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Observations on the Biology and Ecology of Fire Ants in Brazil

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The biology and ecology of the red imported fire ant (Solenopsis invicta) and the black imported fire ant (S. richteri) have been studied extensively in the United States (see reviews by Lofgren et al. 1975; Tschinkel 1982 and Chapter 7; Wojcik 1983), but comparable studies have not been conducted in South America. Silveira-Guido et al. (1968, 1973) reported on S. richteri and other S. saevissima group species present in Uruguay and Argentina; however, these studies must be reevaluated because of taxonomic changes in this group (Buren 1972). In addition many new species need to be described, the status of older names clarified, and the distribution limits of each species demarcated (J. Trager, Univ. of Florida, Gainesville, Florida, is currently revising the genus). There is little published information on S. invicta in South America; this paper presents observations accumulated during a series of trips made by me and other scientists of the Insects Affecting Man and Animals Research Laboratory, ARS, USDA, Gainesville, Florida to the State of Mato Grosso, Brazil over the past 11 years. Where appropriate, comparisons are made with populations of S. invicta in the United States.

DISTRIBUTION

The distribution of S. invicta given by Buren et al. (1974) is essentially unchanged despite recent data from several collecting trips made between 1973 and 1983 by W. F. Buren and associates and USDA personnel to other areas of Brazil, Uruguay, Argentina, Paraguay, and Bolivia.

Also, no new information has been discovered relating to the introduction of S. invicta into the United States since the extensive zoogeographical study by Lennartz (1973). It has been assumed S. invicta entered on products shipped through the Rio de la Plata region of Argentina and Uruguay; however, S. invicta has been found

as far north as Porto Velho, Rondonia, Brazil (Buren et al. 1974). It is not known if its distribution extends further down the Madeira River from Porto Velho towards the Amazon basin or into northeastern Brazil. S. invicta has never been collected from either the Amazon basin or the Rio de la Plata region, although there are collection records of other Solenopsis spp. The presence of S. invicta in the former area could, of course, provide an alternate explanation for importation of S. invicta into the United States.

MOUND SIZE

One of the most obvious manifestations of S. invicta colonies in the United States is their large conspicuous mounds. The absence of these large mounds, however, does not mean that ant colonies are not present, since the presence and/or persistence of the mound is usually dependent on soil type and moisture conditions (Wojcik 1983). It should be stressed that colony size (number of ants) and mound size (height and diameter of the tumulus) are not necessarily related (Banks et al. 1985). Observations in Brazil indicate similar phenomena. During the extensive dry season (May through September) (Coutinho 1982) or other dry periods, S. invicta often do not or cannot construct a mound. However, large mounds can readily be found if appropriate conditions prevail, particularly during the rainy season (Fig. 1a) (Wojcik 1983; Banks et al. 1985). Most of the S. invicta colonies collected in Mato Grosso during the wet season (January to February 1985) had well-developed mounds of average size (20-30 cm high and 30-40 cm wide) that were typical of their mounds in the United States (Anonymous 1958).

During the 1984 dry season in Mato Grosso, the road shoulders of BR-070 from Cuiaba to Caceres (ca 215 km) were cleared by burning. Fire ant mounds (mostly S. invicta) were found along almost the entire length of the highway. These mounds (Fig. 1a, b) were often as large as the largest mounds found in the United States (Anonymous 1958). They were characterized by a coarse surface, often accompanied by vegetative growth. They could readily be distinguished from termite mounds, which had a smoother surface and rarely supported any vegetation. Also, fire ant mounds were much softer than the hard, rock-like termite mounds.

Fire ant colonies collected in January to February 1985 (wet season) were large and mature as indicated by the presence of alates and large numbers of workers and brood of all sizes (Wojcik and Jouvenaz, unpublished). In contrast, few small colonies have been found, a condition that suggests populations in Brazil are in a steady-state condition with a low turnover rate (Wojcik, unpublished; Banks et al. 1985).

In 1984 and 1985, numerous abandoned mounds were found in densities approximating those found at times in the United States

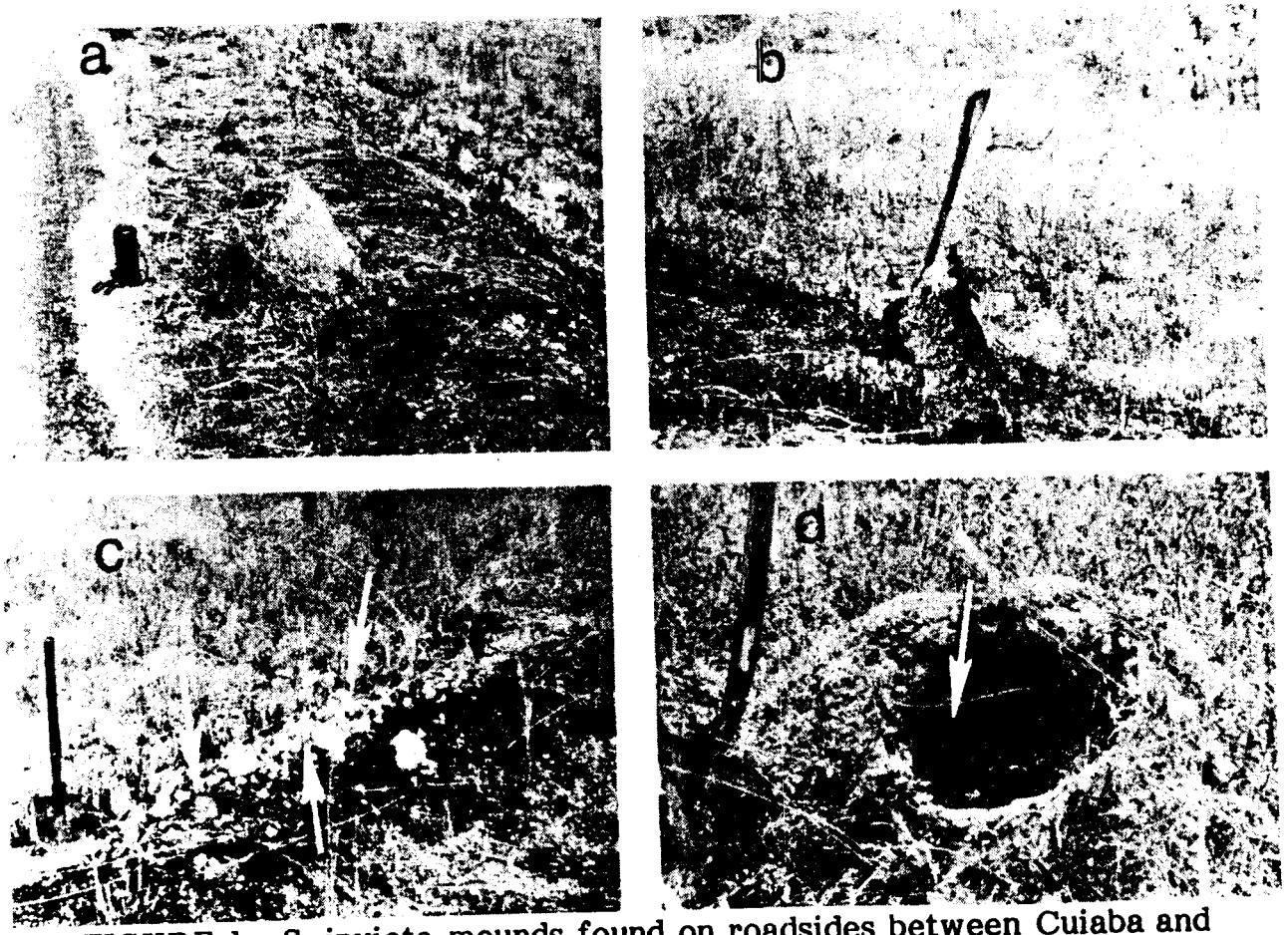

FIGURE 1. S. invicta mounds found on roadsides between Cuiaba and Caceres, Mato Grosso, Brazil during the 1984 dry season. a) 41 cm high mound on roadside. b) 51 cm high mound on roadside in moister area. c) Abandoned mounds (arrows) near active S. invicta mound. d) Active S. invicta colony (arrow) in termite mound.

(Wojcik, unpublished; Hays et al. 1982). This condition was not observed during previous trips, perhaps because mounds abandoned on roadsides were hidden by vegetation and mounds on lawns were rapidly destroyed by mowing machinery. The abandoned mounds observed along roadsides in the 1984 dry season (Fig. 1c) were numerous and of various sizes; in the 1985 wet season, there were about one-third as many abandoned mounds as active mounds. Indeed, when an abandoned mound was located, an active colony was usually found nearby. These active colonies may have migrated from the abandoned mounds.

These observations and those of Banks et al. (1985) negate, for the most part, published statements about the lack of large mounds in South America (Allen et al. 1974; Buren et al. 1974; Williams and Whitcomb 1974) and suggest that mound building behavior is related to temperature, moisture, and soil type rather than behavioral or population differences (see Francke and Cokendolpher, Chapter 9).

NUMBERS OF ANTS PER COLONY

Although estimates of the number of ants per colony in mounds have not been made in Brazil, as in the United States (Markin et al. 1973), some general observations can be made. Based on years of experience in excavating S. invicta colonies in the United States and in South America, it appeared that the number of workers, alates, and immatures in large colonies in South America were about equal to the numbers in large colonies in the United States (Wojcik and Banks, unpublished). Recently, Banks et al. (1985) confirmed this observation when they estimated S. invicta colony size in Brazil with a population index method (Harlan et al. 1981) and found that 65% of the colonies examined had over 50,000 workers and 16% had between 10,000 and 50,000 workers.

NUMBERS OF FERTILE QUEENS PER COLONY

S. invicta had been considered a monogynous species until the reports by Glancey et al. (1975) of a colony that contained hundreds of fertile queens. Subsequently, several other cases of polygyny have been recorded in the U.S. (Lofgren and Williams 1984). We have found no evidence to date for polygyny in any of our surveys in South America.

MATING FLIGHTS

Mating flights are the primary means of natural spread and reinfestation for S. invicta and fire ants in general. When conditions are suitable, unmated males and females fly from the same or different nests to a height of 100 to 300 m and mate (Markin et al.

1971; Bass and Hays 1979). Flights can occur in all months (Morrill 1974) or weeks (Banks et al., unpublished) of the year when conditions are suitable. In the United States, the major peak of flights occurs in the spring with a smaller peak in the fall. In Mato Grosso, alates have been observed in colonies every month of the year (Banks et al. 1985; Wojcik, unpublished). Although no counts were made, Wojcik and Banks (unpublished) found that the numbers and sex of alates in the nests varied considerably just as they do in the United States (Anonymous 1958). Mating flights of S. invicta have been observed in Mato Grosso in January, February, April, May, and November (Banks et al. 1985), March (Williams 1980), and in August (Allen et al. 1974). J. Trager (personal communication) reported that small flights of S. invicta started with the commencement of rains in Cuiaba in October 1984 and continued through November 1984. After continuous heavy rains in early December 1984, very large mating flights of S. invicta occurred throughout the remainder of December 1984.

One apparent difference has been noted in mating flight behavior between North American and Brazilian populations of S. invicta. North American populations are generally reported to fly from 11 AM to 4 PM (Markin et al. 1971; Roe 1973; W. A. Banks, personal communication), although Rhoades and Davis (1967) observed one flight at 9 AM and Hays (1959) stated that flights took place in the morning and were usually completed by noon. In Brazil, S. invicta is reported to fly from 9 AM to 12 PM (W. A. Banks and D. F. Williams, personal communication). While the actual mechanisms that initiate mating flights are not well understood (Lofgren et al. 1975), the importance of the time of day has not been established. The success of mated queens in colony founding has not been studied in South America.

FIRE ANTS IN TERMITE MOUNDS

Fire ant colonies are supposed to be common in termite mounds in Mato Grosso (Whitcomb 1974). I have found this to be true in only one location in southwestern Mato Grosso, one-half way between Varzea Grande and Ilha do Piraim (near Joselandia). In this large grassland that is periodically flooded, 14 of 16 termite mounds in a 2-acre area contained fire ant nests, mostly S. invicta. In contrast, in other areas of Mato Grosso, fire ant colonies were found only occasionally in termite mounds (Fig. 1d). The fire ants rework the tunnels so that the section of the mound they occupy is easily distinguished by differences in tunnel architecture.

It has been suggested (C. S. Lofgren, personal communication) that the presence of S. invicta in termite mounds is a response to periodical flooding (example given above). However, the mound in Fig. 1d was located on an embankment along a highway where there

was no possibility of flooding. Another study by Redford (1984) of termite mounds in Brazil (in cerrado in Goias) has shown other Solenopsis spp. to be common inhabitants of termite mounds. Redford's study was conducted in an area where flooding was not a consideration.

NATURAL FOOD SOURCES

The main food sources of S. invicta in Brazil appear to be other arthropods (Wojcik, unpublished). I have seen S. invicta feeding on carrion, fresh-caught fish, and garbage. The ants readily feed on beef and honey baits (Wojcik 1983). In Brazil, S. invicta is evidently an opportunistic predator and scavenger, as it is in the United States (Lofgren et al. 1975). In the 1984 dry season, I found fire ant mounds along highway BR-174 west of Caceres that contained large amounts of plant material, mostly fragments of rice grains which had fallen or blown off passing trucks. There were no rice fields in the immediate vicinity of the mounds sampled. Previously W. A. Banks and D. P. Jouvenaz (personal communication) had observed large amounts of mascerated plant material (leaf and stem fragments, seeds, and seed husks) in S. invicta mounds near Cuiaba. Thus, in some circumstances (mechanisms unknown), S. invicta will feed on plant material. This behavior has been noted in the United States (Lofgren et al. 1975).

In the United States, S. invicta has been reported tending Homoptera on a variety of plants (Anonymous 1958; Nielsson et al. 1971) including citrus (Adams, Chapter 5). Solenopsis species other than S. invicta have been observed tending Homoptera on citrus in South America (Williams et al. 1975; Bartoszeck 1976). Recently S. invicta were observed tending aphids on citrus (C. S. Lofgren and W. A. Banks, personal communication; Wojcik, unpublished) and feeding on extrafloral nectaries of a plant (family Leguminosae) (Wojcik, unpublished) on the EMPA Research Station at Caceres. These associations have not been previously reported in the literature, probably because of the allopatric distributions of S. invicta and entomologists in South America.

COLONY DENSITIES

Recent data on fire ant populations in Mato Grosso (Wojcik, unpublished; Wojcik 1983; Banks et al. 1985) indicate that published statements (Buren et al. 1978; Buren 1980; Whitcomb 1980) implying that S. invicta populations in Mato Grosso are lower than populations in the United States are not true. These latter authors did not make population counts and based their statements only on observations. General comparisons between North and South America are difficult because of differences in ecology and patterns of land use. The only

valid comparisons are those using comparable habitats. It must be stressed, however, that few if any of the habitats in South America are strictly comparable to any of the habitats in North America (Wojcik 1983). Fire ants are ants of disturbed areas (Buren et al. 1978) and over half of the area of Mato Grosso is classified as cerrado (Santos et al. 1977) which is mostly undisturbed except for periodic grazing and burning (Coutinho 1982). In Mato Grosso, cerrado (floristically described by Eiten 1982) is characterized by fire climax vegetation and soils which have nutrient deficiencies, acid ph, aluminum and/or manganese toxicity, and lateritic hardpans (Coutinho 1982). It is generally agreed that such a moderately disturbed area does not constitute a primary habitat for S. invicta in Brazil (Allen et al. 1974; Wojcik 1983; Banks et al. 1985). Allen et al. (1974) did not find any S. invicta in cerrado; however, Banks et al. (1985) surveyed three small plots (0.031 ha each) in cerrado and found two S. invicta nests. In severely disturbed cerrado such as roadsides, S. invicta nests can be very common (Table 1). For example, roadside populations of S. invicta colonies in Mato Grosso at times exceed average counts from the United States (Banks et al. 1973; Williams and Lofgren 1982). Conversely, many areas in Brazil are without fire ants or have low populations (Whitcomb 1980), a condition that is also found in the United States (Wojcik and Banks, unpublished).

Another way to assess ant population densities is with baits, which have the advantage of being a non-biased collection method (non-biased in reference to minimum human collecting error; see Wojcik et al. 1975 for methods). Bait surveys along transects in the Cuiaba area (Coxipo and Federal University of Mato Grosso) in 1981 showed high populations of S. invicta attracted to meat and honey baits even though medium populations of other ants were also found (see Wojcik 1983, Fig. 2, 3). Bait surveys in the United States from a highly infested area (Baldwin, Florida) and a lightly infested area (Gainesville, Florida) showed similar results.

PATHOGENS AND INQUILINES

Some of the arthropods associated with fire ants in Uruguay and Argentina were described by Silveira-Guido et al. (1973) and in Brazil (mainly in the Sao Paulo area) by Williams (1980). Many of these same or related arthropods have been found in fire ant nests in Mato Grosso. Jouvenaz (1983; Chapter 27) summarized the known data on fire ant pathogens. These references do not provide data on seasonal distribution; thus, in both the 1984 dry season (July to September) and the 1985 wet season (January to February), I collected inquilines and pathogens from the same three plots. Standard samples of 2 1/2 liters of tumulus were collected in 5 liter buckets and the ants and inquilines separated from the soil by water floatation (Jouvenaz et al., in press).

TABLE 1. Colony densities of fire ant nests in Mato Grosso, Brazil and the southern United States.[a]

Habitat	Ant nests per acre			
	Brazil	Florida	Alabama	Texas
Highway (age)[b]				
1-2 yr	66[ce]	2[g]	16[g]	10[g]
3-4 yr	25[cf]			
	9[df]			
4-5 yr	13[e]			
	8[df]			
6-7 yr	23[e]			
10+ yr		10[g]	15[g]	13[g]
		109[j]		
Forest[h]	13[e]	15[i]		
		3[g]	3[g]	2[g]
Lawn	14[e]	22[i]		
	9[f]			

[a]Modified from Wojcik 1983.
[b]The Brazilian highway counts are all from roadsides in disturbed cerrado.
[c]The same highway
[d]The same plot.
[e]Modified from Banks et al. 1985.
[f]D. P. Wojcik and D. P. Jouvenaz, unpublished data.
[g]USDA, 1967, unpublished data, 2% random samples of 64,000 acre blocks.
[h]Brazil data from cerrado; United States data from pine forests.
[i]R. E. Brown, 1979, unpublished data, systematic random sampling over entire state of Florida.
[j]Modified from Williams and Lofgren 1982.

Thelohania solenopsae was not detected in either the 1984 or 1985 collections, although it was commonly found in Mato Grosso on previous trips (Jouvenaz et al. 1980). Parasitic ants, Solenopsis (=Labauchena) spp., were not found in Mato Grosso. Five species have been reported from fire ant colonies (Wilson 1971; Williams 1980; Banks et al. 1985), but none from S. invicta colonies. A parasitic ant would have potential in a biological control program for S. invicta. No phorid flies (Diptera: Phoridae) were collected in 1984 and 1985 even though Williams (1980) collected them from S. invicta colonies and I have collected them at other times in Mato Grosso.

Chrysomelid beetle larvae (Coleoptera: Chrysomelidae) (Kistner 1982) were not collected from S. invicta nests; these case-bearing larvae had been collected once on an earlier trip (Wojcik, unpublished). Other inquilines associated with Solenopsis spp. colonies in South America and not collected in Mato Grosso are: Acarina (Reichensperger 1927); Lepidoptera (Bruch 1926); Hemiptera (San Martin 1966a, 1966b); Strepsiptera (Teson and de Remes Lenicov 1979); Hymenoptera, Diapriidae (Borgmeier 1939), Bethylidae (Bruch 1917); and Coleoptera, Staphylinidae (Frank 1977; Wojcik 1980; Kistner 1982), Pselaphidae (San Martin 1968a, 1968b), Tenebrionidae (Steiner 1982). In addition, many other groups of arthropods are known to be inquilines in the nests of other ants (Wilson 1971; Kistner 1982).

The diseases and inquilines found in S. invicta colonies in the three plots checked in the 1984 dry season and the 1985 wet season are listed in Table 2. The percentage of total collections as shown do not add up to 100%, because it was common to have more than one disease and/or inquiline in each colony; e.g., one colony contained over 100 larvae, pupae, and adults of an Orasema sp. (Eucharitidae), and 12 1/2% of the adult worker ants were infected with an undescribed nematode (Jouvenaz et al., in press). The data on the influence and effects of pathogens on S. invicta is limited (Jouvenaz, Chapter 27). The incidences of the diseases were higher but similar to those given by Jouvenaz et al. (1980). The nematode mentioned above is the first record of these parasitic organisms in Solenopsis in South America. There are several species of myrmecophilous Scarabaeidae (Coleoptera) present in Mato Grosso (Chalumeau 1983), one of which is known to be predaceous on S. invicta (Wojcik 1975). Nothing is known about the hister beetle (Coleoptera: Histeridae), the Thysanura are sometimes predaceous (Wojcik, unpublished), and the Diplopoda are scavengers (Wojcik, unpublished). The Orasema spp. (Hymenoptera: Eucharitidae) are ectoparasites of ant larvae and pupae (Williams 1980), which cause malformation and eventual death of the pupae (Wojcik, unpublished). Any promise that these parasites may have for a biological control program is reduced by the fact that, in all cases where oviposition behavior is known, the eggs are laid in plant tissue, including that of many economically important plants (Clausen 1940; Tocchetto 1942; Nicolini 1950). In at least one case, damage to bananas by an Orasema sp. required bait treatment of the host ants to eliminate the problem (Ostmark and Evers 1976).

Although we have little data on the effects of diseases and/or inquilines on colony longevity, it is reasonable to assume that these organisims reduce colony fitness. It is known that some diseases reduce colony vitality and cause greater mortality under stress conditions (Allen and Knell 1980; Jouvenaz, Chapter 27). Inquilines that eat fire ant immatures (e.g., some scarab beetles and Thysanura) or

cause the malformation and death of fire ant immatures (e.g., Orasema spp.) produce additional stress on fire ant colonies. This combination of additive mortalities and draining of resources has to have some effect on fire ant colony vigor and/or survival. Since the effects of a biological control agent in its homeland are not necessarily indicative of its utility when introduced into a new environment (Doutt and DeBach 1964), the effectiveness of these organisms must be evaluated before they can be discarded from an IPM program for fire ant control.

TABLE 2. Percentage of fire ant nests examined that contained diseases and/or inquilines in Mato Grosso, Brazil.[a]

	1984[b]		1985[c]	
	With other species	By itself	With other species	By itself
Diseases				
Protozoa				
Thelohania	0.0	0.0	0.0	0.0
Vairimorpha	6.7	1.9	5.7	1.6
Mattesia	7.8	3.8	1.9	1.6
Nematode	0.0	0.0	5.7	3.1
Inquiline				
Scarabaeidae	6.3	2.8	31.3	9.4
Histeridae	0.0	0.0	18.7	6.3
Thysanura	0.0	0.0	3.0	0.0
Diplopoda	0.0	0.0	30.3	18.8
Eucharitidae	28.1	16.2	45.5	25.0
Without disease or inquiline	53.1		12.3	

[a]Results from colonies collected on the same 3 plots.
[b]64 colonies collected; 34 contained disease and/or inquilines; 23 colonies contained only a single species of disease or inquiline.
[c]114 colonies collected; 86 contained diseases and/or inquilines; 40 colonies contained only a single species of disease or inquiline.

COLONY LIFE SPAN

Buren et al. (1978) have hypothesized a population model for fire ants in South America based on the assumption that enclaves of fire ant colonies are ephemeral and die out as a result of diseases, parasites, or predators. While these biotic factors certainly have an

effect, other biotic factors, such as habitat, and abiotic factors, particularly the prolonged dry season, cannot be ignored. There are no data on the effects of diseases and/or inquilines on the length of colony life. None of the previously published studies on these organisms followed specific colonies or groups of colonies through several seasons. The statement by Allen and Knell (1980) that mounds over 2 yr of age are seldom found in South America is simply not supported by the facts. From studies by Markin et al. (1973), we know it takes approximately 2 to 3 yr for a colony to amass over 100,000 workers in the United States. Large colonies of this size are seen regularly in Brazil (Banks et al. 1985). The recent data on S. invicta populations in Brazil indicate it is unlikely that the hypothesis of Buren et al. (1978) reflects the real situation in Brazil.

CONCLUSIONS

While many aspects of S. invicta biology in Brazil remain unstudied and unknown, the following points can be made:

1. No new data are available on the origin or method of introduction of S. invicta into the United States.
2. S. invicta builds mounds in Brazil equal in size to the large mounds built in the United States, provided similar soil types are compared.
3. The numbers of ants found in colonies in Brazil are at least equal to the numbers found in colonies in the United States.
4. Polygynous colonies have not been found to date in Brazil.
5. The numbers of alates in mounds in Brazil are similar to numbers in the United States. The importance of the differences between Brazilian and North American populations concerning the time of day of mating flights has not been established.
6. S. invicta is not common in termite mounds in Mato Grosso.
7. S. invicta feed on arthropods, carrion, garbage, meat and honey baits, and extrafloral nectaries, and tend aphids as they do in the United States.
8. Colony densities in Brazil can be similar to those in the United States where similar habitats are considered.
9. The presence of pathogens and/or inquilines is one of many factors influencing S. invicta populations in Brazil.
10. S. invicta colonies in Brazil probably have a life span equal to the life span of colonies in the United States.

The many similarities between North and South American populations of S. invicta should not discourage the seeking of biological control agents in South America for use in North America. It is reasonable to assume that any biological control agents present are exerting pressure on S. invicta populations. These agents must be discovered and studied before we can determine how they can fit into a viable IPM program for fire ant control. The recent estab-

lishment of a cooperative USDA-EMBRAPA fire ant research program at the EMPA laboratory in Caceres, Mato Grosso, Brazil includes studies of the ecology and biology of S. invicta and their natural control agents, so that many unanswered questions about these pests can be resolved.

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