Exotic Ants

Biology, Impact, and Control of Introduced Species

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Introduction

It has been estimated that throughout the world there are over 20,000 species of ants in over 300 genera. Less than half of the ants have been described, because they are innocuous and, except for scientists, few people care (Lattke 1990). These ants are usually grouped according to genera that desperately need taxonomic revisions. The taxonomy of ants is even worse when it comes to describing potential biological control organisms. Often the biocontrol organism is identified to genus or species, but the affected ants are often identified only to genus or common names, such as harvester ant, black ant, etc. (Sweetman 1958). Almost no one is interested in what ails an ant in nature. Scientists who study ants, the true myrmecologists, are mainly interested in the social aspects of ant behavior: how ants function in the colony, how they interact with other ants and arthropods in the environment, and their taxonomy, morphology, and physiology. This is illustrated by the fact that the recent comprehensive book *The Ants* (Hölldobler and Wilson 1990) has less than one page of text on ant pathology in 732 pages on ant taxonomy, behavior, physiology, ecology, etc. Only a few economic entomologists, besides the general public, seem to be interested in developing safe and efficient means to suppress pest ant populations and then usually with pesticides (Lofgren 1990). There is a general perception that ants are not normally serious economic pests. They may become a troublesome nuisance if man significantly interferes with their normal habitat or accidentally transports them to new environments. For example, certain species of leaf-cutting ants are not a serious pest in their natural environment in the tropical forests, but can become a serious threat to large monocultures of cultivated crops when the natural restraints, mainly competitors and predators, are removed (Cherrett 1968 1986; Pollard 1982). The red imported fire ant, *Solenopsis invicta*, is an excellent example of a species that was accidentally introduced into an environment free of any biological restraints, and within a decade they had become a major economic pest (Wilson 1986). Actually, many of the major pest ants in North America were accidentally introduced (see Table 25.1) (Bennett et al. 1988, Smith and Whitman 1992).

The reason these few dozen species of exotic and native ants become pests while their fellow members in the same family and genus remain innocuous is simple. These species become pests when they are somehow released from their natural restraints and interfere with man's well

TABLE 25. 1. Common pest ants found in North America.

Common Name	*Scientific Name*	*Origin*
Acrobat Ant	*Crematogaster* spp.	Native
Allegheny Mound Ant	*Formica exsectoides*	Native
Argentine Ant	*Linepithema humile*	Introduced
Big-Headed Ants	*Pheidole* spp.	Native and Introduced
Black Imported Fire Ant	*Solenopsis richteri*	Introduced
Carpenter Ants	*Camponotus* spp.	Native and Introduced
Cornfield Ant	*Lasius alienus*	Native
Crazy Ant	*Paratrechina longicornis*	Introduced
Ghost Ant[1]	*Tapinoma melanocephalum*	Introduced
Harvester Ant	*Pogonomyrmex* spp.	Native
Large Yellow Ant	*Acanthomyops interjectus*	Native
Little Black Ant	*Monomorium minimum*	Native
Little Fire Ant	*Wasmannia auropunctata*	Introduced
Odorous House Ant	*Tapinoma sessile*	Native
Pavement Ant	*Tetramorium caespitum*	Introduced
Pharaoh Ant	*Monomorium pharaonis*	Introduced
Pyramid Ant	*Dorymyrmex* spp.	Native
Red Imported Fire Ant	*Solenopsis invicta*	Introduced
Small Honey Ant (winter ant)	*Prenolepis imparis*	Native
Thief Ant	*Solenopsis molesta*	Native
Velvety Tree Ant	*Liometopum* spp.	Native
Leaf-cutting Ants	*Atta* spp.	Native
Tropical Fire Ant	*Solenopsis geminata*	Introduced

[1]Not ESA approved common name

being. As stated earlier, leaf-cutting ants only become a problem when they destroy some valuable crop or trees of commercial value. In their native habitat as they go about collecting their leaves for their fungus gardens, their numbers are held in check by varicus predators, competitors and environmental conditions not found in artificial cropping systems, (Cherrett 1986). Several exotic ants that have been introduced on the Galapagos Islands affect the fragile ecosystem. Two ants which are creating a serious problem are the little fire ant, *Wasmannia auropunctata,* and the tropical fire ant, *Solenopsis geminata*. They have outcompeted the native ant fauna and reduced many indigenous arthropod populations on the various islands (Lubin 1984). These species also attack the young of some reptiles, such as the Galapagos tortoises and land iguanas, as well as stinging tourists and natives alike (Williams and Wilson 1987, Williams and Whelan 1991).

A similar situation has occurred with the red imported fire ant, *Solenopsis invicta,* and the black imported fire ant, *S. richteri,* in the United States. In undisturbed areas in their native homeland of South America, they are not a serious pest, but in the southeastern U.S., they are considered to be a major pest and millions of dollars are spent annually to control them (Lofgren 1986). In Florida, the red imported fire ant is the major ant pest that invades homes, hospitals and restaurants and is very difficult to control according to a survey of Pest Control Operators (Bieman and Wojcik 1990). Although the black imported fire ant, *S. richteri,* was first introduced into Mobile, Alabama in the 1920s, ironically its rapid spread may have been initially hampered by another South American ant accidentally introduced into the U.S.A., the Argentine ant, *Linepithema humile*. The black imported fire ant was, however, able to outcompete the Argentine ant and most of our native ants, and to establish itself in several thousand acres within two decades after introduction (Lofgren et al. 1975). Attempts to control this species with various pesticides met with limited success. Then in the late 1930s a more virulent form or species of fire ant, the red imported fire ant, later named *S. invicta,* was imported into Mobile, Alabama. Within twenty years it was the dominant ant in the region (Lofgren 1986). According to Porter et al. (1992), it now represents 97% of the ants collected along roadsides in the region, whereas in Brazil, fire ants represent only 23% of the ants collected and *S. invicta* is not necessarily the dominant fire ant species collected. There are numerous *Solenopsis* species in South America (Trager 1991). Wojcik, (see chapter 23) in a twenty year study in central Florida, showed that *S. invicta* had replaced the tropical fire ant, *S. geminata* and *Pheidole dentata* as the dominant ants found along roadsides in open areas. The impressive and rapid spread of *S. invicta* in the U.S.A. has been aided by such factors as favorable climate, the ant's biology, ecology, and the lack of competitors. Climatic conditions in the southeastern United States are ideal for the two species of fire ants introduced from Brazil and Argentina. *Solenopsis invicta* has a tremendous reproductive potential, more than any of our native ants. Individual or monogyne colonies may have up to several hundred thousand workers whereas polygyne colonies have as many as a million or more workers (Williams 1990). Just obtaining enough food to sustain these large colonies requires a tremendous amount of energy and aggressiveness. Fire ants, because of their need to support large colonies, are omnivorous feeders and very competitive with our native ants. Probably one of the biggest factors influencing the rapid spread of fire ants in the southeastern U.S.A. is the vast changes in the ecology of the region. Following World War II, there was a rapid population movement in the U.S. from the industrial areas of the North to the warm region of the South and West, "the Sunbelt". Forests and farms were eliminated to make room for new homes, recreational areas and industries. Since fire ants are a "weed species" (Tschinkel 1986) that thrives in recently opened disturbed areas, this newly disturbed environment was an ideal situation. In South America there are numerous closely related species of fire ants which may be equally or more competitive than the red imported fire ant (Trager 1991), plus in the tropics many other species of ants of different genera and families compete for the same space and food as the red imported fire ant. Thus, the general conception that the red imported fire ant is not a problem in its home land is true to some degree. However, in some areas of Brazil and Argentina, where climate, agricultural practices and land use are similar to the U.S.A., the red and/or black fire ant populations can be as high as in the U.S.A., often exceeding 200 colonies per acre (Banks et al. 1985). In one area of Argentina, covering several thousand hectares where *S. richteri* is the dominant species, the number of colonies per hectare exceeds 200; yet the farmers there do not consider fire ants a serious pest. Still, the overall population density of fire ants in South America is much less than in the U.S.A. (Porter et al. 1990). The reason for this is more complicated than just a single pathogen, parasite or predator limiting the ants distribution.

If one looks at ants in general, but especially the pest ants, they would seem superficially to be an ideal candidate for control and elimination by biological control agents (Jouvenaz 1986). They are very concentrated, feed one another, usually live in a colony which has a fairly high humidity, the immature stages are immobile in a concentrated mass, and only the queens are able to reproduce. However, over the years, ants seem to have developed techniques, probably through genetic selection, to prevent the invasion of any pathogen, parasite, or predator into their colony that would lead to its elimination. Ants in general are excellent housekeepers and personal groomers. They quickly recognize any invader through chemical cues and attack it in an attempt to kill it and/or remove it from the colony. Some arthropods and other organisms, such as myrmecophiles, have adapted and assumed the chemical cues of a particular fire ant colony and are thus able to survive quite well (Wojcik 1990). The effect of these myrmecophiles on colony survival is not well known, but it is assumed that they have some negative effect (Jouvenaz 1990). Glancey et al. (1981) reported that fire ants do filter out particles as small as 0.88 um, thus eliminating most bacterial and fungal spores before they can infect the ants. Ants are also capable of secreting from their venom and metapleural glands and other exocrine organs a number of chemicals which have antibiotic and anti-fungal properties. These secretions are spread from one ant to another and throughout the colony through grooming (Hölldobler and Wilson 1990, Obin and Vander Meer 1985, Jouvenaz et al. 1972). Since most soils harbor many organisms that are pathogenic to arthropods including ants, these secretions aid in the survival of the colony.

Few pathogens and parasites have been described in the literature for other species of ants other than fire ants and leaf-cutting ants (Kermarrec et al. 1986, Laumond et al. 1979). During the past several decades numerous surveys have been made in South America and throughout the southern United States for potential biological control organisms of fire ants (Jouvenaz et al. 1977, 1986). A limited number of organisms have been identified (Table 25.2) and many of these, such as the fungi of the genera *Beauveria* and *Metarhizium* (Stimac et. al 1989) are nonspecific for fire ants.

TABLE 25.2. Potential biological control organisms for red imported fire ant, *S. invicta*[1].

Organism	*Pathogen*	*Type*
Pseudomonas aeruginosa	Bacteria	non-specific
Serratia marcescens	Bacteria	non-specific
Bacillus thuringiensis	Bacteria	non-specific
Bacillus spheracus	Bacteria	non-specific
**Beauveria bassiana*	Fungus	non-specific
Metarhizium anisopliae	Fungus	non-specific
Aspergillus flavus	Fungus	non-specific
**Thelohania solenopsae*	Protozoa	specific
**Vairimorpha invicta*	Protozoa	specific
Mattesia geminata	Protozoa	specific
Burenella dimorpha	Protozoa	specific

(continues)

TABLE 25.2 *(continued)*

Organism	*Parasites*	*Type*
**Steinernema carpocapsae*	Nematode	non-specific
Heterorhabtidis heliothidis	Nematode	non-specific
**Tetradonema solenopsis*	Nematode	specific
Pyemotes tritici	Mite	non-specific
**Pseudacteon* spp.	Diptera (Phorid fly)	specific
**Apodicrania* spp.	Diptera (Phorid fly)	specific
Orasema spp.	Hymenoptera (wasp)	specific
**Solenopsis daguerrei*	Hymenoptera (ant)	specific

[1]Pathogens and parasites which have been investigated as potential fire ant biological control agents.
*Currently being investigated

The literature on pathogens and parasites of fire ants consists mainly of descriptions and how the organisms affects the individual ant. Limited research has been published on the impact of these organisms on the entire colony. Jouvenaz et al. 1981 did an excellent study of the pathogen, *Burenella dimorpha,* which affects only the tropical fire ant, *S. geminata.* Although usually less than 5% of colonies are infected, at times all the colonies at a single location will be infected (Jouvenaz 1986). Unfortunately, now that *S. geminata* populations have declined in central Florida, this disease is very scarce (Jouvenaz personal communications). The potential of this disease as a biological control agent was never tested in the field.

In an attempt to rectify this deficiency, a limited number of studies with biological organisms have been conducted on field populations of fire ants. Reported here are two studies which have been conducted on wild fire ant populations. The objective of the first study was to determine the impact of a nonspecific pathogen, *Beauveria bassiana,* on fire ant populations infesting potting soil used for nursery plants. The objective of the second study was to determine the impact of a naturally occurring pathogen, *Thelohania solenopsae,* on an indigenous population of fire ants in South America, and to determine its potential as a biological control organism for possible importation into the United States to suppress *S. invicta.*

Beauveria bassiana

Beauveria bassiana is a nonspecific pathogen that is capable of attacking many arthropods. Its potential as a biological control organism has been explored by numerous scientists for various insect pests over the years (Ferron 1978, 1981). Recently there has been renewed interest in this organism for fire ant control. Stimac et al. (1989, 1990) reported high colony mortality (80%) when a strain of this fungus from Brazil was applied to individual fire ant mounds. They also found that it was present in the soil 150 days after treatment. They treated the soils with 200g of a 5% fungal formulation of conidia on rice. Fire ant colony movement (forming of satellite colonies) increased following treatment with the fungal formulation. Because of these and other promising reports (Broome et al. 1976), a series of studies were designed to determine if *B. bassiana* could be used prior to shipment to prevent fire ant infestations in the potting soil used for nursery plants. The strain of *B. bassiana* used in these studies originated from leaf-cutting ants collected in Mexico. A number of concentrations of a dry mycelial formulation mixed with the soil and tested in the laboratory showed that a 0.5% formulation gave the best results. A large field study was set up using treated (0.5% dry mycelium/soil mixtures) and untreated soil in pots with and without plants. The test was run outside under ambient conditions. The pots were infested with polygyne colonies of fire ants that consisted of a set of 5 queens, 1 gram of brood and 3-4 thousand workers. To check if the fungus had any repellent effect, all pots were checked for colony movement. At set intervals for 30 days, the ant colonies in the soil from the pots were examined for any mortality. There was no significant mortality of the ant colonies from the fungus, but there was repellency. A second large study was run using various types of media (potting soil, sand, vermiculite, and various mixtures of these, both sterilized and unsterilized). The set up was basically the same as before, except no plants were used and the pots containing the soil were held at a constant temperature (80°F) and high humidity (80-90% R.H.). A check was made of the mortality of queens, brood and workers exposed to the fungi in the various media. High mortality of the queens, brood and workers occurred in the vermiculite medium (Table 25.3).

A mixture of vermiculite and sterile potting soil produced less mortality of the queens, brood and workers. Potting soil alone produced

TABLE 25.3. Effects of 0.5% *B. bassiana* on red imported fire ants in different substrates after 7 days.

		% Mortality	
Media	*Queens*	*Brood*	*Workers*
Control	9	0	0
Potting Soil	17	0	0
Sterile Potting Soil	25	95	0
Vermiculite	75	100	85
Sterile Potting Soil/ vermiculite 50/50	59	95	50

no effect on brood or workers and queen mortality was insignificant. Therefore, there must be something in the unsterilized soil that inhibits the *B. bassiana*, because almost all the brood was infected with fungus in the sterile potting soil. A series of tests to determine the cause of this lack of effectiveness of the fungus in nonsterilized soil to fire ants, were run. The results were inconclusive except to show that if the potting soil was sterilized, the fungus was effective. Also if a medium was used with a very low organic matter content, such as sand mixtures, the efficiency of the fungus also increased. A small field study in which individual mounds were treated with the fungus, showed that complete colony mortality did not occur, but treated colonies often moved.

To summarize, we found that *B. bassiana* will kill fire ants as reported previously (Stimac et al. 1990). The brood is very susceptible to the fungus, queens are less so and the workers are more resistant, probably because they are more adept at grooming themselves and one another of spores. The fungus does have a repellent effect, but it is not an extremely strong one. Although it can kill ants, unless the queen was infected, it is not efficient in eliminating an entire colony. At present, *B. bassiana* is not recommended for use in protecting potting soil which contains nursery stock from fire ant invasion prior to shipment.

Thelohania solenopsae

Although numerous surveys have been made to determine what pathogens and parasites attack fire ants, almost nothing is known of the effect such organisms have on indigenous ant populations (Jouvenaz et al. 1981). Therefore, a long term study was initiated in Argentina in 1988 to follow what happens to fire ant colonies infested with the microsporidian disease, *Thelohania solenopsae*. We worked with the black imported fire ant, *Solenopsis richteri*, however, some plots contained a few colonies of *S. quinquecuspis*.

The objectives of this study were to determine: (1) what effect, if any, this disease had on the total colony, not individual ants; (2) what percentage of the ants and castes had the disease; (3) does the disease cause the colony to move more frequently; (4) how the disease is spread within the colony from ant to ant and from colony to colony in the field; (5) do healthy ants perceive the infected ants in the colony and remove them, thus eliminating the disease; (6) does this disease require an intermediate host for transmission from ant to ant or colony to colony; (7) is the microsporidian disease, *T. solenopsae*, in *S. richteri* the same as the one described in *S. invicta* from Brazil and, finally, (8) does this disease have any potential as a biological control agent and should it be introduced into the U.S.A.?

Thelohania solenopsae was selected because it was the most common pathogen present in fire ant colonies examined in Argentina. The taxonomic description of *T. solenopsae* and the disease it caused in fire ants in Brazil was given by Knell et al. (1977). Its occurrence in host ant populations had been reported by numerous earlier scientists (Allen and Buren 1974, Allen and Silveira-Guido 1974, Jouvenaz et al. 1980). All attempts to transmit the disease to healthy colonies of fire ants have failed (Jouvenaz 1986). However, recent studies with another microsporidian disease, *Amblyosporidae*, in mosquitoes, have shown that an intermediate host is often required before transmission back into the mosquito population is possible, (Andreadis 1985, 1988; Sweeney et al. 1985, 1988; Becnel 1992). There are sound biological reasons to suspect that alternate hosts may be involved in intercolonial transmission of this microsporidian disease in fire ants. Since there are a limited number of arthropods which are symbiotic with fire ants (Wojcik 1990), they were examined for the disease. Observations by Knell et al. (1977) indicated that this disease did not quickly kill the colony. Often very large, apparently healthy colonies with high infection rates of this pathogen were found in the field; however, the ultimate fate of these colonies after a period of time is not known. In fact, we do not really understand fire ant population dynamics in South America very well.

Materials and Methods

Six circular plots, 40 meters in diameter, were set up in unimproved pastures containing cattle and hogs in Saladillo, Buenos Aires Province, Argentina. Each active fire ant colony was plotted on a map by measuring from a central stake using the four compass quadrants. The plots were almost side by side in a series of pastures. The average number of active colonies per hectare was 198 in the six plots. Three of the plots had fairly high disease rates with 35% of the colonies being infected. The other three plots were relatively free of the disease with only 3% of the colonies being infected.

The number of colonies (mounds) in each plot was checked monthly to determine the viability of each colony. Also, if the colony had moved, we needed to know if the diseased ants moved with the colony. Some colony movement was traced with dyes, but mainly it was with observations on new mounds in close proximity to old abandoned colonies or mounds. We also checked for the presence of brood, workers, sexuals, colony health, and presence of disease. Each colony or mound was measured for its height, width and ant activity. A small glass vial was inserted into the mound for less than 10 minutes to collect the ants. Then the vials were removed, capped and returned to the laboratory for microscopic examination for the disease. In the laboratory, the ants were ground with water in a tissue grinder, then a small drop of the ground material was placed on a glass slide, covered by a cover slip and examined by phase-contrast microscopy at 400x for the presence or absence of *Thelohania* spores. Since this sampling was a mixture of many individual ants with both major and minor workers and probably the reserve and forager ants, we could only determine the presence or absence of the disease in the colony; not the percentage or which castes were infected. Jouvenaz (1986) reported that fire ant workers, sexuals, and queens were infected with this disease in Brazil. We later checked individual ants from each caste and the various age classes, as well as any myrmecophiles present in the colony for the disease.

Results and Discussion

The number of active fire ant colonies per hectare in a short grass pasture habitat of the Saladillo area in Argentina was 100 colonies per hectare which was similar to that in the southeastern United States, especially in north central Florida. Adams (1986) reported 60-150 colonies/hectare as being heavy densities of *S. invicta* in Florida and Georgia. There was a 25% reduction in number of active fire ant colonies in the plots from October to March (spring to early fall) in Argentina. This is similar to what is found with *S. invicta* in the Southern U.S.A. (Hays et al. 1982). Of the active colonies, 75% left their original colony site and moved to a new location, usually within a meter of the original site. This also is similar to what has been observed in the U.S. for *S. invicta* and *S. richteri* (Hays et al. 1982).

There was greater loss of colonies with *Thelohania*, than of non-infected colonies (45% versus 25%) during the first year. Once a colony became infected it remained infected whether it moved or not. We observed no colonies losing their infection. However, this is difficult to verify because of colony movement, since we were not always sure of the origin of each new colony. We later examined whole colonies and found that if the queen was infected then all progeny in the colony were infected. In polygyne colonies, it is speculated that the disease might be vertically transmitted transovarially by the infected queen. How it is transmitted horizontally from ant to ant within the colony or to other colonies is a mystery. Probably an intermediate host is involved but we are unsure what it is, although several myrmecophiles have been found infected with the disease. We do know that in the area where 35% of the colonies were initially infected; 80-90% of the colonies were infected four years later and the number of fire ant colonies had decreased to less than 30/hectare. Large fire ant colonies seem to be able to withstand the disease, as noted by Knell et al. (1977) while small colonies appear to die off implying the size of colonies is important. It is probably dependent on when the colony becomes infected and if all the queens are infected. The results of this study with this microsporidian disease to date show that the fire ants move their colonies as frequently in Argentina as they do in the U.S.A. Over 75% of the colonies had moved to a new site within the first six months of this study. Some colonies moved almost monthly, while others remained in the same site for a long time. Since the colonies were numerous and fairly close together, it does not appear that food supplies or mound disturbance caused this movement. There was a total loss in the number of colonies from the study (ca. 25%) during the first year. This occurred whether or not the colonies were infected. When the area was checked two years later, many more diseased colonies were lost. The presence of *T. solenopsae* seems to cause colony mortality, especially of small colonies. However, it may take several years to show a significant decrease. The disease, *T. solenopsae,* as described by Knell et al. (1977) seems to have a wide range of hosts as spores have been observed in many of the other arthropods inhabiting the fire ant mound. Since no intermediate hosts have been identified yet, we do not know how this disease is spread from ant to ant or one colony to another in nature. All the data presently available makes this organism appear very promising as a potential biological control organism. We are continuing our research to determine how this disease can possibly be used in the field to suppress fire ants.

Summary

A number of potential biological control organisms of ants have been identified in the literature. A few of these have been studied in the laboratory. However, except for some limited personal observations and speculations, little has been done in the field to evaluate the impact any have on various ant species or ant densities. We have reported here on laboratory and field studies of two pathogens, *Beauveria bassiana* and *Thelohania solenopsae,* which infect the red imported fire ant, *Solenopsis invicta.* The fungus *Beauveria bassiana,* a strain from Mexico and Texas,

was studied in the laboratory and in the field. This is a non-specific pathogen and will affect many insects. Its effectiveness is dependent on the substrate it is mixed with. Control in sterile soils or soils with very low organic matter treated with a 0.5% *B. bassiana* dry mycelium mixture was good with infection of the brood, queens and workers. However, its performance was poor in highly organic or non-sterile soils. The brood and then the queens were most susceptible to the fungus. The workers were the most tolerant of the fungus. *Thelohania solenopsae* was a fairly host specific microsporidian disease. *T. solenopsae* studied in field infected colonies for almost four years showed that it had a great effect on the colony structure and its survival. It has great potential for importation into the U.S.A. as a biological control agent.

Although a number of potential biological control organisms which affect fire ants have been identified in South America, we do not know how each affects the entire colony of the ants. We do know that ants seem to be able to survive most infestations unless the colony is placed under stress. Under stress, the disease seems to quickly take over the colony and the colony collapses. We will continue to work out the life history of a number of pathogens and parasites of fire ants and determine what impact each has on the entire colony. A complex of these, if properly released, should have an adverse effect on the imported fire ant population in the United States.

Resumen

Con el fin de reducir poblaciones de las hormigas de fuego, fueron evaluados en el campo, el hongo *Beuveria bassiana,* y el protozoario, *Thelohania solenopsae.* Se había demostrado en el laboratorio que ambos organismos eran letales a las hormigas de fuego. Cuando las hormigas de fuego eran expuestas a *B. bassiana* combinada en una mezcla de suelo, no se observó mortalidad aunque el hongo parecía estimular el movimiento de la colonia. Si el suelo usado era estéril, el hongo afectaba a las hormigas, especialmente la cría y las reinas. El medio como vermiculita o arena,con un poco, o sin materia organica, no inhibió el hongo. Sinemabrog, las hormigas no pudieron ser controladas al usar mezcla de suelo con *B. bassiana.*

El protozoario, *T. solenopsae,* fué muy efectivo en reducir el numero de las colonias de las hormigas de fuego en el campo. Este organismo parece promisorio como un agente potencial de control biologico de las hormigas de fuego. Se necesita sinembargo, mucha investigación antes que este agente pueda ser introducido en el campo.

References

Adams, C. T. 1986. Agricultural and medical impact of the imported fire ants. Pp. 48-57. In: C. S. Lofgren and R. K. Vander Meer [eds.]. *Fire ant and leaf-cutting ants biology and management.* Westview Press, Boulder, CO.

Allen, G. E. and W. F. Buren. 1974. Microsporidian and fungal diseases of *Solenopsis invicta* Buren in Brazil. *J. New York Entomol. Soc.* 82: 125-130.

Allen, G. E. and A. Silveira-Guido. 1974. Occurrence of microsporidia in *Solenopsis richteri* and *Solenopsis spp.* in Uruguay and Argentina. *Florida Entomol.* 57: 327-329.

Andreadis, T. G. 1985. Experimental transmission of a microsporidian pathogen from mosquitoes to an alternate copepod host. *Proc. Nat. Sci.* 82: 5574-5577.

______. 1988. *Anblyospora connecticus* sp. nov. (Microsporida: Amblyosporidae): Horizontal transmission studies in the mosquito *Aedes cantator* and formal description. *J. Invertebr. Pathol.* 52: 90-101.

Banks, W. A., D. P. Jouvenaz, D. P. Wojcik and C. S. Lofgren. 1985. Observations on fire ants *Solenopsis spp.*, in Mato Grosso, Brazil. *Sociobiology* 11: 143-152.

Becnel, J. J. 1992. Horizontal transmission and subsequent development of *Amblyospora california* (Microporida: Amblyosporidae) in the intermediate and definitive host. *Dis. Aquat. Org.* 13: 17-28.

Bennett, G. W., J. M. Owens and R. M. Corrigann. 1988. Truman's scientific guide to pest control operations. 4th Edition. Edgell Communication, Duluth, MN.

Bieman, D. N. and D. P. Wojcik. 1990. Tracking ants in Florida: The results of a Florida ant survey and a key to common structure- invading ants. PCO, Fla Pest Control Service Mag. 1990 (April) 11-13.

Broome, J. R., P. R. Sikorowski and B. R. Norment. 1976. A mechanism of pathogenicity of *Beauveria bassiana* on larvae of the imported fire ant, *Solenopsis richteri. J. Invertebr. Pathol.* 28: 87-91.

Cherrett, J. M. 1968. Some aspects of the distribution of pest species of leaf cutting ants in the Caribbean. *Proc. Amer. Soc. Hort. Sci. (Trop. Reg.)* 12: 295-310.

______. 1986. History of the leaf cutting ant problem. Pp. 10-17. In: C.S. Lofgren and R.K. Vander Meer [eds.]. *Fire ant and leaf-cutting ants biology and management.* Westview Press, Boulder, CO.

Ferron, P. 1978. Biological control of insect pests by entomogenous fungi. *Annu. Rev. Ent.* 23: 409-422.

______. 1981. Pest control by the fungi *Beauveria* and Metarhizium. Pp. 465-482. In: H.D. Buges [ed.]. *Microbial control of pests and plant diseases 1970-1980.* London Academic Press.

Glancey, B. M., R. K. Vander Meer, A. Glover, C. S. Lofgren and S. B. Vinson. 1981. Filtration of microparticles from liquids ingested by the imported fire ant *Solenopsis invicta* Buren. *Insect Soc.* 28: 395-401.

Hays, S. B., P. M. Horton, J. A. Bass and D. Stanley. 1982. Colony movement of imported fire ants. *J. Georgia. Entomol. Soc.* 17: 266-274.

Hölldobler, B. and E. O. Wilson. 1990. *The Ants.* Belknap Press of Harvard University Press Cambridge, Mass.

Jouvenaz, D. P. 1986. Diseases of fire ants: problems and opportunities. Pp. 327-338 In: C.S. Lofgren and R.K. Vander Meer [eds.]. *Fire ants und leaf-cutting ants biology and management.* Westview Press, Boulder, CO.

______. 1990. Approaches to biological control of fire ants in the United States. Pp. 620-627. In: R. K. Vander Meer, K. Jaffe and A. Cedeno [eds.]. *Applied Myrmecology: A world perspective.* Westview Press, Boulder, CO.

Jouvenaz, D. P., G. E. Allen, W. A. Banks and D. P. Wojcik. 1977. A survey for pathogen of fire ants *Solenopsis spp.,* in the Southeastern United States. *Florida Entomol.* 60: 275-279.

Jouvenaz, D. P., W. A. Banks and J. D. Atwood. 1980. Incidence of pathogens in fire ants, *Solenopsis spp.* in Brazil. *Florida Entomol.* 63: 345-346.

Jouvenaz, D. P., M. S. Blum and J. G. MacConnell. 1972. Antibacterial activity of venom alkaloids from the imported fire ant *Solenopsis invicta* Buren. *Antimicrob. Agents Chemother.* 2: 291-293.

Jouvenaz, D. P., C. S. Lofgren, and G. E. Allen. 1981. Transmission and infectivity of spores of *Burenella dimorpha* (Microsporida: Burenellidae) *J. Invert. Path.* 37: 265-268.

Jouvenaz, D. P., C. S. Lofgren and W. A. Banks. 1981. Biological control of imported fire ants: a review of current knowledge. *Bull. Entomol. Soc. Am.* 27: 203-208.

Kermarrec, A., G. Febvay and M. Decharme. 1986. Protection of leaf-cutting ants from biohazards: is there a future for microbiological control? Pp. 339-356. In: C. S. Lofgren and R. K. Vander Meer [eds.]. *Fire ants and leaf-cutting ants biology and management.* Westview Press, Boulder, CO.

Knell, J. D., G. E. Allen and E. I. Hazard. 1977. Light and electron microscope study of *Thelohania solenopsae* n. sp. (Microsporida: Protozoa) in the red imported fire ant, *Solenopsis invicta. J. Invertebr. Pathol.* 29: 192-200.

Lattke, J. E. 1990. Overview. Pp. 71-74. In: R. K. Vander Meer, K. Jaffe and A. Cedeno [eds.]. *Applied myrmecology: a world perspective.* Westview Press, Boulder, CO.

Laumond, C., H. Mauleon and A. Kermarrec. 1979. Donnees nouvelles sur le spectre d'hotes et le parasitisme der nematode entomophage *Neoplectona carpocapsae. Entomophaga* 24: 13-27.

Lofgren, C. S. 1986. History of imported fire ants in the United States. Pp. 36-47. In: C.S. Lofgren and R.K. Vander Meer [eds.]. *Fire ants and leaf-cutting ants: biology and management.* Westview Press, Boulder, CO.

______. 1990. Foreword. Pp. x-xii. In: R. K. Vander Meer, K. Jaffe and A. Cedeno [eds.]. *Applied myrmecology: a world perspective.* Westview Press, Boulder, CO.

Lofgren, C. S., W. A. Banks and B. M. Glancey. 1975. Biology and control of imported fire ants. *Annu. Rev. Entomol.* 20: 1-30.

Lubin, Y. D. 1984. Changes in the native fauna of the Galápagos Islands following invasion by the little red fire ant, *Wasmannia auropunctata. Biol. J. Linn. Soc.* 21: 229-242.

Obin, M. S. and R. K. Vander Meer. 1985. Gaster flagging by fire ants (*Solenopsis* spp): functional significance of venom dispersal behavior. *J. Chem. Ecol.* 11: 1757-1768.

Pollard, G. V. 1982. A review of the distribution, economic importance, and control of leafcutting ants in the Caribbean region with an analysis of current control programmes. Pp. 43-61. In: C. W. D. Brathwaite and G. V. Pollard [eds.]. *Urgent plant pest and disease problems in the Caribbean.* IICA. Misc. Pub.

Porter, S. D., H. G. Fowler and W. P. MacKay. 1990. A comparison of fire ant population densities in North and South America. Pp. 623-624. In: G.K. Veeresh, B. Mallik, C.A. Viraktamth [eds.]. *Social insects and the environment.* Oxford and IBH Publ. Co. Pvt. Ltd., New Delhi, India.

______ . 1992. Fire ant mound densities in the United States and Brazil (Hymenoptera: Formicidae). *J. Econ. Entomol.* 85: 1154-1161.

Smith, E. H. and R. C. Whitman. 1992. NPCA Field Guide to Structural Pests. Natural Pest Control Assoc. Dunn Loring, VA.

Stimac, J. L., S. B. Alves and M. T. V. Camargo. 1989. Controle de *Solenopsis spp.* (Hymenoptera: Formicidae) com *Beauveria bassiana* (Bals.) Vuill. em condições de laboratorio e campo. *An. Soc. Entomol. Brasil* 18: 95-103.

Stimac, J. L., R. M. Pereira, S. B. Alves and L. A. Wood. 1990. Field evaluation of a Brazilian strain of *Beauveria bassiana* for control of the red imported fire ant, *Solenopsis invicta,* in Florida. Proc. 5th Intern. Coll. Invertebr Pathol., Microb. Control.

Sweeney, A. W., E. I. Hazard and M. F. Graham. 1985. Intermediate host for an *Amblyospora* sp. (Microspora) infecting the mosquito, *Culex annulirostris. J. Invertebr. Pathol.* 46: 98-102.

Sweeney, A. W., M. F. Graham and E. I. Hazard. 1988. Life cycle of *Amblyospora dyxenoides* sp. nov. in the mosquito *Culex annulirostris* and the copepod *Mesocyclops albicans. J. Invertebr. Pathol.* 51: 46-57.

Sweetman, H. L. 1958. *The principles of biological control.* W.C. Brown, Dubuque, IA.

Trager, J. C. 1991. A revision of the fire ants, *Solenopsis geminata* group (Hymenoptera: Formicidae, Myrmicinae). *J. New York Entomol. Soc.* 99: 141-198.

Tschinkel, W. R. 1986. The ecological nature of the fire ant: some aspects of colony function and some unanswered questions. Pp. 72-87. In: C. S. Lofgren and R. K. Vander Meer [eds.]. *Fire ants & leaf-cutting ants: biology & management.* Westview Press, Boulder, CO.

Williams, D. F. 1990. Oviposition and growth of the fire ant, *Solenopsis invicta.* Pp. 150-157. In: R. K. Vander Meer, K. Jaffe and A. Cedeno [eds.]. *Applied myremecology: a world perspective.* Westview Press, Boulder, CO.

Williams, D. F. and P. Whelan. 1991. Polygynous colonies of *Solenopsis geminata* (Hymenoptera: Formicidae) in the Galápagos Islands. *Florida Entomol.* 74: 368-371.

Williams, D. F. and M. H. Wilson. 1988. Control of the fire ants, *Ochetomyrmex auropunctata* and *Solenopsis geminata* on the Galápagos Islands. Pp. 61-64. Annual Report 1986-1987, Charles Darwin Research Station.

Wilson, E. O. 1986. The defining traits of fire ants and leaf cutting ants. Pp. 1-9. In: C. S. Lofgren and R.K. Vander Meer [eds.]. *Fire ants and leaf-cutting ants: biology and management.* Westview Press, Boulder, CO.

Wojcik, D. P. 1990. Behavioral interactions of fire ants and their parasites, predators and inquilines. Pp. 329-344. In: R. K. Vander Meer, K. Jaffe and A. Cedeno [eds.]. *Applied myrmecology: a world perspective.* Westview Press, Boulder, CO.