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ARTHROPOD COMMUNITY ASSOCIATED WITH TROPICAL SODA APPLE AND NATURAL ENEMIES OF *GRATIANA BOLIVIANA* (COLEOPTERA: CHRYSOMELIDAE) IN FLORIDA

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Tropical soda apple, *Solanum viarum* Dunal (Solanaceae), is a 1.5-m-tall perennial shrub native to tropical regions of South America. First reported in Florida in 1988, tropical soda apple rapidly became a major weed in pastures and conservation areas across the southeastern United States (Mullahey 1996). In pastures, tropical soda apple competes with forages resulting in reduced stocking rates (Mullahey et al. 1998). Florida ranchers spent an average of \$44 per acre on chemical and mechanical control costs on tropical soda apple in 2006 (Thomas 2007). Additionally, this plant is an alternate host of several diseases of solanaceous crops (McGovern et al. 1994; Adkins et al. 2007).

A biological control program of tropical soda apple was initiated in 1994, and several natural enemies were collected in Brazil, Argentina and Paraguay (Medal et al. 1996), including *Gratiana boliviana* Spaeth (Coleoptera: Chrysomelidae). This host specific beetle was first released into Florida in May 2003, and by 2008 approximately 180,000 beetles had been released (Overholt et al. 2009). Experiments conducted in central Florida demonstrated that beetle populations increased during the summer and remained very low during the coldest months of the year from Dec to mid-Mar (Overholt et al. 2010). Beetle populations were more abundant on plants located in open pastures compared to those in shaded hammocks (Diaz et al. 2011). In a four-year study, Overholt et al. (2010) demonstrated that tropical soda apple densities decreased by 90% two yr after beetle release. Survival from egg to adult in closed cages was 51% compared to 15% in open cages (Marrique et al. 2011), thus revealing the impact of biotic factors on *G. boliviana* populations. Because of the presence in Florida of many solanaceous plants, we inventoried the herbivores associated with tropical soda apple with the hypothesis that many would expand their host ranges to include the novel resource. Additionally, because of the importance of *G. boliviana* as a biological control agent of tropical soda apple, we inventoried its natural enemies in Florida.

Arthropods were collected from 2004 to 2011 at two *G. boliviana* mass rearing facilities in Fort Pierce, Florida and from several natural infestations on ranches or conservation areas in central and south Florida. Collection methods for insect

herbivores and predators included hand catching, aspiration, rearing, and the use of beating cloths. Lepidopteran larvae found feeding on tropical soda apple were reared in the laboratory until adult emergence and then identified. Parasitoids were reared from *G. boliviana* pupae, and field observations of predation were made. Entomopathogens of *G. boliviana* were identified using light microscopy by Dr. Drion Boucias at the University of Florida, and arthropods were identified by personnel at the Florida Department of Agriculture and Consumer Services, Division of Plant Industry (DPI), Gainesville, Florida, and the Systematic Entomology Laboratory, United States Department of Agriculture, Beltsville, Maryland. All arthropods collected from tropical soda apple from 1994 to 2011 are included in the DPI database.

A total of seven mite species and 75 species of insect herbivores were collected from tropical soda apple in Florida (Table 1). The host specificity of these species ranged from *Solanum* specialists to generalists and included major pests of agricultural crops as well as ornamental plants. The high diversity of insect herbivores found in this study is explained in part by the presence of close tropical soda apple relatives in Florida, including 27 species in the genus *Solanum* and 31 species in other genera of Solanaceae (Wunderlin & Hansen 2008). Based on field observations, tropical soda apple is an attractive host for many agriculturally important insect pests such as *Leptinotarsa decimlineata* (Say) and *L. juncta* (Germar) (Chrysomelidae), *Manduca sexta* L. (Sphingidae), *Bemisia tabaci* (Gennadius) (Aleyrodidae), *Aphis gossypii* Glover (Aphididae) and *Lineodes integra* Zeller (Pyralidae) (Table 1), and therefore may serve as a reservoir on which pest populations may increase before moving into crops.

A total of one mite species, 19 species of spiders and 30 species of predatory insects were found on tropical soda apple (Table 2). Predators observed feeding on *G. boliviana* larvae and pupae included *Geocoris punctipes* (Say) (Lygaeidae), *Sinea* sp. (Reduviidae), *Perillus bioculatus* (Fabricius), *Stiretrus anchorago* (Fabricius) (Pentatomidae), *Tupiocoris notatus* (Distant) (Miridae), *Solenopsis invicta* Buren (Formicidae), and the spider *Peucea viridans* (Hentz) (Oxyopidae). The mirid species found in this study are facultative predators,

TABLE 1. HERBIVOROUS ARTHROPODS ASSOCIATED WITH TROPICAL SODA APPLE, *SOLANUM VIARUM*, IN FLORIDA.

Order: Family	Species	Importance
Acari: Acaridae	Undetermined	
Acari: Eriophyidae	<i>Aceria</i> sp.	
	<i>Aculops lycopersici</i> (Masse)	pest of tomato
Acari: Tarsonemidae	<i>Tarsonemus</i> sp.	pest of crops
Acari: Tenuipalpidae	<i>Brevipalpus californicus</i> (Banks)	pest of citrus
	<i>Tetranychus evansi</i> Baker and Pritchard	pest of crops
Acari: Winterschmidtidae	<i>Czenspinksia transversostriata</i> (Oudemans)	
Coleoptera: Anthicidae	<i>Acanthinus argentinus</i> (Pic)	
Coleoptera: Cerambycidae	<i>Styloleptus biustus</i> (LeConte)	
Coleoptera: Chrysomelidae	<i>Diabrotica undecimpunctata</i> Barber	pest of crops
	<i>Disonycha glabrata</i> (Fabricius)	
	<i>Epitrix fasciata</i> Blatchley	pest of solanaceae
	<i>Erepsocassis rubella</i> (Boheman)	
	<i>Gratiana boliviana</i> Spaeth ¹	biocontrol of TSA
	<i>Leptinotarsa decimlineata</i> (Say) ¹	pest of tomato
	<i>Leptinotarsa juncta</i> (Germar) ¹	pest of <i>Solanum</i> spp.
	<i>Plagiometriona clavata</i> (Fabricius)	
Coleoptera: Curculionidae	<i>Faustinus cubae</i> (Boheman)	pest of <i>Solanum</i> spp.
Coleoptera: Elateridae	<i>Conoderus rudis</i> Brown	pest of sweet potato
Coleoptera: Languriidae	<i>Loberus</i> sp.	
Coleoptera: Latridiidae	Undetermined	
Coleoptera: Phalacridae	Undetermined	
Coleoptera: Tenebrionidae	<i>Bothrotes canaliculatus</i> (Say)	
Diptera: Agromyzidae	<i>Liriomyza trifolii</i> (Burgess)	pest of crops
Diptera: Cecidomyiidae	Undetermined	
Diptera: Chloropidae	Undetermined	
Diptera: Ephydriidae	<i>Leptopsilopa similis</i> (Coquillett)	
Diptera: Lauxaniidae	<i>Camptoprosopella verticalis</i> (Loew)	
Diptera: Muscidae	<i>Atherigona orientalis</i> Schiner	fruit fly
Hemiptera: Aleyrodidae	<i>Bemisia tabaci</i> (Gennadius) ¹	pest of crops
	<i>Trialeurodes abutilonea</i> (Haldeman)	pest of crops
Hemiptera: Alydidae	<i>Stenocoris tipuloides</i> (DeGeer)	
Hemiptera: Anthocoridae	<i>Xylocoris vicarius</i> (Reuter)	
Hemiptera: Aphididae	<i>Aphis gossypii</i> Glover ¹	pest of crops
Hemiptera: Cercopidae	<i>Clastoptera xanthocephala</i> Germar	
	<i>Prosapia bicincta</i> (Say)	pest of grasses
Hemiptera: Cicadellidae	<i>Planicephalus flavicosta</i> (Stål)	
Hemiptera: Coccidae	<i>Pulvinaria urticae</i> Cockerell	
Hemiptera: Coreidae	<i>Anasa scorbatica</i> (Fabricius)	
	<i>Leptoglossus</i> sp.	pest of crops
	<i>Phthia picta</i> (Drury)	
Hemiptera: Delphacidae	<i>Delphacodes</i> sp.	
Hemiptera: Dictyopharidae	Undetermined	
Hemiptera: Lygaeidae	<i>Ischnodemus brunipennis</i> (Germar)	
	<i>Paromius longulus</i> (Dallas)	
	<i>Pseudopachybrachius vinctus</i> (Say)	
Hemiptera: Membracidae	<i>Entyllia carinata</i> (Foster)	
Hemiptera: Miridae	<i>Collaria oculata</i> (Reuter)	
	<i>Cyrtopeltis modesta</i> (Distant) ¹	pest of tomato
	<i>Dicyphus minimus</i> Quaintance ¹	pest of tomato
Hemiptera: Pentatomidae	<i>Arvelius albopunctatus</i> (De Geer)	pest of Solanaceae
	<i>Euschistus obscurus</i> (Palisot de Beauvois)	pest of cotton
	<i>Euschistus quadrator</i> Rolston	pest of cotton
	<i>Euschistus servus</i> (Say)	pest of cotton
	<i>Mormidea lugens</i> (Fabricius)	
	<i>Proxys punctulatus</i> (Palisot de Beauvois)	
Hemiptera: Pseudococcidae	<i>Maconellicoccus hirsutus</i> (Green)	pest of crops
	<i>Palmicultor browni</i> nr. (Williams)	
	<i>Planococcus citri</i> (Risso)	pest of crops
Hemiptera: Pyrrhocoridae	<i>Dysdercus</i> sp.	
Hemiptera: Rhopalidae	<i>Niesthrea sidae</i> (Fabricius)	
Hymenoptera: Halictidae	<i>Augochloropsis metallica</i> (Fabricius)	
Lepidoptera: Arctiidae	<i>Estigmene acrea</i> (Drury)	pest of crops
	<i>Hypercompe scribonia</i> (Stoll)	
	<i>Hyphantria cunea</i> (Drury)	
Lepidoptera: Gelechiidae	Undetermined	
Lepidoptera: Noctuidae	<i>Enigmogramma basigera</i> (Walker)	

¹Field observations in Florida suggested that insect populations could increase rapidly on tropical soda apple.

TABLE 1.(CONTINUED) HERBIVOROUS ARTHROPODS ASSOCIATED WITH TROPICAL SODA APPLE, *SOLANUM VIARUM*, IN FLORIDA.

Order: Family	Species	Importance
	<i>Heliothis subflexa</i> (Guenée)	
	<i>Heliothis virescens</i> (Fabricius)	pest of crops
	<i>Mocis latipes</i> (Guenée)	
	<i>Mocis</i> sp.	
	<i>Plathypena scabra</i> (Fabricius)	
	<i>Pseudoplusia includens</i> (Walker)	pest of soybeans
	<i>Spodoptera eridania</i> (Cramer)	pest of crops
	<i>Spodoptera latifascia</i> (Walker)	
	<i>Spodoptera ornithogalli</i> (Guenée)	pest of crops
Lepidoptera: Nymphalidae	<i>Heliconius charithonia</i> (L.)	
Lepidoptera: Pyralidae	<i>Lineodes integra</i> Zeller ¹	pest of Solanaceae
	<i>Pilemia periusalis</i> (Walker)	
Lepidoptera: Sphingidae	<i>Manduca sexta</i> L. ¹	pest of tomato
Lepidoptera: Tortricidae	<i>Platynota flavedana</i> Clemens	
Orthoptera: Tettigoniidae	Undetermined	

¹Field observations in Florida suggested that insect populations could increase rapidly on tropical soda apple.

TABLE 2. PREDATORS, PARASITOIDS AND ENTOMOPATHOGENS FOUND ON TROPICAL SODA APPLE PLANTS, *SOLANUM VIARUM*, OR RECOVERED FROM *GRATIANA BOLIVIANA* IN FLORIDA.

Order: Family	Species	Functional Group
Acari: Ascidae	Undetermined	predator
Araneae: Anyphaenidae	Undetermined	predator
Araneae: Araneidae	<i>Acanthepeira</i> sp.	predator
	<i>Acanthepeira stellata</i> (Marx)	predator
	<i>Argiope aurantia</i> Lucas	predator
	<i>Neoscona arabesca</i> (Walckenaer)	predator
	<i>Neoscona</i> sp.	predator
Araneae: Clubionidae	<i>Cheiracanthium inclusum</i> (Hentz)	predator
Araneae: Corinnidae	<i>Meriola decepta</i> Banks	predator
Araneae: Oxyopidae	<i>Oxyopes salticus</i> Hentz	predator
	<i>Peucetia viridans</i> (Hentz)	predator
Araneae: Salticidae	<i>Phidippus audax</i> (Hentz)	predator
	<i>Phidippus regius</i> C. L. Koch	predator
	<i>Phidippus</i> sp.	predator
	<i>Thiodina</i> sp.	predator
Araneae: Tetragnathidae	<i>Leucauge argyra</i> (Walckenaer)	predator
Araneae: Theridiidae	<i>Coleosoma acutiventer</i> (Keyserling)	predator
Araneae: Thomisidae	<i>Misumenops bellulus</i> (Banks)	predator
	<i>Misumenops celer</i> (Hentz)	predator
	<i>Misumenops</i> sp.	predator
Coleoptera: Carabidae	<i>Calleida decora</i> (Fabricius)	predator
Dictyotera: Mantidae	<i>Thesprotia graminis</i> Scudder	predator
Hemiptera: Anthocoridae	<i>Xylocoris vicarius</i> (Reuter)	predator
Hemiptera: Lygaeidae	<i>Geocoris punctipes</i> (Say) ¹	predator
Hemiptera: Miridae	<i>Engytatus modestus</i> (Distant) ¹	facultative predator
	<i>Macrolophus</i> sp. ¹	facultative predator
	<i>Tupiocoris notatus</i> (Distant) ¹	facultative predator
Hemiptera: Pentatomidae	<i>Perillus bioculatus</i> (Fabricius) ¹	predator
	<i>Podisus mucronatus</i> Uhler	predator
	<i>Stiretrus anchorago</i> (Fabricius) ¹	predator
Hemiptera: Reduviidae	<i>Arilus cristatus</i> (Linnaeus)	predator
	<i>Sinea</i> sp. ¹	predator
Hymenoptera: Braconidae	Undetermined	parasitoid
Hymenoptera: Ceraphronidae	Undetermined	parasitoid
Hymenoptera: Chalcidae	<i>Conura side</i> (Walker) ²	parasitoid
Hymenoptera: Eulophidae	<i>Aprostocetus</i> nr. <i>cassidis</i> ²	parasitoid
Hymenoptera: Eupelmidae	<i>Brasema</i> sp. ²	parasitoid
Hymenoptera: Formicidae	<i>Camponotus tortuganus</i> Emery	predator
	<i>Crematogaster</i> sp.	predator
	<i>Cyphomyrmex</i> sp.	predator
	<i>Dolichoderus pustulatus</i> Mayr	predator
	<i>Pseudomyrmex cubaensis</i> (Forel)	predator

¹Predator observed feeding on *G. boliviana*.

²Parasitoid reared from *G. boliviana* pupae.

³Disease recovered from infected *G. boliviana*.

TABLE 2. (CONTINUED) PREDATORS, PARASITOIDS AND ENTOMOPATHOGENS FOUND ON TROPICAL SODA APPLE PLANTS, *SOLANUM VIARUM*, OR RECOVERED FROM *GRATIANA BOLIVIANA* IN FLORIDA.

Order: Family	Species	Functional Group
	<i>Solenopsis invicta</i> Buren ¹	predator
	<i>Pseudomyrmex gracilis</i> (Fabricius)	predator
Hymenoptera: Pteromalidae	Undetermined	parasitoid
Neuroptera: Chrysopidae	Undetermined	predator
Odonata: Coenagrionidae	<i>Ischnura hastata</i> (Say)	predator
	<i>Ischnura ramburii</i> (Selys)	predator
Orthoptera: Gryllidae	<i>Cyrtoxipha</i> sp.	predator
	<i>Oecanthus</i> sp.	predator
Microspora: Nosematidae	<i>Nosema</i> sp. ³	entomopathogen
Negregarinorida: Lipotrophidae	<i>Mattesia oryzaephili</i> Ormières, Loubes, and Kuhl ³	entomopathogen
Phyllum Bacteria	short gram-negative bacteria ³	entomopathogen

¹Predator observed feeding on *G. boliviana*.

²Parasitoid reared from *G. boliviana* pupae.

³Disease recovered from infected *G. boliviana*.

and they comprised up to 95% of the predators found on tropical soda apple in central Florida (Manrique et al. 2011). Pupal parasitoids of *G. boliviana* included *Conura side* (Walker) (Chalcidae), *Brasema* sp. (Eupelmidae), and *Aprostocetus* nr. *cassidis* (Eulophidae). Because *C. side* also attacks lepidopteran larvae (Mitchell et al. 1997) and because of the taxonomic uncertainty of *Brasema* sp. and *Aprostocetus* nr. *cassidis*, we cannot conclude that any specialist natural enemies attack *G. boliviana* in Florida. The exploitation of *G. boliviana* by these parasitoids was reported three yr after its release in Florida (K. Hibbard, unpublished data). This relatively short time to host exploitation is similar to that which has been documented in other weed biological control programs (Hill & Hulley 1995; Kula et al. 2010, but see Christensen et al. 2011). Two parasitoids have been reported attacking the native *Gratiana pallidula* (Boheman) in Arkansas, i.e., a eulophid, *Tetrastichus*, and a chalcid, *Conura sanguineiventris* (Cresson) (Rolston et al. 1965). However, these were not found attacking *G. boliviana* in Florida. Entomopathogens recovered from *G. boliviana* included *Nosema* sp. (Microspora: Nosematidae), *Mattesia oryzaephili* Ormières (Negregarinorida: Lipotrophidae), and a short gram-negative bacteria. The abundance of parasitoids and entomopathogens of *G. boliviana* was higher inside the mass rearing facilities compared to field conditions where predators (ants, spiders and mirids) were more abundant (Diaz et al. 2011).

SUMMARY

Arthropods associated with the exotic weed tropical soda apple were collected in Florida. We found that tropical soda apple is a suitable host for several insect pests of agricultural and ornamental plants. Additionally, we report several predators, parasitoids and entomopathogens of

Gratiana boliviana, a biological control agent of tropical soda apple.

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