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Direction and timing of dispersal of *Scirtothrips dorsalis* (Thysanoptera: Thripidae) on select ornamental host plant species in south Florida

Andrew I. Derksen[1], Catharine M. Mannion[1], Dakshina R. Seal[1,], Lance S. Osborne[2], and Cliff G. Martin[1]*

Abstract

Chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), is a troublesome pest of agronomic, vegetable, fruit, and ornamental crops. *Scirtothrips dorsalis* dispersal and monitoring were evaluated under field and greenhouse conditions in Homestead and Apopka, Florida, in 2007. A field test examined dispersal from Knock-Out® rose, *Rosa* 'Radrazz' (Rosaceae), onto green buttonwood, *Conocarpus erectus* L. (Combretaceae), and 'Emerald Green' schefflera, *Schefflera arboricola* Forst & Forst 'Emerald Green' (Araliaceae). Fewer adults were caught in traps set north, east, or south than west of rose plants corresponding to the average wind direction. *Scirtothrips dorsalis* flights increased during the morning to early afternoon, peaked about 9:00 a.m. to 2:00 p.m. EST, then decreased to almost no flights by 8:00 p.m. Warmer temperature and lower humidity corresponded to more adults caught per hour with most flights occurring after the accumulation of 300 degree-hours. 'Emerald Green' schefflera was preferred over, or may have been less repelling than, green buttonwood. Yellow sticky-card traps were most effective when placed downwind of suspected host plants, and field sites may need more traps per unit area and longer exposure periods than greenhouse sites. These findings may help managers to better monitor and manage *S. dorsalis.*

Key Words: chilli thrips; *Conocarpus erectus*; *Schefflera arboricola*; *Rosa*

Resumen

Trips de pimienta, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), es una plaga molesta de agronómica, verdura, fruta, y cultivos ornamentales. Se evaluaron la dispersión y el monitoreo de *S. dorsalis* en el campo y el invernadero en Homestead y Apopka, FL, E.U., en 2007. Una prueba de campo examinó la dispersión desde rosa Knock-Out ®, *Rosa* 'Radrazz' (Rosaceae), al botoncillo verde, *Conocarpus erectus* L. (Combretaceae), y a la schefflera 'Emerald Green', *Schefflera arboricola* Forst y Forst 'Emerald Green' (Araliaceae). Menos adultos fueron capturados en trampas puestas al norte, al este, o al sur comparado del oeste de los rosales, que correspondio a la dirección media del viento. Vuelos de *S. dorsalis* aumentaron durante la mañana hasta temprano en la tarde, y alcanzó su punto máximo a las 9:00 h a 14:00 h EST, luego disminuyó a casi ningun vuelos antes de las 20:00 h. Temperaturas mas altas y humedades más bajas correspondieron a más adultos de *S. dorsalis* capturados cada hora con la mayoría de los vuelos producidos después de la acumulación de 300 grado-horas. Schefflera 'Emerald Green' fue mas preferido que (o posiblemente menos rechazo que) botoncillo verde. Trampas de tarjetas pegajosas y amarillas eran más eficaces cuando se colocan a favor del viento de las plantas hospederas sospechosos. Tambien, sitios en el campo pueden necesitar más trampas por unidad de área y por los períodos de exposición más largos que los sitios de invernadero. Estos hallazgos podrían ayudar a los administradores a controlar y gestionar mejor el *S. dorsalis*.

Palabras Clave: chilli thrips; *Conocarpus erectus*; *Schefflera arboricola*; *Rosa*

Chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), is a problematic pest native to southern Asia (Dev 1964; Kumar 2012). Over the last 20 yr, it has expanded its range into much of the world's tropical and subtropical regions. In 2005, it was found established in Florida (Coolidge 2005; Silagyi & Dixon 2006) and Texas (Holtz 2006), and it shows potential for expansion into the remainder of North America (Venette & Davis 2004; Meissner et al. 2005; Nietschke et al. 2008). More than 112 plant species in at least 40 families are hosts to this pest (CABI/EPPO 1997; CABI 2003), such as cotton, *Gossypium* species (Malvaceae); soybeans, *Glycine max* (L.) Merr. (Fabaceae); citrus, *Citrus* species (Rutaceae); and pepper, *Capsicum* L. species (Solanaceae) (Venette & Davis 2004; Meissner et al. 2005; Nietschke et al. 2008). *Scirtothrips dorsalis* also attacks ornamental plants and is a major pest of rose, *Rosa* species (Rosaceae), such as in India, where it adversely affects the number, size, and appearance of flowers (Onkarappa & Mallik 1998; Duraimurugan & Jagadish 2004). Symptoms of *S. dorsalis* feeding include leaf and flower drop, stunting, scarring, bronzing, and deformed growth (Dev 1964; Mound & Palmer 1981; Chandrasekaran 2005). Thus, high *S. dorsalis* densities may result in more injury than the plants can repair or replace and may kill them (Mound & Palmer 1981). Ornamental host plants are particularly vulnerable to feeding injury because even minimal scarring can render a plant too unsightly to be salable.

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Hosts of *S. dorsalis* include popular landscape plants such as ligustrum, *Ligustrum* species (Oleaceae); Indian hawthorn, *Raphiolepis indica* (L.) Lindl. ex Ker Gawl. (Rosaceae); Knock-Out® rose, *Rosa* 'Radrazz' (Rosaceae); green buttonwood, *Conocarpus erectus* L. (Combretaceae); and 'Emerald Green' schefflera, *Schefflera arboricola* Forst & Forst 'Emerald Green' (Araliaceae). 'Emerald Green' schefflera and green buttonwood were identified as important host plants of *S. dorsalis* following reports from nurseries to extension agents in central and southern Florida. Perhaps because of their small size, weak flight, and short life cycles, these thrips generally appear to feed and reproduce on all their hosts. Buttonwood and schefflera are widely distributed in southern Florida and frequently used in hedges or borders, which may help *S. dorsalis* disperse and establish throughout the state (Morse & Hoddle 2006).

According to Mannion et al. (2014), a greater diversity and abundance of thrips (including *S. dorsalis*) was found on or near rose than on or near buttonwood plants. Higher numbers and densities of *S. dorsalis* were found on rose than on buttonwood throughout the year suggesting rose is a more attractive (or less repelling) host plant species (Mannion et al. 2014). At least 19 thrips species including *S. dorsalis* were found on plants and in traps on or near Knock-Out® rose or green buttonwood plants (Mannion et al. 2014). However, *S. dorsalis* accounted for 74% of trap-caught thrips from buttonwoods and 86% from roses in addition to 95% of the thrips found on each host plant species (Mannion et al. 2014).

Daytime flight is not uncommon for flower-feeding thrips such as *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) (Pearsall 2002), which have species-specific responses to different wavelengths of light (Lewis 1973). Chu et al. (2006) found that yellow sticky-card traps caught more *S. dorsalis* adults than sticky traps of other colors, which suggested the thrips are probably diurnal. Local dispersal has been found to be important in the colonization success of thrips, and knowing how thrips disperse in plots is important in finding effective, long-term control strategies (Groves et al. 2003; Nault et al. 2003; Rhainds et al. 2005). An improved understanding of the hierarchy of host plant preference, environmental conditions, and timing of *S. dorsalis* flight activity may help in predicting dispersal rates and in timing pesticide applications. The purpose of this study was to determine the influence of host plant preference, environmental conditions, and time of day on the dispersal of *S. dorsalis*. Recommendations were developed based on the findings.

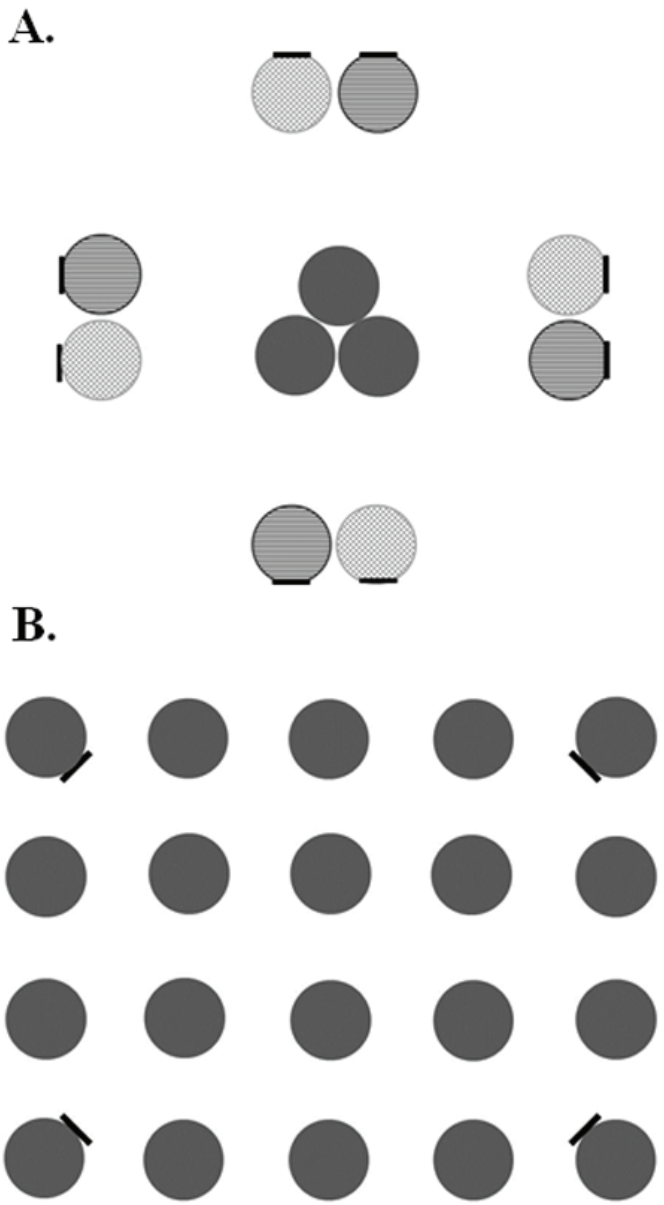


Fig. 1. Experimental setups. **(A)** Population estimates and dispersal from rose to buttonwood and schefflera. Darkest grey represents rose, whereas the 2 lighter grey shades represent buttonwood or schefflera with the same shade of grey representing the same plant species. **(B)** Flight behavior during the day. Circles represent potted rose plants in 11 L containers. Small black rectangles denote locations of yellow sticky-card traps relative to each plot.

Materials and Methods

Two tests were performed: Test 1 (Fig. 1A) was a field test determining host plant preference, injury (damage), and direction of dispersal; and Test 2 (Fig. 1B) was a field and greenhouse test to determine diurnal timing of dispersal. The tests were performed at the University of Florida, Tropical Research and Education Center (TREC), Homestead (25.5°N, 80.5°W), and the Mid-Florida Research and Education Center (MREC), Apopka (28.6°N, 81.6°W), Florida, from Jul to Sep 2007.

ENVIRONMENTAL CONDITIONS

In the dispersal timing test at each greenhouse site, an electronic sensor (HOBO® H8 Pro Series, Onset Computers, Bourne, Massachusetts) recorded temperature, humidity, and degree-hours; it also recorded degree-hours at each field site. At field sites, temperature, humidity, rainfall, and wind speed during the test period were recorded 60 cm above ground by the Florida Automated Weather Network (FAWN) stations in Apopka and Homestead (FAWN 2007). During the test period at Homestead, mean weekly temperatures were 24.7 to 28.7 °C, relative humidity was 70 to 84%, and wind speeds were 4.7 to 10.6 kph (range 0 to 85 kph), with a mean direction of 85 ± 22°, or blowing from east to west (Fig. 2; FAWN 2007). At Apopka, mean weekly temperatures were 25.4 to 29.5 °C, relative humidity was 72 to 82%, and wind speeds were 6.6 to 10.1 kph (range 0 to 84 kph), with a mean direction of 127 ± 72°, or blowing from southeast to northwest (FAWN 2007).

Plants at field sites were exposed to mostly sunny, ambient environmental conditions and irrigated daily by overhead sprinklers on a timer at 6:00 a.m. and 2:00 p.m. EST for half an hour with 93 ± 15 mL of tap water each time. Greenhouses in both locations were exposed to similar conditions as field sites, but had about 60 to 70% light blockage, which moderated the temperature and humidity compared with

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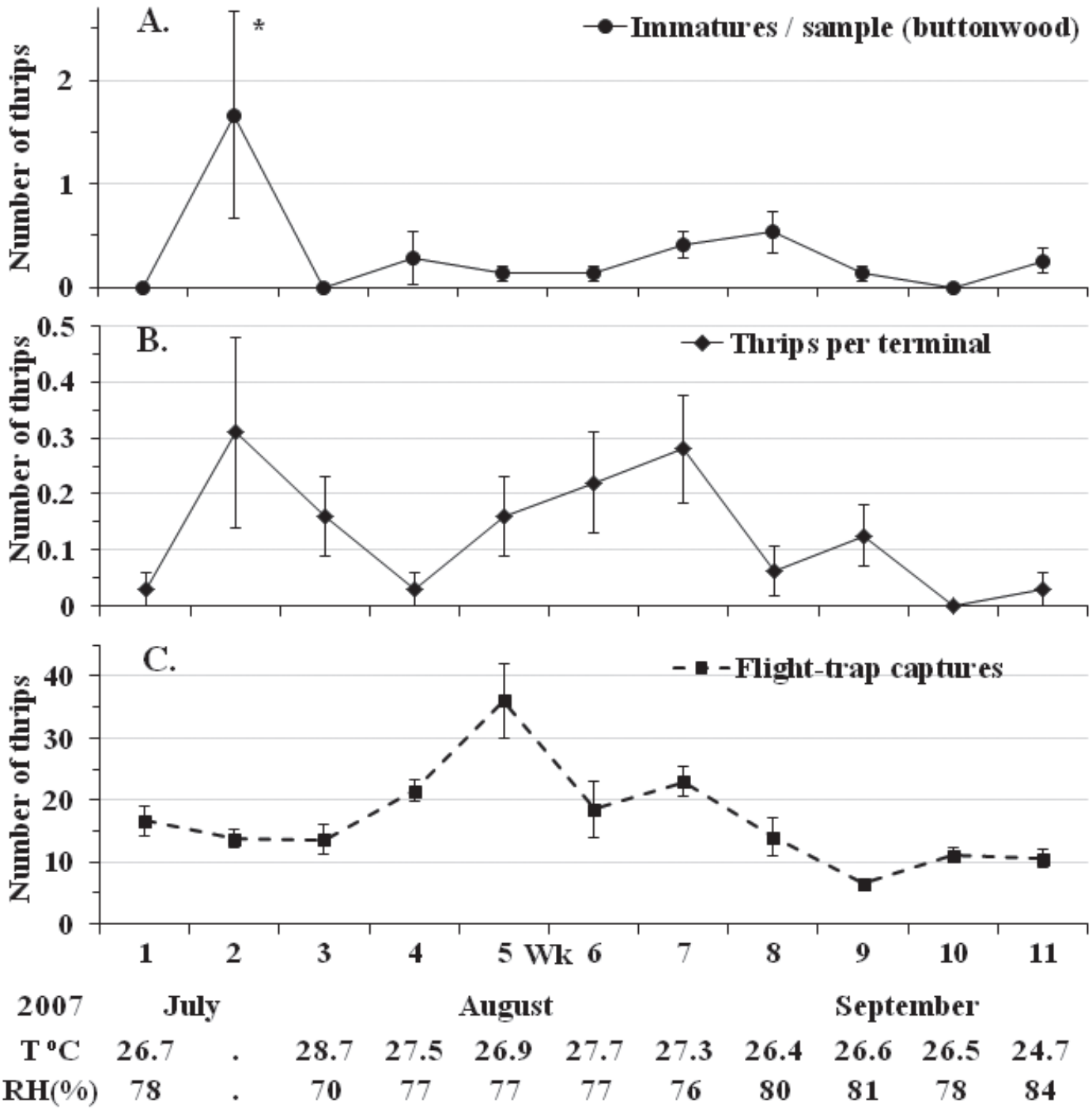


Fig. 2. Population estimates and dispersal of *Scirtothrips dorsalis* to 2 hosts at TREC, 19 Jul to 27 Sep 2007. **(A)** Mean weekly numbers of nymphs and pupae found on buttonwood foliage. **(B)** Mean weekly numbers of adults washed from plant terminals with data from buttonwood and schefflera pooled. **(C)** Mean weekly captures of adults on yellow sticky-card traps behind buttonwood and schefflera plants. Symbols represent means ± SD. An asterisk (*) indicates a significant difference from the other weeks according to 1-way ANOVAs and *t*-test comparisons at $P \leq 0.05$. Mean weekly temperatures (T °C) and relative humidity (RH %) for the 3 mo period are shown parallel to the X-axis (FAWN 2007).

field conditions. At the greenhouse sites, the plants were placed on raised benches, and at field sites, they were on landscape fabric on the ground. All plants were potted in plastic containers of either 11 L (28 cm top diameter) or 0.6 L (10 cm top diameter) in a standard potting medium: 50% Canadian peat moss, 25% pine bark, and the remaining 25% a mixture of perlite and vermiculite (Fafard 3B Mix, Conrad Fafard Co., Agawam, Massachusetts).

Host plants in 11 L containers included the principal study plants, Knock-Out® rose, 'Emerald Green' schefflera, and green buttonwood. In greenhouse tests in 0.6 L containers, pepper and cotton plants were also planted as additional feeding and reproductive hosts for the *S. dorsalis* colonies. Schefflera and buttonwood plants were grown from cuttings harvested at TREC, and the roses were purchased from Treemendous Landscapes, Homestead, Florida. Cotton and pepper plants

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in the greenhouse tests were grown from seed. All plants were fertilized once a month with 4.0 g of 20:20:20 liquid fertilizer granules diluted and applied according to manufacturer's instructions (Peter's Professional, Scotts Co., Marysville, Ohio), and additionally, once every 2 mo with 7.5 g of 15:9:12 pellet fertilizer (Osmocote Plus, Scotts Co., Marysville, Ohio).

TEST 1: POPULATION ESTIMATES AND DISPERSAL TO TWO HOSTS

Dispersal behavior of *S. dorsalis* was evaluated using Knock-Out® rose, 'Emerald Green' schefflera, and green buttonwood plants at the TREC field site from Jul to Sep 2007. Before beginning the test, all schefflera and buttonwood plants were carefully inspected to ensure they were free from thrips. Twelve 8-mo-old Knock-Out® rose plants were randomly selected from an established group of heavily infested plants with densities of 3 *S. dorsalis* individuals per cm^2 on flowers. There were 4 replications, and each consisted of 3 infested rose plants in the center of 4 pairs of plants each with 1 schefflera and 1 buttonwood (Fig. 1A). Each schefflera–buttonwood pair was placed at a cardinal point 1 m north, east, south, and west of each trio of infested rose plants. The central rose plants had overlapping canopies and served as principal sources of *S. dorsalis* to infest buttonwood and schefflera plants. Replications were spaced 1 m apart, which was the distance between a schefflera–buttonwood pair in one replication and the nearest such pair in another replication.

To estimate the number of *S. dorsalis* flights among the host plant species, yellow 7.6 × 12.7 cm sticky-card traps (Stiky Strips, Olson Products, Medina, Ohio) were placed on 1-m-tall posts. Each post was placed in each buttonwood or schefflera container 6 cm from the plant and on the opposite side of the container from the central trio of rose plants (Fig. 1A). Traps were replaced once a week. Used traps were wrapped in clear plastic wrap and stored at −6 °C if they could not be processed immediately. *Scirtothrips dorsalis* populations on buttonwood and schefflera plants were estimated by a weekly random sampling of each plant of 1 terminal bud, which included 5 cm of stem and the growing tip (apical meristem). Hence, the experiment was randomized within each block (replication). These buds were of similar age and development and were consistently selected from similar positions in the plant canopies. All samples were removed with pruning shears and promptly sealed in small plastic containers with 2 drops of 95% ethanol. Samples that could not be processed immediately were refrigerated at −6 °C until processing.

In each sample, numbers of *S. dorsalis* individuals in each visible life stage (2 instars, pupae, or adults) were determined by washing samples with 75% ethanol and pouring the rinsate through a sieve (US standard 230 mesh with 65 µm openings) as described by Seal & Baranowski (1993). Debris from insects on traps and alcohol-washes of samples were examined under a dissection microscope with at least 12× magnification. Using morphological characters, *S. dorsalis* could be distinguished from the other thrips species by the small adult size and distinguishing abdominal, pronotal, and antennal features (Funderburk et al. 2007). Plant samples were dried overnight, and the area of each dried sample was determined using a leaf area meter (LI-3000, LiCor, Lincoln, Nebraska), which allowed *S. dorsalis* density per cm^2 to be determined. Samples were collected from plants and sticky traps once a week for 11 wk from 19 Jul to 27 Sep 2007. Insect voucher specimens were sent to the Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville, Florida, to confirm identification throughout the test. A damage estimate similar to that of Kumar et al. (1996) for pepper was used every week to rate plant quality and feeding damage on a 0 to 5 scale with 0 for no symptoms and 5 for defoliated plants near death.

TEST 2: FLIGHT BEHAVIOR DURING THE DAY

Daily and hourly *S. dorsalis* flight patterns were evaluated in a set of experiments conducted in 2 greenhouses and 2 field sites with 1 greenhouse and 1 field site each at TREC and MREC. Each greenhouse and field site had 20 infested Knock-Out® rose plants spaced 33 cm apart and arranged in a 4 × 5 plant grid (3.4 m^2) (Fig. 1B). Each greenhouse had additional feeding and reproductive hosts for *S. dorsalis* colonies including 300 to 400 cotton and chili pepper plants, which were planted every 2 wk; the MREC greenhouse also had northern highbush blueberries (*Vaccinium corymbosum* L.; Ericaceae). However, field sites were infested with ambient *S. dorsalis* populations and not supplied with additional plants to provide infestation. At each field or greenhouse site, four 7.6 × 12.7 cm yellow sticky-card traps were placed on 1-m-tall posts that were 33 cm from the inside corner of each plot. Preliminary experiments did not detect nocturnal flights for *S. dorsalis*, so traps at all 4 sites were replaced every hour during daylight hours from 6:00 a.m. EST (1 h before dawn) until 9:00 p.m. EST (1 h after dusk). Each diurnal test was repeated on 4 consecutive days at each site, hence there were 16 replications. Traps were collected, wrapped in clear plastic wrap, and stored at −6 °C if they could not be processed immediately. *Scirtothrips dorsalis* adults were identified and counted using similar magnification, techniques, and keys as described for Test 1.

STATISTICAL ANALYSES

Initial 2-way ANOVAs helped to determine if interaction occurred between host plant and dispersal direction for Test 1—population estimates and dispersal direction—, and between location and environment (field vs. greenhouse) for Test 2—daily flight behavior. Treatments were then compared using 1-way ANOVAs or *t*-tests as appropriate. Means were separated using Student's *t*-tests when sample sizes were constant between treatments, or by Tukey–Kramer HSD test for unequal sample sizes. Also, least-square means were used to fit the general linear model and to determine the strength of each relationship between the numbers of thrips caught per hour and temperature or humidity. Although no data were transformed, statistical analyses were conducted with JMP statistical software (SAS Institute 2007).

Results

POPULATION ESTIMATES AND DISPERSAL TO TWO HOSTS

No significant interaction was found between host plant species and dispersal direction for any variable tested including number of thrips caught per trap, plant damage rating, or number or density of thrips of any instar per plant. Therefore, host plant species were pooled to compare dispersal directions, and dispersal directions were pooled to compare host plant species for analyses.

Stadia. The number of nymphs and pupae per plant did not show significant variation during the 11 wk test for schefflera. However for buttonwoods, there was variation in cumulative nymphs and pupae per plant (F = 2.01; df = 10, 313; P = 0.0321) with significantly more nymphs and pupae collected for the 2nd week than on all other sample dates (Fig. 2A). Considering pooled host plants, numbers of adults caught per week did not vary significantly between weeks (Fig. 2B), but numbers of adults per sticky trap did show weekly variation (F = 9.21; df = 10, 274; P < 0.0001) (Fig. 2C). There was no correlation over the 11 wk study period between numbers of adults trapped above pooled host plants and either numbers of adults caught on pooled host plants or nymphs and pupae caught on buttonwoods.

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Host Plant. The amount of damage found on each host plant species was very low (<1%) with minor scarring at petiole bases and wrinkled new growth. However, there was more damage on schefflera than on buttonwood (t = 1.97; df = 350; P < 0.0001) (Fig. 3A). *Scirtothrips dorsalis* density was also higher on schefflera than on buttonwood (t = 2.03; df = 183; P < 0.05) (Fig. 3B), but there were no significant differences in total numbers of nymphs, pupae, and adults sampled among the 2 host plant species. However, significantly more adult thrips were captured on traps placed behind buttonwood than behind schefflera (t = −3.07; df = 245; P < 0.003) (Fig. 3C).

Direction. No significant difference was observed among cardinal directions in *S. dorsalis* damage rating, total number, or population density on plants. However, more adults were caught on sticky traps located west of the roses than on traps located north, south, or east of them (F = 1.97; df = 281; P < 0.0001); this corresponded to the direction of prevailing winds (Fig. 3D).

FLIGHT BEHAVIOR DURING THE DAY

An interaction occurred between location and environment (F = 19.90; df = 1; P < 0.0001); hence, each population was considered independently. At all 4 sites, there was a rapid increase of captures early in the morning with peak numbers from 9:00 a.m. to 2:00 p.m. EST, which then declined to near zero by 8:00 p.m. The MREC greenhouse and TREC field site each reached their peak about 10:00 a.m., the TREC greenhouse site peaked at 12:00 p.m., and the MREC field site peaked at 2:00 p.m. (Fig. 4A and B). There was no significant difference between TREC and MREC field sites in numbers of adults caught per hour. However, there was a difference between TREC and MREC greenhouses (t = −3.17; df = 298; P = 0.0008), with more thrips caught per hour at the MREC than at the TREC greenhouse at 10:00 a.m. (t = −2.17; df = 18; P = 0.0228) and at 7:00 p.m. EST (t = −2.57; df = 18; P = 0.0097) (Fig. 4A). Numbers of adults caught at field sites were lower than those at greenhouse sites at MREC (t = −3.60; df = 13; P = 0.0033) and at TREC (t = −4.57; df = 13; P = 0.0005).

Conditions in the TREC greenhouse were warmer (+2.2 °C; t = 5.99; df = 278; P = 0.0001) and more humid (+2%; t = 2.05; df = 278; P = 0.0205) than in the MREC greenhouse. The TREC field site averaged 3% higher humidity than the MREC field site (t = 3.79; df = 690; P = 0.0002). Temperature was positively correlated with numbers of adults caught per hour at the TREC greenhouse site (r = 0.80; P = 0.0002), the TREC field site (r = 0.67; P = 0.0029), and the MREC field site (r = 0.54; P = 0.0205). Humidity was negatively correlated with numbers of adults caught per hour at the TREC field site (r = −0.64; P = 0.0048) and the TREC greenhouse site (r = −0.80; P = 0.0002). Morning flight peaks occurred at all 4 sites after the accumulation of at least 300 degree-hours (generally about 10:00 a.m.). A second peak occurred at the MREC field site after accumulating 650 degree-hours (about 2:00 p.m.) (Fig. 4A and B). The primary morning peak after 300 degree-hours occurred approximately when external temperatures reached 30 °C at each location.

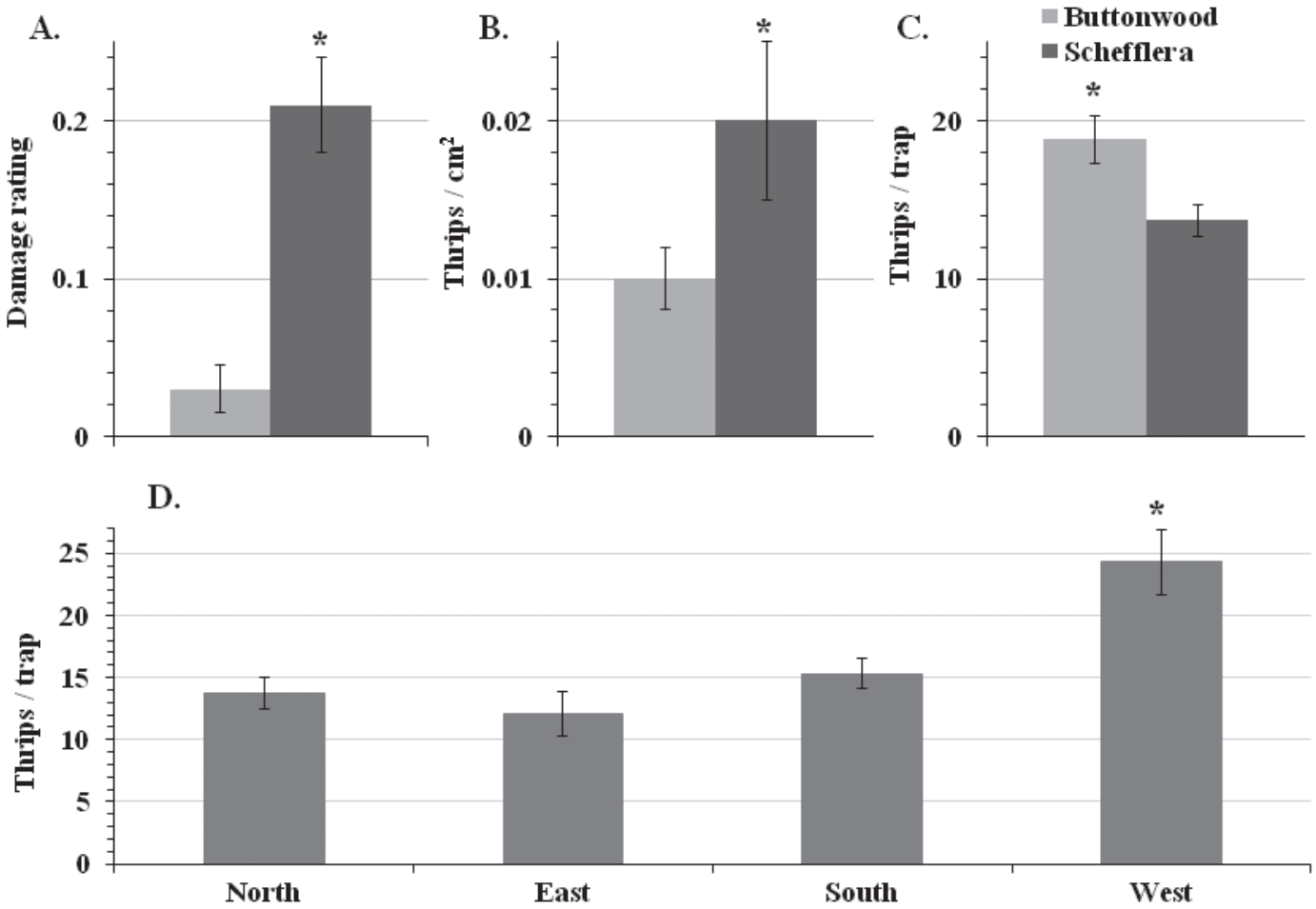


Fig. 3. Population estimates and dispersal of *Scirtothrips dorsalis* to 2 hosts: cumulative data for the 11 wk test period. **(A)** Mean damage ratings on a scale of 0 to 5. **(B)** On-plant densities of *S. dorsalis*. **(C)** Weekly captures of adults on yellow sticky-card traps. **(D)** Weekly captures of adults on yellow sticky-card traps by cardinal direction of traps from plants. Symbols represent means ± SD. An asterisk (*) indicates a significant difference at $P \leq 0.05$ (A–C) between host plant species according to t-tests or (D) from the other host plant pairs at other cardinal orientations based on a 1-way ANOVA followed by a Tukey–Kramer HSD test.

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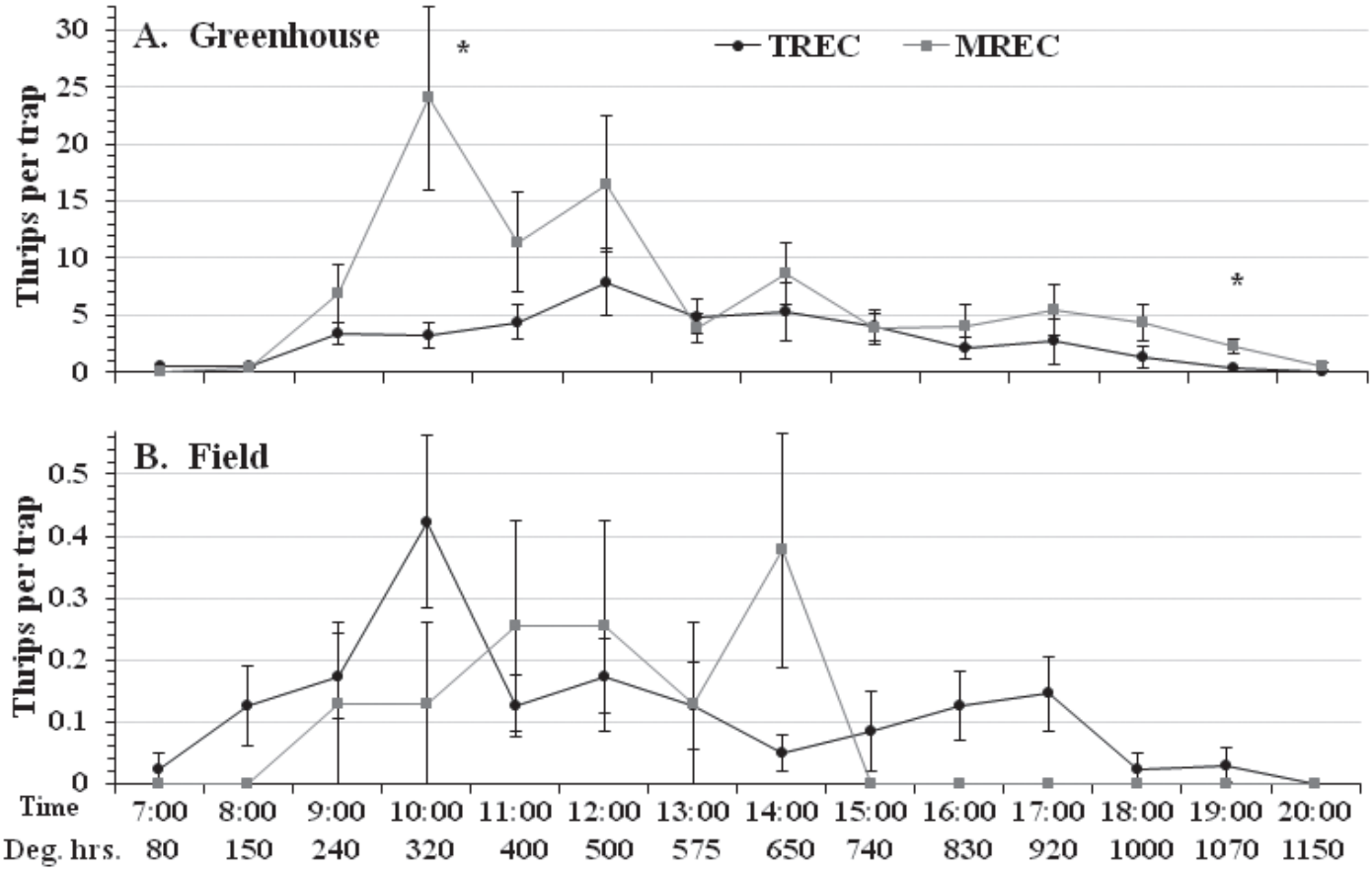


Fig. 4. Flight behavior of *Scirtothrips dorsalis* during the day. Mean hourly captures of adults at **(A)** greenhouse and **(B)** field sites of TREC and MREC by the time sampled and cumulative degree-hours. Symbols represent means ± SD. An asterisk (*) indicates a significant difference between test locations at a given time based on a *t*-test at $P \leq 0.05$.

Discussion

In the field test of dispersal direction, we observed the greatest numbers of adults on traps located west of infested rose plants in the direction of prevailing winds. However, factors other than wind may have influenced the results, for example, thrips moving to shaded surfaces in the evenings and sunlit surfaces in the morning, or habitat cues such as trees external to the experiment. But it is not surprising that most trap captures were in the direction of prevailing winds because *S. dorsalis* is a minute insect with low mass, and the fringed wings provide a large surface area, which renders it easily dispersed by wind (Lewis 1973). Near the ground, where the wind is less strong, local dispersal of very small insects tends to occur within a "boundary layer," or nearly immobilized air protected from disturbance by plant canopy that allows the insects to fly short distances (Taylor 1974). The behavior of *S. dorsalis* populations on St. Vincent in the Lesser Antilles supported this hypothesis (Seal et al. 2006). Within 48 m^2 plots, Seal et al. (2006) found that aggregated population clusters were randomly distributed throughout the field. This finding suggested initial, random colonization events followed by gradual, more local population growth and expansion to adjacent plants (Seal et al. 2006).

Mannion et al. (2014) compared buttonwood with rose (but not schefflera) and found more *S. dorsalis* nymphs on rose than on buttonwood plants, but the percentage of the population that was adult appeared larger on buttonwood. Similarly, in the present study, *S. dorsalis* densities and damage ratings were lower on buttonwood than on schefflera suggesting the latter may be a better host plant species for survival and reproduction of *S. dorsalis*. However, buttonwood appeared to be a more attractive host to adults: more adult thrips were caught in traps near buttonwood than near schefflera. Both Mannion et al. (2014) and the present study used the same number (4) and type of sticky traps per host plant species. However in the present study, traps were distributed 1 per plant container with different host plant species next to each other, whereas in Mannion et al. (2014), traps were placed within separate groups of 20 of the same host plant species. Nonetheless, in the present study and in Mannion et al. (2014), buttonwood appeared less preferred (or possibly more repelling) than the other host plant species, but yielded larger numbers of *S. dorsalis* adults per trap (in the present study) or numerically larger percentages of the sampled *S. dorsalis* populations that were adults on plants (Mannion et al. 2014). Similarly, Masui (2007) found many *S. dorsalis* adults feeding on citrus but fewer nymphs on citrus compared with the other host plant taxa. When adult insects are found feeding on a certain host plant species, they may not necessarily be able to complete development from newly emerged 1st instar to adult (Ananthakrishnan 1993). Whether or not an insect–host plant association occurs for feeding only or for reproduction may therefore be important. Because *S. dorsalis* can infest and possibly complete its reproductive cycle on buttonwoods, this secondary host may serve as a potential reservoir and pathway for thrips moving between roses and other preferred hosts (Mannion et al. 2014). Thus, buttonwood may aid the dispersal of adult thrips to facilitate reproduction on the more desirable host plant species, while also being present in larger adult numbers on or near this secondary host.

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Rose was not included in the group of target plants and was already infested at the outset of the experiment, whereas the other 2 plant species were free of thrips and had to be colonized. Therefore, our results support a preference of *S. dorsalis* for schefflera over buttonwood, but the experiment was not designed to test whether each host plant species was preferred over rose plants. Also, neither buttonwood nor schefflera had mean damage ratings of more than 0.22 out of 5 or densities of more than 0.02 thrips per cm^2 indicating low levels of damage and pest density on each host plant species. In another field test on green buttonwoods in 4 × 5 plant grids (3.4 m^2), Mannion et al. (2014) found similarly low damage (0 to 0.8) and densities (0.002 to 0.07 thrips per cm^2), but damage to Knock-Out® rose flowers varied from 0 to 3.8 with mean densities of 0.17 to 6.3 thrips per cm^2. The apparent low values for *S. dorsalis* density and plant damage on buttonwood in both studies and on schefflera in the present study suggest that neither plant species was a strong host of *S. dorsalis* when compared with Knock-Out® roses. Nonetheless, buttonwood and schefflera have been important hosts of *S. dorsalis* based on nursery reports (Silagyi & Dixon 2006).

In the present study, *S. dorsalis* populations may have remained on Knock-Out® roses instead of migrating to alternate hosts because of the attractiveness of the source plants or because they were too sedentary to disperse from the host. Plants provided with high nitrogen fertilizer are often more attractive to insect pests than those provided with less nitrogen (Slansky & Rodriquez 1987).Hence, the strong attraction of *S. dorsalis* to schefflera and buttonwood in nursery reports (Silagyi & Dixon 2006) may have been caused by heavy fertilization to "push" plant growth, or the plants may have been growing in greenhouses where *S. dorsalis* was unable to escape to outside host plants. Buttonwoods have simple, medium-green, elliptical to obovate, 3 to 8 cm long leaves, whereas scheffleras have palmately compound, mostly dark green, very glossy leaves each with 6 to 10 elliptical-obovate leaflets that are 6 to 13 cm long. Schefflera foliage can appear glossier, denser, and darker green than buttonwood foliage. Based on our samples from plants versus traps, the difference in plant canopy structure may have contributed to the difference in preferred host plants which is supported by Lewis (1997). In color preference tests for *S. dorsalis* adults using sticky traps or flower petals, green, yellow, orange, red, or white were the most attractive colors (Tsuchiya et al. 1995; Saxena et al. 1996; Gahukar 2003; Rani & Sridhar 2003; Chu et al. 2006).

Plant morphological characters such as height, leaf size, petiole length, and leaf internode distance can also affect population levels of *S. dorsalis*, such as on chili peppers (Pramanick & Mohasin 2004). Timing of trap placement relative to periods of highest adult dispersal and prevailing winds may also have affected our results. Hence, possible reasons for our apparently low rates of *S. dorsalis* infestation on buttonwood and schleffera compared with rose plants include differences in plant cultural and environmental conditions; trap timing; plant quality, color, and morphological characters; more attractive host plants elsewhere; and/or barriers to insect movement. Perhaps future studies should investigate the interaction of environmental and host plant factors in determining differences in host plant preference, nonpreference, repellence, or similar effects.

In the test of daily dispersal timing, greenhouses contained potentially higher densities of thrips than field environments because of their abundant inoculation sources, more enclosed spaces, more limited volumes, and lower dispersal wind speeds. It is therefore not surprising that lower mean numbers of adults were trapped in the field than in greenhouse sites suggesting the use of sticky traps to monitor fields may be less cost effective and efficient than their use in greenhouse environments. On the other hand, fewer traps may be needed to monitor a given area in the field than in the greenhouse if the lower field densities of *S. dorsalis* are more uniform because of the lack of restrictive barriers and freer movement of insects. To more effectively monitor for *S. dorsalis* in the field, traps may need to be placed downwind of suspected host plants. Traps should also be exposed for longer time periods than the 1 h used in the present study, but this is typical for field studies, where traps are often set up, checked, and replaced weekly.

We found that both increasing temperature and decreasing humidity were correlated with increased flight activity. However, the periodicity of thrips dispersal may also be linked to the time of day, and we were unable to tell whether thrips prefer to fly at 9:00 a.m. to 2:00 p.m. EST because of the effects of "internal clocks" or because of temperature and/or humidity. Both increasing rainfall (Lewis 1973, 1997; Varadharajan & Veeravel 1995; Saxena et al. 1996; Lingeri et al. 1998; Paul & Konar 2005; Singh 2005) and increasing humidity (Varadharajan & Veeravel 1995; Saxena et al. 1996; Lingeri et al. 1998; Paul & Konar 2005) can reduce thrips population growth rates. The decreasing flight captures with increasing humidity may suggest flight avoidance behavior on rainy days.

There were differences between sites in numbers of adults caught at each time of day and in the timing of daily population peaks. However, flight activity generally increased in early morning, peaked from mid-morning to early afternoon, and then became less frequent until early evening. Arthropods including thrips are poikilothermic, or have body temperatures that vary with the environment, and they require a constant number of degree-hours to accumulate and heat their flight muscles before flying (Ellington 1980). Hence, the pattern involving a diurnal peak in flight numbers followed by reduced activity may be common to *S. dorsalis* and other thrips species.

In summary, our study found or supported an apparent preference of *S. dorsalis* for 'Emerald Green' schefflera over green buttonwood. Also, to maximize trap catches, traps should be placed downwind of attractive hosts. Because hourly captures of adults were much lower in traps placed in the field than in the greenhouse, field sites may need more traps per unit area exposed for longer time periods than greenhouse sites to catch similar numbers of thrips per trap. At all 4 sites, adults had maximum daily flight frequencies after accumulating at least 300 degree-hours, or generally when external temperatures reached about 30 °C. Hence, traps should be left throughout the day to take advantage of the activity periods. These insights have potential value for integrated pest management in trapping, monitoring, and determination of pesticide and other control strategies.

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