'ATAULFO' MANGO FLOWERS CONTAIN A DIVERSITY OF THRIPS (THYSANOPTERA)

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Abstract

'Ataulfo' mango (*Mangifera indica* L.) is the most popular cultivar of mango to have originated in Mexico. Because of its relatively recent discovery, few studies have been carried out on the best agricultural practices for production of this cultivar, and there is wide variation in methods among growers. Among other aspects, the insect fauna associated with this cultivar has not been formally studied. However, numerous growers spray synthetic insecticides on a regular basis against thrips to reduce populations. The present study was conducted with the main objective of determining the diversity of thrips in Ataulfo mango flowers in Chiapas, Mexico. Two representative orchards were selected: the orchard "Tres-A" characterized by an intensive use of agrochemicals, especially broad-spectrum synthetic insecticides directed against thrips, and the orchard "Rancho La Escondida" that does not spray insecticides. Inflorescences were sampled every five days, from Nov 2008 to Feb 2009. The results confirm the presence of 15 species of thrips in 7 genera and 3 families. Species composition was consistent in both orchards. This included phytophagous species in the genera *Frankliniella*, *Arorathrips*, *Haplothrips* and *Scirtothrips*, and the predatory thrips *Aeolothrips microstriatus* Hood, *Franklinothrips orizabensis* Johansen, *Karnyothrips texensis* (Hood) and *K. flavipes* (Jones). *Frankliniella* was the dominant genus: *F. borinquen* Hood, the *F. gossypiana* Hood/ *F. williamsi* Hood complex, *F. cephalica* (Crawford), *F. gardeniae* Moulton, *F. invasor* Sakimura and *F. parvula* Hood. A new species of *Frankliniella* was collected as well. *Frankliniella invasor* was the most abundant species throughout the flowering cycle in both orchards with a mean of 613 individuals per inflorescence. Both mango orchards had statistically similar numbers ($P > 0.05$) of thrips over time. This suggests that the use of broad-spectrum synthetic insecticides is not effective for thrips control and the use of other methods is necessary.

Key Words: Thysanoptera, *Frankliniella*, Ataulfo mango, Chiapas State, Mexico

Resumen

El mango Ataulfo (*Mangifera indica* L.) es el cultivar de mango más popular de origen mexicano. Debido a su descubrimiento relativamente reciente, pocos estudios se han llevado a cabo sobre las mejores prácticas agrícolas de producción de este cultivar, y por lo tanto existe una amplia variación en los métodos utilizados por los productores. Entre otros aspectos, la fauna de insectos asociada a este cultivar no ha sido formalmente estudiada. No obstante, numerosos agricultores aplican insecticidas sintéticos de una forma regular contra los trips de las flores con el fin de reducir sus poblaciones. El presente estudio fue realizado con el principal objetivo de determinar la diversidad de trips en las flores de mango Ataulfo en Chiapas, Mexico. Para ello, fueron seleccionados dos huertos representativos: La huerta "Tres-A" caracterizada por un uso intensivo de agroquímicos, especialmente insecticidas de amplio espectro aplicados contra los trips presentes en las flores, y la huerta "Rancho La Escondida" que no realiza ninguna aplicación de insecticida. Las inflorescencias fueron muestreadas cada cinco días, desde noviembre de 2008 hasta febrero de 2009. Los resultados confirman la presencia de 15 especies de trips en siete géneros y tres familias. La composición de especies fue consistente en ambos huertos. Esto incluyó especies fitófagas en los generos *Frankliniella*, *Arorathrips*, *Haplothrips* y *Scirtothrips*, y los trips depredadores *Aeolothrips microstriatus* Hood, *Franklinothrips orizabensis* Johansen, *Karnyothrips texen-*

sis (Hood) y *K. flavipes* (Jones). *Frankliniella* fue el género dominante: *F. borinquen* Hood, el complejo *F. gossypiana* Hood/ *F. williamsi* Hood, *F. cephalica* (Crawford), *F. gardeniae* Moulton, *F. invasor* Sakimura y *F. parvula* Hood. También fue recolectada una nueva especie de *Frankliniella*. *F. invasor* fue la especie más abundante a lo largo del ciclo de floración en ambas huertas con una media de 613 individuos por inflorescencia. La huerta en donde fueron asperjados rutinariamente insecticidas sintéticos de amplio espectro tuvieron un número de trips estadísticamente similar ($P > 0.05$) con respecto a la otra huerta en donde no fueron asperjados insecticidas. Estos resultados indican que el uso insecticidas sintéticos de amplio espectro no está siendo efectivo para el control de trips y es necesario el uso de otros métodos de control.

Mango (*Mangifera indica* L.) is an economically important species of the family Anacardiaceae. This ancient fruit from the Indo-Burma region has become, after banana, the most important tropical fruit worldwide (Rehm & Espig 1991; Mukherjee & Litz 2009). Mango is commercially cultivated in over 95 countries in tropical and subtropical agroecosystems where it is adapted. This species was introduced into Mexico before 1779 from the Philippines (Purseglove 1972) and it has been intensively cultivated since then. With approximately 185,000 hectares planted, Mexico is typically the fourth largest producer. The international trade of mangoes is dominated by India and Mexico, the biggest exporters worldwide (Evans 2008).

There are more than a thousand cultivars (=varieties) of mango (Mukherjee 1953), from which only around 30 are commercially important and dominate mango plantations worldwide (Galán-Saúco 2009). Mango genotypes are typically divided into two distinct categories: monoembryonic mangoes, which are mostly subtropical (Indian types) and polyembryonic mangos, which are mostly tropical (Southeast Asian types). The fruit skin of Indian types is usually red with a seed that contains a single sexual embryo, and a single plant grows from the seed. Fruits of Asian types are usually yellow. The seed contains several embryos, but only one embryo is zygotic in origin; and three to eight seedlings originate from a single seed (Ram & Litz 2009). Ataulfo is a polyembrionic, yellow cultivar, perhaps the most popular mango from Mexico. It was discovered serendipitously, growing freely in Tapachula, Chiapas, at the end of the 1950's (Magallanes-Cedeño 2004; Infante et al. 2011). Due to its wide acceptance in local and international markets, the popularity of this cultivar has increased rapidly in the last few years, and it currently is produced throughout Mexico, Spain, and in many other countries in Central and South America (Infante et al. 2011).

Ataulfo mango is considered the best agricultural option for farmers along the Pacific Coast; namely, the Soconusco region (Gehrke 2008). At present, there are about 18,000 ha planted (Magallanes-Cedeño 2004). More than 322 species of insects and mites have been recorded as pests of mango (Peña et al. 2009). The *Anastrepha* (Tephritidae) fruit fly complex was considered the single insect-related threat of commercial orchards in the Chiapas State of Mexico. More recently, a complex of thrips has drawn the attention of growers because they appear in large numbers during mango flowering. This increase in the number of thrips is associated with a decline of mango fruit establishment, quality, and yield. Average marketable mango yields in the region have decreased gradually from 15 to 4 tons per hectare between 1980 and 2005 (Gehrke 2008).

Species of Thysanoptera are opportunistic in their way of life (Mound & Teulon 1995). Many of the 5,500 described species are phytophagous, but scarcely 1% is recorded as pests (Morse & Hoddle 2006). Several species of thrips are important pests of mango orchards in Florida, the Caribbean, Central and South America, and Asia (Peña et al. 1998; Galán-Saúco 2009; Aliakbarpour et al. 2010). Thrips in the genus *Frankliniella* damage a great variety of crops (Northfield et al. 2008), including mango, where they feed and reproduce on flowers (Galán-Saúco 2009). Little information is available about the diversity of thrips species found in 'Ataulfo' mango flowers in Chiapas. Preliminary studies have identified *Frankliniella invasor* Sakimura, *F. parvula* Hood, and *F. cephalica* (Crawford) (Thysanoptera: Thripidae) as 3 of the species inhabiting mango inflorescences (Johansen 2002; Santiesteban-Hernández et al. 2011). Numerous growers believe that large numbers of thrips in mango inflorescences cause damage, and insecticides are sprayed on a regular schedule during flowering. The pest status of the individual thrips species has not been determined for mango, and economic thresholds have not been established. Therefore, the benefits of thrips control with insecticides are unknown. Because thrips management should be based on accurate estimates of pest populations, the present study was conducted to determine the complex of thrips species present in 'Ataulfo' mango inflorescences as a first step in rectifying the information shortfalls. The study was conducted in 2 orchards with different agrochemical management: one of them with intensive use of pesticides and the other without insecticide spraying.

Materials and Methods

Site Description

The Soconusco region of 5,776 km^2 is located in the southern Chiapas State, Mexico. Elevation ranges from 1 to 4,100 m asl. The original vegetation in the lowlands was an evergreen tropical forest that has been modified to grow annual crops and tropical fruits. Mangoes are grown in the areas where the weather is hot and humid, with the average temperatures varying from 23.°C to above 30 °C, and where the annual precipitation is about 2,500 mm with a typical rainy season of 8 to 9 mo (Richter 1993).

The research was conducted in 2 commercial orchards planted with 'Ataulfo' mango: "Tres-A" (N 14°48'14"; W 92°20'53"; 30 m asl) and "Rancho La Escondida" (N 14°39'21"; W 92°11'16"; 25 m asl). The orchard "Tres A" is characterized by an intensive use of agrochemicals, especially broad-spectrum synthetic insecticides directed against thrips; in contrast, the orchard "Rancho La Escondida" does not spray any insecticide. The trees in both orchards were 20 to 23 yr old and approximately 20 m in height. Distance among trees is about 15 m. Two hundred and twenty five trees (ca. 5 ha) were chosen and numbered with vinyl paint in each orchard for this study.

In the orchard "Tres A" synthetic insecticides were sprayed five times during the flowering cycle: deltamethrin 12.5 g a.i. ha^{-1} (Decis® 2.5 EC; Bayern CropScience), sprayed on 30 Nov 2008; dimethoate 300 g a.i. ha^{-1} (Aflix® EC; Bayern CropScience), sprayed on 5 and 15 Dec 2008; malathion 500 g a.i. ha^{-1} (Malation 1000® EC; Agroquimica Tridente, Mexico), sprayed on 4 Jan and 4 Feb 2009. Insecticides were applied directly to the panicles of mangoes using a tractor mounted Air-o-Fan air blast sprayer, delivering a spray at 300 L ha^{-1} .

Collection and Identification of Mango Thrips

Mango trees began flowering by the middle of Nov 2008 and ceased flowering by the end of Feb 2009. During this period, samples of flower thrips were collected in both orchards every 5 d. A total of 18 samples per site were taken. On each sample date in each orchard, 5 inflorescences from different trees were collected randomly about 4 m above the ground. Samples were collected between 08:00 and 10:00 Central Standard Time, and each inflorescence was placed in a labeled plastic bag. Samples were immediately taken to the laboratory and processed by rinsing the bag and contents in 70% ethyl alcohol. Thrips were separated into morphotypes using a stereomicroscope.

Thrips of each species were mounted on slides using either Canada balsam or Hoyer's medium. Before the mounting process, specimens were soaked in 5% NaOH and the internal contents were removed. The keys in Mound & Marullo (1996), Moritz et al. (2001), and Hoddle et al. (2008) were used in the identification of species. Further, each species was compared to specimens at the Systematic Entomology Laboratory, ARS, USDA, Beltsville Maryland and the U.S. National Museum, Washington, DC. Voucher specimens are located in the reference collections of 2 of the authors (AG & JF). The possibility that the *Scirtothrips* sp. in the mangoes of Mexico was a cryptic subspecies of *Scirtothrips citri* (Moulton) was evaluated by Deane Zahn and Richard Stouthamer at The University of California, Riverside using molecular analysis procedures described in Rugman-Jones et al. (2010).

The total number of thrips collected in each field was compared using a general linear model (PROC GLM procedure, SAS Institute 2008). Date was treated as a factor to remove variation among dates, with the 5 samples of inflorescences treated as subsamples. The date × field interaction served as the error term. Data was log10-transformed to correct for non-normality and unstable variances. A value of $P < 0.05$ was considered significant.

Results

Identity of Ataulfo Mango Flowers Thrips

Fifteen species of thrips were collected from 'Ataulfo' mango inflorescences (Table 1). The species *Aeolothrips microstriatus* Hood, *Franklinothrips orizabensis* Johansen, *Karnyothrips flavipes* (Jones), and *K. texensis* Hood are predators of small arthropods, including other species of thrips. Phytophagous species were comprised of: *Arorathrips mexicanus* (Crawford), *Frankliniella borinquen* Hood, *F. gossypiana/williamsi* Hood complex, *F. cephalica* (Crawford), *F. gardeniae* Hood, *F. invasor* Sakimura, *F. parvula* Hood, and *Haplothrips gowdeyi* (Franklin). A species morphologically similar to *S. citri* was also collected. Molecular methods based on DNA sequence data revealed that it is a distinct species different from *S. citri* (D. Zahn & R. Stouthamer; personal communication). An undescribed species of *Frankliniella* also was collected (T. Skarlinsky & J. Funderburk, unpublished data). Each of the above species was collected in both orchards, except *F. orizabensis*, which was not collected in the orchard "Tres A".

Population Fluctuation of Thrips

A total of 75,483 thrips were collected in the "Rancho La Escondida" orchard comprised of 79.8% larvae and 20.2% adults. *Frankliniella invasor* was the most common species with 11,573 (75.9%) adult

Table 1. Species of thrips collected from 'Ataulfo' mango flowers in Chiapas State of Mexico.

Order	Suborder	Family	Species
Thysanoptera	Terebrantia	Aeolothripidae	*Aeolothrips microstriatus* Hood *Franklinothrips orizabensis* Johansen
		Thripidae	*Arorathrips mexicanus* (Crawford) *Frankliniella borinquen* Hood *Frankliniella cephalica* (Crawford) *Frankliniella gardeniae* Moulton *Frankliniella gossypiana* Hood *Frankliniella invasor* Sakimura *Frankliniella parvula* Hood *Frankliniella williamsi* Hood *Frankliniella* sp. n *Scirtothrips* sp.
	Tubulifera	Phlaeothripidae	*Haplothrips gowdeyi* (Franklin) *Karnyothrips flavipes (*Jones) *Karnyothrips texensis* Hood

thrips captured, followed by *F. parvula* with 692 (4.5%) adults. Similar results were found in the orchard "Tres A". A total 77,866 individuals were collected: 89.6% larvae and 10.4% adults. *Frankliniella invasor* was the dominant species with 5,106 (63.2%) adults, followed by *F. parvula* with 1,351 (16.7%) adults. It is important to point out that species identification was only possible with the adults, because there are no reliable taxonomic keys for the larvae (Mound & Marullo 1996).

Total numbers of thrips were not significantly different between orchards (F = 1.1; df = 1,17; P = 0.31). The average of thrips over all sample dates in the "Rancho La Escondida" orchard was 834 total thrips per inflorescence. During the first mo, there was a gradual increase in the total number of thrips from 70 per inflorescence on the first sample date to 3,169 thrips on the seventh sample date. Populations decreased afterwards. There were 867 total thrips per inflorescence as an average over all sample dates in the orchard 'Tres A'. Populations increased from 151 thrips per inflorescence on the first sample date to 2,454 thrips per inflorescence on the sixth sample date. The spraying of broad spectrum synthetic insecticides in the "Tres A" orchard apparently did not reduce the total number of thrips. Dimethoate was sprayed after the third sample date. The number of thrips per inflorescence increased from 397 on the third sample date to 1,160 total thrips per inflorescence on the fourth sample date. The same product was sprayed after the fifth sample date and the total number of thrips increased from 1,038 per inflorescence on the fifth sample date to 2,454 per inflorescence on the sixth sample date. Similarly, the total number of thrips increased from 358 per inflorescence on the fifteenth sample date to 1,999 per inflorescence on the sixteenth sample date, following the application of malathion (Fig. 1).

Over 98% of the species of adult thrips collected belong to the genus *Frankliniella*. The adult population abundance of *F. invasor* and *F. parvula* is presented in Fig. 2. The highest abundance of these species in the "Rancho La Escondida" orchard was on the seventh sample date with 613 and 37 adults for *F. invasor* and *F. parvula* per inflorescence, respectively. In "Tres A" *F. invasor* was most abundant on the sixth sampling with 200 adults per inflorescence, while *F. parvula* was most abundant on the seventh sample date with 82 adults per inflorescence.

Discussion

This is the first comprehensive study of the thrips species inhabiting 'Ataulfo' mango flowers. Some of the species of the thrips we collected; namely, *F. bruneri*, *F. cephalica*, *F. invasor* and *F. parvula*, had been previously recorded for mango in Mexico (Johansen 2002). Johansen (2002) also reported that he collected *F. cubensis* Hood from mango. The undescribed species of *Frankliniella* that we collected from mango flowers is very similar morphologically to *F. cubensis*, but it is an undescribed species (Tom Skarlinsky and Joe Funderburk, unpublished). The species of thrips reported for mangoes in other parts of the world are rather diverse. For instance, Grove et al. (2000) reported *Thrips tenellus* Trybom as the dominant species in orchards in South Africa. The species *Thrips hawaiiensis* (Morgan), *Scirtothrips dorsalis* (Hood), *Frankliniella schultzei* (Trybom), and *Megalurothrips usitatus* (Bagnall) were the most common thrips in orchards in Malaysia (Aliakbarpour et al. 2010; Aliakbarpour & Che-Salmah 2011). As far as we know, the species *A. microstriatus*, *F. orizabensis*, *C. simplex*, *F. borinquen*, *F. gardeniae*, *H. gowdeyi*, *K. texensis* and *K. flavipes* are new records of thrips found in mango flowers.

According to Sakimura (1972), the dominant species in this study, *F. invasor*, is native to the

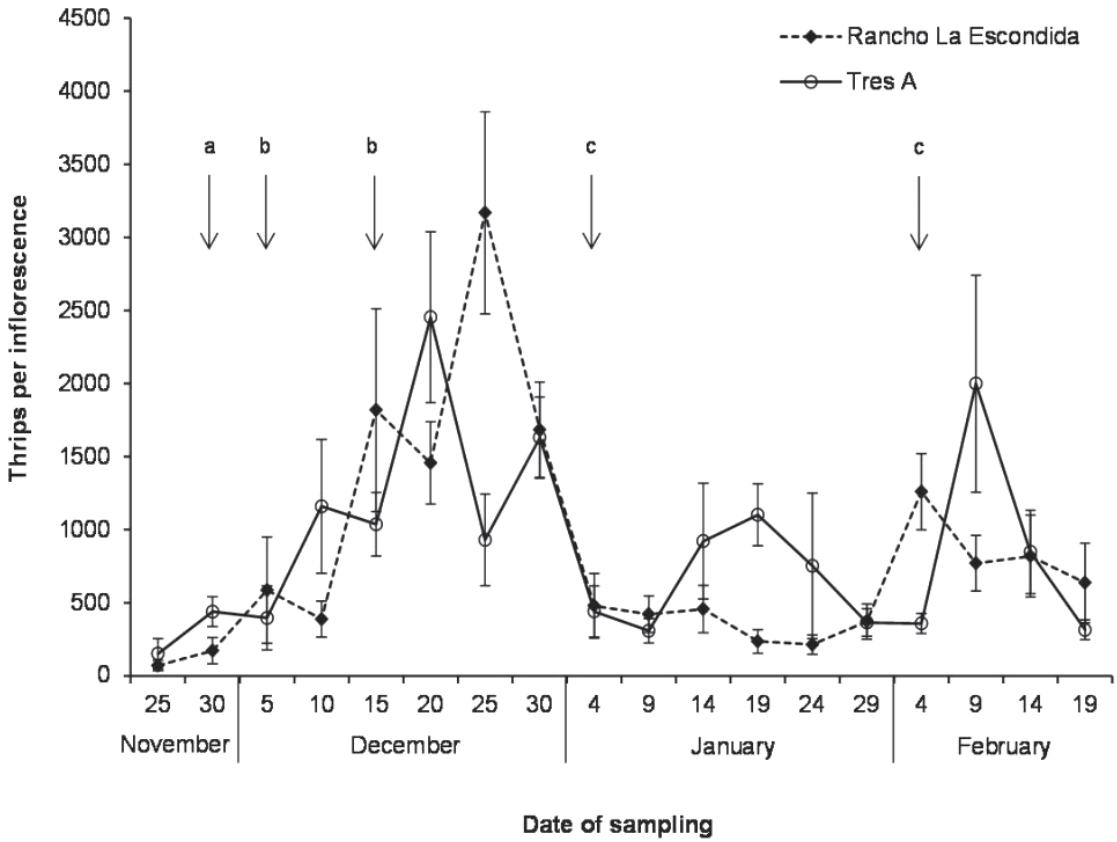

Fig 1. Number of thrips larvae and adults of all species per inflorescence (mean ± SEM, $n = 5$) inhabiting Ataulfo mango flowers on 18 sample dates in 2 orchards of Chiapas State, Mexico. Arrows indicate the dates on which insecticides were sprayed in the orchard "Tres-A": (a) deltamethrin, (b) dimethoate and (c) malathion. No insecticides were applied in the "Rancho La Escondida" orchard.

Caribbean-Central American region, and it was first reported feeding on mango in Hawaii. This opportunistic species is a general flower feeder, commonly found on plants, such as *Allophylus occidentalis*, *Casearia corymbosa*, *Citrus sinensis*, *Coffea arabica*, *Daturia sanguinea*, *Gardenia jasminoides*, *Lawsonia alba*, *Leucaena glauca*, *Mangifera indica*, *Musa* sp, *Persea americana*, *Psidium guajava*, *Psidium molle*, *Pseudobombax* sp., *Rosa centifolia*, *Rubus fruticosus* and *Schwartzia simplex* (Sakimura 1972; Mound & Marullo 1996; Johansen 2002; Cambero-Campos et al. 2009). On the other hand, *F. parvula* has been recorded from *Bixa Orellana*, *Eugenia braziliensis*, *Mangifera indica*, *Mussa* sp. and *Theobroma cacao* (Johansen 1974; Mound & Marullo 1996; Johansen 2002). The presence of *F. parvula* in 'Ataulfo' mango in this study might be related to the fact that plantations of banana (*Musa*), a highly preferred host, were near our mango orchards. *Frankliniella cephalica* and *F. cubensis* have been recorded earlier from Morelos, Mexico, infesting mango flowers (Sánchez et al. 2001). In fact, *F. cephalica* is known to be one of the most ubiquitous flower-living species. The species has been recorded form a wide range of plant species throughout the Caribbean Islands, Florida, and Central America (Brogdon 1955; Mound & Marullo 1996; Viteri et al. 2010).

Species compositions of thrips were similar in the 2 orchards sampled in this study. Prepupal and pupal stages were barely found in the flowers and apparently most of species in mango in this study have an edaphic phase, which is characteristic of species of Thysanoptera (Morse & Hoddle 2006).

Thrips populations fluctuate seasonally, presumably in reaction to environmental factors, such as food availability and climatic factors (Lewis 1973). It has been mentioned that peaks of pollen are often followed by peaks of thrips, since many species are attracted to and feed on open flowers bearing abundant pollen (Yudin et al. 1988). In several systems pollen production is re-

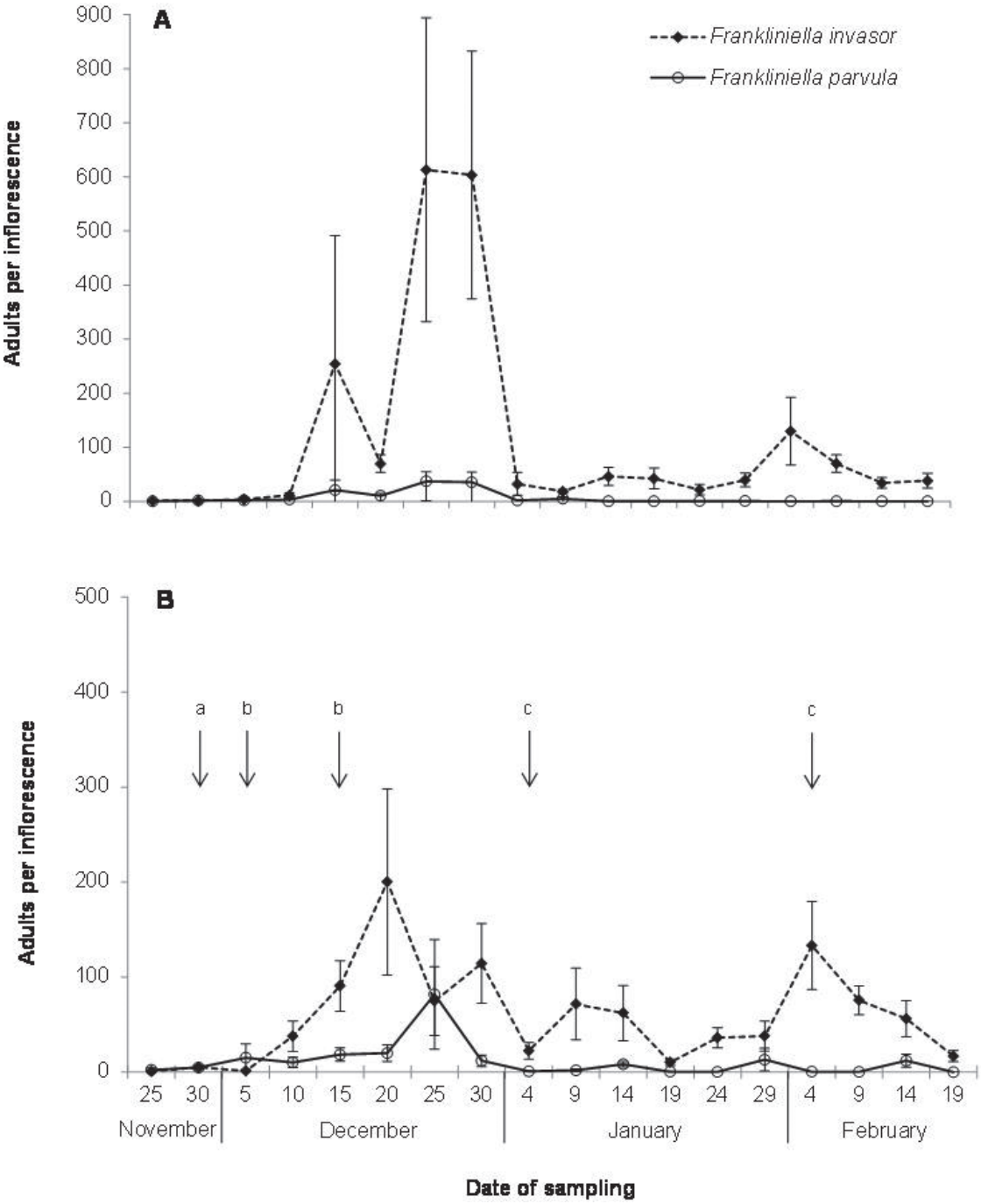

Fig 2. Number of *Frankliniella invasor* and *Frankliniella parvula* adults per inflorescence (mean ± SEM, $n = 5$) on 18 sample dates in 2 Ataulfo mango orchards in the Chiapas State of Mexico. (A) No insecticides were sprayed in the "Rancho La Escondida" orchard and (B) "Tres A" received five sprays of insecticides against thrips. Arrows indicate the dates on which insecticides were sprayed: (a) deltamethrin, (b) dimethoate and (c) malathion.

sponsible for increasing the level of *Frankliniella* thrips (Chyzik et al. 1995; Riley et al. 2011). 'Atualfo' mango trees in the Soconusco region of the Chiapas State in Mexico are successively producing flowers from Nov to Feb, when large amounts of mango pollen are available in the field. Fun-

derburk et al. (2002) stated that population fluctuations of flower thrips are a function of flower density. Similarly, large numbers of opportunistic species of thrips, i.e., *Frankliniella* spp. occurred during 'Ataulfo' mango flowering.

An important contribution of this study was to document the large numbers of thrips that are present in Ataulfo mango in Chiapas, especially *F. invasor* and *F. parvula* populations. The peak number of *F. invasor* adults was over 600 hundred individuals per inflorescence, and it is probable that most of the thrips larvae found in the seventh sampling belong to this species. As far as we know, there are no reports of such large numbers of thrips reported for mango in any part of the world. Our results suggest that thrips in such large numbers may be responsible, at least in part, for declines observed in marketable yields of mango in Chiapas; and studies are needed to better understand the pest status of thrips in mango.

'Ataulfo' mango inflorescences bear an average 3,552 flowers, of which 22% are hermaphrodite and 78% are masculine (unpublished data). Because less than 1% of flowers reach maturity under normal conditions (Nunez-Elisea & Davenport 1983), we assume that flower loss due to thrips injury needs to be great before damage occurs. However, no economic threshold has been estimated, and insecticides are being sprayed on a regular basis instead. Vázquez (1999) mentioned that spraying insecticides against thrips in the Soconusco region has a cost of circa 2 million US dollars per yr. Surprisingly, after 5 applications of insecticides in orchard "Tres A", there was not a detectable reduction in the overall thrips population with respect to "Rancho la Escondida." This observation indicates that the attempt to control thrips with broad-spectrum insecticides is not effective. Studies are needed to evaluate the available insecticides for control of thrips in mango. Dimethoate and deltamethrin, two commonly used insecticides, have a severe impact on natural enemies of thrips (Croft & Brown 1975; Congdon & Tanigoshi 1983; Bellows et al. 1985; Funderburk 2009), and we know that anthocorids are important predators of thrips in mango (unpublished data). So, conservation biological control programs also show potential for preventing damage.

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