Melicoccus bijugatus Jacquin (Sapindaceae), *quenepa*: a new host plant record for the Citrus Fruit Borer, *Gymnandrosoma aurantianum* Lima, 1927 (Lepidoptera: Tortricidae) and the genus *Gymnandrosoma* in Puerto Rico[1]

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Abstract: The Citrus Fruit Borer, *Gymnandrosoma aurantianum* Lima, 1927 (Lepidoptera: Tortricidae), is a major pest of Neotropical fruits. We report this species for the first time from *Melicoccus bijugatus* Jacquin (Sapindaceae), commonly known in Puerto Rico as *quenepa*. Distinguishing features for the three species of *Gymnandrosoma* reported for Puerto Rico, *G. aurantianum, G. leucothorax, and G. trachycerus,* are given.

Key Words: *Melicoccus bijugatus*, new host plant, Citrus Fruit Borer, *Gymnandrosoma aurantianum*, Arthropoda, Hexapoda, Lepidoptera, Tortricidae

Tortricidae are a large (approximately 10,000 described species) and economically important insect family in the order Lepidoptera (Beccaloni et al. 2003; Brown 2005; Brown et al. 2008; Baixeras et al. 2010). *Gymnandrosoma* is a mostly Neotropical genus of oleuthreutine tortricid currently containing nine species, including *G. gonomela* (Lower, 1899) from Australia (Horak 2006) and *G. junina* Razowski and Wojtusiak 2010 from Perú. According to Adamski and Brown (2001), *Gymnandrosoma* adults have the following four synapomorphies that uniquely distinguish them from those of other putatively closely related taxa in the *Ecdytolopha* group of genera, such as *Ecdytolopha*, *Thaumatotibia*, *Pseudogalleria*, and *Cryptophlebia*, of the tribe Grapholitini: 1) forewing 1.95-2.08 longer than wide (Table 4 in Adamski and Brown 2001 and Figure 1, this work), other genera have a larger l/w ratio; 2) male antennae with basal fourth slightly flattened, bearing conspicuously long sensory setae ("cilia" sensu Adamski and Brown 2001) throughout (Figure 58 in Adamski and Brown 2001 and Figure 2A, arrows, this work), 3) male hind tibia with dense, modified,

[1] Submitted on August 15, 2012. Accepted on September 10, 2012. *Melicoccus bijugatus* is also known by many common names in the circum Caribbean region, including ackee, chenet, escanjocote, genip, genipe, ginep, honeyberry, kenepa, kenepier, kinep, kinnup-tree, knippen, limoncillo, mammon, mamoncillo, mamón de Cartagena, quenettier, and Spanish quenette.

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complex sex scaling, known as "hair pencil" (Figure 55 in Adamski and Brown 2001 and Figure 2C, this work), and 4) male genitalia with numerous, relatively short cornuti, arranged quasidiagonally to the longitudinal axis of the aedeagus (Figure 3D, this work) in vesica (same as eversible sac in other insects). Additionally, the male's valve is relatively unmodified and not swollen.

Gymnandrosoma aurantianum Lima, 1927, is a member of the subfamily Olethreutinae. The larvae of *G. aurantianum*, known as the Citrus Fruit Borer (CFB), are a major pest of Neotropical fruits. In addition to fruits of Rutaceae, the citrus family (Urretabizkaya et al. 2010), the CFB has been reported attacking fruits of other Neotropical plant families from a wide botanical spectrum, including ten orders of vascular plants, mostly in the rosid clade (Figure 4). Occasionally, *G. aurantianum* larvae have also been reported to feed on stems and leaves (Adamski and Brown 2001). Herein, we report the CFB for the first time from *Melicoccus bijugatus* Jacquin (Sapindaceae), commonly known in Puerto Rico as *quenepa*. Table 1 summarizes the reported host plants of *G. aurantianum*. In addition to *G. aurantianum*, two other congeneric circum Caribbean endemics, *G. leucothorax* Adamski and Brown, 2001 and *G. trachycerus* Forbes, 1931 have been reported for Puerto Rico.

Gymnandrosoma aurantianum and *G. leucothorax* have been reared from Guava, *Psidium guajava* L. (Myrtaceae) (Adamski and Brown, 2001, pp. 77, 79) raising the possibility that Martorell (1976) report of *G. aurantianum* for guava in Puerto Rico (voucher specimens not located, collected in Trujillo Alto, January 1962 by William Pennock, Rosa Franqui, personal communication to Santiago-Blay, February 2012) could be a misidentification as *G. leucothorax* was described 25 years after Martorell's report.

Life History Stages

Eggs. As far as we are aware, no eggs of *Gymnandrosoma* have been described.

Larvae (Figure 6D) and economic damage. A brief description of the *last* larval instar of all species of *Gymnandrosoma*, with remarks on distinguishing features for *G. aurantianum* and *G. trachycerus*, follows, based on Adamski and Brown (2001, the larvae of *G. leucothorax* have not been described). *Gymnandrosoma* larvae are eruciform, with head dark amber-brown and body translucently yellowish to pale brown, 10-16 mm long. Body with fine, moderately distinct spicules or with granulations; pinnacula extremely large, without spicules or granulations; setae relatively short; distance between Vs on A9 is 1.2-2.0 times the distance between Vs on A8 (1.2 in *G. trachycerus*, 1.5-2.0 in *G. aurantianum*); D2s slightly further apart than D1s on A8. Additionally, the larvae of *G. aurantianum* have a bisetose SV group on A9 (unisetose in *G. trachycerus*).

Parra et al. (2004) report that, "this pest [*G. aurantianum*] … causes losses in the order of 50 million dollars per year to citriculture in the State of São

Paulo" and in Argentina. Anonymous (no date) reports that "[t]he species is widespread in the entire citrus-producing area of the Argentinian north-west. Orange and tangerine trees are affected. Attacks may also occur on grapefruit, lime and lemon trees." Anonymous (no date) report on the mode of attack of *G. aurantianum* on citrics is similar to what we have observed on *quenepa*.

Pupae. The pupae of three species of *Gymnandrosoma*, including *G. aurantianum*, have been described are typical for the Olethreutinae: fusiform, 9.0-12.0 mm long, and 2.5-3.0 mm wide. Pupation occurs in the soil. The pupae of *G. leucothorax* and of *G. trachycerus* have not been described.

Adults. The adults of the three known Puerto Rican species can be distinguished using Figures 1-3 and the characteristics given in the section entitled, Species of Gymnandrosoma reported for Puerto Rico (based on adults).

Methods

Nomenclature. Nomenclature generally follows Adamski and Brown (2001). Illustrated nomenclature of the adult genitalia can be found in Razowski (2003) and in Gilligan et al. (2010). For ease of retrieval, all figured moths now bear a lavender label that reads ("/" separates lines on labels, "//" indicate a different label). "Specimen figured/ Cabrera et al. 2013". Strikeout on a letter indicates a typographic error on the label followed by the correction [inside square brackets]. Accents have been added, when needed, to follow proper Spanish grammar.

Photography. Macrophotographs of the moths (Figure 1) were taken with a Canon photomicroscope. Electron micrographs (Figure 2) were taken using a Philips XL Environmental Scanning Electron Microscope at an accelerating voltage of 16 or 20Kv, pressure of 0.4-0.5Torr, and back scattering electron detection, with the topography only setting, or gaseous secondary electron detection. Genitalia (Figure 3) were imaged with a Visionary Digital imaging system at the Department of Entomology of the National Museum of Natural History.

Specimens Examined. *Gymnandrosoma aurantianum*. Male. 5//S./Naranjo/P/Brasil/XII-939/J. A. Pastriana e.l. Females. First specimen, Panamá. Barro/ Colorado Isl./ April 5-10, 1965/ S. S. & W. D. Duckworth (Figure 1B). Second specimen, Collection/ Wm Schaus//[Guyana], Rockstone/ Esseque[i]bo (Figures 1E-F, for antennal SEM). Genitalia slides. Male and female genitalia. Ex. Orange, Puellate, Pichincha, Ecuador, Lot 42-12495. Slide 28 Oct. 1942 C.H. Moths in alcohol. Genitalia slide number USNM 72327.

Gymnandrosoma leucothorax. Male. Puerto Rico/ Las Piedras/ Ex. Mummified/ *Psidium guajava* fruits/ July 30, 1969/ S. Medina Gaud// PARATYPE. Genitalia slide (data below) from another specimen. Male. Puerto Rico, Las Marías. Genitalia slide number USNM 90889. Female. Puerto Rico. Mayagüez 3-4 August 1955. Collected at light//J. A. Ramos/ Collector//155//PARATYPE. Genitalia slide (data below) from another

specimen. Female. Puerto Rico, no further locality, Genitalia slide number USNM 83308.

Gymnandrosoma trachycerus. Male and female collected in Dominica/ Cent. For. Res./ May 8, 1965/ D. R. Davis. Genitalia slides (data below) from other specimens. Male. Dominica. D. Adamski 3958. Genitalia slide number USNM 81658. Female. Dominica. D. Adamski 3953. Genitalia slide number USNM 81654.

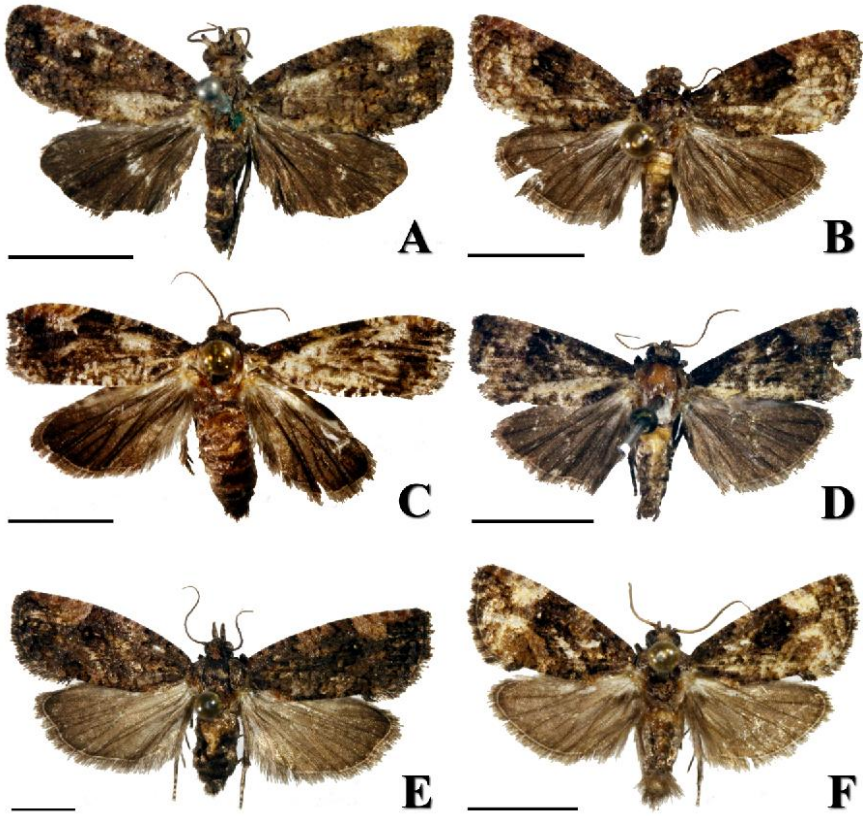

Figure 1. Dorsal view of male and female moths of species *Gymnandrosoma* reported for Puerto Rico. A and B. Dorsal views of male and female, respectively, of *Gymnandrosoma aurantianum*. Other names for the taxon, such as *Ecdytolopha aurantiana*, *Gymnandrosoma aurantiana*, and *Gymnandrosoma aurantii*, are still found in the recently-published papers, adding to a notable list of tortricid names in the literature (Brown 2006). C and D. *Gymnandrosoma leucothorax* Adamski and Brown, 2001. E and F. *Gymnandrosoma trachycerus* Forbes, 1931. Scale line = 1 cm.

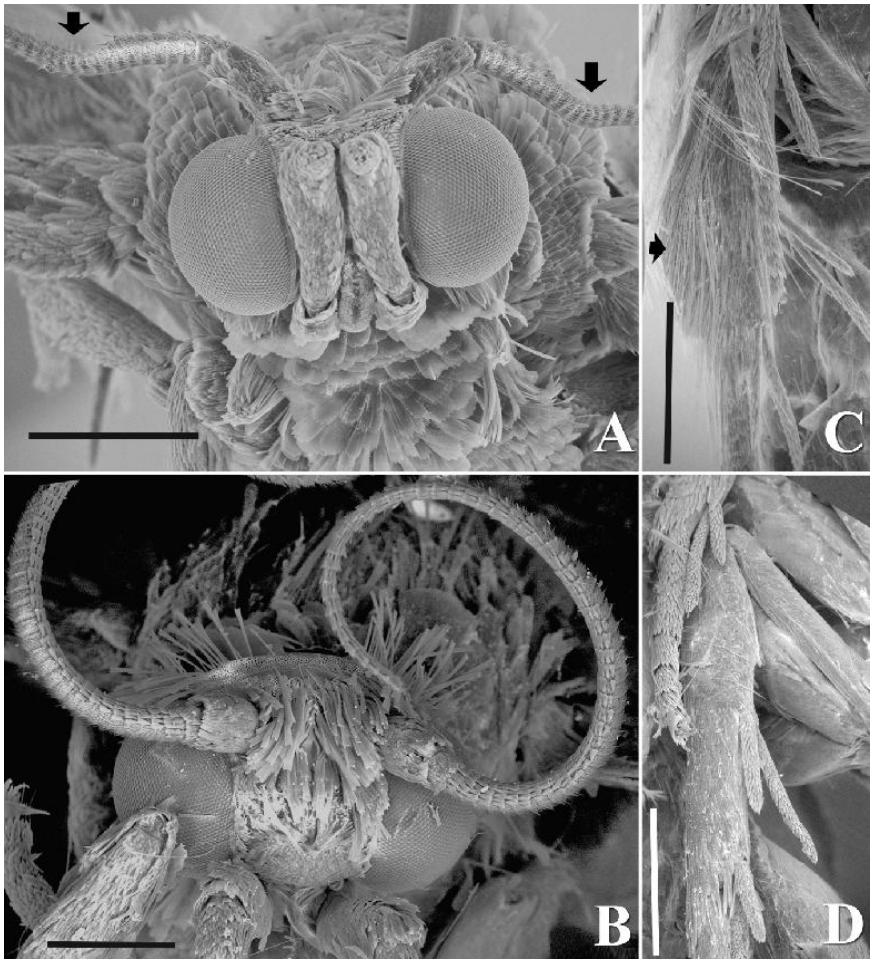

Figure 2. *Gymnandrosoma aurantianum.* A-B. *H*ead, frontal views. A. Male, arrow points to narrowed notch on antennal flagelomeres 6-10. B. Female, note absence of notch. C - D. Hind tibia of male and female, lateral views. D. Hair pencil of male. Scale lines = 500 μm.

Species of *Gymnandrosoma* reported for Puerto Rico (based on adults)

According to Adamski and Brown (2001), four synapomorphies distinguish *G. aurantianum* from other congenerics: 1) male antennal flagellomeres 6-10 compressed forming a notch (Figure 2A, arrows), 2) male valve termination of cucullus with a short lobe (Figure 3A, arrow), 3) male valva setal ridge (extending from arrow) rounded, naked, without microthrichia (Figure 3A), and 4) aedegal vesica with approximately 130 cornuti (see Figure 3D for an example of cornuti). According to Adamski and Brown (2001), three common synapomorphies distinguish *G. leucothorax* from other congenerics: 1)

mesosculetellar setal tuft white (Figure 1D), 2) aedegal vesica with approximately 120 cornuti, and 3) ductus bursae spiraled one revolution (Figure 3F, arrow, note twisting but best seen in living specimens). Although there are no common synapomorphies to consistently distinguish *G. trachycerus* from its congenerics, a number of putative autapomorphies in the adult genitalia are useful for definitive species identification (Adamski and Brown, 2001, p. 72). Some of those traits include, male cucullar ridge pointing ventrolaterally (Figure 3C, arrow); distal portion of sacculus microtrichiate; ductus bursae with a slightly thickened ring anterior forming anterior edge of ostium (Figure 3G, top arrow); paired, elongate, spiculate plates extending from posterior end of ductus bursae nearly to signa of corpus bursae (Figure 3G, lower arrow).

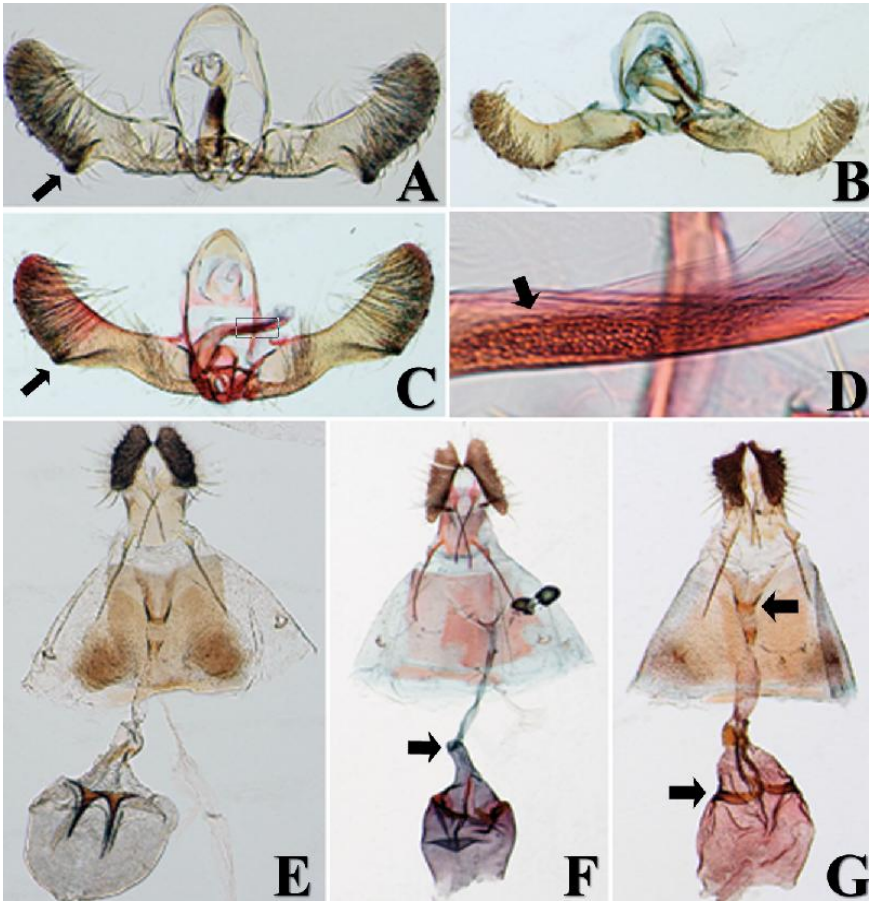

Figure 3. Male and female genitalia of the species of *Gymnandrosoma* reported for Puerto Rico. *Gymnandrosoma aurantianum* (A, male; E, female), *G. leucothorax* (B, male; F, female), and *G, trachycerus* (C, male; D, close-up of area delimited by rectangle in C; and G, female).

Table 1. Host plants (organized alphabetically by scientific name) of *Gymnandrosoma aurantianum* Lima, 1927, including host plant family: order (Angiosperm Phylogeny Group, 2009), geographical area of reports, comments, and references.

Host plants (in alphabetical order) and authorship	**Host plant family and order**	**Country (or area) of report**	**References (in chronological order)**
Annona cherimola L.	Annonaceae: Magnoliales	Brazil, Perú	Schultz 1939; Adamski and Brown 2001; Brown et al. 2008
A. squamosa L.	Annonaceae: Magnoliales	Brazil	Nakano and Soares 1995; Bento et al. 2001
Averrhoa carambola L.	Oxalidaceae: Oxalidales	Brazil	Adamski and Brown 2001; Brown et al. 2008
Citrus spp.	Rutaceae: Sapindales	Argentina, Ecuador, Nicaragua	Lima 1927; White and Tuck 1994; Adamski and Brown 2001; Brown et al. 2008
Cojoba arborea (L.) Britton and Rose (as *Pithecellobium*)	Fabaceae: Fabales	Argentina	Busck 1934; Adamski and Brown 2001; Brown et al. 2008
Cocos nucifera L.	Arecaceae: Arecales	Brazil	Meyrick 1931; Bento et al. 2001
Cupania vernalis A. St.-Hil.	Sapindaceae: Sapindales	South America	Brown et al. 2008
Eriobotrya japonica (Thunb.) Lindl.	Rosaceae: Rosales	Brazil	Adamski and Brown 2001; Brown et al. 2008
Litchi chinensis Sonn.	Sapindaceae: Sapindales	Brazil	Lima 1945; Brown et al. 2008
Macadamia integrifolia Maiden and Betche	Proteaceae: Proteales	Costa Rica, Trinidad & Tobago, Venezuela	White 1993; Blanco-Melzer, et al. 1993, 2001, 2007, 2009; Blanco-Melzer 1994; Adamski and Brown 2001; Brown et al. 2008
Melicoccus bijugatus Jacq.	Sapindaceae: Sapindales	Puerto Rico	This paper
Musa acuminata Colla or *Musa* sp.	Musaceae: Zingiberales	South America	Meyrick 1931

Pithecellobium dulce (Roxb.) Benth.	Fabaceae: Fabales	Puerto Rico	Adamski and Brown 2001; Brown et al. 2008
Plukenetia volubilis L.	Euphorbiaceae: Malpighiales	Perú	Brown et al. 2008
Prunus persica (L.) Batsch	Rosaceae: Rosales	Venezuela	Adamski and Brown 2001; Brown et al. 2008
Psidium guajava L.	Myrtaceae: Myrtales	Brazil	Lima 1927; Martorell 1976 Brown et al. 2008
Punica granatum L.	Punicaceae: Myrtales	Brazil	Adamski and Brown 2001; Brown et al. 2008
Sapindus saponaria L.	Sapindaceae: Sapindales	South America	White 1999; Brown et al. 2008
Theobroma cacao L.	Malvaceae: Malvales	Colombia, Trinidad & Tobago	Meyrick 1931; Adamski and Brown 2001; Brown et al. 2008

Discussion

It is estimated that the sale of *quenepas* represents 899,000 (with more than 157 planted *cuerdas*, 61.7 hectares, and 4.89 million harvested racemes), or approximately 3%, of the total for fruit sales (circa 30 million dollars) in Puerto Rican agriculture during 2009-2010. Currently, the value of *quenepas* is $183.68/100 racemes (Anonymous 2010). Although *M. bijugatus* is a relatively minor component of the Puerto Rican fruit production, the ease of cultivation and ornamental attractiveness of the tree, its pleasantly smelling flowers, delicious fruits (a single tree can yield between 200-600 pounds of *quenepas*), and relative few natural enemies, makes *quenepa* a promising economic possibility, particularly in the fresh fruits market. Additionally, the pulp of the *quenepa*, along with sugar and spices, are used to infuse rum, creating an easy to make alcoholic beverage, called *bilí*. Thus, the fact that *G. aurantianum* is a polyphagous herbivore, makes its find in *quenepa* a cause for concern.

The reports of *G. aurantianum* from *M. bijugatus* come from a commercial fruit tree nursery located in Cabo Rojo and from the Agricultural Experiment Station (Lajas), both located in southwestern of Puerto Rico (Figure 5). Based on reports for other fruits (Adamski and Brown 2001; Bento et al. 2001, Parra et al. 2004), we suggest that adults *G. aurantianum* oviposit on the surface of *M. bijugatus* fruits. After eclosion, possibly one larva (in other larger fruits perhaps more) penetrates and colonizes the *quenepa*. The damage in *quenepa* consists of one small (approximately 1.5 mm diameter) orifice on the fruit through which the larvae penetrates and begins consuming its pulp, altering its color and texture, accelerating fruit deterioration through microbial decomposition and secondary animalcule colonization (Figure 5). A fruit in such condition is unsuitable for sale and human consumption.

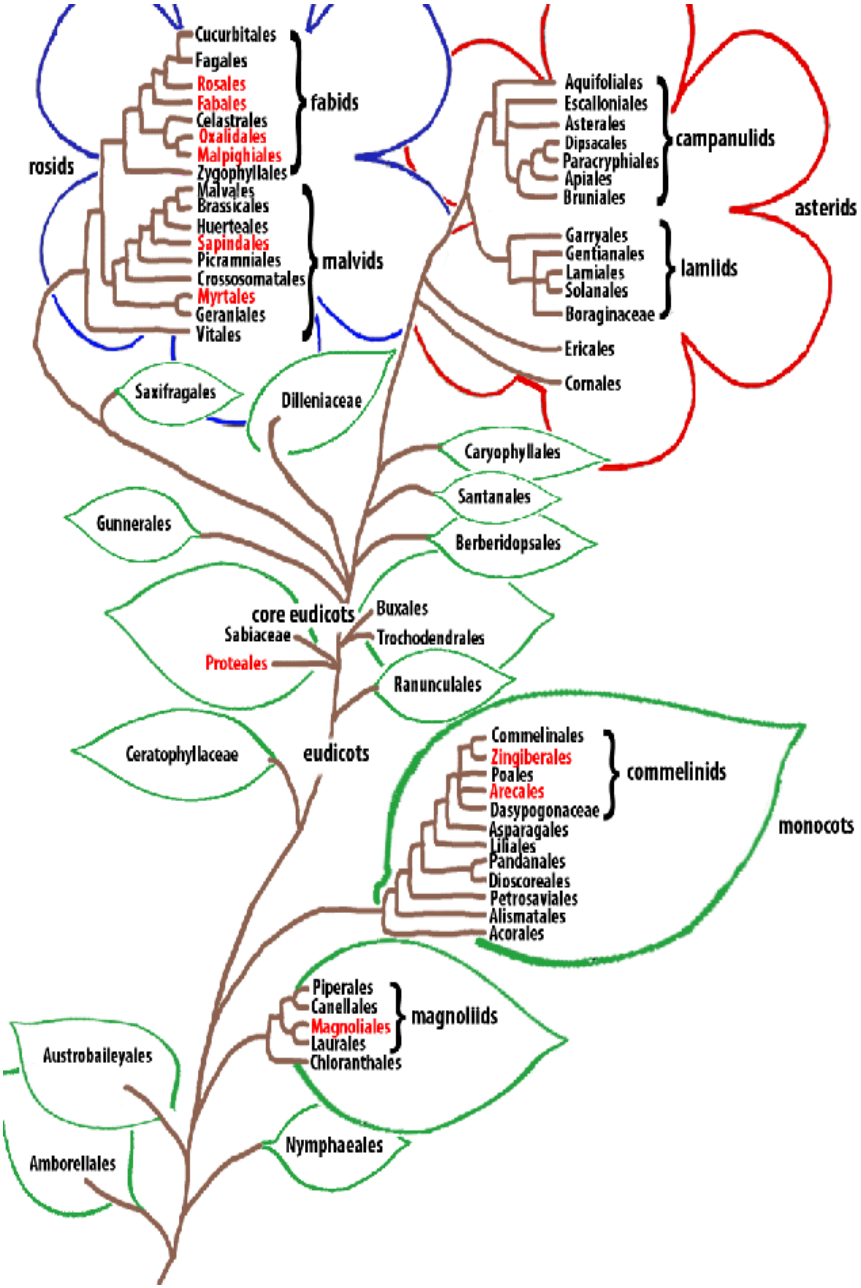

Figure 4. A phylogeny of the flowering plants, or angiosperms, based on Angiosperm Phylogeny Group (2009). The wide taxonomic spectrum of host plants orders (10), mostly in the rosids, reported for *Gymnandrosoma aurantianum* is represented in red font. Corresponding plant families are given in Table 1.

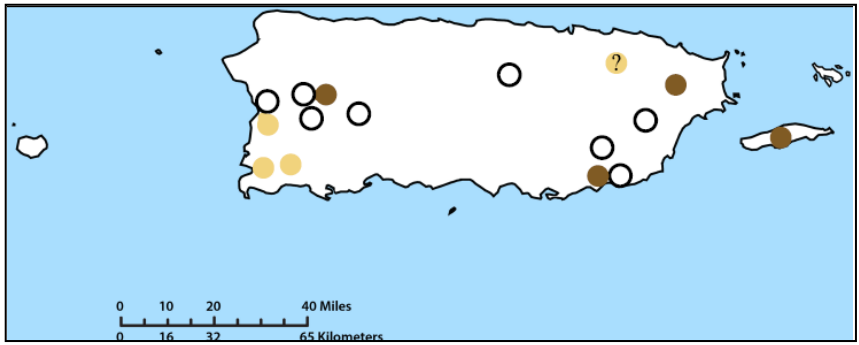

Figure 5. Reported geographical distribution of the three species of *Gymnandrosoma* in Puerto Rico. Golden circles represent the *bona fide* localities for *G. aurantianum* Lima, including the two localities included in this paper, southwesternmost is a commercial nursery in Cabo Rojo and some 10 kilometers east, the second new locality, the Agricultural Experiment Substation in Lajas. The golden circle with the question mark, "?", represents Martorell (1976) record from Trujillo Alto, which we consider doubtful. *Gymnandrosoma leucothorax* Adamski and Brown is represented by white circles within a black rim; *G. trachycerus* Forbes is represented by brown circles.

The damage in *quenepa* was first detected in *M. bijugatus* variety *Tuna* in September 2009 in the Lajas Agricultural Experiment Substation (Figure 5). Only one out of 60 randomly chosen *quenepas* out of several racemes (one raceme may have 25 fruits) sampled (1.7%) had the damage, with no further increases in percent fruit damaged during 2009 and 2010. However, towards September 2011, the end of the fruit collecting season, all varieties planted in the Lajas (AES), including (alphabetically) *Cabo Rojo*, *Doña Fela*, *Ferpa*, *Martínez*, *Pabón*, *Sasa*, *Sotomayor*, *Tuna*, and others, as well as those planted in a commercial nursery located in the city of Cabo Rojo had the *G. aurantianum* damage, with an estimated incidence of 5% amongst the fruits.

What attracts *G. aurantianum* to its host fruits? Chemical attractants appear to be partially responsible for the phenomenon as it is strongly suggested by the existence of pheromone traps for this species (Leal et al. 2001, Ono et al. 2001; Chamberlain et al. 2003; Parra et al. 2004). However, given the wide botanical spectrum of its host plants (Figure 4), we wonder if the chemicals detected by *G. aurantianum* represent a generalized "fruity" smell, just like insects of forensic importance detect the "smell of death", a complex mix of chemicals. Pheromone traps are available for monitoring *G. aurantianum* (Parra et al. 2004) although we have been unable to get them. Thus far, the use of yellow sticky trap in a *Melicoccus bijugatus* plantation at the Lajas Agricultural Experiment Substation, has yielded no *G. aurantianum*. Odor analyses (e.g. Bass and Jefferson 2003; Vass et al. 2004, 2008) of unrelated fruits and finding the chemical commonalities could be done to assess this question. Alternatively, it is possible that *G. aurantianum* is an "architecture" specialist rather than a host plant "taxonomic" specialist, as appears to be the case in Microcorsini (Brown

and Brown 2004). Numerous sensory inputs, including host chemistry and vision, have been shown to be important for insect host finding in insect (Bernays and Chapman, 1994).

Blanco-Metler et al. (2009) report an "inverse relationship between total [egg plus larval] parasitism and the mean of damaged [macadamia] nuts. Parasitoids play an important role in the reduction of the *G. aurantianum* population." In addition, detailed efforts to control the Citrus Fruit Borer with a synthetic sex pheromone have been reported (Parra et al. 2004).

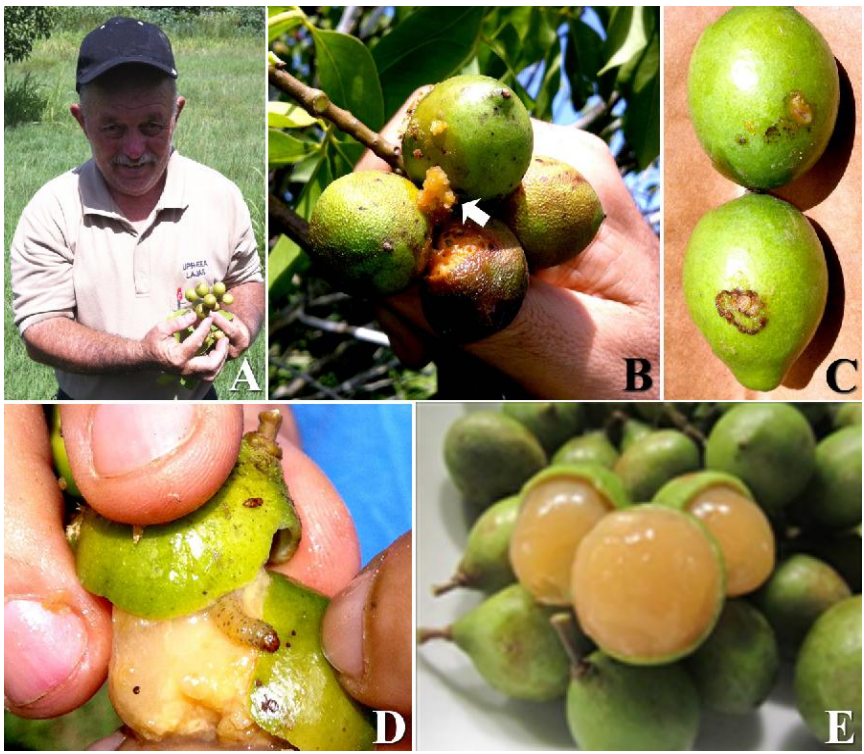

Figure 6. A. Cluster (or *racimo*) of *quenepas* or *Melicoccus bijugatus* fruits held by coauthor SEH. Two or three *racimos*, containing a total of approximately 75 *quenepas*, are often sold in Puerto Rican road sides for $2-5 dollars. B. Semi-dried, sticky *quenepa* material (arrow) between two adjacent fruits, a common sign of damage by *Gymnandrosoma aurantianum* larvae on one fruit. C. Holes on *quenepas* likely caused by *G. aurantianum*, gummy material removed. D. Early *G. aurantianum* larva on the pulp of a *quenepa*. E. Undamaged *quenepas* for comparison. Approximate maximum diameter of a healthy mature fruit is 2-2.5 cm, approximate weight 10-13 grams. Image courtesy of G. Merryman (AboutMyBeaches, http://www.aboutmybeaches.com/tag/quenepas/).

From a biogeographic perspective, we hypothesize that *G. aurantiaum* is a South American species that has been anthropically dispersed into Central

America and the Caribbean through the transport of fruits. *Gymnandrosoma aurantianum* was collected on *Theobroma cacao* seed from Barbados, intercepted in New York supporting the hypothesis that *G. aurantianum* can disperse anthropically (Meyrick, 1931; Adamski and Brown, 2001; Brown et al. 2008). Importation of exotic fruits trees into Puerto Rico (Rivero and Brunner 2009) and ornamental plants (Rivero 2009) has been extensively documented. The detection of *G. aurantianum* in *quenepa*, *Melicoccus bijugatus*, a never before recorded host plant, represents an agricultural concern.

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