Dichromothrips smithi (Zimmermann), a New Thrips Species Infesting Bamboo Orchids *Arundina graminifolia* (D. Don) Hochr. and Commercially Grown Orchids in Hawaii

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Abstract. *Dichromothrips smithi* (Zimmermann 1990), a thrips species native to SE Asia that feeds on orchids, was first detected in Hawaii in 2007. At the time it was detected, it was already widespread on bamboo orchids in the Puna district of the island of Hawaii. The build-up of the pest in bamboo orchids threatens adjacent commercial orchid farms, several of which have reported this species as a pest. A survey on bamboo orchids in the Puna District showed that adults were highly aggregated in flowers. In an unsprayed planting of dendrobium orchids in E. Hawaii, *D. smithi* was the dominant thrips species present over a two-year period. Higher numbers of *D. smithi* adults and larvae were found on bamboo orchids growing as volunteers within this planting, suggesting that bamboo orchids could be used as a trap crop to protect more valuable types of orchids.

Key words: *Dichromothrips smithi*, bamboo orchids, dendrobium orchids, thrips aggregation

Introduction

In the Puna District of east Hawaii island (Hawaii, USA), the bamboo orchid, *Arundina graminifolia* (D. Don) Hochr. (Orchidaceae), is a common roadside plant. Bamboo orchids are native to southeastern Asia, India, Malaysia, and certain Pacific Islands (Wagner et al. 1990). They were first collected on Oahu in 1945 and are locally common in disturbed, mesic to wet forest environments and as a pioneer species on lava fields 75–920 meters in elevation on Kauai, Oahu, East Maui, and the South Hilo and Puna districts of Hawaii (Wagner et al. 1990). Over the past 15–20 years and ending in 2007, entomologists working in the Puna district of Hawaii noted on many occasions that bamboo orchids growing adjacent to thrips-infested plantings of commercial orchids were seldom infested with thrips and never infested heavily (RGH and AHH, personal observations). On October 24, 2007, an orchid grower in the Hawaiian Acres subdivision of Puna reported finding large numbers of a black thrips species on bamboo orchids growing along roadsides in this subdivision. A follow-up investigation the following month revealed that bamboo orchids were heavily infested with this thrips over a large area in the Puna district. Concurrently, there were

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several reports of this same species infesting potted orchids in a variety of genera, including *Dendrobium, Epidendrum, Cattleya,* and *Cymbidium*. This thrips species was subsequently identified by Steve Nakahara of the USDA-ARS Systematic Entomology Laboratory in Beltsville, MD on November 29, 2007 as *Dichromothrips smithi* (Zimmermann, 1990) based on examination of specimens collected from bamboo orchids in the Hawaiian Acres subdivision and from Kapoho (near the eastern tip of Hawaii island) on 24 October 2007 and 8 November 2007, respectively. Native to SE Asia, this species is also a recent immigrant to Korea, apparently arriving prior to 1996 (Lee et al. 2002). In Korea, it damages commercial orchids in the genera *Dendrobium*, *Cymbidium* and *Phalaenopsis* (Lee et al. 2002). Currently it is not known whether *D. smithi* is found on all major Hawaiian islands. However, we know *D. smithi* is also present on the island of Kauai based on examination of a sample collected on a terrestrial orchid species, *Spathoglottis plicata* Blume, on October 7 2011 at the Lihue airport and supplied to us by USDA-APHIS.

Many thrips species are thigmotactic, meaning that they maximize body contact with plant tissues (Kirk 1997). Curiously, *D. smithi* adults on bamboo orchids were frequently found in exposed locations on flower petals and appeared to be aggregated on certain flowers (Figure 1). We observed that while some bamboo orchid blossoms were heavily infested with *D. smithi* adults and nymphs, other blossoms of high quality only a few centimeters away were in some cases completely uninfested. Aggregation behavior is common in Thysanoptera, and in the case of “flower thrips,” these associations are presumed to be the result of host sharing or for purposes of mate finding (Terry 1997). Our first goal was to study the distribution and abundance of this pest on bamboo orchids in the Puna District, known for having many commercial orchid farms that might be affected by this pest. Our second goal was to document the aggregation behavior. In addition, and in the context of a separate study carried out in 2010 and 2011, we collected data on the abundance of *D. smithi* on dendrobium orchid varieties and bamboo orchids in a dendrobium orchid greenhouse not being sprayed with insecticides.

Figure 1. A bamboo orchid blossom infested with adult females of *D. smithi*, which appear black against the light pink color of the petals.

Methods

Bamboo orchid survey. Orchid blossoms were collected along roadsides primarily at lower elevations in the Puna district where scattered groupings of bamboo orchids were common. However, several collections were also made along Highway 11 at higher elevations (up to ~1066 meters) approaching Hawaii Volcanoes National Park (Figure 2). Collections were made from 37 geo-referenced sites

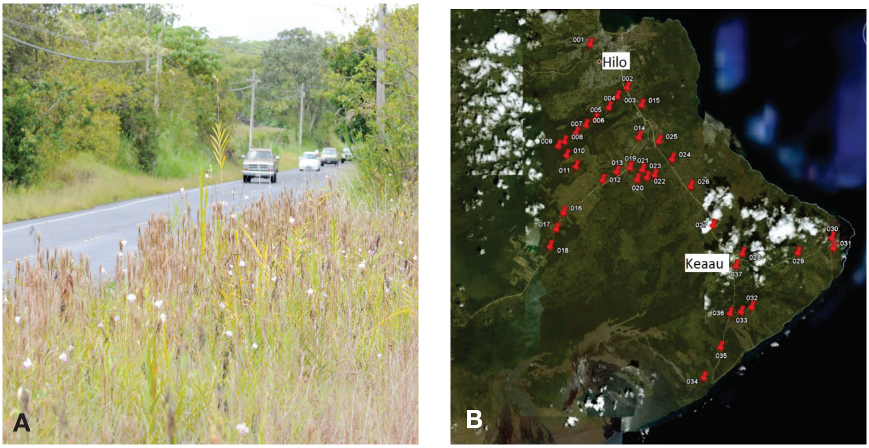

Figure 2. Area where bamboo orchids were common in lower Puna (2a). Locations (marked with red pins) in east Hawaii in which bamboo orchids were surveyed for the presence of *D. smithi* in 2008 and 2009 (2b).

August 19–22, 2008, and again August 27–31, 2009. At each collection site, five blossoms on separate plants within ~5 meters of one another were collected individually into 20-ml vials of 70% ethanol. The criterion for blossom selection was fresh appearance (fully open petals, none of which were dried up). Flowers to be sampled were selected from a distance of 3–4 m (a distance from which thrips were not apparent) to reduce the chance of sampling bias based on infestation level.

In the laboratory, thrips and other insects were washed from blossoms and counted under a dissecting microscope (Figure 3). Species of thrips other than *D. smithi* were extremely uncommon in flowers, so any thrips that were black with a light band at the base of the wing and that had the distinctive appearance of *D. smithi* females (based on size, color, and shape) were counted as such (Figure 4a). Males of this species were recognized based on body shape (similar to females) and coloration (a dark brown head, light brown meso and metathorax, yellow legs, and banded wings, as described in Mound 1976 (Figure 4b). Living female *D. smithi*

Figure 3. *D. smithi* (adults females and larvae) and two unidentified *Orius* predators (lower right area of picture) washed from a bamboo orchid flower blossom and stored in ethanol. Note that predators are similar in length to *D. smithi* adults. Note also orange-colored second instar larva of *D. smithi* (middle left). Large second-instar larvae are distinctly orange in life.

(4c) appear darker brown and more compact relative to specimens of female thrips preserved in ethanol (4a). Large second instar larvae are distinctly orange, and this coloration is preserved to some degree in ethanol (Figure 3).

To document aggregation, we measured population dispersion of adult thrips and thrips larvae using two methods. The first method involved calculating an Index of Dispersion (I_D) using the equation $I_D = s^2 (n–1)/\bar{x}$ where s^2 is the variance in numbers of adults or larvae across all flower blossoms collected and $\bar{x}$ is the mean number. Under the null hypothesis of random distribution, this statistic is approximately χ^2 distributed for n–1 degrees of freedom (Southwood 1978). The second method used to measure dispersion was Taylor's Power Law (Southwood 1978). First, the mean and variance of the number of thrips per blossom was calculated separately for the five blossoms collected at each sample site. Then the $\log_{10}$ of variance was regressed on $\log_{10}$ of mean number thrips per blossom after adding a value of 1 to each data value. Regression slopes >1.0 indicate a clumped distribution (Southwood 1978, Pedigo and Zeiss 1996). Means, confidence intervals, and regression analyses were calculated or performed using an Excel spreadsheet (Microsoft Office 2007, SP2, Microsoft Corporation, Redmond, WA). To determine whether there was evidence that aggregations were related to mate finding, we examined the frequency with which males were found in heavily infested blossoms.

Abundance of *D. smithi* on dendrobium orchids and bamboo orchids in a greenhouse. *D. smithi* were sampled at various intervals from mixed varieties of dendrobium orchids in a greenhouse in Keaau, Hawaii, which had not been used for commercial production for several years. This greenhouse was being used primarily for studies relating to natural control of thrips following releases of thrips predators (*Orius* sp. [Hemiptera: Anthocoridae]). However, these releases

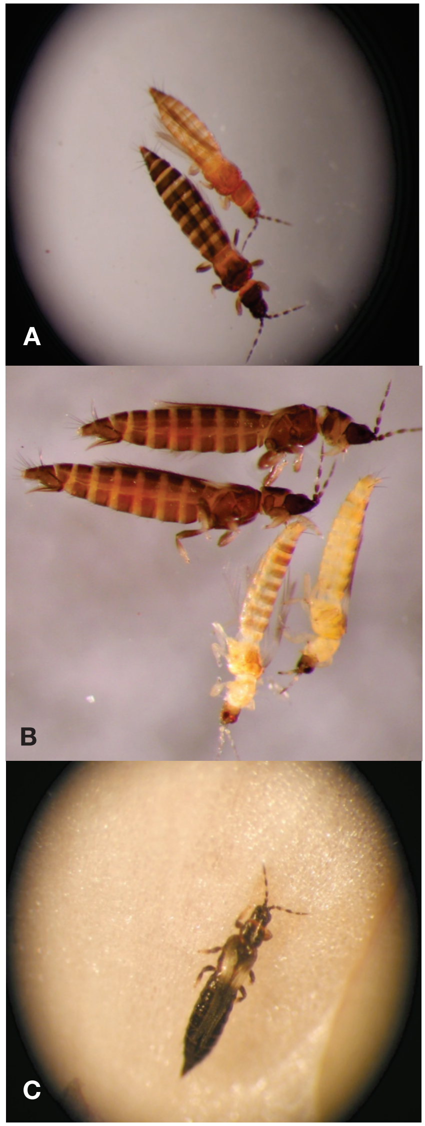

Figure 4. A normal female and a teneral (newly molted, light colored) female *D. smithi* after storage in 70% ethanol (4a). Male and female *D. smithi* in ethanol (4b). The two males are lighter in color. Note that females stored in ethanol appear lighter brown with abdominal segments stretched out in comparison to the live female on blossom tissue pictured in 4c.

Table 1. Average number of *D. smithi* (SD, maximum no.) per blossom in roadside bamboo orchids sampled in the Puna district during the month of August in 2008 and 2009.

Year	No. females	No. males	No. larvae	% blossoms with no thrips	% sites with no thrips on 5 blossoms
2008	3.3 (3.9, 20)	0.1 (0.2, 2)	8.4 (18.8, 140)	13.5	2.7
2009	4.1 (5.6, 39)	0.01 (0.1, 1)	11.7 (29.5, 301)	16.2	5.4

Note: Five blossoms were sampled individually into 70% ethanol from each of 37 sites in East Hawaii, as indicated in Figure 1.

did not appear to reduce thrips populations adjacent to release areas and therefore probably had little effect on data reported herein (Hollingsworth and Calvert, unpublished data). The dendrobium orchids were growing in a coarse cinder medium within 2-gallon plastic bags in rows that were ~ 1 m in width and 1.3 m apart. Fertilization and watering practices varied across the greenhouse and these were not tracked relative to blossoms sampled for data presented herein. However, no pesticide sprays were used on any flowers. Bamboo orchids that were sampled were growing sparsely as volunteers among the dendrobium orchids. Blossom samples from both dendrobium orchids and bamboo orchids from various areas of the greenhouse were collected separately into plastic bags. In the laboratory, 70% ethanol was added to bags in a volume sufficient to allow blossoms to move freely within bags and contents were shaken for ~30 s. The anther cap on each flower was removed by pressing through the plastic bag with a fingernail to allow larval thrips to be washed out of the reproductive structures. Any thrips removed in this fashion were sieved using fine silkscreen material, and then the washing/sieving process was repeated three additional times to collect any additional thrips that were washed from the blossoms.

Results and Discussion

Although *D. smithi* was not documented as present on the island of Hawaii until October 2007, it was already present throughout the Puna district by the time the first survey was carried out in August 2008 (Figure 2). *D. smithi* was recovered at 36 of the 37 sample sites in 2008 and from 35 of these same sites in 2009. *D. smithi* was present even at elevations approaching ~1219 m (4000 ft) along Highway 11 near Hawaii Volcanoes National Park, but numbers of thrips per blossom at higher elevations tended to be lower than numbers found at lower elevations (data not shown). At lower elevations, commonly 10 adult thrips or more were found in a single blossom, and an even greater number of immature thrips were collected. In 2008, the mean number of adult *D. smithi* females and larvae per blossom was 3.3 and 8.4, respectively. Numbers of females and larvae were about 25% higher in 2009 (Table 1). Some blossoms were heavily infested, while others had no thrips. Up to 39 adults and 301 larvae were recovered from single blossoms (in 2009). Only 13.5% and 16.2% of blossoms

Table 2. Dispersion statistics for adults and larvae of *D. smithi* in roadside bamboo orchids using two measures of dispersion.

	Index of Dispersion (I_D)[a]		Slope coefficients[b] (99.5% CI)	
Year	Adults	Larvae	Adults	Larvae
2008	865*	7654*	1.6 (1.3–1.8)	2.2 (2.0–2.4)
2009	1398*	13745*	1.6 (1.3–1.9)	2.2 (2.0–2.3)

*Significantly different from random distribution (= aggregated) at P≤0.005.
[a]Under null hypothesis of random distribution, value of I_D must be between 138 and 237 (corresponding to chi square probabilities <0.995 or >0.005 for N–1 = 184 df). All 185 blossoms sampled from a total of 37 sites were used to calculate Index of Dispersion.
[b]Slope of the regression of $\log_{10}$ of variance over $\log_{10}$ of mean number thrips per blossom. Slopes >1.0 indicate a clumped distribution (Taylor's Power Law). Df for each regression = 1, 35.

were uninfested with *D. smithi* in 2008 and 2009, respectively (Table 1). Dispersion statistics indicated that both larvae and adults were aggregated on flowers, whether the sample unit analyzed was individual flowers or groups of five flowers collected at the same location. Values calculated for the Index of Dispersion (I_D) for adults in 2008 and 2009 (using data from individual flowers for the analysis) were 865 and 1398, respectively. For nymphs, I_D values for 2008 and 2009 were 7654 and 13,745, respectively (Table 2). All of these calculated values greatly exceeded the upper limit critical value for this statistic, which was 237, indicating that thrips were highly aggregated (Table 2). Taylor's Power Law also indicated aggregated distributions for both larvae and adults in both years sampled. In both sample years, slope coefficients were 1.6 for adults and 2.2 for larvae (Table 2). Slopes >1.0 are indicative of clumped distributions. Larvae were much more aggregated than adults, as expected under the assumption that each female deposits multiple eggs within flower petal tissues and larvae do not move between plants.

In 2008, only 9 of the 185 samples contained males of *D. smithi*. Eight of these contained only one male each. In 2009, only two males were found (Table 1).

Two anthocorid species in the genus *Orius* (not identified, Figure 3) were found singly or in pairs in three of the blossom samples in 2008, and from two samples in 2009. These bugs were barely larger than the adult thrips themselves. A few specimens of other thrips species were recovered from samples, but like the anthocorids, these were uncommon. Other than anthocorids, no thrips predators were found in flower blossoms. In the field, ants were observed feeding on nectar from extra floral nectaries of bamboo orchids but not attacking thrips. Flower beetle adults (family Nitidulidae) were occasionally recovered from flowers, and neonate beetle larvae (possibly of this same species) were common. Blossoms were infested with an average of 0.6 beetle larvae in 2008. Although some nitidulid beetles are predators, the presence of beetle larvae and thrips larvae in flowers was statistically uncorrelated (data not shown).

We also monitored populations of *D. smithi* within a dendrobium orchid greenhouse structure with no walls in Keaau intermittently from mid-2009 until mid-2011. No pesticides were sprayed in this

Table 3. Average number of *D. smithi* per flower blossom in white and purple dendrobium varieties and bamboo orchids in an abandoned (unsprayed) commercial greenhouse in Keaau, Hawaii in December 2009.

Row #	Orchid Varieties[a]	No. blossoms[b]	Dec 2009		April 2011	
			Larvae	Adults	Larvae	Adults
1	232	32	1.9	0.3	0.6	0.07
2	800	38	2.1	0.4	1.2	0.18
3	800	45	3.7	0.3	0.8	0.03
4	800	36	4.5	0.6	1.1	0.20
5	503/506	29	2.8	0.3	0.3	0.03
6	1002	29	2.1	0.3	1.0	0.20
7	800	48	3.4	0.5	1.9	0.50
Average dendrobium		-	2.9	0.4	1.0	0.2
Bamboo orchids		9	4.0	3.2	-	-

[a]Orchid blossom colors: 232, Lavender and white; 800, white; 503/506, light and dark purple; 1002, pale lavender. Bamboo orchids were interspersed with commercial orchid varieties and growing as "volunteers".
[b]Number of blossoms sampled, placed into plastic bags, and from which thrips were washed out using 70% ethanol.

greenhouse during this 2-year period. *D. smithi* was the only thrips species found in this greenhouse even though other (more intensively managed) dendrobium greenhouses in this same neighborhood were infested with *Thrips palmi* Karny (unpublished data). In this greenhouse, we collected data on the number of *D. smithi* per flower blossom in dendrobium orchids versus volunteer bamboo orchids growing in the same area. In December 2009, the number of *D. smithi* larvae and adults per blossom on dendrobium orchid varieties averaged 2.9 and 0.4, respectively, while the number of larvae and adults of *D. smithi* on bamboo orchids averaged 4.0 and 3.2, respectively (Table 3). Additional comparisons were made again on four occasions in May, June, and September of 2011. At that time, the number of *D. smithi* larvae and adults on the dendrobium orchids averaged 1.6 and 0.1, respectively, while on the bamboo orchids the average numbers were 6.6 and 1.4, respectively (Table 4). The data displayed in Tables 3 and 4 comparing average *D. smithi* on dendrobium orchids versus bamboo orchids for the five different dates were statistically analyzed. The average number of *D. smithi* (larvae + adults) was significantly higher on bamboo orchids in comparison to dendrobium orchids (P=0.05, paired one-tailed t-test, df = 4, test carried out using Microsoft Excel 2007 software, SP2, Microsoft Corporation, Redmond, WA). Although our results suggest that bamboo orchids were more attractive to *D. smithi* than dendrobium orchids, other possible explanations for this result include differences in plant architecture and blossom density. Bamboo orchid plants frequently have only 1–3 open blossoms

Table 4. Average number of *D. smithi* per flower blossom in commercial orchids versus volunteer bamboo orchids growing in same plant rows in an abandoned commercial greenhouse in Keaau, Hawaii.

			Commercial orchid varieties			Bamboo orchids in same area		
Row	**Orchid varieties**	**Date**	**Blossoms (no.)**	**Larvae**	**Adults**	**Blossoms (no.)**	**Larvae**	**Adults**
5	503/506	5/12/2011	20	2.0	0.1	2	9.5	1.5
4	800	5/27/2011	20	1.8	0.1	3	0.7	0.0
4	800	6/2/2011	20	1.1	0.1	3	9.7	2.7
5	503/506	9/29/2011	10	1.1	0.1	10	18.0	8.9

on each plant. The dendrobium orchids frequently had multiple flower spikes on each cane and each spike generally had 5–10 open blossoms, resulting in higher blossom density per unit area.

As noted in Lee et al. (2002), *Dichromothrips* Priesner, 1932 is a small genus in the family Thripidae, comprised of 18 species, all of which have been collected only from orchid plants. It isn't known how *D. smithi* arrived in Hawaii. However, orchid blossoms imported from SE Asia into Hawaii seem a likely pathway. According to Lee et al. (2002), the distribution of *D. smithi* includes Japan, Taiwan, Malaysia, Singapore, Indonesia, Solomon Islands, India, and Korea. Plants recorded as hosts for *D. smithi*, of which all are orchids, are found in the genera *Vanilla, Arundina, Vanda, Cattleya, Spathoglottis, Cymbidium, Dendrobium,* and *Phalaenopsis* (Mound 1976, Mound and Azidah 2009, Lee et al. 2002). Mound and Azidah (2009) noted that this species is a pest of cultivated vanilla in India.

Although *D. smithi* is an important pest in orchid greenhouses orchids in Korea and Hawaii, anecdotal information from orchid growers in Hawaii suggests that *D. smithi* is easier to control with contact insecticides than *Frankliniella occidentalis* or *T. palmi*, populations of which are known to be resistant to insecticides (RGH, unpublished data). We expect *D. smithi* to maintain susceptibility to commonly used insecticides because the majority of the population in the Puna district exists on wild bamboo orchids, which are not treated. Therefore, the selection pressure for insecticide resistance for *D. smithi* should be lower in comparison with thrips species whose populations are mainly found on treated crop plants.

In conclusion, we found that *D. smithi* was both widespread and abundant on bamboo orchids throughout the lower Puna district of Hawaii island only one year after this species was detected. Statistical results showed that thrips adults were aggregated on flowers but the adaptive significance of this behavior is not known. In unsprayed dendrobium orchids, *D. smithi* was the dominant thrips species present and bamboo orchids appeared to be more attractive than dendrobium orchids. Possibly bamboo orchids could be used in or near commercial orchid plantings as a trap crop for *D. smithi* and treated with insecticides to protect the commercial planting.

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