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Abstract

The ease at which people, plants and animals move across the globe has created the perfect vehicle for transporting pests and disease. The introduction of non-native species into an ecosystem is a cause for great concern. The economic impact alone makes this a situation that effects everyone. The Red Imported Fire Ant, *Solenopsis invicta* Buren has become a major agricultural and urban pest throughout the southeastern United States. In addition, fire ants cause both medical and environmental harm (Stimac and Alves 1994). The cost associated with the control of the RIFA is significant. An estimated cost of about $36 per household is associated with the presence of fire ants (Diffie and Sheppard 1990). State and federal agencies have spent more than $250 million in total to control or eradicate the fire ant. Private agencies and individuals spend $25 to 40 million yearly for chemical pesticides for fire ant control (Stimac and Alves 1994).

Introduction

Solenopsis invicta Buren, the Red Imported Fire Ant is a member of the Hymenoptera family, a native of South America and a member of the *Solenopsis saevissima* species group (Shoemaker et al. 2006). The introduction of this pest into the southern US has created a decade's long battle between the invading pest and the native habitats that they decimate. The RIFA were accidently introduced in to the US; it is believed that the port of Mobile, Alabama was their entry point around the 1930s (Allen et al. 1995). The Red Imported Fire Ant (RIFA) (*Solenopsis invicta*) Buren has been the focus of many federal and state agency cooperation. This insect causes significant economical, health and biological effects.

The ability of the RIFA to rapidly increase in population is attributed to the lack of natural predators here in the US. In South America, the RIFA has developed with equally aggressive species of ants, bacteria and natural enemies (Briano et al. 1997; Messing and Wright 2006). The RIFA has substantially decreased the population of native ants. *Solenopsis invicta* are a very aggressive species and will disrupt native ants mainly through competition. Their presence also impacts total arthropod diversity and abundance (Stiles and Jones 1998).

Fire Ant Biology

RIFA size is the major determining factor of their lifespan. There are three size categories of workers. Minor workers may live 30 to 60 days, media workers 60 to 90 days, major workers 90 to 180 days. Queen ants can live anywhere from two to six years. The complete lifecycle from egg to adult takes between 22 and 38 days (Hedges 1997).

New colonies are formed by two main mechanisms. Mating flights are the primary means of colony propagation. It is also possible for a colony to split off through budding and become an autonomous unit. Colonies are able to start producing reproductive alates once it reaches one year of age. Six to eight mating flights consisting of up to 4,500 alates each occur between the spring and fall (Vinson and Sorenson 1986). The queen is the single producer of eggs and is capable of producing as many as 1,500 eggs per day. Mature RIFA colonies may contain as many as 240,000 workers with a typical colony consisting of 80,000 workers (Vinson and Sorenson 1986).

Ecological History of Ant

Native to South America, these ants were discovered in Mobile, AL, in the 1930s (Vinson 1997). Problems arise when humans come into contact with IFAs. IFAs favor disturbed habitats, the progressive urbanization of the United States has accelerated their expansion, this is most noticeable in the Sun Belt. Polygyne (multiple queen) groups, in which numerous egg-laying queens reside in a single colony permits more than 500 fire ant mounds per acre in some areas. Fire ants attack both humans and animals, this is especially common in rural areas. They also damage farm equipment, electrical systems, irrigation systems, and crops. In urban areas, fire ants build mounds in sunny, open areas, such as lawns, playgrounds, ball fields, parks, golf courses, and along road shoulders and median strips. (Kemp 2000)

Introduction to United States

The black imported fire ant (IFA), *Solenopsis richteri* (a native of Argentina and Uruguay), and the red IFA, *Solenopsis invicta* (a native of Argentina, Paraguay, and Brazil), appear to have entered the United States through Mobile, Alabama, in the early 20th century. Shipments of infested nursery stock and other agricultural products, natural mating flights, and floating on flood waters have contributed to their outward spread. *S. invicta*, the predominant species, infests more than 310 million acres in 12 states as of 1995. (Kemp 2000)

The US Department of Agriculture estimates that IFAs have expanded westward approximately 120 miles per year. Because of their mobility and their ability to establish colonies in diverse habitats, the detection of new infestations is difficult. For example, according to Kemp (2000), an IFA infestation in California that was discovered in 1998 was estimated to have been 3 to 4 years old before it was detected. Thus "new" infestations usually exist several years before detection.

Ecological impacts of the spread of *S. invicta* were documented in central Texas where it impoverished ant, and non-ant arthropod faunas, as well as negatively impacting many types of ground nesting birds and reptiles. (cited in Lebrun 2013)

Distribution

The USDA currently has a 13-state quarantine area for fire ant protection. These states include AL, AR, CA, FL, GA, LA, MS, NC, NM, OK, SC, TN and TX. They have spread from coast to coast and infest over 330 million acres across the southern half of the United States (Korzukhin et al. 2001). The RIFA has most recently spread into Mexico (2005) and infests portions of Australia (2001), New Zealand (2001), Taiwan (2004), and China (2006) (Reinert 2010). The spread of this insect is devastating native populations of invertebrate and lower level vertebrates. The impact on agricultural yields, native insect fauna and the impact on human health have caused this little insect to receive a lot of attention.

North American *S. invicta* colonies occur in densities approximately 10 times greater than their South American counterparts. The fire ant also has a higher rate of reproduction when compared to other species of ants, which has contributed to higher population densities of *S. invicta* in North America. (cited in Mottern, 2004).

Economic Impact

The current economic impact of S. invicta on humans, agriculture, and wildlife in the United States is estimated to range from one-half billion to several billion dollars annually (Thompson and Jones 1996). Since the introduction of the RIFA, it has become a major agricultural and urban pest throughout the southeastern states. In addition, fire ants cause both medical and environmental harm (Stimac and Alves 1994).

In agriculture, the RIFA frequently invades soybean crops and heavy infestations invariably yield fewer soybeans (Banks 1990). In the US, insects, plant pathogens, and weeds reduce crop production by about 37% annually (Pimentel 2000), a statistic that hasn't improved over the past 50 years, despite a tremendous increase in pesticide input.

The insecticide costs, damage to equipment and medical expenses incurred due to fire ants has created a substantial economic impact (Lard et al. 2002). Fire ants are one of the most economically important non-native species in the United States (Pimentel et al. 2000), and they cause an estimated $5 million (US) per year in livestock losses, $16 million (US) per year in control costs, and $75 million (US) per year in damages in Texas agricultural areas alone. From 1957 to 1981, an estimated $172 million has been spent on imported fire ant control in the Southeastern United States. Such expenses are a major concern for conservation and wildlife programs because the Red Imported Fire Ants have extensive economic and ecological impact: are associated with declines in the diversity, abundance and fitness of species from nearly every faunal guild. Overall, biotic invasions are very roughly estimated to cost at least $137 billion annually in the US alone (Pimentel et al. 2000).

Red Imported Fire Ant Control Methods

There are many different management strategies currently being employed to eradicate the RIFA. Insecticide-based eradication of *S. invicta* has proven unsuccessful. Indeed, overuse of insecticides has been shown to exacerbate the red imported fire ant problem, possibly by inadvertently eliminating competing ant species (cited in Mottern et al, 2004). An integrated approach is necessary to stop the spread and damage caused by this ant. Biological, chemical and physical means of control have been employed. The use of pesticides has been very beneficial in killing established colonies but it isn't preventing them from spreading and expanding their territory. Extensive use of pesticides has been cited as a major contributing factor to the RIFA problem. The pesticides are non-specific and kill many non-target arthropods and other ant species. *S. invicta* is often the first ant species to reinvade areas treated with insecticides and often attains higher densities than pretreatment populations (cited in Mottern et. al, 2004).

The first federal quarantine of *S.invicta* in the United States began in 1958, after >25 million hectares in eight states were infested (Callcott and Collins 1996). The control of fire ants through chemical means was one of the first control methods employed against the spread of the pest. Eradication of *S. invicta* from the United States by mass application of pesticides was attempted from the late 1950s to the early 1970s (Williams et. al. 2001). Yet over that period *S. invicta* increased its range (Callcott and Collins 1996). Despite the continual spread of the RIFA chemicals have been one of the most successful measures used in the fight against fire ants.

Historical Control Methods

The United States Congress began funding the control efforts of the RIFA through the USDA (United States Department of Agriculture) in 1957; control through chemical means was begun shortly after. The primary insecticides used were chlorinated hydrocarbons heptachlor and dieldrin (Banks et al. 1985). This joint government cooperative also saw the creation of a laboratory dedicated to the research and development of control methods.

Mirex was also heavily used to control fire ants during their initial invasion. However, in 1976 the U.S. Environmental Protection Agency cancelled the registration of Mirex. Mirex was found to have a harmful impact on the environment through bioaccumulation, which lead to concerns about long term impact on wildlife.

Current Insecticide Use

Research into chemical control has continued, despite the Mirex ban. A total of 92 products have been approved and marketed for the control of fire ants. The control agents currently available are baits, chemicals and insect growth regulators. Baits are relatively safe and effective; they can be broadcast, efficiently treating large areas. The chemical insecticides, hydramethylnon (Amdro) and abamectin (Affirm) along with the insect growth regulator have active ingredients that break down in sunlight making them safe and environmentally friendly. (Lewis 1992)

Several contact insecticidal drenches, dusts and aerosols are registered and marketed in the southern United States for imported fire ant control. These chemicals are acephate, bendiocarb, carbaryl, chlorpyrifos, diazinon, malathion, pyrethrins and certain pyrethroids. Contact poisons are fast-acting and often are used to drench nests or fend off home-invading columns of fire ants. All current baits are slow acting, allowing the active ingredient to be widely distributed among workers, brood and the queen. Bait treatments tend to be more effective over large areas than direct nest treatments. (Lewis 1992) These baits, however, are not species-specific and would also kill native ants wherever they are used. Some researchers believe that the killing of native competitors by Mirex increased the rate of spread of *S. invicta*. (Drees et al. 2006) While imported fire ants are capable of rapidly recolonizing treated areas through mating flights and colony migration, several effective short-term control measures have been developed, including residual contact insecticides and granular or liquid baits.

Biological Control Methods

The red imported fire ant, is a wide spread invasive pest in the southern United States and elsewhere, posing a significant ecological and economic threat to invaded systems (Lofgren 1986). The need to combat this pest is ever present. Chemical usage was the main means of control for many years. The continual use of chemicals was greatly impacting the environment and non-target species. The introduction of an Integrated Pest Management program that included pesticides and natural enemies was necessary to limit the impact of chemicals on the environment.

South American natural enemies of *S. invicta* include at least 18 species of parasitic phorid flies in the genus Pseudacteon Coquillett, 10 known microorganisms, at least three species of nematodes, a parasitic ant, and a parasitic wasp (reviewed in Porter et al., 1997). Conversely, only 2–3 natural enemies attack *S. invicta* in North America (Porter et al., 1997). Porter et al. (1997) argued that the successful invasion and persistence of high population densities of *S. invicta* in North America are at least partly the result of the release of *S. invicta* from attack by natural enemies (Mottern 2004).

Currently, two species of endoparasitic fungus, a microsporidian obligate parasite, a neogregarine parasite, a strepsipteran parasite, and phorid flies in the genus Pseudacteon, which were intentionally introduced, comprise the known self-sustaining, biological control agents in North American S. invicta. Discovery and exploitation of additional biological control agents, from either South or North American populations, could aid the control and suppression of fire ants (cited in Valles 2004).

Natural enemies

The fire ant has many natural enemies in its native environment (Porter et al. 1997). Many of those enemies are from the Dipteran family Phoridae. Currently six species of parasitoid flies have been established in some capacity in the field. *Pseudacteon curvatus* Borgmeier, *Pseudacteon tricuspis* Borgmeier, *Pseudacteon obtusus* Borgmeier, *Pseudacteon litoralis* Borgmeier, *Pseudacteon nocens* Borgmeier, and *Pseudacteon cultellatus* Borgmeier. (Plowes et al. 2011, Porter et al. 2011). The first species introduced was *P. tricuspsis* in 1997. This species is now widely distributed in nine states and Puerto Rico as a result of cooperative release programs between USDA-APHIS, USDA-ARS, and state cooperators. A second decapitating fly *P. curvatus* was released in Florida at 7 sites between 2000 and 2001. (cited in Porter et. al 2010)

Pathogens

The pathogens *Vairimorpha invictae* Jouvenaz and Ellis (1986) (Microsporidia: Burenellidae) and *Thelohania solenopsae* Knell, Allen, and Hazard (1977) (Microsporidia: Thelohaniidae) are obligate intracellular microorganisms specific to fire ants (Briano et al. 2002). Potential biological control agents for imported fire ants include a species of micropathogens in the phylum Microspora. Of the 1200 described species in this phylum, the most common species infecting the imported fire ant is *Thelohania solenopsae*. This pathogen was first discovered from infected, alcohol-preserved ant specimens from Brazil and North America in 1998 (cited in Chen 2004). *T. solenopsae* is known to cause a significant decline in both laboratory and field colonies. Briano and Williams (1997) and Briano et al. (1995) have suggested that these parasites may serve as a potential biological control agent against fire ants (cited in Chen 2004).

Conclusions

The US government has spent the last five decades trying to stop the red imported fire ant. Methods have been employed to stop the spread of their population, to limit their impact on humans and to prevent them from changing the dynamics of ecosystems. The various strategies have included manual removal, chemical control and biological control through bacteria or insect predators. These methods have varying degree of success when used individually. The strategies seem to work in the short run but the ease and speed at which the ant can spread has made this a difficult process. The reasons for failure are debatable, but it is now known that eradication is hindered by the ant's biology and by problems with treatment methods (Drees et al. 2006). The spread of the fire ant can be managed but it will require constant innovation and vigilance.

The chemical control of RIFA will always need to be a part of a good integrated pest management program. The control of fire ants using chemical means can be completed by individual treatment of mounds or through the use of broadcast baits. Individual mound treatment allows for a guaranteed rate of application. This method is the most cost effective in terms of amount of bait used. However individual mound treatment over large areas is cost prohibitive due to the volume of time it would take to individually treat every mound. Broadcasting bait can allow the chemical to be introduced over a wider range but this method places the bait everywhere and it is hard to determine how much of the bait actually comes into contact with the mounds.

The research on the spread of the RIFA and the discussion of multiple control efforts that have been ongoing for the past 40 plus years has led me to believe that eradication of the RIFA is near impossible. The amount of money that has been spent trying to stop the eradication has shown no real change in the spread of the pest. They continue to spread within the quarantine areas. Billions of dollars have been spent in chemicals, research, importation of biological control agents and studying the biological habits of the ant. We seem to have reached an impasse with the RIFA, we work very hard to regulate their movement between quarantined and non-quarantined areas but we cannot eradicate them from the areas they currently inhabit. The movement of livestock and plants is monitored and tightly controlled. People and cars move freely and are capable of transporting fire ants outside of quarantined areas.

The money spent on research hasn't been wasted, it has helped reveal potential areas for control and highlighted the economic impact to various industries. The RIFA has such an impact on different areas like crop production, livestock, native wildlife population, and native ant species that their presence warranted study. The need to eradicate the RIFA exists and the desire to remove them is real but the ants biology has proven too resilient to extermination. The continuation of efforts to control the RIFA will hopefully produce self-sustaining biological control agents. Continuing to spend money on mass chemical applications is not providing enough of a reduction in numbers of RIFA to warrant continuation. As things stand the best outcome of years of research and money spent is to reduce current RIFA populations to levels similar to those in their native South America. Eradication of the RIFA is a non-sustainable option for the United States.

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