2008

Areawide Suppression of Fire Ants

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Introduction

Significance of the pest management problem

The imported fire ants, *Solenopsis invicta* and *S. richteri*, were inadvertently introduced into the USA in the early 1900s and currently inhabit over 129 million ha in Puerto Rico and 12 southern states, from Texas to Virginia (Callcott and Collins, 1996; USDA-APHIS map). Imported fire ants have also become established in isolated sites in California, Arizona, New Mexico and Maryland. Strict quarantine procedures have limited the spread of this pest (Lockley and Collins, 1990), but eventually populations will expand westward in increasing numbers in New Mexico, Arizona and California. They will also move upward along the Pacific coast, southward into Mexico and the Caribbean and northward in Oklahoma, Arkansas and Tennessee and along the eastern seaboard into Maryland and possibly Delaware (Korzukhin *et al.*, 2001).

Mature monogyne (single queen) fire ant colonies contain 100,000 to 250,000 workers (Tschinkel, 1988, 1993) and reach infestation rates of over 130 mounds/ha. In the last few decades, polygyne fire ant colonies (multi-queen colonies) appear to be proliferating in the southern states. With polygyne populations, the number of mounds may reach over 500/ha (Porter *et al.*, 1991; Porter, 1992), resulting in interconnected super-colonies because of the lack of territoriality among polygyne colonies (Morel *et al.*, 1990; Vinson, 1997). Control is difficult because more queens must be killed.

Imported fire ants destroy many ground-inhabiting arthropods and other small animals (Vinson and Greenberg, 1986; Porter and Savignano, 1990; Jusino-Atresino and Phillips, 1994; Wojcik, 1994; Forys *et al.*, 1997; Allen *et al.*, 1998; Williams *et al.*, 2003). Because fire ants are highly aggressive when their nests are disturbed, this often results in painful stings to humans and their pets. Between 30 and 60% of the people in the infested areas are stung each year, with hypersensitivity occurring in 1% or more of those people (deShazo *et al.*, 1990, 1999; deShazo and Williams, 1995), suggesting that over 200,000 persons per year may require medical treatment.

 Areawide Pest Management: Theory and Implementation (eds O. Koul, G. Cuperus and N. Elliott)

Imported fire ants adversely affect yields of several important agricultural crops (Adams, 1986; Lofgren, 1986). Reductions in soybean yields are associated with the ant feeding on germinating seeds and roots of surviving plants, thus lowering plant density and causing estimated annual crop losses of over US$100 million (Adams, 1986; Thompson and Jones, 1996; Shatters and Vander Meer, 2000). Other affected crops include maize, potatoes, aubergine and okra. Studies have demonstrated that imported fire ants can seriously damage young citrus trees (Adams, 1986) by feeding on bark, flowers, newly set fruit and other plant tissue. Tree replacement in established groves (average of five replants/ha) costs US$145.57/ha/year (Adams, 1986; Lofgren, 1986). Imported fire ants will also kill chicks and injure young livestock. In a survey of Texas cattle producers, an estimated US$67 million per year in losses was due to fire ants (Barr and Drees, 1996). Total economic losses (cost of control and damage) in the USA are estimated at nearly US$6 billion per year (Pereira *et al.*, 2002).

Description of current management systems and approaches

Several mound drenches have been developed for fire ant control, but are impractical on a scale other than for residential use. The most effective and environmentally responsible method of control is the use of toxic baits because the fire ant has a very effective foraging and resource distribution system that gets the bait/active ingredient to the target. Fire ant bait is typically composed of a vegetable oil phagostimulant that also acts as a solvent for an oil soluble toxicant. This solution is then absorbed on to a defatted maize grit granule that will absorb 20–30% oil and still maintain flowability. The bait is spread on the ground and the foraging ants find it and bring it back to nest mates. The toxicant must exhibit delayed toxicity to give the foraging workers time to distribute the oil/toxicant to all colony members.

Limitations of current management approaches

Although there are several commercial toxic baits available for imported fire ants, these baits are expensive and many are not registered for large acreage. Most fire ant active ingredients have adverse effects on the environment. Toxic bait development and EPA registration efforts by the chemical industry have primarily focused on the lucrative urban market, and thus few companies have pursued registration of baits for use in agricultural settings. Even when available, toxic baits are expensive and require continuous reapplication because of the rapid reinfestation of treated areas. The non-specific nature of the active ingredients adversely impacts non-target native ant species, as well as the environment. Altogether, chemical treatment strategies alone are not a viable option for large tracts of land such as rangeland and pastures. In addition, with increasing emphasis on quarantine expressed by APHIS, and with mandates from the Department of Defense, the Environmental Protection Agency and the public to reduce risks associated with pesticides, there is a need for a different fire ant strategy.

Anticipated benefits of AWPM

Recent USDA research has led to the availability of self-sustaining biological control agents and, along with effective toxic baits, has provided tools for development of an integrated pest management (IPM) system for suppression of fire ant populations. The advent of these fire ant control tools has led to an ARS headquarters-funded Areawide Pest Management Project (AWPM), the goal of which was to maintain low fire ant populations with reduced need for bait toxicants by using available self-sustaining fire ant biological control agents in conjunction with bait toxicants.

Anticipated benefits are manifold:

- Spread of self-sustaining biological control agents will help restore the ecological balance between the imported fire ant and native fauna.
- Areawide management technology, especially biological control agents, will be transferred to state and federal agencies, as well as to state and private land managers.
- Sustained fire ant population reduction will be achieved.
- Farm workers will be able to work in a safer environment.
- Fire ant economics will be better understood.
- Developed methodology will be transferred to a variety of end-users via web site development and other educational media.
- Pesticide risk will be reduced.

Description of the AWPM Programme and Approaches

AWPM management technologies and approaches

The Imported Fire Ant and Household Insects Research Unit (IFAHIRU) and cooperators have created the single most successful control programme for fire ants to date. Development, assembly and refinement of a complex array of control techniques have resulted in the first AWPM programme for fire ants. The IFAHIRU developed the fire ant bait toxicant concept that has been most effective and environmentally friendly, while simultaneously discovering, importing and releasing fire ant-specific, self-sustaining biological control agents such as microsporidian pathogens and phorid fly (*Pseudacteon*) parasites.

Although the flies cause direct fire ant mortality, they also reduce foraging and mating flight activities, resulting in weakened fire ant colonies and reduced reproductive potential. The microsporidian pathogen stresses infected colonies, resulting in reduced colony lifespan and rendering colony members more susceptible to bait toxicants. Establishment of some of these self-sustaining biocontrol agents was critical to development of an integrated management plan for control of fire ants using an IPM approach (combination of bait toxicants and biological control agents).

Compatibility of the fire ant AWPM programme with other pest management or land improvement practices

Fire ant baits are generally considered also to have an effect on non-target ant species but not the general arthropod diversity; therefore, baits are mainly neutral in terms

of other pest or land improvement practices. It is possible that baits could be admixed with certain types of fertilizer and co-distributed. This process would decrease the overall cost for the use of baits for fire ant control. The self-sustaining biological control agents have been demonstrated to be very specific to the fire ant genus and often species specific; therefore, they are not expected to have negative or positive effects on non-fire ant pest control or on land improvement practices. In contrast, non-fire ant pest treatments may have a negative effect on fire ant populations. Also, land improvement practices may negatively affect fire ant populations, e.g. liquid ammonia fertilizer and controlled burning.

Development and implementation of the AWPM programme

Cooperators

ARS has expertise in parasite and pathogen biological control, as well as molecular biology and chemical ecology. ARS scientific expertise was supplemented with:

- An agricultural economist from Texas A&M University.
- APHIS involvement in large-scale phorid fly rearing and in assisting and advising on the use of aerial bait treatments.
- The education component was directed by a University of Florida extension specialist who developed a web site, educational brochures, videos and other presentation materials. These information tools were used to educate stakeholders, e.g. extension specialists, high-value property owners, local government and the public, about the AWPM programme.
- Each of the AWPM project's cooperators were charged with the task of developing the within-state infrastructure needed to carry out the complex assessments required for execution of the programme and evaluation of programme success.
- Environmental impact was assessed using ARS and state cooperator expertise.
- ARS directed a portion of their research effort toward specific problems associated with the AWPM project.

All of the above contributed to the successful demonstration of the first continuous AWPM programme for fire ants in five US states, representing diverse ecological conditions and over a multiple-year period.

Development and implementation of education and technology transfer programmes

Education programme

The educational component provided extensive positive outreach to our partners and customers, as exemplified by the following:

- A programme web site was created, and updated continuously with new information.
- Videos describing the fire ant microsporidian disease and phorid flies were produced and distributed via the web site and on CD (over 1000 were distributed; included in ARS Congressional Budget hearings package).

- Programme brochures were produced and distributed by direct mailing, insertion in trade magazines and to the public at state agricultural fairs and public presentations (40,000 to 50,000 distributed).

Public interest has been enormous – 42,288 distinct visits to the web site in 2005 and 58,387 in 2006. Part of a video describing the parasitic phorid fly was the subject of an article by a nationally syndicated columnist. This article caused such a huge number of requests to the web site that the server crashed. The areawide web site will continue to be maintained and updated with progress in the newly established 'high value' demonstration sites.

Technology transfer

Phorid fly parasite rearing is complex, labour intensive and not likely to be taken on by private industry. Thus, APHIS provided funding to transfer the ARS-developed phorid fly rearing technology to the Florida Division of Plant Industry (DPI), in Gainesville, Florida. Similar technology was also transferred to the University of Texas, Austin; Louisiana State University, Baton Rouge; and the ARS, Biological Control of Pests Research Unit, Stoneville, Mississippi. The technology transferred included mass rearing of phorid flies, methods of releasing and establishing phorid fly parasites and numerous requests to release flies in the USA. Development of methods to mass rear the phorid fly parasites was essential to the success of the AWPM programme. An unintended consequence of the rearing technology was participation of numerous additional cooperating institutions in phorid fly releases.

The ARS developed novel methods for infecting fire ant colonies with the microsporidian pathogen, *Thelohania solenopsae*. These methods were crucial in facilitating the spread of the disease in fire ant populations in the AWPM programme. In addition, the AWPM project also promoted inoculation and spread of a microsporidian pathogen by university and state department of agriculture cooperators in five other fire ant-infested states. Currently, the technology is being used among high-value properties (e.g. parks, golf courses, hunting clubs, natural areas, military facilities) where fire ant control is highly desirable. These sites are being used to demonstrate that biological control, in combination with toxic bait applications, can be used in many different situations to provide safe, effective, economical fire ant control. Other researchers have adopted these methods for infecting colonies throughout the range of introduced fire ants.

ARS scientists developed a simple and reliable method for estimating fire ant population densities by utilizing a food lure and establishing an action threshold for treatment. Cooperators adopted this method after ARS demonstrated strong correlations between the new method and the previously used mound count and population index methods. The food lure method reduces the time needed to estimate populations by at least 50%, requires no specialized training and is easily transferable, thus simplifying the implementation of fire ant integrated pest management (IPM).

The research component of the project responded to the need for a rapid, sensitive method for detecting the presence of the microsporidian pathogen with an easy-to-use PCR method that was transferred to our project partners, as well as to fire

ant researchers worldwide. Additional fire ant biological control agents from South America are currently in our quarantine facility, undergoing the extensive testing required for obtaining permission for their release in the USA.

Evaluation of the AWPM Programme

Effectiveness of the AWPM programme at controlling fire ant populations

The AWPM programme has had significant impact. Fire ant population levels have been suppressed below target thresholds in all demonstration sites in pastures. For the first time, fire ant control has been maintained at more than 80% over a total area of about 8896 ha for 4–5 years. These properties are now serving as examples for neighbouring property owners, and have provided for a continuing expansion of interest in fire ant IPM in different regions of the USA. Further examples of impact are listed as follows:

- In Florida, fire ant reduction has averaged 88% where the IPM approach was used, as compared with only 71% where fire ants were controlled only by chemical pesticides. In Texas, plots with high phorid fly populations were correlated with lower fire ant populations.
- Sustainable biological control agents were successfully released into all five states where the AWPM programme was implemented, and in dozens of other locations throughout the infested area in cooperation with APHIS and cooperators in each state (see Table 14.1).
- *Pseudacteon tricuspsis*, the first species of phorid fly released, is currently well established in eight states: Florida, Alabama, Georgia, Mississippi, Louisiana, South Carolina, Texas and Arkansas (see Table 14.1).
- Two biotypes of *P. curvatus* have been established in the USA. The first biotype is established on black imported fire ants in Mississippi, Alabama and Tennessee; a

Table 14.1. Total area currently occupied by phorid flies, and the human population impacted. Five hundred thousand phorid decapitating flies (*Pseudacteon tricuspis* and *P. curvatus*) were released at the 83 sites in 12 states.

State	Release sites		Total area impacted (km^2)	Human population in impacted area
	P. tricuspis	*P. curvatus*		
Areawide states:				
Florida	6	10	92,324	13,420,532
Mississippi	2	2	33,249	1,085,755
Oklahoma	6	3	4,023	48,198
South Carolina	5	1	1,959	334,609
Texas	19	2	8,819	953,408
Other states (7)	21	7	120,968	4,211,527
Total	59	25	261,342	20,054,000

second biotype is established in Florida, South Carolina, Texas and Oklahoma on red imported fire ants (see Table 14.1).

- The total area impacted by phorid fly parasites is > 260,000 km^2, an area comprising around 20 million people. We anticipate that, over the next 4–5 years, the flies will expand their range to over 1,200,000 km^2.
- *Thelohania solenopsae*, a microsporidian pathogen that debilitates fire ant queens and eventually kills the colony, is established and spreading in Florida, Texas, South Carolina and Oklahoma – e.g. 60% increase in Florida's IPM site and natural spread from 0–12% infected colonies in the bait toxicant-only site.
- The AWPM project has helped promote inoculations of *T. solenopsae* by university and state department of agriculture cooperators in ten infested states. During the AWPM project it has been documented that the pathogen has become widespread in multiple-queen fire ant populations, where it may be prevalent in well over 155,000 km^2, with infection rates averaging about 51%.
- Phorid flies and the *T. solenopsae* parasite have reduced fire ant populations by at least 1 and 33%, respectively. These reductions have translated into tens of millions of dollars saved for those in impacted areas.
- Farm worker safety has been significantly improved due to reduced exposure to fire ants.
- There have been fewer mechanical and electrical equipment repairs due to fewer fire ants and fewer mounds.

Unintended positive consequences of the AWPM programme

Efforts of the Areawide Suppression of Imported Fire Ants programme have led to several unintended positive results. *Pseudacteon tricuspsis*, the first species of phorid fly released, is currently well established in Alabama, Georgia and Louisiana, in addition to five participating areawide states (see Table 14.1). One biotype of *P. curvatus* has been established on black imported fire ants in Tennessee and Alabama, as well as in Mississippi. A second biotype, *P. curvatus*, is established in Florida, South Carolina, Texas and Oklahoma on red imported fire ants (see Table 14.1). As multiple species of phorid flies spread beyond the confines of areawide field sites, they provide an added benefit for people living within these areas. The presence and expansion of phorid flies also helps the native and endangered species that have been adversely affected by fire ant aggression and environmental domination.

Economic evaluation of costs and benefits of the AWPM programme

Economic surveys were prepared by an agricultural economic team from the Texas A&M University and sent to the farmers involved in the demonstration sites, as well as to the researchers in each state. These surveys assessed the impact of the fire ant pests on farm activities, as well as assessing the costs and benefits of the AWPM programme. These surveys are being analysed, and the data obtained so far have been used to estimate the economic impact of fire ants on both US agriculture and

individual states. Texas and Florida represent approximately 50% of the estimated impact of fire ants in the USA, with the remaining 50% divided among all other infested states, including California. Although California initiated an eradication programme against fire ants, the estimated impact for California assumes that the infestation survives.

Prospects for the long-term sustainability of the AWPM programme

This AWPM project has enabled USDA and its cooperators to implement IPM of fire ants over large areas, over a sustained length of time and in diverse areas of the USA. A significant part of fire ant IPM has been the dissemination of self-sustaining parasites and pathogens in the infested areas. For the most part these biocontrol agents have become established and spread as anticipated or at an even greater rate and population density. In South America fire ant populations are five to ten times lower than in the USA, without the use of pesticides.

If the introduction of natural enemies of the fire ant reduces their population to one-half of what it is in South America, then reductions in the USA would be in the order of 40–45%, significantly reducing pesticide use for fire ant control and diminishing both the human impact of fire ants and their negative effects on agriculture and the environment. Results with biocontrol agents are not dramatic, but they are very encouraging for the long-term future (10–20 years), as additional biocontrol agents are released.

Ongoing and new research initiatives in biological control, bait improvement, biologically based control and new methods of fire ant detection and/or population assessment will continue to be highlighted on the areawide web site. In addition, we will maintain close contact with our demonstration site partners to provide consultation, and transfer new technology as it develops.

Summary and Future Directions

The areawide Suppression of Imported Fire Ants Project has entered the last 2 years of its expected duration. A new protocol has been developed to expand the project from the initial demonstration sites to other, smaller, sites in areas under different land use. Current sites were all established on improved, grazed pastures under cattle production. New demonstration sites were established on 'high value' properties where fire ant control is highly desirable and represents a high economic, environmental and/or aesthetic value (e.g. parks, poultry farms, hunting clubs, natural areas, military facilities, urban horticulture, etc.).

The objective is to expand the AWPM concept to other customers besides cattle farmers and to demonstrate that the concept of using biological controls in combination with toxic bait applications can be used in many different situations. This will apply what has been learned from the large-scale AWPM programme on pastures to properties and owners that have a high probability of continuing the fire ant IPM programme after project funding expires. It is expected that these properties will serve as examples for neighbouring property owners, and thus create a knowledge

base on fire ant management and biological control that will provide for continuing expansion of interest in fire ant IPM in different regions in the USA.

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