*Applied Biosafety, 11*(2) pp. 88-97 © ABSA 2006

# Safety Considerations for Handling Imported Fire Ants (*Solenopsis spp.*) in the Laboratory and Field

James T. Vogt[1] and Joseph P. Kozlovac[2]

[1]USDA Agricultural Research Service, Stoneville, Mississippi, and [2]USDA Agricultural Research Service, Beltsville, Maryland

## Abstract

*Imported fire ants pose two primary threats to humans: the risk of anaphylaxis following stings, and the potential for secondary infection of localized pustules that result from stings. Additionally, fire ant products such as whole-body extract and venom can present risks to laboratory personnel. Whether in concentrated form in the laboratory or retained within the living animal, fire ant venom alkaloids and proteins are biological toxins with potentially severe health effects. Several recommendations are given for minimizing the risk of stings in the laboratory and field with the understanding that most experienced workers are capable of assessing their own tolerance to stings and acting accordingly. Since there are no fail-safe methods for avoiding fire ant stings, all workers who are exposed to imported fire ants should be familiar with the symptoms of anaphylaxis and be prepared to seek immediate medical assistance if they or their coworkers are stung and show symptoms of hypersensitivity.*

## Introduction

Imported fire ants are serious pests to humans and livestock in the southern United States (Vinson, 1997). They were unintentionally imported in cargo ships from South America early in the 20th Century (Lofgren, 1986) and have since spread to infest more than 300 million acres in the U.S. (Figure 1) (USDA, Animal and Plant Health Inspection Service, 2005). Current infestations are likely to expand to the north, and the entire West Coast is susceptible to invasion (Korzukhin et al., 2001). The red imported fire ant (*Solenopsis invicta* Buren) infests the southeastern U.S. from coastal North Carolina to west Texas, with additional infestations in New Mexico and California. Red imported fire ants have also been found in several sites throughout the West Indies (Davis et al., 2001) and were introduced into Australia in the late 1990s (McCubbin & Weiner, 2002) and more recently into Taiwan (CNA News, 2005) and mainland China (China Daily, 2005). The black imported fire ant (*S. richteri* Forel) is currently limited to an area of several counties in northeastern Mississippi and northwestern Alabama (Shoemaker et al., 1994), and south-central Tennessee. A hybrid of the two species also exists in the U.S., occupying a broad band from western Mississippi through Alabama and parts of Georgia (Shoemaker et al., 1994). Red, black, and hybrid imported fire ants exhibit similar aggressive tendencies and stinging behavior and will hereafter be referred to as "imported fire ants."

Imported fire ants reside in colonies of 250,000 or more individual ants, each equipped with strong mandibles and a potent sting. They typically live in the soil in large, earthen nests (commonly referred to as mounds) (Figure 2A) that are created as they excavate underground galleries; however, they can also nest most anywhere sufficient moisture and favorable temperatures are found. Nests are often cryptic, occurring under or within stored equipment, in wall voids (Figure 2B) or rotten wood (Figure 2C), and inside electrical or telephone junction boxes (Figure 2D).

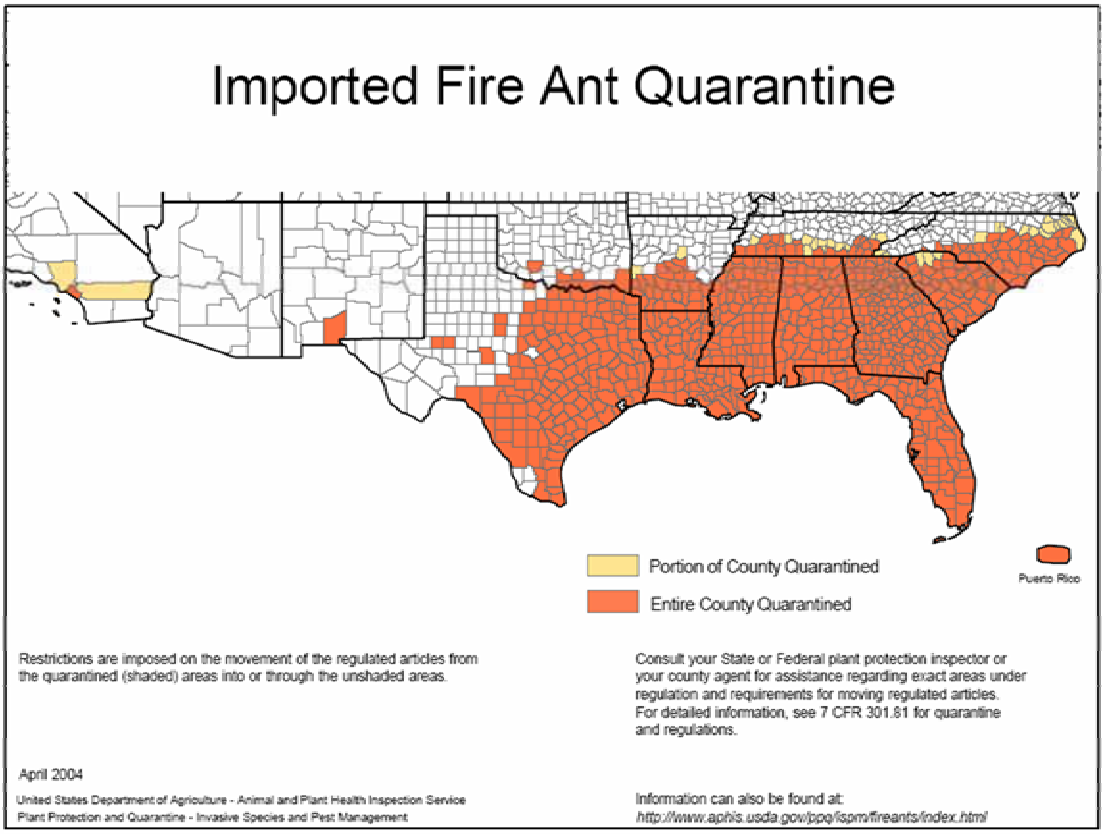
When an imported fire ant worker stings, she first gets a firm grip with her mandibles, then arches her body pointing the gaster downward and stings repeatedly. The intense burning sensation that occurs when the venom is injected accounts for the popular name of "fire ant."

Clinical reaction to the sting can range from localized pustules (Figure 3) to life-threatening anaphylaxis (reviewed by Stafford, 1996). Anaphylaxis is relatively rare but may be very serious when it occurs. The domestic species *S. xyloni* McCook and *S. geminata* (Fab.) are known to have caused serious and fatal reactions (D. R. Hoffman, personal communication), but are much less abundant than the imported fire ants. Sting victims sometimes suffer tens or hundreds of stings, especially in cases where the victim is immobile due to sickness or injury. Unsensitized people can rapidly develop imported fire ant-specific IgE following limited stinging events (Tracy et al., 1995), which can lead to hypersensitivity and the potential for anaphylaxis to occur.

Imported fire ant venom is unlike bee or wasp venom in its composition. It is composed of >95% piperidine alkaloids (MacConnell et al., 1971) and a small amount of several proteins. Piperidine alkaloids are identified by their saturated heterocyclic ring (i.e., piperidine nucleus).

**Figure 1**

Map of imported fire ant infested areas in the United States (courtesy of the U.S. Department of Agriculture, Animal and Plant Health Inspection Service).




The best known piperidine alkaloids are those of poison hemlock, *Conium maculatum* L. Some imported fire ant venom alkaloids have been shown to cause cardiorespiratory depression in experimental animals (Howell et al., 2005). The protein component of the venom is responsible for the development of hypersensitivity. Additionally, cross-reactivity with bee and wasp venom has been demonstrated (Hoffman et al., 1988), so people who are hypersensitive to other stings should avoid imported fire ants. A recent review of the clinical aspects of imported fire ant allergy can be found in Reichmuth and Lockey (2003).

Evidence demonstrates that the more frequently beekeepers are stung, the less common their severe allergic reactions become, but presence of bee venom-specific IgE in beekeepers who are frequently stung and do not experience allergic symptoms suggests that anaphylaxis may still be possible in these individuals (Bousquet et al., 1984). It is possible that frequent imported fire ant stings may serve to desensitize individuals to fire ant venom, but no clinical data support or refute this, and the venom dose received during a fire ant sting differs by several orders of magnitude from the dose received during a bee sting (D. R. Hoffman, personal communication).

In short, imported fire ants produce biological toxins as defined by Kozlovac and Hawley (2005); the alkaloids have broad biological activity and can act as cardiodepressants, and proteins are potential allergens. As delivery mechanisms for these biological toxins, imported fire ants can be considered a hazard in the laboratory and field, and appropriate steps should be taken to reduce the risk of stings for those individuals performing field or laboratory research involving these insects or preparations of fire ant venom.

Decades of research on these pests have generated thousands of published papers, and several laboratories around the world continue to maintain stock colonies for research purposes and in-vivo rearing of parasitoids and diseases. Ongoing field research in imported fire ant-infested areas exposes workers to the potential for stings from the ants. For laboratory tasks such as colony maintenance, supervisors should develop and implement effective standard operating procedures (SOPs) to reduce the probability of stings or venom exposure, and train employees. Both supervisors and workers must be aware of the potential health hazards posed by stinging incidents or venom exposure.

This article represents a synthesis of current knowl-

## Figure 2

(A) Imported fire ant mound in pasture (James T. Vogt, U.S. Department of Agriculture). (B) Loose soil is the only evidence of this fire ant nest in a wall void. Quarter shown for scale. (C) Old fire ant nest in rotting wood. (D) Imported fire ants have carried soil into electrical junction box and are nesting in the box. Note: Photos B, C, and D courtesy of Oklahoma State University Department of Entomology and Plant Pathology.

Figure 2A

Figure 2B

Figure 2C


Figure 2D

edge and recommendations for minimizing imported fire ant stings and allergen risks. Its goal is to provide useful suggestions for supervisors and workers alike as they develop work habits that adequately address imported fire ants and the risks they pose. This paper is not meant to be a comprehensive review of the medical impacts of imported fire ant stings; for that the reader is referred to the recent review by Kemp et al. (2000) and references therein.

Four subject areas are addressed here: identifying imported fire ants, laboratory equipment and personal protective equipment (PPE), best practices in the field, and actions to consider if stung.

## Listserv Survey

The authors conducted a search of the literature, including Extension fact sheets, to collate available information and recommendations on safe practices for handling and/or working with imported fire ants. The Cooperative Extension Service, established in 1914 by the Smith-Lever Act, constitutes one of the largest adult education programs in the world, organized at the federal, state, and county levels in the United States. Additional recommendations came from the experience of the first author, who has more than 12 years of experience in fire

**Figure 3**
Aseptic pustules following multiple fire ant stings
(D. P. Wojcik, Retired, and S. D. Porter, U.S. Department of Agriculture).

ant research and education. Background and general information on PPE, toxins, and safety can be found in Kozlovac and Hawley (2005) and Johnson, Mastnjak, and Resnick (2000). Hoffman (2003) provides an excellent review of Hymenoptera venoms. Finally, an informal poll was conducted among fire ant specialists who subscribe to a popular imported fire ant e-mail listserver. The following questions were sent to participants:

1. Do you have formal SOPs for procedures involving imported fire ants?
2. Do you require PPE (personal protective equipment) for working with imported fire ants in the lab?
3. If your answer to #2 is "yes," please list the PPE.
4. What safety recommendations do you have for:
    a. Maintaining/containing colonies?
    b. Day to day activities (separating brood, etc.)?
    c. Collecting in the field?
    d. Action to take if stung?

Questions 3 and 4 were intentionally open-ended. We tallied numbers 1 and 2 as a percentage of participants answering "yes" or "no," examined the number of unique answers to numbers 3 and 4, and constructed a frequency distribution to determine the most adopted safety measures.

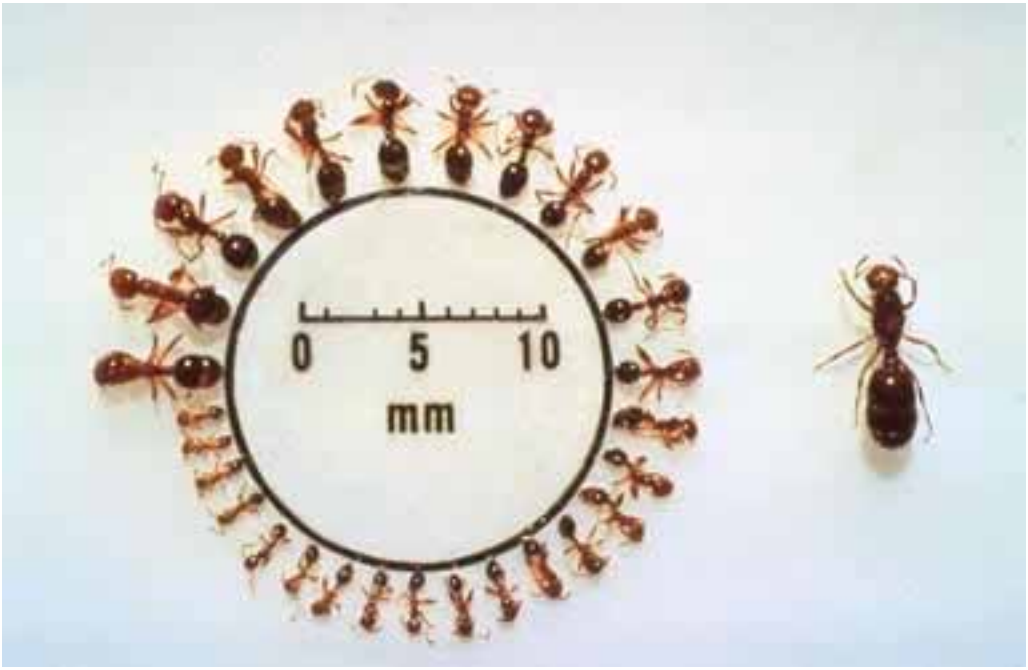
## Identifying Imported Fire Ants

Consultation with a taxonomic expert is necessary for positive identification of imported fire ants to species level. This is currently accomplished using morphological structures (Wojcik et al., 1976) or chemotaxonomic techniques to examine cuticular hydrocarbon profiles of the ants (Vander Meer et al., 1985). For the layperson, general knowledge of the ants and their nest characteristics is sufficient to make a tentative identification, and formation of a characteristic pustule (Figure 3) 12 to 24 hours after a sting is almost certain evidence that fire ants were responsible. Even without a formal identification, supervisors and workers should know whether imported fire ants are present in the area where they are working and take appropriate precautions. This is especially relevant if a person who is unfamiliar with imported fire ants is moving into an infested area.

Imported fire ants are polymorphic; that is, worker size increases on a continuum from about 2.5 mm to 6 mm in length. This is important, as most ant species are either monomorphic (workers are all one size) or dimorphic (there are two distinct size classes of workers). Workers are reddish-brown to nearly black in color (Figure 4). For the reader with experience in insect taxonomy, the

**Figure 4**

Imported fire ant workers array illustrating size range of individuals. The large ant to the right is a reproductive queen (S. D. Porter, U.S. Department of Agriculture).




fire ant antenna is diagnostic for the genus *Solenopsis*, with 10 segments including a 2-segmented club.

Imported fire ants build characteristic mounds that can reach > 1.5 m in diameter and > 1 m in height (Figure 2A). With the exception of brief periods (usually following rainfall) when male and female winged imported fire ants leave the nest to mate and workers repair the mound surface, the mound is closed to the environment with no entrance/exit hole(s) visible. Foraging ants enter and exit the mound underground, in a series of foraging tunnels that branch out through their foraging territory in such a way that an ant generally does not have to travel above ground for more than about 0.5 m to reach any point in the colony's territory (Markin et al., 1975). A single fire ant colony can occupy a relatively large area. Foraging territories of up to 29 $m^2$ have been documented using radiotracers (Showler et al., 1990), and territories of nearly 200 $m^2$ have been documented in pasture (Adams, 2003). Obviously, a person working in an infested area is constantly at risk of being stung even if he or she avoids mounds. It is also important to note that people working or walking through vegetation may risk stings, since fire ants readily forage on plants.

## Laboratory Equipment and PPE

The first problem confronting fire ant researchers who maintain indoor colonies is keeping them confined in buckets or trays. This is usually accomplished by painting or swabbing a Teflon emulsion on the inner sides of the container (e.g., Banks et al., 1981). One product that works well is Fluon® PTFE aqueous dispersion resin (AGA Chemicals Americas, Inc., Bayonne, NJ). The material can be applied in several different ways, but is commonly applied by painting it onto the surface with a sponge brush, taking care not to apply too much or leave bubbles on the surface. With some practice this technique can be used to apply a thin, even layer. The material should be applied in one direction with minimal pressure on the sponge brush to avoid bubbling. The inner surface of the container should be clean and smooth. Some important points about Fluon®:

- Consult the MSDS for appropriate PPE and precautions, including gloves. Avoid dermal contact.
- Clean up spills of wet or dry material to avoid spreading it outside the work area.
- Fluon® is an inhalation hazard when burned.
- Fluon® is not effective at high humidity.
- Care must be taken not to scratch or abrade coated surfaces.

A light dusting of talcum powder on a surface can also prevent imported fire ants from climbing container walls for several days, depending on the number of ants involved. Imported fire ants can easily climb most untreated vertical surfaces and can chew through nonmetallic materials. Electric barriers have also been used to keep

imported fire ants in containers (Howell et al., 1982; Markin, 1968). Petroleum jelly and mineral oil can also be effective at preventing the ants from climbing surfaces for a period of time.

Certain preparations can be made in case fire ants escape the laboratory. We recommend keeping talcum powder handy everywhere imported fire ants are housed or transported for experiments or rearing. If ants breach a Fluon® barrier, a dusting of talcum powder on that surface will contain them long enough for a new container to be prepared. Having a vacuum handy to rapidly collect large numbers of ants, in case part or all of a colony escapes, is also a good idea. (It should be a bagless vacuum, with filter, that is easily cleaned out.) Alternatively, some researchers prefer to keep a broom and dustpan handy for minor escapes. If imported fire ants are housed in a room that is close to sensitive areas where ant escape could result in serious consequences (near other insect cultures, sensitive equipment, etc.), a multilayered containment system is recommended. Such a system might consist of:

1. Fluon® barrier on inside of rearing containers
2. Containers placed on a table or rack with legs immersed in small containers of soapy water, or placed directly in larger pans with soapy water (e.g., Khan et al., 1967). (Oil or talcum powder could be substituted for soapy water.)
3. Sticky insect trapping compound applied around doorframes and across thresholds.

Live ants can be disposed of by dumping them into a bucket of soapy water.

When working with imported fire ants in the laboratory, the following PPE is recommended:

- Laboratory gown or apron
- Latex, nitrile, neoprene, or dishwashing gloves
- Long pants
- Socks
- Shoes (no open toe shoes)

Gloves that fit snugly to give ants fewer folds and creases to grip and that facilitate brushing the ants off the hands are recommended. Household dishwashing gloves are more effective because of the longer cuffs. A light dusting of talcum powder on the gloves will also help prevent the ants from climbing onto an individual's hands (Banks et al., 1981). When handling plastic laboratory equipment with gloves, static electricity can become a problem. Static charges on trays containing imported fire ants can make the ants difficult to handle, causing them to literally fly out of the tray and onto workers. The use of nonstatic gloves or an antistatic gun or grounded mat can minimize problems. Appropriate PPE (e.g., gloves, eyewear, etc.) will depend on the exposure potential of the specific operation.

Small insects are frequently collected using aspirating devices. As a safety precaution, avoid typical mouth aspirating apparatuses for collecting large numbers of imported fire ants (imported fire ants release exocrine gland products when disturbed). Instead, use blowing aspirators, electric aspirators, or negative-pressure aspirators—such as an aspirator connected to a variable-rate valve, and in turn connected to a tank hooked to a vacuum pump. A similar system is described in Banks et al. (1981).

It is a good idea to check clothing periodically to locate imported fire ants before they reach bare skin, noting that imported fire ants are most easily seen against a light-colored background (e.g., white lab gown). Recommendations regarding PPE are given with the understanding that laboratory personnel who are practiced handling imported fire ants have different tolerances for stings. Supervisors may wish to provide gloves but not require workers to wear them, especially for tasks that require a great deal of dexterity, such as microscope work or sorting individual ants.

Training new personnel in effective handling procedures for imported fire ants is essential. Standard procedures for separating life stages of the ants (Banks et al., 1981), rearing procedures for parasitoids (e.g., Vogt et al., 2003), and other day-to-day operations require a certain degree of dexterity and some practice. It is recommended that new workers "shadow" a trained worker for a period of time to become familiar with all aspects of laboratory procedures, including safety and SOPs. Workers must be mindful of loose clothing, jewelry, and long hair, all of which provide easy routes for imported fire ants to reach the skin if dangled into trays or buckets containing ants (Drees & Ellison, 2002).

Chemical ecologists, biochemists, and immunologists may store and handle varying quantities of imported fire ant venom or whole-body extract. Currently, no commercial sources for imported fire ant venom exist, but whole-body extract is available and is used in diagnosis and immunotherapy (Hoffman, 2003). Care should be taken to avoid aerosolizing solutions to avoid sensitization by inhalation. Although fire ant venom is not commercially available, some laboratories may obtain small amounts of lyophilized material for research purposes; it is important to keep containers tightly sealed to avoid inhalation of material (D. Hoffman, personal communications).

## Best Practices in the Field

Hypersensitivity to fire ant venom can occur in an individual at any time after prior sensitization. Field personnel should be issued cellular phones so that they can contact emergency services if necessary. Also, close attention should be paid to where field vehicles are parked, and care should be taken to avoid being stung while exiting the vehicle, in case an imported fire ant mound was disturbed as the vehicle was parked. Vehicle interiors also

should be free of food wrappers, soft drink cans, and any other food sources that might attract foraging ants, which are often called "lard ants" or "grease ants" due to their attraction to greasy foods and sweets. Invasion of vehicles by foraging imported fire ants is a rare occurrence, but if a food source is detected by the ants, several hundred foraging ants can be in a vehicle within a relatively short (2 to 3 hours) time frame (JTV, personal observations). Barr (2003) advises extra caution around picnic sites and restrooms, roadsides (changing a tire or sightseeing), garbage receptacles, and fallen limbs or objects on the ground. With the exception of roadsides, these are areas where imported fire ants may find water, food, and/or structures that may conceal nests.

Clothing should include closed-toe shoes or boots, and socks. The longer the socks, the more time a worker will have to see imported fire ants crawling up the legs before they reach bare skin. Some people prefer to tuck their pants legs into their socks to reduce the ants' access to bare skin and to direct them to areas where they can easily be brushed off the clothing. Wearing socks helps delay stings (Jerome Goddard, personal communications). Unfortunately, no repellents are known to be effective at deterring attacking imported fire ants (Jerome Goddard, personal communications). Workers should watch where they step and check their lower body occasionally to be sure they are free of ants.

Latex, nitrile, neoprene, or dishwashing gloves may be worn in the field for tasks that involve handling imported fire ants. Talcum powder can be lightly dusted on any field equipment used to collect or handle ants—for example, if using a shovel to dig up ant colonies, dust the lower part of the handle to prevent ants from climbing (Banks et al., 1981; Drees & Ellison, 2002). If imported fire ants do get on the skin and begin biting and stinging, it is important to understand that they cannot be shaken or rinsed off. The most effective way to remove them is to brush them off (Barr, 2003). A piece of cloth can help to remove them.

Finally, fire ant populations can be reduced in sensitive areas by judicious use of insecticidal contact poisons and/or baits. Such areas might include areas around buildings (to reduce risk of ants foraging inside), places where equipment is stored on the ground, and places where people congregate for breaks or to process samples. Control of imported fire ants is beyond the scope of this paper; consult your local Agricultural Extension office for current recommendations and be sure to read, understand, and follow all label instructions on control products.

## Actions to Take if Stung

While very rare, a potentially life-threatening systemic reaction to stings can occur in sensitized individuals. This reaction is termed anaphylaxis or anaphylactic shock. All laboratory and field personnel should be required to learn the symptoms associated with anaphylaxis. These are:

- The skin frequently shows symptoms first. Hives, itching, swelling, redness, or a stinging or burning sensation may develop away from the sting.
- The loss of fluid from blood vessels causes a drop in blood pressure and the individual may feel light-headed or even lose consciousness.
- Anaphylaxis can cause obstruction of the nose, mouth, and throat. Individuals may first notice hoarseness or a lump in the throat. If the swelling is very severe, it shuts off the air supply and the individual experiences severe respiratory distress.
- The airways in the lungs can constrict, causing chest tightness, shortness of breath, and wheezing—the classic symptoms of asthma.
- The gastrointestinal tract often reacts, especially if the allergen is something that was swallowed. The person may experience nausea, vomiting, cramping, and diarrhea.
- Women may experience pelvic cramps due to contractions of the uterus (National Jewish Medical and Research Center, 2005).

Numerous Internet sites and Extension fact sheets list symptoms and most include neurological symptoms such as an "impending sense of doom" felt by the victim. Sting victims who voice such concerns should be taken seriously, and medical attention should be sought immediately. Some people are more likely to suffer severe reactions to stings than others; these include multiple-sting victims, people who have suffered stings before, people who have allergies to other insect stings or other severe allergies, and people who are immunosuppressed. It has been recommended that hypersensitive individuals carry an injector kit containing a preloaded epinephrine injector (or syringe) because immunotherapy can be an effective tool to reduce the risk of anaphylaxis (Freeman et al., 1992). People who believe they may be hypersensitive should consult with an allergist (Solley et al., 2002). Fire ant whole-body extract is the only reagent presently available for immunotherapy for fire ant venom allergy (Stafford, 1996). Those who are sensitive to insect stings should probably not begin working with imported fire ants.

Numerous recommendations regarding first aid for fire ant stings can be found in Extension publications and on the World Wide Web. Much of the information is duplicative, and rather than cite numerous sources, this article provides general information (common between sources) that supervisors and workers should be aware of. It should be noted that once a fire ant stings, injecting venom into the skin, pustule formation is not stopped by application of topical steroids, antibiotics, or epinephrine (Parino et al., 1981). For typical reactions to stings (burning sensation, localized reaction, and pustule formation), some reasonable steps can be taken to lessen discomfort and help prevent secondary infection. Alterna-

tively, most people can usually do nothing at all, and the pustules will eventually fade. The majority of available sources have the following suggestions in common:

- Apply a cold compress to the affected area and elevate it.
- Gently wash the affected area with soap and water, taking care not to break the blisters.
- Use over-the-counter sting relief medications if desired.

It is important that sting victims resist the temptation to scratch the affected area, since breaking the blisters or pustules can result in serious secondary infection. Infections can be far more serious than the initial sting and pustule formation.

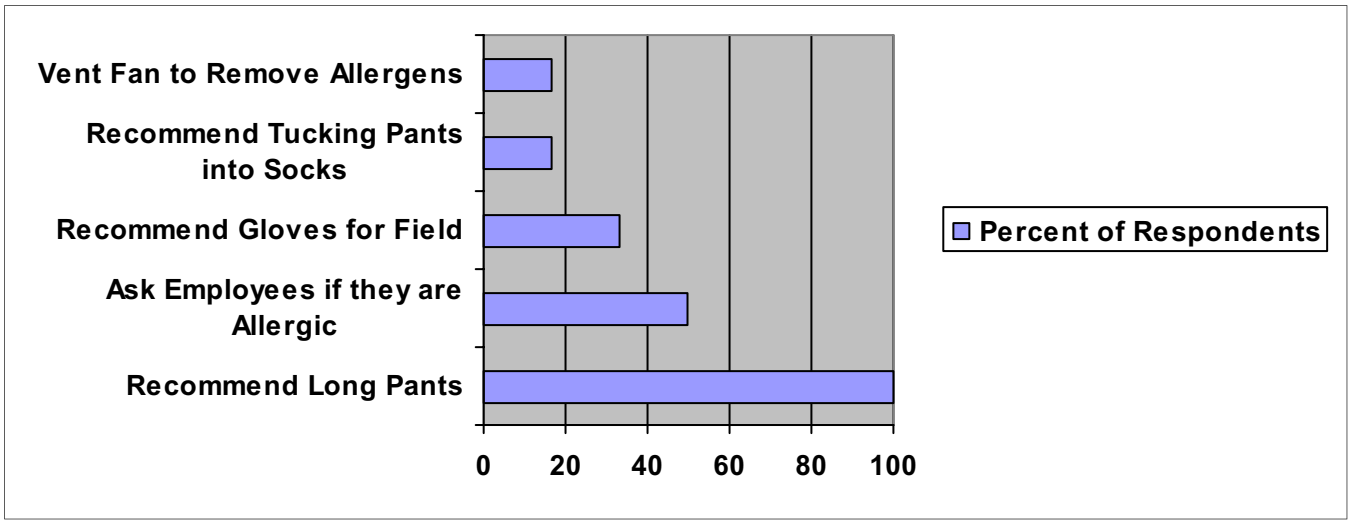
Relatively few people responded (N = 6) to the informal poll distributed by the authors; nonetheless, some interesting information regarding fire ant safety can be gleaned from the responses. None of the respondents had any formal SOPs in place for handling imported fire ants, and no respondents indicated that they required PPE in the laboratory or field, although one indicated that long pants and closed-toe shoes are a requirement in the workplace. Eighty-three percent indicated that they provide gloves in the laboratory and/or field but do not require personnel to wear them; 50% of respondents also provided rubber boots in the field. Additional information from the poll is given in Figure 5. Only one respondent indicated that a vent fan was present in the rearing facility to maintain negative pressure and remove potential allergens; however, the poll's questions were open-ended so it is unclear if other participants may have had similarly equipped facilities. Adequate building ventilation (e.g., BSL-2 laboratory) is recommended for any insect-rearing facility. One respondent indicated that Benadryl® and sting ointments were provided in first aid kits, but epinephrine autoinjectors were not due to legal concerns and the potential consequences of administering medication without the required licensing or training. Providing medication in first aid kits could lead to similar consequences should someone have an adverse reaction to the medication or experience other problems. The general consensus among respondents was that doing nothing (other than avoiding scratching) and allowing the blisters to fade naturally were the best courses of action if stung.

## Conclusion

Imported fire ants are a potential hazard to laboratory and field personnel. Suggested PPE and safety precautions may be useful for lessening the incidence or frequency of stings, but there are no foolproof methods for avoiding stings altogether. The recommendations contained herein are provided for information only, with the realization that individuals who have experience with imported fire ants can generally assess their own tolerance for stings and act accordingly. At a minimum, everyone involved in any aspect of fire ant research who risks stings should be familiar with the symptoms of anaphylaxis. Access to a landline or cellular telephone to summon emergency help if necessary would also be helpful. Surprisingly, the only mention of this in the informal poll, other than asking new hires if they are allergic to stings, was made by two respondents who indicated that "additional precautions" would be taken if a worker exhibited sensitivity to stings. New personnel, especially those who are unfamiliar with imported fire ants, should

**Figure 5**

Results of an informal poll of fire ant researchers indicating the percent of respondents (N = 6) who recommend various safety precautions when working with imported fire ants.



receive appropriate, task-specific training on safety and handling procedures for imported fire ants. Supervisors should be certain that employees understand the risks inherent in working with imported fire ants and encourage them to make informed decisions regarding their risk through consultation with an occupational health professional and/or allergist. Workers should be prepared at all times to deal with potentially life-threatening anaphylaxis and should not hesitate to seek emergency medical care if they or their coworkers experience symptoms. While the vast majority of people have no adverse reaction to stings other than some discomfort and pustule formation, a quick decision to call for help could mean the difference between life and death for an unfortunate few.

## Acknowledgements

We thank Jerome Goddard (Mississippi State Department of Health), Donald R. Hoffman (East Carolina University, Department of Pathology and Laboratory Medicine), Sanford D. Porter (USDA, ARS Center for Medical and Veterinary Entomology), and two anonymous reviewers for many helpful comments on an earlier version of this manuscript.

### Authors' Note

Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. Information is not intended as a substitute for professional medical advice or treatment.

### Copyright Permission Disclaimer



## References

Adams, E. S. (2003). Experimental analysis of territory size in a population of the fire ant *Solenopsis invicta*. *Behavioral Ecology, 14*, 48-53.

Banks, W. A., Lofgren, C. S., Jouvenaz, D. P., Stringer, C. E., Bishop, P. M., Williams, D. F., Wojcik, D. P., & Glancey, B. M. (1981). Techniques for collecting, rearing, and handling imported fire ants. *U.S. Department of Agriculture Bulletin AAT-S-21*, 9.

Barr, C. L. (2003). Welcome to Texas: Avoiding the sting of imported fire ants. *Texas Cooperative Extension Service, Fire Ant Plan Fact Sheet #041*, 4.

Bousquet, J., Menardo, J. L., Aznar, R., Robinet-Levy, M., & Michel, F. B. (1984). Clinical and immunological survey in beekeepers in relation to their sensitization. *Journal of Allergy and Clinical Immunology, 73*, 332-340.

China Daily. (2005). Red fire ant sting sends villagers to hospital. Available at www.chinadaily.com.cn/english/doc/2005-01/26/content_412251.htm. Accessed online 2005.

CNA News. (2005). Onslaught of alien red imported fire ants under control: CKS Airport. Available at http://english.www.gov.tw/index.jsp?action=cna&cnaid=4784. Accessed online 2005.

Davis, L. R., Jr., Vander Meer, R. K., & Porter, S. D. (2001). Red imported fire ants expand their range across the West Indies. *The Florida Entomologist, 84*, 735-736.

Drees, B. M., & Ellison, S. L. (2002). Collecting and maintaining colonies of red imported fire ants for study. *Texas Cooperative Extension Service, Fire Ant Plan Fact Sheet #008*.

Freeman, T. M., Hylander, R., Ortiz, A., & Martin, M. E. (1992). Imported fire ant immunotherapy: Effectiveness of whole body extracts. *Journal of Allergy and Clinical Immunology, 90*, 210-215.

Hoffman, D. R. (2003). Hymenoptera venoms: Composition, standardization, stability. In M. L. Levine & R. F. Lockey (Eds.), *Monograph on insect allergy* (pp. 37-53). Milwaukee, WI: American Academy of Allergy, Asthma and Immunology.

Hoffman, D. R., Dove. D. E., Moffitt, J. E., & Stafford, C. T. (1988). Allergens in Hymenoptera venom. XXI. Cross-reactivity and multiple reactivity between fire ant venom and bee and wasp venoms. *Journal of Allergy and Clinical Immunology, 82*, 828-834.

Howell, G., Butler, J., DeShazo, R. D., Farley, J. M., Liu, H. L., Nanayakkara, N. P., Yates, A., Yi, G. B., & Rockhold, R. W. (2005). Cardiodepressant and neurologic actions of *Solenopsis invicta* (imported fire ant) venom alkaloids. *Annals of Allergy and Asthma Immunology, 94*, 380-386.

Howell, H. N., Moore, W. S., & Granovsky, T. A. (1982). An improved electric barrier for confining insects in containers. *Southwestern Entomologist, 7*, 260-262.

Johnson, B, Mastnjak, R., & Resnick, G. (2000). Safety and health considerations for conducting work with biological toxins. In J. Richmond (Ed.), *Anthology of biosafety II: Facility design considerations* (pp. 88-111). Mundelein, IL: ABSA.

Kemp, S. F., deShazo, R. D., Moffitt, J. E., Williams, D. F., & Buhner, W. A. (2000). Expanding habitat of the imported fire ant (*Solenopsis invicta*): A public health concern. *Journal of Allergy and Clinical Immunology, 105,* 683-691.

Khan, A. R., Green, H. B., & Brazzel, J. R. (1967). Laboratory rearing of the imported fire ant. *Journal of Economic Entomology, 60,* 915-917.

Korzukhin, M. D., Porter, S. D., Thompson, L. C., & Wiley, S. (2001). Modeling temperature-dependent range limits for the fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae) in the United States. *Environmental Entomology, 30,* 645-655.

Kozlovac, J. P., & Hawley, R. J. (2005; In Press). Biological toxins: Safety and science. In D. Fleming & D. Hunt (Eds.), *Biological safety: Principles and practices* (4th ed.). Washington, DC: ASM Press.

Lofgren, C. S. (1986). History of the imported fire ants in the United States. In C. S. Lofgren & R. K. Vander Meer (Eds.), *Imported fire ants and leaf-cutting ants: Biology and management* (pp. 36-47). Boulder, CO: Westview Press.

MacConnell, J. G., Blum, M. S., & Fales, H. M. (1971). The chemistry of fire ant venom. *Tetrahedron, 26,* 1129-1139.

Markin, G. P. (1968). Handling techniques for large quantities of ants. *Journal of Economic Entomology, 61,* 1744-1745.

Markin, G. P., O'Neil, J., & Dillier, J. H. (1975). Foraging tunnels of the red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae). *Journal of the Kansas Entomological Society, 48,* 83-89.

McCubbin, K. I., & Weiner, J. M. (2002). Imported fire ants in Australia: A new medical and ecological hazard. *Medical Journal of Australia, 176,* 518-519.

National Jewish Medical and Research Center. (2005). *Anaphylaxis.* Available at www.nationaljewish.org/medfacts/anaphalaxis.html. Accessed online 2005.

Parrino, J., Kandawalla, N. M., & Lockley, R. F. (1981). Treatment of local skin response to imported fire ant sting. *Southern Medical Journal, 74,* 1361-1364.

Reichmuth, D. A., & Lockey, R. F. (2003). Clinical aspects of ant allergy. In M. L. Levine & R. F. Lockey (Eds.), *Monograph on insect allergy* (pp. 133-151). Milwaukee, WI: American Academy of Allergy, Asthma and Immunology.

Shoemaker, D. D., Ross, K. G., & Arnold, M. L. (1994). Development of RAPD markers in two introduced imported fire ants, *Solenopsis invicta* and *Solenopsis richteri*, and their application to the study of a hybrid zone. *Molecular Ecology, 3,* 351-359.

Showler, A. T., Knaus, R. M., & Reagan, T. E. (1990). Studies of the territorial dynamics of the red imported fire ant (*Solenopsis invicta* Buren, Hymenoptera, Formicidae). *Agriculture, Ecosystems and Environment, 30,* 97-105.

Solley, G. O., Vanderwoude, C., & Knight, G. K. (2002). Anaphylaxis due to red imported fire ant sting. *Medical Journal of Australia, 176,* 521-523.

Stafford, C. T. (1996). Hypersensitivity to fire ant venom. *Annals of Allergy and Asthma Immunology, 77,* 87-95.

Tracy, J. M., Demain, J. G., Quinn, J. M., Hoffman, D. R., Goetz, D. W., & Freeman, T. M. (1995). The natural history of exposure to the imported fire ant (*Solenopsis invicta*). *Journal of Allergy and Clinical Immunology, 95,* 824-828.

USDA, Animal and Plant Health Inspection Service. (2005). *Imported fire ant quarantine.* Available at www.aphis.usda.gov/ppq/maps/fireant.pdf. Accessed online 2005.

Vander Meer, R. K., Lofgren, C. S., & Alvarez, F. M. (1985). Note: Biochemical evidence for hybridization in imported fire ants. *Florida Entomologist, 68,* 501-506.

Vinson, S. B. (1997). Invasion of the red imported fire ant (Hymenoptera: Formicidae): Spread, biology, and impact. *American Entomologist, 43,* 23-39.

Vogt, J. T., Porter, S. D., Nordlund, D. A., & Smith, R. (2003). A modified rearing system for production of Pseudacteon curvatus (Diptera: Phoridae), a parasitoid of imported fire ants. *Biological Control, 28,* 346-353.