VOL. 34, NO. 1 SOUTHWESTERN ENTOMOLOGIST MAR. 2009

Abundance of Asian Citrus Psyllid on Yellow Sticky Traps in Florida, Puerto Rico, and Texas Citrus Groves

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Abstract. Population dynamics of Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae), were studied using yellow sticky traps in citrus groves in Florida, Texas, and Puerto Rico. Four groves were studied in Florida (three sweet orange groves and one grove of mixed *Citrus* spp.) and Texas (four grapefruit groves), and three groves were studied in Puerto Rico (one grove of mandarin oranges and two sweet orange groves). Abundance of Asian citrus psyllid based on trap captures of adults at two groves in Puerto Rico were similar to those in Florida, although several peaks in numbers trapped at one Florida grove far exceeded those at any other grove. Few adults were captured on traps at one of the Puerto Rico groves and at each of the four Texas groves. Less abundance of the psyllid was attributed to the grove in Puerto Rico being higher altitude and cooler. Fewer psyllids captured at two of the four Texas groves during some trapping periods were attributed to applications of insecticides but, overall, fewer adults captured on traps at the Texas groves seemed to be a consequence of differences in abundance of the psyllid. Environmental, biological control, or host plant factors may be less favorable for increases in abundance of Asian citrus psyllid in Texas than in Florida.

Introduction

The Asian citrus psyllid, *Diaphorina citri* Kuwayama, is an important pest of citrus in Florida primarily because it is a vector of *Candidatus* Liberibacter asiaticus Jagoueix, Bové & Garnier (Halbert and Manjunath 2004). This and other species of *Ca*. Liberibacter are phloem-limited bacteria responsible for citrus greening (huanglongbing) disease (Halbert and Manjunath 2004, Hung et al. 2004). Citrus greening is one of the world's most serious diseases of citrus (Bové 2006). Asian citrus psyllid was first found in Florida in 1998 (Tsai et al. 2000) and is now established throughout the citrus-growing region of the state (Michaud 2004). Citrus greening was first found in southern Florida in August 2005 (Bové 2006). Subsequent surveys by the State of Florida and USDA-APHIS revealed the disease was already widespread. Asian citrus psyllid was found during 2001 in both Puerto Rico (Pluke et al. 2008) and Texas (French et al. 2001). Recent surveys have shown that the pest has spread to 32 counties throughout Texas (da Graça et al. 2006). However, citrus greening disease had not been found in Puerto Rico or Texas when this report was written.

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A key component to a management program for citrus greening disease is aggressive control of Asian citrus psyllid (Rogers 2008). Population levels of Asian citrus psyllids are commonly gauged by counting psyllids on citrus flush shoots (young developing leaves as described by Hall and Albrigo 2007) or on yellow sticky traps deployed in citrus trees (Hall et al. 2007). In Florida citrus not treated with insecticide, Hall et al. (2008) reported season-long means of 26.5 eggs, 16.8 nymphs, and 0.27 adult per shoot during a flush of growth in a group of young trees, and of 16.0 eggs, 12.7 nymphs, and 0.31 adult per flush shoot in a group of mature trees. Mean densities frequently exceeded 50 eggs or nymphs per flush shoot. Season-long means of 6 or 10 adults per sticky trap per week were observed in the young and mature trees, respectively, with mean numbers of adults per trap per week frequently exceeding 20. Based on the incidence and spread of citrus greening disease in Florida, disease management programs cannot tolerate great infestations of Asian citrus psyllid such as these.

Pluke et al. (2008) assessed infestation by Asian citrus psyllid eggs and nymphs in citrus at four locations in Puerto Rico. At groves near the cities of Isabela and Corozal where the greatest infestations were observed, season-long means of 1.1 and 0.7 immature Asian citrus psyllid per flush shoot were observed, respectively; percentages of flush shoots infested by eggs and nymphs peaked at 69 and 52%, respectively; and numbers of immatures per flush shoot peaked at 6-15 at each location. These infestations were small compared to those reported in Florida (Hall et al. 2008). In Texas, Setamou et al. (2008) reported means of 0.1 egg, 0.3 nymph, and 0.03 adult per flush shoot in grapefruit and 0.2 egg, 1.2 nymphs, and 0.2 adult per flush shoot in sweet orange. These infestations were small compared to those reported in Florida and the two Puerto Rico groves.

This study was a descriptive sampling project to assess relative population dynamics of adult Asian citrus psyllid in Florida, Puerto Rico and Texas. Yellow sticky traps in citrus trees were used to assess abundance of adults over time (Hall et al. 2007).

Materials and Methods

Phenology and abundance of Asian citrus psyllid in citrus were studied in Florida, Puerto Rico, and Texas. At each location, yellow (a bright yellow hue similar to S-G-390 by Behr Process Corp., Santa Ana, CA) sticky card traps (7.62 x 12.7 cm, Great Lakes IPM, Vestaburg, MI) were placed in 10 trees, with one trap per tree. A twist tie was used to suspend the trap from a branch 1 to 1.5 m above the ground near the outside of the canopy. A hole punched near the upper edge of each trap was used to hang the trap. The traps were deployed and retrieved from the same trees every two weeks. Disposable gloves were worn to avoid contact with the sticky surface of the traps. Traps removed from a tree were placed individually into clear plastic bags. These were transported to a laboratory where a microscope was used to aid in counting psyllids through the plastic bag. When more than 25 psyllids were on a trap or if other insects or debris were on a trap, a marker was used to draw lines as a guide on the plastic bag to prevent recounting or missing individuals. All adults on both sides of each trap were counted. Trapping was initiated during late 2006 and concluded near the end of 2007. Mean number of adult Asian citrus psyllids per tree per trapping period was calculated for each location. Air temperatures and rainfall in the vicinity of each study location were monitored. Mean monthly air temperature and rainfall were computed for each location.

At the onset of the project, the authors agreed to sample groves under minimal spray programs for insect and plant diseases. However, because these groves were managed by different owners, some differences developed during the course of the study in what the growers applied to control insects and diseases. Two groves in Texas were each treated with a broad-spectrum insecticide during the summer that would have controlled psyllids for some period of time.

Florida Locations. Adult psyllids were trapped at four citrus groves (Table 1), all but one regularly irrigated. One was a USDA-ARS variety development grove 13.5 km southeast of the town of Leesburg in Lake County in north-central Florida. One trap was placed within each of 10 blocks of trees, each block containing different varieties of mature citrus trees 3 to 4 m tall: pummelo [*Citrus grandis* (L.) Osbeck], grapefruit [*C. paradisi* Macf.], sweet orange [*C. sinensis* (L.) Osbeck], tangelo [*C. tangerina* Tanaka x *C. paradisi*], and mandarin [*C. reticulata* Blanco]. One block of trees was treated with pyridabin (Nexter) and one was treated with spirodiclofen (Envidor) during April. Neither of these miticides provided any observed control of Asian citrus psyllid (Rogers 2008). Two blocks were treated with abamectin (Agrimek) and oil during July, and one block received this treatment in both June and July. Abamectin and oil provide short-term control of Asian citrus psyllid. A second location was another USDA-ARS research grove near the town of Fort Pierce in Saint Lucie County in east-central Florida. Traps were placed within a 0.4-ha block containing 'Hamlin' sweet orange trees (5 years old, ~1.8 m tall). No spray oils or insecticides were applied during the study at this location. A third location was near the town of Vero Beach in Indian River County about 24 km north of the Saint Lucie County study site. Trapping was at a non-irrigated, 1.0-ha block of 'Temple' tangors [*C. reticulata* Blanco x *C. sinensis* (L.) Osbeck] trees (36 years old, ~3.4 m tall). Tangors are commonly referred to as oranges (Hall and Albrigo 2007). Petroleum spray oil was applied once during April, June, July, and September to control citrus disease. Spray oils are not currently recommended to control the psyllid (Rogers et al. 2008) but can provide short-term suppression. The fourth location was 6.6 km northwest of the town of Immokalee in Collier County in southwestern Florida. Traps were placed in a 0.8-ha area within a large block of young 'Valencia' trees (4 years old, ~1.5 m tall). Spray oil was applied by air to the trees during early December 2006. No other insecticides or spray oils were applied to the trees during the study.

Puerto Rico Locations. Three citrus groves were monitored for Asian citrus psyllid in Puerto Rico (Table 1). One location was near the town of Castañer in the Central Cordillera of Puerto Rico. This grove (~0.3 ha) was on the property of the University of Puerto Rico's Adjuntas Experiment Station and consisted of several varieties of mandarin (2-3 m tall). The site was in the central, mountainous region of Puerto Rico. A second location was at the University of Puerto Rico Corozal Experiment Station near the town of Corozal. Traps were placed in a 2-ha block of 'Valencia' sweet orange (~3.5 m tall). The third location was at the University of Puerto Rico Isabela Experiment Station near the town of Isabela on the north-west coast. Traps were placed in a 0.6-ha block of 'Valencia' sweet orange. Ultrafine (paraffin) spray oil and soap were applied to the trees at the Corozal Experiment Station during August. Paraffin spray oil and soap are not recommended to control psyllids (Rogers 2008) but might provide short-term suppression. Foliage was not treated at the other two study sites.

Texas Locations. Psyllids were trapped at four groves in Texas (Table 1). One location was near Brownsville in southeastern Cameron County. Traps were within a 0.8-ha block containing 'Ruby Red' grapefruit (~3.2 m tall). Fenbutatin-oxide (Vendex) was applied to control mites during March, and azoxystrobin (Abound) was applied in June. Fenbutatin-oxide has given no observed control of Asian citrus psyllid (Rogers 2008), and azoxystrobin is a fungicide. A second location was in Progresso in southeastern Hidalgo County. Traps were placed within a 1.0-ha block containing 'Rio Red' grapefruit (~3.3 m tall). Abamectin and oil was applied twice to control mites, once in March and once in June. A third location was near Raymondville in Willacy County. Trapping was in a 1.0-ha block of 'Ruby Red' grapefruit (~2.9 m tall). Fenbutatin-oxide was applied for mite control in April, and chlorpyrifos (Lorsban) was applied for general insect/mite control in July. Chlorpyrifos is effective against Asian citrus psyllid. The fourth location was in McCook in northwestern Hidalgo County. Traps were placed in a 1.2-ha area within a block of 'Rio Red' grapefruit (~3.3 m tall). Abamectin and oil were applied to control mites during March and June, and carbaryl (Sevin) was applied for general insect control during August. Carbaryl is effective against Asian citrus psyllid.

Table 1. Numbers of Adult Asian Citrus Psyllid Captured on Yellow Sticky Card Traps on Citrus Trees in Florida, Texas and Puerto Rico

Region of citrus production	Latitude longitude	Location within the region, and a nearby city	Elevation above sea level (m)	Citrus scion	Mean ± SEM adults/trap/2 weeks
Florida	28°41'15.24"N 81°53'25.12"W	North central, Leesburg	33	Mix	4.3 ± 0.63
	27°39'16.93"N 80°28'15.80"W	East central, Vero Beach	6	Orange	3.6 ± 0.86
	27°26'08.46"N 80°25'51.31"W	East central, Fort Pierce	6	Orange	11.5 ± 2.45
	26°27'13.96"N 81°21'22.08"W	Southwest, Immokalee	9	Orange	6.9 ± 0.82
Texas	26°25'34.14"N 98°21'57.02"W	Northwest, McCook	80	Grapefruit	0.6 ± 0.17
	26°30'34.20"N 97°48'27.40"W	North central, Raymondville	8	Grapefruit	0.9 ± 0.24
	26°04'13.15"N 98°00'17.86"W	South central, Progresso	24	Grapefruit	0.5 ± 0.17
	25°50'36.75"N 97°23'47.66"W	Southeast, Brownsville	6	Grapefruit	0.1 ± 0.03
Puerto Rico	18°10'24.36"N 66°47'47.58"W	West central, Castañer	686	Mandarin	0.3 ± 0.09
	18°19'32.76"N 66°21'29.52"W	North central, Corozal	220	Orange	2.8 ± 0.60
	18°28'03.18"N 67°02'59.52"W	Northwest, Isabela	130	Orange	3.0 ± 0.89

Results and Discussion

Adult Asian citrus psyllids were trapped at each of the groves in Florida, Texas, and Puerto Rico (Table 1). In Florida, adults were captured during every trapping period at each grove. The largest mean numbers of adults captured per trapping period were 11.0, 22.9, 53.9, and 18.8 per trap at the Leesburg, Vero Beach, Fort Pierce, and Immokalee groves, respectively. Mean numbers of adults captured on traps at the Corozal and Isabela groves in Puerto Rico were similar to those captured at three groves in Florida, while fewer psyllids were captured at the Castañer grove. Adults were collected during 13 of 30 trapping periods at the Castañer grove, during 28 of 30 periods at the Isabela grove, and during all periods at the Corozal grove. The greatest mean numbers of adults captured per trapping period were 2.0, 20.3, and 14.8 at the Castañer, Isabela, and Corozal groves, respectively. Compared to numbers of adults trapped in Florida, relatively few adults were captured at each of the groves in Texas. Adults were collected during nine of 32 trapping periods at the Brownsville grove, 23 of 32 periods at the McCook grove, and 16 or 17 of 32 periods at the other two Texas groves. Most adults captured per trapping period were 0.5, 4.6, 5.0, and 5.2 at the Brownsville, Progresso, Raymondville, and McCook groves, respectively.

Outbreaks of Asian citrus psyllids in Florida are generally most common during April-July but may occur anytime of the year depending upon environmental conditions and the availability of young flush shoots for oviposition and development of nymphs (Hall et al. 2008). Numbers of adults captured on traps at the four groves in Florida during 2007 indicated the psyllid was generally most abundant during April-July (Fig 1). The seasonal profile of numbers of adults on traps in Puerto Rico during 2007 generally seemed similar to Florida based on numbers of adults trapped at the Isabela and Corozal groves, although increases in numbers began about a month earlier in Puerto Rico than in Florida. Pluke et al. (2008) reported similar population trends at Corozal and Isabela during 2004-2005, with peak abundance per flush shoot and peak percentages of shoots infested in February (Isabela) or April (Corozal). Although we captured few adults at the Castañer grove, Pluke et al. (2008) did not observe any Asian citrus psyllids in citrus in this area of Puerto Rico during 2004-2005. We did not draw any phenology comparisons for the four Texas groves (Figs. 1 and 2) or the Castañer grove in Puerto Rico (Fig. 1) either because of insecticide treatments (three locations in Texas) or because so few adults were captured (Brownsville in Texas and Castañer in Puerto Rico).

The results of this trapping study support published data that indicate abundance of Asian citrus psyllids in citrus is greater in Florida than Texas. Population densities based on trap captures of adults at the Isabela and Corozal groves in Puerto Rico were similar to those at the four Florida groves, although several peak trap-captures at the Fort Pierce grove in Florida far exceeded those at any other grove. Numbers of adults captured on traps at these six groves were greater than those at the four Texas groves or at the Castañer grove in Puerto Rico. In Texas, insecticides probably were responsible at times for fewer adult Asian citrus psyllids on traps at the McCook grove from March through September, and at the Raymondville grove during July and August. Numbers of adults on traps at the Progresso grove in Texas probably were fewer for short periods of time because of

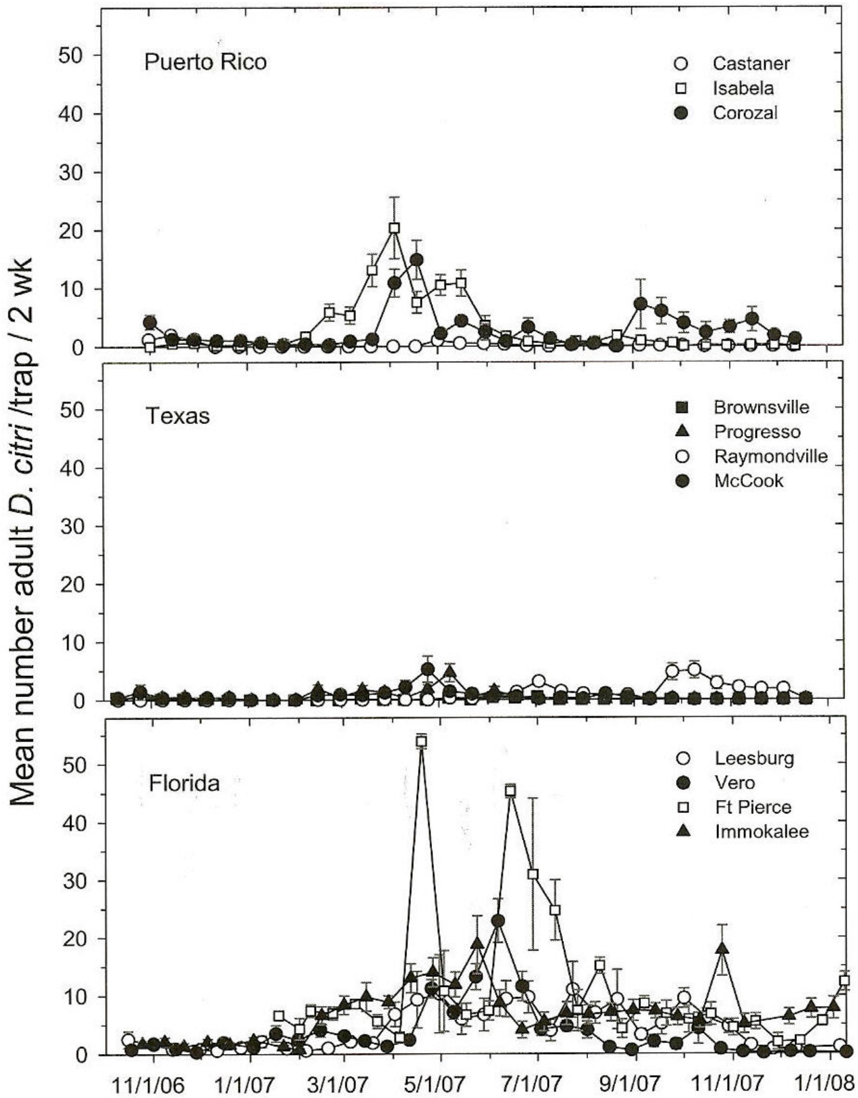

Fig. 1. Abundance and phenology of the Asian citrus psyllid in citrus groves in Florida, Texas, and Puerto Rico as indicated by numbers of adults on yellow sticky traps. Chemical treatments known to suppress the psyllid for short periods of time were applied once to the Corozal grove in Puerto Rico, once or twice to the Progresso and McCook groves in Texas, and once to the Immokalee and three times to the Leesburg groves in Florida. In Texas, broad-spectrum insecticides were applied once to the Raymondville and McCook groves.

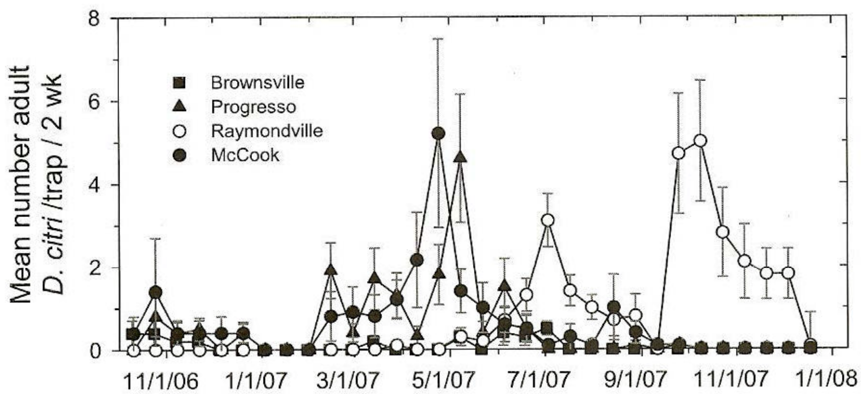

Fig. 2. Abundance of the Asian citrus psyllid in citrus groves in Texas as indicated by numbers of adults captured on yellow sticky traps. Chemical treatments known to suppress the psyllid for short periods of time were applied once or twice to the Progresso and McCook groves, and broad-spectrum insecticides were applied once to the Raymondville and McCook groves.

abamectin and oil sprays during March and June. It was unlikely that the fenbutatin-oxide spray in March or the azoxystrobin spray in June caused any significant reduction in psyllids at the Brownsville grove in Texas.

In Florida, programs to manage psyllids in mature trees require eight or nine applications of insecticide per year (Rogers 2008). None of the Texas groves were subjected to a program of this intensity, with the most intense program being at the McCook grove where abamectin and oil were applied (short-term control) in March and June and carbaryl was applied (longer control) in August. Therefore, it seemed unlikely that insecticides applied at the Texas study sites were entirely responsible for the magnitude of differences between numbers of adult Asian citrus psyllids captured on traps in Texas compared to Florida. Some of the differences in numbers of adults trapped seemed to be a consequence of differences in abundance of the psyllid.

Differences in abundance between geographical areas could occur as a result of differences in temperature, humidity, or other environmental factors. Mean monthly air temperatures at the Corozal and Isabela groves in Puerto Rice were consistently within the range identified as optimum for Asian citrus psyllids, 24-28°C (Liu and Tsai 2000, Fung and Chen 2006) (Fig. 3, Table 2). Air temperatures during our study were colder during the winter and warmer during the summer in Texas than in Florida. Hot weather during the summer in Texas might suppress psyllid infestations. However, air temperatures in Texas generally seemed favorable for the psyllid during March-May, September, and October. Why more Asian citrus psyllids were not at least periodically trapped during March-May at the Raymondville or Brownsville groves, or during September-October at the Progresso or Brownsville groves, was not known. Because the psyllid has been characterized as a species favoring hotter, low-lying coastal areas (Burckhardt 1994, Étienne et al. 2001), less abundance at the Castañer grove in Puerto Rico was probably related to it being a high-altitude, cooler location. Whether or not reduced a pressure at higher altitudes has any influence on abundance of the psyllid is r known, but Asian citrus psyllid on Reunion Island is more common at altitudes low than 500 m (Étienne et al. 2001).

Differences in abundance of Asian citrus psyllid in Florida, Puerto Rico, a Texas could be a consequence of differences in biological control. For examp biological control of the psyllid by an ectoparasitoid, *Tamarixia radiata* Waters (Hymenoptera: Eulophidae), in Puerto Rico (Pluke et al. 2008) was greater than

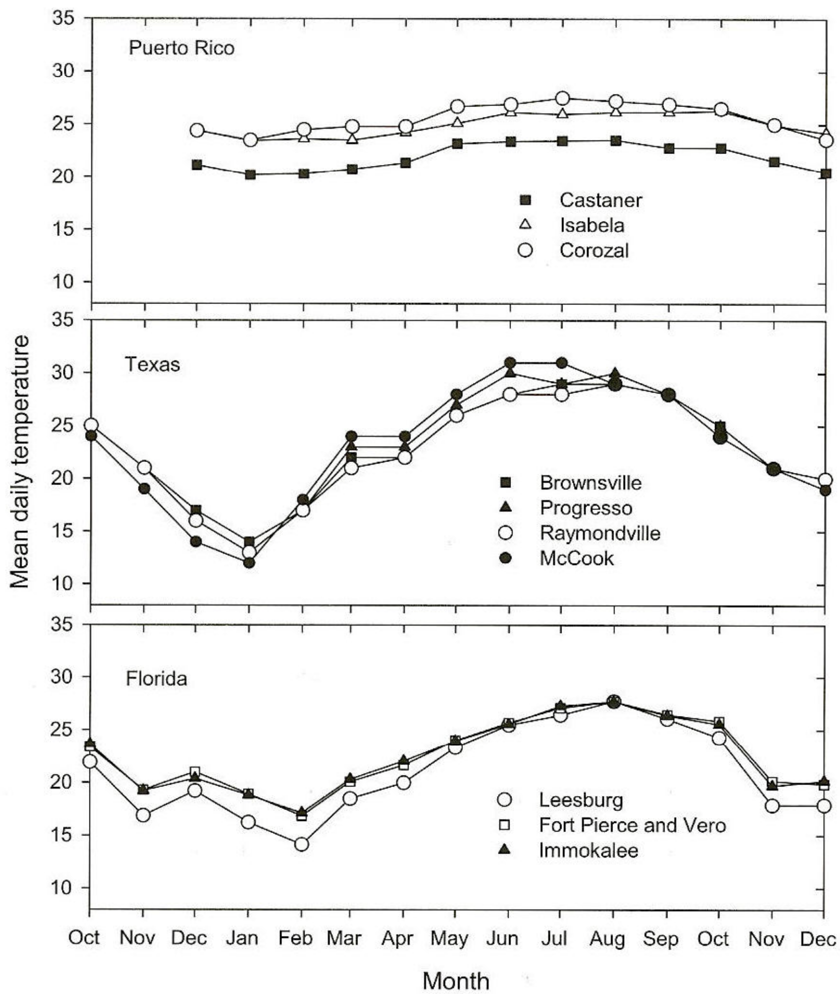

Fig. 3. Mean monthly air temperatures (C) at the citrus groves in Florida, Tex and Puerto Rico.

Table 2. Average Air Temperature and Rainfall During the Study

Region of citrus production	Grove	Mean (SEM) daily air temperature (°C)	Mean (SEM) monthly rainfall (cm)
Florida	Leesburg	21.1 (1.1)	6.8 (1.6)
	Vero Beach / Ft Pierce	22.5 (0.9)	6.9 (1.4)
	Immokalee	22.5 (0.9)	4.1 (1.2)
Texas	McCook	23.1 (1.5)	2.7 (0.8)
	Raymondville	22.6 (1.3)	7.3 (1.9)
	Progresso	23.2 (1.4)	4.6 (1.4)
	Brownsville	22.9 (1.2)	8.0 (1.5)
Puerto Rico	Castañer	21.6 (0.4)	16.0 (2.3)
	Corozal	25.6 (0.4)	15.5 (1.3)
	Isabela	26.1 (0.3)	10.9 (1.0)

Florida (Hall et al. 2008). No published details were available on biological control of the psyllid by *T. radiata* in Texas, although the parasitoid was inadvertently introduced into the state and is established (M. Setamou, unpublished). *T. radiata* may exert better biological control of Asian citrus psyllid in Texas than in Florida, or there may be other natural enemies including predators and pathogens of the psyllid that are unique to or more active in Texas.

Host plant suitability could also affect abundance of the psyllid. Differences in citrus variety (both scion and rootstock), tree age, nutrition, and water availability in conjunction with different environmental conditions could lead to different citrus shoot-flushing patterns and abundance, which would affect abundance of psyllids (Hall and Albrigo 2007). There was considerable variability among our study locations with respect to citrus varieties, age, nutritional programs, and irrigation practices, some of which were atypical of commercial citrus at least for the locations in Florida. Grapefruit constitutes the majority of citrus grown in Texas, and all of the groves we studied in Texas contained grapefruit. No solid stands of grapefruit were studied in either Florida or Puerto Rico. Whether fewer adult psyllids trapped in Texas was related to grapefruit as a host was not known but a possibility, because infestation by Asian citrus psyllid in Texas has been reported to be less on grapefruit than sweet orange (Setamou et al. 2008). Average female longevity on rough lemon is significantly longer than on grapefruit, sour orange, or orange jasmine [*Murraya paniculata* (L.) Jack], and females lay more eggs on grapefruit than on rough lemon, sour orange, or orange jasmine (Tsai and Liu 2000). To our knowledge, grapefruit and sweet orange as hosts of Asian citrus psyllid have not been compared in detail.

The observed differences in numbers of adults captured at the different groves could, to some extent, be an artifact related to yellow sticky card traps. Yellow sticky card traps have been shown useful for detecting and gauging abundance of Asian citrus psyllid (Hall et al. 2007, 2008). However, sunlight and air temperature positively influence numbers of adults trapped, reducing the value of trap counts as indicators of absolute densities (Hall 2008). With the large amounts of rainfall at the groves in Puerto Rico and particularly the Castañer grove (Table 2), these locations might receive less sunlight in a year, which could reduce trap captures as compared to Florida and other sunnier locations. Rain by itself has not been shown to reduce numbers of adult Asian citrus psyllids captured on yellow sticky traps (Hall 2008). In general, differences between Texas and Florida in numbers of adults trapped did not seem to be related to temperature during most months of the study (Fig. 3). However, cool winter temperatures in Texas probably would suppress abundance of psyllids and result in fewer adults captured on traps. Additional research to clarify abundance of Asian citrus psyllids in Texas citrus not sprayed with insecticide would be beneficial.

Acknowledgment

The authors thank and acknowledge the following individuals for their assistance in this research: Matt Hentz, Kathryn Moulton, Chris Knox (USDA-ARS, U. S. Horticultural Research Laboratory, Fort Pierce, FL); Robert Adair (Florida Research Center for Sustainable Agriculture, Vero Beach, FL); Eustorjio Rivas (USDA-APHIS, PPQ, CPHST), and Elkin Vargas (USDA-ARS, TARS). Phil Stansly (University of Florida) provided an excellent review of a draft of the manuscript. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement.

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