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EGG PARASITOIDS OF CITRUS WEEVILS IN GUADELOUPE

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To determine parasitism and mortality factors affecting citrus weevils in Guadeloupe an exploratory trip to the island was taken in the summer of 2006. Guadeloupe was surveyed for egg parasitoids and other natural enemies with the intent of augmenting the parasitoid species that have already been imported and released to control the citrus root weevil, *Diaprepes abbreviatus* (L.) (Coleoptera: Curculionidae), in Florida. *Diaprepes abbreviatus* has been a serious economic pest of citrus and ornamentals in Florida since it was discovered in the mid 1960s (Woodruff 1964); in recent years it has also established in Texas (Skaria & French 2001) and has been found in California (Grafton-Cardwell et al. 2004; Anonymous 2005). Efforts to establish biological control agents of the weevil are ongoing and to date include releases of 5 egg parasitoids attacking *D. abbreviatus* throughout the Caribbean. *Quadrastichus haitiensis* Gahan (Hymenoptera: Eulophidae) was imported from Puerto Rico, *Aprostocetus vaquitarum* Wolcott (Hymenoptera: Eulophidae) from the Dominican Republic, *Ceratogramma etiennei* Delvare (Hymenoptera: Trichogrammatidae) from Guadeloupe (Hall et al. 2001; Peña et al. 2004), *Fidiobia dominica* Evans and Peña (Hymenoptera: Platygastridae), and *Haeckeliania sperata* Pinto (Hymenoptera: Trichogrammatidae) from Dominica (Jacas et al. 2008). Although *Q. haitiensis* and *A. vaquitarum* have established in extreme southeastern Florida (Miami-Dade and Broward counties) following multiple releases since 2000 (Peña et al. 2004), these species have not expanded their range into central Florida (Castillo et al. 2005; Ulmer et al. 2006a). *Ceratogramma etiennei* thrived in the first year after multiple releases near Homestead, FL in 1998 but subsequently failed to establish in the state (Hall et al. 2002; Peña et al. 2004). The lack of establishment of introduced egg parasitoids outside of the extreme southeast region of the state has been linked to climactic conditions as well as pesticide use and seasonal host availability (Hall et al. 2002; Castillo et al. 2005; Ulmer et al. 2006a, 2006b). *Fidiobia dominica* and *H. sperata* were recently released in southern Florida and the results of these releases have yet to be determined.

Most of the citrus growing regions in Guadeloupe are in Basse Terre, the western half of the country. In this area citrus is grown at higher elevations (382 m) that experience slightly lower temperatures. It is possible that parasitoids found attacking *D. abbreviatus* in this area would be more likely to survive and expand into the cooler regions of Florida. On this trip we surveyed the island's citrus growing regions to evaluate the mortality factors and parasitoid species associated with citrus weevils.

Eight locations were surveyed on 19-22 Jun 2006. Depending on the size of the grove, 2 people spent 0.5 to 5 h collecting egg masses at each site, and some fields were surveyed more than once. Egg masses were saved in plastic vials in the field, then trimmed and transferred to glass vials each evening as per Ulmer et al. (2006c). Egg masses were hand carried in an insulated box to the quarantine facility at the Tropical Research and Education Center (USDA-APHIS PPQ form 526, permit no. 68313), Homestead, FL.

Citrus weevil eggs were collected from 5 of 8 sites surveyed on the island and parasitism was observed at 4 of those 5 sites (Table 1). All sites at which weevil eggs were found were stands of pure citrus rather than mixed plantings with other fruit crops. In total 236 egg masses were collected; 20 egg masses were not included in the data (Table 1) because they were overcome by fungal pathogens. Only egg masses for which every host egg could be accounted for are included in Table 2, thus some egg masses, which are included in Table 1 are not included in Table 2. The majority of the egg masses collected were from a single low elevation site; however, several egg masses were also collected from the higher elevation sites (Table 1). A total of 3060 parasitoids emerged from the egg masses collected and 82% of the egg masses collected on Guadeloupe were parasitized by at least 1 species. This is substantially higher than the 12.0% found by Ulmer et al. (2006c) on St. Lucia, but comparable to the 87% found parasitized in Belize by Hall et al. (2002).

Adults of 3 weevil species were collected during the trip: *Diaprepes abbreviatus*, *Famelicus* sp., and *Litostylus* sp. Adults of *D. abbreviatus* were found at all the sites where parasitism occurred but mixed weevil populations were evident at most sites. Though the adults collected were predominantly *D. abbreviatus*, it is likely that some of the egg masses collected were deposited by other weevil species associated with citrus.

Etienne & Delvare (1991) reported *Aprostocetus* sp., *Aprostocetus gala* (= *A. vaquitarum*), *Aprostocetus haitiensis* (= *Quadrastichus haitiensis*), and *Ceratogramma etiennei* in Guadeloupe.

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TABLE 1. CITRUS WEEVIL EGG MASS PARASITISM RATES IN GUADELOUPE BY SITE AND PARASITOID SPECIES.

Site	Altitude (m)	Total masses *n*	Parasitized masses *n* (%)	*Q. haitiensis* *n* (%)	*A. vaquitarum* *n* (%)	*H. cupreus* *n* (%)
16°03.790 N 061°45.702 W	21 ± 8	196	165 (84.2)	143 (73.0)	36 (18.4)	14 (7.1)
16°04.965 N 061°44.693 W	360 ± 9	8	6 (75.0)	1 (12.5)	1 (12.5)	4 (50.0)
16°01.956 N 061°43.593 W	288 ± 19	6	4 (66.7)	2 (33.3)	2 (33.3)	1 (16.7)
16°05.365 N 061°44.394 W	382 ± 9	5	2 (40.0)	0	0	2 (40.0)
26°02.005 N 061°43.336 W	355 ± 12	1	0	0	0	0
Totals*		216	177 (81.9)	146 (67.6)	39 (18.1)	21 (9.7)

*Some egg masses were parasitized by 2 or 3 parasitoid species, therefore the total percent of egg masses parasitized is lower than then the sum of the totals per species.

During the present survey 3 parasitoid species were reared from weevil eggs collected on the island. *Quadrastichus haitiensis* was the predominant parasitoid, attacking two thirds of the egg masses collected (Table 1). *Aprostocetus vaquitarum* was found attacking approximately one fifth of the egg masses collected and *Horismenus cupreus* Ashmead (Hymenoptera: Eulophidae) occurred in about 10% of the egg masses.

Quadrastichus haitiensis has been found parasitizing citrus weevil eggs on various Caribbean islands; its life history was studied by Castillo et al. (2005). After a failed attempt at establishment in Florida in 1969, *Q. haitiensis* was released again in 2000 and is now established in the extreme southeast region of the state (Peña et al. 2004). In 2000, *A. vaquitarum* was introduced into Florida from the Dominican Republic where it is a principal parasitoid of *D. abbreviatus* eggs (Jacas et al. 2005). *Aprostocetus vaquitarum* has been released in several Florida counties and is now considered to be established in parts of southern Florida where levels of parasitism are between 70-90% (Peña et al. 2004). However, attempts to establish *A. vaquitarum* in other areas of the state have been unsuccessful to date (Ulmer et al. 2006a). Though *Horismenus bennetti* Schauff (Hymenoptera: Eulophidae) has been collected previously as a hyper parasitoid associated with egg parasitoids of citrus weevils in the Caribbean and West Indies (Schauff 1987), much less is known about *H. cupreus*. *Horismenus cupreus* has been collected from various Caribbean locations (Thompson 1955; De Santis 1979) but little is known of its biology. In the present study *H. cupreus* was observed as a hyper parasitoid. However, *H. cupreus* was also reared from egg masses at a site where neither of the primary parasitoids were collected, though it is plausible that a primary parasitoid species was also present at the site but not collected, and it is possible that *H. cupreus* is acting as both a primary and hyper parasitoid on the island.

Most parasitized egg masses were attacked by a single species but 11% of egg masses were parasitized by 2 or all 3 of the species found (Table 2). Hyper parasitism by *H. cupreus* is obviously contributing to these numbers but *Q. haitiensis* and *A. vaquitarum* were also found parasitizing the same egg mass with some regularity. Total mortality for egg masses parasitized by only *Q. haitiensis* was 96%, which is very similar to that reported by Ulmer et al. (2006c) on St. Lucia. Mortality among egg masses from which no parasitoids emerged was 27%, attributable to fungus, predators, parasitoid stinging, environmental damage, or infertility. There did not appear to be a difference in the size of the host egg masses preferred by the 3 species collected; all averaged 35-45 eggs per mass.

Though *C. etiennei* was imported into Florida in 1998 for *D. abbreviatus* biocontrol from Guadeloupe, the species was not collected on this trip. It is possible that *C. etiennei* was present but not detected due to spatial or temporal differences in collection. It is also possible that their population has been reduced or eliminated from the island. Given the high rate of parasitism on the island it is possible that *C. eteinnei* has been out-competed by the other parasitoids, which is 1 hypothesis that may explain its disappearance from south Florida after *Q. haitiensis* and *A. vaquitarum* were released. A more extensive survey would be necessary to determine the true status of this parasitoid in Guadeloupe.

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TABLE 2. MORTALITY AND PARASITISM RATES OF WEEVIL EGGS PARASITIZED BY EACH COMBINATION OF PARASITOID SPECIES FOUND IN GUADELOUPE (MEAN ± SE).

Parasites found in the egg mass	Multiple parasites	*n*	Weevil larvae eclosed	Total parasites emerged	Dead parasite larvae or pupae	% Parasitized weevil eggs	Total weevil egg % mortality
Q. haitiensis	—	93	2.6 ± 1.1	28.2 ± 1.8	2.2 ± 0.6	72.7 ± 2.5	95.8 ± 1.5
A. vaquitarum	—	6	0	12.2 ± 3.3	1.2 ± 0.8	84.2 ± 6.9	100
H. cupreus	—	10	0.4 ± 0.3	9.9 ± 2.5	1.2 ± 0.7	89.4 ± 4.4	98.4 ± 1.2
Q. haitiensis & *A. vaquitarum*	*Q. haitiensis* *A. vaquitarum*	7	0	25.6 ± 10.1 2.7 ± 1.5	4.1 ± 2.9 0.7 ± 0.3	52.1 ± 10.3 31.6 ± 13.3	100
Q. haitiensis & *H. cupreus*	*Q. haitiensis* *H. cupreus*	1	0	4 1	0 0	20 40	100
A. vaquitarum & *H. cupreus*	*A. vaquitarum* *H. cupreus*	4	0	4.8 ± 3.0 4.0 ± 2.1	3.8 ± 1.7 1.5 ± 1.2	75.6 ± 13.8	100
Q. haitiensis & *A. vaquitarum* & *H. cupreus*	*Q. haitiensis* *A. vaquitarum* *H. cupreus*	2	0	13.0 ± 4.0 0.5 ± 0.5 1.5 ± 0.5	2.0± 2.0 0.5 ± 0.5 0	35.1 ± 8.6 37.0 ± 19.3	100
Total of all parasitized egg masses	*all*	123	2.0 ± 0.8	24.9 ± 1.6	2.3 ± 0.5	75.2 ± 3.1	96.7 ± 1.1
Egg masses not parasitized	*n/a*	35	37.5 ± 6.3	0	0	0	26.7 ± 6.7

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SUMMARY

Three parasitoids species, *Quadrastichus haitiensis*, *Aprostocetus vaquitarum*, and *Horismenus cupreus* were found attacking *Diaprepes abbreviatus* eggs in Guadeloupe. *Quadrastichus haitiensis* attacked 67.6% of the egg masses, *A. vaquitarum* 18.1%, and *H. cupreus* 9.7%. A parasitism rate of 81.9% was observed and 11% of the parasitized egg masses contained more than 1 species. The total egg mortality per parasitized *D. abbreviatus* egg mass was 96.7%. More information at http://trec.ifas.ufl.edu/pena/

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