6. Pharaoh ants and fire ants

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Summary

Pharaoh ants are cosmopolitan pests that inhabit residential and commercial buildings. While they do not sting, they have the potential to mechanically transmit diseases and thus are of special concern in health care facilities. Their propensity to breach sterile packaging, feed on wounds, and extensively infest large buildings makes them a public health risk. However, published economic impact data on these ants is minimal. Control measures for Pharaoh ants are effective when implemented properly. Baits that contain IGRs or metabolic inhibitors can eliminate infestations within a few weeks. Faster control with applications of non-repellent residual insecticides to building perimeters has been reported. Because Pharaoh ants can be easily transported, monitoring and treatment will be an ongoing process to maintain acceptable control.

Fire ants are stinging, invasive ants from South America that have infested the southern United States since the 1930s. They now seem to be invading other parts of the world, as evidenced by recent infestations in Australia and South-East Asia. Most of Europe is too cold for the proliferation and spread of fire ants. However, countries along the Mediterranean and Black seas have suitable climates for fire ants to become established. The economic cost of fire ants in the United States is an estimated US$ 6.5 billion annually, with the majority of the losses in the urban sector. In infested areas of the United States, 30–60% of the population is stung annually, of which anaphylactic shock was conservatively estimated to occur in 1% of the victims. Litigation settlements of over US$ 1 million have been awarded for deaths related to fire ant stings. The significant impact of fire ants confirms the importance of preventing their establishment in new regions. Countries at risk for infestations should have a centralized coordinated response plan that includes regulatory clearance and manufacturing source(s) for insecticide treatments. To combat these ants, surveillance methods that can detect low levels of fire ant populations are direly needed. Baits can effectively control fire ants and non-repellent residual insecticides can provide extended control. Selection of treatment regimes for controlling fire ants should consider fire ant tolerance and the liability of a treatment regime for each land-use pattern.

In this chapter the biology of each species is briefly reviewed and is followed by discussions of the health hazard they present, their public health and economic impacts, methods of monitoring and control, and a discussion on emerging issues and needs.

6.1. Overview of biology and distribution in Europe and North America

6.1.1. Pharaoh ant biology

Pharaoh ants (*Monomorium pharaonis*) are a worldwide pest associated with human habitats. They are small (2mm long), with color variations that range from yellow to yellowish-brown to even a light red. Pharaoh ants do not sting, but are a nuisance to building occupants and an important contamination concern in medical and food preparation and processing facilities. They can nest in a variety of easily transported items, such as boxes and packaging, sheets of stationery, linen and clothes, and other items that offer harbourage (Smith, 1965). In addition, colonies can be initiated from small groups of worker caste ants and immature ants, or brood (Peacock, Sudd & Baxter, 1955a). Vail & Williams (1994) reported founding colonies from just 5 adult workers, 30 eggs, 19 larvae, and 3 pupae. Since colonies can be easily transported through commerce, the distribution of Pharaoh ants is worldwide, with these ants being present throughout Africa, Australia, Europe, the Hawaiian islands, Japan, North America (Canada and the United States), the Russian Federation and South America (Edwards, 1986; Reimer, Beardsley & Jahn, 1990).

Pharaoh ants can survive in a wide range of environmental conditions, but they thrive in warm, humid conditions of about 27–30°C and 70–80% relative humidity (Peacock & Baxter, 1949; Samšiňák, Vobrázková & Vaňková, 1984). Edwards (1986) indicated that Pharaoh ants could probably survive temperatures up to 45°C, if water was available. Since these types of conditions can occur in microenvironments within buildings, Pharaoh ant colonies typically occur indoors (Sudd, 1962; Smith, 1965). However, they are known to nest outdoors in subtropical climates (Vail, 1996) and even in temperate areas where warmth is maintained (Kohn & Vlček, 1986). The lower limit for colony survival is a sustained temperature of about 18°C. At 6–11°C, colony death can occur within 7 days, yet colonies can survive a few days of such cold and recover if conditions become favourable (Peacock, Waterhouse & Baxter, 1955; Edwards, 1986).

Pharaoh ants do not have mating flights that are typical of other ants. Instead, they mate within or near the nest, and new colonies form when a group of adult workers and brood move, or bud, from the original colony. It is not necessary for a queen(s) to be part of the budding colony (Peacock, Sudd & Baxter, 1955a). Colonies of Pharaoh ants can be comprised of several nests, with free movement among nests. Colony sizes vary tremendously, with 35 adult workers, 35 pupae, larvae or eggs, and a queen being reported as one the smallest natural colonies, while laboratory colonies of 400 queens and 50 000 workers have been reared (Peacock, Sudd & Baxter, 1955a,b; Williams & Vail, 1993) (Fig. 6.1). Egg-to-adult development time for Pharaoh ant workers is 22–54 days (Alvares, Bueno & Fowler, 1993), and adult worker longevity is 9–10 weeks, with queens living up to 39 weeks (Peacock & Baxter, 1950). Edwards (1986), however, observed queens living beyond 52 weeks in the laboratory.

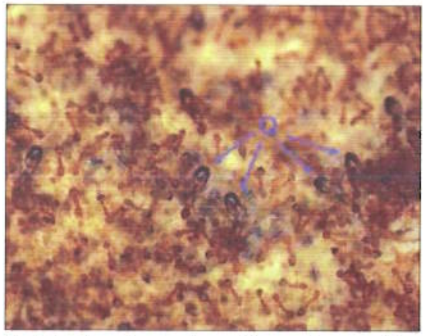


Fig. 6.1. Pharaoh ant colony with several queens (Q)

Source: Photo by S.D. Porter.

6.1.2. Fire ant biology

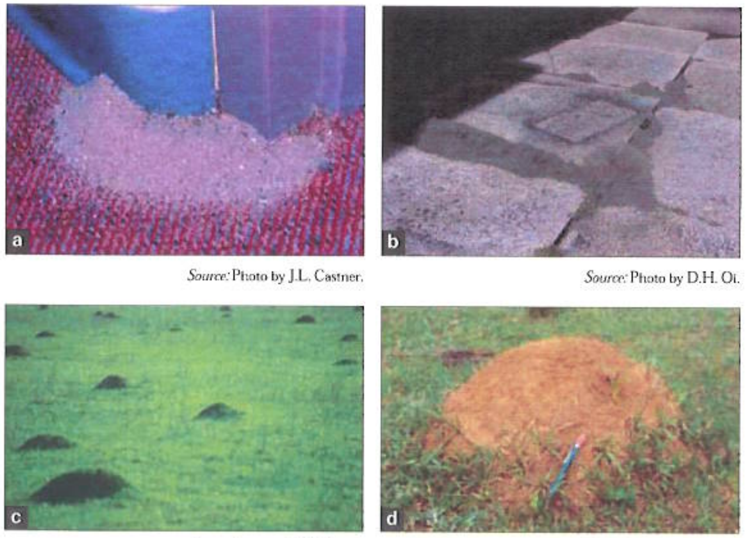
Fire ants are stinging ants whose name most commonly refers to the aggressive and invasive species *Solenopsis invicta*, which has an official common name of the red imported fire ant. They are a reddish brown to black ant, 3.2–6.4 mm in length. In addition to red imported fire ants, the names *fire ant* and *imported fire ant* also refer to another ant species, *Solenopsis richteri*, the black imported fire ant. Both of these species were accidentally introduced separately from South America into the United States before 1935 (Tschinkel, 2006) and have since spread throughout the southern United States. Of the two species, the red imported fire ant is more widespread, with the black imported fire ant restricted to northern pockets in the states of Mississippi and Alabama, and portions of Tennessee. In areas where the species overlap, they have hybridized. The majority of research and control efforts are for red imported fire ants, and most recommendations are applicable to both species. Since 1998, the red imported fire ant has significantly extended its geographic distribution – most likely through commerce. Well-established infestations were reported in California in 1998, in Australia in 2000, in Taiwan, China, in 2004, and in China, Hong Kong Special Administrative Region (Hong Kong SAR), China and in Mexico in 2005. Prior to the entry of black imported fire ants and red imported fire ants into the United States, four other species of fire ants were established in North America: the tropical fire ant (*Solenopsis geminata*), the southern fire ant (*Solenopsis xyloni*), and two species that inhabit the desert (*Solenopsis aurea* and *Solenopsis amblychila*). In areas where they overlapped, the red imported fire ant has displaced the southern fire ant.

Given adequate warmth and moisture, their tremendous reproductive capacity, mobility and stinging ability have allowed the red imported fire ant to become a dominant arthropod in the areas it invaded. Colonies of red imported fire ants can survive and reproduce over a temperature range of 20–35°C, with optimal temperatures of 27–32°C (Porter, 1988; Williams, 1990a). Moisture is critical for the survival of red imported fire ants, where a minimum 510 mm of annual precipitation has been estimated to be a reasonable threshold for sustaining a colony (Korzukhin et al., 2001). Because colonies are very mobile and can easily relocate within a day, red imported fire ants can occupy seemingly inhospitable habitats by moving to more favourable niches as environmental conditions change.

Fire ants develop from eggs, through four stages of larvae, to pupae and finally to adults. Depending on temperature, red imported fire ant development time, from egg to adult, ranges from 20 to 45 days. Adult workers can live as long as 97 weeks; however, depending on size and temperature, life spans normally range from 10 to 70 weeks (Hölldobler

& Wilson, 1990). Queens can live as long as 5–7 years (Tschinkel, 1987), with maximum egg-laying rates of over 2000 eggs a day (Williams, 1990a).

Fire ant colonies also contain a reproductive caste of non-stinging, winged males and females (alates) that initiate new colonies. Alates usually fly from the nest and mate during flight in late spring and early summer (although flights have been reported for all months). These mated females, or newly mated queens, have been reported to fly as far as 19.3 km from the nest (or even farther when aided by wind) during these mating flights, but most land within 1.6 km of their nest (Markin et al., 1971). After landing, newly mated queens move to a protected, moist harbourage – for example, in soil, under debris or in crevices – that can serve as an initial nesting site. Males die after mating. After landing, a queen sheds her wings and lays a clutch of eggs and tends them until adult workers develop from pupae. Worker ants will then tend the queen and additional eggs that are laid, and eventually a colony can grow exponentially. After six weeks, a new nest may be barely noticeable; after six months, however, nests 5–13 cm in diameter can be detected more easily. Very large, mature colonies, a few years old, can construct nests over a 0.9m in basal diameter and 0.9m high. Nest sizes and shapes can vary with habitat and soil type (Fig. 6.2). Over 4500 alates can be produced annually in large colonies (Tschinkel, 1986), but it is speculated that less than 0.1% of the newly mated queens will successfully found a colony (Taber, 2000).



Source: Photo by J.L. Castner.

Source: Photo by D.H. Oi.

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Fig. 6.2. Fire ant nests

Note. (a) Inside a building; (b) under pavement stones; (c) in a pasture; (d) large, old nest in clay soil.

Colonies of red imported fire ants consist of two types:

1. colonies with only a single, fertile queen, or *monogyne* colonies
2. colonies with multiple fertile queens, or *polygyne* colonies.

Monogyne colonies are territorial, and thus fight with other colonies of red imported fire ants. As a result of this antagonistic behaviour, nests are farther apart, with densities of 99–370 nests/ha and with 100 000–240 000 ants per colony. In contrast, polygyne colonies are not antagonistic to other polygyne colonies, and thus queens, workers and immature ants (brood) can move between nests. The visible mound structure of polygyne nests are usually smaller in size and closer together than monogyne mounds, with densities of 494–1976 mounds/ha and with 100 000–500 000 ants per mature colony. Discriminating between individual nests or colonies in polygyne populations is uncertain, but in general, polygyne populations contain nearly twice the number of worker ants (35 million/ha versus 18 million/ha) and biomass per unit area than monogyne populations (Macom & Porter, 1996). Distinguishing between monogyne and polygyne colonies without locating fertile queens can now be accomplished through molecular markers (Valles & Porter, 2003).

6.2. Health hazards

6.2.1. Pharaoh ant infestations: pathogen transmission and contamination

For most residential situations, Pharaoh ants are a nuisance pest – they do not sting and their bite does not pierce human skin. However, their ability to establish colonies without constructing a separate nest structure and their large worker populations can make infestations in large buildings widespread and potentially disruptive to occupants, resulting in less productivity (Eichler, 1990). Of more serious concern are infestations in hospitals, because of the documented potential of Pharaoh ants to carry pathogens. Beatson (1972) isolated pathogenic bacteria of the genera *Pseudomonas, Salmonella, Staphylococcus, Streptococcus, Klebsiella* and *Clostridium* from Pharaoh ants collected in nine hospitals. Beatson also reported on cross-infection of a pneumonia pathogen in piglets by Pharaoh ants, despite the animals being held in an isolation unit. Mechanical transmission of a plague organism from Pharaoh ants that fed on infected animal carcasses demonstrates how their foraging behaviour can lead to transmission of disease (Alekseev et al., 1972). The propensity of Pharaoh ants to forage on wounds (Cartwright & Clifford, 1973; Eichler, 1990) and to infest institutional kitchens, thereby contaminating food, may all provide opportunities for transmitting pathogens. It has also been hypothesized that pathogens carried back to the nest may proliferate in the environs of the warm, humid nest and possibly be passed on to other colony members, increasing the probability of spread (Beatson, 1972; Edwards, 1986). Contamination of sterile instruments and supplies by Pharaoh ants chewing through packaging is a common problem (Beatson, 1972, 1973). Specific documentation of Pharaoh ant contamination affecting patients has not been reported, however.

6.2.2. Fire ant exposure: hazards related to stings and allergic reactions

The painful, burning sensation that is inflicted by the sting of a fire ant is easily the most recognizable hazard to people. While one sting is painful, it is not uncommon for a person to receive numerous stings simultaneously when ants swarm out of their nest to attack an intruder. This greatly intensifies the pain and can cause panic; thus, fear or apprehension of these ants can be present in heavily infested or newly infested areas. Stings are caused by adult worker ants injecting venom that contains mostly alkaloids. Such stings result in the immediate burning sensation at the sting site. Typically, this is followed by a wheal-and-flare response within 20 minutes, and then a sterile pustule forms within 24 hours (Kemp et al., 2000), which is accompanied by intense itching. Itchiness may persist for several days and infection may occur if pustules are broken. Large local reactions may occur in some stung individuals (17–56%), where an itching, hardened, reddish swelling develops several hours after the sting and persists 24–72 hours. This response resembles reactions caused by stings of other insects and may affect an entire extremity. Although no known treatment effectively prevents pustule formation or hastens healing (Kemp et al., 2000), topical insect bite treatments may help reduce itchiness (deShazo, Butcher & Banks, 1990).

Allergic or systemic reactions can vary from generalized itching, swelling and redness to anaphylaxis (a sudden, severe, potentially fatal, allergic systemic reaction). Surveys have reported anaphylactic reactions in 0.6–16% of individuals stung. Anaphylaxis may occur hours after a sting, with the formation of the sterile pustule(s), which distinguishes fire ant stings from other insect stings as the cause of the reaction (Kemp et al., 2000). Systemic reactions to fire ant stings usually occur in individuals sensitized by previous fire ant stings (Freeman et al., 1992). Sensitization rates of 16% and 17% from fire ant stings have been reported by Tracy and colleagues (1995) and Caplan and colleagues (2003), respectively. Thus, potentially 13 million people may be at risk for allergic reactions in fire ant infested areas in the United States (Caplan et al., 2003). Rapid sensitization may also occur. A three-week exposure to a fire ant endemic location by 107 non-sensitized individuals resulted in a sting rate of 51% and the development of fire-ant-specific antibodies in 16% of the subjects (Tracy et al., 1995).

There is also evidence of cross-reactivity with yellow-jacket wasp (*Vespula germanica*) venom. Unlike bee, hornet and wasp venoms that are mostly aqueous solutions containing proteins, red imported fire ant venom is a 95% water-insoluble alkaloid, with the remaining portion being an aqueous solution that contains four major allergenic proteins. It is a portion of these proteins that cross-reacts with *Vespula* venoms. Black imported fire ant venom has three of the four major allergenic proteins found in red imported fire ant venom (Kemp et al., 2000). Immunotherapy with injections of whole body fire ant extracts has been used to treat fire ant allergy (Freeman et al., 1992).

6.3. Exposure and risk assessment, with risk based on geographical location

6.3.1. Pharaoh ant distribution and population monitoring

Colony proliferation by budding, with and without the presence of mature queens and the suitability of small harbourages as nest sites, has contributed greatly to the worldwide spread of Pharaoh ants via commerce. This spread probably occurred before and after the original description by Linnaeus in 1758 of a Pharaoh ant specimen collected in Egypt. Pharaoh ant infestations are documented throughout Europe and North America (Edwards, 1986). In tropical and subtropical climates, infestations can extend outdoors; in temperate areas, heated buildings and man-made heat sinks permit winter survival and even colony growth (Kohn & Vlček, 1986; Vail, 1996). Colonies can have interconnected nest sites, and movement to suitable habitats, as environments change, permits the ants to become established in new sites. The movement of infested articles, packaging and luggage can also initiate infestations in buildings (Smith, 1965). Buildings with a high turnover or exchange of occupants, or shared services (such as laundry and equipment), such as hospitals and hotels, may have a higher risk of infestation (Edwards & Baker, 1981).

Monitoring populations of Pharaoh ants includes visual counts of trailing ants or counts of the number of trails present. Because Pharaoh ants are omnivorous, a variety of food lures (such as raw liver, jelly, peanut butter, honey and sugar solutions) have been used to locate and quantify their presence, generally for research studies (Edwards & Clarke, 1978; Haack, 1991; Oi et al., 1994). In laboratory testing, Williams (1990b) reported lard and several types of honey as being most accepted by Pharaoh ants. In general, a food lure is placed at various intervals on the interior and exterior of a building and near a suspected harbourage, and near food and water sources. After 2–24 hours (depending on foraging activity), lures are examined for Pharaoh ants, with the lure location and number of ants recorded.

6.3.2. Fire ant geographic range and potential expansion

The red imported fire ant is thought to originate from the Pantanal, a flood plain of the Paraguay River in south-western Brazil and parts of Bolivia and Paraguay, where it is adapted to the seasonal flooding and seems to have a confined distribution along the Paraguay and Paraná rivers (Allen et al., 1974; Buren et al., 1974; Vander Meer & Lofgren, 1990). The biotic and abiotic constraints on red imported fire ants found in South America are not present in North America (Buren et al., 1974; Porter, Fowler & Mackay, 1992), and thus its geographic distribution currently covers over 129.5 million ha in 13 states in the United States and in Puerto Rico. It also infests several islands in the West Indies (Davis, Vander Meer & Porter, 2001). Fig. 6.3 shows the counties and states in the United States under the imported fire ant quarantine, where movement of materials that potentially harbour fire ants are regulated. The red imported fire ant has been expanding its geographic range in the United States since its arrival there (Callcott & Collins, 1996). Based on climatic temperature and precipitation data, Korzukhin and colleagues

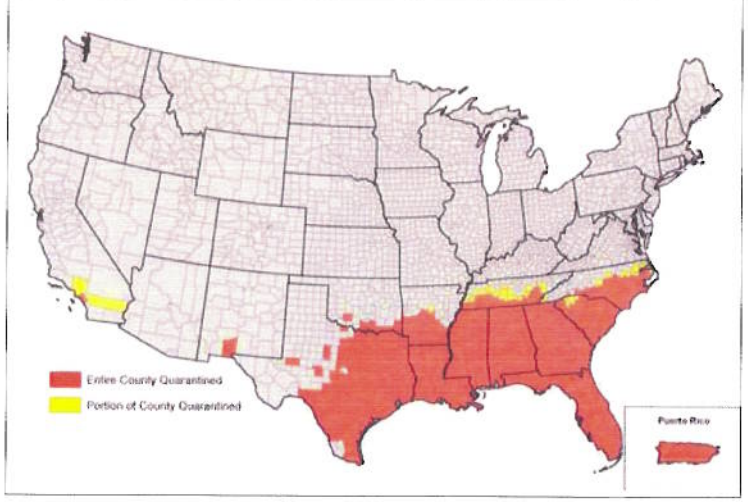

Fig. 6.3. Counties in the United States under imported fire ant quarantine

Source: Map from USDA-APHIS (2006).

(2001) predicted that its range certainly could be extended to include: the more northerly areas of Oklahoma, Arkansas and Tennessee; maritime Virginia; western Texas; and substantial portions of New Mexico, Arizona, California and Oregon. Infestations also could become established in Washington, Utah, Nevada, Delaware and Maryland (Fig. 6.4). Note that these predictions were based on interpolated weather data and do not account for natural and man-made microhabitats that may permit red imported fire ants to survive and become established.

Morrison and colleagues (2004) used worldwide temperature and rainfall patterns to predict the potential global distribution of red imported fire ants. For Europe, the areas surrounding the Mediterranean and Black seas are suitable for establishing fire ant colonies. These include, but are not limited to, the countries of Portugal, Spain, (southern) France, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Albania, Greece and Turkey. Temperature patterns also suggest possible infestations on the south-western coast of France and southern England. For the majority of Europe, temperatures are too cold; however, urbanized areas with artificial heat can provide suitable habitats. These predictions were based on interpolated weather station data and do not account for natural and man-made microhabitats that may permit red imported fire ants to survive and establish colonies. If fire ant incursions do become established in Europe, cold climates will most likely slow and restrict the range of geographic expansion.

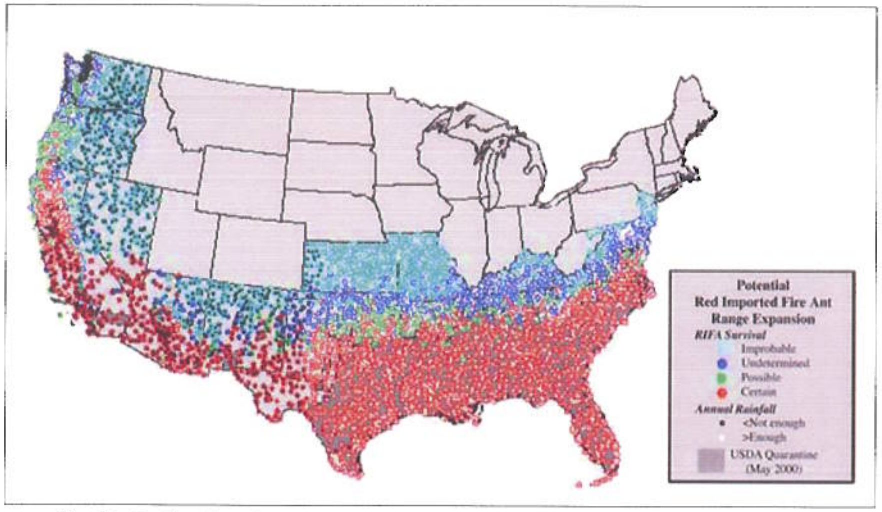

Fig. 6.4. Predicted invasion by red imported fire ants in continental United States

Source: Map from Korzukhin et al. (2001).

6.3.2.1 Fire ant population assessment and monitoring methods

Within infested areas, fire ant populations have generally been quantified by using nest density in 0.05–0.2 ha plots or along measured paths (called transects) established within study sites. In the first method of quantifying fire ant populations, the number of active nests is counted within each plot, and each individual nest is categorized as being inactive, low, moderately active or active. Category assignments are generally based on the number and rate of ants exiting a nest minimally disturbed by the insertion of a thin probe; criteria for activity categories, however, vary among researchers. Another population assessment system, used extensively by United States Department of Agriculture (USDA) researchers, assigns population indices to active nests, according to visual estimates of adult worker numbers and the presence or absence of worker caste brood after the nest is partially opened with a shovel. The absence of worker brood is an indication of a declining colony (Lofgren & Williams, 1982). Dimensions of individual nests also have been measured to calculate nest volume (Tschinkel, 1993). A more traditional method of sampling ants and other arthropods involves setting pitfall traps: arthropods fall and drown in the trap, which consists of a vial or container partially filled with a liquid (such as soapy water or automotive anti-freeze solution) inserted flush to the ground. Traps are collected after a few days to weeks and their contents identified. Pitfall traps are often used to sample both fire ants and other ants, to determine ant diversity and abundance. All the above methods are used for research, are labour intensive and require training.

Monitoring fire ant populations can be simplified by surveying for the presence or absence of fire ants with an attractive food source or lure. Vegetable oils and fatty foods have been used to detect the presence of fire ants, because they mainly attract ants that will feed on lipids. This is in contrast to liquid carbohydrates or foods sweetened with sugar, which will attract all types of ants and thus are not as selective as lipid-based foods. Examples of foods used to survey for the presence of fire ants include potato chips, cookies with high fat content, peanut butter, ground beef, canned fish packed in oil and processed meat products, such as sausages, hot dogs, wieners and canned luncheon meat. If such items are not available, any conveniently handled food with a high fat or lipid content could be substituted. Once the food lure is chosen, it is set on the ground along transects or grid patterns, for 30–60 minutes, and then checked for the presence of fire ants. Combining the use of bait stations with recording actual nest locations, while servicing the stations, can provide an efficient method of monitoring fire ant populations. However, the location of baits with fire ants does not always coincide with individual nest positions (Oi, Watson & Williams, 2004).

Long-range, pheromone-based surveillance traps are currently not available for fire ants. To help prevent fire ant incursions, agricultural border or port inspections of potential nest material or harbourages, such as nursery stock and earth-moving equipment, are necessary. The United States Federal Imported Fire Ant Quarantine, which is enforced by the United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS), lists items whose movement from quarantine areas are regulated by state and federal quarantine officials (USDA-APHIS, 2005) and could serve as a basis for targeted inspections in Europe. Identifying commodities from fire ant infested countries can further narrow inspections to high-risk importations. Making transporters and recipients of regulated items aware of signs of fire ants should also aid in early detection.

6.4. Public health impact

6.4.1. Pharaoh ants: prevalence in hospitals

A survey of half the hospitals in England indicated that Pharaoh ant infestations occurred in over 10% of the hospitals (Edwards & Baker, 1981). In South America, Pharaoh ants were reported to be common in hospitals and health care centres and were thought to be associated with hospital infections (Fowler et al., 1990). Besides the environmental conditions found in hospitals that are conducive to the establishment and growth of Pharaoh ant colonies, Burrus (2004) reported that dextrose solutions and dietary supplements commonly used in hospitals were potential food sources, as drips or spills made them accessible to ants. Pharaoh ants have been reported in giving sets (supplies for intravenous fluids) (Beatson, 1973). Whether patients lost significant amounts of medication or sustenance, either by direct ant feeding from dispensers or by equipment malfunction, was not documented.

6.4.2. Fire ants: stinging incidents

Extreme fire ant sting incidents are not systematically reported nationally or regionally. In urban areas infested with fire ants, an estimated 30–60% of the population are stung annually (deShazo, Butcher & Banks, 1990). A survey of suburban New Orleans conducted in 1973 indicated that 55% of stings occurred in children less than 10 years old (Clemmer & Serfling, 1975). Of individuals that are stung, surveys have indicated that 0.6–16% had anaphylactic reactions (Stafford et al., 1989; Kemp et al., 2000). From a survey of 29 300 physicians, Rhoades, Stafford & James (1989) reported 83 cases of fatal anaphylaxis related to fire ant stings. Of these cases, there was sufficient information to confirm 32 deaths. The fatalities ranged in age from infancy to 65 years, with the majority being healthy individuals. Dependent or immobile residents, such as the disabled, the elderly, young children and infants, are at greater risk of suffering from severe stinging incidents, where hundreds of stings may cause anaphylactic reactions, death or both. In a review of the literature (from 1966 to March 2003) and interviews, deShazo and colleagues (2004) found six cases of massive numbers of fire ant stings on elderly residents within health care facilities, of which four died within a week of being stung. Most extreme or fatal fire ant attacks, however, go to litigation, and many are settled with the stipulation that the details of these incidents are not to be disclosed (R.D. deShazo, University of Mississippi Medical Center, personal communication, April 2005). Similarly, departments of health from individual states may have records of severe stinging incidents, but the release of such information may be limited due to the potential for litigation (J. Goddard, Mississippi State Department of Health, personal communication, April 2005).

6.4.3. Pharaoh or fire ant infestations in health care facilities

Because these ants pose medical risks to patients, of stings and transmitting disease, elimination of infestations can be a major concern to health care managers and staff. Severe infestations of Pharaoh ants inside housing can be maddening, and such infestations have caused homeowners to consider selling their homes (Smith, 1965). Where maintaining sanitary and safe environments is imperative for hospitals and nursing homes, resources must be allocated to eliminate pest infestations. Ant infestations of either or both species can occur within a single building (personal observation). While control strategies within structures are similar for both species, extensive infestations can be exceedingly difficult and costly to control (Wilson & Booth, 1981). As a result, pest control companies often exclude these ant species from their contracts or require a separate contract to secure their services for Pharaoh or fire ant control. Goddard, Jarratt & deShazo (2002) recommend specifying monthly inspections and, if required, treatment and emergency service in contracts for pest control service for fire ants.

6.5. Public cost of infestation

6.5.1. Pharaoh ants: cost of control

Published documentation on costs to the public of infestation by Pharaoh ants was not found; however, the cost to treat a Pharaoh ant infestation can provide a partial indication of the potential economic impact. For example, fees in the United States in 2006 may conservatively range from US$ 35 to US$ 80 to treat a residential house with a structural perimeter of 61 linear meters. Larger buildings would cost more to service, but fees are negotiated, with the price per linear meter decreasing dramatically even though more labour and material would be required.

6.5.2. Fire ants: cost of health-related issues, control and management

The economic impact of fire ant infestations in the United States has been reported from surveys of various sectors in individual states and has been extrapolated across the infested areas of the United States. An extrapolation by Pereira and colleagues (2002) of a Texas survey reported the annual economic impact of fire ants in the United States to be more than US$ 6.5 billion across both urban and agricultural sectors. This impact was composed of costs for repair and replacement (66.1%), treatment (27.3%), medical expenditures (1.1%), and livestock and crop losses (5.5%). Based on a survey of households in Arkansas, Thompson and colleagues (1995) reported an extrapolation of annual losses due to fire ants of US$ 2.77 billion among nine heavily infested states in the United States. In the Arkansas survey, households that owned less than 0.4 ha (1 acre) of land were classified as being urban; they had estimated annual urban losses of US$ 1.2 billion across the infested states of the United States. Annual losses per urban household surveyed in Arkansas were US$ 87.10. Lard, Hall & Salin (2001) reported much higher annual losses of US$ 150.79 per household in five metropolitan areas of Texas (Austin, Dallas, Ft. Worth, Houston and San Antonio). Mean fire-ant-related expenditures per annum adjusted for a typical (or average) household in South Carolina were US$ 118 (Miller et al., 2000). Despite the variation in fire-ant-related losses or expenditures, the studies all concluded that the economic impact of fire ants could be substantial.

When urban household expenditures due to fire ants were categorized according to type of cost, treatments accounted for 53–55% of the expenditures, followed by repair and replacement costs (38–43%), and finally medical costs (2–9%). The medical costs were generally for retail medicines used to alleviate discomfort from fire ant stings (Thompson et al., 1995; Lard, Hall & Salin, 2001). However, a potentially large economic burden due to fire ants is from lawsuits that arise from severe incidents of stinging, especially at health care facilities (deShazo, Williams & Moak, 1999). Examples of awards for lawsuits related to fire ant stings include a 2005 settlement in Florida of US$ 1.875 million for the death of a bedridden patient and a jury award of US$ 1.2 million in the same state to a nursing home resident severely stung in 2002.

Households are a convenient unit for conducting economic impact surveys about fire ants. However, fire ants affect other sectors economically, particularly in the urban setting. For the five Texas cities mentioned earlier in this subsection, Lard and colleagues (2002) reported per city expenditures on fire-ant-related damages and treatments of US$ 53628 a year. These costs were associated with controlling fire ants and replacing and repairing equipment in parks, landscapes, airports and cemeteries. It was also noted that fire ant damage to electrical and communications equipment had a total annual cost to the five cities of US$ 111 million.

6.5.3. Fire ants: cost of eradication

When the red imported fire ant was detected and identification confirmed in California, Australia and China, infestations were already quite extensive, thus making eradication more difficult and expensive. In California, the most recent outbreak was first detected in almond orchards in the Central Valley in 1997, and eradication efforts have been ongoing since then. In 1998, several more infestations, one of which covered at least 12950 ha, were confirmed in the more urbanized areas of southern California (Klotz et al., 2003). By early 1999, additional surveys extended the infestation to 204350 ha among several locations (California Department of Food and Agriculture, 1999). The value of a planned 10-year eradication programme in California was US$ 65.4 million (Jetter, Hamilton & Klotz, 2002). Funding for the first five years of this programme was approved in 2000, but due to budget limitations the funding and effort for eradication were curtailed in 2003. Thus, infestations still persist in California.

Projected damage estimates for the scenario where fire ants become established in both urban households and agriculture throughout California ranged from US$ 387 million to US$ 987 million a year. Relative to the climatic suitability for the establishment of fire ant colonies and to the similarity of crops produced in southern Europe to those produced in California, projected potential additional annual costs to treat fire ants in California citrus groves ranged from US$ 1.49 million to US$ 5.95 million, and for vineyards they ranged from US$ 4.11 million to US$ 16.44 million. This corresponded to a maximum 0.52% of annual farm receipts (Jetter, Hamilton & Klotz, 2002). Eradication of isolated infestations, quarantine programmes and non-irrigated desert environments are most likely to help limit the rapid spread of fire ants in California.

Environmental contamination by pesticides used in these programmes is a potential cost of eradication or control programmes. Insecticides used to eradicate fire ants in California (bifenthrin, fenoxycarb, hydramethylnon, pyriproxyfen, chlorpyrifos and diazinon) were not detected in well water. Fenoxycarb, hydramethylnon and pyriproxyfen, which are active ingredients of fire ant baits, and bifenthrin, a contact pyrethroid, were detected in surface water, mainly from nursery sites. These active ingredients are often used in quarantine treatments of nursery premises and nursery stock. Toxicity testing, using the water flea *Ceriodaphnia dubia*, revealed toxicity that could be directly linked to fire ant insecticide concentrations found in the water at nurseries (Levine et al., 2005). Kabashima and colleagues (2003) have reported practices that reduced bifenthrin run-off at a commercial nursery.

An infestation in Brisbane, Australia occupied more than 40000 ha. Treatments were initiated within two months of discovery, and a centralized eradication programme, coordinated by the Department of Primary Industries and Fisheries (DPIF, Queensland), was implemented within 18 months (Drees & Davis, 2002). After 3.5 years of a 6-year, US$133.5 million eradication programme, 99.4% of infestations were free of fire ants, and intensive surveillance continues for new or undiscovered incursions (DPIF, 2004). While the final outcome of the eradication effort in Australia is yet to be determined, the significant reductions in fire ants in an urbanized environment provides an example of the tremendous commitment, effort and organization needed to even attempt eradication. For a meaningful response to the detection of fire ant infestations, countries at risk for infestation should have regulatory clearance and a manufacturing source(s) for treatments, and a centralized coordinated response plan.

6.6. Control measures for Pharaoh and fire ants

6.6.1. Overview of general ant control tactics

Ants are one of the most diverse families of insects, with over 11800 species described worldwide (Agosti & Johnson, 2005) and with just a tiny percentage being considered pests. For example, Thompson (1990) considered about 35 of over 600 ant species as pests in the continental United States. The first step in implementing a control programme is to confirm the identification of the organism causing damage or the problem. Differentiation of Pharaoh ants or fire ants from other ants can be difficult, especially to untrained personnel or when these ants are a recent introduction. Due to regional differences in ant fauna, having a specialist verify the identity of Pharaoh or fire ants is recommended. Detailed descriptions, taxonomic keys and images of many ant species are available on several university Internet web sites and specialized web sites, such as AntWeb (California Academy of Sciences, 2006).

Pharaoh and fire ants have been the targets of innumerable methods of control. Eliminating extensive infestations from buildings permanently can be difficult to achieve; as with other pests; however, acceptable levels of suppression can be achieved with properly implemented control methods. Three general methods are currently being used to control Pharaoh and fire ants:

1. physical exclusion
2. application of residual contact insecticides
3. distribution of insecticidal baits.

The method (or combination of methods) used depends on the ant species, the extent or nature of the infestation, and the desired level of control, in terms of ant population reduction and speed of reduction.

6.6.1.1. Physical exclusion

Preventing ants from entering a building or structure is the objective of physical exclusion. This approach attempts to eliminate potential points of entry that can be used by ants to gain access to a building. Examples of eliminating entry points include sealing cracks and crevices on building exteriors and maintaining door sweeps and weatherstripping around windows. Removing access could entail pruning back tree branches that are in contact with a structure or relocating favourable harbourages, such as wood and debris piles, away from a building. Of course, making a building completely impervious to ant entry is unrealistic, given that some areas are inaccessible or cannot be made excludable, such as ventilation openings. Thus, it is more practical to focus on sealing areas where ants are observed entering and likely entry areas that are close to ant nests or harbourages. Identifying ants and possessing knowledge of their biology is essential to efficiently targeting exclusion efforts.

6.6.1.2. Residual contact insecticides

A common method of controlling ants has been to apply insecticides to building perimeters – around door frames, windows and other entryways – and also along interior baseboards and to actual ant trails and nests. Depending on the active ingredient and application rate, insecticide applications could result in a temporary barrier that immediately kills or repels ants from the treated area. However, except when nests are directly and thoroughly treated, contact insecticides affect only the non-reproducing worker caste that contact treated surfaces, generally leaving the colony intact. When the residual activity of the insecticide degrades, ants from the unaffected colonies are free to reinvade. If nests are inaccessible or not thoroughly treated, or both, insecticide applications may cause a colony to split into two or more colonies and disperse to other locations, resulting in a more widespread infestation.

Contact insecticides that are not repellent, that have a residual activity of over six months and that do not cause immediate insecticidal effects provide effective control of ants. This combination of characteristics permits extensive insecticide contact with trailing ants, because it circumvents the typical ant behaviour of avoiding deleterious substances. Also, possible insecticide transfer to the colony by trailing ants may have an impact on the colony (Soeprono & Rust, 2004a).

6.6.1.3. Insecticidal baits

Ant baits incorporate a toxicant into a food attractant that is carried to the nest by foraging ants and fed to the colony. Most bait products contain slow-acting toxicants dissolved or suspended in a vegetable oil or a sweetened aqueous liquid or syrup. The oil and sweet solution serve as lipid and carbohydrate food sources, respectively, for the ants. The toxicant-laden food is then absorbed into corn grits or some other carrier that makes the bait easier to handle and apply, as well as more available to the ants. Some baits are formulated as liquids and must be used in a bait dispenser; others are formulated as gels and dispensed through a syringe; still others are formulated as solid baits and delivered in receptacles called stations. Ants either carry the bait back to the colony and extract the toxicant-laden food from the carrier within the nest or extract it from the carrier immediately and carry it back to the colony internally. The slow action of the toxicants allows the foraging ants to feed the toxic bait to the other members of the colony before the foragers themselves die. When the toxicant is fed to the queen(s), she either dies or no longer produces new workers, and the colony will eventually die.

Utilization of the foraging and food sharing (by trophallaxis or regurgitation of food) behaviour of ants to distribute toxicant permits the treatment of inaccessible and undetected colonies. Also, the amount of active ingredient used in baits is lower than that of most formulations of residual contact insecticides. Because these bait toxicants entail delayed action, reducing populations is also delayed. Depending on the active ingredient, baits usually take 1–8 weeks to kill a colony. However, some baits will significantly reduce colony populations within three days. Ingestion of baits by the colony is necessary for effective treatment, and although ingested baits are slower than insecticides that kill immediately on contact, obtaining insecticide contact with most of the ants in a colony can be difficult with fast-acting insecticides. Factors that can interfere with bait foraging and effectiveness include seasonal food preferences of a species, competing food sources, bait spoilage and bait degradation by rain.

Overall, to be successful, the three general methods of ant control require knowledge of the ant species, skill in implementing control measures and diligence. Details on control methods specific to either Pharaoh or fire ants are provided below, in sections 6.6.2 and 6.6.3.

6.6.2. Management practices for Pharaoh ants

The following subsections cover the efficacy of management practices and the implementation of Pharaoh ant control programmes.

6.6.2.1. Efficacy of management practices

The control of Pharaoh ants has evolved and changed over the years, from trapping with raw liver to the application of residual insecticides and the utilization of ant baits (Edwards, 1986). Because Pharaoh ant nests are often difficult to observe (cryptic), inaccessible or both, the application of contact insecticides has generally been discouraged for controlling these ants. Also, the incomplete treatment of nests or the application of repellent, residual insecticides to building perimeters or foraging areas may cause colony fragmentation or migration (Edwards, 1986; Oi, Vail & Williams, 1996; Buczkowski et al., 2005). Moreover, the application of residual insecticides indoors in sensitive areas, such as hospitals and schools, may be perceived as being potentially hazardous. As a safer, more efficient alternative, ant baits have been successfully utilized to control indoor infestations of Pharaoh ants (Edwards & Clarke, 1978; Williams & Vail, 1994; Vail & Williams, 1995). Pharaoh ants can forage on the exterior of buildings, and foraging trails as long as 45m have been recorded (Vail & Williams, 1994). As a result, baits applied only to the exterior of buildings have effectively reduced indoor infestations (Oi et al., 1994; Vail, Williams & Oi, 1996). Recently, the application of non-repellent, residual insecticides to the perimeter of buildings has demonstrated effectiveness (Oi, 2005).

Table 6.1. Some Pharaoh ant baits, 2006

Mode of action	Active ingredient	Comments
Neural disrupter	Fipronil	—
Metabolic inhibitor	Hydramethylnon	—
Mid gut poison	Orthoboric acid	—
Neural disrupter	Sulfluramid[a]	Sulfluramid not sold after 2006
Neural disrupter	Indoxacarb	Label lists ants[b]
IGR	S-methoprene	—
IGR	Abamectin	Can kill adult ants
IGR	Pyriproxyfen[c]	Label lists ants[b], also contains orthoboric acid

[a] Sulfluramid = N-ethyl perfluorooctanesulfonamide.

[b] Label lists "ants" only; Pharaoh ants are not listed specifically.

[c] Pyriproxyfen = Nylar = 2-(1-Methyl-2-(4-phenoxyphenoxy)ethoxy)pyridine.

6.6.2.1.1. Active ingredients in Pharaoh ant baits

Commercially available ant baits that include Pharaoh ants on their label can have active ingredients with different modes of action (Table 6.1). The active ingredients in IGRs, such as methoprene and pyriproxyfen, can cause various deleterious effects, including death of larvae and pupae, deformities in queens and cessation of egg laying by queens. Adult workers are generally unaffected and die naturally (Edwards, 1975; Vail & Williams, 1995; Lim & Lee, 2005). Boric (or orthoboric) acid is a slow-acting mid gut toxicant that will kill Pharaoh ant adults and brood. A continuous supply of a 1% boric acid in a sucrose solution caused the demise of small, laboratory Pharaoh ant colonies in four weeks (Klotz et al., 1996). Also, metabolic inhibitors can kill small laboratory Pharaoh ant colonies within two weeks (Klotz et al., 1996).

6.6.2.1.2. Non-repellent residual insecticides

Pharaoh ants that follow the traces or scent of other colony members (trailing) on the exterior of buildings may warrant the application of insecticides to the exterior perimeter of these buildings. Non-repellent, slow-acting insecticides permit increased ant contact with treated surfaces (Soeprono & Rust, 2004b), and there is evidence that sprays for building perimeters that contain fipronil can be transferred to colonies by trailing ants (Soeprono & Rust, 2004a). In this manner, an insecticide treatment on the exterior of buildings may eliminate indoor colony infestations (Oi, 2005).

6.6.2.2. Implementation of Pharaoh ant control programmes

To implement a Pharaoh ant control programme, the following four steps are suggested.

1. Confirm the identification of the problem pest as being the Pharaoh ant (see section 6.6.1).

2. Map the extent of the infestation; it may be useful in determining where treatments should be placed or applied. Food lures that are easily handled yet attractive to Pharaoh ants, such as peanut butter on index cards, can be placed at set intervals or on potential activity sites to locate trails and harbourages. Good sanitation practices should be followed during surveys, so that alternative sources of food will not compete with lures or baits.

3. Select bait that Pharaoh ants will feed on (if bait is to be used), given that food preferences may change relative to the nutritional needs of the colony. Also, consider the type of active ingredient in the bait and its potential speed of efficient treatment relative to how soon control must be obtained. If Pharaoh ants are trailing extensively on the exterior of the building, treatment with a non-repellent, slow-acting insecticide may be useful, if exterior baiting is not effective or population declines are too slow.

4. Evaluate treatment efficacy periodically, through visual surveys, staff interviews or monitoring with food lures. Evaluations should be used to adjust future treatments and determine sources of reinfestation.

The control of Pharaoh ant infestations in both large building and small residential dwellings is feasible with the proper use of currently available materials. Reductions of 75–84% have been reported within 2–10 weeks; reductions of 100% have been reported after 16 weeks, using IGR baits (Edwards & Clarke, 1978; Vail, Williams & Oi, 1996; Lee et al., 2003); and reductions of 99% have been reported in 1 week, with metabolic inhibiting baits (Oi et al., 1994; Oi, Vail & Williams, 1996). However, when colonies located near baits are killed too quickly, rapid reinfestation by other colonies can occur. In contrast, slow-acting IGRs that do not affect workers can result in more thorough bait distribution among several colonies and a longer suppression of populations (Williams & Vail, 1994; Vail, Williams & Oi, 1996; Oi, Vail & Williams, 2000). Also, the application of non-repellent residual insecticides has provided 100% control in one week (Oi, 2005). Controlling Pharaoh ant infestations, especially in large facilities, will most likely be an ongoing process, requiring constant monitoring and treatment, as new colonies may enter with new occupants, merchandise or both.

6.6.3. Management practices for fire ants

The efficacy of management practices, home remedies and control devices, natural enemies and biological control agents, and implementation of fire ant control programmes are covered in the following subsections.

6.6.3.1. Efficacy of management practices

Fire ant control methods are based primarily on research on red imported fire ants, but are applicable to black imported fire ants and their hybrid. Because nests are often visible as mounds of excavated soil, fire ant control can be directed at individual colonies. Depending on the number of nests that need to be treated and on their accessibility, two approaches to applying treatments can be utilized. If only a few nests are in a limited area (say, less than 50 nests/ha), locating and treating individual nests would be feasible. If nest densities are high or the nests cannot be located because the management area is too large or difficult to survey (for example, nests are concealed by vegetation), or for all the preceding reasons, broadcasting a treatment over an infested area without locating individual nests is more practical.

6.6.3.1.1. Broadcasting fire ant bait

Fire ant baits that can be broadcast over an area are usually granular formulations comprised of slow-acting toxicants dissolved in vegetable oil (such as soybean oil), which is absorbed into corn grits. Most fire ant baits have a very low broadcast application rate of 1.1–2.2 kg/ha and are dispensed with manual seeders or larger seeders mounted on a tractor or all-terrain vehicle. For rough terrain, blowers have also been used. Aerial application is another option for area-wide and whole-community treatment programmes. Because individual nests do not have to be located and treated, broadcasting bait is a very efficient treatment method, both in terms of control and labour (Barr, Summerlin & Drees, 1999). Calibrating seeders accurately and dispensing bait evenly can be difficult. However, since foraging ants move to where baits are distributed, exact precision in application is not an absolute requirement. Also, broadcast application rates may not be effective for very small areas. For example, for 30 m^2, only 5g of bait should be applied at a recommended broadcast application rate of 1.65 kg/ha, which is well below label recommendations of 10.0–56.7 g/nest.

Fire ant baits do not have any residual activity. They usually must be collected by foraging fire ants within 1–2 days, before they become non-palatable, usually because of exposure to moisture prolonged heat, air and sunlight. Also, some active ingredients in baits are susceptible to photolysis (Vander Meer, Williams & Lofgren, 1982). To facilitate timely foraging, bait applications should be made when environmental conditions are conducive to foraging (air temperatures between 25°C and 32°C and no rain or irrigation 12–24 hours after broadcasting (Ferguson, Hosmer & Green, 1996)). Recalling that the oil in baits serve as a food source that colony members must ingest, baits must be fresh (oil should not be rancid) and, if possible, applied near nests to improve accessibility and competition with natural food sources. Seasonal food preferences may also affect bait acceptance. During the early summer, fire ants actively forage on oils to replenish depleted lipid reserves (Tschinkel, 1993); at this time, fire ant baits that contain oils are readily foraged, and alternative lipid sources, such as seeds and insects, are less available. However, weather permitting, fire ants will feed on baits throughout the year.

6.6.3.1.2. Active ingredients in fire ant baits

When broadcast properly, commercially available fire ant baits can reduce fire ant populations by over 90%. The mode of action of the active ingredients used in the baits will dictate the speed of its efficient action. Baits that contain metabolic inhibitors and neural disrupters can cause colony death as fast as one day to two weeks. Baits also can have active ingredients that interfere with reproduction; these are often referred to as IGRs. IGRs can prevent queens from laying eggs, and they cause a caste shift from workers to reproductive ants. As workers die off naturally, they are not replaced. Thus, colonies treated with IGRs will eventually succumb because workers will not be available to tend the queen(s), and she (they) will die. IGR baits may take 5–10 weeks to eliminate colonies, because IGRs do not affect adult workers.

While IGR baits require many weeks to kill colonies, in large treated areas (>0.4 ha), control can last for as long as a year. During the slow colony decline, remnant colonies will execute newly mated queens that try to reinfest treated areas. The duration of control in smaller areas is shorter, because they are more easily reinfested from adjacent areas. In contrast, the faster-acting metabolic and neural disruptive baits create a colony void that can be quickly reinfested within two months. Table 6.2 lists characteristics of fire ant baits that contain various active ingredients. For quick and extended suppression, one bait product is a mixture of metabolic inhibitor and IGR active ingredients.

6.6.3.1.3. *Broadcasting residual insecticides*

Broadcasting residual insecticides over an infested area attempts to eliminate fire ant populations and prevent reinfestation of the treated area. The most effective materials have been non-repellent, slow-acting contact insecticides, with residual activity for over six months. The absence of both repellency and the immediate death of ants facilitate insecticide contact with foraging ants and colonies located in treated areas. On the other hand, immediate death or repellency due to irritation often elicits avoidance of treated areas by fire ants (Oi & Williams, 1996) and reduces control to a short-lived suppression of fire ants. Reductions in fire ant nests of over 90% for over a year have been documented for the broadcast application of a granular insecticide containing fipronil (Barr & Best, 2002; Barr et al., 2005). Products with other active ingredients are available, but the level and duration of control they provide has not been as good. Product cost can be prohibitive for large areas and the application of contact residual insecticides must be more evenly distributed than baits.

Table 6.2. Some fire ant baits, 2005

Mode of action	Active ingredient	Speed of efficacy	Comments
Neural disrupter	Fipronil	4–6 weeks [a]	—
Metabolic inhibitor	Hydramethylnon	1–4 weeks [b]	—
Neural disrupter	Spinosad	3–14 days [c]	Organic certification
Neural disrupter	Indoxacarb	2–3 days [d]	—
IGR	Abamectin	6–8 weeks [e]	Some adult worker death
IGR	Fenoxycarb	4–8 weeks [f]	—
IGR	S-methoprene	8–10 weeks [g]	Registered for "croplands"
IGR	Pyriproxyfen	4–8 weeks [h]	Registered for various crops
Metabolic inhibitor + IGR	Hydramethylnon + S-methoprene	1–3 weeks [i]	IGR extends control

[a] From product label: EPA Registration Number 432-1219; Collins & Callcott (1998).

[b] From product label: EPA Registration No. 241-322; Barr (2004).

[c] From product label: EPA Registration No. 62719-304-239

[d] From Barr (2004).

[e] From Lofgren & Williams (1982); Williams (1985).

[f] From product label: EPA Registration No. 100-722; Collins et al. (1992).

[g] From product label: EPA Registration No. 2724-475.

[h] From product label: EPA Registration No. 1021-1728-59639.

[i] From product label: EPA Registration No. 2724-496; Barr et al. (2001).

6.6.3.1.4. *Treating nests individually*

Fire ant nests are often visible mounds of excavated soil that contain brood, adults and one queen or more. The visibility and accessibility of fire ant nests makes direct treatment of colonies feasible, where the objective is to eliminate the colony by killing the queen and most of the stinging adult workers. If the queen is not killed or functionally sterilized, she will continue to lay eggs and the colony will recover. In the case of multi-queen colonies, all the queens must be killed, thus making effective treatments especially difficult. Individual nest treatments are time consuming and labour intensive, because each mound must be located and treated (Barr, Summerlin & Drees, 1999). However, colonies treated properly with fast-acting insecticides can be eliminated more quickly than colonies treated with baits and residual insecticides with slow modes of action. Individual nest treatments, however, may cause the fire ants to relocate and create a new nest. Even if the queen is killed, surviving ants may still inhabit the treated nest or make a new nest until they die naturally, which may take over a month. Thus, it may be necessary to re-treat remaining nests that contain large numbers of stinging workers.

Mounds can be treated individually by chemical and non-chemical methods. Chemical methods include insecticides that are most commonly formulated as baits, liquid drenches, granules or dusts. Products formulated as drenches, granules or dusts generally contain active ingredients that are contact insecticides that will immediately affect treated ants. Because fire ant colonies move to occupy optimal temperature strata within a nest throughout the day, treatments should be applied when the colony is concentrated near the nest surface. Thus, optimal treatment times are generally limited to when air temperatures are cool (about 20–25°C) and the sun warms the nest surface. When properly treated, colonies may be eliminated within a few hours to a few days after treatment.

Bait products used for broadcast bait applications can be applied to individual nests. Because ants will distribute the bait to the colony, the emphasis with bait applications is to ensure baits are available when and where fire ants are foraging. Bait application to individual nests is relatively simple, where the recommended amount of bait, usually 15–75 ml (1–5 tablespoons), is sprinkled around the base of the nest. As with broadcast bait applications, the use of baits for individual nest treatments usually takes one to several weeks to eliminate colonies. However, there are now bait products that will kill colonies within three days.

Non-chemical treatment methods include pouring hot water onto the nests or physically excavating them. Scalding or boiling water (88–100°C) has been used to eliminate 20–60% of colonies, where about 11 litres of hot water were poured onto nests (Tschinkel & Howard, 1980). One variation of this technique uses steam generators that inject scalding water. The other non-chemical method, excavating colonies, is inefficient and impractical.

6.6.3.1.5. *Combinations of baiting, residual insecticides and individual nest treatments*

Each type of method used for fire ant control has advantages and disadvantages relative to speed of efficacy, residual activity and ease of application. Because fire ant stings represent a hazard, quick inactivation of colonies is often a priority. Treating nests individually with contact insecticides is potentially the fastest method to eliminate colonies; however, successful treatment can be difficult and inefficient. The combination of broadcasting bait followed by treating hazardous nests individually permits the efficient treatment of many colonies and the rapid suppression or elimination of the most dangerous colonies. It is generally recommended to bait first and then treat selected nests individually with a contact insecticide at least a day later. Baiting first allows colonies to forage and distribute baits without impediment from contact insecticides. In addition, colonies not successfully controlled by individual nest treatments may eventually succumb to ingested bait.

An alternative strategy is to combine the individual treatment of hazardous nests with a broadcast, non-repellent, residual contact insecticide. Non-repellent, contact insecticides may not suppress colonies immediately, thus the additional application of faster-acting insecticides to individual nests compensates for the delayed activity. If both types of treatments are contact insecticides, the sequence in which they are used is not critical.

The recent introduction of fire ant baits that suppress or kill colonies in 1–3 days may provide an acceptable time frame for effective treatment and may reduce the need for treatment combinations. Also, the application of a non-repellent, contact insecticide at least a day after baiting could retard reinfestation.

6.6.3.2. Home remedies and control devices

There are many home-made remedies and mechanical control devices that have not been scientifically proven to consistently eliminate fire ant colonies. Often, these so-called cures, which are usually directed at an individual nest, will kill many ants and the colony will abandon the nest. This gives the false impression that the colony was killed. Some home remedies also are dangerous to apply and contaminate the environment. These remedies include the use of gasoline or other petroleum products, battery acids, bleaches, and ammonia and other cleaning products. Such so-called remedies should never be used.

6.6.3.3. Natural enemies and biological control agents

Numerous organisms can prey on individual fire ants. Newly mated queens are attacked by other fire ants and other ant species and by dragonflies, spiders, lizards, birds and other general predators, but this predation does not reduce established fire ant populations. Direct applications of parasites and pathogens, which include mites, nematodes and fungi, to fire ant nests have not resulted in long-term control under field conditions (Williams et al., 2003). In general, these organisms required direct contact with individual ants and may be described as biological pesticides rather than self-propagating biological control agents that can spread naturally to other fire ant colonies.

In contrast, some parasites and pathogens have infiltrated the life-cycle of fire ants and are self-sustaining. These include two species of phorid flies (*Pseudacteon tricuspis* and *Pseudacteon curvatus*) and the microsporidium (protozoan) *Thelohania solenopsae*, which are well established in the United States (Williams et al., 2003). The phorid flies have been shown to reduce the short-term foraging activity of fire ants (Morrison & Porter, 2005) and reductions in field populations infected with *T. solenopsae* have been documented (Oi & Williams, 2002). While biological control agents are detrimental to fire ants, their impact at the population level may only be apparent with the establishment of several types of agents and after several years (Morrison & Porter, 2005). As such, the usefulness of these agents for immediately reducing the risk of fire ant stings in the urban environment is limited.

6.6.3.4. Implementation of fire ant control programmes

To implement a fire ant control programme, the following four steps are recommended.

1. **Confirmation.** Confirm that fire ants are the species causing the problem (see section 6.6.1).

2. **Determine where control is needed.** Fire ant population densities and distribution will vary with the degree to which habitats are conducive to colony growth. Determining whether control is needed should be based on the extent fire ants can be tolerated for specific land use patterns. Locating and mapping areas where fire ant control is required will help limit potential treatment areas.

3. **Design monitoring and treatment regimes.** Assess fire ant population levels when conditions are conducive to the type of monitoring method used. For example, if the number of fire ant nests in an area will be used to estimate ant populations, soil should be moist and vegetation low so that nests are easily seen. If food lures are used, set lures when weather conditions are conducive to fire ant foraging (see subsection 6.3.2.1 on monitoring fire ant populations). Consider deadlines for achieving control when scheduling sites for monitoring and treatment. Many fire ant treatments take at least a few weeks to obtain population reductions.

   The intensity of the control effort should reflect the potential hazard fire ants present, which is a function of the probability of a fire ant sting and the consequences if a sting occurs (such as a lawsuit). Treatment regimes relative to fire ant tolerance and liability will vary among land-use patterns. For example:

   a. no treatment is needed for freeway median strips;

   b. an annual broadcast application of an IGR bait is needed for an infrequently used park; and

   c. a broadcast application of baits in the spring, summer and fall, plus an individual treatment of hazardous nests with fast-acting contact insecticides or baits and weekly monitoring for new nests or the presence of fire ants are all needed for a toddler playground.

   Thresholds have been used to initiate bait applications in cattle pastures. For example, to maintain a fire ant population below five nests per 1000 m^2 (50 nests/ha), fire ants on more than 40% of monitoring food lures would trigger bait applications (Pereira, 2003; R.M. Pereira, unpublished data, 2005). Thresholds based on the percentage of fire ants on monitoring lures would have to be adjusted for site layout (such as landscaping and land-use pattern), fire ant tolerance and monitoring scheme.

4. **Evaluation and adjustment of control programme.** Mapping areas where fire ant infestations are located and recording pre- and post-treatment population levels allow the control programme to be evaluated. Monitoring population levels at times when the potential for stings is high (such as the outdoor recreational season) will provide an indication of a treatment's efficacy and timeliness. Population levels can be based on nest densities, the percentage of lures with fire ants, the number of sting incidents or complaints, or a combination of these indicators. Maintaining site-specific historical records of treatment regimes, dates and weather conditions during treatment applications and population levels will allow for more precise adjustments to control programmes.

The examples of treatment regimes listed above are simple illustrations of possible control programmes. More complex programmes have been proposed that are tailored to more specific environments, such as health care facilities (Goddard, Jarratt & deShazo, 2002). These published programmes are only models and generally must be modified to suit site-specific needs.

6.7. Emerging problems and policy options

Early detection and a rapid response to eliminate infestations are vital to prevent the establishment of both fire ant and Pharaoh ant colonies in new areas. In the long run, preventing establishment is also more cost effective than eradication of established populations.

6.7.1. Fire ants

With regard to fire ants and countries at risk for fire ants becoming established, surveillance mechanisms, clearance for treatments, a manufacturing source(s) for treatments and centralized coordinated response plans should be kept in place. As discussed in section 6.5.3, the eradication programme in Australia has shown the best potential of being a model for fire ant eradication in a relatively large urban area. Moreover, initiatives to prevent the incursion of invasive ants, such as the Pacific Ant Prevention Plan (Invasive Species Specialist Group, 2004), are being developed. The Plan was generated for the Pacific islands and countries. The Pacific Invasive Ant Group provides guidelines that address legislation or policy to prevent entry of invasive ants, with a focus on red imported fire ants and outlines surveillance and response procedures for preventing ants from becoming established. These guidelines are broad in scope and adaptable to other at-risk regions, such as southern Europe.

The need to efficiently improve the ability to detect low levels of fire ant populations is dire. Current monitoring methods that utilize food lures are time sensitive and lack species specificity; also, the placement of lures must be within the foraging range of a colony, which can be small for small colonies. Alternatively, visual surveys for nests made by teams of inspectors are very labour intensive, and quality assurance must be maintained. Thus, research to develop more sensitive and efficient surveillance tools is needed to support plans and programmes to prevent and eradicate fire ant incursions.

While preparation for fire ant eradication is prudent for at-risk areas, improvements in fire ant IPM, including pesticide application, are needed for well-established fire ant infestations. Products with active ingredients that have long residual activity can provide control of fire ants for over nine months. These products are contact insecticides that require thorough coverage of an area to maintain control (reductions of more than 90%). Inadequate coverage and the proliferation of similar products (albeit less expensive) that may not have the same efficacy can lead to reapplications and greater exposure to pesticides. Fire ant baits, however, typically result in the application of less active ingredient per unit area than residual contact treatments (Drees, 2003). While the residual activity of fire ant baits is limited, as a tool for controlling these ants these baits are efficient and environmentally compatible. Integrating the efficient use of both baits and long-lasting residual contact insecticides, relative to the risk management of fire ant stings and exposure to pesticides, would improve fire ant IPM.

6.7.2. Pharaoh ants

With regard to Pharaoh ants, the first step towards control is physical exclusion. Access to a building, especially to such sensitive facilities as hospitals, must be reduced to a minimum by internal and external structural measures (such as sealing of cracks and crevices and moving possible garden harbourages away from a building). Also, regular monitoring and targeted insecticide application by specialists is fundamental and should be compulsory.

6.7.3. Research

Research on the dynamics of the reinfestation of treated areas and how to significantly delay reinfestation of sensitive areas (such as hospitals and preschool playgrounds) by fire ants and Pharaoh ants, while minimizing pesticide use, is needed to develop improved control strategies.

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7. Flies

Jerome R. Hogsette and Jens Amendt

Summary

Flies constitute a major group of nuisance species in rural and urban environments worldwide. Many species are collectively called filth flies, because of their association with potentially contaminated substrates, such as food wastes, faeces, animal manures and carrion. Through this association, they can quite easily and accidentally become disease vectors, by transmitting pathogens, especially those that cause enteric infections (such as *Salmonella* and *Campylobacter*), from contaminated to uncontaminated substrates. The epidemiological association of flies with various diseases is well documented and it has been established that certain flies are capable of contaminating food with pathogens. Nevertheless, there is still much discussion about the role filth flies play in actually transmitting pathogens to people and, more importantly, about the extent to which this transmission leads to disease. In fact, in urban areas of the northern hemisphere, the main complaint at present is about the annoying presence of flies, but rising temperatures due to changes in the climate may lead in the future to an increase in fly populations and a concomitant increase in fly-borne diseases.

A number of management practices or techniques can be used in urban areas to combat flies, and they are presented here. Among these practices is trapping. Outdoors and indoors, it is a good way to manage fly populations around homes, apartments and stores. Many fly traps do not involve the use of pesticides and are safe to use around people and their companion animals. Indoors and outdoors, sanitation is the key to effective fly control. Elimination of food leftovers, breeding sites and shelter will minimize fly populations. It is therefore important to inform the public and health care officials about fly biology and management. Benchmarks for a good fly-management programme include further research on fly biology, the development of perimeter control techniques, the restriction of pesticide use to outbreak scenarios, the use of regular monitoring and the improvement of control devices.