

A NOVEL FORM OF CARIBBEAN FRUIT FLY (TEPHRITIDAE) SUPPRESSION: CLASSICAL BIOLOGICAL CONTROL OF THE PREFERRED HOST *PSIDIUM CATTLEIANUM* SABINE (MYRTACEAE)

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Abstract. The adventive Caribbean fruit fly, *Anastrepha suspensa* (Loew), is a common agricultural pest known for its wide host range of almost 100 species, including several important fruit crops. Caribbean fruit fly infestations can cause direct yield loss; and its presence can affect shipments to quarantine sensitive markets. In Florida, various control techniques have been used with limited success. A novel approach for reducing fruit fly populations is classical biological control of their preferred naturalized host plants. In addition to being an important host, strawberry guava, *Psidium cattleianum* Sabine, also is considered a highly invasive plant. Strawberry guava is native to southeastern Brazil, but is present in Florida, Hawaii, and throughout the Caribbean. In Brazil, a survey of the entomofauna associated with strawberry guava identified five potential biological control agents. The most promising was a leaf-galling scale insect, *Tectococcus ovatus* Hempel (Hemiptera: Eriococcidae). Large infestations of *T. ovatus* cause premature leaf drop and inhibit fruiting, thereby reducing fruit fly breeding sites. Preliminary host specificity testing in Florida indicates that *T. ovatus* is highly host specific and may be a good candidate for classical biological control of strawberry guava.

The Caribbean fruit fly, *A. suspensa*, which is native to the West Indies, immigrated into Florida multiple times in the early half of the 20th century. The insect failed to become established until 1965, when the species eventually spread throughout central and southern Florida (Swanson and Baranowski, 1972). Once discovered, an eradication program was not immediately implemented because the Caribbean fruit fly was not initially thought to attack citrus, a major fruit crop in Florida (Greany and Rihard, 1993). In 1968, discovery of this fruit fly in commercial grapefruit caused multiple domestic and foreign markets to initiate quarantines on Florida's fresh citrus exports. Initially, citrus shipments were fumigated with ethylene dibromide, until the Environmental Protection Agency banned the chemical for this purpose in 1984 (Nguyen et al., 1992). The banning of ethylene dibromide led to the implementation of alternative Caribbean fruit fly control

methods, including the sterile insect technique and classical biological control (Baranowski et al., 1993). This also led to the creation of the Caribbean fruit fly-free protocol, which involves an integrated approach of trapping, spraying, and removal of preferred hosts (Fla. Dept. Agr. Cons. Serv., 2005). One of these preferred hosts is strawberry guava, *Psidium cattleianum* (Nguyen et al., 1992), which also is a highly invasive weed in natural areas (Inst. Food Agr. Sci., 2005; Langeland and Burks, 1998). However, complying with the protocol can be problematic because it is the responsibility of the grower to negotiate with property owners regarding removal of preferred hosts on adjacent property. This problem is compounded by the commercial sale of strawberry guava as an ornamental species in Florida (Wirth et al., 2004).

Strawberry guava is native to the coastal regions of southeastern Brazil, and has been introduced to other countries worldwide (Weber, 2003). There are two varieties of the plant, both of which are present in Florida, a yellow fruiting form, *P. cattleianum* var. *lucidum* and a red fruiting form, *P. cattleianum* var. *cattleianum* (Wikler, 2000). Strawberry guava is considered invasive in Florida, Hawaii, and in several countries throughout the Caribbean. Factors that contribute to the invasiveness of the plant are the ability to reproduce clonally, high fruit/seed count, the dispersal of seeds by birds and mammals, and a lack of natural enemies. Strawberry guava has had devastating effects on the native ecosystems of Hawaii and is considered the worst pest plant in the archipelago (Smith, 1985). Consequently, in the early 1990s, the U.S. National Park Service and the University of Hawaii collaborated with the Federal University of Paraná in Brazil to investigate potential biological control agents (Wikler et al., 1999). Five potential arthropods were identified, the most promising of these was a leaf-galling scale insect, *Tectococcus ovatus* (Vitorino et al., 1999). Gall formation and feeding by *T. ovatus* acts as a nutrient sink and high infestations can cause premature leaf drop, may reduce photosynthetic ability, and inhibit fruit production.

Introducing natural enemies that directly impact the fitness of strawberry guava may ultimately affect Caribbean fruit fly populations by reducing breeding sites in natural areas. In addition, reducing the seed bank of strawberry guava will help natural area managers control this invasive plant within state parks and preserves. Prior to the release of any natural enemy, the host range of the proposed agent must be evaluated in the area of release. The purpose of this study was to determine the host specificity of *T. ovatus* as a potential biological control agent for strawberry guava in Florida.

Materials and Methods

A laboratory colony of *T. ovatus* was established from insects obtained from the colony at the Hawaii Volcanoes National Park, Quarantine Facility in Volcano, Hawaii. No-choice tests were used to evaluate *T. ovatus*, due to the rigorous nature of these tests. Twenty first instar *T. ovatus* crawlers were transferred individually to new flush growth of each test

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plant using fine forceps. The tests were replicated three times; the yellow fruiting form *P. cattleianum* f. *lucidum* was used as a control. Test plants were planted in 3.8, 7.6, or 11.4 L pots, and ranged in height from 25-45 cm. The testing arena consisted of an acrylic cylinder 46 cm tall and 15 cm in diameter. The test cylinders were ventilated with six holes 6 cm in diameter. The top of the cylinder and all ventilation holes were covered with a fine screen, with a mesh size of 150 × 150 µm (Green.tek, Inc., Edgerton, Wis.), to prevent *T. ovatus* crawlers from escaping. Once the insects were transferred to the test plant, a cylinder was placed over the plant with the bottom of the cylinder being partially buried in the soil. The plants were then placed in the quarantine greenhouse. Average temperature inside the cylinders was 28.1 ± 1.4°C and average humidity was 59.4 ± 8.6%. Test plants were exposed to natural light conditions supplemented with artificial light. Auxiliary fluorescent lighting (40 Watts) in the greenhouse

was set on a 14: 10 light: dark photoperiod. The duration of each test was 2 weeks. Upon completion of the test, plants were inspected for the presence of *T. ovatus* or evidence of gall development.

All experiments were conducted at the Florida Department of Agricultural and Consumer Services, Division of Plant Industry Biological Control Quarantine Laboratory, Gainesville, Florida. Voucher specimens were deposited in the Florida State Collection of Arthropods, Gainesville, Florida.

Results and Discussion

To date, 42 species representing 16 plant families have been tested. *Tectococcus ovatus* only completed its life cycle on the two varieties of *P. cattleianum* (Table 1). *Tectococcus ovatus* survived longer than the 2 week test period on the closely related *Psidium friedrichsthalianum* O. Berg. This species is not

Table 1. Results of *T. ovatus* host specificity testing. A "+" indicates feeding damage or gall development whereas a "-" indicates a lack of feeding damage and gall development.

Test plant	Family	<i>T. ovatus</i> damage
<i>Psidium cattleianum</i> var. <i>cattleianum</i> Sabine	Myrtaceae	+
<i>Psidium cattleianum</i> var. <i>lucidum</i> Sabine	Myrtaceae	+
<i>Psidium friedrichsthalianum</i> O. Berg	Myrtaceae	± ²
<i>Psidium guajava</i> L.	Myrtaceae	-
<i>Acacia sellowiana</i> (O. Berg) Burret	Myrtaceae	-
<i>Eugenia axillaris</i> (Sw.) Willd.	Myrtaceae	-
<i>Eugenia foetida</i> Pers.	Myrtaceae	-
<i>Eugenia uniflora</i> L.	Myrtaceae	-
<i>Myrciaria cauliflora</i> (C. Martius) O. Berg	Myrtaceae	-
<i>Pimenta dioica</i> (L.) Merr.	Myrtaceae	-
<i>Pimenta racemosa</i> (P. Mill.) J. W. Moore	Myrtaceae	-
<i>Syzygium malaccense</i> (L.) Merr. & Perry	Myrtaceae	-
<i>Syzygium paniculatum</i> Gaertner	Myrtaceae	-
<i>Callistemon citrinus</i> (Curtis) Staph	Myrtaceae	-
<i>Callistemon viminalis</i> (Gaertn.) G. Don ex Loudon	Myrtaceae	-
<i>Eucalyptus camaldulensis</i> Dehnhardt	Myrtaceae	-
<i>Leptospermum scoparium</i> J. R. & G. Forst.	Myrtaceae	-
<i>Calyptanthus pallens</i> Griseb.	Myrtaceae	-
<i>Calyptanthus zuzygium</i> (L.) Sw.	Myrtaceae	-
<i>Eugenia confusa</i> DC.	Myrtaceae	-
<i>Eugenia rhombea</i> Krug & Urban	Myrtaceae	-
<i>Mosiera longipes</i> (Berg) McVaugh	Myrtaceae	-
<i>Myrcianthes fragrans</i> (Sw.) McVaugh	Myrtaceae	-
<i>Decodon verticillatus</i> (L.) Ell.	Lythraceae	-
<i>Lagerstroemia indica</i> L.	Lythraceae	-
<i>Tetrazygia bicolor</i> (P. Mill.) Cogn.	Melastomataceae	-
<i>Punica granatum</i> L.	Punicaceae	-
<i>Conocarpus erectus</i> L.	Combretaceae	-
<i>Chrysobalanus icaco</i> L.	Chrysobalanaceae	-
<i>Nyssa biflora</i> Walt.	Nyssaceae	-
<i>Daphnopsis americana</i> (P. Mill.) J. R.	Thymelaeaceae	-
<i>Ilex cassine</i> L.	Aquifoliaceae	-
<i>Ilex</i> × <i>attenuata</i> Ashe	Aquifoliaceae	-
<i>Quercus hemisphaerica</i> Bartr. ex Willd.	Fagaceae	-
<i>Persea americana</i> P. Mill.	Lauraceae	-
<i>Myrica cerifera</i> (L.) Small	Myricaceae	-
<i>Saccharum officinarum</i> L.	Poaceae	-
<i>Eriobotrya japonica</i> (Thunb.) Lindl.	Rosaceae	-
<i>Prunus angustifolia</i> Marsh.	Rosaceae	-
<i>Prunus persica</i> (L.) Batsch	Rosaceae	-
<i>Taxodium distichum</i> (L.) L. C.	Cupressaceae	-
<i>Pinus elliottii</i> Engelm.	Pinaceae	-

²*T. ovatus* survived longer than the 2 wk test period; test was extended to 4 wks but no damage or gall formation was observed.

native to the U.S., although it is cultivated as a minor ornamental in Florida. After this 2 week period, no visible damage was noticed and no gall formation had occurred, therefore the test was allowed to continue for a 4 week period, after which time no surviving *T. ovatus* were found. This procedure was repeated for all three replicates of *P. friedrichsthalianum*.

The family Myrtaceae is a rather large family containing several commercially important ornamental and fruit species. Therefore, finding a biological control agent that is species specific was a high priority. Due to its close relationship to common guava, *Psidium guajava* L., strawberry guava was originally considered to have a low potential for biological control (Wikler et al., 1999). However, there was no damage observed on common guava by *T. ovatus*. These results have been confirmed in both Brazil (field test) and Hawaii (laboratory test) (Vitorino et al., 1999; M. T. Johnson, unpublished data). Although common guava is considered invasive and is not recommended for cultivation in the southern parts of Florida, it is grown as a minor food crop in the state (Inst. Food Agr. Sci., 2005).

Tectococcus ovatus has been recorded on another South American guava species, *Psidium spathulatum* Mattos (Vitorino et al., 1999). This species is native to southeastern Brazil, and is not naturalized or cultivated in Florida or the Caribbean. In a catalog compiled by Da Costa Lima (1936), *T. ovatus* was reported as feeding on the leaves of a plant known only as “embira”. Further investigation revealed that “embira” refers to two species in different families, *Daphnopsis racemosa* Gris. (Thymelaeaceae) and *Rollinia salicifolia* Schltdl. (Annonaceae). Both of these plants are not present in the continental U.S. or the Caribbean, and therefore would not be vulnerable to attack. However, there are members of the genus *Daphnopsis* and *Rollinia* in the Caribbean. *Daphnopsis americana* (Mill.) JR Johnst. was obtained from the Virgin Islands and was not damaged by *T. ovatus* in host range tests. *Rollinia mucosa* (Jacq.) Baill. also is a fruit tree native to the Caribbean, but this species has not yet been tested.

One of the advantages to using a gall-forming insect is they tend to have narrow host ranges, thereby minimizing the chances of non-target effects (Harris and Shorthouse, 1996). The results of this study thus far confirm this observation, suggesting that *T. ovatus* is highly host specific and may be a good candidate for release in Florida. However, a conflict of interest may arise due to the continued sale of strawberry guava by the nursery industry. Common guava is not considered invasive in central and northern Florida, and may be a suitable replacement in these areas (Inst. Food Agr. Sci., 2005). In south Florida, a native plant substitution guide was developed by the Florida Exotic Pest Plant Council (Ferriter, 2003). Recommendations were based upon similarity of aesthetic values and fruit characteristics. Three recommended substitutions for straw-

berry guava are *Myrcianthes fragrans* (Sw.) McVaugh, *Rapanea punctata* (Lam.) Lundell, and *Capparis cynophallophora* L.

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Literature Cited

- Baranowski, R. M., H. Glenn, and J. Sivinski. 1993. Biological control of the Caribbean fruit fly (Diptera: Tephritidae). *Florida Entomol.* 76(2):245-251.
- Da Costa Lima, A. 1936. Terceiro catalogo dos insectos que vivem nas plantas do Brasil. Directoria da Estatistica da Producao, Rio de Janeiro.
- Ferriter, A. 2003. Explore your alter-natives: a plant substitution guide for south Florida. *Wildland Weeds* 6(4):1-2.
- Fla. Dept. Agr. Cons. Serv. 2005. Caribbean fruit fly-free protocol. <http://www.doacs.state.fl.us/onestop/plt/cffprotocol.html>.
- Greany, P. D. and C. Rihard. 1993. Caribbean fruit fly status, economic importance, and control (Diptera: Tephritidae). *Florida Entomol.* 76(2):209-211.
- Harris, P. and J. D. Shorthouse. 1996. Effectiveness of gall inducers in weed biological control. *Can. Entomol.* 128:1021-1055.
- Inst. Food Agr. Sci. 2005. Conclusion from the IFAS assessment of the status of non-native plants in Florida's natural areas. University of Florida, Inst. Food Agr. Sci.
- Langeland, K. A. and K. C. Burks. 1998. Identification and biology of non-native plants in Florida's natural areas. University of Florida, Gainesville.
- Nguyen, R. U., C. Poucher, and J. R. Brazzel. 1992. Seasonal occurrence of *Anastrepha suspensa* (Diptera: Tephritidae) in Indian River County, Florida, 1984-1997. *J. Econ. Entomol.* 83(3):813-820.
- Smith, C. W. 1985. Impact of alien plants on Hawaii's native biota, pp. 180-250. In *Proc. 4th Conf. Natural Sciences, Hawaii Volcanoes National Park*. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.
- Swanson, R. W. and R. M. Baranowski. 1972. Host range and infestation by the Caribbean fruit fly, *Anastrepha suspensa* (Diptera: Tephritidae), in south Florida. *Proc. Fla. State Hort. Soc.* 85:271-274.
- Vitorino, M. D., J. H. Pedrosa-Macedo, and C. W. Smith. 1999. The biology of *Tectococcus ovatus* Hempel (Heteroptera: Eriococcidae) and its potential as a biocontrol agent of *Psidium cattleianum* (Myrtaceae), pp. 651-657. *Proc. X Intl. Symp. Biol. Ctrl. Weeds*, Bozeman, Montana, 4-14 July, 1999.
- Webber, E. 2003. Invasive plant species of the world: A reference guide to environmental weeds, 548 pp. In E. Weber (ed.). CABI Publishing, Cambridge.
- Wikler, C. 2000. *Psidium cattleianum*, deliciously dangerous in Hawaii. *Wildland Weeds*. 3(3):5-10.
- Wikler, C., J. H. Pedrosa-Macedo, M. D. Vitorino, M. G. Caxambú, and C. W. Smith. 1999. Strawberry guava (*Psidium cattleianum*)—prospects for biological control, pp. 659-665. *Proc. X Intl. Symp. Biol. Ctrl. Weeds*, Bozeman, Montana, 4-14 July, 1999.
- Wirth, F. F., K. J. Davis, and S. B. Wilson. 2004. Florida nursery sales and economic impacts of 14 potentially invasive landscape plant species. *J. Environ. Hort.* 22(1):12-16.