

## MANAGEMENT OF PEST MOLE CRICKETS IN FLORIDA AND PUERTO RICO WITH A NEMATODE AND PARASITIC WASP

N. C. LEPLA<sup>1</sup>, J. H. FRANK<sup>1</sup>, M. B. ADJEI<sup>2\*</sup> AND N. E. VICENTE<sup>3</sup>

<sup>1</sup>University of Florida, Institute of Food and Agricultural Sciences, Department of Entomology and Nematology  
P.O. Box 110630, Gainesville, FL 32611-0630

<sup>2</sup>University of Florida, Range Cattle Research and Education Center  
3401 Experiment Station, Ona, FL 33865-9706

\*Deceased

<sup>3</sup>University of Puerto Rico, Agricultural Experiment Station, P.O. Box 9030, Mayaguez, PR 00681-9030

### ABSTRACT

Non-indigenous invasive mole crickets, *Scapteriscus vicinus* Scudder (Orthoptera: Gryllotalpidae) in Florida and *S. didactylus* (Latreille) (the "changa") in Puerto Rico, are being managed with an entomopathogenic nematode, *Steinernema scapterisci* (Nguyen and Smart) (Rhabditida: Steinernematidae), and a parasitic wasp, *Larra bicolor* L. (Hymenoptera: Sphecidae). Pest mole cricket populations have declined by 95% in north central Florida since these specialist natural enemies were released and established in the 1980s. Commercial production of the nematode was initiated, nearly 70 billion were applied in 34 Florida counties, and their establishment, spread, and impact on mole crickets were monitored. The infected mole crickets dispersed the nematode rapidly, so that within 6 months these parasites were present in most of the insects trapped in experimental pastures. Three years later, mole cricket populations were reduced to acceptable levels and the bahiagrass had recovered. The nematode was released for the first time in Puerto Rico during 2001 and has persisted; the wasp was introduced in the late 1930s. The geographical distribution of the wasp is being expanded in Florida and Puerto Rico by planting plots of *Spermacoce verticillata* (L.), a wildflower indigenous to Puerto Rico and widely distributed in southern Florida. Pastures, sod farms, golf courses, landscapes, and vegetable farms in Florida and Puerto Rico are benefiting from biological control of invasive mole crickets.

Key Words: mole crickets, changa, biological control, *Steinernema scapterisci*, *Larra bicolor*, *Spermacoce verticillata*, bahiagrass

### RESUMEN

Los grillo topos invasores no indígenas, *Scapteriscus vicinus* (Orthoptera: Gryllotalpidae) en el estado de Florida y *S. didactylus* ("changa") en Puerto Rico, están siendo manejados por el nematodo entomopatógeno, *Steinernema scapterisci* (Rhabditida: Steinernematidae) y la avispa parasítica, *Larra bicolor* (Hymenoptera: Sphecidae). Las poblaciones de los grillo topoplagas han declinado un 95% en el norte central de la Florida desde que estos enemigos naturales especialistas fueron liberados y establecidos en los 80s. Consecuentemente, la producción comercial del nematodo fue iniciada, casi 70 billones fueron aplicados en 34 condados de la Florida, y se realizó un monitoreo para evaluar su establecimiento, dispersión e impacto sobre los grillo topos. Los grillo topos infectados dispersaron los nemátodos rápidamente, tanto que después de 6 meses estos parásitos estaban presentes en la mayoría de los insectos atrapados en los pastos experimentales. Tres años después, las poblaciones de los grillo topos fueron reducidas a niveles aceptables y los campos de pasto 'bahía' se recuperaron. El nematodo fue liberado para la primera vez en Puerto Rico durante del 2001 y ha persistido; la avispa fue introducida al final de los 30s. La distribución geográfica de la avispa se esta extendiendo en la Florida y Puerto Rico por medio de la siembra de parcelas de *Spermacoce verticillata*, una flor silvestre indígena a Puerto Rico y distribuida ampliamente en el sur de la Florida. Los campos de pasto, las operaciones comerciales de césped, los campos de golf, los paisajes y las fincas de hortalizas en la Florida y Puerto Rico se están beneficiando del control biológico de los grillo topos invasores.

Non-indigenous invasive species are causing ever increasing economic and environmental damage to the Caribbean Region, including Florida. Two species of non-native pest mole crickets,

*Scapteriscus vicinus* Scudder in Florida and *S. didactylus* (Latreille) in Puerto Rico, are among the most damaging. Their tunneling and feeding cause significant economic losses to pastures, golf

courses, sod farms, sports fields, residential lawns, and vegetable farms. In Puerto Rico, *S. didactylus* was recognized long ago as a general pest of agriculture, and the loss of forage for livestock grazing on pastures severely infested with *S. vicinus* has become a serious problem for beef and dairy cattle in Florida. For decades, the worst pest insects on the 20 plus golf courses in Puerto Rico and 1400 or more in Florida have been mole crickets. Puerto Rico and the southern states suffer in excess of \$200 million annually in damage and control costs due to invasive mole crickets (Frank & Parkman 1999). However, this situation is changing as populations of biological control agents increase, spread, and become effective in suppressing these pests (Frank & Walker 2006).

Chemical controls are available for mole crickets in lawns, golf courses, and sod farms (Buss et al. 2002) but can be expensive and are not always effective, in addition to incurring environmental risks and providing only short-term relief. Public concern has been increasing because of the possible overuse and misuse of chemicals on turf and the potential for ground water contamination (FDEP 2002). Some golf course and sports complex managers have attempted to minimize the use of insecticides due to local restrictions and concern about the health of their members. This has led to unacceptable levels of damage to turf as a result of mole cricket tunneling and feeding. Chemical control in pastures is prohibitively expensive (Frank & Parkman 1999). Consequently, cattlemen, turf producers, golf course managers, and others have been seeking a cost-effective, environmentally safe, and permanent means of minimizing mole cricket damage.

This project was conducted to advance biological control of invasive mole crickets, *Scapteriscus* spp., in Florida and Puerto Rico by fully deploying and evaluating an entomopathogenic nematode, *Steinernema scapterisci* (Nguyen and Smart), and a parasitic wasp, *Larra bicolor* F. (Fig. 1). The nematode was introduced into Florida from Uruguay in the 1980s, commercialized in 2001, and applied on bahiagrass in at least half of the 67 Florida counties (Adjei et al. 2006). Nematode applications were also made at several sites in Puerto Rico from 2001 to 2004. The nematode is effective, multiplies within infected mole crickets, and spreads rapidly as the insects disperse (Parkman et al. 1993).

The wasp was imported from Bolivia and released at Gainesville, Florida in 1988 (Frank & Sourakov 2002). It became established and is spreading (Frank et al. 1995) but has not yet colonized all of Florida (Frank & Walker 2005). The adult wasps can fly and distribute themselves but they require a nectar source, especially the wildflower, *Spermacoce verticillata* (L.). This wildflower is widespread in southern Florida (Wunderlin & Hansen 2003) and considered an

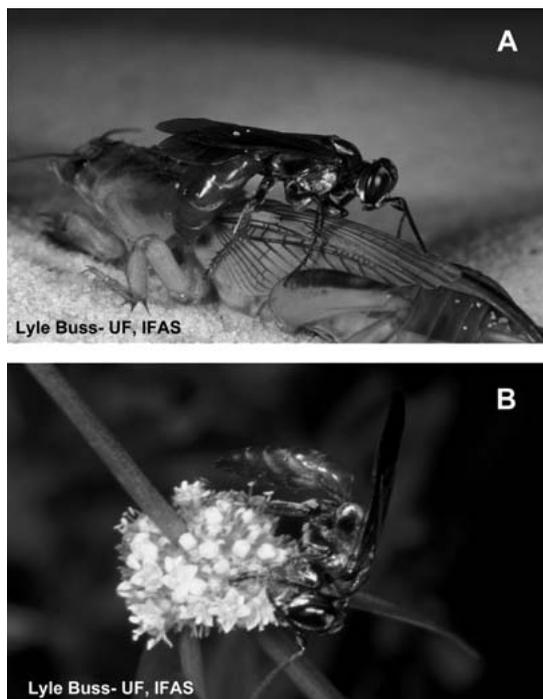


Fig. 1. The parasitic wasp, *Larra bicolor* (length 22 mm) (A) Ovipositing on an invasive mole cricket, *Scapteriscus vicinus*, and (B) feeding on nectar of *Spermacoce verticillata*.

unimportant weed (Murphy et al. 1998). Plants growing in road margins and turf are typically small and produce few flowers because of mowing and the use of herbicides. Nevertheless, they probably are capable of sustaining sparse *L. bicolor* populations because they can flower all year. In northern Florida, the plant is reported only from Alachua and St. Johns counties (Wunderlin & Hansen 2003); and it freezes to the ground in winter (Arévalo & Frank 2005).

Since *L. bicolor* was introduced into Puerto Rico from Brazil in the late 1930s (Wolcott 1938), it could have colonized the entire country (Castner & Fowler 1984) but it is not conspicuous. Its primary nectar source, *S. verticillata*, is native to Puerto Rico (Liogier 1982) and most abundant in sandy places near the coasts. Urbanization, especially along the coasts, has diminished *S. verticillata* habitats and the plant is typically viewed as a weed and destroyed. Wolcott (1941a, b) speculated that, if *S. verticillata* were permitted to grow as a beneficial plant, *L. bicolor* would be more abundant and widespread. Regardless, even unmanaged populations of the wasp have achieved partial biological control of pest mole crickets (Cruz & Segarra 1992), a vast improvement over the situation in the early 1900s when mole crickets were considered to be the most seri-

ous general pests of agriculture in Puerto Rico (Zwaluwenburg 1918).

While significant research has been conducted on *S. scapterisci* and *L. bicolor*, and their effectiveness in controlling mole crickets has been established (Frank et al. 2005), additional work was needed to more efficiently produce, distribute, and evaluate the impact of these natural enemies in new locations (Leppla et al. 2004). The objectives of the current project conducted in Florida and Puerto Rico are to (1) continue trapping mole crickets and determining the infection levels and spread of *S. scapterisci*, (2) plant plots of *S. verticillata* in as many locations as possible to provide nectar for adult *L. bicolor*, (3) accelerate the natural spread of the wasps by capturing them from established populations and moving them to new sites, and (4) educate collaborators, extension agents, master gardeners, cattlemen, golf course superintendents, and the general public about the use and benefits of *S. scapterisci* and *L. bicolor* for biological control of invasive mole crickets.

#### MATERIALS AND METHODS

The *S. scapterisci* nematode product, Nematac®S, was produced by MicroBio, UK, under an exclusive license for its use from the University of Florida, the patent holder, and provided by Becker Underwood, Ames, Iowa (<http://www.beckerunderwood.com>). The nematodes were shipped directly to the University of Florida or the University of Puerto Rico (UPR) at Mayagüez and stored for no more than 1 month at about 10°C. As recommended by Becker Underwood, nematodes were mixed in water and applied as an amount equivalent to about 2.5 billion per ha. Applications were made without irrigation, early in the morning or late in the afternoon to avoid direct sunlight.

Nematode applications were made throughout much of Florida in 2000 and 2001 by injecting them 1.5 cm below the soil surface with a modified slit-seeder (Adjei et al. 2005). To determine the degree of spread, nematodes were applied in 6.08 m wide by 41.3 m long strips covering 1/2, 1/4, or 1/8 of 0.4-ha plots distributed across a 10-ha bahiagrass pasture during Sep 2000 in Polk County. Pitfall traps used to capture mole crickets for estimating levels of infection and impact of the nematode (Hudson 1989) were installed in each plot: 3 in nematode-treated strips, 3 in untreated strips, and 6 in the untreated control plots. More than 600 mole crickets were trapped in the plots for 3 months prior to applying the nematodes and none were found to be infected. The percentage of bahiagrass in the pasture was recorded as green, yellow, or dead (brown, bare ground, or weeds). This was accomplished by randomly tossing a m<sup>2</sup> quadrat with 100 subdivisions 5 times in each plot.

In Puerto Rico, nematodes were applied for the first time ever in Nov 2001 and again in Aug 2003 on an irrigated golf course with clay loam soil near Aguadilla and at an organic vegetable farm in Aguada. Commercial spray equipment was used at the golf course to apply nematodes on 0.5-acre plots. A pitfall trap was installed near the center of each of 5 treated and 5 untreated plots. At the vegetable farm, a hand-held watering container was used to sprinkle nematodes on five 2 × 7-m plots. Applications were made early in the morning at both locations followed by enough irrigation to soak the surface of the soil.

Mole crickets from all sites in Florida and Puerto Rico were pitfall-trapped at 7-d intervals. Additional 24-h collections were made biweekly in Florida to assure that the mole crickets were alive when taken to the laboratory. Regardless of source, captured mole crickets were provided with food and water, held until dead, and assayed for presence of nematodes (Woodring & Kaya 1988). Effectiveness and spread of the nematodes was evaluated by determining the percentage of trapped mole crickets that were infected and by monitoring an associated decline in the number of mole crickets.

To detect and redistribute the wasp, *S. verticillata* plants were grown at sites in Florida and Puerto Rico. Wasps destined for release in Florida were captured at *S. verticillata* plots in the Gainesville area, chilled, and transported to the new sites. Releases were made no earlier than dusk on the day of capture, and each site received 24-30 presumably mated females. Wasp populations were highest in Sep through Nov, so these were the most appropriate months for the adults to be captured. In Puerto Rico, small *S. verticillata* plants collected from an overgrown pasture at Playa Anasco were transplanted into several plots at the golf course and vegetable farm where the nematodes had been applied. These plots provided nectar sources to attract and retain the wasps. Plants were also planted within 1-2 meters of each of 5 pitfall traps at 5 other locations in Nov-Dec 2004. The plants had been dug from sandy soil as small plants in Jul and grown for 3-4 months in pots containing wet peat to recover from transplantation. They were placed in the field to determine the presence of wasps.

#### RESULTS AND DISCUSSION

During spring 2001, after the nematodes had been applied in the Florida pasture during the previous fall, 80% of the 328 trapped mole crickets were infected, including those from both the treated and untreated plots. Infected mole crickets thus spread the nematodes across the entire 10-ha pasture in less than 1 year. This indicated that nematodes can be introduced in strips receiving about 0.3 billion infective juveniles per ha to

avoid much more expensive broadcast applications of 2.5 billion per ha. Three years later, the proportion of infected mole crickets stabilized at 20-35%, the number of mole crickets trapped declined by 85% (Fig. 2), and the bahiagrass cover increased by 40-95% (Adjei et al. 2006).

In Puerto Rico, *S. didactylus*, was trapped at both sites where nematodes were applied and relatively small numbers of *S. abbreviatus* were discovered at the organic vegetable farm. Mole crickets captured at the golf course in Aguadilla contained steinernematid nematodes but those from the vegetable farm were not infected. Persistence of infected mole crickets at the golf course for more than 7 months indicated that the nematode became established. According to research conducted in Florida, the nematode is not likely to persist for more than 10 weeks in soil without passing through host mole crickets (Nguyen & Smart 1989). At Aguadilla, more than 225 mole crickets were trapped between Nov 2001 and Oct 2002, and some of these insects were infected every month until the end of Jun 2002 when assays ceased. A total of 28 mole crickets were infected. Thus, we determined that *S. scapterisci* infected and killed *S. didactylus* mole crickets in Puerto Rico

Parasitism of *S. vicinus* by *L. bicolor* averaged about 24% at 2 locations near Gainesville, Florida throughout the fall seasons of 1999 and 2000. *Larra bicolor* has several annual generations, whereas *S. vicinus* has but one, so the average generational mortality of the mole cricket may approach 70% (Frank & Walker 2005). Due to this initial success, wasps were released in fall 2002 in northern Florida at Quincy in Gadsden County and Palmetto in Manatee County. They were recovered in both counties during May and Nov 2004. Wasps have not yet been captured following releases in fall 2004 in Bay and St. Lucie counties. The wasps spread naturally to Bradford, Pinellas, and Sumter counties during the summer of 2004 and to Hernando County by Oct 2004. In all, the wasps were reported from 22 counties by Jun 2005. Wasps observed at *S. verticillata*

plots in Puerto Rico have not yet been confirmed as *L. bicolor*.

*Larra bicolor* feeds at nectaries of plants in addition to *S. verticillata* and could have used them to disperse widely in northern Florida. However, the duration of visits to *S. verticillata* compared with 4 other plants, *Conoclinium coelestinum* (L.) DC, *Elephantopus elatus* Bertol., *Passiflora coccinea* Aubl., and *Solidago fistulosa* Mill., indicated that *S. verticillata* is significantly more attractive (Arévalo & Frank 2005). Consequently, plots of *S. verticillata* are being maintained in Duval, Hillsborough, and Pasco counties where the wasp is assumed to be present but has not been detected. Extension agents and master gardeners in 30 counties have each been provided with at least one potted *S. verticillata* plant to attract the wasps.

Cattle, landscape, turf and allied industries, and the general public in Florida and Puerto Rico will benefit greatly by having long term, cost-effective biological control that minimizes the damage caused by invasive mole crickets. Establishing natural enemies that recycle, leaving only periodic pest resurgence in isolated areas, can eliminate most of the damage caused by these pests. Nematac®S nematodes persist in irrigated clay loam soils, spread rapidly, induce high levels of infection, and kill pest mole crickets. The nematodes can be applied in strips from which they will move to fill the gaps, thus reducing the cost to 1/8 as much as broadcast applications. Hopefully, the wasp will function additively with the nematode to reduce mole cricket populations. The wasps will forage for mole crickets more effectively if *S. verticillata* plants are available as a source of nectar. The long-term financial and environmental costs of this biological approach to mole cricket management will be much less than continued reliance on chemical insecticides.

#### ACKNOWLEDGMENTS

The authors thank the following at University of Florida: Khuong Nguyen for identifying the nematodes found in mole crickets, Esther Dunn for distributing *S. verticillata* plants to extension agents and master gardeners, Scott Portman for initiating the study on nectar sources for *L. bicolor* in Florida, Lyle Buss for contributing the photographs in Fig. 1, and Jennifer Gillett for preparing Fig. 2. The nematodes were donated by Becker Underwood through the efforts of Tom Hinks. Members of the Mole Cricket State Program Workgroup and *IPM Florida* coordinated the work in Florida. Edda Martínez and Linnette Rosario, students from UPR, collected the mole crickets from traps in Puerto Rico. Staff of the Florida Department of Agriculture and Consumer Services, Division of Plant Industry provided technical assistance. Housing in Puerto Rico was arranged by Ricardo Goenaga, USDA, ARS. Tom Walker and Eileen Buss at University of Florida contributed especially helpful reviews of the manuscript. This research was supported by the Florida Agricultural Experiment Sta-

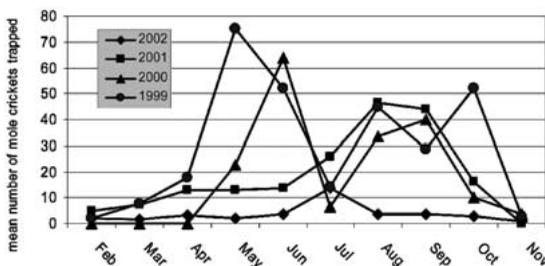


Fig. 2. Mean monthly pitfall-trap catches of *Scapteriscus* spp. mole crickets before (1999) and after (2000-2002) applying the nematode, *Steinernema scapterisci*, on a bahiagrass pasture in central Florida.

tion, an appropriation from the Florida State Legislature, and USDA, CSREES, T-STAR Special Research Grants, and approved for publication as Journal Series No. R-10974.

REFERENCES CITED

ADJEI, M. B., G. C. SMART, JR., J. H. FRANK, AND N. C. LEPPLA. 2006. Control of pest mole crickets (Orthoptera: Gryllotalpidae) in Bahiagrass pastures with the nematode *Steinernema scapterisci* (Rhabditida: Steinernematidae). *Florida Entomol.* 89: 532-535.

ARÉVALO, H. A., AND J. H. FRANK. 2005. Nectar sources for *Larra bicolor* (Hymenoptera: Sphecidae), a parasitoid of *Scapteriscus* mole crickets (Orthoptera: Gryllotalpidae), in northern Florida. *Florida Entomol.* 88: 146-151.

BUSS, E. A., J. L. CAPINERA, AND N. C. LEPPLA. 2002. Pest mole cricket management. University of Florida, IFAS, ENY-324. (<http://edis.ifas.ufl.edu>)

CASTNER, J. L., AND H. G. FOWLER. 1984. Distribution of mole crickets (Orthoptera: Gryllotalpidae: *Scapteriscus*) and the mole cricket parasitoid *Larra bicolor* (Hymenoptera: Sphecidae) in Puerto Rico. *Florida Entomol.* 67: 481-484.

CRUZ, C., AND A. SEGARRA. 1992. Potential for biological control of crop pests in the Caribbean. *Florida Entomol.* 75: 400-408.

FDEP. 2002. Florida Green Industries Best Management Practices for Protection of Water Resources in Florida. Florida Department of Environmental Protection. 60 p.

FRANK, J. H., T. R. FASULO, D. E. SHORT, AND A. S. WEED. 2005. MCricket: Alternative Methods of Mole Cricket Control. University of Florida, IFAS. <http://molecrickets.ifas.ufl.edu>.

FRANK, J. H., AND J. P. PARKMAN. 1999. Integrated pest management of pest mole crickets with emphasis on the southeastern USA. *Integrated Pest Management Reviews* 4: 39-52.

FRANK, J. H., J. P. PARKMAN, AND F. D. BENNETT. 1995. *Larra bicolor* (Hymenoptera: Sphecidae), a biological control agent of *Scapteriscus* mole crickets (Orthoptera: Gryllotalpidae), established in northern Florida. *Florida Entomol.* 78: 619-623.

FRANK, J. H., AND A. SOURAKOV. 2002. Larra Wasps; *Larra analis* Fabricius; Mole Cricket Hunters, *Larra bicolor* Fabricius (Hymenoptera: Sphecidae). Featured Creatures EENY-268. <http://creatures.ifas.ufl.edu>.

FRANK, J. H., AND T. J. WALKER. 2006. Permanent control of pest mole crickets (Orthoptera: Gryllotalpidae: *Scapteriscus*) in Florida. *American Entomol.* 52: 138-144.

HUDSON, W. G. 1989. Field sampling and population estimation of the tawny mole cricket (Orthoptera: Gryllotalpidae). *Florida Entomol.* 72: 337-343.

LEPPLA, N. C., J. H. FRANK, N. VICENTE, AND A. PANTOJA. 2004. A Commercial Nematode for Mole Cricket Control. *Proc. Caribbean Food Crops Society.* 40: 249-254.

LIOGIER, A. H. 1982. Flora of Puerto Rico and Adjacent Islands. A Systematic Synopsis. Editorial de la Universidad de Puerto Rico. Rio Piedras, Puerto Rico.

MURPHY, T. R., D. L. COLVIN, R. DICKENS, J. W. EVEREST, D. HALL, AND L. B. MCCARTY. 1998. Weeds of Southern Turfgrasses. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

NGUYEN, K. B., AND G. C. SMART, JR. 1989. Preliminary studies on survival of *Steinernema scapterisci* in soil. *Proc. Soil Crop Sci. Soc. Fla.* 49: 230-233.

PARKMAN, J. P., J. H. FRANK, K. B. NGUYEN, AND G. C. SMART. 1993. Dispersal of *Steinernema scapterisci* (Rhabditida: Steinernematidae) after inoculative applications for mole cricket (Orthoptera: Gryllotalpidae) control in pastures. *Biol. Control* 3: 226-232.

WOODRING, J. L., AND H. K. KAYA. 1988. Steinernematid and Heterorhabditid Nematodes: A Handbook of Techniques. Arkansas Agricultural Experiment Station, Southern Cooperative Series Bulletin 331: 1-30.

WOLCOTT, G. N. 1938. The introduction into Puerto Rico of *Larra americana* Saussure, a specific parasite of the "changa" or Puerto Rican mole cricket, *Scapteriscus vicinus* Scudder. *J. Agric. Univ. Puerto Rico* 22: 193-218.

WOLCOTT, G. N. 1941a. The establishment in Puerto Rico of *Larra americana* Saussure. *J. Econ. Entomol.* 34: 53-56.

WOLCOTT, G. N. 1941b. The dispersion of *Larra americana* Saussure in Puerto Rico. *Revista de Agricultura, Industria y Comercio de Puerto Rico* 33: 607-609.

WUNDERLIN, R. P., AND B. F. HANSEN. 2003. Guide to the Vascular Plants of Florida, Second Edition. University Press of Florida, Gainesville.

ZWALUWENBURG, R. H. VAN. 1918. The changa or West Indian mole cricket. *Puerto Rico Agric. Exp. Sta. Bull.* 23: 1-28.