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Introduction

The Red Imported Fire Ant ('RIFA', for short) infestation in southern California is an example of the increasing number of exotic pest species invading California. This pest is of particular importance due to the combined threat to industry, human health, and domestic and wild animal life. The California Department of Food and Agriculture (CDFA) and the County Agricultural Commissioners are at the forefront of dealing with the exclusion, detection and mitigation of this pest in California. However, due to the rapid urbanization of California, their job has become increasingly difficult and complex. In Orange County, woody ornamental production nurseries represent a 1997 farm gate value of $140,627,100 and are the number one agricultural crop in the county. The surrounding counties of San Diego, Riverside, and Los Angeles, when added to Orange County, had a total combined gate value of $438,775,140 in 1997. This industry has felt the most immediate economic impact due to the CDFA and USDA quarantine and treatment regulations that they must comply with. However, nurseries are just one part of the equation. Successful eradication or control of the RIFA will require the cooperation and education of all stakeholders from agriculture, public agencies, landscaped areas, golf courses, and the general public.

History

The Red Imported Fire Ant, *Solenopsis invicta*, originates in lowland areas of South America, particularly Argentina and Brazil. When it is not ambiguous we will refer to them as 'fire ants', although there are other fire ants in California (see below). There has likely been more than one introduction of this ant into the United States by means of cargo ships unloading at Mobile, AL. The most recent introduction, responsible for the widespread dispersal of the ant in this country, occurred about 1940. Infestation maps of the RIFA show the advancing wave as concentric circles moving away from Mobile. Today this ant infests all the southern states from Texas to Florida, including the Carolinas. Their northern limit reaches southern Oklahoma, Arkansas, Virginia and Tennessee.

Arid conditions in western Texas have been an impediment to their spread, but they now occur in most of eastern and south central Texas. Periodic outbreaks have occurred in desert cities from El Paso in the east, through New Mexico and Arizona, and into California. These outbreaks have been associated with commerce, with the ants arriving on trucks, trains, or other vehicles. These infestations have occurred near irrigated areas. Because of their localized nature, these outbreaks have been quickly eradicated.

New housing developments, with their inflow of building materials, trees and plants, and dirt-moving tractors, are particularly susceptible to new outbreaks. For example, in the late 80's a new infestation occurred in Lubbock, TX, north of the fire ant range, when developers brought in infested trees from East Texas. In spite of the cold winters in Lubbock, the ants found warmth near buildings and under sidewalks and have not been completely eradicated after more than 10 years of control efforts. In California

there have been several fire ant introductions over the last 10 years. In most previous cases these infestations were confined to a single property and eradication efforts were successful. In 1997-1998 fire ants hitchhiked to California on honeybee hives from Texas that were brought in for fertilization of almond groves. Apparently, the ants did not spread from those locations (near Bakersfield and Fresno) and eradication efforts there are on-going.

The most recent fire ant outbreaks in California are more serious because they are not confined to a single property or location. Furthermore, they may have gone unnoticed for 2-3 years, giving them time to spread. In Orange County they have now been found in Trabuco Canyon, Rancho Santa Margarita, Laguna Niguel, Mission Viejo, Coto de Caza, San Juan Capistrano, Los Alamitos, west Anaheim, Buena Park, and Cypress. In Riverside County there have been outbreaks in the Coachella Valley, including Palm Springs, Palm Desert, Cathedral City, Rancho Mirage, and Indio. There is also a small outbreak in the Moreno Valley. In San Bernardino County there was a residential find near Fontana. In Los Angeles County they have been found near El Monte. And there have been a few more scattered finds: in Bakersfield in Kern County and San Marcos in San Diego County. The California Department of Food and Agriculture has quarantined all of Orange County, a good part of the Coachella Valley, and a small area in the Moreno Valley.

Biology

The Red Imported Fire Ant prefers moist, temperate environments. Years ago the USDA prepared a map predicting the ant's future spread in the US. They used a 10 F minimum temperature line as a predictor. The maps show that if the ant reaches the West Coast, it could inhabit coastal areas all the way from California north to Washington. These predictions assume water availability, particularly in desert areas. Irrigation can provide the necessary moisture, at least on a local level. In the eastern part of the country these predictions have thus far been accurate.

Several features of fire ants make them a nuisance pest. Like bees and wasps, they are stinging insects and inject a venom. In order to sting, they must first grab the skin with their mandibles for leverage; they then curl their abdomens to insert the stinger. This process takes several seconds so that ants can be brushed off faster than they can sting. Their venom contains piperidines, which produce a burning sensation responsible for the "fire" in fire ant. Within a day a blister-like pustule frequently forms. The pustule can become infected and leave scars if not properly treated. Some hypersensitive individuals may need to take desensitizing injections if they are near fire ants.

Like all social insects, fire ants are holometabolous, which means that they undergo complete metamorphosis. The queen can lay hundreds of minute eggs each day. Individual eggs are nearly microscopic, but are usually stacked in large piles. After about 7-10 days the eggs hatch into grub-like larvae. The workers feed the larvae, which quickly molt and grow in size. In another 1-2 weeks the larvae molt into a quiescent stage, the pupae. These look like curled-up adults and cannot move. Over the next 1-2 weeks the pupae pigment and acquire the reddish-brown color of the adults. In a final molt these pupae become adults.

Fire ants are polymorphic, meaning that the workers are variable in size. The largest workers are called 'majors', the smallest are 'minors', and the rest are

'intermedias'. These caste differences are determined by how much food the larvae are given during their development. Those fed the most become the largest workers. In addition, new queens develop from larvae that are fed much more than the workers. These virgin queens (female reproductives) are larger than any of the workers and have wings. The male reproductives, also with wings, are also larger than workers, but are black in color instead of reddish brown. The male and female reproductives are both referred to as 'alates', meaning that they have wings.

The male and female reproductives in fire ant colonies have mating flights when conditions are appropriate. They normally prefer warm weather rain followed by sunshine and no wind. In the eastern part of the country, these conditions usually pertain in the Spring. In California, the absence of a real winter suggests that mating flights could happen year-round. On such occasions there is frenzied activity around the fire ant mound. The workers appear to chase the males and winged queens to make them fly. The reproductives frequently climb blades of grass before taking off. To be successful, mating flights must be coordinated over a large area so that males and females from different colonies can form a large mating swarm hundreds of feet above ground and mate with individuals of other colonies.

After mating, the males and females fall back to the ground. Although fire ants are not strong fliers, with the help of a little wind they can probably move several miles before landing. The males die shortly after landing. The newly-mated queens quickly remove their wings and search for moist, soft soil where they dig a small hole. Occasionally more than one queen will cooperate in digging this first hole. If the hole is satisfactory, the queen will seal its entrance and start laying eggs almost immediately. She regurgitates food from her stomach to feed her first brood when they hatch. After about 3 weeks her first workers emerge. These are very small workers called 'minims'. They open the entrance, extend the tunnels, and start searching for food. From that point on the queen devotes herself to laying weeks and is fed by her workers. One author (LG) once estimated after a major mating flight at Texas A&M university that about 30,000 newly-mated queens landed on the stadium's astroturf! Of course, they could not dig holes in the astroturf and most died in the hot sun. We do not advocate covering a whole state with astroturf, although it would undoubtedly help eliminate fire ants.

In all ants, sex determination depends on whether eggs are fertilized. Fertilized eggs produce diploid females; un-fertilized eggs give rise to haploid males. All workers in ant colonies (even those that have soldier castes) are females and are usually sterile. The only males are the short-lived male reproductives. The queen actively determines the sex of her offspring. During mating the queen stores millions of sperm in her spermatheca -- enough to last for many years. To produce females (new workers or queens) the queen fertilizes an egg she is laying by opening a valve on her spermatheca to allow the release of sperm. On the other hand, to produce males the queen keeps the spermathecal valve closed and does not fertilize the egg she is laying.

The Red Imported Fire Ant that was originally introduced in Mobile was described as having one queen per mound, or 'monogyne'. Colonies of this type are highly territorial and will fight with neighboring colonies. However, the predominant form in Texas has become the 'polygyne' form, meaning that there are many queens per colony. The coexistence of hundreds of queens in a colony was first described from Mississippi in 1972. They were discovered in a city dump, appropriately named "Queen City." This site

was apparently a single giant colony extending over several acres with thousands of queens. At about the same time the polygyne form was spreading through eastern Texas and reached the Austin area in the 1980's. By the mid 1990's it had become difficult to find any monogyne colonies in Texas. It is highly likely that if the California infestation originated in Texas, it is probably polygyne.

The polygyne fire ant can have hundreds of mounds per acre compared to the 30-40 typical for the monogyne form. Many of these mounds are connected underground so that brood and queens can quickly move between them. Polygyne ants are not territorial and can frequently mix with little fighting. Researchers have shown that the total egg production for the multiple queens exceeds that of the single queen in a monogyne colony. Thus, there are more mounds and more ants per acre in polygynous ants. Polygyne ant colonies can reproduce by budding, where some of its queens and workers advance to a new location. This process allows them to saturate a field in a relatively short time.

One key question about the introduction of the fire ant to California is whether conditions are appropriate for mating flights. In our new infestations many of the mounds contain male and female reproductives. But how often does California have warm-weather rain followed by a calm, sunny afternoon? Irrigation can supply the moisture, but if it is not synchronized over a large area only some reproductives will fly. Some of the new mounds that we have seen are in grassy areas not near anything recently planted, suggesting that they must have flown to these locations. If mating flights are successfully promulgated by irrigation, eradication efforts will prove very difficult. This species has never been eradicated from any state once it has been firmly established.

There are some unusual aspects to the behavior of the RIFA that make it a significant pest. Research at Texas A&M has shown that these ants have an affinity for electricity. They frequently invade traffic signal boxes and short them out by chewing on insulation. Home air conditioners that sit outside on the ground meet a similar fate. In agricultural settings, the ants like to chew on soft plant tissues such as okra. They frequently build their mounds up against tree trunks and sometimes they damage the bark and underlying living tissue. They tend and defend aphids and scale insects from predators, making biocontrol efforts difficult. They will sting people who are caring for trees and other plants. Their mounds are frequently built up high enough to interfere with farm machinery. Flood irrigation can help spread the RIFA because this species responds to floods by forming rafts of living ants that get carried by the water to new locations. The queen and brood are within these rafts so that a new mound can spring up instantly wherever they touch land again!

Fire ants can be beneficial to some crops. It is documented in Louisiana that sugar cane production is improved due to predation by the ants on pests. The same may be true for cotton, where the boll weevil falls victim to the ant. The fire ant poses a threat to all ground dwelling species. For example, nestlings of ground-nesting birds, such as terns and quail, can be killed. Endangered species such as the kangaroo rat, and some flies and butterflies, would be in jeopardy. In Texas the fire ant has been implicated in the disappearance of the horned lizard, largely because their food supply (harvester ants) are being eliminated by fire ants. Since ants are low in the food chain, their effects can be profound on predators such as hawks that rely on ground-nesting rodents. Recreational use of parks and lakes becomes more difficult. For example, the ants congregate near lakes and make it difficult to get into boats without being stung. Hunters, campers, and hikers need to

take precautions on where they step.

Identification

All fire ants belong to the genus Solenopsis and are characterized by having a 2-segmented petiole (the narrow waist between the thorax and abdomen), 10-segmented antennae with a 2-segment club, and a sting. There are two native fire ant species likely to be encountered in California and confused with the RIFA. The more common one, the Southern Fire Ant (*Solenopsis xyloni*), 2.5-4.5 mm in length, is found in coastal and inland regions. It is very similar in appearance to the RIFA. Besides technical differences requiring the use of a hand lens or microscope, the Southern Fire Ant differs from the RIFA in that it is bicolored, with a reddish head and thorax and a dark brown abdomen. By contrast, the RIFA is an almost uniform dark reddish-brown and 3-6 mm long. Furthermore, the Southern Fire Ant mounds are irregular craters, while the RIFA mounds are frequently built up into domes. The other native fire ant in California that could be confused with the RIFA is the Desert Fire Ant (*Solenopsis aurea*). It is golden-yellow in color and about 3 mm long. The Desert Fire Ant is not found in coastal areas, but would occur in desert areas such as the Coachella Valley. All three species are polymorphic, i.e., the workers are of mixed sizes. Another characteristic difference between these species is the aggressiveness of the workers. Although they will all sting, the ferocity of the RIFA is notable. Any object touching their mound is immediately attacked and stung and the workers will quickly run up a stick that touches the mound.

Not to be confused with the fire ants are the harvester ants. Some of these are commonly known as “red ants”. The California Harvester Ant is all red, larger (6 mm), and more robust in appearance than fire ants. They also have a potent sting. Their mounds are usually irregular craters devoid of grass, with several openings and nearby piles of seeds and chaff. They are not aggressive unless disturbed.

Treatment options

Texas A&M University and their extension service have developed the “two step” approach to fire ant control for homeowners. These principles can also apply to other settings. The idea is to first put out a granular ant bait and then leave colonies undisturbed for several days, giving the workers time to bring the material into the nest and have it spread to all the workers, brood, and queens. The advantage of a bait is that it can get into mounds that are not visible or accessible and could be applied aerially. Fire ant baits are usually corn-cob grits impregnated with soybean oil and an active ingredient. In Texas the most popular baits contain hydramethylnon (Amdro®), fenoxycarb (Award®), and avermectin (Ascend®). Only the latter two products are currently available for use in California. Award® is an insect growth regulator (IGR) which can take 5-10 weeks or more to sterilize the queens and prevent further production of adults.

The second step in this treatment plan calls for individual mound treatments where the mounds are easily accessible. Mound treatments can use dusts, liquid drenches, and granular products that are watered into the mound. These methods quickly destroy these mounds. The homeowner can use any product labeled for use on ant mounds around structures.

In quarantine fire ant situations the USDA has approved a number of products with differing certification periods. Chlorpyrifos drenches of plants provide 30 days of certification. The longest certification is given to incorporation of Talstar® granular nursery products (which are pyrethroids) into potting soil. The USDA certifies these treatments for 180 days. The California Department of Food and Agriculture recommends soil incorporation of the Talstar, plus treatment of the infested grounds with ant baits. Some ant baits, such as Distance and Award, contain IGRs (insect growth regulators). Others, such as Amdro, have hydramethylnon. The IGRs require about 6 weeks to reduce fire ant numbers, while the Amdro can show a significant effect in several days. Most fire ant baits are yellow in color because they use corn cob grits and soybean oil as the carrier for the pesticide. Conditions in California will likely require modification of programs that have been adopted in other states. Local research could help determine which treatments have the least negative impacts on native ant species. Native species provide competition and resistance to the fire ant invasion. We should begin immediate studies to see which products work best in California.

The USDA and the University of Texas have begun the first biocontrol program to control fire ants. There is a tiny South American fly, called a phorid, that is a natural parasite of fire ants. It lays its egg in the neck region of the worker ant. The larva that hatches from this egg eventually consumes the ant's brains and causes the ant's head to drop off. The new fly then emerges from the head of the ant. These flies are being mass reared and released in Florida and Texas. It is too early to know the success of this program and whether the fly will survive in North America. Researchers are also investigating other parasitic insects and even protozoa from South America. The principle is to reestablish a balance between the fire ant and its environment so that its numbers are reduced.

Conclusions

Experience in southern states infested by RIFA has shown education to be an important component of any control attempts in agricultural and urban areas. CDFA has made it very clear that their efforts alone will not control this pest. Although RIFA has the ability to fly short distances, it can travel great distances as a hitchhiker. Thus, an Integrated approach of exclusion, detection, control, evaluation of control strategies, university research, and education will be needed if this pest is to be eradicated or controlled. There is very little known about how the biology and control of RIFA in California will differ from other states where it now occurs. However, it is of the utmost importance that growers and the general public report any ant they suspect to be RIFA, and not try to hide or control RIFA on their own. Exotic species that are introduced without their natural enemies and parasites have a proven record of being very difficult to control, and capable of explosive increases in population size and distribution. The University of California Division of Agriculture and Natural Resources, through Cooperative Extension and UCR Department of Entomology researchers, plans to develop educational materials for nurseries and home owners in conjunction with the Nursery Growers Association and the California Association of Nurserymen. CDFA has established a toll-free telephone Pest Response hotline for residents to report the locations of any fire ant colonies, and a website at www.cdfa.ca.gov.

Biography

Dr. Les Greenberg has a Ph.D. in Entomology from the University of Kansas. He worked for the fire ant research lab at Texas A&M University for 15 years. He has over 25 scientific publications on bees and ants. He currently is an Associate Research Entomologist at the University of California, Riverside. He is currently on the Science Advisory Panel for the Orange Co. Fire Ant Authority, and heads the university fire ant research program.

Dr. John H. Klotz also has a Ph.D. in Entomology from the University of Kansas. He has nearly 20 years of experience working with ants, and has published widely on Carpenter ants. At this time he is an Assistant Professor with both research and extension responsibilities. John gives frequent talks on ant control around California and is primarily concerned with urban and structural pests**.**

John Kabashima has a M.S. in Pest Management from the University of California at Riverside, where he is currently a doctoral candidate in the Department of Entomology. He also has a M.B.A. from Pepperdine University. He is currently the Environmental Horticulture Advisor with the University of California Cooperative Extension in Orange and Los Angeles Counties, and is stationed at the South Coast Research and Extension Center in Irvine, California, where he specializes in all aspects of nursery production. He has been involved in the development of Integrated Pest Management programs for pests such as the Nantucket Pine Tip Moth, Ash Whitefly, Green Shield Scale, and most recently the Giant Whitefly.

Dr. Cheryl Wilen has a Ph.D. in Botany and Plant Sciences (with an emphasis in Weed Science) from the University of California at Riverside. She is currently the Integrated Pest Management (IPM) Area Advisor in southern California, and is stationed at the San Diego County office of the University of California Cooperative Extension. Cheryl conducts a program of applied research and education in the use of IPM in landscapes and production nurseries. She is a frequent speaker in southern California on topics ranging from the safe use of pesticides to weed control in landscape and production nursery situations.