HOST-SPECIFIC ATTRACTION OF *PSEUDACTEON* FLIES (DIPTERA: PHORIDAE) TO FIRE ANT COLONIES IN BRAZIL

SANFORD D. PORTER
USDA-ARS, Center for Medical, Agricultural and Veterinary Entomology
P.O. Box 14565, Gainesville, FL 32604

ABSTRACT

Pseudacteon fly host-specificity tests were conducted in the field in southeastern Brazil with *Solenopsis* fire ants in the *saevissima* and *geminata* complexes. These parasitic flies showed a strong preference for fire ants in the *saevissima* complex. No *Pseudacteon* flies were attracted to three *Solenopsis geminata* (F.) colonies when they were set out in trays, but many flies were quickly attracted to three trays with *saevissima* complex colonies when they were set out between the *S. geminata* colonies. Even when both species of ants were placed together side by side, more than 99% of flies hovered over trays with *saevissima* complex ants. When all of the *saevissima* colonies were removed, leaving only the *S. geminata* colonies available, about 95% of flies flew away. Several flies, however, did transfer to the *S. geminata* colonies for a few minutes and at least one fly (*P. wasmanni*) attacked a few *S. geminata* workers. Altogether, 588 parasitized workers were collected from the *saevissima* complex colonies compared to 12 from the *S. geminata* colonies. Two hundred-sixty-two flies emerged from the *saevissima* complex colonies (52% *Pseudacteon tricuspis* Borgmeier, 39% *Pseudacteon litoralis* Borgmeier, 4.6% *Pseudacteon wasmanni* Schmitz, 2.7% *Pseudacteon pradei* Borgmeier, 0.4% *Pseudacteon curvatus* Borgmeier). No adult flies emerged from the *S. geminata* colonies. These results demonstrate that *P. tricuspis* and *P. litoralis* are highly specific to *saevissima* complex fire ants and strongly indicate that they would pose little threat to native fire ants should they be released as biocontrol agents for imported fire ants in the United States.

Key Words: biological control, host specificity, parasite, parasitoid, Brazil, *Solenopsis*

RESUMEN

Testes de especificidade de moscas do genero *Pseudacteon* a formigas hospedeiras foram conduzidos em condições de campo no sudeste do Brasil. Foram utilizadas formigas do genero *Solenopsis*, denominadas lava-pé, pertencentes aos complexos *saevissima* e *geminata*. Estas moscas parásitas apresentaram uma forte preferencia pelas formigas do complexo *saevissima*. Nenhuma das moscas foram atraídas pelas tres colonias de *Solenopsis geminata* (F.), quando depositadas em bandejas, entretanto, as mesmas foram rápidamente atraídas à tres bandejas contendo o complexo *saevissima* quando elas foram colocadas entre colonias de *S. geminata*. Mesmo quando ambas as especies de *Solenopsis* foram colocadas juntas, lado a lado, mais de 99% das moscas sobrevoaram a bandejas contendo o complexo de formigas *saevissima*. Após todas a colonias de *saevissima* terem sido removidas, permanecendo apenas colonias de *S. geminata*, cerca de 96% das moscas voaram, abandonando as bandejas. Várias moscas, entretanto, entraram em contato com colonias de *S. geminata* por alguns minutos e pelo menos uma mosca da especie *Pseudacteon wasmanni* Schmitz atacou algumas operarias de *S. geminata*. No total, 588 operarias parasitades foram coletadas no complexo de colonias de *saevissima*, comparado com 12 de colonias de *S. geminata*. Duzentos e sesenta e duas moscas emergiram de colonias do complexo *saevissima* (52% *Pseudacteon tricuspis* Borgmeier, 39% *Pseudacteon litoralis* Borgmeier, 4,6% *P. wasmanni*, 2,7% *Pseudacteon pradei* Borgmeier, 0,4% *Pseudacteon curvatus* Borgmeier). Nenhuma mosca adulta emergiu de colonias de *S. geminata*. Estes resultados demonstram que *P. tricuspis* e *P. litoralis* são altamente sepecíficas ao complexo de formigas lava-pé no complexo *saevissima*. Estes resultados sugerem que estas moscas parásitas apresentam pouca ameaça a formigas lava-pé nativas, se estas forem introducidas como agentes biocontroladores nos Estados Unidos.

Host specificity is an important issue that needs to be resolved before the introduction of exotic biocontrol agents. Almost 20 species of *Pseudacteon* flies in South America are known to attack species of fire ants in the *saevissima* complex of the genus *Solenopsis* (Disney 1994, Porter et al. 1995a, unpublished data). Larvae of these flies have the unusual habit of decapitating their living hosts and pupating inside the empty head capsule (Porter et al. 1995b). Field collection data indicate that most, if not all, of the species that attack fire ants are specific to fire ants (Borgmeier 1969, Borgmeier & Prado 1975, Williams & Whitcomb 1974). Field tests in Brazil also demonstrated that these flies are not attracted to ants in other genera (Porter et al. 1995a). Almost all of the flies in these tests (Porter et al. 1995a) were attracted to *saevissima* complex fire ants; however, a few flies were also attracted to fire ants in the *geminata* complex. The objective of the present study was to compare the host specificity of additional *Pseudacteon* species to *geminata* and *saevissima* complex fire ants in the field. In particular, I wanted to determine rates of attraction and successful parasitism. The suitability of *saevissima* and *geminata* complex fire ants as hosts for *Pseudacteon* flies is an important biocontrol question because all native fire ants in the United States are in the *geminata* complex (Trager 1991), while both of the imported fire ants in the United States are in the *saevissima* complex.

MATERIALS AND METHODS

Three fire ant colonies in the *saevissima* complex were collected from the EMBRAPA, CNPMA research station about 5 km south of Jaguariuna, São Paulo State, Brazil. One of these colonies was keyed to *Solenopsis invicta* Buren. The other two col-

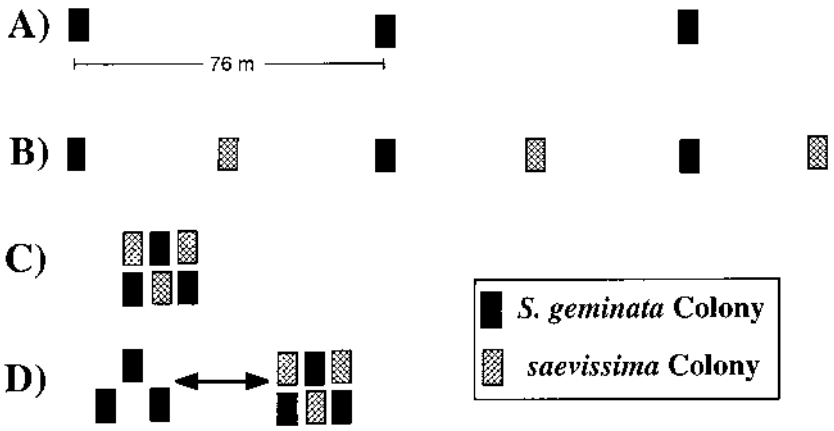

Fig. 1. Arrangement of trays with *Solenopsis geminata* and *saevissima* complex fire ants during four successive tests: A) Only *S. geminata* trays spaced 76 m apart (30 min), B) Both *S. geminata* and *saevissima* complex trays, alternately separated 38 m apart (30 min), C) Both *S. geminata* and *saevissima* trays grouped side by side at a single location (30 min), D) Alternating sequence of test *S. geminata* trays grouped together without and with the *saevissima* trays (15-20 min each test, two cycles).

onies were ambiguous between *S. invicta* and *Solenopsis saevissima* (F. Smith); both had the frontal streak, but rugous sculpture only covered half or less of the postpetiole. Three *Solenopsis geminata* (F.) colonies were collected from the CEPLAC research station about 10 km east of Itabuna, Bahia, Brazil. These colonies were the black form of *S. geminata* found in the Antilles and west Africa (Trager 1991). All test colonies lacked a mother queen and all sexuals were removed from the *S. geminata* colonies. Test colonies were placed in 40 by 26 by 8 cm nest trays. Colonies contained 3,000-10,000 workers. The sizes of the *saevissima* complex colonies were reduced to match paired *S. geminata* colonies. Field tests were conducted at two sites approximately 10 km apart to the north and east of Rio Claro, São Paulo State, Brazil along the road to Araras (8-10 April 1996).

At each site, the three *S. geminata* colonies and three *saevissima* complex colonies were set out in trays in four sequential tests as illustrated (Fig. 1). In the first test only *S. geminata* colonies were available. This was done to ensure that the *saevissima* complex ants were not diverting flies away from the *S. geminata* ants. In the second test, both kinds of ants were available at alternately spaced locations. This test was designed to show that the flies were readily attracted to their normal host (*saevissima* complex fire ants). In the third test, all six colonies were grouped together at the location having the highest fly activity. Several times during this test, the flies were shooed out of the trays and allowed to reassort themselves among the colonies. This test was designed to determine if the flies would distinguish between *S. geminata* and *saevissima* complex ants at close range after they had discovered the ants. In the fourth test, all of the *saevissima* complex colonies were removed, leaving only *S. geminata* colonies for 15-20 min. The *saevissima* colonies were then returned for about 15 min after which they were removed again leaving only the *S. geminata* colonies. This final test cycle was conducted to determine if the flies would attack *S. geminata* colonies when they were the only choice. All four tests were repeated at each site on a sec-

ond day after switching the locations of the *saevissima* complex colonies and the *S. geminata* colonies.

The numbers of active flies were estimated every 10 minutes during each test run. Flies attracted to *S. geminata* colonies were collected, identified, and quickly released. No species identifications were made for flies attracted to the *saevissima* complex colonies because of the large numbers involved. At the conclusion of these tests, all six colonies were returned to the lab and checked for pupating larvae. Flies emerging from these pupae were identified to species. *P. tricuspis* flies matched the figure in Borgmeier & Prado (1975). Voucher specimens of flies and ants have been deposited with the Museu de Zoologia, Universidade de São Paulo, Brazil; EMBRAPA's CNPMA research center in Jaguariuna, SP, Brazil, and the Florida State Collection of Arthropods, Florida Department of Agriculture and Consumer Service, Division of Plant Industry, Gainesville, Florida, U.S.A.

A Fisher's exact test (Statview 4.5, Abacus Concepts, Inc., Berkeley, CA, 1995) was used for 2 by 2 contingency tables to determine if the appearance of flies over test colonies was independent of the species of ants in the colony. A Wilcoxon Signed Rank test (Statview 4.5) was used to compare the total number of flies that appeared over the three *saevissima* complex colonies with totals from the three *geminata* colonies. Totals for each species were paired by site and trial (n = 4 pairs). A non-parametric test was used because sample variance was not equal between species due to the large number of zeros associated with the *S. geminata* colonies.

RESULTS

Pseudacteon flies were not attracted to any of the *S. geminata* colonies during the first 30 min when they were the only test colonies available (Fig. 1A). Similarly, no *Pseudacteon* flies were attracted to any of the *S. geminata* colonies during the second 30 min when the *saevissima* colonies were also available (Fig. 1B). However, flies were quickly attracted to the *saevissima* complex colonies on 9 of 12 opportunities (3 colonies $\times$ 2 sites $\times$ 2 trials; 2-way contingency table, Fisher's Exact P-value = 0.0003). On average, a total of 14.3 flies were active over the *saevissima* complex colonies at each ten minute observation compared to zero over the *S. geminata* colonies (Fig. 2; Wilcoxon Signed Rank Test, P = 0.068). While not quite significant, this P-value and those following for the Wilcoxon tests are the lowest possible given the number of colonies tested.

When the six colonies were all placed together (Fig. 1C), the three *saevissima* complex colonies attracted flies on 12 of 12 possible opportunities compared to 1 of 12 for the *S. geminata* colonies (Fisher's Exact P-value < 0.0001). The average number of flies active over the three *saevissima* trays during this period was 15.4 per observation compared to 0.12 flies over the *S. geminata* trays (1 *P. litoralis* for 1 observation; it hovered but did not attack; Fig. 2; Wilcoxon Signed Rank Test, P = 0.068).

In the final test, the three *S. geminata* colonies attracted flies during 4 of 12 possible opportunities while the *saevissima* colonies attracted flies on 10 of 12 possible occasions (Fisher's Exact P-value = 0.0361). On average, 12.1 flies were active over the three *saevissima* colonies compared to an average of 0.62 flies (5 flies total) that were active when only the three *S. geminata* colonies were present (Fig. 2; Wilcoxon Signed Rank Test, P = 0.068). One *Pseudacteon wasmanni* Schmitz female was observed systematically attacking *S. geminata* workers for several minutes. The other four flies mostly hovered without attacking. When the three *saevissima* colonies were returned along side the *S. geminata* colonies, all of the flies returned almost immediately to the *saevissima* colonies. Consequently, no flies were active over adjacent *S. geminata* colonies during periods of this test cycle when both species were grouped together (Wilcoxon Signed Rank Test, P = 0.068).

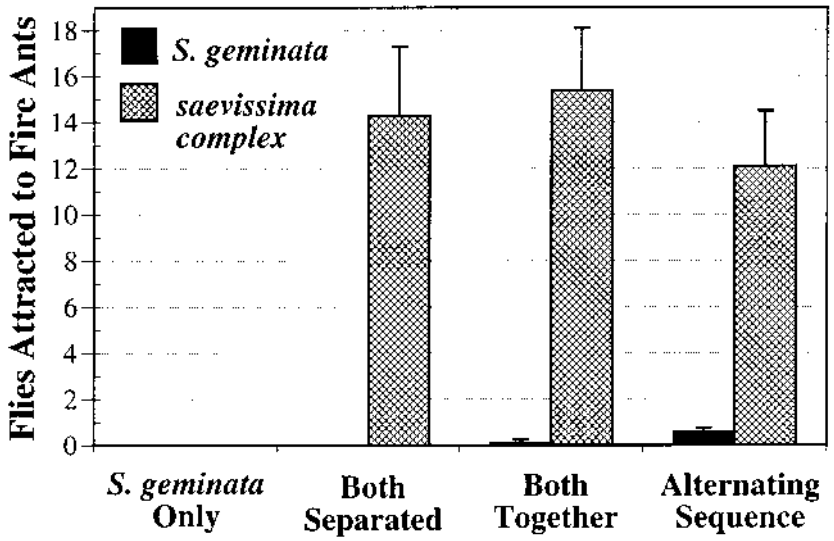

Fig. 2. Comparative abundance of parasitic *Pseudacteon* flies attracted to three *Solenopsis geminata* and three *saevissima* complex fire ant colonies in four successive time periods during which 1) only *S. geminata* colonies were available, 2) both kinds of colonies were available but separated, 3) both kinds of colonies were together side by side, 4) and both kinds of colonies were available in an alternating time sequence. Values are means of the total number of flies found in the three trays at each of four observation periods. Standard errors of the mean are indicated for each bar.

On two occasions, a dozen or so flies were placed in sealed trays with *S. geminata* fire ants so they could not escape. Most of the flies simply spent their time resting on the side of the tray or trying to escape. Two male flies hovered over the *S. geminata* workers, but no females hovered or attacked.

All six test colonies were checked for pupating fly larvae. Twelve pupating larvae were removed from two of the three *S. geminata* colonies. Four of these larvae pupated, but none emerged. Upon dissection, I identified one pupa as a female *P. wasmanni* and two as males of the same species. Although none of these flies emerged as adults, they were well developed and it seems likely that at least some *P. wasmanni* can complete development in *S. geminata.* In contrast to the small numbers of pupae in the *S. geminata* colonies, I collected 588 pupating larvae from the three *saevissima* complex colonies (320, 100, and 168, respectively). From these larvae, 262 adult flies emerged including the following five species: *Pseudacteon tricuspis* Borgmeier (52%), *Pseudacteon litoralis* Borgmeier (39%), *P. wasmanni* (4.6%), *Pseudacteon pradei* Borgmeier (2.7%), and *Pseudacteon curvatus* Borgmeier (0.4%) plus several unidentified males (1.5%). The ratio of males to females was approximately 1:1 for both *P. tricuspis* (64:71) and *P. litoralis* (54:49).

Discussion

Both *P. tricuspis* and *P. litoralis* flies showed a strong preference for the *saevissima* complex colonies over the *S. geminata* colonies. Neither species was observed attacking *S. geminata* workers, but large numbers were observed attacking the *saevissima* com-

plex colonies. Altogether, I reared 131 *P. tricuspis* flies and 102 *P. litoralis* flies from the three *saevissima* complex colonies, but none from the three *S. geminata* colonies. *P. pradei* and *P. curvatus* also were recovered only from the *saevissima* complex colonies; however, larval numbers for these two species were not sufficiently high to determine host preferences. A few *P. wasmanni* were reared from both the *saevissima* and *geminata* complex colonies. Schmitz (1914) originally reported that *P. wasmanni* attacked *S. geminata* in Joinville, Santa Catarina, Brazil; however, this report is probably in error because the nearest confirmed *S. geminata* population is in Viçosa, Minas Gerais which is more than 1000 km to the north (Fowler et al. 1995). In contrast to Porter et al. (1995a), no *P. wasmanni* or *P. pradei* females were attracted to individual *S. geminata* colonies during the initial two tests; however, one *P. wasmanni* did transfer to an *S. geminata* colony in the fourth and final set of tests. Fowler et al. (1995) reported that *P. curvatus* hovered over *S. geminata* workers from Viçosa but did not attack them.

The fact that no phorids came to the *S. geminata* colonies during the first 30 min, when they were the only fire ants available, demonstrated that most, if not all, of the *Pseudacteon* species in the two test areas had little long-range attraction to *S. geminata* fire ants. Probably, these flies simply did not recognize the odor cues produced by this fire ant even though it is in the same genus as the *saevissima* complex ants. The rapid accumulation of *Pseudacteon* flies over the *saevissima* colonies in the second 30-min period suggests that they were waiting nearby for an appropriate host.

The fact that almost no phorids attacked the *S. geminata* colonies during the third 30 min period when they were side by side with the *saevissima* colonies demonstrated that the host preferences of most flies were highly specific even at close range when flies could presumably locate their hosts visually. A high degree of host specificity was further demonstrated by the removal of the *saevissima* colonies. When the flies were given the choice of attacking *S. geminata* workers or nothing, a large majority of the flies, including all of the *P. tricuspis* and *P litoralis*, simply disappeared, choosing to attack nothing. However, when the *saevissima* colonies were returned, most of the flies returned as well, usually within 1-2 minutes. The adjacent *S. geminata* colonies were completely ignored even though the flies often had to fly directly over them to reach the *saevissima* complex ants.

In conclusion, the two most common phorids in this study (*P. tricuspis* and *P. litoralis*) both appear to have highly specific host-attraction preferences for *saevissima* complex ants (including *S. invicta*). Laboratory specificity tests with *S. geminata* and *S. invicta* from the United States also indicate highly specific preferences for *S. invicta* (Gilbert & Morrison 1997, Porter & Alonso unpublished). Considered together, these data indicate that *P. tricuspis and P. litoralis* would pose little or no risk to native *Solenopsis* fire ants.

ACKNOWLEDGMENTS

Special thanks are extended to J. H. C. Delabie and his students for help in collecting the *S. geminata* colonies. I am also grateful to L. A. Nogueira de Sá and G. J. de Moraes for arranging the use of EMBRAPA/CNPMA facilities during this study. L. Alonso, L. Morrison, and C. Porter read the manuscript and provided a number of useful suggestions.

REFERENCES CITED

BORGMEIER, T. 1969. New or little-known phorid flies, mainly of the Neotropical region (Diptera: Phoridae). Stud. Entomol. 12: 33-132.

BORGMEIER, T., AND A. P. PRADO. 1975. New or little known Neotropical phorid flies, with description of eight new genera (Diptera: Phoridae). Stud. Entomol. 18: 3-90.

DISNEY, R. H. L. 1994. Scuttle flies: The Phoridae. Chapman & Hall, London. 467 p.

FOWLER, H. G., S. CAMPIOLO, M. A. PESQUERO, AND S. D. PORTER. 1995. Notes on a southern record for *Solenopsis geminata* (Hymenoptera: Formicidae). Iheringia, Ser. Zool. 79: 173.

GILBERT, L. E., AND L. W. MORRISON. 1997. Patterns of host specificity in *Pseudacteon* parasitoid flies (Diptera: Phoridae) that attack *Solenopsis* fire ants (Hymenoptera: Formicidae). Environ. Entomol. 26: 1149-1154.

PORTER, S. D., H. G. FOWLER, S. CAMPIOLO, AND M. A. PESQUERO. 1995a. Host specificity of several *Pseudacteon* (Diptera: Phoridae) parasites of fire ants (Hymenoptera: Formicidae) in South America. Florida Entomol. 78: 70-75.

PORTER, S. D., M. A. PESQUERO, S. CAMPIOLO, AND H. G. FOWLER. 1995b. Growth and development of *Pseudacteon* phorid fly maggots (Diptera: Phoridae) in the heads of *Solenopsis* fire ant workers (Hymenoptera: Formicidae). Environ. Entomol. 24: 475- 479.

SCHMITZ, H. 1914. Die myrmecophilen Phoriden der Wasmann'schen Sammlung. Zool. Jahrb. System. 37: 509-66, Taf. 29-30.

TRAGER, J. C. 1991. A revision of the fire ants, *Solenopsis geminata* group (Hymenoptera: Formicidae: Myrmicinae). J. New York Entomol. Soc. 99: 141-198.

WILLIAMS, R. N., AND W. H. WHITCOMB. 1974. Parasites of fire ants in South America. Proc. Tall Timbers Conf. Ecol. Anim. Control Habitat Manage. 5: 49-59.