, 8
Dates combined	1.4±0.1a	1.6±0.2a	1.5±0.3a	0.32	0.7293	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-9. Mean number (± standard error) of whitefringed beetles per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.1±0.1a	0.4±0.2a	0.5±0.2a	3.77	0.0535	2, 12
5 July	0.2±0.1a	0.2±0.1a	0.0±0.0a	2.00	0.1780	2, 12
12 July	0.1±0.1a	0.3±0.2a	0.3±0.2a	0.87	0.4434	2, 12
19 July	0.2±0.1a	0.7±0.3a	0.1±0.1a	2.05	0.1711	2, 12
26 July	0.4±0.3a	0.2±0.1a	0.2±0.1a	0.60	0.5645	2, 12
2 August	0.8±0.2a	0.6±0.2a	0.4±0.2a	1.16	0.3471	2, 12
9 August	0.4±0.2a	0.4±0.2a	0.4±0.1a	0.06	0.9420	2, 12
14 August	0.7±0.3a	1.2±0.4a	0.9±0.3a	0.65	0.5418	2, 12
21 August	1.2±0.6a	1.4±0.6a	1.4±0.4a	0.06	0.9435	2, 12
28 August	1.9±0.7a	1.5±0.5a	1.4±0.3a	0.29	0.7542	2, 12
4 September	3.7±1.6a	2.1±0.8a	2.4±0.9a	1.83	0.2017	2, 12
12 September	1.6±0.4b	2.2±0.6b	3.5±1.00a	13.89	0.0008	2, 12
21 September	0.0±0.0b	0.0±0.0b	0.2±0.1a	9.00	0.0041	2, 12
25 September	0.1±0.1b	0.2±0.1ab	0.3±0.2a	4.50	0.0348	2, 12
Dates combined	0.8±0.2a	0.8±0.1a	0.9±0.1a	0.05	0.9484	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-10. Mean number (± standard error) of grasshoppers per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	0.7±0.2a	1.3±0.7a	0.3±0.3a	1.38	0.3062	2, 8
12 July	1.0±0.4a	0.4±0.1a	0.7±0.3a	0.92	0.4351	2,8
19 July	0.6±0.1a	0.4±0.1a	0.6±0.3a	0.17	0.8465	2, 8
27 July	0.6±0.3a	0.2±0.2ab	0.0±0.0b	4.35	0.0526	2, 8
3 August	0.2±0.2a	0.4±0.2a	0.1±0.1a	1.37	0.3082	2,8
10 August	0.6±0.4a	0.4±0.2a	0.1±0.1a	1.12	0.3725	2, 8
16 August	0.6±0.3a	0.2±0.1a	0.3±0.2a	1.09	0.3827	2, 8
23 August	0.3±0.2a	0.1±0.1a	0.7±0.4a	1.57	0.2651	2, 8
29 August	0.8±0.5a	1.9±1.7a	0.8±0.6a	0.59	0.5747	2, 8
5 September	0.2±0.1a	0.1±0.1a	0.2±0.1a	0.18	0.8371	2, 8
13 September	0.1±0.1a	0.3±0.2a	0.1±0.1a	0.75	0.5029	2, 8
21 September	0.2±0.1a	0.0±0.0a	0.1±0.1a	2.00	0.1975	2, 8
27 September	0.0±0.0a	0.1±0.1a	0.0±0.0a	1.00	0.4096	2, 8
3 October	0.0±0.0a	0.0±0.0a	0.2±0.1a	2.00	0.1975	2, 8
12 October	0.1±0.2a	0.2±0.1a	0.0±0.0a	0.86	0.4600	2, 8
Dates combined	0.4±0.1a	0.4±0.1a	0.3±0.1a	0.52	0.5954	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-11. Mean number (± standard error) of grasshoppers per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	2.0±0.9ab	2.1±0.9a	0.4±0.1b	4.98	0.0266	2, 12
5 July	5.2±2.2a	4.3±2.1ab	1.6±0.6b	4.00	0.0466	2, 12
12 July	4.2±1.6a	4.6±1.5a	1.9±0.6b	7.97	0.0063	2, 12
19 July	3.7±1.0a	3.6±0.8a	3.4±0.7a	0.10	0.9015	2, 12
26 July	2.1±0.6ab	2.9±1.1a	0.0±0.0b	6.00	0.0156	2, 12
2 August	1.8±0.5a	1.6±0.3a	0.2±0.1b	15.31	0.0005	2, 12
9 August	0.9±0.1a	1.0±0.5a	0.4±0.1a	3.41	0.0673	2, 12
14 August	1.6±0.4a	1.2±0.2a	0.9±0.2a	2.13	0.1614	2, 12
21 August	1.6±0.4a	1.8±0.5a	1.0±0.3a	2.66	0.1106	2, 12
28 August	1.9±0.7a	1.7±0.5a	0.9±0.5a	1.55	0.2526	2, 12
4 September	2.8±1.4a	3.3±1.3a	2.0±0.5a	1.27	0.3152	2, 12
12 September	2.8±1.1a	2.5±0.9a	2.1±0.6a	0.76	0.4869	2, 12
21 September	0.8±0.3a	0.7±0.3a	0.6±0.3a	0.28	0.7597	2, 12
25 September	1.2±0.4a	0.7±0.3a	0.4±0.2a	2.02	0.1748	2, 12
Dates combined	2.3±0.3a	2.3±0.3a	1.1±0.1b	13.31	<.0001	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-12. Mean number (± standard error) of stink bugs per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
12 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2,8
19 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
27 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
3 August	0.2±0.2a	0.1±0.1a	0.0±0.0a	1.00	0.4096	2,8
10 August	0.0±0.0a	0.0±0.0a	0.1±0.1a	1.00	0.4096	2, 8
16 August	0.1±0.1a	0.1±0.1a	0.2±0.2a	0.14	0.8690	2, 8
23 August	0.1±0.1a	0.1±0.1a	0.2±0.2a	0.80	0.4823	2, 8
29 August	0.0±0.0a	0.3±0.2a	0.5±0.3a	2.95	0.1099	2, 8
5 September	0.1±0.1a	0.0±0.0a	0.2±0.4a	0.50	0.6243	2, 8
13 September	0.7±0.5a	0.3±0.2a	0.1±0.1a	0.92	0.4351	2, 8
21 September	1.2±0.4a	0.9±0.4a	1.3±0.7a	0.26	0.7771	2, 8
27 September	2.0±0.6a	1.2±0.4a	1.5±0.3a	0.74	0.5081	2, 8
3 October	1. 3±0.4a	2.1±0.6a	1.1±1.5a	1.80	0.2262	2, 8
12 October	1.1±0.5a	0.6±0.5a	0.6±0.1a	0.37	0.7025	2, 8
Dates combined	0.4±0.1a	0.4±0.1a	0.4±0.1a	0.30	0.7885	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test). Stink bugs included southern green, brown, and green stink bugs combined.

Table 2-13. Mean number (± standard error) of stink bugs per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 12
5 July	0.1±0.1a	0.0±0.0a	0.0±0.0a	1.00	0.3966	2, 12
12 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 12
19 July	0.1±0.1a	0.0±0.0a	0.0±0.0a	.	.	2, 12
26 July	0.0±0.0a	0.1±0.1a	0.0±0.0a	1.00	0.3966	2, 12
2 August	0.1±0.1a	0.0±0.0a	0.0±0.0a	3.00	0.0878	2, 12
9 August	0.1±0.1a	0.1±0.0a	0.1±0.1a	0.43	0.6610	2, 12
14 August	0.2±0.2a	0.1±0.1a	0.2±0.1a	0.36	0.7050	2, 12
21 August	0.1±0.1a	0.0±0.0a	0.2±0.2a	1.26	0.3191	2, 12
28 August	0.4±0.1a	0.2±0.2a	0.7±0.2a	2.23	0.1503	2, 12
4 September	1.0±0.4a	0.8±0.4ab	0.2±0.1b	5.02	0.0260	2, 12
12 September	0.7±0.4a	0.7±0.3a	0.5±0.1a	0.20	0.8523	2, 12
21 September	0.4±0.2a	0.8±0.4a	1.0±0.4a	0.62	0.5525	2, 12
25 September	1.7±0.6a	1.1±0.3a	1.0±0.4a	0.80	0.4717	2, 12
Dates combined	0.3±0.1a	0.3±0.1a	0.3±0.6a	0.28	0.7552	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test). Stink bugs included southern green, brown, and green stink bugs combined.

Table 2-14. Mean number (± standard error) of green cloverworms per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	0.1±0.1a	0.4±0.2a	0.4±0.2a	1.03	0.3992	2, 8
12 July	0.0±0.0a	0.2±0.1a	0.0±0.0a	4.00	0.0625	2,8
19 July	0.2±0.1a	0.3±0.3a	0.4±0.3a	0.74	0.5085	2, 8
27 July	0.2±0.1a	0.0±0.0a	0.0±0.0a	1.00	0.4096	2, 8
3 August	0.8±0.6a	0.4±0.3a	0.1±0.1a	0.87	0.4546	2,8
10 August	5.2±1.6a	4.2±1.5ab	0.8±0.5b	6.43	0.0216	2, 8
16 August	2.4±1.3a	1.9±0.9ab	0.3±0.2b	7.68	0.0137	2, 8
23 August	0.8±0.5a	0.5±0.3a	0.1±0.1a	2.65	0.1307	2, 8
29 August	1.3±0.6a	1.3±0.8a	0.9±0.4a	0.39	0.6889	2, 8
5 September	0.5±0.4a	0.3±0.4a	0.5±0.3a	0.31	0.7435	2, 8
13 September	1.7±0.9a	1.8±1.0a	0.4±0.4a	1.54	0.2713	2, 8
21 September	2.6±1.2a	1.0±0.7a	2.8±1.5a	1.65	0.2515	2, 8
27 September	1.4±0.9a	0.2±0.2a	1.7±0.8a	2.47	0.1461	2, 8
3 October	0.0±0.0a	0.2±0.2a	0.1±0.1a	0.61	0.5675	2, 8
12 October	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
Dates combined	1.1±0.2a	0.9±0.2ab	0.6±0.1b	3.21	0.0423	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-15. Mean number (± standard error) of green cloverworms per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.0±0.0a	0.1±0.1a	0.0±0.0a	1.00	0.3966	2, 12
5 July	0.1±0.1a	0.0±0.0a	0.0±0.0a	1.00	0.3966	2, 12
12 July	0.0±0.0a	0.1±0.1a	0.1±0.1a	1.20	0.3349	2, 12
19 July	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.16	0.8557	2, 12
26 July	1.2±0.7a	1.2±0.5a	0.0±0.0a	2.83	0.0986	2, 12
2 August	1.1±0.5a	2.2±0.9a	0.2±0.2a	3.44	0.0658	2, 12
9 August	0.6±0.5ab	0.9±0.5a	0.0±0.0b	4.73	0.0306	2, 12
14 August	1.9±0.4a	0.7±0.3a	0.8±0.4a	2.53	0.1207	2, 12
21 August	2.4±0.5a	1.9±0.4a	2.2±0.6a	0.77	0.4847	2, 12
28 August	1.9±0.9a	1.6±0.5a	0.6±0.1a	2.72	0.1064	2, 12
4 September	0.4±0.2b	0.8±0.3a	0.4±0.2b	6.14	0.0146	2, 12
12 September	2.2±0.9a	4.1±2.1a	3.4±1.5a	1.07	0.3738	2, 12
21 September	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 12
25 September	0.0±0.0a	0.1±0.1a	0.0±0.0a	1.00	0.3966	2, 12
Dates combined	0.8±0.1a	1.0±0.2a	0.6±0.1a	2.19	0.1135	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-16. Mean number (± standard error) of soybean loopers per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
12 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
19 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
27 July	0.0±0.0a	0.8±0.8a	0.0±0.0a	1.00	0.4096	2, 8
3 August	0.0±0.0a	0.8±0.8a	0.0±0.0a	1.00	0.4096	2,8
10 August	0.0±0.0a	0.8±0.8a	0.2±0.1a	0.86	0.4600	2, 8
16 August	1.2±0.5a	1.0±0.4a	1.0±0.4a	0.20	0.8192	2, 8
23 August	1.7±0.9a	2.5±1.4a	2.7±1.2a	0.58	0.5798	2, 8
29 August	0.9±0.5a	1.1±0.4a	1.3±0.6a	0.26	0.7758	2, 8
5 September	1.7±0.7a	0.6±0.3a	1.2±0.5a	1.11	0.3764	2, 8
13 September	1.5±0.5a	1.3±0.6a	1.4±0.5a	0.03	0.9728	2, 8
21 September	1.7±0.5a	1.7±0.6a	1.3±0.5a	1.34	0.3137	2, 8
27 September	1.7±0.3a	1.7±0.4a	2.0±0.6a	0.34	0.7213	2, 8
3 October	1.2±0.4a	0.7±0.3a	1.1±0.2a	0.88	0.4533	2, 8
12 October	0.2±0.1a	0.2±0.1a	0.2±0.1a	0.25	0.7847	2, 8
Dates combined	0.7±0.5a	0.7±0.5a	0.8±0.1a	0.31	0.7305	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-17. Mean number (± standard error) of soybean loopers per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 12
5 July	0.0±0.0a	0.0±0.0a	0.1±0.1a	1.00	0.3966	2, 12
12 July	0.1±0.1a	0.0±0.0a	0.0±0.0a	1.00	0.3966	2, 12
19 July	0.0±0.0a	0.0±0.0a	0.1±0.1a	1.00	0.3966	2, 12
26 July	0.0±0.0a	0.1±0.1a	0.0±0.0a	1.00	0.3966	2, 12
2 August	0.0±0.0a	0.1±0.1a	0.0±0.0a	1.00	0.3966	2, 12
9 August	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 12
14 August	1.7±0.4a	1.0±0.3a	0.9±0.2a	3.69	0.0565	2, 12
21 August	1.7±0.4ab	1.1±0.3b	2.7±0.8a	4.06	0.0451	2, 12
28 August	5.6±1.0a	5.0±1.9a	4.4±1.2a	0.35	0.7113	2, 12
4 September	1.9±0.5a	2.0±0.6a	2.1±0.8a	0.05	0.9483	2, 12
12 September	1.4±0.1a	1.8±0.6a	1.2±0.2a	0.60	0.5664	2, 12
21 September	0.3±0.2a	0.4±0.2a	0.5±0.2a	0.30	0.7492	2, 12
25 September	1.1±0.3a	1.3±0.6a	0.5±0.2a	2.10	0.1652	2, 12
Dates combined	1.0±0.2a	0.9±0.2a	0.9±0.2a	0.17	0.8470	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-18. Mean number (± standard error) of velvetbean caterpillars per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
12 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
19 July	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 8
27 July	0.0±0.0a	0.0±0.0a	0.1±0.1a	1.00	0.4096	2, 8
3 August	0.2±0.2a	0.0±0.0a	0.0±0.0a	1.00	0.4096	2,8
10 August	0.6±0.4a	0.7±0.2a	0.4±0.1a	0.23	0.8000	2, 8
16 August	1.2±0.4a	0.9±0.6a	1.1±0.4a	0.15	0.8599	2, 8
23 August	0.8±0.3a	1.2±0.6a	0.7±0.3a	0.32	0.7329	2, 8
29 August	0.9±0.2a	0.4±0.1a	0.5±0.4a	1.82	0.2226	2, 8
5 September	0.7±0.4a	0.7±0.3a	1.4±1.0a	0.53	0.6105	2, 8
13 September	1.9±1.2a	0.9±0.8a	2.4±1.5a	0.46	0.6463	2, 8
21 September	6.2±1.4a	3.7±2.1a	7.6±4.2a	0.59	0.5758	2, 8
27 September	4.4±2.4a	2.3±1.3a	3.0±1.6a	0.56	0.5930	2, 8
3 October	7.2±3.2a	6.8±4.3a	5.5±3.1a	0.15	0.8617	2, 8
12 October	4.0±1.8a	3.2±1.8a	5.0±2.4a	0.50	0.6251	2, 8
Dates combined	1.9±0.4a	1.4±0.4a	1.8±0.5a	0.58	0.5629	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-19. Mean number (± standard error) of velvetbean caterpillars per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 12
5 July	0.0±0.0a	0.0±0.0a	0.1±0.1a	1.00	0.3966	2, 12
12 July	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.00	1.00	2, 12
19 July	0.1±0.1a	0.0±0.0a	0.1±0.1a	0.50	0.6186	2, 12
26 July	0.1±0.1a	0.1±0.1a	0.0±0.0a	0.50	0.6186	2, 12
2 August	0.1±0.1a	0.1±0.1a	0.0±0.0a	1.00	0.3966	2, 12
9 August	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 12
14 August	1.3±0.3a	0.9±0.3a	1.2±0.6a	0.19	0.8274	2, 12
21 August	2.5±0.9a	1.7±0.5a	1.6±0.4a	0.84	0.4543	2, 12
28 August	2.7±1.2a	1.9±0.9a	2.1±1.1a	0.36	0.7077	2, 12
4 September	1.0±0.5a	2.2±1.1a	0.6±0.2a	3.19	0.0776	2, 12
12 September	51.5±20.6a	49.2±18.9a	53.7±21.2a	0.23	0.7948	2, 12
21 September	0.1±0.1a	0.0±0.0a	0.0±0.0a	2.00	0.1780	2, 12
25 September	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.00	1.00	2, 12
Dates combined	4.2±1.9a	4.0±1.7a	4.2±1.9a	0.01	0.9911	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-20. Mean number (± standard error) of spiders per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	1.2±0.3a	1.0±0.4a	1.9±0.6a	1.58	0.2632	2, 8
12 July	1.2±0.5a	0.4±0.1a	0.7±0.2a	1.25	0.3380	2,8
19 July	1.1±0.4a	1.8±0.7a	1.1±0.4a	0.98	0.4176	2, 8
27 July	0.6±0.1a	0.7±0.2a	0.2±0.1a	1.17	0.3593	2, 8
3 August	0.7±0.5a	0.7±0.2a	0.4±0.2a	0.37	0.7006	2,8
10 August	1.1±0.4a	1.4±0.4a	0.7±0.4a	1.19	0.3541	2, 8
16 August	1.1±0.4a	1.3±0.4a	0.6±0.3a	1.10	0.3797	2, 8
23 August	1.0±0.3a	1.2±0.5a	0.6±0.2a	0.83	0.4705	2, 8
29 August	0.4±0.3a	0.6±0.3a	0.6±0.2a	0.17	0.8465	2, 8
5 September	0.5±0.2a	0.2±0.1a	0.2±0.1a	1.60	0.2603	2, 8
13 September	0.7±0.3a	0.4±0.1a	0.5±0.3a	0.24	0.7941	2, 8
21 September	0.2±0.2a	0.7±0.3a	0.9±0.1a	3.59	0.0773	2, 8
27 September	0.4±0.1a	0.7±0.3a	0.5±0.2a	0.81	0.4773	2, 8
3 October	1.3±0.2a	1.0±0.4a	0.7±0.4a	1.09	0.3819	2, 8
12 October	0.6±0.3a	0.3±0.2a	0.4±0.3a	0.40	0.6830	2, 8
Dates combined	0.8±0.1a	0.8±0.1a	0.7±0.1a	1.22	0.2987	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-21. Mean number (± standard error) of spiders per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.6±0.1a	0.4±0.1a	0.5±0.2a	0.44	0.6555	2, 12
5 July	1.0±0.3a	1.1±0.2a	0.4±0.1a	3.79	0.0529	2, 12
12 July	0.8±0.3a	1.9±0.5a	1.0±0.3a	2.68	0.1087	2, 12
19 July	2.4±0.3a	2.4±0.8a	1.0±0.2a	3.94	0.0484	2, 12
26 July	0.7±0.2a	1.0±0.2a	0.3±0.1a	2.71	0.1069	2, 12
2 August	0.6±0.1a	0.6±0.2a	0.4±0.3a	0.45	0.6480	2, 12
9 August	0.6±0.2a	0.5±0.2a	0.2±0.1a	1.90	0.1922	2, 12
14 August	1.0±0.1a	1.4±0.3a	1.0±0.3a	0.65	0.5392	2, 12
21 August	1.7±0.4a	1.7±0.3a	1.5±0.5a	0.27	0.7659	2, 12
28 August	1.5±0.6a	1.3±0.4a	1.0±0.2a	0.32	0.7344	2, 12
4 September	0.8±0.2a	1.3±0.3a	1.3±0.3a	0.94	0.4177	2, 12
12 September	1.2±0.4a	1.0±0.3a	1.1±0.3a	0.13	0.8781	2, 12
21 September	2.0±0.8a	1.1±0.5a	1.1±0.4a	1.53	0.2551	2, 12
25 September	0.6±0.2a	0.2±0.1a	0.2±0.4a	2.02	0.1751	2, 12
Dates combined	1.1±0.1a	1.1±1.1a	0.8±0.1b	4.22	0.0156	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-22. Mean number (± standard error) of bigeyed bugs per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	3.1±0.9a	2.8±1.6a	3.0±1.00a	0.02	0.9815	2, 8
12 July	0.7±0.4a	0.2±0.2ab	0.0±0.0b	4.67	0.0454	2,8
19 July	0.8±0.4a	0.5±0.1a	0.5±0.2a	0.74	0.5054	2, 8
27 July	0.4±0.2a	0.1±0.1a	0.2±0.2a	1.09	0.3811	2, 8
3 August	0.3±0.2a	0.1±0.1a	0.4±0.2a	2.36	0.1561	2,8
10 August	0.2±0.2a	0.2±0.1a	0.2±0.2a	0.09	0.9140	2, 8
16 August	0.6±0.2a	0.4±0.2a	1.0±0.5a	1.70	0.2433	2, 8
23 August	1.2±0.6a	2.0±0.6a	1.8±0.9a	0.37	0.7050	2, 8
29 August	0.7±0.9b	1.9±0.5a	0.4±0.1b	16.41	0.0015	2, 8
5 September	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.00	1.0000	2, 8
13 September	0.3±0.2a	0.2±0.1a	0.6±0.3a	3.45	0.0829	2, 8
21 September	2.4±0.6a	1.7±0.4a	2.4±0.5a	0.90	0.441	2, 8
27 September	0.5±0.3a	0.2±0.1a	0.6±0.2a	0.74	0.5085	2, 8
3 October	0.2±0.1a	0.7±0.5a	0.2±0.2a	0.45	0.6549	2, 8
12 October	0.5±0.3a	0.1±0.1a	0.3±0.2a	0.95	0.4264	2, 8
Dates combined	0.8±0.1a	0.7±0.1a	0.8±0.1a	0.09	0.9123	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-23. Mean number (± standard error) of bigeyed bugs per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.1±0.1a	0.0±0.0a	0.1±0.1a	0.43	0.6610	2, 12
5 July	0.1±0.1a	0.1±0.1a	0.3±0.1a	2.17	0.1573	2, 12
12 July	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.27	0.7659	2, 12
19 July	0.0±0.0a	0.1±0.1a	0.1±0.1a	1.29	0.3119	2, 12
26 July	0.2±0.4a	0.0±0.0a	0.0±0.0a	2.45	0.1278	2, 12
2 August	0.0±0.0a	0.2±0.2a	0.0±0.0a	2.00	0.1780	2, 12
9 August	0.0±0.0a	0.1±0.1a	0.0±0.0a	1.00	0.3966	2, 12
14 August	0.1±0.1a	0.2±0.1a	0.2±0.1a	2.33	0.1393	2, 12
21 August	0.4±0.2a	0.4±0.2a	0.3±0.1a	0.17	0.8431	2, 12
28 August	0.6±0.2a	0.5±0.2a	0.4±0.1a	0.13	0.8805	2, 12
4 September	0.1±0.1a	0.1±0.1a	0.1±0.1a	0.11	0.8957	2, 12
12 September	0.4±0.2a	0.3±0.1a	0.4±0.4a	0.05	0.9529	2, 12
21 September	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 12
25 September	0.2±0.1a	0.2±0.1a	0.2±0.2a	0.08	0.9206	2, 12
Dates combined	0.1±0.3a	0.2±0.0a	0.2±0.0a	0.05	0.9537	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-24. Mean number (± standard error) of damsel bugs per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	0.2±0.2a	0.2±0.1a	0.6±0.3a	1.09	0.3823	2, 8
12 July	0.0±0.0a	0.2±0.1a	0.2±0.1a	1.60	0.2603	2,8
19 July	0.2±0.2a	0.7±0.3a	0.6±0.4a	1.37	0.3088	2, 8
27 July	0.1±0.1a	0.0±0.0a	0.1±0.1a	0.40	0.6830	2, 8
3 August	0.4±0.2a	0.0±0.0a	0.3±0.2a	2.80	0.1197	2,8
10 August	0.3±0.2a	0.2±0.2a	0.2±0.1a	0.57	0.5862	2, 8
16 August	1.1±0.3a	1.1±0.4a	0.3±0.2a	3.60	0.0767	2, 8
23 August	1.8±0.2a	1.7±0.4a	1.2±0.2a	1.27	0.3323	2, 8
29 August	1.4±0.6a	1.1±0.6a	0.7±0.3a	0.62	0.5603	2, 8
5 September	0.2±0.1a	0.2±0.1a	0.2±0.1a	0.00	1.00	2, 8
13 September	0.7±0.4a	0.5±0.2a	0.2±0.2a	0.58	0.5795	2, 8
21 September	2.7±0.7a	2.1±0.9a	3.7±1.2a	3.47	0.0820	2, 8
27 September	1.8±0.8a	1.5±0.7a	1.9±0.7a	0.14	0.8678	2, 8
3 October	1.8±0.6a	1.5±0.4a	3.3±1.4a	3.00	0.1068	2, 8
12 October	0.2±0.2a	0.7±0.3a	0.4±0.2a	0.90	0.4429	2, 8
Dates combined	0.9±0.1a	0.8±0.1a	0.9±0.2a	0.56	0.5718	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-25. Mean number (± standard error) of damsel bugs per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre+ Amdro 1.5 lb/acre	F	P	df
27 June	0.0±0.0a	0.0±0.0a	0.1±0.1a	2.00	0.1780	2, 12
5 July	0.0±0.0a	0.2±0.1a	0.1±0.1a	1.31	0.3051	2, 12
12 July	0.1±0.1a	0.2±0.1a	0.4±0.1a	1.39	0.2858	2, 12
19 July	0.1±0.1a	0.3±0.1a	0.2±0.4a	1.50	0.2621	2, 12
26 July	0.2±0.1a	0.1±0.1b	0.1±0.1b	9.00	0.0041	2, 12
2 August	0.0±0.0a	0.1±0.1a	0.0±0.0a	2.00	0.1780	2, 12
9 August	0.0±0.0a	0.0±0.0a	0.1±0.1a	1.00	0.3966	2, 12
14 August	0.6±0.2a	0.6±0.2a	0.5±0.2a	0.14	0.8721	2, 12
21 August	1.1±0.4a	0.5±0.2a	1.3±0.4a	3.09	0.0825	2, 12
28 August	2.9±0.9a	4.7±1.8a	2.6±0.6a	1.62	0.2392	2, 12
4 September	0.8±0.4a	0.6±0.2a	0.5±0.2a	1.15	0.3505	2, 12
12 September	1.4±0.6a	0.9±0.2a	1.1±0.5a	0.57	0.5783	2, 12
21 September	0.2±0.2a	0.2±0.1a	0.0±0.0a	2.00	0.1780	2, 12
25 September	0.2±0.1a	0.1±0.1a	0.1±0.1a	0.90	0.4323	2, 12
Dates combined	0.5±0.1a	0.6±0.2a	0.5±0.1a	0.30	0.7406`	2, 285

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-26. Mean number (± standard error) of lady beetles per 25 sweeps in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1 qt/acre + Amdro 1.5 lb/acre	F	P	df
5 July	0.2±0.1a	0.3±0.2a	0.0±0.0a	2.36	0.1561	2, 8
12 July	0.1±0.1a	0.2±0.2a	0.1±0.1a	0.18	0.8371	2,8
19 July	0.0±0.0b	0.6±0.1a	0.6±0.2a	8.91	0.0092	2, 8
27 July	0.2±0.1b	1.4±0.4a	1.7±0.7a	9.30	0.0082	2, 8
3 August	0.2±0.2a	0.8±0.4a	1.9±1.4a	1.51	0.2768	2,8
10 August	0.3±0.2a	0.3±0.2a	0.7±0.3a	1.10	0.3774	2, 8
16 August	0.8±0.5a	0.8±0.2a	1.4±0.8a	1.58	0.2639	2, 8
23 August	0.8±0.6a	2.1±1.00a	1.4±0.7a	0.64	0.5511	2, 8
29 August	0.4±0.3a	0.6±0.2a	0.7±0.4a	0.26	0.7807	2, 8
5 September	0.3±0.2a	0.3±0.3a	0.2±0.1a	0.21	0.8145	2, 8
13 September	1.0±0.7a	0.3±0.2a	1.2±0.6a	0.44	0.6609	2, 8
21 September	2.2±1.0a	3.9±1.2a	3.8±1.4a	1.17	0.3572	2, 8
27 September	2.5±0.9a	7.0±2.5a	5.3±1.5a	3.57	0.0780	2, 8
3 October	3.3±0.5a	3.6±1.0a	3.0±0.9a	0.11	0.8986	2, 8
12 October	1.5±0.7a	1.1±0.4a	1.3±0.2a	0.33	0.7299	2, 8
Dates combined	0.9±0.2b	1.6±0.3a	1.5±0.2ab	3.69	0.0266	2, 218

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

Table 2-27. Yield (bushels/acre) in three different fire ant suppression treatments applied in soybean at two sites, Tift Co. GA, 2000 and 2001.

Test site	Untreated	Amdro 1.5 lb/acre	Lorsban 1qt/acre+ Amdro 1.5 lb/acre	F	P	df
			2000			
Bradford	13.1±2.9a	11.8±2.9a	12.6±1.1a	0.11	0.9027	2, 4
Shannon	19.3±1.9a	19.6±4.9a	17.3±2.0a	0.52	0.6319	2, 4
			2001			
Bradford	22.0±1.8a	22.3±3.7a	20.3±1.9a	0.27	0.7713	2, 6
Shannon	41.5±2.00a	39.4±3.6a	33.9±4.6a	1.12	0.3866	2, 6

Treatment means for each site and year followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

CHAPTER 3

THE IMPACT OF *SOLENOPSIS INVICTA* BUREN ON GROUND PREDATORS IN GEORGIA SOYBEANS[1]

[1] Seagraves, M. P. and R. M. McPherson. To be submitted to Environmental Entomology.

Abstract

The red imported fire ant, *Solenopsis invicta* Buren, has been reported to contribute to the biological control of key soybean pests. However, *S. invicta* may negatively affect other ground dwelling natural enemies such as ground beetles and earwigs. Information on the compatibility between natural enemies is key for anticipating the success of biological control in agricultural cropping systems with multiple interacting entomophagous species. Ground arthropods were monitored in soybean using pitfall traps in the 2000 and 2001 growing seasons to determine their response to selected fire ant controls. Three treatments were examined: (1) an untreated check, (2) Amdro (hydramethylnon) bait, and chlorpyriphos in combination with Amdro. Fire ant capture in pitfall traps was much lower in the treatments as opposed to the untreated control. Reduced fire ant density plus chemical treatment impacted the abundance of some ground predators. Spiders were often significantly more abundant in the untreated fire ant control plots, wheras the earwig *Labidura riparia* Pallas was more abundant in the chlorpyriphos and Amdro plots presumably due to the removal of natural enemies, particularly fire ants. This soybean study supports the assumption that spiders are compatible with fire ants as natural enemies and that earwigs are not. Additionally, lesser cornstalk borer, *Elasmopalpus lignosellus* Zeller, numbers were not affected by the removal of fire ant predation or the chemical treatments

Key words: Red imported fire ant, *Solenopsis invicta*, *Glycine max*, *Labidura raparia,* arthropod ground predators, natural enemy interactions.

The red imported fire ant, *Solenopsis invicta* Buren, is considered a pest due to the medical risk presented to man and livestock, damage to structures, and detrimental effects on native fauna (Taber 2000, Lofgren 1986). However, beneficial aspects of *S. invicta* have been reported in the area of agricultural pest management. The impact of *S. invicta* predation on the boll weevil in cotton has been well documented, and in some years *S. invicta* prevents economic damage from the boll weevil in east Texas (Sterling et al. 1984, Sterling 1978). Ants have been observed attacking all stages of the sugarcane borer, *Diatraea saccharalis* F. (Negm and Hensley 1969). When sugarcane was treated with the fire ant insesticide bait Mirex, borer infestation levels increased by 53% and damage increased by 69%, these changes were attributed to the decrease in *S. invicta* numbers in treated plots (Reagan et al. 1972). However other experiments indicate that native ants are more important in sugarcane borer suppression (Adams et al. 1981).

Sterling et al. (1979) reported that *S. invicta,* even at high densities, did not negatively impact natural enemies in cotton. However it has been widely reported that *S. invicta* preys on natural enemies of crop pests or reduces their effectiveness by disturbing them (Lopez 1982, Vinson and Scarborough 1989, 1991, Tedders et al. 1990, Eubanks 2001).

Soybean fields in the southern United States are often heavily infested with *S. invicta*, with a range of 22.2-207.5 active mounds per ha (Banks et al. 1990). The number of active mounds is reduced with conventional tillage (Morrill and Greene 1975). With the increasing adoption of conservation tillage, abundance of fire ants could increase in crop fields. *S. invicta* has been reported to be an important predator of key soybean pests such as stink bugs and the velvetbean caterpillar (Krispyn and Todd 1982, Stam et al. 1987, Elvin et al. 1983). Kidd and Apperson (1984) concluded that fire ants forage mainly on the soil surface and rarely forage higher than 20 cm on soybean plants.

The ground arthropod predator complex in soybeans consists mainly of earwigs, ground beetles, tiger beetles, along with ants usually dominated by *S. invicta*. Predation by this complex is the main biotic mortality source for pupae of the velvetbean caterpillar in Louisiana soybeans (Lee et al. 1990). *S. invicta* was the main predator in this assemblage, accounting for 77.5 to 96.5% of all predation on velvetbean caterpillar pupae. Decreased numbers of ground predators, namely fire ants, in heptachlor-treated soybeans led to higher numbers of velvetbean caterpillar and green cloverworm larvae (Brown and Goyer 1982). Brown and Goyer (1982) also noted that fire ants were observed preying on carabid larvae, and that there were significantly more ground beetles in plots where fire ants were suppressed. Lee et al. (1990) also observed higher numbers of the carabid beetles *Calosoma alternans sayi* Dejean and *Pterostichus chalcites* Say, and the striped earwig, *Labidura riparia* Pallas, in fire ant suppressed plots. Similarly, Gross and Spink (1969) reported higher numbers of *L. riparia* in yards and fields that had been treated with heptachlor and mirex, both of which are highly toxic to fire ants.

The literature suggests that while fire ants are important natural enemies of pests they may also interfere with other ground predators. The objective of the present investigation was to elucidate the relationship between fire ants and other predatory ground arthropods in soybeans. This project was designed to examine the response of soybean ground arthropods to selected fire ant suppression treatments.

Methods

Tests were conducted at two private farms (Bradford and Shannon) in Tift, Co. Georgia in 2000 and 2001. These sites were utilized because reduced tillage was practiced at both locations, and tillage is reported to suppress the number of active fire ant colonies (Morrill and Greene 1975).

Soybeans (Deltapine 6200 RR) were planted into wheat stubble with a no-till drill planter with 7 in. row spacing at the Bradford farm on 7 June 2000. At the Shannon farm, soybeans (Northern King RR) were planted on 14 June 2000 in 6 ft. beds with 36 in. row spacing with a strip-till planter into rye stubble. Glyphosate (Roundup ultra, Monsanto Corp.) was applied at both locations for weed control approximately two weeks after planting. Soybeans were planted on the same two farms for the 2001 growing season (Shannon on 4 June 2001 and Bradford on 11 June 2001) with identical cultural practices, except the Shannon farm was planted into a fallow field after herbicide burndown instead of into rye stubble, as the year before. The test sites were partitioned into plots that averaged 0.8 acres each and the plots were assigned to one of three treatments: (1) Untreated/control, (2) Amdro (hydramethylnon) bait broadcast at 1.5lbs/acre, or (3) broadcast applications of Lorsban (chlorpyriphos) (1 qt/acre) + Amdro (1.5 lbs./acre). Amdro was applied with a hand spreader over the entire Amdro-treated plot; however, a 15 ft untreated border was left on all 4 edges to try and minimize overlap of treatment effects on foraging ant populations. Chlorpyriphos (Lorsban 4E) was applied at 1 qt./acre over the entire designated area of the Lorsban-treated plots. Treatments were arranged into a randomized block design with three replications at each farm in 2000 and four replications in 2001.

Amdro was applied five days after planting in both fields in 2000 and again in early July when fire ants were detected at low numbers in the treated plots. The Lorsban applications were made with a tractor-mounted sprayer in appropriate plots two days after the Amdro applications. In 2001 initial treatments of Amdro and Lorsban were made just after planting. The Shannon farm received another application of Amdro on 28 June since fire ants were detected in treated plots. Both farms were retreated with Amdro on 28 June and chlorpyriphos on 23 July to assure fire ant suppression in the treated plots. A late season (mid-September) application of Dimilin and Boron was applied to the Shannon farm in 2000 for control of velvetbean caterpillars. In 2001, late season applications of Karate (Shannon farm) and Scout (Bradford farm) were made to control pests. No other pesticides were applied on either farm or either year.

Ground arthropods were monitored in the experimental plots using pitfall traps. Traps were constructed by placing a 500 ml plastic cup into the ground into which an identical container was placed so that its lip was flush with the ground. To the inner cup 200 ml of ethylene glycol and 100 ml of water was added to kill and preserve captured specimens. A section of roofing shingle propped up with heavy nails on the 4 corners provided a barrier to flooding and debris. Two traps were randomly placed in the interior of each plot at least 50 ft from the edges. Traps remained in the field for seven days, then the inner cup was removed, capped, labeled and returned to the lab where arthropods were identified and counted. In 2000, three weekly collections were obtained from each farm between late July and late August. In 2001, four weekly samples were collected between late June and late August. Insect counts for each species and each date and for the overall season were analyzed using GLM procedure (SAS Institute 1990). Differences in means were separated using Tukey's studentized range test.

Results

Fire ants. The seasonal mean number of *S. invicta* individuals captured in pitfall traps differed significantly between treatments for both years (Table 3-1, 2000 $F=9.89$, $P=0.0003$, $df=2, 38$; 2001 $F=23.40$, $P<0.0001$, $df=2, 75$), with more ants trapped in the untreated plots than the treated plots. In both years, the highest mean number of fire ants caught in the pitfall traps occurred in the untreated plots on every sampling date (Table 3-2). In 2000, treatment effects differed on the sampling dates (Table 3-2), although a clear trend was seen on all dates that fire ants were more abundant in the plots not treated with Amdro or Lorsban + Amdro. In 2001, significantly more fire ants were captured in the untreated plots than either of the treated plots on all sampling dates besides the first (26 June). A great deal of variation existed in the number of ants captured in the untreated plots in late August. In 2000, this date was when the greatest number of fire ants were captured in our traps; however, this time of year was when the lowest numbers of ants were captured in 2001.

Spiders. In the 2000 season, significantly more spiders were captured in the untreated plots in comparison to the plots treated with fire ant suppression insecticides ($F=11.94$, $P<0.0001$, $df=2, 38$, Table 3-1). Treatment differences were apparent on the first two sampling dates in 2000 (Table 3-3); however, on the last date (20 August) no differences between treatments were detected. In 2001, numbers of spiders captured did not differ among treatments on any sampling date (Table 3-3). However, on most dates there tended to be a lower mean spider capture ($P= 0.06$-0.07) in the chlorpyriphos + Amdro treatment than the untreated and Amdro plots. When the spider catch was analyzed over all of the 2001 sampling dates, the chlorpyriphos + Amdro treatment was significantly lower than the other two treatments (F=4.51, P=0.0142, df=2, 75). Spider populations appeared to remain relatively constant throughout both seasons.

Predaceous beetles. This predaceous group consisted almost entirely of ground beetles (Carabidae), but included an occasional tiger beetle (Cicindellidae) and rove beetle (Staphylinidae). In neither year were any differences in seasonal mean pitfall capture of predaceous beetles detected between treatments (Table 3-1) (2000, F=0.13, P=0.8752, df=2, 38; 2001, F=1.71, P=0.1879, df=2, 75), nor were any differences among treatments found on any individual sampling date on either year (Table 3-4). In 2000, numbers of predaceous beetles appeared to be relatively constant until late August, when numbers were lower in many plots. With more sampling dates spread over more time in 2001, the capture data indicate there was a peak of beetle numbers in the middle of July (Table 3-4).

Earwigs. Although a rare specimen of Carcinophoridae was captured on occasion, the predominate earwig captured at our study sites was *Labidura riparia* Pallas, the striped earwig. In 2000, significantly more earwigs were captured in the chlorpyriphos + Amdro treatment than in the untreated plots (Table 3-1)(F=7.17, P=0.0023, df=2, 38). This same pattern between earwig capture and treatments was seen on all sampling dates in 2000, but was significant only on 20 August (Table 3-5). In 2001, a similar overall pattern was seen with earwig capture, as the number captured in the chlorpyriphos + Amdro treatment was significantly greater than the number captured in the untreated plots (F=6.55, P=0.0024, df=2, 75). This difference between treatments was apparent on three of the four individual sampling dates as well (Table 3-5). In 2001 there were significantly more earwigs at the Bradford farm than the Shannon farm (F=32.03, P<0.0001, df=1, 75). As previously mentioned, there was a difference in cultural practices between these two farm sites. At the Bradford site, soybeans followed a wheat crop and at the Shannon site, soybeans followed herbicide treatment in a fallow field. Table 3-6 presents the means for earwigs caught per trap on each sampling date at the two study sites in 2001. Very few earwigs were present throughout 2001 at the Shannon farm (ranged from 0 to 4.1 per trap), however the difference between the chlorpyriphos + Amdro treatment and the untreated plots was statistically significant on 22 August. At the Bradford farm, where earwigs were much more abundant, a treatment effect was significant on the three later sampling dates. When earwig capture is looked at for all dates combined on the Bradford farm, the Amdro alone and chlorpyriphos + Amdro treatments were significantly greater than the untreated one (Table 3-6). At both locations, earwig abundance tended to increase throughout the season with the lowest numbers being captured on the first sampling date and the highest on the later sampling dates.

Lesser cornstalk borer. Lesser cornstalk borer *Elasmopalpus lignosellus* Zeller (Lepidoptera: Pyralidae), larvae were captured in pitfall traps in 2000 but not in 2001. This coincides with lesser cornstalk borer outbreaks that were occurring in Tift Co. during the dryer conditions of 2000, whereas the wetter 2001 season had no borer infestations. Most borers were captured on the first sampling date 24 July 2000 (Table 3-7) and there was characteristic borer damage (plants breaking at soil surface and wilting) at that time. No treatment differences were detected for the 2000 season (F=0.05, P=0.9555, df=2, 38), nor were any differences were observed on any sampling date (Table 3-7).

Others. Crickets (Orthoptera: Gryllidae) were abundant at both sites and both years, but no differences between treatments were detected. Mole crickets (Orthoptera: Gryllotalpidae) were not abundant during this study and only 8 were captured in total. On two occasions, fire ants were observed consuming a dead mole cricket at our study sites (personal observation). Click beetle adults (Coleoptera: Elateridae), scarab beetle adults (Coleoptera: Scarabaeidae), and false darkling beetle adults (Coleoptera: Melandryidae) were often captured in abundance in our pitfall traps but no differences were seen between treatments or dates for any of these species.

Discussion

The fire ant suppression insecticide treatments did elicit a change in the composition of the ground predator assemblage. Fire ants were suppressed in both the Amdro and Amdro + chlorpyriphos treatments relative to the untreated check. In both years, the highest numbers of spiders were captured in untreated plots. It appears that spider abundance is not negatively impacted by fire ant presence and at times spiders are more numerous in areas of high fire ant density. This may be due to a specific defensive behavior (standing motionless and avoiding detection) that spiders undertake in the presence of ants (M. D. Eubanks, personal communication). This suggests that spiders and fire ants may be compatible as natural enemies in soybean and other crops. In our study, we saw no difference in carabid beetle numbers between treatments, although Brown and Goyer (1982) and Lee et al. (1990) observed higher populations of ground beetles in fire ant suppressed plots. When earwigs where abundant, higher numbers were found in the plots treated with chlorpyriphos and Amdro bait in comparison to the untreated areas. This is likely due to a decrease in earwig natural enemies in the treated plots of which fire ants seem important. This is inferred since no difference was seen between the chlorpyriphos + Amdro treatment and the Amdro alone treatment. This agrees with the results reported by Gross and Spink (1969) that earwigs were more abundant in areas that had been treated to suppress fire ants. Additionally, cultural practices may have impacted earwig numbers in our study although these observations are limited. Notably, very few earwigs were captured in our sampling in soybeans planted into a field that had no cover crop or wheat double crop. The importance of earwigs in contributing to biological control of agricultural pests has not been well quantified, but we conclude that earwigs and *S. invicta* are not compatible because earwig numbers are inversely related to the number of fire ants.

The change in the ground predator assemblage due to fire ant suppression insecticides did not impact populations of lesser cornstalk borer in 2000 the only year with sufficient numbers to evaluate. Additionally, foliar pests such as caterpillars and stink bugs were not affected by the insecticide treatments and the subsequent changes in the ground predator complex (Chapter 2). Although *S. invicta* negatively impacts some natural enemies (i.e., earwigs), fire ants appear to be compatible and at times were positively correlated with higher numbers of ground-dwelling spiders. Our data presented here should provide information that will be useful in the implementation of biological control by fire ants and other ground predators in integrated pest management strategies for soybean and other crops throughout the range of *S. invicta*.

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Table 3-1. Seasonal means (± standard errors) of ground arthropod predators captured per pitfall trap in three different fire ant suppression treatments applied in soybean Tift Co. GA, 2000 and 2001.

Predator Sampled	Untreated	Amdro 1.5 lb/acre	Lorsban 1qt/acre + Amdro 1.5 lb/acre
		2000	
Fire ants	33.2±8.8a	2.6±0.6b	5.5±2.1b
Spiders	5.8±0.6a	3.5±0.5b	2.2±0.4b
Predatory Beetles*	3.0±0.9a	3.3±0.5a	2.9±0.9a
Earwigs**	5.0±1.4b	9.5±3.1ab	15.2±3.9a
		2001	
Fire ants	19.5±3.4a	3.6±0.7b	3.6±1.1b
Spiders	3.1±0.5a	2.7±0.5a	1.8±0.3b
Predatory Beetles*	5.0±1.4a	4.4±0.9a	2.9±0.7a
Earwigs**	3.2±1.1b	11.6±4.1ab	17.2±3.0a

Treatment means within rows followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

* Mostly Carabidae but includes some Ciccindellidae and Staphylinidae.

** Almost entirely *Labidura riparia* Pallas, the striped earwig, with occasional individuals of Carcinophoridae.

Table 3-2. Mean number (± standard errors) of fire ants captured per pitfall trap in three different fire ant suppression treatments applied in soybean Tift Co. GA, 2000 and 2001

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1qt/acre + Amdro 1.5 lb/acre	F	P	df
			2000			
7/24/00*	22.7±2.6a	3.3±1.4b	7.4±4.2b	17.27	0.001	2,8
8/7/00	26.2±13.1a	2.3±1.1a	0.1±0.1a	4.92	0.040	2,8
8/20/00	51.5±22.5a	1.3±0.6b	9.0±4.5ab	5.98	0.026	2,8
			2001			
6/26/01	20.6±7.1a	6.1±2.0a	8.9±3.6a	3.65	0.057	2,12
7/16/01	28.1±7.8a	4.7±1.5b	4.7±1.4b	7.69	0.007	2,12
8/7/01	21.6±7.8a	2.2±0.7b	0.2±0.2b	7.53	0.008	2,12
8/22/01	7.6±1.7a	1.4±0.8b	0.6±0.3b	16.49	0.0004	2,12

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

* Dates indicate when traps were retrieved, traps were placed in field one week prior to retrieval.

Table 3-3. Mean number (± standard errors) of spiders captured per pitfall trap in three different fire ant suppression treatments applied in soybean, Tift Co. GA., 2000 and 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1qt/acre + Amdro 1.5 lb/acre	F	P	df
			2000			
7/24/00*	5.3±1.00a	3.0±1.2b	2.7±1.0b	8.27	0.0113	2, 8
8/7/00	7.1±1.2a	3.0±0.5b	1.2±0.4b	17.69	0.0012	2, 8
8/20/00	4.9±1.1a	4.7±0.9a	2.7±0.8a	1.58	0.2647	2, 8
			2001			
6/26/01	4.4±1.7a	4.9±1.5a	2.6±0.9a	3.23	0.0757	2, 12
7/16/01	3.5±0.7a	3.7±0.6a	2.4±0.7a	1.09	0.3676	2, 12
8/7/01	1.9±0.4a	1.7±0.5a	0.7±0.2a	3.45	0.0656	2, 12
8/22/01	2.6±0.6a	1.8±0.3a	1.4±0.3a	3.26	0.0738	2, 12

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

* Dates indicate when traps were retrieved; traps were placed in the field one week prior to retrieval.

Table 3-4. Mean number (± standard errors) of predaceous beetles captured per pitfall trap in three different fire ant suppression treatments applied in soybean Tift Co. GA., 2000 and 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1qt/acre + Amdro 1.5 lb/acre	F	P	df
			2000			
7/24/00*	3.8±1.6a	4.0±0.8a	2.1±0.9a	0.84	0.4664	2, 8
8/7/00	4.3±1.9a	3.7±1.0a	3.4±2.3a	0.19	0.8289	2,8
8/20/00	0.8±0.2a	2.3±0.9a	3.1±1.2a	3.14	0.0984	2, 8
			2001			
6/26/01	5.8±1.6a	4.2±1.0a	3.6±0.8a	1.06	0.3766	2, 12
7/16/01	11.6±4.6a	10.1±2.2a	5.7±2.3a	1.00	0.3963	2, 12
8/7/01	2.1±0.8a	2.2±0.7a	1.1±0.3a	0.99	0.4002	2, 12
8/22/01	0.7±0.2a	1.2±0.3a	1.1±0.4a	1.28	0.3141	2,12

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

* Date represents day trap was removed, traps were placed in field one week prior to removal

Table 3-5. Mean number (± standard errors) of earwigs captured per pitfall trap in three different fire ant suppression treatments applied in soybean Tift Co. GA., 2000 and 2001.

Sampling Date	Untreated	Amdro 1.5 lb/acre	Lorsban 1qt/acre + Amdro 1.5 lb/acre	F	P	df
			2000			
7/24/00*	2.9±1.9a	7.7±6.7a	7.7±5.3a	1.14	0.3669	2, 8
8/7/00	4.6±1.7a	7.7±4.1a	10.3±4.0a	3.10	0.1007	2, 8
8/20/00	7.6±3.6b	13.2±6.00ab	27.6±8.1a	5.32	0.0339	2, 8
			2001			
6/26/01	0.9±0.6a	0.6±0.2a	0.4±0.2a	0.51	0.6149	2, 12
7/16/01	1.9±0.6b	7.6±3.4ab	10.4±3.4a	5.64	0.0187	2, 12
8/7/01	1.9±1.0b	9.6±3.7ab	15.3±5.4a	10.65	0.0022	2, 12
8/22/01	8.2±3.8b	28.7±14.5ab	42.7±15.7a	6.35	0.0132	2,12

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

*date represents day trap was removed, traps were placed in field one week prior to removal.

Table 3-6. Mean number (± standard error) of earwigs captured per pitfall trap in three different treatments at two test sites in Tift Co. GA, 2001.

Date and Test site	Untreated	Amdro 1.5lb/acre	Lorsban 1qt/acre + Amdro 1.5 lb/acre	F	P	df
26 June*						
Bradford	1.9±1.1a	1.1±0.2a	0.9±0.1a	0.51	0.6939	2, 6
Shannon	0.0±0.0a	0.0±0.0a	0.0±0.0a	.	.	2, 6
16 July						
Bradford	2.1±0.4b	14.2±4.9ab	18.7±2.3a	5.74	0.0404	2, 6
Shannon	1.7±1.2a	1.0±0.4a	2.1±1.5a	0.80	0.4930	2, 6
7 August						
Bradford	1.6±0.7b	15.1±6.00ab	27.1±3.4a	9.67	0.0133	2, 6
Shannon	2.1±2.1a	4.1±3.00a	3.6±2.7a	4.22	0.0718	2, 6
22 August						
Bradford	16.0±5.3b	55.6±22.3ab	81.7±11.7a	5.79	0.0397	2, 6
Shannon	0.5±0.2b	1.7±0.9ab	3.7±1.4a	5.09	0.0510	2, 6
Dates combined						
Bradford	5.4±2.00b	21.5±7.5a	32.1±8.3a	12.62	<.0001	2, 33
Shannon	1.1±0.6a	1.7±0.8a	2.3±0.8a	0.92	0.4096	2, 33

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test). Bradford farm no-till planted into wheat residue. Shannon farm strip-till planted into fallow field after herbicide burndown.

* Dates indicate when traps were retrieved; traps were placed in field one week prior to retrieval.

Table 3-7. Mean number (± standard errors) of lesser cornstalk borer captured per trap in three different fire ant suppression treatments applied in soybean, Tift Co. GA, 2000.

Sampling date	Untreated	Amdro 1.5 lb/acre	Lorsban 1qt/acre + Amdro 1.5 lb/acre	F	P	df
24 July*	7.7±7.5a	4.7±2.8a	7.6±6.4a	0.07	0.9358	2, 8
7 August	0.2±0.2a	0.0±0.0a	0.2±0.2a	0.50	0.6243	2, 8
20 August	1.2±1.2a	1.9±1.3a	0.9±0.5a	0.75	0.5029	2,8
Dates combined	3.0±2.5a	2.2±1.1a	2.9±2.2a	0.05	0.9555	2, 38

Treatment means for each date followed by the same letter are not significantly different (P>0.05, Tukey's studentized range test).

* Dates indicate when traps were retrieved; traps were placed in field one week prior to retrieval.

CHAPTER 4
A GLASS VIAL BIOASSAY TO DETERMINE RESDIUAL SUSCEPTIBILITY OF THE RED IMPORTED FIRE ANT TO SELECT AGRICULTURAL INSECTICIDES[1]

[1] Seagraves, M. P. and R. M. McPherson. To be submitted to Journal of Entomological Science.

Abstract

The red imported fire ant, *Solenopsis invicta* Buren, is an abundant predator in cropping systems throughout its range. It has been documented to be an important predator of numerous crop pests, as well as being a pest itself. Information on the impact of insecticides on natural enemies such as fire ants is necessary for the integration of biological and chemical control tactics in an effective pest management program. Therefore, a residual vial bioassay was developed to determine the dosage-mortality responses of *S. invicta* workers to four commonly used insecticides: acephate, chlorpyriphos, methomyl, and l-cyhalothrin. Ants in coated scintillation vials were examined for mortality after 6 h of exposure. Fire ant workers showed a dose-mortality response to all four chemicals. Methomyl (LC_{50} 0.04 μg/vial) was the most toxic followed by chlorpyriphos (LC_{50} 0.11 μg/vial) and acephate (LC_{50} 0.76 μg/vial). Of the chemicals assayed, it took a much higher concentration of lambda-cyhalothrin (LC_{50} 2.30 μg/vial) to kill 50% of the workers compared to the other three chemicals. The results of this study while limited in scope suggest that it may be possible to use a discriminating dose of lambda-cyhalothrin to control the target pest while conserving fire ants in the agricultural systems where their predatory behavior is beneficial.

Key words: Red imported fire ant, *Solenopsis invicta*, toxicology, methomyl, chlorpyriphos, acephate, l-cyhalothrin.

The red imported fire ant, *Solenopsis invicta* Buren, is a voracious consumer of numerous other arthropod species and often is the most abundant predaceous arthropod in crop fields throughout its range. *S. invicta* has been reported to be a key natural enemy of agricultural pests in a variety of systems. In east Texas cotton, *S. invicta* is the most important predator of boll weevil, *Anthonomus grandis* Boheman, larvae, often preventing economic damage from this pest (Sterling 1978, Sterling et. al 1984). When radiolabeled eggs of *Heliothis virescens* F. were exposed in a cotton field, fire ants accounted for 85.3% of radioactive predators collected (McDaniel and Sterling 1979). *S. invicta* also is an important component of the predator assemblage attacking the sugarcane borer (Negm and Hensley 1969, Reagan et al. 1972). Many reports indicate that *S. invicta* is a major predator of velvetbean caterpillar, *Anticarsa gemmatalis* Hubner, a major soybean pest in the southern United States (Buschman et al. 1977, Brown and Goyer 1982, Elvin et al. 1983, Lee et al. 1990). In addition, Krispyn and Todd (1982) reported that fire ants could reduce populations of the southern green stink bug, *Nezara viridula* L., another key pest of soybeans. The nymphal stages were much more vulnerable to ant predation due to their aggregation in clumps.

S. invicta is characterized as an indiscriminate predator attacking not only pest arthropods, but also other predaceous natural enemies (Wilson and Oliver 1969, Lofgren et al. 1975, Tedders et al. 1990, Lee et al. 1990, Eubanks 2001). Parasitic wasps have been reported to be dramatically impacted by the presence of fire ants and by direct predation on parasitized hosts (Lopez 1982, Vinson and Scarborough 1991). Despite being prolific intraguild predators, fire ants are still able to reduce the populations of some pest species (Eubanks 2001). Insecticides have been demonstrated to interfere with the biological control provided by fire ants in a sugarcane agroecosystem (Negm and Hensly, 1969).

S. invicta has also been reported to be a crop pest of soybean. The presence of fire ant mounds has been reported to interfere with harvesting machinery, indirectly affecting yield (Adams et al. 1976). Lofgren and Adams (1981) reported that soybean yield reductions in fire ant-infested fields were not solely due to mound interference with the harvester, but also some possible crop damage (i.e. seed predation, root feeding).

Although the status of *S. invicta* in agriculture is currently unsettled, most researchers concede that at least some beneficial aspects exist from the predatory nature of this species. The most practical approach for using biological control in ephemeral crop systems that experience high pest pressure is the conservation of natural enemies. Integrating natural enemy conservation into IPM systems that are dominated by curative chemical controls is difficult, yet utilizing selective of pesticide materials and rates to conserve natural enemies is the biological control approach most available to growers (Ruberson et al. 1998). Successful integration of pesticides and natural enemies requires information on the direct and indirect effects of pesticides on natural enemies. Although a great number of studies have evaluated pesticides against *S. invicta* as a means to control it as a pest, little work has been done to determine which insecticide or rate could be used to conserve *S. invicta* in agroecosystems. Thus, this study was undertaken to examine the toxicity of four compounds, in three different chemical classes, that are commonly used in row crop agriculture.

Materials and Methods

A glass vial residual bioassay was used to evaluate the susceptibility of fire ant workers to four commonly-used agricultural insecticides. Glass scintillation vials (20ml) were triple washed with liquid detergent and water then triple rinsed with acetone prior to being treated. A known quantity of technical grade active ingredient of acephate (Orethene 97PE, Valent USA Corp., Walnut Creek, CA 94596-8025), chlorpyriphos (Lorsban 4E, Dow AgroSciences, Indianapolis, IN 46268-1189), methomyl (Lannate LV, Dupont, E. I. De Nemours Inc., Wilmington, DE 19880-0038), or lambda-cyhalothrin (Karate Z, Syngenta, Greensboro, NC 27419-8300) was dissolved in acetone and serially diluted to the desired dose. The insecticide-acetone solution was placed into cleaned glass scintillation vials using an Isco micropipetter (Instrumentation Specialties Co., Lincoln, NE 68504) set at 0.5 ml. After addition of the solution, the vials were placed on a rolling machine (American Wyatt Corp., Cheyenne, WY 82007) set on the low speed with the open end of the vials facing a blowing fan for around 30 min. Once the acetone solvent had completely evaporated, leaving insecticide residue evenly distributed on the interior, the vials were removed and capped.

S. invicta workers from two colonies gathered in Tift Co., GA were used for all assays. These colonies were maintained in separate 19-L plastic containers (33 x 23 x 38 cm) held in the laboratory. Polytetrafluoroethylene (Fluon AD 1, Northern Products, Woonsocket, RI) was placed around the edge of each container to prevent escape of ants. Colonies were fed lepidopteran pupae and honey, and moisture was maintained by adding water (around 90-120 ml) each week. Workers were gathered from the colonies by placing a glass stirring rod at the top of the mound and allowing workers to climb aboard, then 5-10 ants were put into each treated vial. Six hrs. after placement in the treated vials the ants were examined and mortality was recorded. Individual ants were considered dead when they did not move even when prodded with a needle. Controls for each trial consisted of ants being placed in vials treated only with acetone. Vials were held in the laboratory at 23±3° C with lights on during the 6 h exposure period.

Eight to 11 concentrations of each chemical were assayed on at least three different dates and with both colonies, with 10 vials per concentration. Data were pooled since no differences in colonies or dates were noted. Mortality for each concentration was adjusted to reflect mortality in the control treatment. From the data collected LC_{50}'s, LC_{95}'s, 95% confidence limits, slopes, and regression analyses for each of the four insecticides examined were obtained using Probit analysis (Daum 1970). The concentration-mortality response lines were generated using non-linear regression analysis (SAS Institute 1990).

Results and Discussion

The LC_{50}'s, LC_{95}'s, slopes, and regression F values from the Probit analysis are reported in Table 4-1. Within the six hour-assay period, *S. invicta* showed a dose-mortality relationship with all four of the chemicals assayed. The pyrethroid insecticide lambda-cyhalothrin (LC_{50} 2.30 μg/vial) required a significantly higher dose than the other chemicals to elicit 50% mortality (Table 4-1). This was unexpected since pyrethroids are noted for their potency per unit of active ingredient for controlling numerous agricultural pests. The carbamate methomyl (LC_{50} 0.04 μg/vial) was the most toxic insecticide followed by the organophospates chlorpyriphos (LC_{50} 0.11 μg/vial) and acephate (LC_{50} 0.76 μg/vial). The comparative LC_{95} responses were similar; however, the l-cyhalothrin value was much higher (41.45 μg/vial) than the values for the other three products (varying from 0.58-2.36 μg/vial). The slopes (Table 4-1) of the concentration-mortality lines (Figs. 1-4) were similar for chlorpyriphos (2.00), methomyl (1.50), and lambda-cyhalothrin (1.31). The slope for acephate was 3.35 which was much greater than the other three compounds, indicating the dose-response was less sensitive per unit of acephate than it was for the other assayed chemicals.

Since *S. invicta* appears to me more tolerant of lambda-cyhalothrin than the other assayed chemicals, pyrethroid insecticides may be compatible with the exploitation of the fire ant predatory behavior in agricultural cropping systems. Insecticides that are less damaging to natural enemies can be a useful tool in managing secondary pests. Results obtained from residual bioassays such as the one describe here do not necessarily translate into effects that are seen in the field (Ruberson et al. 1998). Residual tests do not account for the movement of chemicals across trophic levels through the consumption of treated prey, nor are they able to simulate the architectural or chemical complexity of a crop environment. Although limited in scope, the results of our bioassay were intriguing in that the LC_{50} for lambda-cyhalothrin was an order of magnitude greater than the LC_{50}'s for acephate, chlorpyriphos, and methomyl. This high dose is required despite the potency of pyrethroids against various insect pests even at low rates.

Tests on the toxicity of topically-applied insecticide compounds are also needed before any conclusions about the integration of chemical pesticides and fire ants as natural enemies can be made. More importantly, field evaluations of the impact of chemical applications on fire ant colony health, foraging activity, etc. are needed to begin to understand some of the complex interactions taking place in an agroecosystem. Now that baseline susceptibility has been established for four commonly used insecticides using a vial bioassay, populations thought to be resistant to these chemicals can be quickly confirmed. This knowledge on the dose-mortality relationship of ants with specific chemicals can be useful for selecting chemical control options that effectively reduce the target arthropod pests while enhancing the conservation of the predaceous fire ant populations.

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Table 4-1. Susceptibility of red imported fire ant workers to residual assays of acephate, chlorpyriphos, l-cyhalothrin, and methomyl 6h after exposure, 2001.

Chemical	LC_{50}* (95% CI)	LC_{95}* (95% CI)	Slope ± SE	F	df
Acephate	0.76(0.50-1.04)	2.36(1.55-6.94)	3.35±0.69	23.7**	1,7
Chlorpyriphos	0.11(0.07-0.17)	0.77(0.42-2.63)	2.00±0.33	37.1**	1,8
Methomyl	0.04(0.03-0.06)	0.58(0.35-1.36)	1.50±0.16	87.1**	1,8
l-cyhalothrin	2.30(1.57-3.59)	41.45(17.29-239.49)	1.31±0.21	40.1**	1,11

* Concentration (μg/vial) that kills 50% (LC_{50}) or 95% (LC_{95}) of fire ant workers, calculated by linear regression fitted to a probit model with 95% confidence intervals.

** All F values for regression analysis are highly significant ($p<0.01$).

Fig. 4-1. Concentration-mortality response of fire ants to acephate in vial bioassay

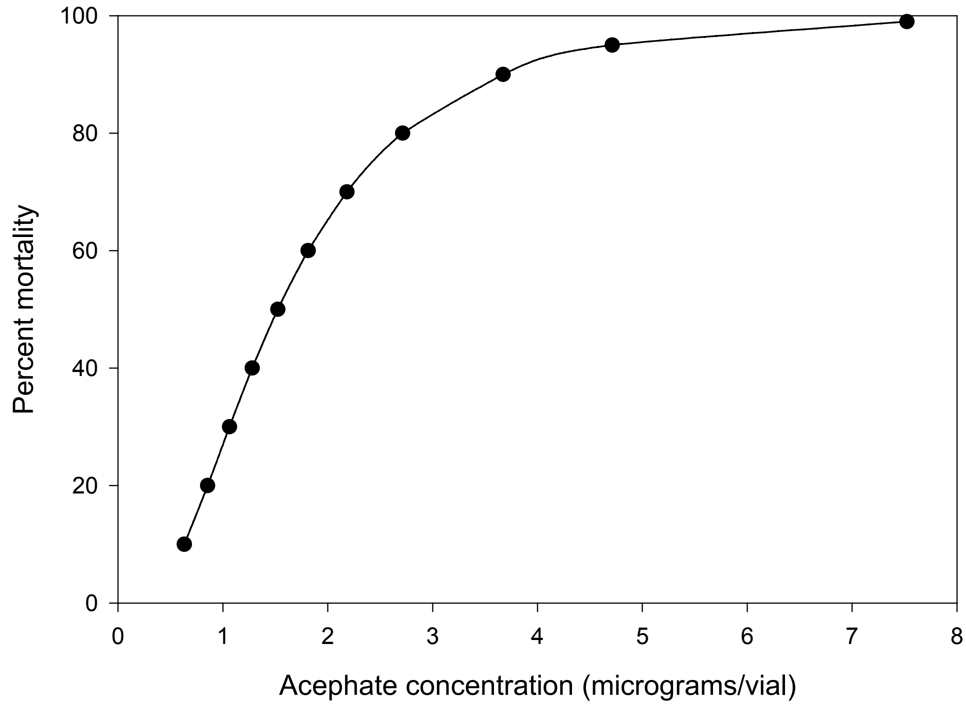


Fig. 4-2. Concentration-mortality response of fire ants to chlorpyriphos in vial bioassay

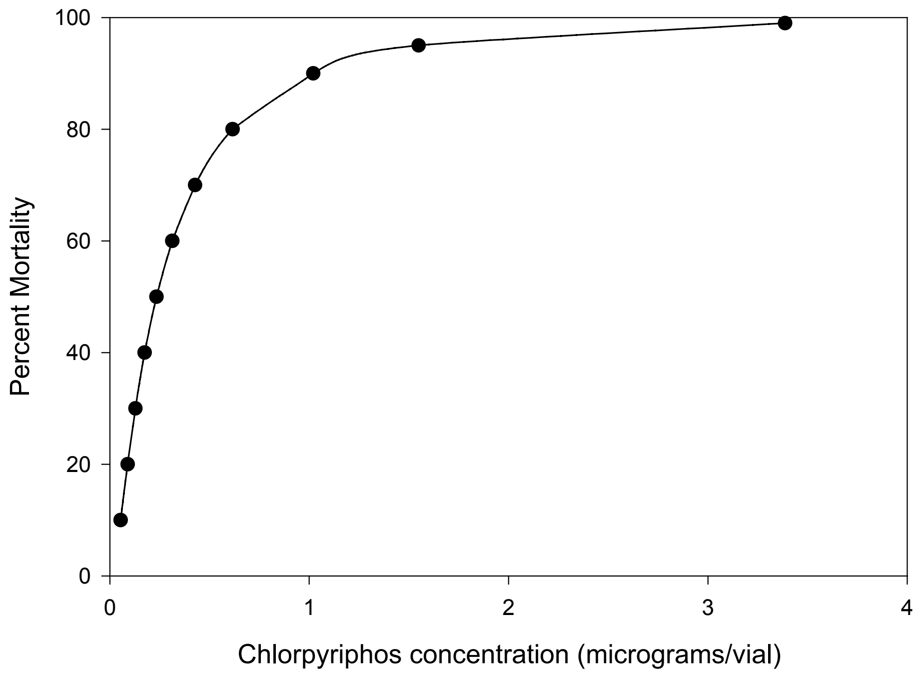


Fig. 4-3. Concentration-mortality response of fire ants to methomyl in vial bioassay

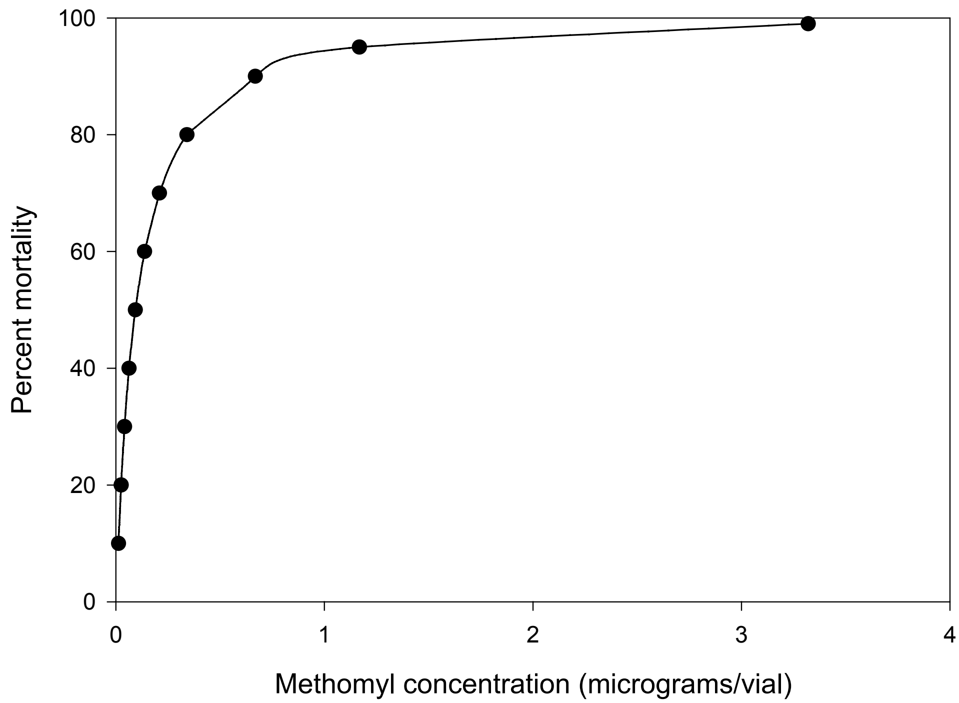
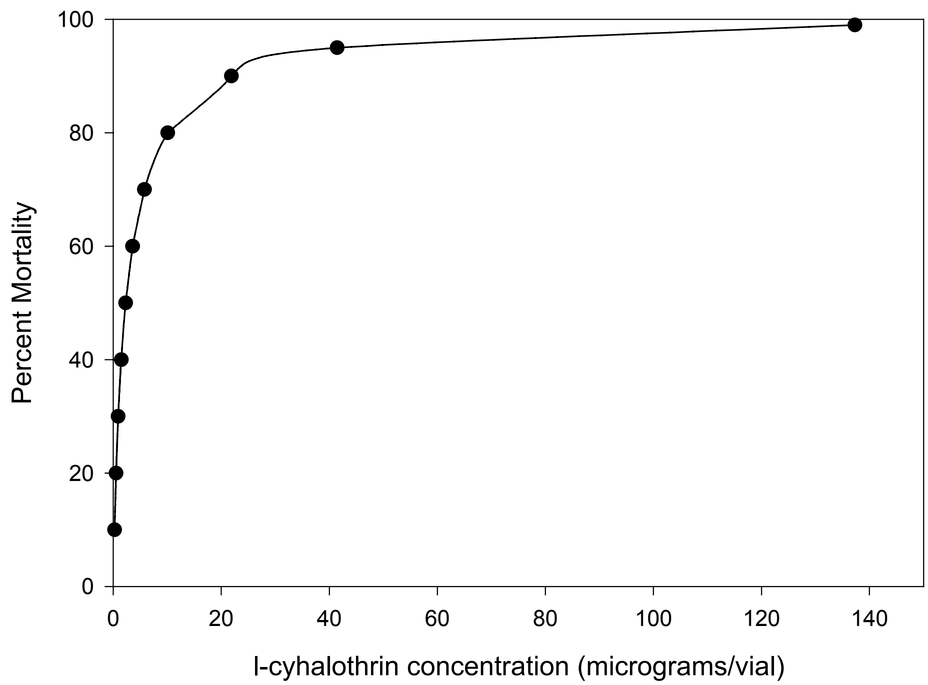


Fig. 4-4. Concentration-mortality response of fire ants to l-cyhalothrin in vial bioassay



CHAPTER 5

RESEARCH SUMMARY

Soybean arthropods were monitored in three different fire ant suppression treatments in 2000 and 2001. The treatments examined included an untreated control, Amdro bait, and chlorpyriphos in combination with Amdro bait. Our goal was to gain insight into the role of fire ants in soybeans by examining the impact of these fire ant suppressive treatments on soybean pest and natural enemies. When lepidopteran eggs were exposed in the different treatments, significantly fewer eggs were remaining after 24 hrs in the untreated naturally infested fire ant control in comparison to the treated areas. Additionally, when soybean looper pupae were exposed in the different treatments both in the canopy and on the soil surface, significantly fewer pupae were recovered after 24 hrs. in the untreated plots. This indicates that *S. invicta* is a major biotic mortality factor of the sessile stages of holometabolous insects, particularly any species that occur in these stages on the soil surface. However, our sampling did not reveal differences between the treatments for most foliage inhabiting pest insects or their associated predators. The threecornered alfalfa hopper, *Spissistilus festinus* (Say), did occur in significantly lower numbers in the untreated control, indicating that *S. invicta* may have a negative impact on this pest. However, no evidence of this effect was seen in 2001 despite threecornered alfalfa hopper's being more abundant. In 2000, coccinellid beetles were significantly more abundant in the Amdro treated areas, suggesting that *S. invicta* may directly reduce lady beetle populations or that lady beetles prefer areas of low ant density.

Ground arthropods were also monitored in both years. The fire ant suppression treatments created a more apparent change in the ground arthropod fauna than they did in the foliage insects. Namely, *S. invicta* was captured significantly more in pitfall monitoring in the untreated areas than the treated agreeing with our data obtained from monitoring ant foraging with hotdog baits. In the 2000 season spiders were more abundant in the untreated areas in comparison to the fire ant suppressed areas. Although spider numbers were highest in the untreated plots in 2001, they were not significantly different from the Amdro treatment. We concluded that ground-dwelling spiders are not negatively impacted by fire ants and at times are positively associated. Our data suggests that these two generalist predators are compatible as natural enemies. Predaceous beetles were not impacted by our treatments. Earwigs occurred in significantly higher numbers in the chlorpyriphos + Amdro treated areas and at times the Amdro alone areas. Although correlative in nature, our data suggest that fire ants are a key natural enemy of earwigs. These changes in the ground predator assemblage had no impact on a lesser cornstalk borer, *Elasmopalpus lignosellus* Zeller, outbreak in 2000.

The residual toxicity of the commonly used agricultural insecticides acephate, chlorpyriphos, methomyl, and l-cyhalothrin to fire ant workers was investigated. Dosage-mortality curves were generated for each chemical using data from a glass vial bioassay as well as LC_{50}'s and LC_{95}'s. Our results indicated that the carbamate methomyl was most toxic followed by the organophosphates acephate and chlorpyriphos. Interestingly the pyrethroid l-cyhalothrin required a much larger dose to elicit 50% mortality in our assay. This is interesting since pyrethroids are noted for their potency per unit of active ingredient on certain agricultural pests. Although limited in scope, our study suggests the possibility of developing a discriminating dose of l-cyhalothrin to conserve *S. invicta* while still being effective against the target pests. The integration of biological and chemical tactics is a key element to evolving IPM programs and pesticide selectivity is the most readily available method of natural enemy conservation available to growers.

The fire ant suppression treatments had no discernable effect on soybean yield in our tests in either year. This demonstrates that in a side by side test soybeans in areas infested with fire ants do not necessarily incur economic damage from seed predation or root-feeding. After establishment of the soybean stand in 2001 no differences were seem in the number of plants per meter between treatments.

Our results should provide a foundation of information for researchers and extension personnel dealing with the impact of *S. invicta* in soybean production in the southeastern United States. Additionally this information should prove useful in the design of biologically based IPM programs for soybean and possibly other crops as well.