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DISTRIBUTION OF CHILLI THRIPS, *SCIRTOTHRIPS DORSALIS* (THYSANOPTERA: THRIPIDAE), IN PEPPER FIELDS AND PEPPER PLANTS ON ST. VINCENT

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ABSTRACT

Scirtothrips dorsalis Hood is a significant pest of various vegetable, ornamental, and fruit crops. Its biology and management are little known in the agro-ecosystems in western hemisphere. We investigated distribution patterns of *S. dorsalis* in fields and plants of `Scotch Bonnet' pepper, *Capsicum chinense* Jacq., on St. Vincent in 2004 and 2005. *Scirtothrips dorsalis* adults and larvae were abundant on top leaves of the pepper plants followed by middle leaves, lower leaves, flowers and fruits. The spatial distribution of *S. dorsalis* adults and larvae on pepper was analyzed by using Taylor's power law and Iwao's patchiness regression. These results were compared with the Index of Dispersion, Mean Crowding, Green's Index and Lloyd's Patchiness Index. In Oct 2004, the distributions of *S. dorsalis* adults on the top leaves were aggregated in 24- and 48 m^2-plots. In the smaller plots adults were distributed in a regular pattern. The distribution of larvae on the top leaves was aggregated irrespective of plot size. In Williams Farms on Mar 2005, the distribution of adults was aggregated in the largest plots (48 m^2). In all other plots, the distribution of adults was regular as described by Taylor's power law and Iwao's patchiness regression. In Baptist Farms on March 2005, the distribution of adults according to both models was aggregated irrespective of plot size. The optimum number of samples from a 24 m^2 plot was 9 with a precision of 40% when there were 0.5 individuals per top leaf of 'Scotch Bonnet' pepper. However if the estimated density was 2 individuals per top leaf, 9 samples from a same sized area were sufficient at the 10% precision level. This information is essential to the development of a scouting-based integrated management program for *S. dorsalis*. Based on this information, incipient infestations of S. dorsalis easily can be detected by examining young top leaves.

Key Words: *Scirtothrips dorsalis*, spatial distribution, within plant distribution, pepper, invasive alien species, Caribbean

RESUMEN

Scirtothrips dorsalis Hood es una plaga importante de varias especies de hortalizas, plantas ornamentales y frutales, pero se conoce poco su biología y manejo. En los años 2004 y 2005 investigamos el patrón de la distribución en el campo de *S. dorsalis* en pimentón 'Scotch Bonnet" en un campo comercial en St. Vincent. Los adultos y las larvas de *S. dorsalis* fueron más abundantes en las hojas terminales de 'Scotch Bonnet' seguido el contéo de las hojas del centro, hojas inferior, y las partes reproductivas. El patrón de distribución del de adultos y larvas de *S. dorsalis* en el campo de pimentón 'Scotch Bonnet' fué determinado usando la lay de poder de Taylor y la regresión de Iwao's. Estos resultados fueron comparados con el Índice de Dispersión, punto máximo significativo de afluencia o población de estos (Mean Crowding), Green's Index y Lloyd's Patchiness Index. La distribución de adultos y larvas de *S. dorsalis* en las hojas terminales fué agregada (patrón de agregación) independientemente del tamaño de la parcela (6, 12, 24, y 48 m^2). En las frutas, la distribución de adultos fue agregada en pequeñas parcelas (6 y 12 m^2), pero en forma regular o al azar en las parcelas grandes (24 y 48 m^2). La distribución larval fue agregada (patrón de agregación) en las frutas en todas las parcelas. El número óptimo de la muestra fué 9 con un 40% de nivel de precisión, cuando hay 0.5 individuales por hoja terminales de pimentón 'Scotch Bonnet'. Entonces si el estimado de la densidad fué de 2 individuos por hoja terminal, luego 9 muestras serian suficientes a un nivel de precision del 10%. Fué observado daño económico en plantas con 0.5 to 2 individuos por hoja terminal.

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Scirtothrips dorsalis Hood is a major pest of various vegetable crops, cotton, citrus, and other fruit and ornamental crops in eastern Asia, Africa, and Oceania (Ananthakrishnan 1993, CABI/EPPO 1997, CABI 2003). This pest occurs on all above-the-ground plant parts of its hosts, and creates damaging feeding scars on them (Chang 1995). In India, *S. dorsalis* is a severe pest of chilli pepper and hence is known as the chilli thrips (Thirumurthi et al. 1972), and in Japan as the yellow tea thrips (Toda & Komazake 2002). Among the economically important hosts of this pest listed by Venette & Davis (2004) are banana, bean, cashew, castor, corn, citrus, cocoa, cotton, eggplant, grapes, kiwi, litchi, longan, mango, melon, onion, passion fruit, peach, peanut, pepper, poplar, rose, sacara, soybean, strawberry, sweet potato, tea, tobacco, tomato, and wild yams (*Dioscorea* spp.). The Florida Nursery, Landscape and Growers Association considers *S. dorsalis* one of the thirteen most dangerous exotic pest threats to their industry (FNGLA 2003). Venette & Davis (2004) indicated that the potential geographic distribution of *S. dorsalis* in North America would extend from southern Florida north to the Canadian border, as well as to Puerto Rico and the entire Caribbean region. It appears that most of Latin America is suitable for colonization by this alien invasive species. *Scirtothrips dorsalis* is a vector of various viral and bacterial diseases, including peanut bud necrosis virus, chlorotic fan spot virus of peanuts, and tomato spotted wilt virus (TSWV) (Amin et al. 1981; Mound & Palmer 1981; Ananthakrishnan 1993).

Efficient detection and reliable identification of *S. dorsalis* are key prerequisites for developing practices for managing it. Various methods have been employed by entomologists to determine the presence of *S. dorsalis*. Bagle (1993) and Gowda et al. (1979) sampled for this pest by dislodging larvae and adults from young shoots or inflorescences onto black cardboard and counting the recovered insects. Suwanbutr et al. (1992) rinsed thrips from plant material with 70% ethanol and counted individuals collected on a fine muslin sieve. Takagi (1978) constructed a sticky suction trap to monitor the flight of *S. dorsalis* and other tea pests. Okada & Kudo (1982) used a similar suction trap for monitoring flight behavior of *S. dorsalis* and other thrips. Saxena et al. (1996) reported that *S. dorsalis* adults were attracted to white sticky traps. Adults also may be attracted to yellowish-green, green, or yellow boards (Tsuchiya et al. 1995). Chu et al. (2006) evaluated the effectiveness of the non-sticky 'CC' trap illuminated with a light-emitting diode (Chu et al. 2003) for capturing *S. dorsalis* and other thrips. Seal and Baranowski (1992) separated *Thrips palmi*, a related species to *S. dorsalis*, from bean leaves by washing with 70% ethanol.

During 1984-2002, USDA-APHIS inspectors at various U.S. ports-of-entry reported *S. dorsalis* 89 times on imported plant materials belonging to 48 taxa (USDA 2003). Most commonly the pest was associated with cut flowers, fruits, and vegetables. On Jul 16, 2003, T. L. Skarlinsky, a Plant Protection and Quarantine officer, intercepted *S. dorsalis* at the port of Miami, Florida, on *Capsicum* spp. from St Vincent and the Grenadines, West Indies. This was the first interception at a U.S. port of this thrips on a shipment from a port of origin in the Western Hemisphere. Skarlinsky (2003) made a preliminary assessment of the distribution and abundance of *S. dorsalis* on St.Vincent and found it on pepper at several sites.

St.Vincent is a volcanic island located at latitude 13°15' N and longitude 61°12' W within the Windward Islands in the eastern Caribbean. Temperatures fluctuate between 18° and 32°C, the dry season extends from December through Jun, and the rainy season lasts from Jul through Nov. The island's average annual rainfall ranges from about 1,500 mm on the southeast coast to about 3,800 mm in the interior mountains. Vegetable and fruit crops are produced year round for domestic consumption and export.

There are no published reports on within-plant and field distribution patterns of *S. dorsalis*. Such information is essential in the development of tactics and strategies for managing this pest. Beginning in Oct 2004, we undertook studies on the spatial distribution patterns of *S. dorsalis* adults and larvae on St. Vincent, as part of a larger effort to determine the pest's host range, geographical distribution and natural enemies, and to develop efficient methods of detection, monitoring, and control. Here we report on the thrips' within plant distribution on pepper and spatial distribution in pepper fields.

MATERIALS AND METHODS

Within plant and field distributions of *S. dorsalis* were investigated in a field of `Scotch Bonnet' (Habanero type) pepper, *Capsicum chinense* Jacq., on Williams Farms in Oct during rainy season, 2004 (Field 1) and in Mar, 2005 (Field 2); and on Baptist Farms (Field 3) in Mar during dry season, 2005. All fields were located at Georgetown, St.Vincent, and each field was about 3,035 m^2. `Scotch Bonnet' pepper had been planted into the deep soil in each field 2-3 months prior to these studies. The plants were spaced 90 cm apart within the row with 1.2 m between rows. Plants were maintained by using standard cultural practices recommended for St. Vincent. The pepper plants were not treated with insecticides but they received the recommended fungicide and fertilizer applications. Plants were sprayed with mancozeb and chlorothalonil at 7-10 d intervals and irrigated weekly or as necessary through drip

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tubing. For the purpose of studying distribution patterns of *S. dorsalis*, an area of 332 m^2 of each field was divided into 60 equal plots, each 4.6 m long and 1.2 m wide, and each plot contained 5 pepper plants.

Within `Scotch Bonnet' Pepper Plant Distribution

Five plants were randomly selected from each of five plots at different locations in all three fields. From each plant, a set of 3-4 leaves was collected from each of the top, middle, and bottom strata. In addition, three flowers and three fruits were collected from each plant. Thus, from each plot 1 -20 leaves were collected from each pepper plant stratum, and 15 flowers and 15 fruits were collected per plot. All samples of each category from a plot were placed in zip-lock bags each labeled to indicate the field, plot, plant stratum, and plant part. Samples were transported to the laboratory for further processing. Adults and larvae in each sample were washed off the plant parts with 70% ethanol and collected by pouring the ethanol through a sieve (6.35 cm dia., 500 Tyler equivalent mesh; 25 micrometer opening; USA Standard Testing Sieve; ASTME-11 Specification, W. S. Tyler, Inc., made in USA) (Seal & Baranowski 1992). Identifications of adult and larval thrips were based on the morphology of adult and larval forms and their identities were confirmed with recent taxonomic keys (Mound & Kibby 1998). Adults of *S. dorsalis* were distinguished from other thrips based on body transparency and color, and the presence of a dark cuticular thickening medially on tergites III to VII. Tergites of *S. dorsalis* adults have three discal setae in the lateral microtrichial fields (Mound & Kibby 1998). Also the forewing cilia are straight. The larvae of *S. dorsalis* were separated from those of other thrips species based on color and size, and confirmed by observing the funnel shaped setae on the head and abdominal segment IX.

Within `Scotch Bonnet' Pepper Field Distribution

The within field distribution of *S. dorsalis* was studied in plots of four different sizes- 6, 12, 24, and 48 m^2. Spatial distribution of *S. dorsalis* in 'Scotch Bonnet' pepper fields was studied in two years (Oct, 2004 on Williams Farms and Mar, 2005 on both Williams and Baptist Farms) by collecting the terminal leaf contained in a group of 3-4 leaves at the tip of a branch. From each of five randomly selected plants/plot the terminal leaf was excised and placed separately in a ziplock bag to prevent escape of *S. dorsalis*. The bags were marked with the date, plot number, and plant number. All bags were transported to the laboratory for further processing by the method described above to record *S. dorsalis* adults and larvae in each leaf sample. Each year each field was sampled six times following the same procedure.

The spatial distribution patterns of *S. dorsalis* were determined by using Taylor's power law (Taylor 1961) and Iwao's patchiness regression (Iwao 1968). Taylor's power law parameters were obtained by the regression of $\log_{10}$-transformed variances, s^2, on $\log_{10}$-transformed mean number of *S. dorsalis* adults and larvae per sample, i.e., by means of the linear regression model: $\log s^2 = \log a + b \log x$ (Taylor 1961). According to this model a b value > 1 denotes a population with an aggregated distribution, a b value significantly < 1 denotes a regular distribution, and a b value not significantly different from 1 denotes a random distribution. The fit of each data set to the linear regression model was evaluated by calculating the r^2, *F*, *df*, and *P* values. Student's t-test was used to determine if the slopes (*b* values) obtained by means of the linear regression procedure were equal to 1, significantly < 1, or significantly >1 (Neter & Wasserman 1974). Separate regression equations were calculated for different sample types and plot sizes. Variation in plot size was achieved by pooling data from adjacent plots to obtain a range of sizes from the smallest (6 m^2) to the total field size. In a similar manner, Iwao's patchiness regression was calculated for each data set. Iwao's patchiness regression ($x^* = \alpha + bx$), which may be seen as parallel to Taylor's power law, is the regression of mean crowding, x^*, on the mean × (Lloyd 1967; Iwao 1968). The factor α depends on the size of the sampling unit and β is the index of aggregation in the population. The fit of each model to data from various plot sizes was determined based on the values of *r2*, *F*, *df*, and *P* as calculated by using the General linear model (GLM) procedure of SAS (SAS 1988). GLM procedures were also used to perform analyses of variance of dependent variables (log of the variance of adults in Taylor's power law, and mean number of adults in Iwao's patchiness regression) of data collected from the various plots.

An index of dispersion (ID) was calculated as follows:

$$ID = \frac{s^2}{x}$$

Where x is the mean number of *S. dorsalis* individuals per sample and s^2 is the sample variance. Values of ID greater than 1.0 indicate an aggregated distribution of samples. ID is distributed as a chi-square variable with n-1 degrees of freedom (Elliott 1977), and therefore provides a test of significant departure from randomness (i.e., a test of aggregation). A generalized pattern of *S. dorsalis* distribution was determined from Taylor's power law and Iwao's patchiness regression by combining the first set of data on *S. dorsalis* adults in terminal leaves from three fields (one field in 2004; two fields in 2005). Finally, Mean Crowding (m^*),

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Green's Index (C_x) and Lloyd's `Patchiness' Index (m^*/m) were calculated by combining data on *S. dorsalis* adults from terminal leaves collected in the above mentioned three fields.

$$\text{Mean Crowding, } m^* = m + \left(\frac{\delta^2}{m} - 1\right) \quad \text{(i)}$$

$$m = \sum_{j=1}^{Q} \frac{x_j}{Q} \quad \text{(ii)}$$

In equation (ii), m = mean density; x^j = no. individuals/plot (Q); j = plots (1 – Q).

$$\delta^2 = \frac{\sum_{j=1}^{Q} x_j^2 - \left[\left(\sum_{j=1}^{Q} x_j\right)^2 / Q\right]}{Q} \quad \text{(iii)}$$

δ^2 = the square of the variance.

Thus, in equation (i), mean crowding equals the difference between the ratio of the variance to mean density minus 1 plus the mean density itself. In a random distribution, the variance and mean density are equal, so the quantity in parentheses disappears, and m* and m become equal. In the instance of Lloyd's Patchiness Index, the value of m* is divided by m (m^*/m) or [m + (δ^2/m – 1)]/m. Green's Index can be calculated as: (δ^2/m – 1)/($\sum$x – 1).

These parameters were compared with other characterizations of the *S. dorsalis* distribution pattern.

Sample Size Requirements

In order to estimate the population density at a given level of reliability, the number of samples, *n*, required for a particular plot size was determined by the equation (Wilson & Room 1982):

$$N = c^2 t a x^{b-2}$$

Where *c* is the reliability (half of the width of the confidence interval as a percentage of the mean), *a* and *b* are the coefficients of Taylor's power law, *x* is the mean density, and *t* is Student's t-value determined with *n* - 1 degrees of freedom. This *t* value is approximately 2.0 when *n* is large. Sample sizes were determined at three levels of precision (0.10, 0.20, and 0.40) for densities of 0.5, 1.0, and 2.0 adults or larvae per sample. These densities were selected based on the number of *S. dorsalis* collected per sample during the two-year study, and on our observation of economic damage associated with this range of pest density.

Statistical Analysis

Data on the within plant distribution were subjected to square root (x + 0.25) transformation to stabilize error variance (Steel & Torrie 1980). Transformed data were analyzed with software provided by Statistical Analysis System (SAS 1988). General linear model procedures were used to perform the analysis of variance. The Waller-Duncan K ratio *t* test was used to separate treatment means where significant (P < 0.05) differences occurred (Waller & Duncan 1969).

Results and Discussion

Within Plant Distribution of *S. dorsalis*

We found *S. dorsalis* on all above-ground pepper plant parts in three fields during Oct 2004 (rainy season), and Mar 2005 (dry season), respectively (Table 1). In Field 1 (rainy season), the mean number of *S. dorsalis* adults and larvae was greatest on the top leaves, 2nd greatest on middle leaves and least on bottom leaves, flowers, and fruits (adults: F = 7.77; df = 4, 15; P < 0.05; larvae: F = 13.93; df = 4, 15; P < 0.05; total: F = 16.88; df = 4, 15; P < 0.05). The mean number of *S. dorsalis* adults and larvae did not differ statistically among those found on the bottom leaves, flowers, and fruits. The lowest number of adults was found on fruits, and the fewest larvae were found in flowers, but these means were not significantly different from the corresponding means for bottom leaves and fruits.

In Field 2 (dry season), the mean numbers of *S. dorsalis* adults and larvae were also larger on the top leaves than on other plant parts; although not significantly larger than those on the middle leaves (adult: F = 3.36; df = 4, 15; P < 0.05; larva: F = 7.61; df = 4, 15; P < 0.05) (Table 1). The mean number of adults was greater on the middle leaves than on bottom leaves, flowers, and fruits, but these differences were not statistically significant. The mean number of larvae was lowest in the flowers, although not significantly lower than on bottom leaves and fruits. The cumulative mean number of *S. dorsalis* was the greatest on the top leaves followed by middle leaves and finally by the other plant parts (total: F = 16.88; df = 4, 15; P < 0.05).

In Field 3 (dry season), the mean number of S. dorsalis adults on the top leaves was significantly larger than on any other plant part (adult: F = 4.94; df = 4, 15; P < 0.05) (Table 1). Similarly, the mean number of larvae was the largest on the top leaves, but not significantly larger than on the middle leaves (larva: F = 6.45; df = 4, 15; P < 0.05). When adult and larval data were combined, the mean number of *S. dorsalis* on the top leaves was significantly greater than on any other plant part (total: F = 12.93; df = 4, 15; P < 0.05). Although

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TABLE 1. WITHIN PLANT DISTRIBUTION OF *S. DORSALIS* ADULTS AND LARVAE ON `SCOTCH BONNET' PEPPER PLANTS IN THREE FIELDS IN ST. VINCENT BASED ON SAMPLES TAKEN DURING OCT 2004 (FIELD 1), AND MAR 2005 (FIELDS 2 AND 3).

	Mean number of *Scirtothrips dorsalis*		
Location on Pepper plant	Adults	Larvae	Total
Field 1 (Oct 2004, rainy season)			
Top leaf	4.50 a	5.50 a	10.00 a
Middle leaf	1.75 b	2.00 b	3.75 b
Bottom leaf	0.50 b	0.75 c	1.25 c
Flower	0.75 b	0.25 c	1.00 c
Fruit	0.25 b	1.00 bc	1.25 c
Field 2 (Mar 2005, dry season)			
Top leaf	2.25 a	4.25 a	6.50 a
Middle leaf	1.00 ab	2.25 ab	3.25 b
Bottom leaf	0.25 b	0.75 bc	1.00 c
Flower	0.50 b	0.25 c	0.75 c
Fruit	0.50 b	0.75 bc	1.25 c
Field 3 (Mar 2005, dry season)			
Top leaf	3.75 a	4.00 a	7.75 a
Middle leaf	1.25 b	1.75 ab	3.00 b
Bottom leaf	0.75 b	0.50 bc	1.25 bc
Flower	0.25 b	0.25 c	0.50 c
Fruit	0.50 b	1.00 bc	1.50 bc

Means within a column for each field followed by the same letter do not differ significantly ($P > 0.05$, Waller-Duncan k ratio procedure (Waller & Duncan 1969)).

the number found on middle leaves was larger than either on fruits or bottom leaves, these differences were not statistically significant. The least number of life forms was recorded in flowers, but this number was not statistically different from the number either on the bottom leaves or on the fruits.

The within plant distribution of *S. dorsalis* on pepper differs from that of *Thrips palmi* Karny in that the latter is very abundant in pepper flowers (Seal 1996, 2001).

Within Field Distribution of *S. dorsalis* in 2004

In 2004, for adults (Table 2) the values of r^2 obtained with both Taylor's power law (r^2 = 0.54 – 0.99) and Iwao's patchiness distribution (r^2 = 0.45 – 0.99) were moderate to large for all plot sizes.

TABLE 2. TAYLOR'S POWER LAW AND IWAO'S PATCHINESS REGRESSION PARAMETERS PERTAINING TO THE DISTRIBUTION OF *S. DORSALIS* ADULTS IN A 'SCOTCH BONNET' PEPPER FIELD BASED ON TOP LEAF SAMPLES ON WILLIAMS FARMS, ST. VINCENT DURING OCT 2004.

	Taylor's power law			Iwao's patchiness regression		
Plot size (m^2)	r^2	a	b	r^2	α	β
6	0.54	0.07	0.93 REG	0.45	0.31	0.93 REG
12	0.63	0.03	0.94 REG	0.62	0.19	0.92 REG
24	0.76	0.02	1.08 AGG	0.73	0.008	1.05 AGG
48	0.99	0.009	1.20 AGG	0.99	-0.28	1.29 AGG

AGG, aggregated distribution, b significantly > 1; REG, regular distribution, b significantly < 1. These distributions are significant at $P \leq 0.05$ based on Student's t-test. Numbers of plots (n) are 48, 24, 12, and 6 for the fields sized at 6, 12, 24, and 48 m^2, respectively. (Taylor's Power law. 6 m^2: F =54.01, df = 1, 46, P = 0.001; 12 m^2: F = 38.68, df = 1, 22, P = 0.001; 24 m^2: F = 32.79, df = 1, 10, P = 0.001; 48 m^2: F = 94.21, df = 1, 4, P = 0.001; Iwao's patchiness regression. 6 m^2: F = 37.77 , df = 1, 46, P = 0.0001; 12 m^2: F = 36.12, df = 1, 22, P = 0.0001; 24 m^2: F = 26.52, df = 1, 10, P = 0.0004; 48 m^2: F = 112.23, df = 1,4, P = 0.0005).

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This indicates a good fit of both models to the data on adults with top leaves as the sampling unit. In both models, the values of *F* for various plot sizes were significant (Table 2). The distribution of adults in the two larger plots sizes (24 and 48 m^2) was aggregated. The slope values for these two plot sizes in either model were significantly greater than 1.00 (P > 1.00). For larval populations on top leaves (Table 3), the r^2 values obtained with both Taylor's power law and Iwao's patchiness regression showed a good fit to the data (r^2 = 77 – 99) for all of the plot sizes. Similarly, the *F* values in both models for all plot sizes were significant. The slope in either model was significantly greater than 1.00 (P > 0.05) indicating that the distribution of larval populations in all plots, irrespective of size, was aggregated.

With respect to data collected on *S. dorsalis* adults in March 2005 on Williams Farms, the analyses with from both Taylor's power law and Iwao's patchiness regression were in agreement that the distribution of adults on top leaves was regular irrespective of plot size (Table 4). The values of r^2 from Taylor's power law ranged from 0.21 to 0.99, indicating moderate to good fit to the data collected from 6, 12, and 48 m^2 plots. The values of r^2 and F (r^2 = 0.09; F = 0.95, df = 1, 10, P = 0.35) were low for data from 24 m^2-plot. The value of r^2 (r^2 = 0.07) from Iwao's patchiness regression also was low for 24 m^2-plot (indicating poor fit to the data). The *F* value (F = 0.74, df = 1, 10, P = 0.409) for the corresponding data set was insignificant. The values of r^2 ranged from 0.24 to 0.99 for the 6, 12, and 48 m^2 plots (indicating a moderate to good fit to the data). The values of *F* calculated for the data of these plots were significant.

The distribution patterns of *S. dorsalis* adults in 2004 was regular in smaller plots (6- and 12 m^2-plots) and aggregated in larger plots (24- and 48 m^2-plots). However, in 2005 the distribution of adults was regular irrespective of plot size. The distribution pattern of *S. dorsalis* larvae was aggregated in all plot sizes. Both Taylor's power law and Iwao's patchiness regression were in agreement in describing the distribution of *S. dorsalis* adults in pepper fields.

On Baptist Farms (Table 5) the adult distribution on top leaves based on Taylor's power law was

TABLE 3. TAYLOR'S POWER LAW AND IWAO'S PATCHINESS REGRESSION PARAMETERS PERTAINING TO THE DISTRIBUTION OF *S. DORSALIS* LARVAE IN A '*SCOTCH BONNET*' PEPPER FIELD BASED ON TOP LEAF SAMPLES ON WILLIAMS FARMS, ST. VINCENT DURING OCT 2004.

Plot size (m^2)	Taylor's power law			Iwao's patchiness regression		
	r^2	a	b	r^2	α	β
6	0.59	-1.49	2.52 AGG	0.89	-13.07	1.65 AGG
12	0.76	-2.63	3.33 AGG	0.92	-19.06	1.88 AGG
24	0.98	-3.74	4.11 AGG	0.99	-19.48	1.90 AGG
48	0.99	-5.64	5.49 AGG	0.99	-29.87	2.30 AGG

AGG, aggregated distribution, b significantly > 1. These distributions are significant at $P \le 0.05$ based on Student's *t*-test. Numbers of plots (n) are 48, 24, 12, and 6 for fields sized at 6, 12, 24, and 48 m^2, respectively. (Taylor's Power law. 6 m^2: F =66.30, df = 1, 46, P = 0.001; 12 m^2: F = 70.07, df = 1, 22, P = 0.001; 24 m^2: F = 73.11, df = 1, 10, P = 0.001; 48 m^2: F = 94.21, df = 1, 4, P = 0.001; Iwao's patchiness regression. 6 m^2: F = 2.77 , df = 1, 46, P = 0.0001; 12 m^2: F = 247.7, df = 1, 22, P = 0.0001; 24 m^2: F = 390.90, df = 1,10, P = 0.0001; 48 m^2: F = 332.23, df = 1, 4, P = 0.0001).

TABLE 4. TAYLOR'S POWER LAW AND IWAO'S PATCHINESS REGRESSION PARAMETERS PERTAINING TO THE DISTRIBUTION OF *S. DORSALIS* ADULTS IN A 'SCOTCH BONNET' PEPPER FIELD BASED ON TOP LEAF SAMPLES ON WILLIAMS FARMS, ST. VINCENT DURING MAR 2005.

Plot size (m^2)	Taylor's power law			Iwao's patchiness regression		
	r^2	*a*	*b*	r^2	α	β
6	0.21	0.16	0.54 REG	0.24	1.00	0.55 REG
12	0.40	0.12	0.64 REG	0.51	0.65	0.70 REG
24	0.09	0.47	-1.47 REG	0.07	3.40	-1.21 REG
48	0.99	-0.55	5.18 AGG	0.99	-4.87	4.57 AGG

REG, regular distribution, b significantly < 1; RAN, random distribution, *b* not significantly different from 1. These distributions are significant at $P \le 0.05$ based on Student's *t*-test. Numbers of plots (*n*) are 48, 24, 12, and 6, and 48 for fields sized at 6, 12, 24, and 48 m^2, respectively. (Taylor's Power law. 6 m^2: F =12.42, df = 1, 46, P = 0.0001; 12 m^2: F = 14.65, df = 1, 22, P = 0.0001; 24 m^2: F = 0.95, df = 1, 10, P = 0.35; 48 m^2: F = 99.21, df = 1, 4, P = 0.0001; Iwao's patchiness regression. 6 m^2: F = 14.88 , df = 1, 46, P = 0.0001; 12 m^2: F = 23.30, df = 1, 22, P = 0.0001; 24 m^2: F = 0.74, df = 1, 10, P = 0.409; 48 m^2: F = 211.30, df = 1, 4, P = 0.0001).

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TABLE 5. TAYLOR'S POWER LAW AND IWAO'S PATCHINESS REGRESSION PARAMETERS PERTAINING TO THE DISTRIBUTION OF *S. DORSALIS* ADULTS IN A 'SCOTCH BONNET' PEPPER FIELD BASED ON TOP LEAF SAMPLES ON BAPTIST FARMS, ST. VINCENT DURING MAR 2005.

	Taylor's power law			Iwao's patchiness regression		
	r^2	a	b	r^2	α	β
6	0.60	-0.25	2.10 AGG	0.64	-0.96	1.71 AGG
12	0.64	-0.32	2.57 AGG	0.57	-1.16	1.87 AGG
24	0. 92	-0.50	3.33 AGG	0.98	-2.89	2.81 AGG
48	0.98	-0.63	4.00 AGG	0.99	-3.57	3.23 AGG

AGG, aggregated distribution, b significantly > 1; REG, regular distribution, b significantly < 1. These distributions are significant at $P \le 0.05$ based on Student's t-test. Numbers of plots (△) are 48, 24, 12, and 6 for fields sized at 6, 12, 24, and 48 m², respectively. (Taylor's Power law. 6 m²: F =68.72, df = 1, 46, P = 0.0001; 12 m²: F = 38.32, df = 1, 22, P = 0.0001; 24 m²: F = 109.18, df = 1, 10, P = 0.0001; 48 m²: F = 333.56, df = 1, 4, P = 0.0001; Iwao's patchiness regression. 6 m²: F = 80.67, df = 1, 46, P = 0.0001; 12 m²: F = 28.83, df = 1, 22, P = 0.0001; 24 m²: F = 471.28, df = 1, 10, P = 0.0001; 48 m²: F = 615.17, df = 1, 4, P = 0.0001).

regular in the smallest plots (6 m²) and aggregated (b > 1.00; P < 0.05) in all of the larger plots. However Iwao's patchiness regression showed an aggregated adult distribution in all plot sizes including the smallest. The high r² values (r^2 = 0.61 - 0.99) indicated a good fit of the data from all plot sizes to both Taylor's power law and Iwao's patchiness regression. The F values calculated from the data of all plot sizes in both models were significant.

General Pattern of Distribution of *S. dorsalis* Adults

When the cumulative data on adults from three fields, two on Williams Farms (Field 1: Oct 2004, and Field 2: Mar 2005), and one on Baptist Farms (Field 3: Mar 2005) were considered, the distribution of *S. dorsalis* adults on top leaves was aggregated irrespective of plot size (Table 6). The value of b ranged from 1.10 to 1.63 for Taylor's power law and from 1.28 to 1.82 for Iwao's patchiness regression. Hence both methods consistently gave slope values corresponding to an aggregated distribution from cumulative data involving one set of samples collected in the rainy season and two collected in the dry season.

The values of Index of Dispersion, Mean Crowding and Lloyd's Patchiness Index were >1 in all plots indicating an aggregated pattern of distribution of *S. dorsalis* adults in top leaves (Table 7). Green's Index did not fit the data on adults on terminal leaves and hence showed negative values for plots of all sizes. Both Taylor's power law and Iwao's patchiness regression were in agreement with Index of Dispersion, Mean Crowding and Lloyd's Patchiness Index in denoting an aggregated pattern of distribution of *S. dorsalis* adults on top leaves.

TABLE 6. TAYLOR'S POWER LAW AND IWAO'S PATCHINESS REGRESSION EQUATIONS PERTAINING TO GENERAL DISTRIBUTION PATTERNS OF *S. DORSALIS* ADULTS ON TOP LEAVES OF `SCOTCH BONNET' PEPPER BASED ON CUMULATIVE DATA COLLECTED FROM THREE FIELDS, TWO ON WILLIAMS FARMS (FIELD 1, OCT 2004 AND FIELD 2, MAR 2005), AND ONE ON BAPTIST FARMS (FIELD 3, MAR 2005).

Plot size (m²)	n	r^2	Equation
		Taylor's power law	
48	6	0.83	$\log s^2 = -0.02 + 1.63 \log x$
24	12	0.73	$\log s^2 = -0.01 + 1.51 \log x$
12	24	0.56	$\log s^2 = 0.02 + 1.22 \log x$
6	48	0.43	$\log s^2 = 0.04 + 1.10 \log x$
		Iwao's patchiness regression	
48	6	0.89	$x^* = -0.95 + 1.82\, x$
24	12	0.82	$x^* = -0.88 + 1.77\, x$
12	24	0.59	$x^* = -0.27 + 1.36\, x$
6	48	0.56	$x^* = -0.10 + 1.28\, x$

In the table n is the number of samples, r^2 is the proportion of the sum of squares accounted for by the regression, x represents the mean of the samples, s^2 is the variance, and x^* is the mean crowding index. Slopes (b values) of all equations are significantly different from 1.0 (P > 0.05), indicating aggregated distributions of *Scirtothrips dorsalis* adults on terminal leaves.

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TABLE 7. VARIOUS STATISTICAL INDICES PERTAINING TO THE GENERAL PATTERN OF DISTRIBUTION OF *S. DORSALIS* ADULTS ON TOP LEAVES BASED ON CUMULATIVE DATA COLLECTED FROM THREE `SCOTCH BONNET' PEPPER FIELDS, TWO ON WILLIAMS FARMS (FIELD 1, OCT 2004 AND FIELD 2, MAR 2005), AND ONE ON BAPTIST FARMS (FIELD 3, MAR 2005).

Plot size (m^2)	Index of Dispersion	Mean Crowding	Green's Index	Lloyd's Mean Crowding
6	1.23	1.30	0.02	1.24
12	1.18	1.25	0.01	1.19
24	1.16	1.24	0.004	1.17
48	1.23	1.30	0.02	1.01

Value > 1.0 indicates an aggregated pattern of distribution.

Southwood (1978) observed that when a population in an area becomes sparse, the chances of an individual occurring in any sample unit are so low that the distribution is effectively random. In the present study, the overall abundance of *S. dorsalis* was low but frequent occurrence in various samples indicated an aggregated pattern. Such aggregated distribution in the field is also typical of *T. palmi* (Seal 1996; Seal & Stansly 2000). Southwood (1978) also reported that the dispersion of the initial insect invaders of a crop is often random. We found that S. dorsalis adults were localized in certain parts of the crop field. The infestation started along 6 m wide strip at one edge of one field and proceeded with the prevailing wind from south to north along a roughly 6 m-wide band.

Number of Leaf Samples Necessary for Reliably Estimating S. dorsalis.

Mean densities of S. dorsalis adults ranged from 0.5 to 1.0 per top leaf sample in fields that suffered economic damage (Seal & Ciomperlik, field observation). This information was used to determine the optimum sample size (OSS) for estimating densities of *S. dorsalis* adults in pepper fields based on the method of Wilson & Room (1982). The OSS becomes large when the desired level of precision is high (i.e., within 10% of the mean) and when the average density of insects per sample is low. We found that given an average adult thrips density of 0.5 per sample and a 10% precision level, the number of leaf samples required to estimate *S. dorsalis* abundance in 24 m^2 is 140 (Table 8). It would be prohibitively labor intensive to collect such a large number of samples from a small pepper field. By relaxing the precision level to 40% in this example, the number of samples required to obtain an estimate of the population density can be reduced to 9 for the same size field (24 m^2), and this is practical. The population density of *S. dorsalis* strongly affects the number of samples required. Thus, if the density were assumed to be 2 adults per sample, then number of samples needed for an estimate at the 10% precision level would be 9.

The following may be concluded: (1) *S. dorsalis* populations maintained pest status in dry and rainy seasons alike. (2) *S. dorsalis* populations

TABLE 8. NUMBER OF TERMINAL LEAF SAMPLES REQUIRED FOR RELIABLE ESTIMATES OF *S. DORSALIS* ADULT POPULATION DENSITIES IN `SCOTCH BONNET' PEPPER FIELDS ON ST. VINCENT.

		Sample size* at the following levels of precision		
Field size (m^2)	Mean adults per sample	0.10	0.20	0.40
6	0.5	94	23	6
6	1.0	36	9	2
6	2.0	14	4	1
12	0.5	93	25	6
12	1.0	32	8	2
12	2.0	10	3	1
24	0.5	140	35	9
24	1.0	36	9	2
24	2.0	9	2	1

*Sample size values each rounded to the nearest whole number.

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tend to be most abundant on top leaves; (3) S. dorsalis populations tend to be aggregated irrespective of plot size; (4) the optimum sample size in `Scotch Bonnet' pepper plots, when the estimated population density is 2.0 per top leaf sample, is 9 with a 10% precision level. The above information should be considered in developing management programs against *S. dorsalis* for various host crops.

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