Physiology And Behavior Of The Imported Fire Ant

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Research on the behavior and physiology of fire ants is essential for the development of innovative fire ant control methods that keep pace with our changing needs. The fire ant social structure is complex and contains many vital elements. The more we understand this structure the closer we come to devising environmentally safe control methods. The following describes some of the research that has been done and how it relates to fire ant control. Also identified are areas of research for which we know very little and should be investigated.

There are 11 general categories of behavioral responses in social insects:

1. Alarm
2. Attraction
3. Recruitment to new food source or nest
4. Trail following
5. Grooming, including assistance at molting
6. Trophallaxis, exchange of food
7. Exchange of solid food particles
8. Group effect, social facilitation or inhibition
9. Recognition of nest-mates
10. Caste Determination, inhibition or stimulation
11. Control of competing reproductives

Most of the above behaviors are mediated by chemicals produced by the ants themselves. When this occurs the specific chemicals are called pheromones. Many of these categories have been investigated over the past 10-20 years.

Recruitment Pheromone

One of the reasons the fire ant is so successful is its highly efficient foraging strategy. It is composed of the following elements:

A. Hunting by solitary workers who move away from the nest in irregular looping patterns.
B. The worker locates a food source and inspects it.
C. If the food source is large the worker returns to the nest laying a chemical trail.
D. At the nest additional workers are recruited and follow the chemical trail to the food.
E. Additional foragers reinforce the trail.
F. When the food is gone the trail is no longer reinforced and the volatile chemical trail dissipates.

The fire ant recruitment pheromone has been studied extensively. The source of the pheromone is the Dufour's gland, which is attached to the base of the sting apparatus. A worker makes a trail by releasing the Dufour's gland contents through the sting, which is periodically touched to the surface on which it is walking. The recruitment process has been reduced to three subcategories: attraction, orientation induction, and trail following. Workers are extremely sensitive to the pheromones. For example, one teaspoon of the trail following component is enough to apply an eighth inch wide trail around the world over 5,000 times. The powerful species-specific chemicals responsible for worker attraction also have been isolated. In other situations the Dufour's gland contents elicit colony migration and alarm.

Control Potential - The recruitment pheromones are currently being investigated for use in fire ant monitoring traps and in species-specific bait formulations. The attractive part of the recruitment pheromone may be useful in luring workers into traps, as well as an aid in making toxic baits fire ant specific. The trail following pheromone could increase the probability of detecting incipient fire ant colonies in areas not now infested. Both of these pheromones if introduced into a colony at high concentrations could disrupt the social structure of that colony and provide a non-insecticide method of control.

Dealation Inhibitory Primer Pheromone

A mature fire ant colony can produce up to 5,000 winged female sexuals (female alates) a year. Normally these sexuals will leave their home nest on mating flights in search of males. After insemination many physiological changes occur in the queen; i.e. loss of wings, wing muscle histolysis, ovariole development, production of pheromones, and egg production. These same changes can occur within a colony simply through the loss of an alates wings (dealation). Drs. Fletcher and Blum at the University of Georgia discovered that the queen of a colony produces a pheromone that inhibits the dealation process (Vinson, Lofgren and Vander Meer, 1986). Because the behavior is not immediately released by this pheromone it is classified as a "primer" pheromone. Production of this pheromone prevents the female alates from competing with the queen for colony resources. If the queen of a colony dies the alates present will dealate and start to produce all the pheromones associated with queens. They will also produce unfertilized eggs, which will develop into males. Eventually the colony will die through the natural attrition of the remaining workers.

Control Potential - University of Georgia researchers observed that in orphaned colonies dealation of the alates present began within 24 hours and that a few days later workers started to kill some of the dealates until only a few were left. They postulated that workers can tolerate only certain levels of queen pheromones and an excess prompts workers to eliminate the source until tolerable levels are reached again. Hypothetically, high doses of these queen pheromones could be introduced into a normal colony, which would induce workers to execute their own queen. Unfortunately, at the present time the source of the dealation inhibitory primer pheromone and its chemistry is unknown. Therefore, there is more research to be done on this system before it can be evaluated.

Queen Attractant Pheromone

Fire ant queens normally have an entourage of workers around them. It was found that the queen produces a pheromone in her poison gland that is highly attractive to workers. The queen has control over the release of this pheromone through the sting apparatus. Three chemical components have been isolated from extracted queens that elicit worker attraction. These compounds have been synthesized in small quantities and worker response was found to be species-specific (Vinson, Lofgren and Vander Meer).

Control Potential - Like the trail pheromone the queen pheromone may be useful in fire ant monitoring traps, bait toxicants, and in the disruption of the social structure of the colony.

In related research it was discovered that the queen can deposit material from her poison gland or Dufour's gland onto the eggs she deposits. This process puts the queen worker attractant on the eggs, as well as small amounts of the antimicrobial venom alkaloids (see below). This gives the eggs a head start in surviving in their subterranean habitat. Besides the survival advantage, this mechanism has implications in the areas of caste determination, the evolution of Formicidae, and control of sexuals.

Fire Ant Chemical Defense

A dominating feature of fire ant workers is their aggressive behavior and their potent sting. Their venom is unusual because instead of being composed of proteins like most other ants, its major constituents are piperidine alkaloids. These alkaloids have a range of physiological activities; i.e. histamine release, hemolysis, and antibiotic activity. When people are stung the ants are acting in a defensive rather then offensive manner, and although there is a lot of fire ant/people interaction, the most serious enemies of the fire ant are other ants. When approached by an intruder ant, a fire ant worker will raise and shake its abdomen while simultaneously releasing venom via its extended sting. This disperses it into the air where it may repel the intruder. If the intruder is not repelled, then the fire ant can accurately fling the venom at the intruder. If that also fails, direct application of the venom or stinging usually does the job. This graded hierarchy of defensive behaviors minimizes potentially incapacitating interactions.

A slightly modified version of gaster vibration was also observed in brood tending workers. Chemical analysis of the surface of brood and nest soil demonstrated that workers apply small amounts of the venom inside their own nest, probably to function as an antimicrobial agent. A moist subterranean habitat should be ideal for bacterial and fungal growth, but fire ant colonies are "clean". In nature a constant war is going on between the ants and their potential pathogens, where the pathogen evolves a way to get around the ant's defense and the ant is always evolving new defenses.

Control Potential - Two fungal pathogens have been discovered that have potential in fire ant control, one by Dr. Stimac, University of Florida and the other by Dr. Jouvenaz, USDA. These fungi were isolated from fire ant colonies and have evolved with the ants. Although the fire ant does have physical mechanisms to protect themselves from pathogens; i.e. a particle filtration system, the fungicidal venom alkaloids appear to be their main defense. It may be possible to screen for fungal strains that are least affected by the fire ant alkaloids, and therefore obtain the most virulent pathogen.

Nest-mate Recognition

Nest-mate recognition occurs when a resident ant evaluates the odor of a potential intruder via its antennae. If the intruder smells like the resident everything is fine, but if it is sensed as being different, aggression occurs. In fire ants the recognition chemicals come from both environmental (soil, food, etc.) and genetic sources (the ants themselves). Since in a given colony, odors are distributed uniformly among colony members through social interactions, each colony has approximately a uniform chemical profile. Also, because there is variability in the environmental and genetic cues no colony has exactly the same chemical profile.

Fire ants had been thought of as having only one queen per nest (monogyny); however, the reality of the situation in the United States today is that we have increasing populations of multiple-queen fire ant nests (polygyny). In monogynous populations each nest is discrete and the workers from one nest are aggressive toward workers from other nests. However, the opposite is true for polygynous populations. Here each nest can contain hundreds of queens and the workers from one nest will accept workers from other nests as nest-mates, even if they are from monogynous colonies! This supports the idea that polygynous populations are acting as huge super-colonies, with free exchange of queens and workers.

Utility and Control Potential - Polygynous populations have been empirically shown to be more difficult to control than monogynous colonies. A simple aggression bioassay that readily identifies a population as to type with 100 percent accuracy has been developed by the USDA, Gainesville, Florida, that requires only a few workers collected from nests with a minimum of nest disturbance. The differential aggressive response of monogyne and polygyne workers is then used to distinguish the type of colony. This will be an aid to future research and control of polygynous populations. The chemistry of fire ant nest-mate recognition cues is unknown; however, it has potential in making toxic baits more acceptable, and in disrupting the social harmony of a colony, especially in polygynous populations. In addition, intraspecific aggression bioassay results are significantly different from interspecific results; therefore the bioassay may help sort out complex fire ant taxonomic problems both here and in South America.

Fire Ant Parasites

There are many fire ant parasites that live happily within the nest (myrmecophiles) and are unmolested by the normally aggressive fire ant workers. How these parasites integrate into the host colony has been investigated by the USDA, Gainesville, Florida. In general, the parasites have a mechanism for surviving in the nest long enough to acquire, through interactions with the ants and the nest soil, the nest-mate recognition cues of its host colony. For instance, a beetle that feeds on fire ant larvae has an armored exoskeleton and plays dead when attacked. After about 24 hours in the host nest the beetle has acquired its host odor and is no longer attacked. In another case, the tiny first instar larva of a parasitic wasp enters a fire ant nest undetected due to its small size. It too passively acquires its host colony odor. There is a lot more to learn about parasite/host interactions, but our understanding of how they integrate into fire ant colonies should increase the probability for successfully using these parasites as bio-control agents for fire ants.

Food Flow

A great deal is known about the types of food consumed by the ants and how they are distributed within the colony. Colony size, degree of starvation, age of the worker, are all variables in food flow. The types of food brought into the colony by foraging workers are distributed differently within the colony. Workers primarily use carbohydrates, whereas proteins are fed to the queen and larvae. Only the 4th instar larvae ingest solid food, all other forms ingest only liquids. The presence of 4th instar larvae have a dramatic influence on queen egg production, which implies a positive role in queen nutrition for the 4th instar larvae.

<u>Utility</u> - Baits utilize food materials as both a toxicant solvent and a phagostimulant; therefore knowledge of how food materials are distributed and fire ant food preferences are essential in order to make the most effective use of a toxicant. The importance of the 4th instar larvae in queen egg production implies that disruption of this larval stage; i.e. by specific pathogens, may have profound effects on the colony size.

Conclusion

Although we have a much better understanding of fire ant physiology and behavior now then we did ten years ago, there are many important gaps in our knowledge. The following are representative of areas in need of research:

A) Very little is known about what initiates mating flights, what causes the frenzied activity during the flights, and where and how the two sexes locate each other 100 to 200 meters in the air.

B) In mature colonies, what is the mechanism that determines whether an egg laid by the queen develops into a worker or sexual (caste determination) and what are the mechanisms of caste regulation?

C) The nutritional requirements of fire ants is virtually unknown. We do know that laboratory reared colonies are not as large and vigorous as field colonies.

D) The endocrinology and neurophysiology of fire ants is essentially unknown territory.

All of these areas and many others not mentioned are important to our understanding of the fire ant and ultimately to its management.