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NEPA, ESA, BATS and the IFA

Charles H. Bare

There are a number of Federal laws and regulations concerning the environment that impact the decisionmaking processes in the Federal Government. Some of these laws and regulations affect the imported fire ant (IFA) research community, and in particular those involved in the biological control of the IFA.

There are two laws, in particular, which have the greatest impact on Federal agencies. The first of these laws is the National Environmental Policy Act of 1969 (NEPA).

NEPA requires Federal agencies to consider the environmental consequences of their actions before initiating the action. The Act states that "All agencies of the Federal Government shall...include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on--

1. the environmental impact of the proposed action,

2. any adverse environmental effects which cannot be avoided should the proposal be implemented,

3. alternatives to the proposed action,

4. the relationship between local and short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

5. any irreversible and irretrievable commitment of resources which would be involved in the proposed action should it be implemented.

The regulations developed to enforce NEPA were developed by the Council on Environmental Quality (CEQ), an organization established by NEPA. The regulations require Federal agencies to prepare environmental assessments (EA) to address the five criteria listed, above.

Basically, an EA is a short document usually not over 50 pages long that analyzes the environmental impacts of the proposal and results in a finding of no significant impact (FONSI).

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1Senior Operations Officer, Domestic and Emergency Operations, Plant Protection and Quarantine, Animal and Plant Health Inspection Service, United States Department of Agriculture, 4700 River Road, Unit 134, Riverdale, MD 20737-1236
The FONSI is merely a conclusion based on the facts and analysis presented in the EA that states the proposed action will not have a significant impact on the quality of the human environment.

If a FONSI cannot be reached, CEO regulations require the preparation of an environmental impact statement (EIS).

An EIS is a much more detailed statement of the proposed action’s effects on the environment. These documents are usually over 150 pages long, and often made up of several volumes when all of the supporting documents like human health and environmental risk assessments are included.

In cases where the Federal agency is proposing an action that involves controversy or encompasses a large area, the EA step is skipped and the EIS process is initiated from the very beginning. In 1981, an EIS was prepared for the imported fire ant control program.

An EIS results in another document known as a record of decision (ROD). The ROD documents the selection and rationale for selecting a particular alternative from the list of alternatives analyzed in the EIS. The ROD must be prepared before the proposed action can begin.

The second Act which impacts Federal agencies is the Endangered Species Act of 1973, as amended (ESA). This Act was passed by Congress to provide for a Federal mechanism to protect and conserve threatened and endangered species. The section of the Act which most impacts Federal agencies is Section 7.

Section 7 of the Act applies only to Federal agencies, and ensures that their actions do not jeopardize the continued existence of a listed species or destroy or adversely modify species’ critical habitats. The Act also requires Federal agencies to consult and confer with the US Fish and Wildlife Service (FWS) in making those determinations.

The documentation necessary to determine if agency actions will jeopardize listed species, or not, is called a biological assessment and the agency proposing the action is responsible for its preparation. The conclusions drawn in the biological assessment must have the concurrence of the FWS for the proposed action to proceed.

When the biological assessment is submitted to the FWS, a process known as formal consultation is initiated. During this formal consultation period no irreversible or irretrievable commitment of Federal resources can be made. Formal consultation results in a document called a biological opinion.

The biological opinion is prepared by the FWS and details the FWS reaction to the biological assessment.

In the biological opinion, the FWS will make a determination of whether the action will
"jeopardize" or "not jeopardize" the continues existence of listed species or adversely modify their critical habitat. If the conclusion is the proposed action will not jeopardize the continued existence of listed species, the proposed action can proceed.

If the FWS issues a "jeopardy" opinion, they are required by law to present to the Federal agency "reasonable and prudent alternatives" to the proposed action that will allow it to proceed.

The major difference between NEPA and the ESA is that NEPA is procedural and ESA is absolute in its requirements. That is, as long as you follow the procedures set out in NEPA, the proposed Federal action can take place. The action can proceed even if you have disclosed significant environmental consequences. The key is to disclose the consequences and show that steps will be taken to mitigate their effects.

The ESA, on the other hand, requires that listed species must be protected from being adversely affected by the Federal action. There can be no mitigation of effects. Listed species and their critical habitat must be protected and protective measures must be part of program plans if the proposed action is to proceed.

BATS stands for Biological Assessment and Taxonomic Support. It is a Staff within the Plant Protection and Quarantine program of APHIS. It is within BATS that the requirements of NEPA and ESA come into play as far as importation, interstate transport, and field release of nonindigenous organisms for biological control of the IFA is concerned.

Under its broad legislative authority, APHIS regulates the movement of plant pests into, through, and within the United States. BATS assesses requests for permits to import, move between states, and release into the environment nonindigenous organisms which are or may become plant pests.

It is important to keep in mind that APHIS' authority to regulate extends only to plant pests, or nonindigenous organisms which may become plant pests if released into the environment. In order to make the determination of the status or potential status of nonindigenous organisms, BATS conducts a risk assessment. This risk assessment provides a basis for determining if an organism is or may become a plant pest if released into the environment.

For BATS to conduct the risk assessment, certain information on the organism is required from the person or organization requesting the permit. This information is obtained through the applicants completion a PPQ Form 526.

The PPQ Form 526 is the application for a permit, and from the information supplied on it, BATS will determine if the organism is or can become a plant pest. If the determination is that the organism is or has the potential to become a plant pest, a permit from APHIS is required. But in order to take the Federal action of issuing a permit, APHIS must prepare an environmental
assessment as required by NEPA. The EA must be prepared by APHIS, but BATS may request the applicant to prepare a draft under BATS guidance.

Concurrent with the preparation of the EA, the FWS must be consulted on whether the issuance of the permit may adversely affect listed threatened and endangered species. If there may be an affect, a biological assessment must also be prepared.

If the analysis conducted in the EA results in a FONSI, and there will be no affect on listed threatened and endangered species, a permit can be issued to the applicant. If a FONSI can not be reached, NEPA requires the preparation of an EIS before the permit can be issued. This means that a significant impact on the environment is expected to result from the issuance of the permit and the impact must be fully analyzed before the permit can be issued.

The above discussion on the permitting process has been simplified. There are several other steps that must be taken that will not be discussed here, except to say that ordinarily applications to import nonindigenous organisms into approved quarantine facilities for testing and evaluation do not normally go through the risk assessment process.

What happens if an organism is not considered to be a plant pest? The answer is, APHIS has no authority to regulate the organism. The organism can be brought into the United States, moved between states, and released into the environment without an APHIS permit. BATS can provide a "courtesy permit" to expedite the importation through agricultural inspection at our ports of entry.

Even though APHIS has no regulatory authority over organisms which are not plant pests, it does not mean that the Federal agency, university, or private industry involved does not have other responsibilities.

If you are a Federal agency, your actions may still be subject to the provisions of NEPA and ESA. Remember, Federal agencies must consider the environmental effects and the affect the action may have on listed species before taking action. Each agency should have a contact person to help you making these determinations.

If you are with a university or in private industry, your actions may be subject to regulation under state law. You should contact the state department of agriculture in the state where you will be conducting your program for more information.

Finally, to get a PPQ Form 526 to get the process started, you can make your request in a number of ways:

2. Via a fax service by calling (301)734-3560 and entering the number 526 when asked for the document number you want. Follow the voice prompts for the information to be faxed to you.

3. You may call Barbara Jenkins on (301)734-5609 and request the PPQ Form 526, or

4. You may write to Debbie Knott, USDA APHIS PPQ BATS OPRA, 4700 River Road, Unit 133, Riverdale, MD 20737-1236.

In summary, NEPA and Section 7 of the ESA apply to Federal agencies. APHIS, through BATS, regulates the importation, interstate movement, and release into the environment of nonindigenous organisms which are or may become plant pests. If the organism is not regulated by APHIS, NEPA and the ESA may still apply if you are a Federal agency. State law may apply if you are from a university or from private industry.
The University of Arkansas Cooperative Extension Service, in conjunction with the Arkansas Center for Technology Transfer - University of Arkansas, is developing an interactive, computer-based educational program to address environmentally responsible control of imported fire ants. The finished program will contain scanned photographic images, graphics, text, video and audio bites. Program content will consist of information about the ant's social structure, life and reproductive cycles, historical and demographic data, health and environmental concerns, and safe, effective control methods and techniques. The finished program will be made available to the Extension Services in all fire ant infested states as well as other interested public organizations. The program is intended to be delivered by several other mechanisms including classrooms, kiosks and via the Internet.
THE INFORMATION AGE:
WHAT'S OUT THERE?

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3505 25th Ave., Bldg. 16
Gulfport, MS 39501

E-MAIL LISTSERVER SITES (mailing lists you subscribe to):

FIREANTS - fireants@tifton.cpes.peachnet.edu
managed by Tom Woody/Stan Diffie at the Coastal Plains Experiment
Station in Tifton, GA. Small list dedicated to IFA related
discussions.

SOCIAL INSECTS - socinsct@uacsc2.albany.edu
has about 200 participants and is dedicated to social insects

ENTOMOLOGY - entomo-1@listserv.uoguelph.ca
large international list with participants from Europe, South
Africa, Australia, Asia, etc. Very lively discussions related to
ingsects.

WORLD WIDE WEB SITES:

NATIONAL AGRICULTURAL PEST INFORMATION SYSTEM (NAPIS) Homepage -
hp://ceris.purdue.edu/napis
Dave McNeal (USDA, APHIS, PPQ) & Jim Pheasant (Purdue Univ.)
Has information on IFA, including current regulations (Code of
Federal Regulations), historical geographic maps (best available
data), etc. Also has information on numerous other pests.

TED RADCLIFFE'S GOPHER STATE IPM Site Homepage -
hp://www.ent.agri.umn.edu/academics/classes/ipm/ipmsite.htm
Ted Radcliffe & Bill Hutchison (Univ. of Minnesota)
Site will be used as a text book for an IPM class and will contain
information on IFA (chapter by Tim Lockley) as well as 200 other
chapters related to IPM.

FORMIS - Ant Bibliography (info from Sanford Porter)

Online searches can be conducted at:
IUSSI gopher site in Australia: spider.enfo.csiro.au
(look under taxonomy/Nat. Insect Col. /IUSSI)
the Univ. of Florida Library catalog via telnet
(contact S. Porter, sdp@nervm.nerdc.ufl.edu)
or via the web at http://129.93.236.82.bibwww/
   (there may be some trouble with this site. contact S. Porter
   if you have problems)

Free compressed versions of FORMIS for Mac/IBM via FTP:
Australia: spider.ento.csiro.au (IUSSI)
Iowa State Entomology Gopher: gopher.ent.iastate.edu

Several of the universities have web homepages and gopher sites. There may be
other sources of IFA information available or soon to be available. If anyone
has information on other electronically available information on IFA please
contact me with the site name and address. If you have any questions on the
above information, please call and I will tell you what I can and put you in
touch with the proper person to best assist you.
Fire Ant Alarm Pheromones

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The red imported fire ant, *Solenopsis invicta*, has several purported sources of alarm pheromones. Crushed heads from workers and worker Dufour’s glands produce an alarm reaction; however, for this paper we will concentrate on the excitant pheromone produced by sexuals during mating flights.

Reproduction in the *S. invicta* begins with nuptial flights during which male and female alates (winged reproductives) leave their nests and mate several hundred meters in the air (Markin et al. 1971). Males take flight before females and form large aggregations into which the females fly (Markin et al. 1971). Mating flights may take place year round but occur primarily during the summer months, when suitable conditions most frequently arise.

The surface of a fire ant mound normally has no entrance or exit holes (Markin et al. 1975). However, just prior to a mating flight, workers create holes in the mound surface from which workers and winged alates emerge (Markin et al. 1971). At this time, workers swarm excitedly over the mound and exhibit many characteristics of what has been classified as alarm behavior, including frenzied running, rapid back and forth movement, and increased aggression (Markin et al. 1971, Obin and Vander Meer 1994). Workers often aggregate around alates as they climb up vegetation to take flight and sometimes attempt to pull the alates back down.

Obin and Vander Meer (1994) induced *S. invicta* flights in the laboratory and showed that chemical cues from both male and female alates but not from workers, attracted workers, induced alarm-recruitment behaviors in the workers, and promoted alate retrieval by workers. They proposed that volatile substances produced by the alates were responsible for eliciting the worker reactions. We report here the glandular source(s) of chemical substances responsible for inducing worker excitement in *S. invicta* workers prior to mating flights.

Methods and Materials

Source of Alates. Colonies were induced to fly in the laboratory by watering the soil of each colony one day prior to testing in order to simulate rainfall. On the day of each test we increased the temperature in the lab room to 30°C and augmented the available light with additional incandescent lamps (see Obin and Vander Meer 1994). Alates were collected and flown from colonies collected year round.

"Mating flight activated" (MFA) alates were obtained from these laboratory colonies after a flight was initiated. Alates were collected as they climbed up tongue depressors placed in the tubs, and were weighed and tested immediately.

Bioassay Procedure. Our bioassay consisted of a set of worker groups from mature *S. invicta* colonies maintained in the laboratory. Workers and test alates were always collected from different colonies. Approximately 100 workers and a small amount of brood from each colony were placed in small covered petri dishes with moist *Castone®* bottoms. Red cellophane placed over the petri dishes induced the workers to stay with their brood in the dishes. These sub-colonies were maintained in individual plastic trays that were coated with *Fluon®* on the sides to prevent escape. Ants were allowed to acclimate to the dishes for at least two hours before the lids and cellophane were removed.
The bioassay was conducted by an observer and assistant. The assistant prepared test samples for the observer so that the observer did not know the sample identity. Test samples consisted of 3 ml of air drawn by a syringe from a control or sample vial (samples are defined below). The assistant then assigned each sample arbitrarily to a worker group, such that all worker groups were tested with each of the test samples and controls. The observer positioned the syringe 1-2 cm directly above a part of the selected worker group, then slowly released 1 ml of air over the workers. Reactions were characterized by the observer either as no reaction, when workers did not change their behavior in any way or simply raised their heads and antennated the air, or as an excited reaction, in which at least one worker reacted with rapid movement. If workers moved rapidly toward the source of the airstream, the reaction was noted as possible attraction. A Y-tube bioassay was used to measure attraction (see Vander Meer et al. 1988). Only overwintering and summer female MFA alate poison sac extracts were evaluated for attraction.

**Sample Preparation.** Each sample to be tested in the bioassay was placed in a 7-ml glass scintillation vial and tightly capped. Tests with live alates consisted of five live alates placed in a vial and shaken immediately before each air sample was drawn. Vials were shaken to disturb the alates and induce them to release the excitant pheromone. Tests of alate body parts included one individual head, thorax, or gaster. Each body part was obtained from different alates to minimize cross contamination. Alates were chilled to 8°C before body parts were separated with micro dissecting scissors. Each body part was placed toward one end of a thin strip of filter paper (Whatman #1, qualitative, 3 cm x 0.5 cm), then the filter paper was folded over and the body part was crushed with a hammer. The filter paper with the crushed body part was immediately placed in a sample vial for bioassay.

Solutions of glandular products were made from mandibular glands, post-pharyngeal glands, and poison sacs excised in water under a binocular dissecting microscope from alates that had initiated pre-flight activity. Mineral oil was used as the solvent to slow the rate of release of the chemical compounds. For each test, five ul of solution (1.6 alate equivalents) was applied to a thin strip of filter paper (dimensions above) and placed in a sample vial.

**Data Analysis.** Data were analyzed using the McNemar test for significance of changes (Sokal and Rohlf 1981). This statistic is used for comparisons in which the same individuals are tested repeatedly and is appropriate for our analyses because the same worker groups were exposed to several test samples and a control in each bioassay. This statistic compares the number of worker groups that displayed an excited reaction to the test sample but not to the negative control to the number of groups that reacted to the negative control but not to the test sample.

**Results and Discussion**

Air from vials containing live mating flight activated (MFA) female alates elicited highly significant excited reactions in *S. invicta* worker groups in summer and winter tests. In addition, workers reacted with excitement to summer male alates, as well as to winter non-flying female and male alates. Live winter MFA female alates that were not shaken before testing also elicited significant reactions.

Crushed heads of all alate categories stimulated highly significant excitement in the workers. Results for crushed female thoraces were variable while crushed male thoraces elicited excitement at a lower level of significance than crushed heads (p<0.05 vs. <0.001, respectively). It is not clear yet whether the thorax results are due to contamination by substances released from the mandibular glands during separation of the body parts or if a glandular source from the thorax is responsible. Crushed gasters of all female alate categories but not male gasters produced some level of excitement in the workers, as did crushed poison gland solutions from winter MFA females. Overwintering female alates are abnormal in that they produce a queen pheromone in the poison gland, which is usually only produced and released by inseminated queens or dealated virgin females (Vander Meer *et al.* 1980). Our Y-tube bioassay results showed significant worker
attraction to overwintering but not summer female MFA poison sac extracts. Thus, our excitant bioassay results for this treatment category could be confounded by worker attraction.

Mineral oil extracts of mandibular glands from MFA female and male alates produced significant excitation in workers. Tests with winter MFA females were heterogeneous, with four highly significant replicates (80%, each with p<0.005) and one with an equal number of reactions to the test sample as to the control. Crushed heads without mandibular glands did not elicit excitation in workers (p>0.05) while heads with intact glands tested at the same time elicited excitation at a highly significant level (p<0.001). No excitation was elicited by post-pharyngeal gland solutions from any of the alate categories.

Our results show that the mandibular glands are a source of an excitant pheromone in both female and male S. invicta alates. In our bioassay, S. invicta workers consistently reacted with rapid movement and frantic running when exposed to live alates, crushed heads, and mandibular gland solutions. These results support Obin and Vander Meer’s (1994) suggestion that the "alarm" and recruitment reactions exhibited by workers towards alate residues during mating flights were likely derived from the alate mandibular glands.

Although other crushed body parts from male and female alates elicited some excitation, only the head elicited a strong reaction from both sexes of alates. This is significant because within a fire ant population, colonies may produce only males, females, or both sexes. It is likely that the alates are responsible for initiating mating flight activity in response to environmental conditions, because the opening of the mound surface and swarming of workers are only associated with mating flights. It is also probable that the glandular source for this very specific activity is the same for both sexes. Thus, all evidence points to the mandibular glands as the source of mating flight excitant pheromones.

Studies of chemical communication associated with mating flights have mainly focused on sex attraction pheromones (e.g. Hölldobler 1971 and Hölldobler 1976). Pheromones involved in pre-flight activity have received little attention but most likely are as important to the mating process as are those responsible for mate attraction.

Mandibular glands have been identified as the source of alarm pheromones in many ant species, particularly in the subfamily Myrmicinae (see review by Hölldobler and Wilson 1990). Despite the small size of S. invicta's mandibular glands, we have demonstrated that the chemical contents of alate mandibular glands elicit significant excitation in workers. We are currently working to identify the chemical compounds in the mandibular glands responsible for producing the excited reactions.

References Cited

Characterization of the Discontinuous Gas Exchange Cycle in Red Imported Fire Ants
(Solenopsis invicta Buren)

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INTRODUCTION

The discontinuous nature of gas exchange has been demonstrated in many adult insects (Lighton 1994). The typical discontinuous gas exchange cycle (DGC) consists of three phases: Closed phase, when spiracles are closed and very little external gas exchange takes place; flutter phase, in which spiracles open and close very rapidly, allowing ingress of O₂ while limiting loss of water; open phase, during which the spiracles open, allowing egress of CO₂ which is accompanied by a water loss component. The DGC is thought to be an adaptation to reduce respiratory water loss in insects. This hypothesis, however, has not been satisfactorily addressed (Hadley and Quinlan 1993, Lighton et al. 1993, Lighton and Garrigan 1995).

Experiments are currently underway in our laboratory to determine presence or absence of a DGC in all castes and life stages of Solenopsis invicta. In cases where a DGC is noted, we are characterizing the salient characteristics of the cycle. This is, to our knowledge, the first investigation of discontinuous gas exchange in S. invicta, arguably one of the most important pest formicids in the Southeastern U. S. since its introduction into Mobile, AL in the 1930s (Buren 1972). The large, mound-building colonies of this species and underground foraging tunnels may have particular relevance in considering ambient gas concentrations and their possible effect on the nature of the DGC.

MATERIALS AND METHODS

Worker ants were collected from a field colony near Notasulga, AL and used for experiments within three days of capture. During captivity, field-collected ants were given water and a sugar solution ad libitum, and were kept in the laboratory at 22° C with an approximate 12:12 photoperiod.

Ants from the laboratory colony were collected and used immediately. The laboratory colony is one of many begun in June 1995 from a single mated queen, collected in Lee Co., AL after a mating flight. The colony was provided crickets, water and a sugar solution ad libitum, and maintained under a 12:12 photoperiod. The colony nested in a 15 X 150 mm test tube, partially filled with water and tightly plugged with cotton.

Respirometry was carried out using a Sable Systems TR-3 respirometry system (Sable Systems, Salt Lake City, UT, USA). A schematic of the system is presented in Fig. 1. Each ant was given 10 min to acclimate to the respirometer chamber prior to beginning a run. If an ant did not exhibit a DGC within three consecutive 44 min recordings, it was discarded and a new ant was used. Data were analyzed using DATACAN (Sable Systems) and SigmaStat (Jandel Corporation, San Rafael, CA, USA).
RESULTS AND DISCUSSION

A typical trace from a recording of a worker DGC is shown in Fig. 2. Field-collected workers ventilated with an average frequency of 5.37 mHz; laboratory-reared workers ventilated with an average frequency of 2.89 mHz (Table 1.). We have encountered some difficulty in observing the DGC in worker ants thus far in this study, and suspect that this is due in part to static electricity problems and configuration of the respirometry chamber. Static frequently built up inside the chamber, making it impossible for the ants to assume a resting posture. Nonetheless, some individuals remained motionless and values of some relevant characteristics of the DGC are presented here. These means differ significantly between the lab and field colonies (ANOVA, P<0.05) but determination of the cause is impossible until more data are gathered. Possible contributing factors could include colony age, nutritional status, differences in environment between the laboratory and field, genetic (colony) effects, or a combination of these. Values presented here fall within the norm for ant species investigated thus far (Lighton 1994). Further investigations, using several laboratory colonies (and thus controlling for colony age, nutrition, etc.) are planned.

In addition to data reported here, we have observed a well-defined DGC in other red imported fire ant castes. Founding queens, male alates and female alates all exhibit a DGC. More individual recordings are needed in order to properly characterize the DGCs of the above castes. This work is currently underway in our laboratory.

SUMMARY

Adults of all castes of the red imported fire ant exhibit a DGC. The characteristics of the DGC in workers of S. invicta are similar to those of other ant species. We conclude that the red imported fire ant is a good model insect for investigations of the DGC as it relates to caste in ants. Further investigations are underway in our laboratory to investigate mass and temperature effects on the DGC, and to compare DGC characteristics between castes.
Literature cited


Figure 1. Configuration of respirometry system.

Figure 2. Periodic CO$_2$ emission in a worker of *Solenopsis invicta*.
Table 1. DGC characteristics for red imported fire ant workers.

<table>
<thead>
<tr>
<th>COLONY</th>
<th>n</th>
<th>Interburst Duration ± SE (min)</th>
<th>Burst Duration ± SE (min)</th>
<th>Total DGC Duration ± SE (min)</th>
<th>DGC Frequency ± SE (mHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory</td>
<td>61 obs., 4 indiv.</td>
<td>6.21 ± 0.57</td>
<td>1.28 ± 0.03</td>
<td>7.49 ± 0.58</td>
<td>2.89 ± 0.19</td>
</tr>
<tr>
<td>Field</td>
<td>67 obs., 4 indiv.</td>
<td>2.58 ± 0.17</td>
<td>0.99 ± 0.02</td>
<td>3.57 ± 0.18</td>
<td>5.37 ± 0.25</td>
</tr>
</tbody>
</table>
Field Assessment of the Fundamental Net Reproductive Rate of Solenopsis invicta

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Summary: An assessment of the fundamental net reproductive rate of Solenopsis invicta Buren populations in a natural environment is presented. It is based on measurements of: 1) survival of individuals at various phases of development at low population density, and 2) parallel measurements at their steady-state density. The method used a population of S. invicta in southern Arkansas. Survivorship of incipient (0-12 day-old) and juvenile (50-150 day-old) colonies were studied. Two different steady-state ant communities were used: one dominated by S. invicta and the other by Pheidole dentata Mayr. The latter community modeled pre S. invicta conditions. Experiments with incipient colonies were conducted in May-June and those with juvenile colonies in August-September 1994. Survival of incipient colonies was 0.82 and 0.80 and survival of juvenile colonies was 0.74 and 0.58, in these two ant communities, respectively. Based on results of our experiments and published results we used in our calculations, the estimated mean fundamental net reproductive rate of S. invicta was 5.1 with a one standard error confidence interval of $0.7 < \bar{X} < 34$.

This research was funded via special Congressional appropriations through the USDA/APHIS/PPQ. The results do not necessarily express APHIS' views.
Surface Scouting Activity of the Red Imported Fire Ant: a New Survey Method

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Where they are found, the polygyne form of the red imported fire ant (RIFA) occurs at several times the density of the monogyne form (Macom and Porter, in press). Because monogyne populations of the fire ant have clearly defined and defended territories, monogyne infestations may have patches between colony territories that have resources that are not exploited readily by foragers. Alternatively, monogyne colonies may defend more territory (and the resources that are associated with that area), then they usually require (Macom and Porter, in press). As polygyne populations do not show intraspecific aggression, they do not have as well defined a territory. This allows for a more thorough coverage of infested land by colonies in polygyne situations and possibly permits a more complete harvest of available resources by foraging workers (Porter and Savignano, 1990).

We designed a new method to determine if surface scouting densities are uniform throughout an infested area, without being attractive or removing workers from the environment. This technique, known here as the multiple stick array (MSA) method, is constructed with 24 wooden sticks (dimensions of $20 \times 2 \times 0.2$ cm ea.). We numbered each stick and placed them flush to the ground. The sticks are arranged into four sub-arrays of six sticks each and are laid out in the field at least 12 hours prior to observation. MSA's are observed for five minute intervals and all RIFA's crossing the sticks in that period are noted. Comparisons of activity levels can be made across space (stations of MSA's placed across a field) or time (hourly or every other hour). Below is a boxplot of ant activity from a 24 hour period in early September 1995, data compiled from the sub-array level of observation. This data was collected at a single MSA station in a polygyne infested field. Temperature at ground level is shown also.

References Cited


Response of the Red Imported Fire Ant to Magnetic Fields in the Nest Environment

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ABSTRACT: Magnetic fields (MFs) were applied to laboratory colonies of the red imported fire ant, Solenopsis invicta, to determine if ant behavior was affected. Weak, alternating-current electromagnetic fields caused fire ant workers to deposit eggs and larvae near the MF source in experimental colony containers. Ants did not react to stronger, static MFs. Our results reveal that MF type (i.e., alternating versus direct current) may be important to ant response, and fire ants may use MF information in nesting activities and in orientation.
Response of the Red Imported Fire Ant To Magnetic Fields in the Nest Environment

T.J. Slowik, H.G. Thorvilson, and B.L. Green Dept. of Plant and Soil Science and Dept. of Engineering Technology Texas Tech University, Lubbock, Texas
Introduction

- Insects use magnetic field (MF) information to orient and navigate

- Nest-building in social hymenopterans is affected by MFs:
  - direction of honey bee combs can be manipulated with MFs
  - some wasps build irregular nests towards decreasing MF strength
Ant Response to MF Cues:

- Anderson and Vander Meer (1993) reported that the red imported fire ant:

  - took longer to establish bait trails when the ambient MF was reversed after an acclimation phase

  - can sense MF information -- RIFA foraging behavior is affected by MF cues
Research Questions:

Is the RIFA affected by MFs in its non-navigational behaviors also?

Do MFs affect RIFA intracolony behavior in the nest environment?
Research Objectives:

Determine whether MFs affect the placement of eggs and larvae by RIFA workers within the colony's brood box.

(unpublished data suggested that RIFA workers move brood towards strong electromagnetic fields)
RIFA Colonies:

• polygynous colonies from Lubbock, TX, summer 1995 (average size = 650 ants)

• maintained in 40 x 27 x 15 cm "shoeboxes", each wrapped externally with paper

• each colony with a 12 x 12 x 3.5 cm clear, sealed, plastic "brood box" containing queens, brood, and attending workers
RIFA Colony Brood Box

- transparent top
- 5 entry holes
- sides wrapped externally with black tape

- top "boxed-off" into 16 3x3 cm squares with wax pencil
Magnetic Fields Used:

Electromagnetic field (EMF) -

- generated by solenoid
- MF changes polarity 60 times/sec. (60 Hz)
- weaker intensity of 0.56 Gauss

Rare earth magnetic field (REMF) -

- generated by 1 x 0.5 cm rare earth magnet
- static MF - polarity constant
- stronger MF of 2.582 Gauss
MF Application to Colony

- Rare Earth Magnet
- Electromagnet
- Colony Container
- Brood Box
MF Intensities:

REM: 2.58 G
0.40 G

EM: 0.47 G
0.40 G

Control: 0.33 G
0.36 G

Gauss: 0.33 G
0.40 G

Colony Treatments:

• MF applied for 24 hrs.

• Brood box number rating recorded

• Brood box reoriented, MF applied to different side

• Experiment replicated over ten consecutive days

• All colonies received EMF, REMF, and Control
Brood Box Number Ranking

• number of brood ranked in each of the 16 blocks of the brood box:

0  -  no brood in block
1  -  1-5 brood in block
2  -  6-10 brood in block
3 -  9  - successive increase of 5 brood in a block
10 -  45 or more brood in block
Brood Ranking (cont’d.)

- rankings of four blocks closest to applied MF summed, converted to percentage (index B) of entire box’s brood ranking

```
1 1 1
1 2 2
1 1 1
```

- mean index B determined for each ten-day treatment period

60 %
Statistical Analysis (ANOVA)

• RBD with 3 treatments (EMF, REMF, Control), over 5 colonies

• compare mean index B for each treatment over ten-day period

• look for significant difference in B indices for treatments

• confirm mean index B difference via FPLSD
Results:

- significant difference detected among treatments \( P < 0.001 \)
- no differences among colonies
- FPLSD test detected significant difference \( (a = 0.05) \) between mean index B of:
  - EMF and REMF treatments
  - EMF and Control treatments
Results (cont'd.):

• ants “stacked” and moved brood closest to applied EMF

• MFs did not change brood box temperatures and did not create detectable sound, or vibrations

• brood was not significantly deposited near REMF source

• brood randomly scattered in REMF, Control
Discussion:

- RIFA responds to electromagnetic fields
- MF type (fluctuating vs. static) important - frequency may also be important
- electromagnetic fields are present in electrical apparatuses that are often infested
- RIFA could use MF information as "template" in nest building/orientation
- colony workforce on one "nest plan"
Detection of Magnetism in the Red Imported Fire Ant Using Magnetic Resonance Imaging

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Dept. of Plant and Soil Science¹ and Dept. of Engineering Technology², Texas Tech University, Lubbock, TX 79409

ABSTRACT: Red imported fire ant (Solenopsis invicta) workers, queens, and alates were analyzed by magnetic resonance imaging for the presence of internal magnetic material. Images of ants showed distortion patterns similar to those of honey bees and monarch butterflies, both of which possess magnetic material that may be used for orientation. Bipolar ring patterns indicated ants also possess small amounts of ferromagnetic material that could aid in electromagnetic sense.
Lubbock, Texas
Texas Tech University
and Dept. of Engineering Technology
Dept. of Plant and Soil Science
T.J. Slowik, B.L. Green, and H.G. Thorton

Using Magnetic Resonance Imaging
Red Imported Fire Ant
Detection of Ferromagnetism in the
Magnetic Resonance Imaging (MRI)
may also function in navigation
possess internal iron concentrations which
ants respond to magnetic fields and

which they employ in navigation
internal ferromagnetic materials (magnetite)

naturally magnetic - they possess
honey bees and monarch butterflies are

Insects are magnetic:
Magnetite as MRI Contrast Agent

Pathology used in current studies of mammalian biodegradability typically superparamagnetic iron oxides which normally do not show distinct MRIs contrast agents darken or mark tissues.
be used to confirm or detect it?

If the RfA possesses internal concentrations of iron or other ferromagnetic material such as magnetite, could MRI

Research Question:
Using MRI, determine if the red imported fire ant possesses significant, detectable magnetic material in its body.
Arthropods used in assays:

- red imported fire ant workers (16), alates (9), and queens (9)
- honey bee (*Apis mellifera*) workers
- monarch butterflies (*Danaus plexippus*)
- common earwigs (*Forficula auricularia*)
- buffalo treehoppers (*Stictocephala bizania*)
- brown dog ticks (*Dermacentor variabilis*)
(Texas Tech Univ. Health Sci. Center, courtesy of Dept. of Radiology)

- Phase image sequence mode
- Magnitude image sequence mode
- Software package with 1.5 Tesla magnet and A2.7 Siemens 635P Clinical MRI System

MRI analysis:
honey bee

magnetite

wax drop

ants

butterfly

tick

(2% NaCl)

Insects submerged in saline solution.

Plastic Petri dish with wax or glue

arthropods attached to bottom of

Specimen Layout
did not differ from saline background image
other arthropods, glue, and wax
bees in magnitude image mode
all ants showed similar ring patterns to
magnetic created large image distortion
honey bees and monarchs (both modes)
distinct, bi-polar ring patterns around

Results
at 0.5 milligrams - 1.0 microgram
much less intense than those of magnetite
material not quantified, but insect patterns
images of ants in two modes
Jack of resolution may explain differing
accurately assess smaller arthropods like ants
clinical MRI may not have resolution to
results confirm bee and butterfly magnetism

Discussion
Red Imported Fire Ants, Solenopsis *invicta*, and Loggerhead Sea Turtles, *Caretta caretta*: Their Relationship

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Tifton, Georgia  31793
INTRODUCTION- Red imported fire ants have been documented to prey on several species of hatchlings and their eggs. Drees (1994) reported 100% mortality of hatchling waterbirds in fire ant infested areas. Mount et al. (1981) suggested fire ants attack and consume eggs of the lizard *Cnemidophorus sexlineatus*. Mount (1981) also reported that a colleague found fire ants raiding a chicken turtle nest.

Loggerhead sea turtles, *Caretta caretta*, nest in temperate zones, such as the barrier islands along Georgia’s coast. This endangered species is known to migrate thousands of miles between nesting seasons and return to the same beach year after year to lay their eggs. The nesting season in Georgia lasts from late May to early October. The 200-300 pound female drags her body ashore after mating and digs a 2-3 feet deep nest with her rear flippers. She will lay between 100-150 leathery eggs which will hatch in 60 days. The hatchlings emerge at night and use the moon's light to guide them to the sea. It is estimated that only 1 in 10,000 actually survive to reproductive age.

A Turtle Watch program has been in existence at Sea Island, GA for 6 years. These volunteers patrol the beach nightly during the nesting season, looking for signs of nesting and/or hatching. If nests are found close to the tideline, they are moved to a safer location on the beach. During the course of patrolling and logging data, volunteers were noting the presence of imported fire ants in the turtle nests.

The volunteers keep data on the location of each nest, the date that the eggs were laid, whether the nest was moved, and the success of hatching. Sixty days after the eggs were laid in a particular nest marked the beginning of nightly observations of the nest. If the hatchlings in a nest had not emerged by the 67th day, the nest was excavated and a determination was made as to the reason. If hatchlings did emerge on time, on the third night following the initial emergence, the nest was excavated. At this time, stragglers were set free and egg counts were made. Included in the final data were number of eggs present, number hatched, number piped, and number of dead turtles.

MATERIALS AND METHODS- Two 1 mile stretches of beach were sampled in 1995. The South Beach represented non-developed beach while the North Beach consisted of recreational and residential beachfront property. Four transects of thirty bait stations were run monthly from March until August. Transect A was located at the edge of the adjoining yard, Transect B was located in a burme approximately 20 m from A, Transect C was on the edge of the beach another 20 m from B, and Transect D was on the tideline approximately 50 m from Transect C. Because of the width of the South Beach, only two transects were run from May through August. The stations consisted of approximately 2 grams of canned tuna in a 16 X 100 mm disposable culture tube. At dusk, the tubes were placed flat on the ground and left for one hour, at which time they were stoppered and carried back to the lab. Alcohol was added to the tubes, and the ants were counted and separated according to morphological characters. A rating system was used to index the number of ants caught at each station. Samples were sent to the USDA Lab in Gainesville, FL and were identified by Mr. Greg Knue and Mr. Lloyd Davis.
RESULTS AND DISCUSSION- Nine species of ants were collected in the bait stations during 1995. *Solenopsis invicta* individuals were captured more often than individuals of any other species, representing 69% of all the ants collected. *Dorymyrmex bureni* comprised 15% of the collections, and *D. medeis* and *Pheidole morrisi* constituted 6% and 7% of the collections, respectively. The remaining five species made up 1% or less of the collections each.

On the South Beach, the overall composition of ant species varied widely from month to month. *D. bureni* was found in more traps than any other species in March (85%), *S. invicta* was found in more traps in April (61%), and *D. medeis* was found in more traps throughout the remainder of the study (32-56%).

On the North Beach, *S. invicta* and *D. bureni* were found in an equal number of traps in March, 42% each. From April through August, *S. invicta* completely dominated the bait stations, occupying from 52 to 71% of the traps.

While *S. invicta* dominated the traps in all four transects, they were especially dominant at the tide line. Generally, only *S. invicta* and *D. bureni* were found in this area. Along the yards and beach's edge, *S. invicta* was often found to be the dominant species; however, it was not always found in a majority of the traps.

Turtle Watch volunteers marked and monitored 101 turtle nests in 1995. However, two hurricanes passed near this area during the summer, destroying over 40% of the nests. In addition, the nest location data did not correlate well with the bait station locations. This forced a compilation of ant data for a large area, i.e. data from several stations were combined to give a general rating for an area. Using a weighted regression to plot the turtle mortality against the area rating showed a 24% correlation between the presence of imported fire ants and loggerhead sea turtle mortality. While this correlation was influenced significantly by the observation of one nest with 100% mortality, the possibility of fire ants destroying an entire nest is important.

Data from the Turtle Watch program showed the presence of fire ants in 14% of the turtle nests when the nests were excavated. In addition, some unhatched eggs collected from nests possessed small holes indicating an intrusion from a predator, possibly imported fire ants.

The evidence to date is circumstantial. Imported fire ants do appear to be a cause of some loggerhead sea turtle mortality; however, no real data exists to support this hypothesis. Twenty-four percent is not a strong correlation; however, if 24% of the mortality of an endangered species is due to fire ants, a control/management plan would be in order to prevent this damage.
REFERENCES


Percent Relative Abundance of Ant Species, Sea Island 1995

- Aphaenogaster flemingi (1)
- Dorymyrmex bureni (15)
- Dorymyrmex medeis (6)
- Forelius pruinosum (1)
- Monomorium minimum (1)
- Paratrechina vividula (1)
- Pheidole morrisi (7)
- Pheidole vinelandica (1)
- Solenopsis invicta (69)
Ant Species Collected on Sea Island, 1995

North Beach

South Beach

Percent of Traps

Mar Apr May Jun Jul Aug

S. invicta D. bureni D. medeis P. vividula others

Mar Apr May Jun Jul Aug

S. invicta D. bureni D. medeis P. vividula others
Update on Fire Ants, sea turtles, and alligators

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Red Imported Fire Ants, *Solenopsis invicta* Buren, are reported in green and loggerhead sea turtle nests in the Florida Keys. Preliminary tests conducted with non-viable eggs indicated the RIFA could not breach intact eggs.

The presence of RIFA in alligator nests in Florida was confirmed & initiated tests to determine predation on hatchlings. Laboratory tests indicate that RIFA do not invade unbreached eggs. Alligator eggs, hatching under laboratory conditions in RIFA mounds, do suffer mortality and experience statically significant reduction in growth.

¹This article represents the results of research only. Mention of a proprietary product does not constitute an endorsement or recommendation for its use by the USDA or the University of Florida.
ABSTRACT

Red imported fire ants are present in sea turtle nests in the Florida Keys. The presence of RIFA in alligator nests in Florida was confirmed. Tests indicate that RIFA do not invade unbreached non-pipping eggs. Alligator eggs suffer mortality hatching under laboratory conditions in RIFA colonies. Hatchlings experience statically significant reduction in growth.

INTERPRETIVE SUMMARY

This is the first report of Red imported fire ants, _Solenopsis invicta_ Buren, in endangered sea turtle nests and alligator nests in Florida. Tests indicate that RIFA do not invade non-pipping eggs. Alligator eggs suffer mortality hatching under laboratory conditions in RIFA colonies. Alligator hatchlings experience statically significant reduction in growth.
EFFECT OF RED IMPORTED FIRE ANTS ON SMALL MAMMALS: LAKE CONROE DAM, MONTGOMERY CO., TX

E. K. Pedersen¹, W. E. Grant¹, S. B. Vinson², M. T. Longnecker³, J. B. Martin², and B. M. Drees²

INTRODUCTION

The red imported fire ant (Solenopsis invicta) is an exotic species introduced to the US half a century ago and currently spreads over 100 million ha. Imported fire ants reportedly cause reductions in native arthropod fauna (Porter and Savignano 1990). Although experimental studies report alteration in habitat use by small mammals in the presence of fire ants (Smith et al. 1990, Killion and Grant 1993, Stoker 1993, Ferris 1993, Killion et al. 1995, Pedersen et al. 1995), the effects are subtle and some reports are contradictory. The objective of this study was to examine experimentally habitat use patterns of small mammals in the presence versus the absence of fire ants.

METHODS

This study was conducted at the San Jacinto River Authority compound at Conroe Lake, SW of Houston, TX, from May 1994 to September 1995. The study area consisted of a 3.24 ha open grassland divided into 10 areas 72x45m (Figure 1). Five alternating areas were treated in May 1994 and June 1995 with ant poison (Amdro®, active ingredient: amidinohydrazole 0.88%) to reduce density of fire ants (treated areas) (Drees et al. 1995). The remaining five areas contained naturally occurring densities of fire ants (untreated areas). Three 320 m parallel transects perpendicular to the

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treatments were established. Along each transect, 61 trap stations were placed 12 m apart. One Sherman live trap baited with bird seed was placed at each trap station. Traps located on the border of treated and untreated areas were considered separately (border). Treated and untreated areas each contained 41% of the traps, and the border contained 18% of the trap stations.

Trapping occurred 5 consecutive nights each month, except for October 1994. During the first night of each month, and as needed thereafter, granulated fire ant contact poison (Diazinon 5%) was placed underneath each trap, regardless of treatment. This procedure was necessary to prevent fire ant-induced mortality of trapped animals.

Fire ant activity was monitored by placing a vial containing cat food at each trap station once a month during the experiment, except during December 1994 and April 1995 (Martin et al. 1995).

Traps were set at dusk and checked in the morning from 07:00-13:00 during winter and from 06:00-10:00 during summer. Each small mammal captured was identified to species, marked with a unique ear tag, and released at the capture location.

Data were divided into 2 periods, summer (May-September 1994 and May-September 1995), and winter (November 1994-April 1995). Level of fire ant activity was the criterion used for data partitioning; fire ant activity was low in winter and high in summer. Capture per unit effort (CPUE) of small mammals was calculated by season and treatment as number of animals caught divided by the number of nights the traps remained open.

RESULTS

During the sampling period of 16 months a trapping effort of 13,418 trap-nights yielded a low (7%) trap success, even though the number of small mammals caught was relatively high: 171 cotton rats (Sigmodon hispidus) and 744 pigmy mice (Baiomys tailory). The white-footed mouse (Peromyscus leucopus) and the harvest mouse (Reithrodontomys sp.) were present in the area but were excluded from the current analysis due to low numbers.

Ninety-five percent of cotton rat captures occurred during summer. Pigmy mice were captured during both seasons, but were relatively more abundant during winter. During summer CPUE for cotton rats was higher in treated areas (0.034) than in border
(0.020) and untreated (0.013) areas, whereas during winter CPUE was low (<0.002) in all treatments (Figure 2). Pigmy mice were virtually absent during summer 1994. During summer CPUE for pigmy mice was distributed evenly over the 3 treatments with values of 0.055, 0.050, and 0.052 for treated, border and untreated, respectively. During winter CPUE was higher in untreated (0.078) than in treated (0.068) and border areas (0.052).

CONCLUSIONS

Thus based on this analysis cotton rats alter habitat use in the presence of fire ants during summer and pigmy mice do not alter use of habitat in the presence of fire ants in either season. During winter this pattern is not surprising; fire ants are less active and less aggressive during cool weather. However, during high fire ant activity (summer) CPUE in all areas were similar, indicating no treatment effect.

A generalized conclusion regarding impact of fire ants on native small mammals based on this and previous studies cannot be reached since the response seems to be species-specific. Each species has a different life history strategy influences its particular ecological interactions with an exotic species such as the red imported fire ant.

LITERATURE CITED


Figure 1. Study area showing 5 treated and 5 untreated areas crossed by 3 parallel transects where traps were placed. Conroe Lake Dam, Montgomery Co. TX.
Figure 2. Capture per unit effort (CPUE) for cotton rats and pigmy mice in treated, border, and untreated areas, during summer and winter. Conroe Lake Dam, Montgomery Co. TX, May 1994-September 1995.

Cotton rat

Pigmy mouse

64
THE EFFECTS OF FIRE ANTS ON RANGELAND
PLANT COMMUNITY SPECIES COMPOSITION AND DISTRIBUTION

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and
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Introduction

The red imported fire ant (Solenopsis invicta Buren) has become an integral part of many ecosystems throughout the southern United States. Densities commonly reach over 300 mounds per acre in many polygyne-infested parts of Texas, with densities of 30-40 mounds per acre in monogyne-infested areas. Though extensive research has been conducted on fire ant control and on the environmental impact of pesticides used in control, relatively little work has been done on what impact fire ants themselves have on the ecology of an area, as a whole. A particularly neglected area of study is what effects fire ants have on plants, specifically, plant species composition and distribution. Since plants are the basis of every food chain, fire ants may be causing ripples that are felt through entire ecosystems.

Two questions must first be addressed when examining plant-ant interactions. First, do fire ants have any impact on plants? Though there is ample evidence that many ant species have specific relationships with plants, there is little regarding the red imported fire ant. The second question is, if there are impacts, what mechanisms are behind them? It is hypothesized that there are two broad ways in which fire ants affect the plant species in an ecosystem: direct and indirect. Direct effects include activity by foraging ants such as differential seed predation or distribution and removal of insect or rodent herbivores, for example. Indirect effects include those caused by ant mound-building activity such as the opening of bare soil in continuous plant stands, increased/decreased soil fertility, seed trapping, and burial of surrounding seeds as an ant mound weathers.

Any of these factors can result in changes in a community’s plant species composition and distribution. For instance, undisturbed grasslands are relatively resistant to invading species. The thick litter layer and heavy ground-level shade present in an established prairie or pasture make it very difficult for a seed to germinate and survive to flowering. (Harrington, 1991): Even under moderate grazing, species composition is relatively stable. Invasion by other species only occurs after disturbances such as fire or overgrazing remove the turf cover, thus giving seeds access to both the ground and sufficient sunlight. (Noy-meir, 1989)

It is hypothesized that fire ant mounds, particularly abandoned ones, provide not only the opening, but ideal growing conditions for invading species. Fire ant mounds have been found to have higher nutrient levels (Blust, 1981), and are composed of loose, friable soil ideal for seed capture and germination. The implications of this phenomenon, should it occur, are extensive. In a grazed pasture, the appearance of bare spots and undesirable species means
lost forage and/or increased use of herbicides. In a wildlife management situation, the
introduction of new species may be desirable as it promotes the heterogeneity of resources
favorable to many game and wildlife species.

There were many factors taken into consideration when addressing this problem. First and
foremost, it was deemed necessary to see what was happening under actual field conditions.
Second, since roughly two-thirds of the state of Texas is pasture or rangeland it was decided
to focus on a grassland-type ecosystem. Unfortunately, the combination of the number of
plant species, the number of possible ant effects, and the number of environmental variables
makes the number of specific plant-ant-environmental interactions virtually infinite. Targeting
one, or even a few, plant species at the beginning of a field test could have easily been
fruitless so it was decided to, essentially, look at all of them. Since controlling for all of
these potential factors was impossible, it was assumed that they would be the same across
any chosen test site. It then remained to alter a single variable - the fire ant population. This
was accomplished by means of repeated bait applications on half the blocks of a replicated-
block experimental design.

Given the amount of effort involved in conducting such a large scale test, it was also decided
to build in a set of nested variables and controls within the treatment blocks that might help
determine the mechanisms of a plant-ant interaction should any be found. Because so much
about this subject was a mystery at its inception, the experimental design, became known as
the "shotgun approach" to field research - take a shot and hope you hit something.

Materials and Methods

The sites chosen for the work were located at Granger Lake in Williamson County, Texas.
Both sites are owned by the U.S. Army Corps of Engineers (USACE) and managed, in part,
by the Texas Parks and Wildlife Department. Public access is restricted on both sites. The
first and largest site consisted of about 29 acres of upland composed of black, heavy clay
soil. Vegetation was dominated by switchgrass (Panicum virgatum L.) to the point of being a
monoculture in some areas. Results from this site, though very similar to those of the other
site, are not discussed in this paper.

The second site was located below the dam and consisted of 15 acres of black, clay soil. The
site had been heavily disturbed during dam construction in the mid-1970's and lain fallow
until 1990. At that time, USACE and other organizations initiated a plan to restore the site to
a tall-grass native prairie. At the time of test initiation, summer 1993, grass composition
consisted primarily of little bluestem (Schizachyrium scoparum Nees.), King Ranch bluestem
(Bothriochloa ischaemum (L.) Keng var. songarica (Ruhr.) Celarier & Harlan ), and sideoats
grama (Bouteloua curtipendula (Michx.) Torr.), with scattered clumps of Indiangrass
(Sorghastrum anvenaceum), Switchgrass, and silver bluestem (Bothriochloa laguroides var
torreyana (DC.) Herter). Broad-leaf plants included Croton monanthogynus (Michx.)
scattered throughout, with some areas almost solid. Also present in significant numbers were
Texas bluebonnet (Lupinus subcarnosus Hook.), lemon bee balm (Monarda citriodora var.
citriodora Cerv.) and numerous other wildflower and early succession species.
The site was divided into 12 one-acre square blocks in a four-by-three pattern. Treatments were assigned as shown in Figure 1 to minimize the effect of slope and drainage which ran parallel to the long axis of the plot arrangement. The first treatment of Amdro® was applied in July of 1993 to the plots indicated. Amdro® was used because of its faster suppression of ant activity than other baits. Subsequent applications of Logic® were made in June, 1994 and every six months thereafter. Four more plots were treated similarly during the fall of 1994. The remaining four plots served as untreated controls.

Within each of the treatment plots six sets of sub-plots were established in October-November 1993. Ten sets were established in the control plots to help compensate for natural mound abandonment. Six sets of sub-plots were established similarly in the 1994 fall-treated plots. Sub-plot sets were established by locating an active fire ant mound and marking it with a three-foot piece of reinforcing rod with a metal label attached. A 12-foot piece of 3/4-inch PVC pipe, marked in the center and at five-foot radius on each side, was centered on the mound. The orientation of the pipe was randomized by spinning a pencil in the air and letting it land, then placing the pipe parallel to the pencil.

A 12d duplex nail with an attached strip of surveyor’s tape was then placed in the ground by each mark and in a north-south orientation on the edges of the fire ant mound. Another nail was placed 11 inches out from the first on one end of the pipe to designate the untreated control sub-plots. Nothing further was done to the control sub-plots or active mounds.

On the other end of the pipe, a five-gallon bucket with the bottom cut out (for a diameter of 11 inches) was placed on the ground at the five-foot mark. Vegetation was removed from inside the bucket and the ground was thoroughly disturbed with a garden soil cultivator. Two shovelfuls of soil, dug from a nearby area, were placed into the bucket and firmed into a hemi-spherical shape by hand. The bucket was then removed and a nail marker placed on the outside edge of the "fake mound" aligned with the first nail and central mound. See Figure 2 for a diagram of the sub-plot arrangement.

In May, 1994, vegetative sampling was initiated on the marked plots. The belt sampling device consisted of a block of oak hardwood, approximate dimensions: 4 x 6 x 3/4 inches. Two 3/16-inch diameter steel rods were set into holes drilled in the wood block so that the rods remained parallel to each other and 5 cm apart for their entire length. The rods were nicked at 10 cm increments for a total of 60 cm. The marks were further highlighted with black electrical tape.

To sample a sub-plot, the rods on the belt sampler were lined up with the marker nails and slid through any vegetation so that they were within an inch or two of the ground. The block was then centered on the mound or sub-plot with a marker nail on one side. All plant species rooted within each 5 cm X 10 cm quadrat, delineated by the rods and marks, were identified, counted and recorded on a pre-prepared data sheet. The procedure was repeated for all three sub-plots within each set and for every set in the test.

This method provided species identification, the number of plants of each species, and the location of each plant (within 10 cm) of the center of every sub-plot. Data for each species
were then grouped into categories for analysis as follows:
1) by treatment group (ants/no-ants) and distance from sub-plot center,
2) by sub-plot type (mound/control/disturbed) and distance from sub-plot center,
3) by treatment group, sub-plot type, and distance from center.
Means were separated using PC SAS ANOVA, and Tukey's studentized range test ($p < 0.05$).

Fire ant suppression treatments and vegetative analysis are ongoing at this time, with evaluations taken May-June, and October each year, depending on weather conditions and plant growth.

**Results and Discussion**

One of the first things noticed when evaluating the test sites for the first time in May, 1994 was the very conspicuous concentration of lemon bee balm (*Monarda citriodora*) around many of the marked fire ant mounds. Keeping in mind that the mounds were marked and sub-plots established months after bee balm flowered in the late spring, it is unlikely that there was any bias, conscious or otherwise, towards marking these particular mounds.

Results were striking. When analyzed only by sub-plot (Figure 3), **fire ant mounds** had significantly more bee balm plants per quadrat within 30 cm of the center than either the control or disturbed "fake mound" subplots. Significant differences disappeared outside this radius, though numerical differences persisted. When analyzed only by treatment type, ants (untreated) versus no-ants (treated), significant differences also appeared within the inner 10 cm radius circle of all sub-plots combined (Figure 4). Bee balm was more common in areas with fire ants. Large numerical differences persisted throughout the 60 cm radius, but were not significant due to the great variation between sub-plot types.

These differences were magnified when the quadrat means were separated by both sub-plot type and treatment type (Figure 5). Significant differences were again found between sub-plot types within a 30 cm radius with further separations between treatment types. Note that not a single bee balm plant was found, out of 144 quadrats, around a disturbed site in a treated (no-ant) plot. Curiously, and perhaps importantly, observations indicate that these phenomena did not occur on the marked mounds in the second year. This data for this period have been collected, but not yet analyzed.

This phenomenon was not entirely unexpected, though its magnitude was a surprise. Simply looking at the test site gave evidence. If a clump of bee balm was noticed, it was almost guaranteed that there was an abandoned fire ant mound beneath it. On the other hand, not every fire ant mound had a clump of bee balm associated with it. Many, in fact, had none. It would appear, then, that the time of either mound formation or abandonment in relation to bee balm seed dispersal has something to do with the presence of so many plants. Determination of this mechanism is underway in laboratory trials.

The second striking observations to come from the test concerns the plant *Croton monanthogynus* or prairie tea. It will be referred to as "croton" here. This plant forms
extensive patches within the test site, becoming the dominant flowering species in September and October. At the time of evaluation, it was just reaching the four to eight-leaf stage, but was easily recognizable due to its scaly, oblong leaves and reddish stems. This made for an excellent opportunity to study its germination since many seedlings did not survive the long, hot, dry summers and cracking soil of the area.

Croton was analyzed in an identical manner as was bee balm, but the results were exactly opposite! When analyzed across sub-plot type (Figure 6), croton was significantly more common within the disturbed sub-plots, differences disappearing outside of 20 cm from the sub-plot center. When analyzed across treatments (Figure 7), croton was found to be significantly more common in the inner 10 cm radius of all sub-plot types in treated areas - areas without fire ants.

Again, the differences were magnified when analyzed across all factors (Figure 8). Various combinations of factors separate from each other within 20 cm of the sub-plot center, then disappear outside this range. Keep in mind that the disturbed sub-plot diameter was 11 inches, or 14 cm radius, so it is only the inner 10 cm circle that is completely within the disturbed area. The next ring (10 cm -20 cm) was only half disturbed originally, but was largely covered by eroding soil off the "fake mound" by the time of evaluation.

It is the inner circle of disturbed sub-plots in treated areas that have significantly higher numbers of croton plants than any other sub-plot type in that range. The next ring has significantly more plants than around any mound sub-plot type, and significantly more that the undisturbed sub-plots in untreated areas. Though not significantly different there are large numerical differences between disturbed/treated, disturbed/untreated, and undisturbed/treated sub-plots.

Table 1 summarizes the differences in location of bee balm and croton. Clearly, there are different mechanisms at work here. To begin looking at some of these, one must look at the characteristics of the two species. Lemon bee balm was the original source of citronella, a commonly used organic insect repellent. Why, then, would they be most abundant around abandoned colonies of tens-of-thousands of insects? Might the ants be collecting the seeds then discarding them around the mound when they found them distasteful? Perhaps the expanding or eroding mound structure or greater fertility enhanced bee balm seed germination without any differential ant seed distribution at all. Remember that bee balm clumps occurred mostly around abandoned mounds. Maybe when the plants started growing, their repellent oils made the ants abandon the mound. On the other hand, the plants were much more common in areas with foraging ants. At this point, there is are indications that both ant activity, (seeds around the mound) and mound structure (fertility, burial, etc.) play a role.

This theory is supported to some extent by a field adjacent to the test site that was burned and heavily plowed the year after this test was established in preparation for prairie restoration. The field had a huge flush of bee balm growth the spring after disturbance, indicating that burial and/or nutrient uplifting is favorable for bee balm germination. Bee balm was much less common the following year. Though not formally evaluated, there were
also few visible fire ant mounds in this field after burning, plowing, or during the following year and no visible bee balm clumps.

Some *Croton* spp. have oil glands, are aromatic, and are reputed to have medicinal and/or toxic properties to both humans and livestock. They also provide much food for wildlife, particularly birds (Correl and Johnston, 1979). Also, many plant species, including some *Croton* spp. have developed ant-dispersal mechanisms (Heithous, 1981) and are used by ants for food. (Brown, et. al., 1979) It is very possible that *Croton monanthogynus* shares similar characteristics and is used by fire ants as a food source as suggested by the plants’ increased abundance in ant-free areas.

*Croton* spp. are also known to increase in abundance under conditions of heavy grazing (Correl and Johnston, 1979). On this particular site, *Croton monanthogynus* appears to favor the upper parts of the field where it forms almost solid patches across the drier, more clayey areas where few other species are found. This fact has been supported by other vegetation evaluation methods conducted, but not reported here. So, it appears that croton competes poorly with other plants and/or in areas of higher fertility and/or better water relations. This would help explain why croton is more common on mechanically disturbed sites rather than on ant mounds.

Several other species differences were noted in the data from this evaluation, though they were not statistically significant at the 95% confidence level, due largely to low overall occurrence. Ragweed (*Ambrosia psilostachya* DC.) was found to be much more prevalent in untreated plots. Sunflower (*Helianthus* spp.) was more abundant and much more robust around fire ant mounds. Sideoats grama an important mid-grass of native prairies, was found in dense rings around some mounds and exhibited increased vigor, height and earlier seed production than grass growing in surrounding areas.

Conversely, ant colonies seem to be unusually attracted to clumps of little bluestem, the grass most associated with native prairies in Central Texas, versus any other bunchgrass. During the hot summer, many mounds appear in these dense grass clumps, possibly for shade or water and nutrients. Though ants do not kill a grass bunch, it sometimes seems to lag behind nearby bunches, possibly reducing its competitiveness. Then there is goldenrod (*Solidago* spp.), common across both test sites, and apparently not affected at all by ant presence, mounds, or soil disturbance.

**Conclusion**

It is apparent that either red imported fire ant activity, their mounds, or both have some effects on some plant species. There is evidence that several mechanisms are involved including seed predation, seed dispersal, and altered edaphic factors including increased soil fertility and disturbance. However, as amply demonstrated by the bee balm versus croton findings, the mechanisms are strongly species specific. Also, as suggested by the presence of bee balm rings around some mounds but not others, seasonal and environmental factors play a role in these mechanism. Though it is very likely that fire ants are having measurable
effects on plant species composition and location across a wide range of ecosystems, those
effects may not only be species-specific, but site-specific.

Defining the impact of fire ants on an ecosystem or plant community may require detailed
investigation into the plant species composition, environmental factors, and edaphic
conditions of any site under consideration for fire ant management. But, coupled with defined
agricultural and wildlife goals, fire ants or their control may become a useful tool in the
management of these systems.

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Acknowledgments

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Many thanks to the U.S. Army Corps of Engineers, Granger Lake Unit, for their cooperation
in allowing us the use of these and other sites for our work.
<table>
<thead>
<tr>
<th>Species</th>
<th>Subplot Preference</th>
<th>Ant Presence</th>
<th>Possible Mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bee Balm</td>
<td>around aband. mounds</td>
<td>more abundant</td>
<td>incr. fertility disturbance burial repellent oils</td>
</tr>
<tr>
<td>Croton</td>
<td>on disturbed sites</td>
<td>less abundant</td>
<td>low fertility denudation low competition attractive oils</td>
</tr>
</tbody>
</table>

**Figure 1. Diagram of Lower Field plot layout**

**Figure 2. Diagram of subplot layout**

MD - Active mound  
CK - Undisturbed  
D - "Fake mound" Disturbed Site
Figure 3. Bee Balm Subplot Analysis

Bars with different letters are significantly different (p<0.05)
Sub-plot n = 64

Figure 4. Bee Balm Treatment Analysis

Bars with different letters are significantly different (p<0.05)
CK n=40  TRT n=24

Figure 5. Bee Balm Subplot X Treatment Analysis

Bars with different letters are significantly different (p < 0.05)
Economic Impact of Fire Ants on Arkansas Livestock Farms - a Survey

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School of Forest Resources, University of Arkansas, Monticello, AR 71656-3468.

Summary

A questionnaire was mailed in October 1994, to 2,144 randomly selected farm operators. This represented 10% of a mailing list maintained by the Federal Farm Service Agency (formerly the Agricultural Stabilization and Conservation Service) for the 25 imported fire ant infested counties in southern Arkansas.

There were 452 (21%) questionnaires returned. Upon receipt, each questionnaire was dated, numbered, and entered into a Paradox database. 209 responses were removed because they did not have fire ants present on their farm, they included contradictory statements, or they were determined to be non-farmers. Final adjustments removed 99 row crop and tree farmers that were not involved in livestock production. This left 144 (7%) responses to assess imported fire ant damage to livestock farms.

Survey participants were asked these questions for the previous 12 month period;

- acres managed for what farming operation.
- acreage infested and treated for fire ants.
- kind and how many head of livestock.
- damages incurred due to fire ants and a dollar amount of that loss.

Analysis of the data was done with SPSS-PC software. There were three natural divisions of livestock production; cattle, swine and poultry. To assess unique losses associated with each type of farm, only those responses that indicated they were exclusively in that type of livestock farming were considered for each category. The average number of livestock on the farm for the survey compares well with the average livestock per farm for southern Arkansas (Fig. 1). This gives some confidence that our survey represents average losses for livestock farms in southern Arkansas.
Treatment for fire ants is conservative on cattle farms, with only about 15% of the infested acreage treated (Fig. 2). Poultry and swine farms treated a larger percentage, perhaps because they tend to be smaller and easier to treat. The sample size for each farm type reveals that damage estimates for cattle farms will be more accurate than estimates for swine or poultry farms.

Damage categories were determined from survey responses. Cattle farms suffered losses in worker time lost (repairing damage caused by fire ants), mower breakage, cattle injured/killed, feed eaten and/or contaminated by fire ants, insecticides used to combat fire ants, hay and pasture yield losses, building damage, electrical damage (such as pumps and motors), medical treatment for stings, and damage to air conditioners (Fig. 3). This produced a total yearly loss per farm of $327 ± $68 (s.e.). Swine farms only reported damage in the electrical category ($50/year), giving a yearly total loss of $50 ± $50. Poultry farms had losses to mowers ($217/year) and to chickens ($83/year), resulting in a loss of $300 ± $300 per year.

Using 1992 Census of Agriculture - County Summary Highlights data (http://govinfo.kerr.orst.edu/ag-stateis.html), these dollar losses were expanded to all cattle, swine and poultry farms for fire ant infested counties in southern Arkansas. A list of fire ant infested counties was obtained from the National Agricultural Pest Information System (http://www.ceris.purdue.edu:80/napis/pests/ifa/).

Total losses for fire ant infested counties in southern Arkansas were assessed at $1.2 ± 0.25 million for cattle farms (3,722 farms), $12 ± 12 thousand for swine farms (246 farms), and $300 ± 300 thousand for poultry farms (1,025 farms). Livestock losses to fire ants for southern Arkansas totaled just over $1.5 million dollars. This research was funded via special Congressional appropriations through the USDA/APHIS/PPQ. The results do not necessarily express AHPIS' views.
Fire Ant Impact on Arkansas Row Crop Farms - Survey Results.

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University of Arkansas, Monticello, AR 71656-3468.

Introduction
This manuscript reports results of a survey to assess the impact of imported fire ants (Solenopsis invicta Buren) on row crop farms in southern Arkansas. It expands results reported at the 1994 fire ant conference (Thompson and Jones 1994).

Methods
A questionnaire was mailed to 2,144 randomly selected farm operators. This represented 10% of a mailing list maintained by the Federal Farm Service Agency for the 25 imported fire ant infested counties in southern Arkansas. After removing responses that did not have fire ants, and those that were no longer in farming operations, 243 valid replies were used to assess imported fire ant damage to farm operations. To analyze for row crop damage the data set was further reduced by eliminating farms that did not grow row crops (corn, cotton, oats, rice, sorghum, soybean, and wheat) and by eliminating farms with fewer than 10 acres in row crops. Thirty three (33) farms remained in the data set. Survey participants were asked these questions for the previous 12 month period:
- acres managed for specific farm operations, like crops.
- acreage infested with and treated for fire ants.
- damages incurred due to fire ants and a dollar amount of that loss.

Census of Agriculture (1992) data were used to obtain production information. Fire ant infested counties were obtained from the National Agricultural Pest Information System. The SPSS-PC statistical package was used for data analysis.

Results
Figure 1 shows our survey population by farm size. This population includes small farms and exceedingly large farms, with few in between. Figure 2 compares our survey population to the state population for acres planted to the row crops. Our survey population mimics the state population, so we feel confident that our survey population represents the total row crop population of southern Arkansas. Many Arkansas row crops are grown on large farms situated on riverbottom soils of the Arkansas, Mississippi, Ouachita, Red, and Saline rivers in southern Arkansas.

Table 1 shows the number of farms growing each crop and the mean number of acres by crop. Soybeans, cotton and rice are the dominant crops. Oats and corn should be considered inconsequential because of their low frequency.

Figure 3 shows the acres of each crop infested by fire ants and the infested acres treated to control fire ants. Although 66% of the acreage was infested, only 1% was treated.

Table 2 shows mean losses to fire ants by loss category. Electrical losses, including losses to air conditioners, pumps, switches and other such devices, topped the list. Fire ants are known to be attracted to electrical equipment. Combine losses are second in magnitude. These losses are mostly due to mounds that plug or physically damage such machines. Losses
are most common in soybean fields because the combine’s cutting head is run close to the ground to harvest seed from the short plants. Our experience in Arkansas indicates that fire ants are a problem mostly when soybeans follow winter wheat in no-till systems. In these situations, the soil remains relatively undisturbed for almost a year, which encourages colony development. Yield losses were reported only for soybean ($24/farm) and cotton ($8/farm). Yield losses occur in soybeans when the cutter head is raised to avoid fire ant mounds and by direct damage to seeds by fire ants.

Table 3 shows fire ant losses on a per acre and per farm basis by crop. This information allows us to estimate losses beyond our survey population. According to the 1992 Census of Agriculture, total harvested area in corn, cotton, oats rice, sorghum, soybean, and wheat in the infested counties we surveyed was 879,825 acres. If we multiply this acreage by our mean loss per acre of $0.44, we get a mean annual loss of $387,000 to fire ants in row crop in southern Arkansas. This loss is substantial. Moreover, we suspect our survey underestimated losses to fire ants because many farmers probably placed a low value on their own time (i.e., the farmer works all day, regardless of where or on what). We argue that repairing equipment damaged by fire ants is not required work in agricultural production, so it should be considered a loss when it occurs). With a standard error of $0.23/acre, the 95% confidence interval for this calculation is $0 to $792,000, mean annual loss per year. Obviously, with the small sample size, and only 7 of 33 farmers reporting damage, we may have no problem or a 3/4 million dollar problem. Clearly, additional information is needed to assess where along this continuum losses really occur. We did not do a similar calculation for losses by farm because the number of row crop farms is difficult to assess from Census of Agriculture or USDA/NASS sources (i.e., a farm that produces cotton, rice and soybeans may be counted three times, once for each crop).

In conclusion, fire ants caused obvious economic impact to row crop farmers. However, compared to the impact to livestock producers (see Jones et al (1996) in this Proceedings) and at urban and residential homesteads (Thompson and Jones 1994) row crop losses are relatively minor.

Acknowledgements
This research was funded via special Congressional appropriations through the USDA/APHIS/PPQ. The results do not necessarily express APHIS’ views.

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Table 1. Number of farms with crops and mean acreage for these farms.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Farms</th>
<th>( \bar{x} ) ac/farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>27</td>
<td>550</td>
</tr>
<tr>
<td>Rice</td>
<td>19</td>
<td>390</td>
</tr>
<tr>
<td>Wheat</td>
<td>12</td>
<td>192</td>
</tr>
<tr>
<td>Sorghum</td>
<td>12</td>
<td>70</td>
</tr>
<tr>
<td>Cotton</td>
<td>11</td>
<td>102</td>
</tr>
<tr>
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<td>121</td>
</tr>
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<tr>
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<td>33</td>
<td>1053</td>
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Table 2. Mean losses per farm by loss category.

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<td></td>
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<td>3</td>
<td>100</td>
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<tr>
<td>All</td>
<td>132</td>
<td>56</td>
<td>1345</td>
<td>7</td>
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Table 3. Fire ant losses per acre and losses per farm by crop.

<table>
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<tr>
<th>Crop</th>
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<th>se</th>
<th>Loss/farm ($) Mean</th>
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<tbody>
<tr>
<td>Soybean</td>
<td>0.37</td>
<td>0.19</td>
<td>137.96</td>
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<tr>
<td>Cotton</td>
<td>0.10</td>
<td>0.07</td>
<td>101.82</td>
<td>68.33</td>
</tr>
<tr>
<td>Rice</td>
<td>0.39</td>
<td>0.21</td>
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</tr>
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<td>Wheat</td>
<td>0.80</td>
<td>0.57</td>
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<td>1.09</td>
<td>123.75</td>
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</tr>
<tr>
<td>Corn</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Oats</td>
<td>32.50</td>
<td>26.50</td>
<td>423.33</td>
<td>306.94</td>
</tr>
<tr>
<td>Mean</td>
<td>0.44</td>
<td>0.23</td>
<td>131.82</td>
<td>55.70</td>
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Figure 1. Row crop farm size in survey.

Figure 2. Comparison of crop acreage for our survey and southern Arkansas.

Figure 3. Acres infested and treated for imported fire ants.
Expanding the Arkansas Fire Ant Farm Survey Over the South

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Introduction

Imported fire ants (Solenopsis invicta and S. richteri) currently infest 12 southern states, 746 counties, 503 thousand square miles, 321 million acres, and conceivably 52 million people.

As an example of how loss estimates over large areas can be generated, Diffie et al. (1991) reported mean losses to fire ant in Georgia as: $21 for control, $4 for medical treatment, and $10 for damage; for a mean overall loss of $35 per household. Bass et al. (1992) used Diffie’s mean to expand fire ant losses statewide. They estimated the number of affected urban and rural households at 1,000,000 and multiplied this by the $35 mean loss per household to get a total annual impact in Georgia of $35 million. If we take this reasoning one step further and expand the mean losses in Georgia by the 18,968,000 households in the South (1990 census) we can estimate annual losses of $663.9 million to fire ants. Again, using similar reasoning, Thompson et al. (1994) expanded fire ant losses over the rural South using information obtained from a 1993 Arkansas survey. With 1,516,000 rural households (1990 census) in the South and a mean loss of $298 per rural survey respondent, which included many farmers, this calculated out to an annual loss of $451.8 million in the rural South. So, regardless of whether losses were estimated in Georgia or Arkansas, it is apparent that fire ant impact on the South is substantial.

Much of the fire ant literature on economic effects deals with impacts to agricultural crops (e.g., Jemal and Hugh-Jones 1993). However, none of these crop studies attempted to project losses beyond the local conditions. Although this may be sound science, it circumvents the need for information about the impacts of fire ants over large geographic areas, like southern Arkansas and the South. To partially rectify this problem, several recent studies, some using unconventional techniques, are published in these proceedings (Jones et al. 1996, Semenov et al. 1996, Semevski et al. 1996, Thompson et al. 1996). Results of these studies are summarized here to provide an overall view of this problem and to comment on how these studies may help focus future research efforts.

Methods

We used agricultural information reported by the USDA National Agricultural Statistics Service (NASS) for counties that were completely infested with fire ants. In our calculations we represent the 95% confidence interval about the mean as ± twice the standard error.

Results

Survey. Table 1 shows the estimated mean annual livestock and agricultural crop losses to imported fire ants over the South. The unit losses in this table were derived from responses to a 1994 farm survey requesting estimates of actual losses to fire ants (Jones et al. 1996, Thompson et al. 1996). The units are derived from NASS data. Because of small sample sizes (N) for some commodities, variation was substantial. We used mean losses for each crop. Of course, this assumes that losses in one crop are independent of losses in another. This may not be the case with the crop survey data because a typical eastern Arkansas farm grows 5 or more crops (e.g., cotton, rice, soybean, sorghum and wheat) each year and some fire ant induced damages (e.g., electrical devices common to all farming operations) would have been cataloged over several crops. Regardless of the potential for double counting, we used individual crops because some are common to only a few states (e.g., rice and sorghum) while others are common across most states (e.g., corn, cotton, soybeans and wheat). In the final computation, total livestock and crop losses exceeded $90 million annually (Table 1). Because total crop losses are about 11% of total livestock losses, they are comparatively less important.
Table 1. Estimated mean annual livestock and agricultural crop losses to imported fire ants over the South.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Unit</th>
<th>Unit loss (N)</th>
<th>Mean loss</th>
<th>95% CI ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigs/Hogs</td>
<td>19,239 farms</td>
<td>$50 ± 50 (4)</td>
<td>$960,000</td>
<td>0 - 2,880,000</td>
</tr>
<tr>
<td>Chickens</td>
<td>24,572 farms</td>
<td>300 ± 50 (6)</td>
<td>7,370,000</td>
<td>0 - 22,110,000</td>
</tr>
<tr>
<td>Cattle</td>
<td>228,212 farms</td>
<td>327 ± 68 (115)</td>
<td>74,630,000</td>
<td>43,588,000 - 105,662,000</td>
</tr>
<tr>
<td><strong>Total livestock</strong></td>
<td></td>
<td></td>
<td><strong>82,960,000</strong></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>2,963,936 ac</td>
<td>0.00 ± 0.00 (1)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cotton</td>
<td>4,464,836 ac</td>
<td>0.10 ± 0.07 (11)</td>
<td>446,000</td>
<td>0 - 1,072,000</td>
</tr>
<tr>
<td>Rice</td>
<td>1,396,052 ac</td>
<td>0.39 ± 0.20 (19)</td>
<td>544,000</td>
<td>0 - 1,103,000</td>
</tr>
<tr>
<td>Soybean</td>
<td>5,308,933 ac</td>
<td>0.37 ± 0.19 (27)</td>
<td>1,964,000</td>
<td>0 - 3,982,000</td>
</tr>
<tr>
<td>Sorghum</td>
<td>1,942,052 ac</td>
<td>2.37 ± 1.09 (12)</td>
<td>4,603,000</td>
<td>37,000 - 8,836,000</td>
</tr>
<tr>
<td>Wheat</td>
<td>2,046,330 ac</td>
<td>0.80 ± 0.57 (12)</td>
<td>1,637,000</td>
<td>0 - 3,970,000</td>
</tr>
<tr>
<td><strong>Total crop</strong></td>
<td></td>
<td></td>
<td><strong>9,194,000</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td></td>
<td><strong>92,154,000</strong></td>
<td></td>
</tr>
</tbody>
</table>

Based on the 1994 Arkansas farm survey (Thompson et al. 1996), economic losses in yields for two important crops were $0.11/ac (± 0.11) for cotton and $0.02/ac (± 0.02) for soybeans. If we multiply the 4,464,836 ac of annual southern cotton production in infested areas by $0.11/ac we get a $491,000 annual loss (95% CI = $0 to $1,473,000). And, if we multiply the 5,308,933 ac of annual southern soybean production in infested areas by the $0.02/ac yield loss we get a $106,000 annual loss (95% CI = $0 to $318,000). Although these losses may seem notable, other studies published in this Proceedings, and reiterated below, suggest that fire ant impacts may be quite different.

**Modeling.** Semenov et al. (1996) used models to calculate the net impact of fire ants on crop yields for corn, cotton, sorghum, soybean, and wheat. Cotton yield was positively affected (3%) while soybean yield was negatively affected (3%). This positive effect on cotton calculates to a net annual gain of $58.3 million for southern cotton producers (3,734,160,000 lb annual production * 0.03 gain = 112,024,800 lb gained * $0.53/lb value = $58,252,000 benefit). The negative effect on soybean yields calculates to a net annual loss of $31.1 million for southern soybean producers (195,585,000 bu annual production * 0.03 loss = 5,867,550 bu lost * $5.30/bu value = $31,098,000). So, we see that cotton is benefitted considerably by fire ants and that losses in soybeans are much greater than the survey would suggest.

Semevski et al. (1996) took a different strategy. They analyzed the fire ant literature and then modeled the system to estimate fire ant impacts on crop production. They estimated total annual losses to fire ants at $271 million. More specifically, cotton and soybean show trends similar to Semenov’s model (Table 2), with positive effects on cotton and negative effects on soybeans.

Table 2. Overall imported fire ant loss estimates for cotton and soybean in the South.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Annual loss/gain (million$)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>+ 15.6</td>
<td>Semevski et al. 1996</td>
</tr>
<tr>
<td></td>
<td>+ 58.2</td>
<td>Semonov et al. 1996</td>
</tr>
<tr>
<td></td>
<td>- 0.4</td>
<td>Thompson et al. 1996</td>
</tr>
<tr>
<td>Soybeans</td>
<td>- 125.7</td>
<td>Semevski et al. 1996</td>
</tr>
<tr>
<td></td>
<td>- 31.1</td>
<td>Semonov et al. 1996</td>
</tr>
<tr>
<td></td>
<td>- 1.9</td>
<td>Thompson et al. 1996</td>
</tr>
</tbody>
</table>
Remember, these models represent mostly yield losses. Not represented are equipment failure and other items described by Thompson et al. (1996). A comparison of Table 1 with the above calculations shows considerable disparity. Especially important is the net gain in cotton production reported by the model and the losses reported by our farm survey. Perhaps, the 3% changes in yield reported by Semeonv's model are too small to be detected by farmers. Anyway, the differences are striking.

Discussion
If we look specifically at cotton and soybean (Table 2) it is clear that something is amiss. Either farmers are underestimating the impacts of fire ants or our quantitative assessments are overestimating these same effects. We suspect the former is true. Most farmers probably have difficulty assessing fire ant impacts because impacts are sometimes subtle. Obvious impacts, like clogged combines and damaged electrical equipment, are easy to observe and to assess. However, less striking changes in yield, either positive or negative, are likely to be overlooked.

In conclusion, it is essential to assess actual economic impacts of fire ants because any program aimed at fire ant control must be based on sound economic analysis of the problem. This is why we think additional research on specific aspects of the direct effects of fire ants on crops are of low priority. Instead, a higher priority should be placed on studying indirect effects, such as the relative importance of fire ants in controlling other crop pests, social and environmental consequences, and tradeoffs of insecticide applications. Perhaps another area of high priority for agriculture should be studying the effects fire ants have on livestock production, especially ant and pest interactions in pastures. At the moment, impact on livestock is the biggest hole in our knowledge of fire ant impacts on agriculture.

Acknowledgements
This research was funded via special Congressional appropriations through the USDA/APHIS/PPQ. The results do not necessarily express APHIS' views.

Literature
FIRE ANT-RELATED ECONOMIC LOSSES VERSUS OPERATION SIZE
in CATTLE PRODUCTION:
Results of the Texas Cattle Producer's Survey

Charles Barr, Extension Associate
and
Bastiaan M. Drees,
Professor and Extension Entomologist

Background

In 1994, the Texas Agricultural Extension Service with cooperation from the Texas and Southwestern Cattle Raiser’s Association (TSCRA), mailed a detailed survey on fire ant-related economic losses to TSCRA members in 72 fire ant-infested counties. The impetus of the survey was to document these losses in order to develop Integrated Pest Management programs for the red imported fire ant. Survey results indicated that fire ant-related losses were both widespread and costly, though with substantial variations, even between ranches in the same county. Because of these variations, it is imprudent to make a "one-size-fits-all" management plan. Rather, an operation-by-operation cost analysis is called for in which losses are balanced against treatment costs so that fire ant management can be justified economically.

Nevertheless, survey comments, among other sources, indicate that there is still widespread interest in large-scale fire ant treatment programs. In urban and suburban settings, there is rarely an economic component involved in making treatment decision, other than out-of-pocket costs. In agricultural situations, however, the cost of treating large areas must be balanced by the economic benefits of reducing fire ant damage. Consequently, the need exists for some way to estimate or predict losses without going through detailed cost analyses of every property involved.

Choosing a Predictor

To develop an accurate method of estimation, it is necessary to have an accurate independent variable, or predictor, on which to base the estimates. A ranch must have two things to be called a ranch - cattle and land on which to raise them. Though there are ant-related losses associated directly with cattle, the number of head varies on almost a weekly basis for many operations and is dependent on constantly fluctuating weather and economic factors. Acreage, however, has many advantages for this purpose. Despite land sales, leases and changes in production status, the amount of land on which cattle and hay are raised is relatively constant. Most fire ant-related costs are at least indirectly associated with the amount of land in production. Acreage in agricultural production is publicly accessible information, whether in the form of county tax records or state and national census figures. Finally, acreage in
production was provided by nearly all respondents to the Cattle Producer’s Survey from which the economic information was extracted.

Frequency of Fire Ant Damage

There are two components to predicting fire ant-related losses - frequency and the loss per-respondent amount. This report will deal primarily with loss amount since it is a much more complicated subject. However, any loss on a per operation basis must be tempered by the fact that not every operation suffers every type of loss. In fact, most operations suffer just a few types of loss on a regular basis.

Of the 4,521 surveys mailed to TSCRA members, 1,540 were returned, or 34%. Of these, 1,090 (70.8%) included some dollar figure for economic loss due to fire ants. Perhaps more importantly, this means that nearly 30% of respondents within the fire ant-infested portion of the state reported no fire ant damage. It was necessary to group the detailed areas of loss into categories for meaningful analysis in this report. Surprisingly, only 309 respondents (28.3% of those reporting losses) reported a loss in every broad category. Further examination revealed that only 65 respondents (5.9%) reported a loss in every area of the survey excluding personal injury, losses to other animals, and hunting. Losses in hay production were not included in this figure since they were analyzed separately.

It is important to note that all dollar figures reported here are on a per respondent basis only for those responding in each category. "Zero" responses are not included since it is inappropriate to predict losses where losses do not occur.

Analysis Method Development

With 1,090 surveys to analyze, the total number of economic responses in the included categories came to almost 13,000. Therefore, it was necessary to examine these data in both graph form and through the use of statistics in order to comprehend them. This brought about its own set of problems. Reported acreage ranged from 1 to 70,000 acres and loss values ranged from $10 to nearly $70,000 per year. To further complicate matters, response numbers were heavily weighted towards the lower end of the acreage range. Over one-third of respondents had operations of less than 300 acres with over two-thirds less than 1,000 acres. This meant that graphs over the entire range of values crowded the great majority of responses into one little corner, obscuring important details.

To help resolve this situation, the data set was narrowed using the following criteria. To be included in this analysis a survey must have: included a dollar value in one of the chosen categories, included a positive acreage figure, and fallen within two standard deviations of the mean for total losses and acreage. Despite this seemingly stringent set of conditions, 957 respondents were included in the data set with acreages ranging up to 11,000 and losses to about $7,300 annually.
Figure 1 shows a scatterplot of the data for total losses vs acreage with a line drawn for a simple linear regression. Note that the regression line is highly significant with almost no probability of it being the result of chance. Also notice that with an R² of 0.02 it is a very, very poor fit, meaning that it does a poor job of describing the data. Since the whole object of this analysis is predictive, accurately describing the data is paramount. After many attempts at various regression analysis methods, it was found that a moving average, the second line in Figure 1, gave the best and most easily understood representation of the data.

A moving average is simply taking a point and averaging the values of a set number of points on either side of it, a "window", then plotting that value against the original point. The "window" then moves to the next data point and the process is repeated. The advantage of a moving average is that it smooths out "noisy" data by diluting unusually high and low values with more common values closer to the mean. It is also a simple mathematical procedure that is easy to understand compared to regression methods. Its main disadvantage is that it inherently "lowers the peaks and raises the valleys." Those peaks and valleys that remain also tend to shift slightly along the X-axis as the window width is adjusted. Therefore, actual values found from a graph of a moving average must be used with caution. What a moving average does is give a better graphical representation of the data.

Graphing Loss Categories

Figure 2 shows the major loss categories across the entire acreage range. Note that the lines are virtually flat after about 2,000 acres. This is due to relatively few respondents above that acreage and the wildly scattered degree of losses they suffered. Figure 3 includes only those respondents with less than 2,000 acres of land. As mentioned earlier, the dollar amounts associated with the various categories are less important than the shape of the lines.

Pesticide use, the very bottom line, is almost flat across its entire length. Analysis of the individual pesticide use data explains this phenomenon. The majority of fire ant pesticides are used around the home. Whether a ranch is one acre or 1,000 acres, there is usually just one homesite and it only takes so much pesticide to treat that relatively small area.

Note how cattle injury and death rises at a steeper slope than the other lines. Since the number of cattle in an operation is perhaps most closely tied to the number of acres than any other category, its proportional rise is to be expected. The leveling out of the line as acreage increases is probably due to two factors. The first is that there are more large ranches in the western and southern parts of the state where there are fewer fire ant problems. The second is probably one of perceptions. A rancher with a few dozen cattle is more likely to notice fire ant-related losses than a rancher with several hundred. These losses are no more or less real, they are just more likely to be noticed and reported.

The next item of interest is the intriguing "bump" in the material and equipment damage total on the very low end of the acreage scale. Figure 4 includes only these categories. Note that the range of values on the Y-axis is less than half that of Figures 2 and 3 so the line appears much more jagged despite the increase in size of the moving average "window" from 200 to
300 data points. At this resolution, the "bump" around 200 acres is readily apparent for both electrical damage and shredder damage. There is no such bump for hay and feed losses.

It was first thought that this might be a mathematical anomaly due to a few extreme damage reports and/or greatly varying numbers of respondents between the four categories. However, electrical damage was reported by 637 respondents (63%), the highest incidence of any category in the entire survey except pesticide use. Shredder damage was reported by only 304 respondents (27.9%), the lowest of the four categories. Ruined feed and hay had 359 and 416 responses respectively. Examination of the data also shows that most of the extreme responses were in feed and hay. Consequently, it can only be assumed that the "bump" is a real phenomenon. But why?

The answer lies in the nature of the ranches, and ranchers, of this size range. Two-hundred acres in any part of Texas is not a full-time ranch, particularly with today's cattle prices. Therefore, it can be safely assumed that the operators of these ranches must also have off-farm jobs or other sources of income. Under most circumstances, that 200 acres will, in fact, provide very little income - to the point that the ranch becomes a "weekend place" rather than a serious money making enterprise. However, it is large enough to require a significant amount of attention. This size operation has its own set of fire ant-related problems versus larger and smaller ranches.

This point can be illustrated by an all-too-real example. Suppose the owner arrives at his ranch for the weekend and finds that fire ants have hit him in all four of the categories shown in Figure 4. He removes the infested feed bags and hay bales from the storage shed, dumps them outside, and lets the ants have them - end of story. He has no desire to spend his weekend without water since the ants have shorted out his well switch, nor does he have the desire to mess with fixing it and get himself electrocuted. So, he calls an electrician and pays $50 an hour plus parts. While waiting for the electrician, he climbs on his tractor to shred an overgrown pasture. After a time, he hits the inevitable fire ant mound, strips a gearbox and bends a blade which tears the housing. Not having the time, equipment, desire, or, possibly, expertise to fix it himself, he loads the broken shredder onto a trailer and hauls it into town where he pays $40 an hour shop time plus parts and picks it up the next weekend. Someone who lived on his ranch and operated it as more of a business would have the tools, the welder, and the expertise, and would make time during the week to fix everything to avoid paying those labor costs that cut so deeply into the pocketbook.

**Prediction Equations**

As useful as the above mentioned graphs are for "seeing" what is going on, they still do not serve very well as a predictor. What is still needed is an equation, or equations, into which one can plug acreage and get an estimated dollar loss. After many attempts, the best way found to do this was by manually fitting linear regression lines across acreage ranges so that their endpoints matched as closely as possible. The result is shown in [Table 1](#) with [Figure 5](#) illustrating the equations graphically for comparison to the moving regression line. Due to the difficulty of fitting these lines, only the relationship between total losses and acreage was
Table 1. Loss prediction equations.

<table>
<thead>
<tr>
<th>Acreage range</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 100</td>
<td>loss = $7.71(ac) + $337</td>
</tr>
<tr>
<td>100 - 950</td>
<td>loss = $0.84(ac) + $1,009</td>
</tr>
<tr>
<td>&gt; 950</td>
<td>loss = $0.02(ac) + $1,790(^1)</td>
</tr>
</tbody>
</table>

\(^1\) Not significant at p < 0.05

determined. Note that Figure 5 only goes up to 2,000 acres and that the line past 950 acres is not statistically significant. This is due to relatively few responses and the high degree of loss variability among these respondents. A simple average calculated for these responses was almost identical to the regression line over this range.

An Area-wide Economic Treatment Justification Example

What the statistically significant linear regression equations provide is a way of estimating total losses for groups of ranches. This is best illustrated through a hypothetical example as shown in Table 2. The important thing to note is that the number of acres to be treated stays the same: 10,000. How these acres are divided is what makes the area-wide treatment program economically feasible or not. Clearly, Scenario 2 is the only practical one economically. Why the huge difference?

Table 2. Hypothetical area-wide treatment scenarios.

<table>
<thead>
<tr>
<th></th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Acreage</td>
<td>10,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Average Ranch Size</td>
<td>500</td>
<td>80</td>
</tr>
<tr>
<td>Number of Ranches</td>
<td>20</td>
<td>125</td>
</tr>
<tr>
<td>Estimated loss/ranch/yr(^1)</td>
<td>1,429</td>
<td>983.80</td>
</tr>
<tr>
<td>Cost per acre to treat</td>
<td>$10</td>
<td>$10</td>
</tr>
<tr>
<td>Total treatment cost</td>
<td>$100,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Total Losses/yr</td>
<td>$28,580</td>
<td>$122,975</td>
</tr>
<tr>
<td>Net Gain/Loss</td>
<td>-$71,420</td>
<td>+$22,975</td>
</tr>
</tbody>
</table>

\(^1\) Calculated using regression equations.

incremental. For instance, almost every ranch needs at least one water well and its electrical equipment is susceptible to fire ant damage. In fact, a ranch may only need one water well up to a certain size. Beyond that, it may need two. The same holds true for electrical breaker boxes, feed barns, shredders, or anything else. The point is that every ranch needs at least one of these things and that "one thing" is susceptible to damage. Therefore, it is not so much the size of the ranch as it is the very existence of the ranch. The economic feasibility, indeed profit, in Scenario 2 comes from the fact that there are 125 ranches instead of 20 ranches on that 10,000 acres.

But what about the 20 ranchers in Scenario 1? Must they just live with over $1,400 in losses each year? No. Those items causing the most loss to virtually every rancher are located on very small amounts of land. It is quite likely that the owners of those 500-acre ranches are suffering almost all their losses on less than 100 acres. If they were each to treat only 100 acres, their total treatment costs would drop from $100,000 to $20,000, they would realize a profit of over $8,000 between them, and solve the majority of their problems.
Conclusions

• Individual ranchers are strongly encouraged to do their own cost/benefit analysis regarding fire ant losses before initiating any type of treatment program.

• The frequency of fire ant-related damage must be given equal weight to per-operation losses when making loss estimates for multiple ranches.

• All dollar amounts listed in this report must be treated as estimates. There is tremendous variability depending on numerous factors including geography, topography, weather, climate, and ranch management practices.

• Generally speaking, it is not feasible for ranchers with over 200 acres to treat their entire property.

• Any group or governmental organization planning a large-scale fire ant treatment program should look at the character of the agricultural industry in that area, not just total acreage to be treated, in order to economically justify treatment.

• Areas with high concentrations of small ranches, such as are found around many cities in Texas, are more likely to benefit economically from large-scale fire ant treatments.
Figure 1. Total economic loss vs acreage.

Figure 2. 100/100 moving average for all loss categories and all acres.

Figure 3. 100/100 moving average for all loss categories, ≤2000 acres.
Figure 4. Material and equipment damage, 150/150 moving average, ≤2000 ac.

Figure 5. Prediction equations and confidence intervals, ≤2000 ac.
Interactions of *Solenopsis invicta* with Sugarcane Homoptera

A. W. Woolwine and T.E. Reagan

Abstract

Behavioral interactions between *S. invicta* and the yellow sugarcane aphid (YSA) [*Sipha flava* (Forbes)], west indian canefly (WIC) [*Saccharosydne saccharivora* (Westwood)], rusty plum aphid (RPA) [*Hysteroneura setariae* (Thomas)], and the pink sugarcane mealybug (PSM) [*Saccharicoccus sacchari* (Cockerell)] were studied in replicated sugarcane field plots during two summer months in Louisiana. Despite the large quantities of honeydew produced by WIC and YSA, we observed no tending by *S. invicta*; however substantial predation on these insects was observed. *S. invicta* tended RPA and PSM but no predation was observed.

*S. invicta* were observed on 35 to 50% of the nodes with PSM colonies. This association was significant (*P*<0.01) on each of five collection dates. Lower nodes without adhering leafsheaths accounted for most of the nodes without PSM, and these nodes had no associated ants. Ants were most frequently observed foraging in the upper parts of the stalk.

In a study where pyrethroid insecticides used for borer management caused a flare-up of YSA (8-fold increase), corresponding season long fire ant abundance measured by pitfall traps increased 2.5-fold over untreated plots. Unlike specialist predators and parasitoids that have a lagged response to pest species buildup, the generalist feeding behavior of *S. invicta* and the presence of a constant source of carbohydrates, 'honeydew', seems to increase the stability of the sugarcane agroecosystem. These data confirm that mealybugs may be an important determinant of *S. invicta* foraging behavior in the canopy of sugarcane and could influence their subsequent predation on the major pest, the sugarcane borer.

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Economic Impact of Imported Fire Ants on Selected Crops: 
a Synthesis from the Literature.

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University of Arkansas, Monticello, AR 71656-3468.

Summary The cause-effect relationships between density (mound/ha) of imported fire ants (*Solenopsis invicta* Buren and *Solenopsis richteri* Forel) and changes in crop yield for corn, cotton, hay, potato, sorghum, soybean, sugarcane and vegetables were obtained through processing published experimental data. While estimating actual fire ant impact at a given location, we assessed direct economic effects on crop production (change in yields) and costs of insecticide control (when applied). An example of the data used in our analysis is shown in Table 1. Using relationships between change in yield and fire ant density, we developed mathematical functions to analyze impact on crop production. Cost-benefit analysis assessed when insecticides might be applied. Integration of monetary equivalents of direct fire ant impact on crop production and fire ant control expenditures over nine heavily infested southern states (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas) revealed annual losses of $271 million (Table 2). Note that fire ants improved yields in cotton and sugarcane and decreased yields substantially in soybean.

This research was funded via special Congressional appropriations through the USDA/APHIS/PPQ. The results do not necessarily express APHIS' views.

<table>
<thead>
<tr>
<th>Yield, fire ant affected</th>
<th>Yield, no ants</th>
<th>Yield loss, %</th>
<th>Fire ant mound density per ha</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,980</td>
<td>2,875</td>
<td>-31</td>
<td>142</td>
<td>Adams (1977) experiment</td>
</tr>
<tr>
<td>3,379</td>
<td>3,520</td>
<td>-4</td>
<td>109</td>
<td>Adams (1976) experiment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-3</td>
<td>93</td>
<td>Wilson &amp; Eads (1949) survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-3</td>
<td>93</td>
<td>Wilson &amp; Eads (1949) survey</td>
</tr>
<tr>
<td>1,114b</td>
<td>1,709</td>
<td>-35</td>
<td>108</td>
<td>Adams (1983) experiment</td>
</tr>
<tr>
<td>1,545</td>
<td>1,952</td>
<td>-21</td>
<td>160</td>
<td>Adams (1983) experiment</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>-13</td>
<td>116</td>
<td>Braun (1982); Banks et al. (1990)&quot;</td>
</tr>
</tbody>
</table>

" litres per ha; " kg per ha; " Braun provided loss data, Banks density data
Table 2. Annual impact of imported fire ants on selected agricultural commodities in infested areas of the southern United States.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area in Production (million ha)</th>
<th>Impact ($/ha)</th>
<th>Total (million $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>1.35</td>
<td>-27.63</td>
<td>-37.26</td>
</tr>
<tr>
<td>Cotton</td>
<td>2.40</td>
<td>+6.50</td>
<td>+15.60</td>
</tr>
<tr>
<td>Hay</td>
<td>2.34</td>
<td>-34.35</td>
<td>-80.38</td>
</tr>
<tr>
<td>Potato</td>
<td>0.03</td>
<td>-229.55</td>
<td>-7.35</td>
</tr>
<tr>
<td>Sorghum</td>
<td>1.48</td>
<td>-16.20</td>
<td>-24.00</td>
</tr>
<tr>
<td>Soybeans</td>
<td>2.57</td>
<td>-48.93</td>
<td>-125.74</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>0.31</td>
<td>+0.18</td>
<td>+0.06</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.18</td>
<td>-68.85</td>
<td>-12.39</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>-271.46</td>
</tr>
</tbody>
</table>
Detecting Fire Ant Effects on Crop Production Using a Statistical Model.

S. Semenov, F. Semevski and L. Thompson

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University of Arkansas, Monticello, AR 71656-3468.

Summary: Official government data on crop yield and harvested acreage, organized by states, counties, and years, as well as by the first general invasion of a county by either *Solenopsis invicta* Buren or *S. richteri* Forel, were subjected to analysis using a statistical model. Data cover the years 1979-1992 and only those counties in nine southern states (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas) that were invaded by 1992. Crops examined were corn, cotton, sorghum, soybean, and wheat. Analysis showed that mean percentage change in crop yield was low (Table). Cotton yield was positively affected (3%, 1% s.e.), while soybean yield was negatively affected (-3%, 1% s.e.). Effects on yields and harvested acreage for other crops were undetectable, i.e. their sign remains unknown based on a two standard error confidence interval. These estimates reflect influences of all environmental factors, such as direct biological influences that fire ants have on plants, plus indirect effects on plants, pests, and harvest interference, as well as consequences of insecticide applications.

This research was funded via special Congressional appropriations through the USDA/APHIS/PPQ. The results do not necessarily express APHIS' views.

Table. Fire ant caused percentage changes in crop yield and harvested acreage for crops in the southern U.S.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield $h_0$</th>
<th>$\sigma$</th>
<th>Harvested acreage $h_0$</th>
<th>$\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>0.01</td>
<td>0.01</td>
<td>-0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.03</td>
<td>0.01</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.01</td>
<td>0.01</td>
<td>0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>Soybean</td>
<td>-0.03</td>
<td>0.01</td>
<td>-0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.00</td>
<td>0.01</td>
<td>-0.03</td>
<td>0.04</td>
</tr>
</tbody>
</table>

$h_0$ magnitude of fire ant caused changes in crop production
$\sigma$ standard deviation of $h_0$
The Red Imported Fire Ant in North Carolina: History of the Introduction, Geographic Spread, and Control

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Lloyd Garcia
Plant Protection Section
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Introduction and Geographic Distribution. The red imported fire ant (RIFA), Solenopsis invicta Buren, was first discovered in North Carolina in 1952 in nurseries in Mecklenburg and Wake Counties (Culpepper, G. H. 1953. Status of the imported fire ant in the southern states in July 1953. USDA, Bur. Entomol. & Plant Quar. Special Rpt. E-867. Washington, DC.). These initial infestations of the RIFA were eliminated, and no additional ants were found until 1957 when some colonies were detected in Brunswick County. The origin of this spot infestation is unknown, but probably resulted from the importation of ant-infested nursery stock. Since these initial discoveries, the distribution of the RIFA in North Carolina was not systematically monitored until 1971 when federal quarantine regulations were imposed on RIFA infested areas.

There is no question that the RIFA has rapidly spread across NC from the coastal plain into the piedmont. The number of counties that were entirely or partially under quarantine regulations has increased from 6 in 1971 to 29 in 1995 (Callcott, A. A. and H. L. Collins. 1996. Invasion and range expansion of imported fire ants (Hymenoptera: Formicidae) in North America from 1918-1995. Florida Entomologist: Accepted for publication.) (Fig. 1).
An examination of the spread of the RIFA in NC reveals that the geographic distribution of the ant has escalated on an approximate 7-10 year cycle (Fig. 2). Between 1971 and 1977, the RIFA quarantine zone contained only 11 counties. In 1983-1985 an additional 8 counties were added, and in 1992-1995 another 9 counties were included.

![Graph: Number of Counties Added to Quarantine Zone vs. Year](image)

**Fig. 2.** Year that counties in North Carolina were added to the federal quarantine zone for the red imported fire ant. Data were taken from Callcott and Collins (1996).

The geographic spread of the RIFA increased most rapidly during the late 1980s to present. The numbers of counties that were entirely infested (under federal and state quarantine) increased from 1 in 1971, to 8 in 1985, to 11 in 1988, and to 24 in 1995 (Fig. 3). Of greatest concern to regulatory agencies has been the increasing number of incipient infestations that have been reported in land areas outside of the quarantine zone (Fig. 4). Some of these spot infestations have been quite large in that several hundred mounds were involved.

![Map: Imported Fire Ant Quarantine Area](image)

**Fig. 3.** Area of North Carolina included in the 1995 federal quarantine zone for the red imported fire ant.
The total amount of RIFA-infested acreage (estimated from USDA, APHIS, PPQ survey maps) in North Carolina has increased 10 fold from approximately 314,048 hectares (≈775,699 acres) in 1971 to about 4,130,734 hectares (≈10,202,912 acres) in 1995 (Fig. 5). A total of 29 counties (24 entirely and 5 partially) representing approximately 32.5% of the total land area of North Carolina are currently included in the RIFA quarantine zone (Fig. 3 and 5).

**Fig. 4.** Map of North Carolina showing spot infestations and movement of the quarantine zone for the red imported fire ant from 1988-1992.

**Fig. 5.** Amount of red imported fire ant-infested land in North Carolina and numbers of counties included in the federal quarantine zone.

*Control Efforts.* The North Carolina Dept. of Agriculture (NCDA) and the Cooperative Extension Service (CES) are public agencies responsible for reducing the impact of the RIFA on the citizens of NC. The NCDA has entered into a cooperative agreement with the U. S. Dept. of Agriculture-Animal and Plant Health Inspection Service in which the NCDA has assumed responsibility for detecting and eradicating RIFA infestations beyond the existing USDA quarantine line. Inside the quarantine zone, the NCDA regulates the movement of articles that may harbor the RIFA so that the threat of transporting the RIFA to non-infested areas is reduced. The NCDA operates an inspection and certification program involving over 2,100 nurseries and turf farms representing in excess of about 3,600 hectares (≈8,900 acres).
Of this total, there are over 410 nurseries and turf farms located within the quarantine zone which are potential sources for long-distance movement of the RIFA. These establishments are monitored with compliance agreements. RIFA compliance agreements have also been established with various commercial soil, peat and hay moving operations. The NCDA operates a community assistant program to provide technical assistance and insecticidal baits to communities within the limits of available resources. Each county Cooperative Extension Center within the quarantine zone has available on demand information on currently recommended methods of control for the RIFA. Assistance to the general public is also provided through the Plant Disease and Insect Clinic at N. C. State University (NCSU). Infestations outside of the quarantine zone are commonly identified when ants submitted via county Cooperative Extension Centers to the Plant Disease and Insect Clinic are found to be RIFAs.

General treatment strategies for eradicating RIFA infestations outside the quarantine zone, as outlined in the NCDA's 1995 edition of the Imported Fire Ant Operational Guidelines, include: mound-specific and broadcast treatments. Mound-specific treatments are used when possible. Insecticidal baits and contact toxicants are generally used in combination against RIFA colonies. In landscapes where there is little risk of people being stung, bait is usually applied first followed by an application of contact toxicant directly to each RIFA mound one week later. However, in high risk areas, such as in playgrounds and industrial parks, mounds are drenched with a contact insecticide and a follow-up application of bait to each mound is then made.

RIFA infestations outside of the quarantine zone are reported to the NCDA when ants sent to the NCSU Plant Disease and Insect Clinic via county Cooperative Extension Centers are identified to be the red imported fire ant. Colonies are also discovered when the NCDA personnel conduct their yearly survey to determine if an extension of the quarantined area is warranted. Outlying infestations usually involve just a few colonies associated with the use of imported nursery plants in landscaping operations. However, some infestations have consisted of hundreds of RIFA colonies. The numbers of RIFA mounds outside of the quarantine zone that have been treated has grown exponentially since 1988.

For example, in 1988, outside of the quarantine zone, there were no mounds treated with bait and only 4 RIFA colonies treated with insecticide drench. A large increase in treatment effort occurred in 1994 when bait was applied to 4,962 mounds and 8,273 colonies were drenched with insecticide. In 1995, the number of colonies treated increased approximately 3-4 fold with 18,449 and 23,055 RIFA mounds treated with bait and insecticide drench, respectively (Fig. 6).

Regulatory efforts to eliminate RIFA infestations discovered outside of the quarantine zone are reflected in the amount of insecticide used (Fig. 7). In 1995, the amount of Dursban 4E concentrate used in treating RIFA mounds increased approximately 8 fold relative to 1994, from 55 liters (≈ 96 pints) to 436 liters (≈ 768 pints). Likewise the amount of Amdro Fire Ant Bait used has increased in a linear fashion from 23 kg in 1992 to over 1500 kg of bait in 1995. This increase in insecticide use (Figs. 7) is due in part to an increase in temporary personnel who have been deployed along the quarantine line to identify and treat isolated infestations in an attempt to limit the advance of the RIFA.
The RIFA will undoubtedly continue to be a major nuisance and public health pest in North Carolina for years to come. The technology to completely eradicate this pest species does not exist. However, the RIFA can be controlled and even eliminated over small areas through the judicious use of chemical insecticides. Where it is not a problem, the ant should be left alone. Needless to say, the NCDA and the CES will continue to play major roles in educating the public about fire ants and the available methods to control them locally and to prevent their spread.
FIRE ANT CONTROL PROGRAMS FOR THE 1996 OLYMPIC VENUES

Beverly Sparks, Extension Entomologist, The University of Georgia, Athens, Georgia, 30602 and Doug Allen, Ph. D., Fire Ant Management Systems, Athens, Georgia

ACOG (the Atlanta Committee for the Olympic Games) will host the Games of the XXVIth Olympiad in 1996. The Games begin with the Opening Ceremony on July 19, 1996 and conclude 16 days later on August 4, 1996. Most events will be held in and around the Atlanta area, however several cities throughout the southeastern United States will serve as venue sites. Other cities in Georgia serving as venues for Olympic competitions include Athens, Columbus and Savannah. In addition, Birmingham, Alabama, Miami and Orlando, Florida, Ducktown, Tennessee and Washington, D.C. will host Olympic events. More than 10,700 athletes from 200 nations will take part in these Olympic Games. Approximately two million visitors are expected in and around the Georgia venue sites during the Games.

Concerns about the safety of athletes, animals, and visitors at various venues prompted ACOG officials to contact The University of Georgia in the fall of 1994 for information concerning the treatment of red imported fire ant (Solenopsis invicta) populations. Areas of particular concern included the newly constructed, Georgia International Horse Park, the Wassaw Sound, Wolf Creek Shooting Complex, and the Lake Lanier Island Venues, the Atlanta Olympic Village Venue on the campus of Georgia Tech and the soccer venue located on the campus of The University of Georgia.

Fire ant control programs developed for these venue sites include a semi-annual applications of a bait product (Amdro or Award at 1.5 to 2.0 lbs per acre) plus a supplemental program that eliminates the remaining individual mounds with a contact insecticide. This fire ant control program was awarded to a private contractor at four venue sites (Georgia International Horse Park, Lake Lanier, Wolf Creek and Wassaw Sound). The estimated cost of the fire ant control program at these sites is $100.00/acre/year. The estimated cost of the programs used at the Atlanta Olympic Village (Georgia Tech campus) and The University of Georgia venues is $14.75/acre/year (costs for insecticide only, applications were made by system employees).
INTRODUCTION:

In May 1958 a Federal quarantine prohibiting movement of certain regulated articles was invoked in an effort to prevent artificial spread of imported fire ants. Nursery stock is a regulated article that is usually shipped outside the quarantine area after it has been treated with an insecticide to render the stock IFA free. Registration of 11 quarantine treatments in use today were based on efficacy data generated by our laboratory using techniques and procedures described herein.

Each year our laboratory investigates several candidate potting media toxicants for use in certification of nursery stock shipped outside the IFA quarantine area. Two primary types of tests involved are preplant incorporation and drench treatments. Those that show promise in preliminary trials are targeted for further testing for phytotoxicity as well as the effects of environmental conditions and various soil types.

Current quarantine treatments include bifenthrin, chlorpyrifos, diazinon, tefluthrin. Rates and use patterns are as follows:

<table>
<thead>
<tr>
<th>CERTIFICATION PERIOD</th>
<th>RATE (ppm) TALSTAR</th>
<th>RATE (ppm) FIREBAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>7-12</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>13-24</td>
<td>15</td>
<td>--</td>
</tr>
<tr>
<td>Continuous</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>
### Drench Treatments for Containerized Nursery Stock

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Dose Rate</th>
<th>Certification Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorpyrifos 4EC</td>
<td>4 fl oz/100 gal H₂O</td>
<td></td>
</tr>
<tr>
<td>Chlorpyrifos 2EC</td>
<td>8 fl oz/100 gal H₂O</td>
<td>30 days</td>
</tr>
<tr>
<td>Chlorpyrifos 1EC</td>
<td>16 fl oz/100 gal H₂O</td>
<td></td>
</tr>
<tr>
<td>Diazinon AG-500</td>
<td>1 pt/100 gal H₂O</td>
<td>10 days</td>
</tr>
<tr>
<td>Diazinon 50WP</td>
<td>1 lb/100 gal H₂O</td>
<td></td>
</tr>
<tr>
<td>Bifenthrin 10WP</td>
<td>25 ppm</td>
<td>180 days</td>
</tr>
</tbody>
</table>

Current chlorpyrifos labels registered for use in nursery situations include:

- **All-Pro™ Dursban® 4E**
  - Sureco®, Inc.
  - Fort Valley, GA

- **Dursban® 4E-N**
  - United Horticultural Supply™
  - Fremont, NE

Preplant incorporation is the preferred treatment over drenches due to longer residual activity, worker protection standards, and simpler logistics. The minimum desired residual activity is 30 days for drenches and 24 months for incorporated treatments.

**Materials and Methods:**

**Incorporation Treatments:**

Candidate toxicants are blended into the potting soil using portable cement mixers in 1.5 cu. ft. batches. Currently, our laboratory uses a 3:1:1 (by volume) mix of pine bark: sphagnum peat moss: sand. This mix is also used for most horticultural studies conducted by the Mississippi Agriculture and Forestry Experiment Station (MAFES). The treated soil is then placed in standard trade gallon nursery pots and placed outdoors under simulated nursery conditions with overhead irrigation (ca 1-1½) to weather naturally. Rates are
based on discussions with the producer, or label rates if the product is already labelled for other uses. Media from 3 pots of each treat is collected, composted, and subjected to standard alate female bioassay at monthly intervals.

Phytotoxicity Trials:

Phytotoxicity trials are conducted much the same way as the treatments described for incorporation treatment with live plants added. Plants to be used are selected based on availability and popularity of use in the industry. Cultivars of both woody and herbaceous type plants are used. Incorporation treatments are done by planting the plants into treated media at 1X, 3X, and untreated rates. The 1X rate is the optimum rate determined in previous trials with the product being tested. The 3X rate is then three times this rate to determine phytotoxic effects in the event of over-application. The plants are then subjected to normal nursery practices for a specified time (generally one year). At the end of the growing time the plants are sacrificed and a top growth weight is determined. A top growth and a comparative root rating is also made at this time using the following scales:

**Top Rating Scale**

1. Plant healthy
2. Slight yellowing, wilting or other mild symptoms such as marginal chlorosis
3. Symptoms more severe, leaf drop, necrosis
4. Severe stunting, abnormal leaf or stem structure
5. Plant dead

**Comparative Root Rating Scale**

0. Roots dead
1. Least developed
2. Mean development
3. Best developed

Drench Treatments:

Standard trade gallon nursery pots are filled with nursery media. The filled pots are left for 3-5 days under simulated nursery conditions (ca 1-1½"
irrigation per week) to allow the media to become fully saturated before treating. Individual pots are then drenched using rates determined as previously described. Each pot is drenched with a volume of solution equal to 1/5 the volume of the pot (i.e. 400 ml solution for trade gallon pots). Media from 3 pots of each treatment is collected, composited, and subjected to standard alate female bioassay at weekly or monthly intervals.

Alate Queen Bioassay:

Alate queen bioassay is accomplished by confining field collected alate queens for 7 days in a test chamber containing potting media that has been treated with a candidate insecticide. The test chambers are 2.5" x 2.5" plastic flowerpots equipped with a labstone bottom placed on a bed of damp peat moss. The labstone prevents queens from escaping through the bottom drain holes while also acting as a wick to absorb moisture from the underlying bed of peat moss. Plastic petri dishes are inverted over the tops of the pots to prevent escape. Each pot (replicate) contains 5 alate queens with 4 replicates used per treatment. After 7 days the replicates are examined and percent mortality is determined. This procedure enables us to compare dose rates, formulations, aging intervals, etc.

RESULTS:

Results to date with 5 recently evaluated candidates are summarized in the following tables:

I. FIPRONIL 0.1G
Incorporated into media

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>100</td>
<td>24+</td>
</tr>
<tr>
<td>300</td>
<td>24+</td>
</tr>
</tbody>
</table>

1993 trial - MAFES media

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>10+</td>
</tr>
<tr>
<td>25</td>
<td>10+</td>
</tr>
<tr>
<td>50</td>
<td>10+</td>
</tr>
</tbody>
</table>

1995 trial - various nursery media

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Flowerwood</th>
<th>Wight</th>
<th>Windmill</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1</td>
<td>6+</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>10+</td>
<td>6+</td>
<td>2</td>
</tr>
<tr>
<td>25</td>
<td>10+</td>
<td>6+</td>
<td>4+</td>
</tr>
<tr>
<td>50</td>
<td>10+</td>
<td>6+</td>
<td>4+</td>
</tr>
</tbody>
</table>

105
FIPRONIL 0.1G
Phytotoxicity

Ratings for Cultivars Grown in 4-in. Containers and Sacrificed at 100 Days Post-treatment.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>RATE</th>
<th>MEAN TOP BIOMASS RATING</th>
<th>MEAN TOP BIOMASS WT (g)</th>
<th>MEAN ROOT RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatsia japonica</td>
<td>1X</td>
<td>1.0a</td>
<td>10.3a</td>
<td>2.3a</td>
</tr>
<tr>
<td>(Japanese Aralia)</td>
<td>3X</td>
<td>1.0a</td>
<td>8.1a</td>
<td>2.0a</td>
</tr>
<tr>
<td></td>
<td>CK</td>
<td>1.0a</td>
<td>8.1a</td>
<td>2.0a</td>
</tr>
<tr>
<td>Rademachera spp.</td>
<td>1X</td>
<td>1.0a</td>
<td>7.5a</td>
<td>2.0a</td>
</tr>
<tr>
<td>(China Doll)</td>
<td>3X</td>
<td>1.0a</td>
<td>9.5a</td>
<td>2.3a</td>
</tr>
<tr>
<td></td>
<td>CK</td>
<td>1.0a</td>
<td>7.3a</td>
<td>2.0a</td>
</tr>
</tbody>
</table>

Means within a cultivar followed by the same letter are not significantly different (LSD test, P=0.05).

Ratings for Cultivars Grown in 4-in. Containers and Potted Up to 1-gal. Containers.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>RATE</th>
<th>MEAN TOP BIOMASS RATING</th>
<th>MEAN TOP BIOMASS WT (g)</th>
<th>MEAN ROOT RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatsia japonica</td>
<td>1X</td>
<td>1.7a</td>
<td>19.6a</td>
<td>2.1a</td>
</tr>
<tr>
<td>(Japanese Aralia)</td>
<td>3X</td>
<td>1.7a</td>
<td>21.6a</td>
<td>2.0a</td>
</tr>
<tr>
<td>sacrificed at 6 months</td>
<td>CK</td>
<td>2.9a</td>
<td>9.2b</td>
<td>1.4a</td>
</tr>
<tr>
<td>Rademachera spp.</td>
<td>1X</td>
<td>1.1a</td>
<td>53.1a</td>
<td>2.0a</td>
</tr>
<tr>
<td>(China Doll)</td>
<td>3X</td>
<td>1.1a</td>
<td>47.8a</td>
<td>2.0a</td>
</tr>
<tr>
<td>sacrificed at 9 months</td>
<td>CK</td>
<td>1.1a</td>
<td>53.1a</td>
<td>2.1a</td>
</tr>
</tbody>
</table>

Means within a cultivar followed by the same letter are not significantly different (LSD test, P=0.05).
Ratings for Cultivars Grown in 1-gal. Containers.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>RATE</th>
<th>MEAN TOP BIOMASS RATING</th>
<th>MEAN TOP BIOMASS WT(g)</th>
<th>MEAN ROOT RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Raphiolepis indica</em> (Indian Hawthorn)</td>
<td>1X</td>
<td>1.0a</td>
<td>76.5a</td>
<td>1.9a</td>
</tr>
<tr>
<td></td>
<td>3X</td>
<td>1.0a</td>
<td>74.5a</td>
<td>2.0a</td>
</tr>
<tr>
<td></td>
<td>CK</td>
<td>1.0a</td>
<td>88.6a</td>
<td>2.3a</td>
</tr>
<tr>
<td><em>Rhododendron spp.</em> (Azalea)</td>
<td>1X</td>
<td>1.9a</td>
<td>22.9b</td>
<td>1.4a</td>
</tr>
<tr>
<td></td>
<td>3X</td>
<td>2.0a</td>
<td>24.8b</td>
<td>1.7a</td>
</tr>
<tr>
<td></td>
<td>CK</td>
<td>2.1a</td>
<td>9.4a</td>
<td>1.8a</td>
</tr>
<tr>
<td><em>Ilex cornuta</em> 'Burfordi Dwarf'</td>
<td>1X</td>
<td>1.0a</td>
<td>52.1a</td>
<td>2.0a</td>
</tr>
<tr>
<td>Dwarf Burford Holly</td>
<td>3X</td>
<td>1.0a</td>
<td>57.1a</td>
<td>1.7a</td>
</tr>
<tr>
<td></td>
<td>CK</td>
<td>1.0a</td>
<td>59.3a</td>
<td>2.1a</td>
</tr>
<tr>
<td><em>Gardenia jasminoides</em> 'Radicans'</td>
<td>1X</td>
<td>1.0a</td>
<td>90.0ab</td>
<td>2.0a</td>
</tr>
<tr>
<td>Dwarf Gardenia</td>
<td>3X</td>
<td>1.0a</td>
<td>77.1b</td>
<td>2.0a</td>
</tr>
<tr>
<td></td>
<td>CK</td>
<td>1.0a</td>
<td>104.4a</td>
<td>2.1a</td>
</tr>
<tr>
<td><em>Buxus sempervirens</em> 'Wintergreen'</td>
<td>1X</td>
<td>1.0a</td>
<td>54.5a</td>
<td>2.1a</td>
</tr>
<tr>
<td>Wintergreen Boxwood</td>
<td>3X</td>
<td>1.0a</td>
<td>43.96b</td>
<td>2.1a</td>
</tr>
<tr>
<td></td>
<td>CK</td>
<td>1.0a</td>
<td>48.4ab</td>
<td>1.9a</td>
</tr>
<tr>
<td><em>Scindapsus aureus</em> 'Marble Queen'</td>
<td>1X</td>
<td>1.6a</td>
<td>191.3a</td>
<td>2.3a</td>
</tr>
<tr>
<td>Marble Queen Pothos*</td>
<td>3X</td>
<td>1.0a</td>
<td>162.8a</td>
<td>2.0a</td>
</tr>
<tr>
<td></td>
<td>CK</td>
<td>1.0a</td>
<td>139.4a</td>
<td>1.9a</td>
</tr>
</tbody>
</table>

Means within a cultivar followed by the same letter are not significantly different (LSD test, P=0.05).

*Sacrificed at 8 months post-treatment*
## II. LAMBDA-CYHALOTHIRIN

### Incorporated

**Commodore® 10WP - various trials**

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>29</td>
</tr>
<tr>
<td>25</td>
<td>--</td>
</tr>
<tr>
<td>50</td>
<td>31</td>
</tr>
<tr>
<td>100</td>
<td>31</td>
</tr>
</tbody>
</table>

**Commodore 10WP - Short term/ roses**

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>South</td>
</tr>
<tr>
<td></td>
<td>Ran Pro</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>30</td>
<td>6</td>
</tr>
</tbody>
</table>

* no irrigation added

**Commodore 1.5G - various nursery trials**

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Windmill</td>
</tr>
<tr>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>50</td>
<td>12</td>
</tr>
</tbody>
</table>

* trial destroyed by nursery workers

### Scimitar® 10WP - 1992 Turkey Creek trial

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>50</td>
<td>27</td>
</tr>
</tbody>
</table>

### LAMBDA-CYHALOTHIRIN

**Drench**

**Karate® IEC - 1990, 1991**

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>11</td>
</tr>
<tr>
<td>50</td>
<td>18</td>
</tr>
<tr>
<td>100</td>
<td>18</td>
</tr>
<tr>
<td>200</td>
<td>18</td>
</tr>
</tbody>
</table>

**Commodore 10WP - 1992**

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>100</td>
<td>16</td>
</tr>
</tbody>
</table>
does not include short-term/rose trial

\[ y = 11.62 + 0.27x \]
\[ r = 0.49 \]

Lambdas-Cyhalothrin Incorporated Into Various Potting Media
III. CYFLUTHRIN
Incorporated

Early trial with various formulations

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Tempo 2.5G</th>
<th>Tempo 0.1% dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>25</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>150</td>
<td>--</td>
<td>11</td>
</tr>
</tbody>
</table>

Various granular carriers. 100 ppm - 1995

<table>
<thead>
<tr>
<th>Carrier</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB*</td>
<td>6</td>
</tr>
<tr>
<td>Bentonite</td>
<td>9+</td>
</tr>
<tr>
<td>KB</td>
<td>9+</td>
</tr>
<tr>
<td>SB**</td>
<td>9</td>
</tr>
<tr>
<td>UB**</td>
<td>9</td>
</tr>
</tbody>
</table>

*only enough material for 6 mth. treatment
**only enough material for 9 mth. treatment

CYFLUTHRIN
Drench

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tempo 1ME</td>
</tr>
<tr>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td>25</td>
<td>--</td>
</tr>
<tr>
<td>50</td>
<td>--</td>
</tr>
<tr>
<td>100</td>
<td>&lt;1</td>
</tr>
<tr>
<td>200</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

SILAFLUOFEN
Incorporated - 0.5% dust

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>25</td>
<td>erratic</td>
</tr>
<tr>
<td>50</td>
<td>6</td>
</tr>
</tbody>
</table>
### IV. SILAFLUOFEN
Drench - 800 g Al/L

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>1300</td>
<td>6</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>6500</td>
<td>6</td>
<td>10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>13000</td>
<td>6</td>
<td>15</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>1+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>1+</td>
</tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td>300</td>
<td>1+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500</td>
<td>1+</td>
</tr>
</tbody>
</table>

### V. FENPROPATHRIN
Drench

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>9</td>
</tr>
<tr>
<td>200</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rate (ppm)</th>
<th>Months Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>&lt;1</td>
</tr>
<tr>
<td>93</td>
<td>6</td>
</tr>
</tbody>
</table>

### CONCLUSIONS:

**Incorporated Treatments**

Fipronil (Rhône-Poulenc) is the most promising candidate under trial at this time, providing excellent residual control at rates of 25 and 50 ppm. It also has the possibility of use as a tiered treatment. Phytotoxicity trials indicate only 1 case of possible adverse effect (Dwarf Gardenia at the 3X rate) and more trials will be initiated.
Lambda-cyhalothrin (Commodore/Scimitar - Zeneca) may be affected by media type, however it has demonstrated consistently good activity for 12 months at 25 ppm in a variety of media types.

Cyfluthrin (Tempo - Miles/Bayer) has shown little promise as a quarantine treatment due to relatively short residual activity, however application rates (50 ppm) may not have been high enough. When formulated onto various carriers (Olympic Horticultural Products) cyfluthrin has provided 9+ months residual at 100 ppm.

Silafluofen (AgrEvo Environmental Health) in preliminary trials has provided 6 months residual at 50 ppm using the dust formulation. The company is not producing a granular formulation at this time.

**Drench Treatments**

Lambda-cyhalothrin (Commodore/Karate - Zeneca) has provided excellent results (≥ 11 months) regardless of formulation at 25 ppm and higher.

Cyfluthrin (Tempo - Miles/Bayer and Optem - Whitmire) results have varied greatly with formulation. Only Tempo 2EC provided any residual activity (4 mths at 25 ppm, 13+ mths at ≥ 50 ppm).

Silafluofen (AgrEvo Environmental Health) shows promise at rates of ≥ 50 ppm.

Fenpropathrin (Danitol/Tame - Valent) has provided excellent control for 6 months at 93 ppm.
ORGANIC PLUS FIRE ANT KILLER and ORGANIC SOLUTIONS MULTIPURPOSE FIRE ANT KILLER (originally evaluated using Permaguard D-21) are dust formulations containing pyrethrins (0.2%, 0.1%), piperonyl butoxide (1.1%, 1.0%) and diatomaceous earth (97.9%) or silica dioxide (83.3%). Pyrethrins are extracted from pyrethrum daisies, piperonyl butoxide is a synthetic synergist and silicone dioxide is the chemical composing the bodies of fossilized diatoms found in diatomaceous earth. These products are registered by the Environmental Protection Agency for treatment of the red imported fire ant, Solenopsis invicta Buren (Hymenoptera: Formicidae). We conducted a series of trials to evaluate these products and others considered to be ‘organic’ (Bonide® Rotenone 5 Insecticide, Insecto™ Formula 7, Natural Guard™ Nicotine Sulfate, Gardenville® Diatomaceous Earth), comparing efficacy to standard treatments including acephate (Valent® Orthene® Turf, Tree & Ornamental Spray, Orthene® Systemic Insect Control), chlorpyrifos (Ortho-Klor® Soil Insect and Termite Killer) or diazinon (Rigo’s Best Diazinon® 2E), water only treatment and untreated controls.

Materials and methods

Trial 1. Plots, 40 ft. wide and variable in length, containing 10 active fire ant mounds each, were established in ornamental turf in Brazos County, 12 May 1993. Plots were arrayed by length and blocked into four sets of eight plots each. Treatments listed below were randomly assigned to each of four blocks and applied to individually flagged mounds according to directions, 14 May.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Organics Plus™ (0.2% pyrethrins + 1.1% piperonyl butoxide + 90% diatomaceous earth)</td>
<td>4 tbsp./1 gal./mound</td>
</tr>
<tr>
<td>2. Insecto™ Formula 7 (pump oil + sugar + linseed oil + mint oil + ammonium + coloring + water)</td>
<td>3 oz./3 gal./mound</td>
</tr>
<tr>
<td>3. Bonide® Rotenone 5 Insecticide (5% rotenone + 10% other cube resins)</td>
<td>1 rounded tbsp./2 gals. applied in 4 ft. diam. around mound</td>
</tr>
<tr>
<td>4. Natural Guard™ Nicotine Sulfate (10% nicotine (alkaloid))</td>
<td>1 tbsp./1 gal./mound</td>
</tr>
<tr>
<td>5. Gardenville® Diatomaceous Earth</td>
<td>4 tbsp./gal./mound</td>
</tr>
<tr>
<td>6. Orthene® Turf, Tree &amp; Ornamental Spray (75% acephate dust)</td>
<td>1 tbsp./gal./mound</td>
</tr>
<tr>
<td>7. water drench</td>
<td>1 gal./mound</td>
</tr>
<tr>
<td>8. untreated check</td>
<td>dry</td>
</tr>
</tbody>
</table>
Two hours following completion of treatments (5:30 pm), one plot from each treatment except for Orthene® Turf, Tree and Ornamental Spray was inspected for ant activity in the ten mounds treated. At 3, 7, 14 and 30 days following treatment, plots were evaluated using the minimal disturbance method. Mounds were considered "active" (harbor an active ant colony) if a dozen or more ants emerged from the lightly disturbed mound and displayed defensive behavior, a method similar to that used by Frankem, 1983. New mounds occurring in each plot were also noted. Notes were also taken on any phytotoxicity which occurred as a result of the treatment. Post-treatment fire ant activity was analyzed based on the number of treated mounds and the total number of mounds per treatment plot using analysis of variance (ANOVA) and the Tukey's Studentized Range Test (P ≤ 0.05) (PC SAS). Percent control was calculated from a pre-treatments level of 10 mounds.

**Trial 2.** Six treatments were evaluated to reduce the number of red imported fire ant mounds in treated areas. Treatments included:

1) PermaGuard™ D-20 (0.2 % pyrethrins, 1 % piperonyl butoxide plus diatomaceous earth) - 4 tbsp./gal./mound  
NOTE: Quanta Lab (9330 Corporate Dr. #703, Selma, TX 78154-1257; 210/651-5799; FAX: 210/651-9271) analysis of this material documented 0.1 % pyrethrins plus 0.9 % piperonyl butoxide (Report #950S1004, 26 April 1995).

2) PermaGuard™ D-21 (0.1 % pyrethrins, 1 % piperonyl butoxide plus diatomaceous earth) - 4 tbsp./gal./mound  
NOTE: Quanta Lab analysis of this material documented 0.1 % pyrethrins plus 0.6 % piperonyl butoxide (Report #950S1003, 26 April 1995).

3) Ortho-Klor® Soil Insect and Termite Killer (12.8 % chlorpyrifos) - 2 tbsp./gal/mound

4) Orthene® Systemic Insect Control (9.4 % acephate liquid) - 2 tbsp./gal/mound

5) Untreated control - 1 gal. water per mound

6) Permaguard D-20 applied with a Ortho® Dial'n Spray Hose-End Sprayer driven by a Shurflo® Diaphragm Pump powered by a 12 volt battery that delivers 40 psi. calibrated to deliver 2 lbs. Permaguard® in 50 gal. water per acre after spraying each mound within the treated area using an inward spiral spray pattern until the mound structure collapsed.

Four sets of replicated plots of equal width and variable length, containing ten (10) red imported fire ant mounds were established for each treatment (40 mounds treated per treatment). Treatment blocks were assigned by arraying plot length from longest to shortest and treatments were randomly assigned within each block. Each mound was marked with a plot flag and received one of the six treatments. Periodically (3, 7, 14 and 31 days; on 6, 10, 17 Feb. and 6 March, respectively) following treatment, treated mounds and plots were inspected for ant activity using the minimal disturbance method. Results were analyzed using Analysis Of Variance (ANOVA) and means separated using Tukey's Studentized Range Test (P ≤ 0.05).

**Trial 3.** Products evaluated in this trial are labeled to treat fire ant infested areas in sites listed using the methods listed below:
Treatment

1) Organic Solutions™
   Multipurpose Fire Ant Killer
   (0.1% pyrethrins;
   1.0% piperonyl butoxide,
   silicon dioxide 83.3%)

2) Valent™ Orthene® Turf, Tree &
   Ornamental Spray
   (acephate 75%)

3) Rigo’s Best Diazinon® 2E
   (diazinon 25.0%)

Method and rate appearing on product label

As a dust: For best results, dust the perimeter of the mound first.
With a stick, disturb the mound, then dust mound in a
   circular motion working toward the
   center until the entire mound is thoroughly dusted.

Mound drench or "Water Method": Use 0.6 oz. (4 Tablespoons) to one
gallon of water. For best results, saturate the perimeter of the mound first
working toward the center of the mound in a circular motion (you may want
the mixture to puddle). An ant mound 12-14 inches in diameter requires
about one gallon of the mix.

Hose-end sprayer: Use 16 oz. (1 lb.) per 1000 square feet of area. Use of
a hose-end sprayer for lawns, add a small amount of water to the jar and add
the amount needed for the measured area, stir to make a slurry, then add the
remaining water to the top of the jar. Empty entire contents of the jar on the
premeasured area.

2 teaspoons/mound

1 fl. oz. in 3 gals. of water/125 sq. ft.
Spot spray ant hills

Twenty four plots were established in a shredded wayside area 22 to 44 feet wide and varying
in length as to contain ten red imported fire ant mounds each. Fire ants in this location were
assumed to be of the multiple queen (polygyne) form. Each mound was marked with a colored
plot flag. Plots were arrayed from longest to shortest and divided into four blocks or replicates.
Each of six treatments listed below were randomly assigned, one to each block.

Treatments

1) untreated control
2) Organic Solutions™
   Multipurpose Fire Ant Killer:
   mound drench
   dust treatment
   broadcast spray
3) diazinon 2E broadcast
4) acephate 75% WP

Rate

1 2 3 4 5 6

---

4 tbsp./gal./mound
2 tbsp./mound
4 tbsp./gal./thorough coverage of mounds & plot
(1.77 oz./0.89 gal./mound + 14 oz./7.0 gal./1,000 sq. ft.)
8 fl. oz./24 gal./1,000 sq. ft.
2 tsp./mound

All treatments were applied, August 17, 1995. Recent light rains had occurred and soil was
moist. However, temperatures were in the 90 to 100 degree F range throughout much of this
trial period. Casey Cornwell, a technical representative from Organic Solutions was present to
apply the broadcast treatment of the Multipurpose Fire Ant Killer using a hydraulic sprayer
provided by Organic Solutions. Volume of solution and amount of product used was measured
by timing treatments and determining flow rate. To treat individual ant mounds in broadcast
treatment plots, 1.77 oz. Organic Solutions was used per mound (10 mounds treated) in 0.89
gal. water. Then the plots were oversprayed using 14.0 oz Organic Solutions per 1,000 sq. ft. in 7.0 gal. water. Diazinon was applied with a hose-end sprayer powered by a battery powered Shurflo RV Automatic Demand Pump, drawing diluted insecticide from a 40 gallon plastic container. Additional mounds detected during treatment were treated and marked with contrasting color flags so that they would not be included in subsequent monitoring efforts.

Periodically (4, 7, 14, 27 days) following treatment, marked mounds were inspected for ant activity using the minimal disturbance method. After the last evaluation, the plots were mowed to a height of 4 inches. Two days thereafter (Sept. 15), all active fire ant mounds were counted within each plot. Results were analyzed using analysis of variance (ANOVA) and means were separated using Tukey's Studentized Range test ($P \leq 0.05$).

Results and Discussion

The "strip plot" or "railroad track" method. The experimental design employed in these trials was developed to provide two types of efficacy data: 1) the effect of a treatment as measured by ant activity on four uniform sets (plots) of 10 marked red imported fire ant mounds; and 2) the ability of individual mound treatments to reduce the total number of ant mounds in treated areas. By arraying plot length to produce blocks within which treatments are randomly assigned, the mean plot length for each treatment becomes uniform (Table 1). In this way, the probability of fire ant colonies migrating in or out of any given set of treatment plots is equal. Furthermore, the presence of a number of 'new' (unmarked) mounds which appeared between treatment plots were considered to be relocated fire ant colonies, called 'satellite' mounds. These were separately documented and included in evaluations. This method is considered to be an improvement over previous methods used (Franke 1983) because it addresses the issue of colony relocation following treatment.

Trial 1. Of the 'organic' treatments tested, Organics Plus™ Fire Ant Killer caused the most rapid reduction in ant activity. The number of active mounds of ten treated was: Organics Plus™ - 2; Insecto™ Formula 7 - 10; Bonide® Rotenone 5 Insecticide - 9; Natural Guard™ Nicotine Sulfate - 10; GardenVille® Diatomaceous Earth - 9; water drench - 10; and untreated check - 9. Fire ant activity in mounds following treatments is presented in Table 2. Organics Plus™ and Orthene® Turf, Tree and Ornamental Spray treatments resulted in statistically similar reductions of ant activity. These treatments produced a rapid, 80 to 85 percent, elimination of ant activity in treated mounds within 3 days of treatment. Percent control continued to increase, reaching 95 to 98 percent at 14 and 30 days following treatment, respectively. Insecto™ Formula 7 drenches resulted in a slow decline in ant activity. Natural Guard™ Nicotine Sulfate and Gardenville® Diatomaceous Earth treatments produced no significant reductions of red imported fire ant mound numbers throughout this trial. Gardenville® Diatomaceous Earth is not an EPA registered insecticide for fire ant control. Plots treated with Orthene® and the untreated control had fewer 'satellite' mounds recorded following treatment than other treatments. No phytotoxicity was observed.

Trial 2. The average plot size was 750 sq. ft. On the day of treatment, the temperature ranged from 64.5 to 68.2 degrees F and relative humidity from 50 to 43 percent. Individual mound
drenches of flagged mounds required about 2.4 man-minutes per mound ($0.17 per mound at minimum wage of $4.25 per hour). Per mound cost for treatments was $0.48/mound for Orthene® Systemic Insect Control and $0.55/mound for Ortho-Klor® Soil Insect & Termite Killer.

Ten ounces of Permaguard® were mixed per gallon of water and used to fill the sprayer. The Ortho® Dial’n Spray Hose-End Sprayer, set at 8 oz rate, emitted 1.62 gal water/minute and sprayed out 13.5 fl oz dissolved pesticide per minute. Permaguard™ was dispensed at 0.0176 oz per minute. The amount of spray used on the hose-end treated plots is listed below:

<table>
<thead>
<tr>
<th>Plot no./length</th>
<th>Spray time/plot</th>
<th>Spray time/10 mounds</th>
<th>Total amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 15 ft</td>
<td>19 sec. (4.3 fl. oz.)</td>
<td>80 sec. (18 fl. oz)</td>
<td>= 1.74 oz. Permaguard® D-20 = 2.25 oz.</td>
</tr>
<tr>
<td>7 46 ft</td>
<td>59 sec. (13.3)</td>
<td>69 sec. (15.5)</td>
<td>= 1.53 oz.</td>
</tr>
<tr>
<td>23 24 ft</td>
<td>31 sec. (7.0)</td>
<td>56 sec. (12.6)</td>
<td>= 1.91 oz.</td>
</tr>
<tr>
<td>24 18.5 ft</td>
<td>24 sec. (5.4)</td>
<td>85 sec. (19.4)</td>
<td></td>
</tr>
</tbody>
</table>

Four tablespoons of Permaguard™ D-20 weighs 22.2 grams or 0.78 oz. Plots receiving individual mound drenches for 10 mounds received 7.8 oz. product.

The Permaguard® formulations performed differently, with D-20 (0.2% pyrethrins, 1% piperonyl butoxide plus diatomaceous earth) providing significantly better elimination of ant activity than D-21 (0.1% pyrethrins) 3 days following application (Table 3). Permaguard™ D-20, applied as an individual mound treatment eliminated ant activity in treated mounds more quickly than did Orthene® Systemic Insect Control (9.4% acephate), and performed statistically similar to Ortho-Klor® Soil Insect and Termite Killer (12.8% chlorpyrifos) throughout the trial. From 1 to 4 weeks following application, all individual mound treatments significantly reduced ant activity in treated mounds relative to ant activity in untreated control (water drench only) mounds and performed statistically the same, providing 75 to 100 percent suppression of ant activity in treated mounds.

The surface application of Permaguard™ D-20 significantly reduced the number of ant mounds 1 to 4 weeks following treatment relative to the untreated control (water drench only) plots by 50 to 53 percent. Apparently, the "spiral pattern spray" to individual mounds failed to deliver sufficient product to eliminate ant activity in treated mounds to the extent that 1 gallon individual mound treatments achieved. However, less material was applied to the plots using the surface treatment (1.9 oz. versus 7.8 oz for individual mound treated plots). (Note: The individual mound treatment rate of PermaGuard™ would have resulted in the application of 28.3 lbs. per acre for 581 ant mound infestation in this study area. Obviously, in areas with fewer mounds per acre would require less material.)

None of the treatments applied appeared to greatly aggravate colony movement (Table 4), although more "new" colonies appeared in the plots treated with the surface application of PermaGuard™ D-20. However, new mounds appeared in the plots during the course of this 4 week long trial. By the fourth week, only the Ortho-Klor® Soil Insecticide and Termite Killer
(chlorpyrifos 12.8%) treated plots contained significantly fewer mounds than did the untreated control plots, having 65 percent fewer mounds. The other treatments performed statistically similar to Ortho-Klor® Soil Insecticide and Termite Killer, achieving percent reductions of active fire ant mounds ranging from 58 to 13 percent.

This trial was conducted in February, and was characterized by mild and wet climate conditions. Field plots were mowed 1 and 27 Feb. Conceivably, colony migration into mowed plots from adjacent high grass areas may have increased because of the mowings or because of natural ant behavior during this period of the year. Further testing with these treatments will provide additional confidence in the results generated from this trial.

**Trial 3.** All treatments significantly reduced the number of red imported fire ant mounds treated within 4 days except the dry dust treatment of Organic Plus Multipurpose Fire Ant Killer (Table 5). This treatment remained less effective than the rest even though periodic rain showers occurred during the monitoring period (Aug. 19, 23, Sept. 13) that were sufficiently heavy to dissolve most of the powdered insecticide into the soil. Thereafter, all except the dust treatment performed, providing 95 to 100 percent elimination of active ant mounds treated. The dust treatment did significantly reduce the number of active ant mounds 36 to 54 percent relative to the number in untreated plots, but not to the same degree as did the rest of the treatments.

New mounds occurring in treatment plots 29 days after treatment resulted either from 1) treated colonies moving away from treatment spots and forming a new "satellite" colony; 2) treated colonies moving away from treatment spots and forming more than one new ant mound, a process referred to as "shattering"; or 3) migration of colonies into the treatment plots from untreated adjacent areas. Organic Solutions Multipurpose Fire Ant Killer treatment plots were found to harbor as many or more new unmarked mounds at that time than those found in untreated plots (Table 5). Only the acephate and diazinon treated plots contained significantly fewer total ant mounds at the end of the trial than untreated plots, providing 69 and 98 percent suppression of mound numbers, respectively.

**Acknowledgements**

We are grateful to S. Bradleigh Vinson, Dr. Roger Gold, Harry Howell and Bill Summerlin for their assistance in conducting Trial 1.

**Literature Cited**

Table 1. Length of plots (feet and inches and total feet) containing 10 active Red Imported Fire Ant mounds each before treatment, Brazos Co., Texas 1993 (Trial 1).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Block</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
<td>Total length</td>
</tr>
<tr>
<td>Organics Plus™</td>
<td>21' 1&quot;</td>
<td>25' 9&quot;</td>
<td>28' 4&quot;</td>
<td>35' 6&quot;</td>
<td>110.66</td>
</tr>
<tr>
<td>Insecto™ Formula 7</td>
<td>24' 0&quot;</td>
<td>20' 0&quot;</td>
<td>27' 6&quot;</td>
<td>46' 8&quot;</td>
<td>123.17</td>
</tr>
<tr>
<td>Bonide® Rotenone 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insecticide</td>
<td>23' 9&quot;</td>
<td>26' 4&quot;</td>
<td>27' 0&quot;</td>
<td>56' 2&quot;</td>
<td>133.25</td>
</tr>
<tr>
<td>Natural Guard™</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nicotine sulfate</td>
<td>26' 0&quot;</td>
<td>34' 2&quot;</td>
<td>34' 8&quot;</td>
<td>38' 2&quot;</td>
<td>133.01</td>
</tr>
<tr>
<td>Gardenville® Diatom-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>aceous Earth</td>
<td>20' 9&quot;</td>
<td>24' 5&quot;</td>
<td>32' 8&quot;</td>
<td>37' 2&quot;</td>
<td>115.01</td>
</tr>
<tr>
<td>Orthene® Turf, Tree and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ornamental Spray water</td>
<td>20' 1&quot;</td>
<td>24' 7&quot;</td>
<td>29'10&quot;</td>
<td>46' 2&quot;</td>
<td>122.65</td>
</tr>
<tr>
<td>drench</td>
<td>21' 6&quot;</td>
<td>26' 2&quot;</td>
<td>27' 6&quot;</td>
<td>38' 1&quot;</td>
<td>113.25</td>
</tr>
<tr>
<td>untreated check</td>
<td>17' 4&quot;</td>
<td>17'10&quot;</td>
<td>22' 5&quot;</td>
<td>45' 5&quot;</td>
<td>103.00</td>
</tr>
</tbody>
</table>
Table 2. Number of treated mounds of ten containing active Red Imported Fire Ant colonies following treatment using 'organic' insecticide products, Brazos Co., Texas, Trial 1, treated May 1993.

<table>
<thead>
<tr>
<th>Product</th>
<th>17 May</th>
<th>21 May</th>
<th>27 May</th>
<th>11 June</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 day</td>
<td>7 day</td>
<td>14 day</td>
<td>30 day</td>
</tr>
<tr>
<td>Organics Plus™</td>
<td>2.00b</td>
<td>2.00d</td>
<td>0.25b</td>
<td>0.50b</td>
</tr>
<tr>
<td></td>
<td>(80)</td>
<td>(80)</td>
<td>(98)</td>
<td>(95)</td>
</tr>
<tr>
<td>Insecto™ Formula 7</td>
<td>4.75b</td>
<td>4.00bcd</td>
<td>0.25b</td>
<td>0.50b</td>
</tr>
<tr>
<td></td>
<td>(53)</td>
<td>(60)</td>
<td>(98)</td>
<td>(95)</td>
</tr>
<tr>
<td>Bonide® Rotenone 5</td>
<td>4.50b</td>
<td>3.25cd</td>
<td>3.25b</td>
<td>1.50b</td>
</tr>
<tr>
<td>Insecticide</td>
<td>(55)</td>
<td>(68)</td>
<td>(68)</td>
<td>(85)</td>
</tr>
<tr>
<td>Natural Guard™</td>
<td>8.50a</td>
<td>6.50abc</td>
<td>7.75a</td>
<td>6.50a</td>
</tr>
<tr>
<td>Nicotine sulfate</td>
<td>(15)</td>
<td>(35)</td>
<td>(23)</td>
<td>(35)</td>
</tr>
<tr>
<td>Gardenville®</td>
<td>8.00a</td>
<td>8.25ab</td>
<td>8.25a</td>
<td>6.75a</td>
</tr>
<tr>
<td>Diatomaceous Earth</td>
<td>(20)</td>
<td>(17)</td>
<td>(18)</td>
<td>(33)</td>
</tr>
<tr>
<td>Orthene® Turf and Ornamental Spray</td>
<td>1.50b</td>
<td>1.25d</td>
<td>0.25b</td>
<td>0.25b</td>
</tr>
<tr>
<td>water drench</td>
<td>(85)</td>
<td>(88)</td>
<td>(98)</td>
<td>(98)</td>
</tr>
<tr>
<td>untreated control</td>
<td>9.00a</td>
<td>7.75ab</td>
<td>8.00a</td>
<td>6.25a</td>
</tr>
<tr>
<td></td>
<td>(10)</td>
<td>(23)</td>
<td>(20)</td>
<td>(38)</td>
</tr>
</tbody>
</table>

No. active fire ant mounds/10 (Percent control in parentheses)

**F**

<table>
<thead>
<tr>
<th></th>
<th>15.47</th>
<th>8.76</th>
<th>21.95</th>
<th>27.27</th>
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</table>

**P**

<table>
<thead>
<tr>
<th></th>
<th>0.0001</th>
<th>0.0001</th>
<th>0.0001</th>
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**MSE**

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<tr>
<th></th>
<th>1.809</th>
<th>3.400</th>
<th>2.149</th>
<th>1.208</th>
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**Min. Sig. Diff.**

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<tr>
<th></th>
<th>3.1904</th>
<th>4.3735</th>
<th>3.4767</th>
<th>2.6071</th>
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</table>

**R-square**

<table>
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<tr>
<th></th>
<th>0.8805</th>
<th>0.8066</th>
<th>0.9126</th>
<th>0.9285</th>
</tr>
</thead>
</table>

d.f. = 21; Studentized Range = 4.743

1 Mean no. fire ant active mounds/10 treated per plot. Means followed by the same letter are not significantly different according to ANOVA and the Tukey's Studentized Range Test ($P \leq 0.05$). Percent reduction of ant activity in mounds in parentheses.
Table 3. Mean number active ant mounds following application of individual red imported fire mound treatments, Brazos Co., Texas, Trial 2, treated 3 Feb. 1995.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>3 days</th>
<th>1 week</th>
<th>2 week</th>
<th>4 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>untreated control</td>
<td>10.00 a..</td>
<td>10.00 a..</td>
<td>8.75 a..</td>
<td>9.25 a..</td>
</tr>
<tr>
<td>1 gal. water/mound</td>
<td>6.00 b..</td>
<td>2.50 bc</td>
<td>1.25 c</td>
<td>2.00 bc</td>
</tr>
<tr>
<td>Permaguard™ D-21 (0.1% pyrethrins, 1% PBO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 tbsp./gal./mound</td>
<td>1.50 cd</td>
<td>0.25 c</td>
<td>0.25 c</td>
<td>1.00 c</td>
</tr>
<tr>
<td>Permaguard™ D-20 (0.2% pyrethrins, 1% PBO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 tbsp./gal./mound</td>
<td>9.75 a..</td>
<td>4.75 b.</td>
<td>4.75 b.</td>
<td>5.00 b.</td>
</tr>
<tr>
<td>surface treatmentb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lbs./50 gal./acre Orthene® Systemic Insect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (9.4% acephate EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 tbsp./gal./mound Ortho-Klor® Soil Insect</td>
<td>4.00 bc</td>
<td>1.00 c</td>
<td>1.00 c</td>
<td>1.25 c</td>
</tr>
<tr>
<td>and Termite Killer (12.8% chloropyrifos)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 tbsp./gal./mound</td>
<td>0.00 d</td>
<td>0.00 c</td>
<td>0.00 c</td>
<td>0.00 c</td>
</tr>
</tbody>
</table>

| F     | 22.32 | 30.40 | 17.80 | 13.12 |
| P     | 0.0001| 0.0001| 0.0001| 0.0001|
| MSE   | 1.952 | 1.200 | 1.7111| 2.333 |
| Min. Sig. diff. | 3.2104 | 2.5166 | 3.0052 | 3.5093 |
| d.f.  | 15    | 15    | 15    | 15    |

a Means followed by the same letter are not significantly different using analysis of variance (ANOVA) and the Tukey's Studentized Range Test ($P \leq 0.05$).

b Permaguard™ D-20 applied with a Ortho® Dial'n Spray Hose-End Sprayer driven by a Shurflo® Diaphragm Pump powered by a 12 volt battery that delivers 40 psi. to spray plot surface after spraying each mound within the treated area using an inward spiral spray pattern until the mound structure collapsed.
Table 4. Mean number of new mounds appearing per plot and total number of active ant mounds per plot following treatment of individual red imported fire ant mounds, Brazos Co., Texas, 1995.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean no. active mounds/plot*</th>
<th>No. &quot;satellite&quot; mounds/plot*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 weeks</td>
<td>4 weeks</td>
</tr>
<tr>
<td>untreated control</td>
<td>10.25 a..</td>
<td>11.50 a.</td>
</tr>
<tr>
<td>Permaguard™ D-21</td>
<td>2.75 .bc</td>
<td>7.25 ab</td>
</tr>
<tr>
<td>Permaguard™ D-20</td>
<td>1.00 ..c</td>
<td>4.25 ab</td>
</tr>
<tr>
<td>Permaguard™ D-20 surface</td>
<td>7.50 ab.</td>
<td>8.75 ab</td>
</tr>
<tr>
<td>Orthene® Systemic Insect</td>
<td>2.25 .bc</td>
<td>5.00 ab</td>
</tr>
<tr>
<td>Ortho-Klor® Soil Insect</td>
<td>0.50 ..c</td>
<td>3.50 .b</td>
</tr>
</tbody>
</table>

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$F$</td>
<td>6.35</td>
<td>5.23</td>
<td>0.69</td>
<td>2.14</td>
</tr>
<tr>
<td>$P$</td>
<td>0.0011</td>
<td>0.0029</td>
<td>0.6934</td>
<td>0.0972</td>
</tr>
<tr>
<td>MSE</td>
<td>6.275</td>
<td>6.964</td>
<td>2.919</td>
<td>11.986</td>
</tr>
<tr>
<td>Min. Sig. diff.</td>
<td>5.755</td>
<td>6.0626</td>
<td>3.9254</td>
<td>7.9337</td>
</tr>
<tr>
<td>d.f. = 15; Critical value = 4.595</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letter are not significantly different using analysis of variance (ANOVA) and the Tukey’s Studentized Range Test ($P \leq 0.05$).
Table 5. Mean number of active red imported fire ant mounds per plot, with 10 mounds treated per plot in four replicated variable sized plots, Trial 3, treated 17 Aug. 1995, Burleson Co., Texas.

<table>
<thead>
<tr>
<th>Treatment and rate</th>
<th>Mean no. fire ant mounds per plot/10 initially treated</th>
<th>Total mounds per plot (new)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aug 21 Day 4</td>
<td>Sept 15</td>
</tr>
<tr>
<td></td>
<td>Aug 24 Day 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aug 31 Day 14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sept 13 Day 27</td>
<td></td>
</tr>
<tr>
<td>untreated check</td>
<td>9.8a*</td>
<td>(8.8)</td>
</tr>
<tr>
<td>Organic Solutions®</td>
<td>9.5a</td>
<td>16.3a</td>
</tr>
<tr>
<td>dust treatment</td>
<td>5.5b</td>
<td></td>
</tr>
<tr>
<td>(2 tbsp./mound)</td>
<td>4.0b</td>
<td></td>
</tr>
<tr>
<td>mound drench</td>
<td>4.8b</td>
<td></td>
</tr>
<tr>
<td>(4 tbsp./gal./mound)</td>
<td>16.8</td>
<td></td>
</tr>
<tr>
<td>broadcast spray</td>
<td>0.8b</td>
<td>21.5a</td>
</tr>
<tr>
<td>(4 tbsp./gal./thorough coverage of plot)</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>acephate 75% WP</td>
<td>0.0b</td>
<td>13.3a</td>
</tr>
<tr>
<td>(2 tsp./mound)</td>
<td>0.3c</td>
<td></td>
</tr>
<tr>
<td>diazinon 2E broadcast</td>
<td>0.3c</td>
<td></td>
</tr>
<tr>
<td>(8 fl. oz./24 gal./1,000 sq. ft.)</td>
<td>11.82</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0c</td>
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</tr>
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<tr>
<td></td>
<td>MSD</td>
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</tr>
<tr>
<td></td>
<td>d.f. = 8</td>
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</tbody>
</table>

* Means in columns followed by the same letter are not significantly different using analysis of variance (ANOVA) and means were separated using Tukey's Studentized Range test ($P \leq 0.05$).
Effects of Tannic Acid, *Benzoic* Acid and *Azatin* EC™ on True Stop™ and True Growth™ Efficacy on the Red Imported Fire Ant Solenopsis invicta Buren Control

Doudou D. Faye  
Senior Entomologist  
Sphere Corp.  
Rt 4 Box 172, Georgetown, TX 78628  
(512) 515 6032

Abstract

Tannic acid and *benzoic* acid were used as additives to evaluate a sub-dose of True Stop™ Fire Ant Insecticide on the Red Imported Fire Ant -RIFA- (Solenopsis invicta Buren) control. *Azatin* EC™ from Agridyne Technologies Inc., Salt Lake, UT was also tested at fungus gnat control rate. A binary *Azatin* EC™+True Growth™ (TGAZ), a soil amendment refine liquid cow manure used as solvent in the manufacturing of True Stop™ was also studied. Parameters measured included mound activity, visual mortality rating, and control achieved after excavation. Decreased activity was noticed in all treatments but especially in the binary TGAZ up to 72h post-treatment. Among the additives used, benzoic acid performed slightly better than the *tannic* acid in regard to mound activity. Mortality measured as bone pile formation was more conspicuous on treatments having True Stop™ as a component. Tannic acid even though less effective than benzoic acid in reducing mound activity, its effect yielded better control than the benzoic acid at the end of the study period. Additional screening are needed for an optimum amount of additive or *Azatin* EC™ to use. Necrophoresis was more observed in True Stop™ treated mounds. The production of oleic acid as a decomposition of dead insects (in this case *fire* ant) and the presents of this fatty acid in True Stop™ could explain this occurrence. Furthermore, the adequate use of organic additive in botanical insecticide formulation may be an relatively less expensive way to prolong residual effect potency of the pesticide compared to most synergists.

Introduction

Several additives are reported to either enhance pesticide remanence or induce synergistic properties. Organic pesticides have the characteristics of being sensitive to several environmental factors among them: photosensitivity, and hydrolysis. These factors can alter or hinder their efficacy.

Plants produce a wide range of *allelochemicals* that could inhibit the insect ability to detoxify compounds. These *allelochemicals* therefore prevent or retard pesticide resistance when added in minute amount to the pesticide (Barbosa and Saunders 1985, and Berenbaum 1983 and 1988). Felton and Dahlman 1984, Salama et al. 1984 and 1986, and Ludlum et al. 1991, tested inorganic salts and aromatic compounds to enhance Bacillus thuringiensis (*B.t.* ) subsp. *kurtaski* activity.

Tannic acid extracted from *Taxus* sp. plants was reported to cause larval mortality by inducing gut necrosis and severe tissue damages resulting in degenerative epithelium (Bernays et al. 1980, Steintly and Berenbaum 1985, Raubenheimer and Simpson 1990 and Raubenheimer 1992). Gibson et al. 1995 used *tannic* acid as an inexpensive additive to synergize several sublethal concentrations of *B.t.* on Heliotis virescens (F.).

Kanga et al. 1995, and Kanga et al. 1995 used benzoic acid to extend insecticide life at low temperature on cotton bollworm, Heliotis *virescens* (F.), boll weevil, *Anthonomus grandis grandis* (Boheman) and house flies, Musca domestica (L.) control. The authors reported that the process prevents hydrolysis of the compounds due to atmospheric water...
vapor. Most plant derived pesticides are easily degraded by several biotic and abiotic factors (light, soil type and water pH, microorganisms, etc). Rotenone from the legume plants (*Derris* spp., *Lonchocarpus* spp. and *Tephrosia* sp.) possesses a broad range of pesticidal properties. Neem plant (*Azadirachta indica* Juss; Meliaceae) extract, especially the oil with its high content of azadirachtin has been used for centuries in India and Africa for insect pest and pathogen control. Neem was reported effective against more than 200 species of insects, mites and nematodes (Gaby Stoll, 1987; Schmutterer 1990). Azadirachtin (AZ), the main active ingredient found mainly in the seed is a steroid-like tetranortriterpenoid (limonoid) Its closely related isomers range from AZ A to AZ G. While AZ A acts more as biocide and anti feeding agents, AZ E is mostly responsible for the IGR effects found on insects exposed to neem product. Schmutterer reported Neem efficacy on fire ant (N.R.C. 1992).

True Stop™ formulation was used at reduced label rate by adding a minute amount of either benzoic acid or tannic acid to evaluate performance on RIFA. Azatin EC™, a commercial formulation of Neem oil from Agridyne Technologies Inc.was also tested alone and by adding 12ml of the technical formulation to quart (= 840ml) of True Growth™, the refined liquid cow manure soil amendment and solvent of True Stop™ Fire Ant Insecticide to study the effect of the formulation on RIFA control.

**Materials and Methods**

Field test was conducted in 16 acres rangeland in Blanco, Blanco county, 50 miles west of Austin. Flagged ant mounds were selected under the criteria of size (average of 10-12" diameter), activity (presence of brood and a rating of 5 after minimum disturbance). Six treatments of 19 mounds each were assigned in a completely randomized design and consisted of: water alone (untreated check), Azatin EC™ (label rate used for fungus gnat control), True Stop™ alone at label rate (29 oz/5 gal.), 2/3 label rate of True Stop™ and 12 ml of tannic acid (TSTA), 2/3 label rate of True Stop™ and 12 ml of benzoic acid (TSBA), and the binary one quart (=840 ml) of True Growth™ and 12ml Azatin EC (TGAZ). The tannic acid (powder form) and benzoic acid (crystalline form) were thoroughly dissolved in water prior to mixing. Applications were made by copiously drenching the mounds with the designated treatment. Parameters measured consisted of visual Activity When Disturbed (AWD), visual mortality rating (bone piles formation) at 1h, 24h, 72h and 14 Days After Treatments (DAT). At the 14th DAT, control treatment efficacy was evaluated by excavating the mounds and recording mounds as alive if brood presence was noticed (no control achieved) and dead when no brood was found (control achieved).

Additional observations were made to account for the distance traveled by the workers to select a graveyard site. We believe that this activity is related to the severity of the ants exposure to the toxicant. Knock down and full contact pesticides are more likely to confined most of the dead ants inside the mound and therefore bone piles are not conspicuous. Slow acting pesticides tend to prolong necrophoric activity. Furthermore, the nature of the chemical constituent(s) and corps decomposition biochemicals (indoles, amines, mercaptans and fatty acids) are reported to trigger necrophoresis (Blum 1970, Wilson et al. 1958, Hölldobler and Wilson 1990, and Tschinkel 1976). Therefore, the presence or absence of bone piles and location on mound vicinity (top or side) were reported to have a preliminary information on the richness of the compounds used or their probable ability to trigger corps removal behavior.

Analysis of variance was performed on AWD and mortality at 95% confidence. Control in each treatment was evaluated by assessing the number of dead mound (no brood present after excavation) over the total number of mounds per treatment. Fisher LSD was utilized to account for significant effect on ANOVA (p ≤ 0.0001).
Results and Discussion

Activity rating (0-5)

With the exception of the water treatment (control), activity was significantly reduced during the 1, 24, 72h and 14 days post-treatment. Within 1 hour post-treatment, there was a significant lethargy observed in the TGAZ treatment (Fig. 1). Observation at 24h and 72 after treatment indicated less activity in the TGAZ and TSBA with Azatin ECTM alone and True Stop™ alone performing equally; TSTA was only more effective than the control (Fig. 2, and 3). There was no reading at 7 days after treatment due unfavorable weather conditions. At 14 DAT, final reading was made, prior to excavation. The following rating was recorded in decreasing magnitude of activity (Table 1):

Control (4.53) > Azatin ECTM alone (2.34) TSTA (2.26) > TSBA (1.42) > TGAZ (1.00) > True Stop™ (0.47).

Table 1. Comparative response of RIFA activity, mortality and percent of control associated with different drench treatment regimes at 14 DAT.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Dose (/18.9L)</th>
<th>AWD</th>
<th>Visual ranking (0-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mortality</td>
</tr>
<tr>
<td>Azatin EC</td>
<td>12 ml</td>
<td>2.34</td>
<td>2.17</td>
</tr>
<tr>
<td>True Stop</td>
<td>900ml</td>
<td>0.47</td>
<td>4.34</td>
</tr>
<tr>
<td>TSTA</td>
<td>600ml+12ml</td>
<td>2.26</td>
<td>3.59</td>
</tr>
<tr>
<td>TSBA</td>
<td>600ml+12ml</td>
<td>1.42</td>
<td>2.67</td>
</tr>
<tr>
<td>TGAZ</td>
<td>900ml+12ml</td>
<td>1.00</td>
<td>2.20</td>
</tr>
<tr>
<td>Untreated</td>
<td>Water</td>
<td>4.53</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Means in same column with critical difference ≤ calculated F-LSD are not significantly different at p = 0.0001.

Significantly higher activity was noticed in the untreated plots (4.53). Plots treated with Azatin EC, TSTA and TSBA show a statistically similar activity level of 2.34, 2.26 and 1.42 respectively) with the combination TSBA showing less activity. True Stop at label rate had the highest reduction of activity (0.47) than the binary TGAZ but no significant effect was found between the two (Table 1).
Mortality rating

This was performed by visual observation of the amount of bone piles on and around mounds. It was found that most pesticides with synthetic solvent do not allow excessive bone pile. True Stop™, even though having a potent active ingredient but in a small amount (0.62%) and an organic solvent did not confer a rapid kill. This allow workers of dying mound to be active for several days in necrophoric activity. As the mounds die slowly, the production of oleic acid in the corpses increases and triggers additional bone pile activity. Therefore, this parameter is not quite adequate for evaluating different formulation, but gives a relative estimate of treatment response. More biochemical studies are needed to validate this hypothesis relating oleic acid production and necrophoric activity using these compounds.

*Mortality reading 24 hours post-treatment indicated significant treatment effects. TSTA and TSBA performed equally (2.79 vs. 2.32). TSTA was provided a higher kill than True Stop™ alone (2.13) while TSBA did not differ significantly. Azatin EC™ and TGAZ had the lowest kill. At 3 DAT, TSTA, True Stop™ alone and TSBA performed similarly (3.57, 3.41, and 3.03 respectively) and were significantly different from the equally performing Azatin EC™ and TGAZ. At 14 DAT, prior to excavation of the mounds, final mortality rating indicated no significantly higher mortality between the True Stop™ at label rate (4.34) and in the TSTA (3.6). There was no significant difference between the TSTA and TSBA treatments (3.6 vs. 2.7 respectively), but a slightly higher mortality trend in the TSTA plots. Azatin EC, TGAZ and TSBA performed equally the same with relatively higher mortality on the TSBA plots (2.17, 2.2, and 2.7 respectively) (Table 2 & Fig. 4). There was no visual bone pile associated with the untreated plots (Table 3).

Table 2. Comparative response of RIFA activity, mortality and percent of control associated with different drench treatment regimes at 14 DAT.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Dose (/18.9L)</th>
<th>Visual ranking (0 - 5)</th>
<th>% Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AWD</td>
<td>Mortality</td>
<td></td>
</tr>
<tr>
<td>Azatin EC</td>
<td>12 ml</td>
<td>2.34</td>
<td>2.17</td>
</tr>
<tr>
<td>True Stop</td>
<td>900ml</td>
<td>0.47</td>
<td>4.34</td>
</tr>
<tr>
<td>TSTA</td>
<td>600ml+12ml</td>
<td>2.26</td>
<td>3.59</td>
</tr>
<tr>
<td>TSBA</td>
<td>600ml+12ml</td>
<td>1.42</td>
<td>2.67</td>
</tr>
<tr>
<td>TGAZ</td>
<td>900ml+12ml</td>
<td>1.00</td>
<td>2.20</td>
</tr>
<tr>
<td>Untreated</td>
<td>Water</td>
<td>4.53</td>
<td>0.00</td>
</tr>
<tr>
<td>df</td>
<td>5, 90</td>
<td>5, 90</td>
<td>-</td>
</tr>
<tr>
<td>LSD</td>
<td>1.069</td>
<td>0.938</td>
<td>-</td>
</tr>
<tr>
<td>p</td>
<td>0.0001</td>
<td>0.0001</td>
<td>-</td>
</tr>
<tr>
<td>n</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

Means in same column with critical difference ≤ calculated F-LSD are not significantly different at p = 0.0001.
The higher incidence of bone piles associated mainly with True Stop™ treatment leaves us to strongly believe in the high production or accumulation of oleic acid, a fatty acid known to trigger necrophoresis behavior (Table 3). This assumption will be closely investigated as it could be a component to include in fire ant insecticide formulation to induce discrimination of contaminated or moribund ants by clean, healthy ants within a mound.

Table 3. Visual mortality ranking in relation to bone pile location in mound vicinity

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mortality†</th>
<th>Location on mound vicinity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Top</td>
</tr>
<tr>
<td>Azatin EC</td>
<td>**</td>
<td>√</td>
</tr>
<tr>
<td>True Stop</td>
<td>******</td>
<td>√</td>
</tr>
<tr>
<td>TSTA</td>
<td>***</td>
<td>√</td>
</tr>
<tr>
<td>TSBA</td>
<td>***</td>
<td>√</td>
</tr>
<tr>
<td>TGAZ</td>
<td>**</td>
<td>√</td>
</tr>
<tr>
<td>Untreated</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

†Ranking: ****** = High; *** = Moderate; ** = low; - = none

Furthermore, the distance of the bone pile from the mound could be a function of the degree of contact and rapid or slow kill associated with most insecticides. It was observed that insecticides with low knock down effect allow the ants to spend more time on corps removal and deposit at relatively long distance from the mound (3-5 ft). Compared to rapid knock down compounds that either allow a deposit on mound top or no removal at all (Table 2). The weakness in just relying on visual indices lies on the fact that mortality may occur without concomitant bone piles, especially if the pesticide has a quick knock down and killing effect. True Stop™ that is already rich in oleic acid will have more visual bone pile.

Mound control

The final treatment performance expressed in percent of control (number of dead mounds / total number of mounds per treatment) showed a 94.7% control on True Stop™ treatment, followed by TSTA (71.3%), Azatin EC™ (57.9%), TSBA (53.4%), TGAZ (42.1%) an Untreated control (5.3%) (Table 4, Fig 4). The untreated plots with a 5.3% mound reduction did not show bone pile formation. Azatin EC™ and TGAZ performance could be better investigated at a wider range of application rates. The label rate used to control fungus gnat may not be appropriate for fire ant control. Furthermore, the short study period may not have favored the Azatin EC™ performance, specially since the author did not know the main isomer(s) present as a.i. in the formulation.
Table 4. Comparative effects of different treatments on RIFA activity, mortality and control at different post-treatment periods. Blanco, TX. 1996.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Doses (mL/18.9L)</th>
<th>Visual Ranking (0 - 5)</th>
<th>Activity When Disturbed (AWD)</th>
<th>Mortality</th>
<th>%Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1h</td>
<td>24h</td>
<td>72h</td>
<td>14d</td>
</tr>
<tr>
<td>True Stop™</td>
<td>12</td>
<td>2.67</td>
<td>2.66</td>
<td>1.67</td>
<td>0.47</td>
</tr>
<tr>
<td>Azatin ECT™</td>
<td>840</td>
<td>2.45</td>
<td>2.74</td>
<td>1.71</td>
<td>2.34</td>
</tr>
<tr>
<td>TSTA</td>
<td>560+12</td>
<td>2.53</td>
<td>2.97</td>
<td>2.21</td>
<td>2.26</td>
</tr>
<tr>
<td>TSBA</td>
<td>560+12</td>
<td>2.26</td>
<td>2.37</td>
<td>1.99</td>
<td>1.42</td>
</tr>
<tr>
<td>TGAZ</td>
<td>840+12</td>
<td>1.55</td>
<td>1.42</td>
<td>1.13</td>
<td>1.00</td>
</tr>
<tr>
<td>Untreated</td>
<td>water</td>
<td>5.00</td>
<td>4.45</td>
<td>4.55</td>
<td>4.53</td>
</tr>
</tbody>
</table>

| df  | 5.90 | 5.90 | 5.90 | 5.90 | 5.90 | 5.90 | 5.90 | 5.90 |
| FLSD| 0.486| 0.581| 0.550| 1.069| 0.486| 0.689| 0.938| -    |
| p   | 0.001| 0.001| 0.001| 0.001| 0.001| 0.001| 0.001| -    |
| n   | 19   | 19   | 19   | 19   | 19   | 19   | 19   | 19   |

Means in the same column with critical difference ≤ calculated F-LSD are not significantly different. p = 0.0001

Conclusion

Fire ant control was achieved to a wide range of efficacy with regard to the treatments imposed. In all the treatments under study, only True Stop™ at label rate was utilized according to label rate. Since Azatin ECT™ was not labelled for fire ant control, the label rate for fungus gnat control was used. The test results showed that a higher rate should be utilized or a longer period of time given to take into account the IGR effect. However, Azatin ECT™ in combination with True Growth™ refined liquid manure solvent had the lowest activity rating up to 72 hours post-treatment. The additive tannic acid and benzoic acid were used as the substitute of the 1/3 of the True Stop™ label rate. Control achieved with these combinations suggested that more amount of the additives would be needed for more efficient performance. Further screening will consider a wider range of additives and Azatin ECT™ amount. In addition, Azatin ECT™ properties may require more than a short period of 14 days (this study duration) to visualize its IGR effect.

With the assumption of high incidence of fatty acid production such as oleic acid on True Stop™ treatment, the most conspicuous bone pile accumulation on these plots could suggest an interest in providing additional amount of this necrophoric trigger in drench formulation.

The botanical pesticides studied present a short REI, and a rapid biodegradation. This could limit their choice when long lasting residual effect is needed. The use of rational and proper amount of additives such as tannic and benzoic acids could be an inexpensive way to enhance organic pesticide efficacy.
Acknowledgments

We are grateful to Ms. L. Ethridge for providing her land, and to Mr. Dale Hehmeyer for his consistent support and help throughout the study period.

Reference Cited


ATTRACTION AND EFFICACY OF HYDRAMETHYLNON BAITS AGAINST IMPORTED FIRE ANTS

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Gulfport, MS 39501

INTRODUCTION:

Traditionally, imported fire ant baits are composed of soybean oil plus an active ingredient impregnated onto a corn grit carrier. In 1995, we tested two new hydramethylnon bait formulations. Both of these baits contained hydramethylnon as the active ingredient, but varied in other ways. American Cyanamid (Wayne, NJ) supplied us with an experimental queen pheromone enhanced Amdro® bait (---% pheromone, 0.73% hydramethylnon). MaxForce® Ant Killer Granular Bait contains 1% hydramethylnon, but is formulated on a carrier containing proteins, fats, sugars, oils and carbohydrates, including ground-up silk worm larvae. This product is marketed by The Clorox Company (Oakland, CA).

MATERIALS AND METHODS:

Laboratory bait acceptance trials:
In order to evaluate attractiveness of the various formulations, a standard bait acceptance trial was performed. Our method was modified from the procedure described by Lofgren et al. (1961). Field collected colonies were brought to the laboratory in plastic dish pans, and allowed to acclimate for 3-4 days prior to testing. A control bait was prepared by mixing fresh soybean oil and pregelated defatted corn grits in a 30:70 weight to weight ratio. The candidate baits included MaxForce, the pheromone enhanced Amdro formulation and a standard commercial Amdro formulation. These baits were subjected to two bait acceptance trials; one trial using "normally" starved ants (3-4 days), and one using ants which had been excessively starved for 14 days. Four grams of a candidate bait contained in a petri dish were placed on the surface of each of five test colonies. Simultaneously, four grams of the
freshly prepared standard bait in an identical dish were placed approximately 4-5 inches from the candidate bait. Foraging workers were then provided a free choice to feed on the bait of their preference. After a 24 hour feeding period, the dishes were removed and the amount of each bait removed was determined by weighing. Differences between the mean amounts of candidate and non-toxic bait removed were compared by a t-test (P=0.05).

A second acceptance trial was performed where the queen pheromone enhanced Amdro and MaxForce were the candidates baits, and commercial Amdro was used as a standard. The test procedure described above was followed, but only "normally" starved ants were used.

A final bait acceptance trial compared all three hydramethylnon baits to each other. Four grams of each bait was introduced into each of five "normally" starved colonies by the method previously described. After a 24 hour feeding period, the dishes were removed and the amount of each bait removed was determined by weighing. Differences between the mean amounts of each bait removed were separated by ANOVA and LSD test (P=0.05).

Field trial:
Test plots were established in Harrison Co., MS. The pheromone enhanced Amdro, and commercial Amdro were applied at 1.5 lbs/acre. The MaxForce bait was applied at ca 2 lbs/acre due to difficulties calibrating this particular formulation. Each treatment was applied to three 1-acre test plots May 25, 1995 using a shop-built spreader (Collins 1988) on a farm tractor. Prior to application, a ¼-acre circular subplot in the center of each 1-acre test plot was evaluated by recording the number of active colonies present. Plots were also evaluated at six-week intervals after treatment until reinfestation occurred. Colony mortality was calculated from the raw data, and mean percent colony mortality of each treatment at each posttreatment evaluation period was compared by ANOVA and Tukey's test (P=0.05).

RESULTS:

Laboratory bait acceptance trials:
Hydramethylnon baits compared to a non-toxic standard bait: Under the
"normal" conditions, there was no significant difference between the amount of MaxForce and the amount of the non-toxic standard removed (Table 1). Numerically, the ants removed more of the MaxForce than the corresponding non-toxic standard, showing a slight preference for that bait. Significantly less of the pheromone enhanced Amdro and the commercial Amdro was removed compared to the corresponding non-toxic standard bait.

The excessively starved colonies showed no preference for bait type and readily removed >95% of the bait available (Table 1).

MaxForce and pheromone enhanced Amdro compared to a commercial Amdro bait: In two trials, significantly more MaxForce was removed compared to a commercial Amdro standard (Table 2). When the pheromone enhanced Amdro was compared to a commercial Amdro standard, there was no significant difference in the amount of bait removed.

Hydramethylnon baits compared to each other: In two separate trials, different results were obtained. In trial I, the amount of MaxForce removed by test colonies was significantly greater than the amount of pheromone enhanced Amdro or commercial Amdro removed (Table 3). On average, the ants removed 97.5% of the MaxForce bait provided compared to 43% and 52% of the pheromone enhanced Amdro and commercial Amdro, respectively.

In trial II, no bait was removed in a significantly greater quantity than the others (Table 3). The ants removed an average of 63% of the MaxForce provided, 71.5% of the pheromone enhanced Amdro, and 37% of the commercial Amdro.

Field trial:
At 6 weeks after treatment, all treatments provided 86.7 to 95.8% reduction in number of pretreatment colonies (Table 4). At 18 weeks after treatment, all treatments provided >92.7% reduction in number of colonies. By 24 weeks after treatment, reinfestation was noted in all plots. The high check mortality at the 12 and 18 week counts is indicative of the time of year the count was taken; August and September when it is extremely hot and dry in south Mississippi and we normally see a decrease in IFA activity (unpublished data).
However, the excessively high mortality seen in the untreated check plots at 18 weeks question the validity of these results. High check mortality similar to this trial were experienced in all trials conducted in south Mississippi and Alabama in the summer of 1995.

DISCUSSION:

MaxForce was more attractive than other baits in laboratory bait acceptance trials. Although some variation occurred in some rating intervals, in general, MaxForce also provided numerically better control in the field. However, the difference was not statistically significant. The pheromone enhance Amdro was effective as, but not better than, the commercial Amdro. American Cyanamid will not pursue the development of this pheromone enhanced bait.

Table 1. Attractiveness of Hydramethylene non IFA Bait Formulations Compared to a Non-Toxic Bait. (2 way test)

<table>
<thead>
<tr>
<th>Bait</th>
<th>Mean amount of bait removed (g)*</th>
<th>3-4 day starvation**</th>
<th>14 day starvation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MaxForce</td>
<td>3.88a</td>
<td>4.00a</td>
<td></td>
</tr>
<tr>
<td>Non-toxic standard</td>
<td>3.28a</td>
<td>3.82a</td>
<td></td>
</tr>
<tr>
<td>Pheromone Enhanced Amdro</td>
<td>3.34a</td>
<td>3.90a</td>
<td></td>
</tr>
<tr>
<td>Non-toxic standard</td>
<td>5.00b</td>
<td>4.00a</td>
<td></td>
</tr>
<tr>
<td>Commercial Amdro</td>
<td>3.00a</td>
<td>4.00a</td>
<td></td>
</tr>
<tr>
<td>Non-toxic standard</td>
<td>4.88b</td>
<td>4.00a</td>
<td></td>
</tr>
</tbody>
</table>

* Means within a paired group and within a column followed by the same letter are not significantly different (t-test, P=0.05).

** In this trial, 5.0g of each bait was introduced to the colonies, not 4.0g. N = 5 colonies per bait exposure.
Table 2. Attractiveness of MaxForce and Pheromone Enhanced Amdro to Standard Commercial Amdro. (2 way test)

<table>
<thead>
<tr>
<th>Bait</th>
<th>Mean amount of bait removed (g)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial I</td>
</tr>
<tr>
<td>MaxForce</td>
<td>3.34a</td>
</tr>
<tr>
<td>Commercial Amdro</td>
<td>1.08b</td>
</tr>
<tr>
<td>Pheromone Enhanced Amdro</td>
<td>1.86a</td>
</tr>
<tr>
<td>Commercial Amdro</td>
<td>1.32a</td>
</tr>
</tbody>
</table>

* Means within a paired group and within a column followed by the same letter are not significantly different (t-test, P=0.05).

N = 5 colonies per bait exposure

Table 3. Comparison of Attractiveness of Three Hydramethylnon Baits. (3 way test)

<table>
<thead>
<tr>
<th>Bait</th>
<th>Mean Amount Removed* (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial I</td>
</tr>
<tr>
<td>MaxForce</td>
<td>3.90 ± 0.10a</td>
</tr>
<tr>
<td>Pheromone Enhance Amdro</td>
<td>1.72 ± 0.61b</td>
</tr>
<tr>
<td>Commercial Amdro</td>
<td>2.08 ± 0.71b</td>
</tr>
</tbody>
</table>

* Means within a column followed by the same letter are not significantly different (LSD test, P=0.05).

N = 5 colonies per bait exposure
Table 4. Efficacy of Various Fire Ant Baits Against Field Populations of Imported Fire Ants.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean no. pretreat colonies</th>
<th>Mean % decrease in number of colonies*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(6)</td>
<td>(12)</td>
</tr>
<tr>
<td>MaxForce</td>
<td>15.3</td>
<td>95.8a</td>
</tr>
<tr>
<td>Standard Amdro</td>
<td>23.3</td>
<td>94.3a</td>
</tr>
<tr>
<td>Pheromone Amdro</td>
<td>21.7</td>
<td>86.7a</td>
</tr>
<tr>
<td>Check</td>
<td>25.3</td>
<td>31.1b</td>
</tr>
</tbody>
</table>

* Means within a column followed by the same letter are not significantly different (Tukey’s test, P=0.05).

References Cited


Evaluation of Insecticides for Individual Mound Control of Red Imported Fire Ant in Residential Landscapes.

James A. Reinert & Steven J. Maranz
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17360 Coit Road
Dallas, TX 75252-6599

Introduction

The red imported fire ant (RIFA), *Solenopsis invicta* Buren, is possibly the most serious pest of urban landscapes in Texas and throughout the southeastern states where it has become well established. It was accidentally introduced from South America and became established in Mobile, AL in 1918 (Anon. 1994). RIFA reached Texas during the 1950s and has continued to spread across the state (Drees & Vinson 1991). It is now distributed throughout the eastern half of Texas with confirmed localized colonies as far west as Ector and Swisher counties and as far north as the row of counties along the Red River from Bowie at the Louisiana border westward to Wichita county (Porter et al. 1991). Populations have also been reported in at least five counties north of the Red River in Oklahoma.

Although the RIFA is considered an active predator of pest insects in some agricultural crops, it causes considerable damage to turfgrass by its extensive mound building and outreaching tunnels from these mound. Damage consists of shading and killing of the turfgrass, damage to lawn mowers and other maintenance equipment, and disruption of other maintenance practices. Even more important, however, is the medical problems associated with RIFA stinging and biting. These ants sting repeatedly and attack anything or anyone near the colony when it has been disturbed. For this reason, control measures are often necessary in urban landscapes around residential and commercial buildings and in parks and other recreational turf facilities.

Materials and Methods

The following studies were conducted on landscape bermudagrass, *Cynodon dactylon* (L.) Pers. or bermudagrass dominant mixed grass turf in urban landscapes in Dallas, Texas. Bait, dust, and granular formulations of several insecticides were applied to individual mounds of RIFA during the Summer and Fall of 1995.

In each experiment, mound activity was assessed 1-2 days before treatments were applied. Mound activity was determined by stomping hard (4-5 times) on the soil or turf ca. 1 ft. from the mound in a circle around each mound. Upon disturbance, an active mound would yield many very active workers. For the final rating in each test, each colony which did not show activity by the stomping test was also excavated to a depth of ca. 8 inches with a small shovel.
to determine mound activity. If no live ants were found upon this added disturbance, the colony was considered dead.

In Experiment 1, bait formulations of sulfluramid (Finitron) and hydramethylnon (Amdro) (Fig. 1) were applied to individual mounds of RIFA in residential lawns in Plano, TX on 30 June 1995. Measured amounts of bait material was applied evenly over and immediately adjacent to each mound with a hand held shaker. An untreated undisturbed check was included for comparison. A randomized complete block design was used with 15 replications of one RIFA mound per treatment in each replicate. Mounds were blocked by pretreatment assessment of colony size, that is the largest colonies were used in the first replication. Efficacy of the baits was assessed at 2-wk., 3-wk., and 4-wk. posttreatment.

Experiment 2 and 3 were conducted on the landscape at the Texas A&M University Research & Extension Center at Dallas, TX. In Experiments 2, dust formulations of two synthetic pyrethroids, deltamethrin and cyfluthrin (Tempo), at several rates and treatment procedures (Fig. 2) were applied on 13 November 1995. Acephate (Orthene) was included as a non-pyrethroid standard and both a water check (1 gal. of water sprinkled over each mound) and an untreated check were included. Treatments were applied either as mound only or as treatments of the mound and a 6 inch perimeter area around the mound. Twelve replicates of one mound per treatment were use in the study. Efficacy was evaluated at 3-day, 1-wk., and 2-wk. after applications were applied. Mounds treated with either cyfluthrin or acephate that were still active at the 1-wk. rating, were retreated at their initial rates.

For Experiment 3, Fall treatments (applied on 14 November 1995) of granule formulations of deltamethrin and diazinon at several rates (Fig. 3) were applied either as over the mound and 6 inch perimeter area, or with a walk-behind drop fertilizer spreader. Two treatments of deltamethrin were applied with the drop spreader delivering either 2 or 3 lb. per 1,000 ft.² over a 4 ft.² area encompassing the mound. Each chemical treatment was washed in with 1 gal. of water per mound. Diazinon 5G was used as the standard control and both a water check (1 gal. of water sprinkled over each mound) and an untreated check were included. The experiment included 12 replicates with one mound per treatment per replicate. Efficacy was evaluated at 3-day, 1-wk., and 2-wk. after applications were applied.

The percentage mortality provided by each chemical treatment was determined and the means were separated using exact confidence intervals calculated from binomial distribution (Steel & Torrie. 1960).

**Results and Discussion**

Fig. 1 shows significant control was provided with both rates of sulfluramid and the hydramethylnon treatments. Additionally, there was no statistical difference between the 2 treatment rates for sulfluramid. Only one colony that was treated with the 3 teaspoon rate of
sulfuramid and one that was treated with hydramethylnon relocated within ca. 3 ft. of the original mound. Both colonies were weakened, but were still alive at the 4-wk. rating. All bait treatments were significantly better than the untreated check.

All dust treatments (Fig. 2) provided increasingly better control with time. The chemical treatments were all significantly better than the checks and each provided better than 90% control within 2 wk. following treatment. The highest rate of both cyfluthrin and deltamethrin stimulated significant RIFA colony entrance relocation to within 4 inches to 2 ft. from the treated area. This trend indicates that a lower rate may be better for the individual mound treatment method, however, most of the relocated colonies were dead by the 2-wk. evaluation.

All granule treatments also provided increasingly better control in time, with the highest rate of deltamethrin providing 100% control by the 2-wk. rating. The diazinon standard provided 90.9% control but failed to control one of the RIFA mounds. All other treatments provided 66.7% control by the 2-wk. evaluation. The 4 tablespoon rate of deltamethrin (58.3% at 3-day) and to a lesser extent the 1 tablespoon rate (25% at 1 wk.) (stimulated significant RIFA colony entrance relocation. Relocation of the entrance usually was within 4 inches to 2 ft. from the treated area. Many of these colonies, however, were inactive at the end of the experiment. The cooler day and night time temperatures during these fall experiments (Experiment 2 and 3) may have slowed the chemical activity as compared to the much higher temperatures during summer treatments.

Literature Cited


Fig. 1. Percent mortality of individual mounds of RIFA treated with bait formulations - 1995.

- Sulfluramid (Finitron) 0.55%B 4 tsp/M&P
- Sulfluramid (Finitron) 0.55%B 3 tsp/M&P
- Hydramethylnon (Amdro) 0.73%B 5 tbsp/M&P
- Untreated Check
Fig. 2. Percent mortality of individual mounds of RIFA treated with dust formulations - 1995.

- Check
- Water Check
- Cyfluthrin (Tempo) 0.1%D - 2/3 tbsp/M
- Cyfluthrin (Tempo) 0.1%D - 1 tbsp/M
- Deltamethrin 0.05%D - 1 tbsp/M
- Deltamethrin 0.05%D 1 tbsp/M&P
- Deltamethrin 0.05%D 4 tbsp/M
- Deltamethrin 0.05%D 4 tbsp/M&P
- Deltamethrin 0.05%D 8 tbsp/M
- Deltamethrin 0.05%D 8 tbsp/M&P
- Acephate (Orthene) 75%S - 2/3 tbsp/M
Fig. 3. Percent mortality of individual mounds of RIFA treated with granular formulations - 1995.

- Check
- Water Check
- Deltamethrin 0.1%G 1 tbsp/M&P
- Deltamethrin 0.1%G 4 tbsp/M&P
- Deltamethrin 0.1%G 8 tbsp/M&P
- Deltamethrin 0.1%G 2 lb/1000 ft - Spreader
- Deltamethrin 0.1%G 3 lb/1000 ft - Spreader
- Diazinon 5%G 5 1/3 tbsp/M&P
UPDATE ON USDA-ARS BIOLOGICAL CONTROL STUDIES ON FIRE ANTS

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The Red Imported Fire Ant, Solenopsis invicta, is a major urban and agricultural pest throughout the entire southeastern United States. This species is one of the most abundant insect pests in North America with average densities of 20-30 mounds/acre and 100-200 ants/ft². High densities of this pest in the United States appear to be at least partially the result of biological release from natural enemies in South America where fire ant populations are usually 1/5 of what they are in the United States. Natural biological control agents are almost entirely absent in the United States. We feel that the introduction of natural enemies from South America could sufficiently shift the biological balance in the United States so that our native ants could compete with this imported pest which could reduce populations here to levels similar to those found in South America.

Over three dozen species of natural fire ant enemies have been identified in South America. We propose to focus our efforts on the following three potential natural agents: (1) the microsporidium Thelohania solenopsae, (2) a parasitic ant Solenopsis [Labauchen] daguerrei, and (3) phorid flies (Diptera).

Results to date with T. solenopsae have been promising and indicate that this pathogenic protozoan may offer potential for reducing the size of fire ant populations in the U.S. Laboratory studies in Argentina showed that healthy colonies lived longer than infected ones. Individual workers separated from healthy colonies and kept in complete starvation lived an average of 26% longer than infected workers under the same conditions (4.1 vs. 3.3 days). In field studies, the size of infected colonies was smaller than noninfected ones and the overall density of the infected populations declined by more than 80%.

While surveying for pathogens in the U.S. for use as biological control agents for imported fire ants, Solenopsis invicta, we recently discovered fire ant workers infected with spores from a microsporidium. Seventy-five percent of the colonies were infected. We believe that this microsporidium may be the same Thelohania solenopsae found in fire ant colonies in Brazil and Argentina. Studies using rRNA sequencing procedures (Polymerase chain reaction - PCR products of the 16SrRNA gene) to determine this are underway and will be completed within two months. This is the first time that a microbial pathogen has been discovered in imported fire ants in the United States. Its potential for use as a biological control agent against the imported fire ants in the U.S. is unknown at the present time.
The parasitic ant, *Solenopsis daguerrei*, is especially intriguing because it lacks a worker caste; only queens and males are ever produced. *S. daguerrei* queens enter fire ant colonies and attach themselves to the mother queen. Previous studies have demonstrated that this parasite inhibits the fire ant mother queen and her egg production, thus causing the ant colony to collapse and eventually die out. Since *S. daguerrei* queens attach themselves to fire ant queens, this species could be especially useful in controlling the multiple-queen form of the fire ant.

Present laboratory studies underway in Gainesville, Florida as follows: (1) mating under laboratory conditions, (2) yoking studies on newly introduced *S. invicta* queens and introduction into IFA colonies, and (3) species-specificity of *S. daguerrei*. Field studies being conducted in Argentina are: (1) mound size of parasitized and non-parasitized colonies, (2) caste composition of parasitized and non-parasitized colonies, and (3) polygyny of the parasite and host.

More than a dozen species of phorid flies (Diptera) attack fire ants in South America. Up to seven species have been found at a single site. Phorid flies appear to be common and active throughout most of the year in South America. The presence of phorid flies can substantially reduce fire ant foraging activity in daylight hours. Reduced foraging activity should greatly facilitate competition from ants that would otherwise be excluded from food sources in fire ant territories. The available evidence suggests that individual phorid species are very specific and would attack only ants in the genus *Solenopsis*. Recent research has solved 3 major rearing problems:

1) We have developed techniques for handling and feeding adult flies that has increased their longevity from 2-3 days up to a week or more. This has made it easier to ship the flies to the US and hold them for testing.

2) We have discovered how to increase the pupation rate of mature maggots from less than 10% to between 70-80%.

3) We have been able to increase successful emergence of the adults from about 10% to 80%. This means that more than half of the maggots in the lab colonies now develop into adults.

4) We are currently working on the 4th major problem and that is to have newly emerged flies vigorously attack fire ants in the laboratory. Solving this last problem will hopefully close the loop in our efforts to rear these flies in the laboratory. This accomplishment would greatly facilitate further studies of these flies and our efforts towards field releases.

Recent tests of phorid specificity conducted in the laboratory indicated that at least 5 species of South American phorid flies will attack IFA in North America. Results of specificity tests indicate that these flies have a strong preference for the red imported fire ant over the native fire ant, *Solenopsis geminata*. Attacks were observed on both monogyne and polygyne fire ant colonies. All sizes of workers were attacked although different phorid species do appear to have different size preferences.
The Relationship Between *Caenocholax fenyesi* (Strepsiptera: Myrmecolacidae) and its Host *Solenopsis invicta*

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Summary

The male of *Caenocholax fenyesi* Pierce is a strepsipteran parasitoid of the red imported fire ant, *Solenopsis invicta* Buren (Kathirithamby and Johnston 1992). *Caenocholax fenyesi* belongs to the family Myrmecolacidae, which is unique among the Strepsiptera by exhibiting heteronomy. All males in the family Myrmecolacidae are parasitoids of ants, while females parasitize members of the Orthopteroidea (Kathirithamby 1989).

Myrmecolacid strepsipterans have a complex life cycle, along with their heteronomous host relationship. The female strepsipteran, including the neotenic adult stage, remains endoparasitic within its host, extending only its cephalothorax to the outside of the host. Triungulins, or first instar larvae, are produced viviparously and leave the female via a brood canal, that is part of the female cephalothorax. The triungulins must then find and infect a new host. Triungulins are heavily sclerotized, with walking legs and caudal bristles that allow them to jump onto potential hosts. Upon finding a future host, the triungulin bores into this host, between sclerites, and almost immediately molts to the second instar larva. The second instar larva, termed a secondary larva, is maggot-like in appearance. This apodous secondary larva is endoparasitic. The secondary larva molts to a third instar, or tertiary larva, which is also endoparasitic. This larval form has a head capsule and rudimentary prolegs on the last abdominal segments. There may be more than one instar of tertiary larva before the pupal instar. The pupal stage of the male protrudes its cephalotheca outside its ant host, between abdominal sclerites. The adult male emerges through the cephalotheca and uses sensory structures on its flabellate antennae and maxillary palps to locate the female still in its orthopteroid host. Upon finding the female, the male deposits sperm via the brood canal of the female. Eggs are found free within the hemocoel of the female abdomen, where fertilization takes place.

The distribution of *C. fenyesi* is poorly known. It has been recorded in the United States from the states of Florida, Georgia, Alabama, Mississippi, Louisiana, Texas, and Arizona (Cook 1996). Except for collections from Texas, all collections are of males collected at traps and there has been no association with its host. The Arizona collection of a single male at a light trap in 1960 (Johnson and Morrison 1979) presents a problem in assuming its host relationship because the known host, *S. invicta*, has not been found in this region. *Caenocholax fenyesi* has also been recorded from several locations outside the United States, all from areas that are not known to have *S. invicta*. 
Caenocholax fenyesi is known from collections, at light, from Andros Island, Bahamas; three sites in Mexico; Guatemala; Costa Rica; Nicaragua; Panama; Ecuador; Chile; and Argentina (Cook 1996). This leads us to assume that C. fenyesi has at least two male hosts and that the host association of S. invicta may be due to a recent host switch.

The habitat of C. fenyesi is a function of its host’s habitat. The female C. fenyesi remains endoparasitic, even in the adult stage, and is thus confined to its host’s habitat. Male C. fenyesi emerge from their hosts as adults but are very short lived and are confined to an overlap of male and female host habitats. We have found that stylopized S. invicta were found in all habitats of Brazos County, Texas (woodland, savanna, and grassland). There was no significant difference between prevalence of stylopized ants in woodland and savanna habitats. Grasslands were found to have lower percentages of stylopized ants and a smaller percentage of infected colonies than other habitats.

Several aspects of the life history of C. fenyesi have been examined in our studies. The developmental time of male C. fenyesi appears to be about six months. This is not, however, a bivoltine species. Emergence occurred throughout the year, with a peak in mid summer. Emerging adult males live for an average of less than two hours, with a maximum observed adult life-span of three hours. This allows the adult male a minimal amount of time to locate a female and mate before dying. Size of adult males varied from 0.7 to 1.52 mm total length. There is a direct correlation of male total length to the size of the host in which they developed. The smallest male C. fenyesi developed in minor workers of S. invicta, while the largest developed in major workers. Superparasitism of S. invicta occurred in very small numbers (less than four percent of stylopized ants). The largest number of parasitoids observed in a single host was two, with both parasitoids capable of completing development.

The host of C. fenyesi females was found to be a bush cricket, Hapithus agitator Uhler (Orthoptera: Gryllidae: Eneopterinae). This host, stylopized with a female C. fenyesi was collected in a malaise trap in Lick Creek Park, Brazos County, Texas. Hapithus agitator occurs in very small numbers in this region and might be the limiting factor, resulting in colonies of S. invicta presently being stylopized at a rate of about ten percent. Caenocholax fenyesi may be controlling the population of H. agitator more efficiently than that of S. invicta.

Female C. fenyesi were found to have a large reproductive potential. The females found in our survey were estimated to contain almost 500,000 eggs each. All stylopized female hosts were also superparasitized, supporting from two to four female C. fenyesi. This gives reason to believe that if numbers of female hosts and thus, female C. fenyesi, can be manipulated, the level of S. invicta being infected could be significantly increased.

With the results of our study, we can now evaluate the biological control potential of C. fenyesi to impact S. invicta populations. There are several factors in favor of C. fenyesi having the potential to become a biological control agent of S. invicta. First, C. fenyesi is a native parasitoid. The risks associated with introduction of an exotic parasitoid are not present. We have found no other native ant that male C. fenyesi are stylopizing. Second, C. fenyesi was found to stylopize all castes of S. invicta, including reproductives. Third, C. fenyesi attacks ants from both monogyne and polygyne colonies. Fourth, stylopization affects more ants than those directly infected. The
behavior of styloped S. invicta is affected in a way that eliminates it from carrying on its part in the social structure of the ant colony (Cook 1996). This results in the weakening of the social structure of the colony. Fifth, this system has the potential to become a self-sustaining system that will bring about some level of control, if larger numbers of triungulins are naturally available to infect S. invicta. Finally, we believe that the numbers of C. fenyesi can be manipulated to increase the stylopization level of S. invicta. The scarcity of the female host appears to cause a bottleneck that results in low numbers of female C. fenyesi and therefore, insufficient numbers of triungulins are available to infect significant numbers of S. invicta.

We are presently beginning research on three methods to increase the numbers of triungulins available to infect S. invicta. The obvious solution is to increase the numbers of the female host, H. agitator. To do this we plan to raise this cricket species in culture to make them available for release, thus increasing the number of available female hosts. Along with this, suitable habitat must be present to support the release of H. agitator. Another option is to bring about a host switch to a more plentiful cricket species. We have reason to believe that female C. fenyesi are presently not host specific, due to its occurring in areas that H. agitator is not known to occur. There is also evidence that other known female myrmecolacids are not host specific (J. Kathirithamby, personal communication). The final option is to raise C. fenyesi in vitro, making it possible to distribute triungulins to areas where fire ant control is desired. In this case, triungulins could be applied in the form of a biological insecticide.

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THE ANTS OF MOBILE COUNTY ALABAMA REVISITED

Timothy C. Lockley

ABSTRACT

A survey was conducted in the fall of 1995 and the spring of 1996 in Mobile County Alabama along the same north-south transects used in a previous survey conducted in 1974. Comparisons of the two surveys showed significant shifts in dominant and subdominant species of ants.

MATERIALS AND METHODS

Three approximately parallel roads running north to south through Mobile County were surveyed as study transects. These roads, between 40 and 70 km long, had been surveyed in a previous study (Glancey et al. 1976). Bait stations were established at ca. 0.75 km intervals. Two baits (Bryan Vienna sausage and honey) were used at each of the 290 stations. Baits were placed in separate snap-top containers and set ca. 1.0 m apart. Each container was marked with a survey flag and left undisturbed for ca. 1 hour. Baiting was carried out beginning at 08:30 and continued until 14:00 in the fall survey and between 10:30 and 14:00 in the spring survey. After retrieval, bait containers were placed in a cooler and returned to the Imported Fire Ant Station at Gulfport MS for separation and identification of the specimens. Data were compared with that reported in Glancey et al. 1976.

RESULTS AND DISCUSSION

In the survey conducted in September 1995, 24347 ants were collected. They were represented by 21 species from 10 genera Solenopsis invicta, Linepithema humilis, Pheidole fallax obscurithorax, Pheidole moerens and Brachymyrmex spp. represented 97.9% of all ants collected. Five species were reported in the 1995 survey that were not cited in the 1976 report (Odontomachus sp., P. fallax obscurithorax, Pheidole floridana, Pheidole metallescens and Pheidole tysoni). Two species collected by Glancey were not found in the 1995 survey.
(Aphaenogaster nr. texana and Crematogaster clara). In the survey carried out in April 1996, eleven species in eleven genera were collected from the same sites surveyed in September 1995. Among these Crematogaster clara, Leptothorax pergandei, and Stenemmasp. were new species. Since the initial survey conducted in 1974, numbers of the red imported fire ant (RIFA) have declined sharply. In 1974, RIFA represented 84.3% of all the ants collected and was recovered from 37.6% of the sites baited. In 1995, numbers of RIFA collected fell to 47% of the total and were taken from only 25.9% of the sites. During this same period, the Argentine Ant (AA) had increased in numbers from 13.1% of the total in 1974 to 41.5% in 1995. In the 1974 survey, AA was collected from only 8.5% of the sampling sites; in 1995, these sites had increased to 27.9%. In the 1996 survey, RIFA represented 50.1% of all the ants collected and was taken from 38.5% of the sampling sites. The Argentine ant was collected at 18.9% of the sites and accounted for 44.8% of all ants collected. Along with subdominant species (Monomorium minimum and Brachymyrmexsp.), RIFA and Argentine ants represented 98.8% of all ants in the 1996 survey. Another introduced species, Pheidole fallax obscurithorax, (PFO) represented 3.4% of the total ants collected and was taken at 17.2% of the sites in 1995 but dropped to less than one percent of the total ants in 1996 and was taken from only 5.4% of the collection points. PFO had not been collected by Glancey in his survey; but had been known from Baldwin Co. AL.

One possible explanation for the decline in RIFA numbers and distribution may be the rapid urbanization of Mobile Co.; yet, the decline was consistent throughout the rural, suburban and urban areas surveyed. The two dominant and the senior subdominant species (RIFA, AA and PFO) are all introduced and the fluctuations in numbers of ants and sites where collected may be the results of competition among "weeds". Is this fluctuation occurring throughout the monogyne range of RIFA? It will require similar surveys over similar periods of time to answer that question. If RIFA populations are inherently unstable, or are subject to pressure by other competitive species, then perhaps RIFA isn't the ecological juggernaut it is feared to be.
Using GIS to Examine Historical Territory Expansion of the
Red Imported Fire Ant

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Summary: Because a Geographic Information System (GIS) is a powerful spatial analysis tool with exceptional capabilities to analyze complex data sets, we conducted a preliminary assessment of the potential for using GIS to model red imported fire ant (RIFA), *Solenopsis invicta Buren*, range expansion. The model presented here was generated from county infestation records provided by the USDA, APHIS, PPQ and state regulatory agencies (Figure). Our GIS system and a statistical package analyzed data and generated figures. Data included first year of RIFA infestation by counties within states, and east-west and north-south coordinates (Lambert Projection) for the midpoint of each county. A non-linear, extreme-value function best fit the data. The model is:

\[
Year = a + b \cdot e^{- \left( \frac{x - e}{c} \right)} \cdot e^{- \left( \frac{y - f}{g} \right)}
\]

where,
\[a = 1993.9; \quad b = 44.8; \quad c = 1,089,115.6 \text{ m}; \quad d = 760,387.3 \text{ m};\]
\[e = \log_{10}(2.71828182); \quad f = -1,620,874 \text{ m}; \quad g = 341,138.2 \text{ m}; \quad \text{and}\]
\[y = \text{north-south position (meters, Lambert Projection)}\]

From first records in Mobile Alabama, the model shows rapid RIFA range expansion east, west and southward (Figure). Northern expansion has occurred slower than estimated by the model and southwestern expansion has occurred faster than estimated. A plot of infestation by county showed that range expansion was most prominent in the late 1950s and almost nonexistent in the late 1970s and early 1980s.

This research was funded via special Congressional appropriations through the USDA/APHIS/PPQ. The results do not necessarily express APHIS' views.
County Fire Ant Data (1934 - 1994)
Modeled Fire Ant Expansion
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