Host Specificity Evaluation for Gynaikothrips uzeli (Thysanoptera: Phlaeothripidae) on Ornamental Ficus (Rosales: Moraceae)

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Host specificity evaluation for *Gynaikothrips uzeli* (Thysanoptera: Phlaeothripidae) on ornamental *Ficus* (Rosales: Moraceae)

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Abstract

The weeping fig thrips *Gynaikothrips uzeli* Zimmerman (Thysanoptera: Phlaeothripidae) is an invasive pest that is being spread via shipments of ornamental *Ficus* (Rosales: Moraceae). We tested 50 *Ficus* cultivars from 12 species for their suitability as hosts for *G. uzeli* under greenhouse conditions. Results showed that *G. uzeli* reproduced well only on *F. benjamina* L.; other species were much less suitable. Plants of *F. benjamina* sustained folded leaf galls in new growth within 2 to 3 d of being exposed to adult thrips. In subsequent tests, we noted some differences among 27 *F. benjamina* cultivars in terms of the degree of infestation (number of leaves galled) and reproductive output of *G. uzeli* over 1 to 2 generations. Plant variegation did neither affect the number of galled leaves nor the number of thrips recovered in our studies. Our results suggest that genetic variation exists among *F. benjamina* cultivars in resistance to *G. uzeli* infestation. Additionally, *Ficus* species other than *F. benjamina* may be substituted in cases where *G. uzeli* is potentially troublesome.

Key Words: *Gynaikothrips ficorum*; *Ficus benjamina*; *Ficus microcarpa*; leaf gall

Resumen

El thrips formador de agallas, *Gynaikothrips uzeli* Zimmerman (Thysanoptera: Phlaeothripidae) es una especie invasiva que ha empezado a dispersarse en envíos de *Ficus* (Rosales: Moraceae) ornamentales. Nosotros evaluamos la capacidad como plantas hospederas de *G. uzeli* en 50 cultivares de 12 especies de *Ficus* bajo condiciones de invernadero. Los resultados indicaron que *G. uzeli* se reprodujo bien solamente en *F. benjamina*; otras especies fueron menos adecuadas. Plantas de *F. benjamina* presentaron hojas plegadas con agallas en los nuevos brotes de crecimientos 2–3 días después de haberse expuesta a los adultos de thrips. En las posteriores evaluaciones, nosotros notamos algunas diferencias entre 27 cultivares de *F. benjamina* en términos del grado de infestación (número de hojas con agallas) y reproducción de *G. uzeli* durante 1–2 generaciones. Las plantas variegadas no afectaron el número de hojas con agallas tampoco el número de thrips recuperado en nuestros estudios. Nuestros resultados sugieren que existe variación genética entre cultivares de *F. benjamina* en relación con la resistencia a la infestación por *G. uzeli*. Adicionalmente, especies de *Ficus* diferentes a *F. benjamina* pueden ser sustituidas en casos en donde *G. uzeli* es potencialmente problemático.

Palabras Clave: *Gynaikothrips ficorum*; *Ficus benjamina*; *Ficus microcarpa*; hojas con agallas

Gynaikothrips (Thysanoptera: Phlaeothripidae) comprises approximately 40 species of dark brown to black thrips that originate in Southeast Asia and that induce galls on developing leaf tissues of *Ficus* species (Rosales: Moraceae) (Dang et al. 2014). These galls cause aesthetic impacts to ornamental *Ficus*, although they are otherwise not harmful, and provide habitat for other arthropods (inquilines), including natural enemies of *Gynaikothrips* (Mound & Morris 2005; Tree & Walter 2009). In recent years, *Gynaikothrips* species have colonized Asia, Africa, and Central America, probably through international trade in *Ficus* plants. For example, the weeping fig thrips *G. uzeli* Zimmerman was discovered in the United States in Florida in 2003 and spread rapidly throughout the southeastern states via shipments of ornamental weeping fig (*F. benjamina* L.) originating from nurseries in southern Florida (Held et al. 2005). This pest has since been reported from at least 10 states in the contiguous United States, as well as Hawaii and Puerto Rico (Cabrera-Asencio et al. 2008; Held & Boyd 2008a; Dara & Hodel 2015), and from Brazil (Cavalleri et al. 2011), Australia (Tree 2012), India (Tyagi 2012), Panama (Goldarazena et al. 2012), and Syria (Ali 2014).

Weeping fig thrips is very similar to the earlier-described Cuban laurel thrips, *G. ficorum* Marchal, which has been known from the continental United States since at least 1887 (Denmark 1967). The only known difference between *G. uzeli* and *G. ficorum* is the length of the pronotal setae (Mound et al. 1995). However, these species are associated with different hosts. Whereas *G. uzeli* is known to infest *F. benjamina*, *G. ficorum* is primarily associated with Chinese Banyan, *F. microcarpa* L.f., and has established a pantropical distribution wherever this plant occurs (Mound et al. 1995; ThripsWiki 2015).

Although host plant is thought to be a good indicator to differentiate *G. uzeli* and *G. ficorum*, identification of *Ficus* species by entomologists may not be entirely reliable. A recent study reported that *G. ficorum* was able to produce leaf galls on both *F. benjamina* and *F. microcarpa* under greenhouse conditions, whereas *G. uzeli* was able to induce galls only on *F. benjamina* (Tree et al. 2015). However, the ability of *G. uzeli* to feed upon or reproduce on other *Ficus* species is unclear. Furthermore, preferences of *G. uzeli* among cultivars of *F. benjamina* have not been reported. We therefore conducted host specificity tests of *G. uzeli* among various *Ficus* species and on various cultivars of *F. benjamina*.

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Materials and Methods

THRIPS AND PLANTS

All experiments were conducted in research greenhouses at the Mid-Florida Research and Education Center, Apopka, Florida. Fifty cultivars of *Ficus* from 12 species were collected and maintained in a germplasm conservation greenhouse (Fang et al. 2007) and propagated through stem cutting. Propagated plants were grown as stocks in pots (11.4 L) with a sphagnum peat-sand based substrate and fertilized periodically with 10 g of controlled-release granules (15-9-12 Osmocote Plus, the Scotts Co., Marysville, Ohio) per pot. Thrips (*G. uzeli*) were collected from natural infestations on *F. benjamina* 'Midnight' and used to start a colony that was cultured in a separate greenhouse on the same cultivar.

EVALUATION OF *FICUS* SPECIES

The 50 cultivars were tested in the 1st experiment for their suitability as hosts for *G. uzeli* under greenhouse conditions. Cuttings were made from stock plants, and rooted cuttings were transplanted into 10 cm diameter pots fertilized with 15-7-15 (Multicote 8 at 3 g per pot + 1.2 mg minors). Plants were approximately 6 mo old (post transplanting) and 30 cm tall when used. Plants were placed individually in cages, and each cage also had *F. benjamina* 'Midnight' as a known positive (susceptible) control. There were 3 replicates per cultivar. Cages were maintained under greenhouse conditions. Five adults thrips removed from the colony were placed in each cage. Cages were examined after 3 d and again after 60 d, when approximately 2 generations of thrips may have occurred. All cultivars with leaf galls containing reproducing populations of *G. uzeli* were noted.

EVALUATION OF *F. BENJAMINA* CULTIVARS

Because *F. benjamina* was clearly the most susceptible species to *G. uzeli*, we conducted 2 further choice tests to more thoroughly evaluate various cultivars of *F. benjamina* to determine their relative susceptibility to this insect under greenhouse conditions. Some cultivars were variegated with yellow or pale green coloration. Rooted cuttings were transplanted as before, when new growth suitable for galling behavior of *G. uzeli* was available.

A choice study was conducted to evaluate feeding preferences among 23 cultivars. Four plants of each cultivar in 15 cm diameter pots were similarly pruned and placed in a randomized block design inside a greenhouse bay in late summer (Aug). Two hundred *G. uzeli* adults were added to the center of the greenhouse bay on 3 occasions (after 22, 29, and 36 d) when new growth was appearing on plants. Plants were about 40 cm tall at this time. The number of thrips-galled leaves was counted from test plants on 3 subsequent occasions (days 52, 69, and 92 after the initial infestation). The numbers of thrips were evaluated at the end of the study by collecting plant terminals and extracting thrips in the laboratory in 70% ethanol and counting life stages under a binocular microscope.

A 2nd study was conducted the following year to evaluate feeding preferences among 27 cultivars. Young plants (2 mo old in 10 cm diameter pots) were pruned to 15 cm prior to tests and used when approximately 3 new leaves were available. A single plant of each variety was placed in a random order in a nylon mesh cage (60 × 60 × 60 cm), and 100 adults of *G. uzeli* were added in a vial in the center of the cage and allowed to distribute naturally (Fig. 1). The study was conducted (replicated) on 3 separate occasions, based on the availability of plants. In each case, the number of leaf galls per plant was counted at 2, 4, and 6 wk after infestation. Thrips were counted at the final assessment by placing galled leaves in 70% ethanol and by extracting thrips in the laboratory.

DATA ANALYSES

Plant injury (galled leaves) and the number of thrips recovered in the tests were compared among all cultivars with 1-way ANOVA, with means separated via Tukey's HSD test following a log($n + 1$) transformation to control for data normality. The same response variables were similarly compared between cultivars that exhibited variegation and those that did not.

Results

EVALUATION OF *FICUS* SPECIES

Gynaikothrips uzeli was recovered from all 27 cultivars of *F. benjamina* in these tests, but was not generally recovered from other *Ficus* species (Table 1). The first leaf galls were observed with 3 d of introduction of thrips. Of the 454 leaf galls counted at day 60, we noted only a single leaf gall on an *F. carica* L. and *F. neriifolia* Smith plant, but we did not confirm that thrips were able to complete their reproduction on these species.

EVALUATION OF *F. BENJAMINA* CULTIVARS

In the 1st study, leaf galls were observed on 22 of the 23 *F. benjamina* cultivars tested; only the variegated 'Dwarf Nina' did not become infested in this test. The proportion of galled leaves increased over time, reaching more than 30 leaves per plant for some varieties and with >1,000 thrips recovered (Table 2). Overall, the majority (about 60%) of recovered thrips were larvae. The infestation degree (at the end of the study) varied among cultivars in terms of both the number of galled leaves ($F_{22,69}$ = 10.5; P < 0.001) and the number of thrips recovered ($F_{22,69}$ = 8.8; P < 0.001). Plant variegation did not affect the number of galled leaves ($F_{1,90}$ = 1.4; P = 0.25) or the number of thrips recovered ($F_{1,90}$ = 1.6; P = 0.21).

In the 2nd study, leaf galls were recovered from 26 of the 27 varieties of *F. benjamina*; only 'Midnight Princess' did not become infested (Table 3). However, compared with the previous study, the number of leaf galls was relatively low (average of 1.4 per plant at week 6) and neither the overall injury level at the end of the study ($F_{26,54}$ = 0.58; P = 0.94) nor the total number of thrips recovered from plant extractions at week 6 ($F_{26,54}$ = 0.6; P = 0.92) varied among cultivars. Plant variegation affected neither the number of galled leaves ($F_{1,79}$ = 0.12; P = 0.70) nor the number of thrips recovered ($F_{1,79}$ = 0.24, P = 0.63).

Discussion

There is little information concerning host preference of *G. uzeli* on *Ficus* species. Our studies documented the apparent host specificity of *G. uzeli* for *F. benjamina* when exposed to young plants under greenhouse conditions in central Florida. As reported earlier (Tree et al. 2015), we found that *G. uzeli* was unable to reproduce on *F. microcarpa*; however, we extended this observation to several other *Ficus* species. Although it appeared that adult thrips can feed sporadically on other *Ficus* species, they did not induce galling or lay eggs. There is a report of *G. uzeli* infesting tomato in India, although no reproduction was observed (Chavan et al. 2014).

Fig 1. Cage setup for *Ficus benjamina* variety choice test with *Gynaikothrips uzeli* in the greenhouse (year 2).

We also documented some differences among cultivars of *F. benjamina*. In general, all cultivars appeared to be susceptible; however, we noted differences in the 2nd study, with some varieties such as 'Profit Compacta' and 'Dwarf Nina' having fewer thrips than others. A possible explanation is that genetic variation in resistance to *G. uzeli* infestation exists among cultivated *F. benjamina* (Fang et al. 2007), particularly for those adapted to Florida environmental conditions, such as 'Dwarf Nina', 'Pandora', 'Profit Compacta', and 'Silver Cloud'. The use of more pest resistant cultivars in production may reduce economic loss in *Ficus* production. Differences also may have reflected host plant growth, because the generation of new leaves available for galling was not always consistent among species or cultivars. We noted lower overall density of thrips in the final study, which may have affected their dispersal and host selection behavior.

Our studies confirmed the inability of *G. uzeli* to initiate galls in fully expanded leaves; only leaves under differentiation could be induced to gall. We noted that adult thrips selected young expanding leaves, apparently causing rapid cell differentiation on the upper surface, and causing the leaf to fold along the mid-vein and purplish spots to develop inside the gall within 2 to 3 d. Females deposited white cylindrical eggs in batches of 100 or more, and a generation of thrips developed inside each gall over approximately 4 wk. We observed that the galls were relatively persistent and did not immediately fall off plants once the new generation of thrips had departed. Galls made by *G. uzeli* can be inhabited by inquilines, including other members of the Phlaeothripidae, as well as mealybugs, scales, whiteflies, and various natural enemies (Mound et al. 1995; Held et al. 2005).

Ficus benjamina and *F. microcarpa* are among the most widely cultivated ornamental figs (Fang et al. 2007). The 'leaf-fold' galls made by *G. uzeli* in *F. benjamina* contrast the 'leaf-roll' galls made by *G. ficorum* in *F. microcarpa* (Mound et al. 1995). However, the ability of *G. ficorum* to induce leaf galls on *F. benjamina* (Tree et al. 2015) suggests the possibility for inter-specific competition in areas where both thrips species are sympatric. The fact that *G. ficorum* is rarely reported from *F. benjamina* in the field suggests that *G. uzeli* might be a superior competitor on this host, although this remains to be confirmed experimentally.

Due to its cryptic habitat, control of *G. uzeli* with contact insecticides is not effective (Held & Boyd 2008b). In established landscapes, natural enemies can prevent large outbreaks of this pest. In southern Florida, the predatory pirate bug *Montandoniola confusa* Streito and Matocq (Hemiptera: Anthocoridae) is an effective predator (Arthurs et al. 2011). Desiccated (fed upon) eggs inside old leaf galls are the most common sign of *M. confusa* activity in the landscape (authors' personal observations). Other natural enemies of *G. uzeli* include the predatory thrips *Liothrips takahashii* Moulton (Tree et al. 2015) and *Androthrips ramachandrai* Karny (de Melo et al. 2013) (Thysanoptera: Phlaeo-

Table 1. Species and cultivars of *Ficus* in which leaf galls initiated by *Gynaikothrips uzeli* were recovered (+) at 3 and 60 d post infestation under greenhouse conditions.

Species	Cultivar	3 d	60 d ([b])
F. benjamina L.	Spearmint[a]	+	+ (2)
	Snow White[a]	+	+ (5)
	Common	+	+ (15)
	Kiki	—	+ (1)
	Florida Spire	—	+ (2)
	Variegata (Jacobson's) [a]	—	+ (16)
	Nightingale[a]	—	+ (10
	Little Denmark	—	+ (13)
	Little Gold Angel[a]	—	+ (34)
	Mini Lucie Ficus	—	+ (23)
	Silver Cloud[a]	—	+ (24)
	Pandora	+	+ (13)
	Starlight (Fantasia) [a]	—	+ (12)
	Nicole[a]	—	+ (24)
	Profit Compacta[a]	—	+ (9)
	Dwarf Nina[a]	—	+ (7)
	Ninet Blue Dwarf[a]	—	+ (7)
	Stacey	+	+ (36)
	Nikki ExoticAngel[a]	+	+ (23)
	Tropical Rainforest	—	+ (22)
	Midnight Cut (cuttings)	—	+ (22)
	Midnight TC (tissue culture)	—	+ (15)
	Midnight Princess	+	+ (16)
	Monique	+	+ (41)
	Wintergreen	—	+ (23)
	Indigo	—	+ (17)
	Unknown variegated #1	+	+ (3)
	Unknown variegated #2	+	+ (18)
F. altissima Blume (council tree)	Variegata[a]	—	—
F. binnendijkii Miq. (Long leaved fig)	Amstel King	—	—
	Alii	—	—
F. carica L. (common fig)	Brown Turkey Fig	—	+ (1)
F. deltoidea Jack (mistletoe fig)		—	—
F. elastica Roxb. ex Hornem (rubber fig)	Robusta Tineke[a]	—	—
	Burgundy Rubber Plant	—	—
	Dercose[a]	—	—
	Melany	—	—
	Cabernet	—	—
F. lyrata Warb. (fiddle-leaf fig)	Little Fiddle ExoticAngel	—	—
	Little Fiddler AgroStarts#2	—	—
	Fiddle leaf fig	—	—
F. microcarpa L.f. (Chinese banyan)	Ginseng	—	—
	Kay	—	—
F. neriifolia Sm.		—	+ (1)
F. pumila L. (creeping fig)	Arina	—	—
	Curly[a]	—	—
	Sunny[a]	—	—
	Sunny Jensen[a]	—	—
	Pumila	—	—
F. sagittata Vahl.	Silverleaf	—	—
F. subulata Blume	Narrow leaf	—	—

[a]Variegated.
[b]Number of leaf galls per cage.

thripidae), as well as generalist predators including green lacewings and spiders, and at least 2 eulophid parasitoid species that specialize on phlaeothripine thrips (LaSalle 1994; Held et al. 2005). Preserving the activity of these natural enemies will help reduce the need for insecticides.

In conclusion, this study provides new information on the host selection of *G. uzeli*. It appears that this species can complete its life cycle only on *F. benjamina*, not on other *Ficus* species. Among the 27 *F. benjamina* cultivars tested, variation existed in response to *G. uzeli* infestation. The recent (2014) detection of this pest in Los Angeles

Table 2. Mean numbers of curled leaves observed at 3 points in time and numbers of adult and larval *Gynaikothrips uzeli* thrips at the end of the study for 23 *Ficus benjamina* cultivars (year 1).

	No. of curled leaves per plant[b]				Final thrips count/plant[b]		
Cultivar[a]	52 d	69 d	92 d	Tukey's	Adult	Larvae	Tukey's
Kiki	0.0	3.5	7.5	abcdef	25.8	38.8	abcdef
Florida Spire	0.5	1.0	38.0	a	116.0	145.0	abc
Spearmint[a]	0.8	7.0	26.5	abc	618.5	1062.5	a
Snow White[a]	0.3	16.0	31.8	ab	496.5	756.8	ab
Common	4.3	6.5	12.0	abcde	159.5	136.0	abc
Variegata (Jacobson's)[a]	0.3	2.5	21.8	abc	134.5	460.0	abc
Nightingale[a]	0.0	5.0	11.8	abcd	21.8	47.8	abcdef
Little Denmark	0.8	7.8	20.8	abc	115.3	283.5	abc
Little Gold Angel[a]	0.3	3.8	6.8	abcdef	97.5	79.8	abcd
Mini Lucie Ficus	0.0	2.8	10.0	abcdef	28.8	36.0	abcdef
Silver Cloud[a]	0.0	1.0	0.8	efg	0.8	0.3	ef
Pandora	0.0	1.8	2.5	defg	4.0	6.5	def
Starlight (Fantasia)[a]	0.0	0.5	0.8	efg	21.8	1.5	def
Nicole[a]	0.3	0.3	5.8	cdefg	13.8	29.8	cdef
Profit Compacta[a]	0.0	0.3	0.3	fg	1.0	0.3	ef
Dwarf Nina[a]	0.0	0.0	0.0	g	0.0	0.0	f
Midnight Cut (cuttings)	1.3	1.8	6.0	bcdefg	74.3	16.5	bcdef
Midnight TC (tissue culture)	0.8	2.0	2.5	defg	93.0	29.8	abcdef
Midnight Princess	0.5	0.8	3.3	defg	42.5	16.0	cdef
Monique	0.8	1.8	9.0	abcdef	59.5	48.0	abcde
Indigo	0.8	1.3	2.0	defg	11.8	11.3	cdef
Wintergreen	1.5	2.0	2.3	defg	65.8	17.0	bcdef
Unknown variegated[a]	0.0	0.3	0.3	fg	0.3	0.0	f

[a]Variegated.
[b]Data are average of 4 plants per cultivar; means followed by the same letter are not significantly different by Tukey's HSD at $P < 0.05$ level; comparisons were for no. of curled leaves and total thrips life stages per plant on day 92.

Table 3. Mean numbers of curled leaves observed at 3 points in time and numbers of *Gynaikothrips uzeli* life stages at the end of the study for 27 *Ficus benjamina* cultivars in greenhouse cages (year 2).

	No. of curled leaves per plant			Final count per plant at week 6		
Cultivar[a]	2 wk	4 wk	6 wk	Adult	Larva	Egg mass
Kiki	0.3	0.7	0.7	54.3	13.3	0.7
Florida Spire	0.7	1.0	1.3	18.0	15.0	1.3
Spearmint[a]	0.7	1.3	1.7	16.0	4.7	1.3
Snow White[a]	0.3	1.3	1.3	8.7	16.7	2.3
Common	2.0	2.0	2.3	58.3	9.0	3.0
Variegata (Jacobson's)[a]	0.7	1.3	1.3	47.0	54.7	1.3
Nightingale[a]	0.0	0.3	0.3	6.0	12.3	0.3
Little Denmark	1.0	1.0	1.7	37.7	18.0	1.0
Little Gold Angel[a]	0.7	0.7	1.0	18.3	25.3	1.7
Mini Lucie Ficus	2.3	2.3	2.3	107.3	8.7	2.3
Silver Cloud[a]	1.3	1.7	2.3	41.0	28.0	1.3
Pandora	1.0	2.3	3.0	87.0	82.0	3.7
Starlight (Fantasia)[a]	1.3	1.3	1.3	39.3	6.3	1.3
Nicole[a]	0.7	1.0	1.7	47.0	17.3	2.0
Profit Compacta[a]	0.0	1.0	1.0	33.0	39.0	1.3
Dwarf Nina[a]	1.0	1.0	1.3	23.0	7.7	1.3
Ninet Blue Dwarf[a]	1.3	1.7	2.0	45.7	22.7	2.0
Stacey	0.0	1.0	1.0	38.3	63.7	1.3
Nikki Exotic Angel[a]	0.0	1.0	1.0	44.0	18.7	1.7
Tropical Rainforest	0.7	0.7	0.7	31.3	32.0	0.7
Midnight Cut (cuttings)	0.7	1.3	2.0	68.3	30.0	1.7
Midnight TC (tissue culture)	0.0	0.3	0.7	12.7	19.0	1.0
Midnight Princess	0.0	0.0	0.0	0.7	0.0	0.0
Monique	0.0	0.7	0.7	30.3	4.7	0.3
Indigo	1.0	1.3	1.3	72.0	45.3	1.7
Wintergreen	2.0	3.0	3.3	123.3	58.0	7.0
Unknown Variegated 1[a]	0.0	0.3	1.0	4.7	34.3	1.3

[a]Variegated. Data are average of 3 plants per cultivar.

County, California (Dara & Hodell 2015) confirms that this invasive species is still spreading and that further efforts to improve its detection and management are warranted.

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