Scirtothrips dorsalis (Thysanoptera: Thripidae): Scanning Electron Micrographs of Key Taxonomic Traits and a Preliminary Morphometric Analysis of the General Morphology of Populations of Different Continents

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SCIRTOTHRIPS DORSALIS (THYSANOPTERA: THRIPIDAE): SCANNING ELECTRON MICROGRAPHS OF KEY TAXONOMIC TRAITS AND A PRELIMINARY MORPHOMETRIC ANALYSIS OF THE GENERAL MORPHOLOGY OF POPULATIONS OF DIFFERENT CONTINENTS

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Abstract

The chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) is an emerging pest of many economically important vegetable and ornamental crops grown in the United States. Accurate identification of this pest is a fundamental requirement in development of effective quarantine and management strategies. Using scanning electron microscopy, high resolution images of important taxonomic traits of this pest were produced, which will aid research, regulatory and extension personnel to identify this pest. High resolution images were obtained for identifying characters of *S. dorsalis* including tergites with antecostal ridges; head with 3 pairs of ocellar setae, metanotum presenting longitudinal striations with medially located pair of setae; veins of forewing presenting widely spaced setae; segment VIII with complete posteromarginal comb of microtrichia; and sternites lacking discal setae but covered with rows of microtrichia except in the antero-medial region. Further, a preliminary comparison of morphological traits of *S. dorsalis* populations from different geographical regions was conducted, which can help in understanding the phenotype of this pest. Specimens of *S. dorsalis* were obtained from 5 distinct geographical regions: New Delhi, India; Shizouka, Japan; Negev, Israel; St. Vincent and Florida in the United States. Fourteen morphological characters of each population of *S. dorsalis* were measured and compared among the 5 populations. No significant differences were observed between the body lengths of the various *S. dorsalis* populations, which ranged from 0.85 mm (Negev) to 0.98 mm (Florida). When comparing 12 morphological characters, we found no significant differences among New Delhi, St. Vincent, Negev and Florida populations. However, when *S. dorsalis* populations of these 4 regions were compared with Shizouka, significant differences were detected for either 2 or 5 morphological characters depending on the population, suggesting the Japan population is more robust i.e., longer and wider mesothorax and metathorax, and wider abdomens. Also, the mean lengths of body size among different populations did not vary directly or inversely with latitude.

Key Words: chilli thrips identification, high resolution, morphometric analysis

Resumen

El trips de pimiento, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) es una plaga emergente de muchos cultivos horticolas y ornamentales de importancia económica en los Estados Unidos. La identificación exacta de esta plaga es un requisito fundamental en el desarrollo de cualquier estrategia eficaz de cuarentena y de gestión. Usando la imagen de microscopio electrónico de barrido de alta resolución de esta plaga se produjo lo que se ayuda de los productores y el personal de extensión para identificar esta plaga con gran facilidad. Además, una comparación de las características morfológicas de las poblaciones de *S. dorsalis* de diferentes regiones geográficas se llevó a cabo lo que puede ayudar en la comprensión del fenotipo de esta plaga. Se obtuvieron especímenes de *S. dorsalis* de cinco regiones geográficas distintas: Nueva Delhi, India; Shizouka, Japan; Negev, Israel; St. Vincent y la Florida en los Estados Unidos. Se medido y se compararon catorce caracteres morfológicos de cada población de *S. dorsalis* entre las cinco poblaciones. No se observaron diferencias significativas entre la longitud del cuerpo de las diferentes poblaciones de *S. dorsalis*, que varia entre 0.85 mm (Negev) a 0.98 mm (Florida). Al comparar los 12 caracteres morfológicos, no se encontraron diferencias significativas entre las poblaciones de Nueva Delhi, San Vicente, Negev y de la Florida. Sin embargo, cuando se compararon las poblaciones de *S. dorsalis* de estas cuatro regiones con la poblacion de Shizouka, se detectaron diferencia significativas en 2 o 5 caracteres morfológicos según la población, la cual indica que la población de Japón es mas robusta (es decir, el mesotórax y el metatórax son más largos y anchos, el abdomen es más ancho). Además, el promedio de la longitud del cuerpo entre las poblaciones no varía en relación directa o inversamente con la latitud geográfica.

Scirtothrips dorsalis Hood commonly known as the Assam thrips, castor thrips, chilli thrips, berry thrips or yellow tea thrips (Dev 1964; Asaf-Ali et al. 1973; Seal & Klassen 2005; Masui 2007) is a highly polyphagous adventive pest species that originated in south Asia. With liberalization of trade in agricultural products and the historic growth in tourism during the past 3 decades, this tropical and subtropical pest has spread to all habitable continents except Europe. *S. dorsalis* has been intercepted numerous times on various flower, fruit and vegetable consignments imported into Europe, but failed to establish a durable population on that continent (Vierbergen & Gagg 2009). Recently an incursion was also noted in a glasshouse of a botanical garden in the United Kingdom, but eradication measures were taken and pest was controlled successfully (Annie-Sophie Roy, pers. comm.). In the Americas, *S. dorsalis* gained its first foothold in Venezuela, where, since 2000, it has been causing damage to grapevine, *Vitis vinifera* L. (Vitaceae) (MacLeod & Collins 2006; Seal et al. 2010). Since 2003 when Skarlinsy (2003) found *S. dorsalis* established in St. Vincent, this species has been found widely distributed in the Lesser Antilles and Puerto Rico (Ciomperlik & Seal 2004; Klassen & Seal 2008) and Surinam (Ciomperlik et al. 2005). In 2005 *S. dorsalis* was found established in Palm Beach County Florida on ‘Knockout’® rose (Rosa X ‘Radrazz’) (Coolidge 2005), and in 3 counties of Texas. Now *S. dorsalis* is established in 30 counties in Florida and in 8 counties in Texas with confirmations in Alabama and Louisiana in 2009 and New York in 2010. In Florida, the pest became rapidly distributed throughout the state by the retail trade in nursery plants. Osborne (2009) found this pest reproducing on more than 50 plant species in Florida.

Detection of *S. dorsalis* larvae and adults in fresh vegetation is difficult due to their thigmotactic behavior and tiny stature (larvae < 1 mm; adults < 2 mm). Eggs are deposited within plant tissues and may take a week for the larvae to emerge. Consequently, chances of transportation of *S. dorsalis* through state, regional, and international trade of plant materials for all life stages is high (Seal and Kumar 2010). *S. dorsalis* life stages occur on meristems and other tender tissues of all above ground parts of the host plant. The feeding by this pest causes extensive areas to be darkened with scars on various plant parts, stunted growth of young leaves, reduced yield and unmarketable fruit.

Kuriyama et al. (1991) reported *S. dorsalis* to be a weak flier, and that the most important route of invasion into the greenhouse was by introduction of infested pots and not aerial immigration. According to Meissner et al. (2005) the major pathways of spread of this pest are air passengers and crew and their baggage, mail including mail delivered by express carriers, smuggled plant parts and windborne dispersal.

Genus *Scirtothrips* comprises more than 100 species of thrips and *S. dorsalis* is one of the most studied pests in the genus due to their economic importance and global distribution. Due to the small size of thrips and morphological similarities, the identification of species in this genus is a challenge to non-experts. The morphological traits of taxonomic importance for identification of *S. dorsalis* are well defined in the literature. With slide mount images, Hoddle & Mound (2003) illustrated a taxonomic identification key of *S. dorsalis* along with 20 other *Scirtothrips* species in Australia. They noted that only 2 of the 21 species of *Scirtothrips* have microtrichial fields extending fully across the sternites, i.e., *S. aurantii* and *S. dorsalis*. In *S. aurantii*, the microtrichia almost cover the entire surface of the sternites, whereas in *S. dorsalis* they are restricted to a complete band across the posterior half of each sternite. Thus, a clear and accurate taxonomic characterization is required to distinguish between such species of *Scirtothrips*. The taxonomic traits of *S. dorsalis* illustrated by Skarlinsky (2004) and Hoddle (2009) illustrated with thrips slide mount images are very helpful. Nevertheless, photographs taken at higher magnifications and resolutions using advanced techniques like Scanning Electron Microscope (SEM) would be especially helpful to research, regulatory and extension personnel and, also, for teaching. The accurate and rapid identification of this invasive and potentially devastating pest is essential to implement effective plant quarantine and integrated control strategies.

A significant pathway of *S. dorsalis* into the Caribbean from south Asia was assumed to be passengers whose ancestors had arrived from India as indentured servants following the abolition of slavery (Klassen et al. 2002). Many of these families are known to travel back and forth to visit relatives in India. Thus, we conjectured that the south Florida strain was derived from the populations in India. However, when we compared measurements of morphological features of the Florida 2009 strain to measurements of a population in India reported by Raizada (1976), we noted that the 5 characters (body length, antennal length, prothorax length, forewing length and hind wing length) out of 9 characters studied by Raizada was bigger in Florida (2009) strain. On the other hand, the Florida population of *S. dorsalis* was smaller compared with Indian population (1976) in 3 morphological characters, i.e., head length, abdomen width and ovipositor length. Thus, we felt there might be merit in making a preliminary comparison of the measurements of the morphological traits selected by Raizada with corresponding measurements of traits of populations from different continents and other widely separated locations.

The objectives of this study were a) to produce high-resolution images of identifying characters of *S. dorsalis* using SEM, and b) to determine if certain morphological characters of *S. dorsalis* adults differ significantly in size among populations from different geographic regions of the world.

Materials and Methods

Sample Collection

Year of sample collection, geographical location (longitude and latitude), host plant, preservative, and sample source are reported in Table 1. Samples of *S. dorsalis* were obtained from 5 widely separated locations: New Delhi, India (2008); Shizouka, Japan (2009); St. Vincent Island, West Indies (2006); Negev, Israel (2009); and Florida, USA (2009). The specimens from New Delhi, India reported by Raizada in 1976 had been sampled from cotton (*Gossypium hirsutum* L.), castor (*Ricinus Communis* L.), pepper (*Capsicum* spp.) and other crops. Actual sampling technique depended on the individual sampler, but once adults were collected, they were immediately placed in 70-95% ethanol and eventually mailed to the Tropical Research and Education Center, UF/IFAS, Homestead, Florida, maintained at -20 °C and later slide mounted for morphometric analysis.

Identification of Specimens

Thrips specimens were transferred to vials containing 75% alcohol for 10 min and then for 5 min to a 10% KOH (potassium hydroxide solution) solution prepared in 50% ethanol. While placed in KOH solution, the insect was gently pounded in the abdominal region using a fine insect pin to aid the removal of its abdominal contents. For gradual dehydration, the speci-

TABLE 1. *SCIRTOTHRIPS DORSALIS* POPULATIONS AND HOSTS FROM WHICH SAMPLES WERE COLLECTED IN DIFFERENT YEARS.

Year collected	Geographical location (latitude and longitude)	Host	Preservative	Source of specimens
1976[1]	India—New Delhi; 28.38 N, 77. 12 E	Various[2]	70% alcohol	Dr. Usha Raizada, Lady Irwin College -University of Delhi, India
2008	India—New Delhi; 28.38 N, 77. 12 E	Pepper	95% ethanol	Dr. D. R. Seal, University of Florida, Homestead, Florida, USA
2006	St. Vincent Island, West Indies; 13.15 N, 61.12 W	Pepper	70% ethanol	Mr. M. L. Richards, Ministry of Agriculture and Fisheries, St. Vincent, Richmond Hill, Kingstown, St. Vincent and the Grenadines, West Indies
2009	United States—Homestead, Florida; 25.28 N, 80.28W	Pepper	70% ethanol	Mr V. Kumar and Dr. D. R. Seal, University of Florida, Homestead, Florida, USA
2009	Israel—Negev; 30.50 N, 34.91 E	Pepper	95% ethanol	Dr. Phyllis Weintraub, Entomology Unit, Gilat Research Center, D. N. Negev 85280, Israel
2009	Japan—Shizouka; 34.55 N, 138.19 E	Tea	95% ethanol	Dr. Masui Shinichi, Shizuoka Prefectural Research Institute of Agriculture and Forestry Tea Research Center, 1706-11 Kurasawa, Kikugawa-cho, Ogasa-gun, Shizuoka 439-0002, Japan

[1]Population previously reported by Raizada (1976).
[2]Mexican marigold (*Tajetes erecta* L.), pomegranate (*Punica granatum* L.), cotton (*Gossypium* spp.), castor (*Ricinus communis* L.), pepper (*C. annum*) and many others.

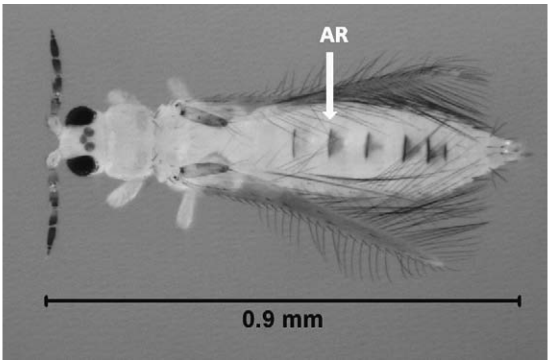

Fig. 1. Dorsal view of *S. dorsalis* adult presenting dark brown antecostal ridge (AR) on tergites.

men was passed through a series of alcohol concentrations starting from 65%, followed by 75%, 85%, 90% and 95% for 5-8 min in each concentration. Each specimen was placed ventrally on a slide with a small drop of Hoyerís mounting media and covered with a glass cover slip. The adult female thrips were identified and their morphological traits were compared using taxonomic characteristics described by Hoddle and Mound (2003), Skarlinsky (2004) and Hoddle et al. (2009) with a dissecting microscope at a minimum of 10X magnification. Further, *S. dorsalis* samples collected from Florida were subjected to morphological characterization using scanning electron microscopy to produce high quality pictures, displaying features used for its identification.

Scanning Electron Microscopy

Adult *S. dorsalis* females from Florida were collected in 30% ethanol and dehydrated in a graded series of 50%, 70%, 95%, and twice in 100% ethanol for 30 min in each gradation. Samples were kept in 100% ethanol overnight. On the next d, samples were dried in 50% and 100% of hexamethyldisilizane (HMDS:ethanol) for 30 min each. Thereafter, samples were sputter coated with gold/palladium using the Hummer sputtering system (Anatech, USA) and subsequently examined under a Hitachi S-4800 SEM operated at 10-12 kV.

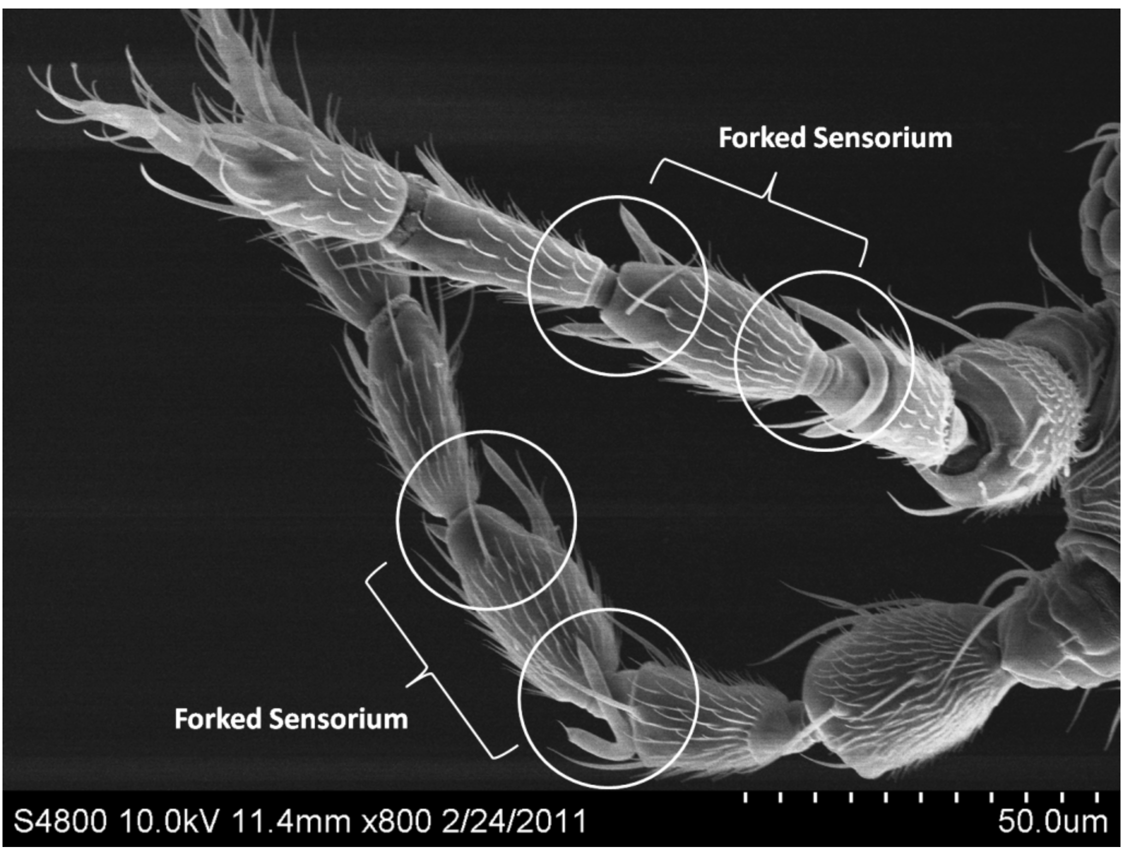

Fig. 2. Eight segmented antenna with third and fourth segments each presenting a forked sensorium.

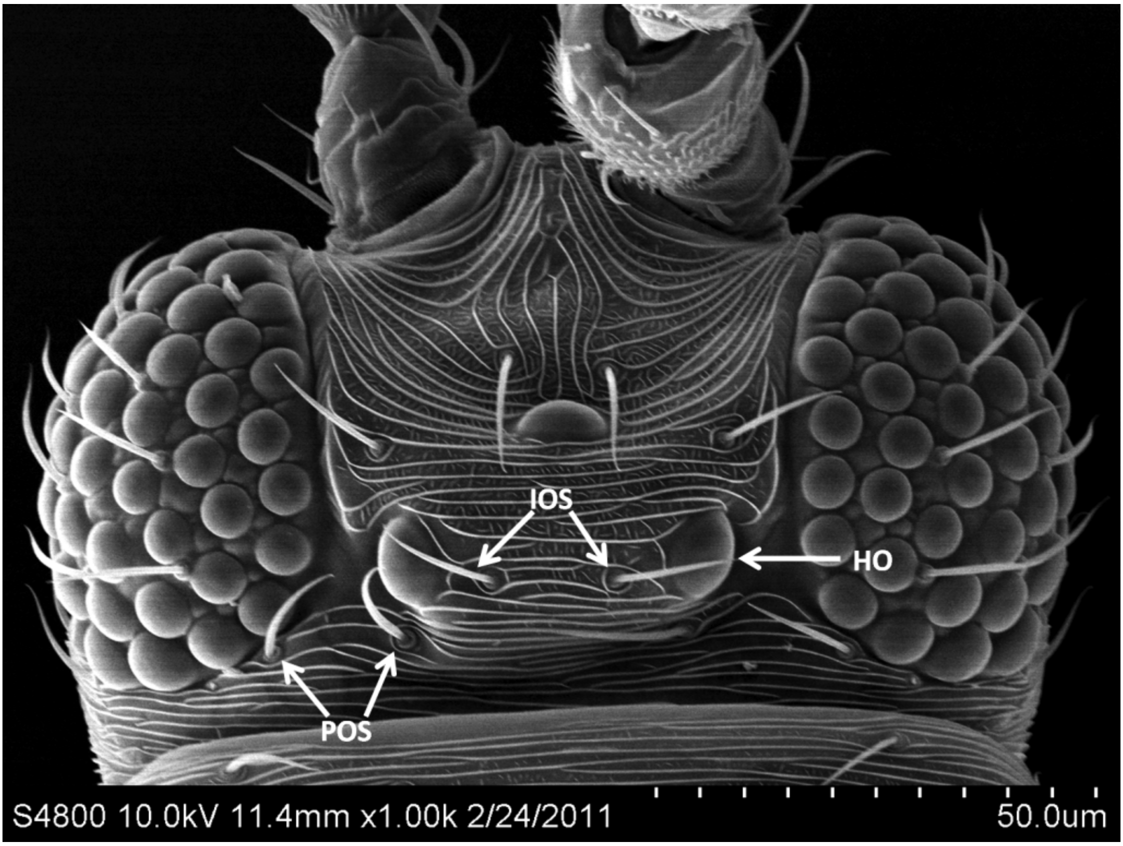

Fig. 3. Dorsal view of *S. dorsalis* head with ocellar triangle, interocellar setae (IOS), hind ocelli (HO) and postocular setae (POS).

The following characters were used for positive identification and morphological comparison of *S. dorsalis* populations prior to morphometric analysis: Body of adult *S. dorsalis* is pale yellow in color bearing dark brown antecostal ridge (AR) on tergites and sternites (Fig. 1). Head wider than long, bearing closely spaced lineation and a pair of eight segmented antennae with third and fourth segment each presents a forked sensorium (Fig. 2). Of the three pairs of ocellar setae, the third pair, also known as interocellar setae (IOS), arises between the 2 hind ocelli (HO) (Fig. 3) and is nearly the same size as the two pairs of post ocellar setae (POS) on the head. Pronotum presents closely spaced transverse lineation (Fig. 4). Pronotal setae (anteroangular, anteromarginal and discal setae) are short and approximately equal in length. Posteromarginal seta-II is broader and 1.5 times longer than posteromarginal setae-I and III. Posterior half of the metanotum presents longitudinal striations; medially located metanotal setae arise behind anterior margin, campaniform sensilla are absent (Fig. 5). Forewings are distally light in color with posteromarginal straight cilia, on distal half, first and second veins bear 3 and 2 widely spaced setae, respectively (Fig. 6). Abdominal tergites III to VI, each present a pair of small medially located setae (Fig. 7). The posteromarginal comb on segment VIII is complete, tergite IX of female presents medially located discal microtrichia (Fig. 8). Discal setae absent on sternites, sternites covered with rows of microtrichia excluding on the antero-medial region (Fig. 9), i.e., a complete band of microtrichia traverse the posterior half of each sternite.

Morphometric Measurements of Major Body Traits

We studied 14 morphological characters in 5 populations of *S. dorsalis* and compared the results with the measurements previously reported by Raizada (1976). Raizada (1976) subjected 9 characters of *S. dorsalis* adults to morphometric analysis and in the present study; we added mea-

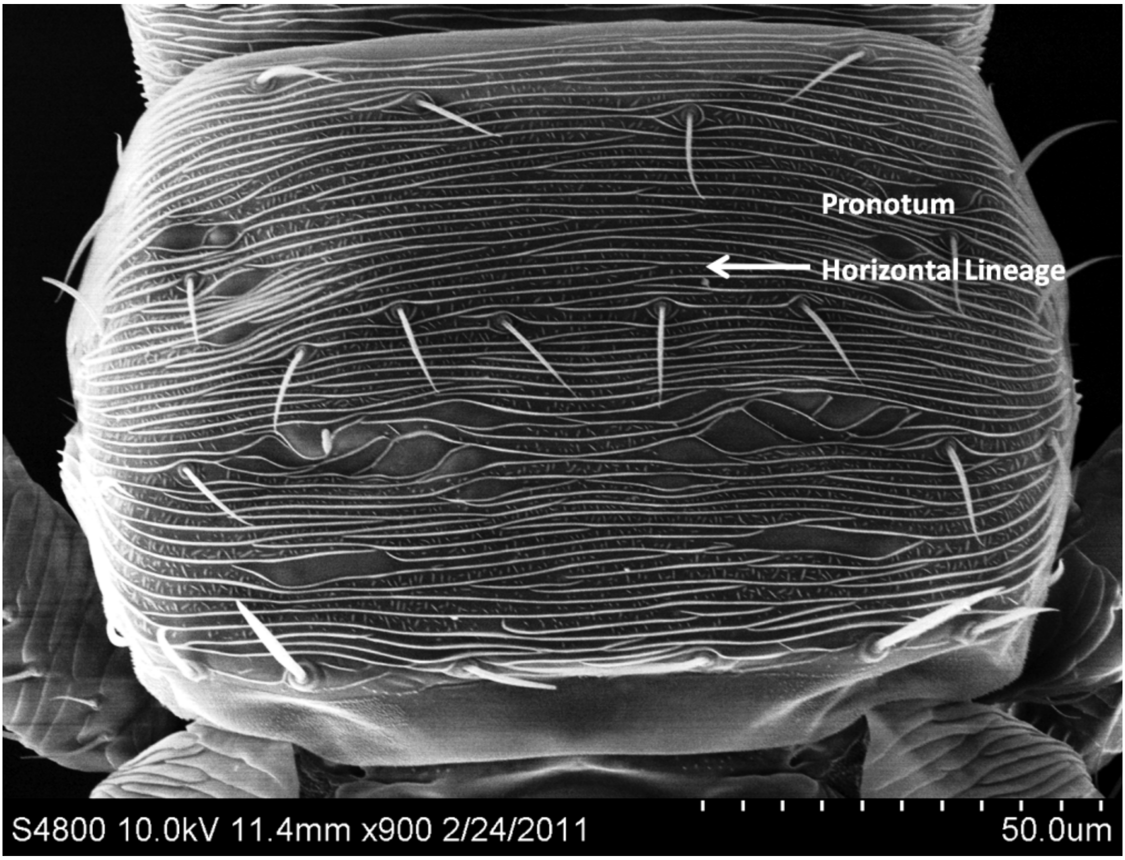

Fig. 4. Pronotum of *S. dorsalis* presenting horizontal closely spaced sculpture lines.

surements of the pro, meso, and meta thorax for comparison. The objective of this study was to make a preliminary determination of whether certain morphological characters of *S. dorsalis* adults differ in size among populations from different geographic regions of the world.

We selected 10 specimens from each of the 5 populations for morphometric analysis. The sources of these 5 populations are listed in Table 1. A single specimen of *S. dorsalis* was placed on each slide with a drop of water: ethanol (50:50) to protect the specimen from dehydrating. The specimen was spread before measurements were taken. Fourteen morphological traits of 10 specimens from each region were quantified by measuring the lengths of the body, antennae, head, prothorax, mesothorax, metathorax, ovipositor, forewing and hind wing; and the widths of the head, abdomen, prothorax, mesothorax, and metathorax (Table 2) using an automontage advanced photography software program (Auto-Montage Pro software, version 5.02, Syncroscopy, Frederick, MD) and a Leica MZ 12.5 stereomicroscope.

Statistical Analysis

Data on the measurement of various body parts of thrips pertaining to different geographical regions were subjected to the square root (x + 0.25) transformation to stabilize variance. Transformed data were analyzed using one-way analysis of variance (ANOVA, SAS Institute Inc. 2003). The differences among means of length and width of body segments from different geographical regions were separated using Tukey's HSD procedure ($P < 0.05$). Untransformed means and standard errors are reported in Table 2.

Results

Scanning Electron Microscopy

The results of the scanning electron microscopy investigation are depicted in Figs. 2-9 and described in the figure captions.

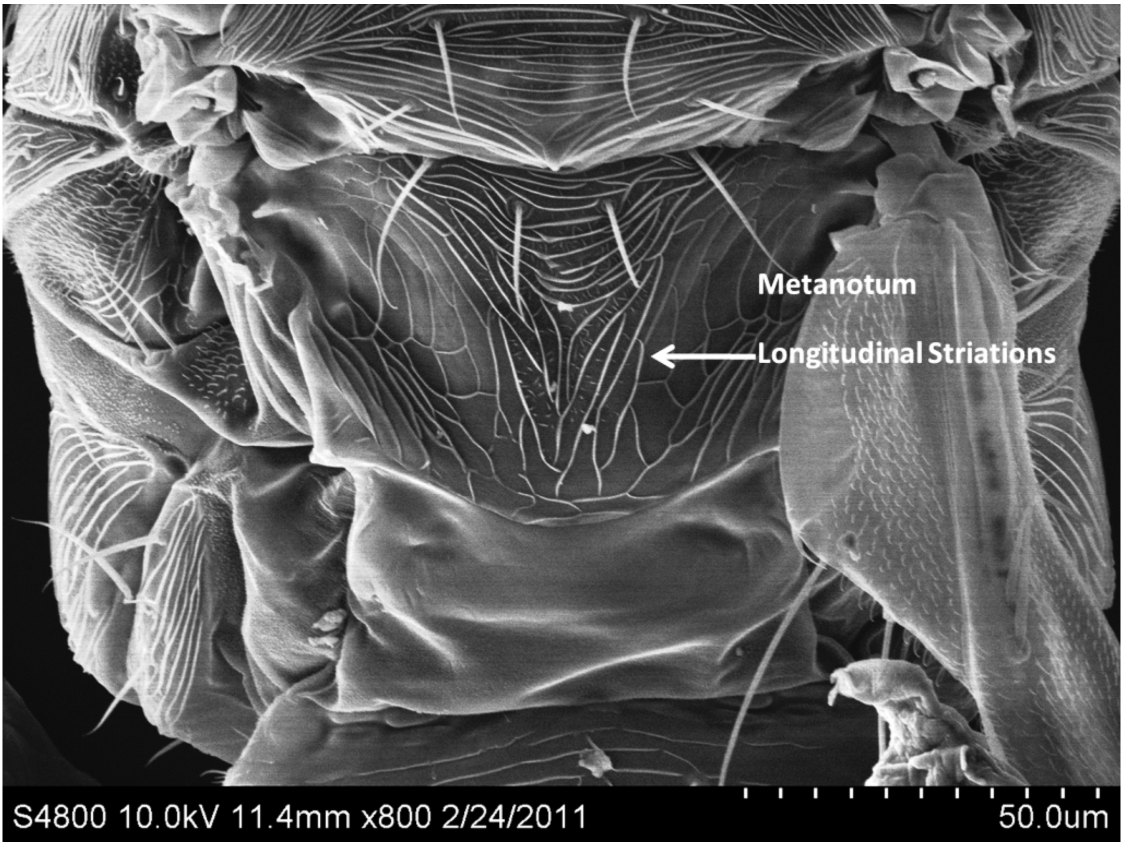

Fig. 5. Posterior half of the metanotum presents longitudinal striations; medially located metanotal setae arise behind anterior margin, campaniform sensilla are absent.

Morphometric Measurements of Major Morphological Features of *Scirtothrips dorsalis*

No significant differences were detected between the 5 *S. dorsalis* populations for 9 of the morphological characters measured in this study, i.e., body length, antennal length, length of head, width of head, length of prothorax, width of prothorax, length of ovipositor and lengths of the forewings and the hindwings (Table 2). However, statistically significant differences were detected among the 5 populations for mesothorax (length and width), metathorax (length and width) and width of abdomen.

New Delhi, India (2008) Population

The population from New Delhi did not differ significantly from the Florida, St. Vincent or Negev populations for any of the morphological characters under consideration. Significant differences were detected between this population and the population from Shizouka in that both the metathorax length and abdomen width were smaller in the New Delhi population (Table 3).

Florida, USA (2009) Population

The Florida population was not significantly different from the populations of New Delhi or Negev for any of the 14 morphological characters that were measured (Table 3). The Florida population was characterized by a significantly smaller metathorax than the St. Vincent population, but there were no significant differences between these 2 populations for the other 13 characters that were measured. Five morphological characters of the Florida population were significantly smaller than the Shizouka population. These differences were most significant with respect to the lengths and widths of the mesothorax, metathorax and width of abdomen (Table 3).

St. Vincent Island, West Indies (2006)

The St. Vincent population had a significantly longer metathorax than the populations from

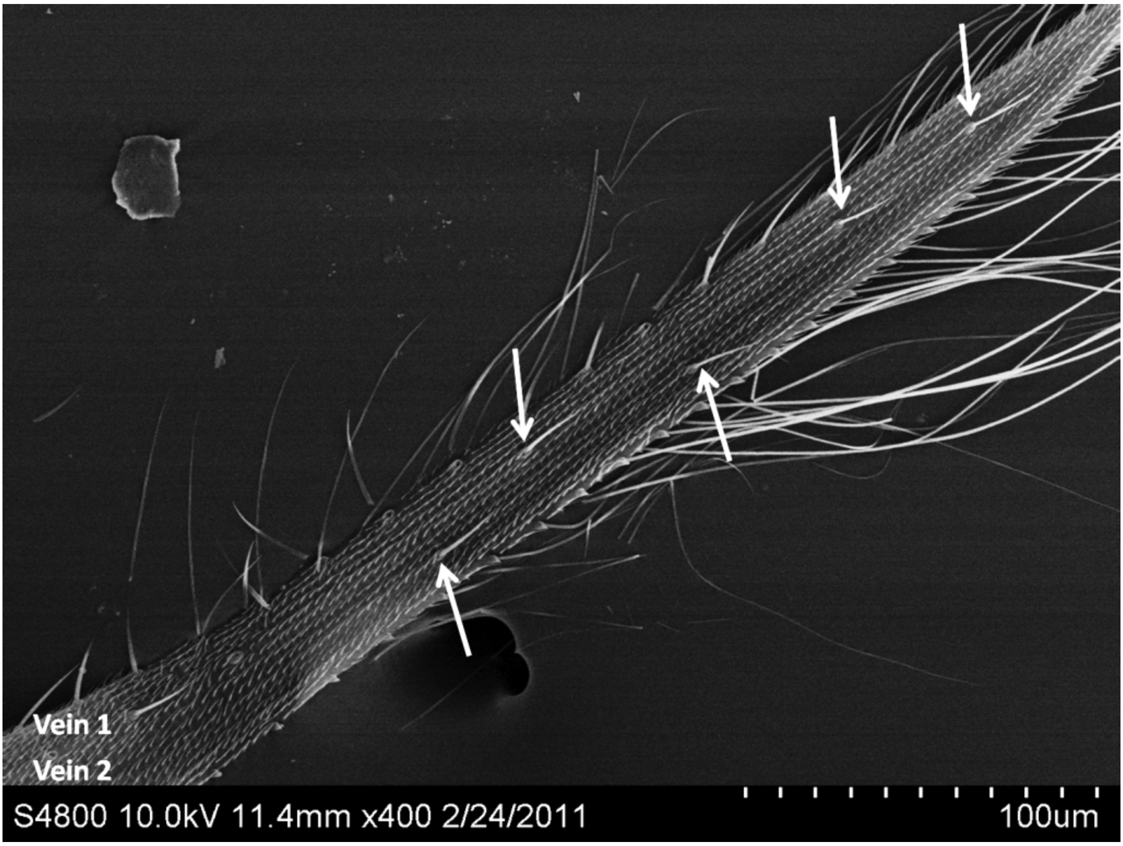

Fig. 6. Shaded forewing of *S. dorsalis* is light in color distally with first and second vein presenting 3 and 2 widely spaced setae, respectively.

Florida and Negev and a significantly narrower abdomen compared with Negev and Shizouka populations.

Shizouka, Japan (2009) Population

The *S. dorsalis* population from Shizouka differed significantly from the other 4 populations for 2 or 5 morphological characters, depending on the population, suggesting that the Japan population is more robust (i.e., mesothorax and metathorax are longer and wider, and abdomen is wider) (Table 3). The metathorax was longer and the abdomen was wider than the New Delhi population. Further, the Shizouka population had a wider mesothrorax, metathrorax and abdomen, and longer mesothrorax and metathorax than the Florida population. The metathorax and abdomen of Shizouka were also wider than the St. Vincent population. Furthermore, the Shizouka population mesothorax was wider and metathorax longer compared with the Negev population.

Negev, Israel (2009) Population

The population from Negev did not differ statistically from the New Delhi (2008) and Florida (2009) populations in any of the morphological traits under study, but differed significantly in 2 features with St. Vincent (metathorax length and abdominal width) and Shizouka populations (mesothorax width and metathorax length).

The mean lengths of the antennae of the New Delhi (1976) population were numerically very similar to these of the Negev (2009) population, but shorter than those of all other populations in this study. However, the differences in the measurements of all the remaining traits between the New Delhi (1976) and the other populations in this study were numerically small.

Discussion

Since its development in early 1950s, SEM is considered as an efficient morphological identifi-

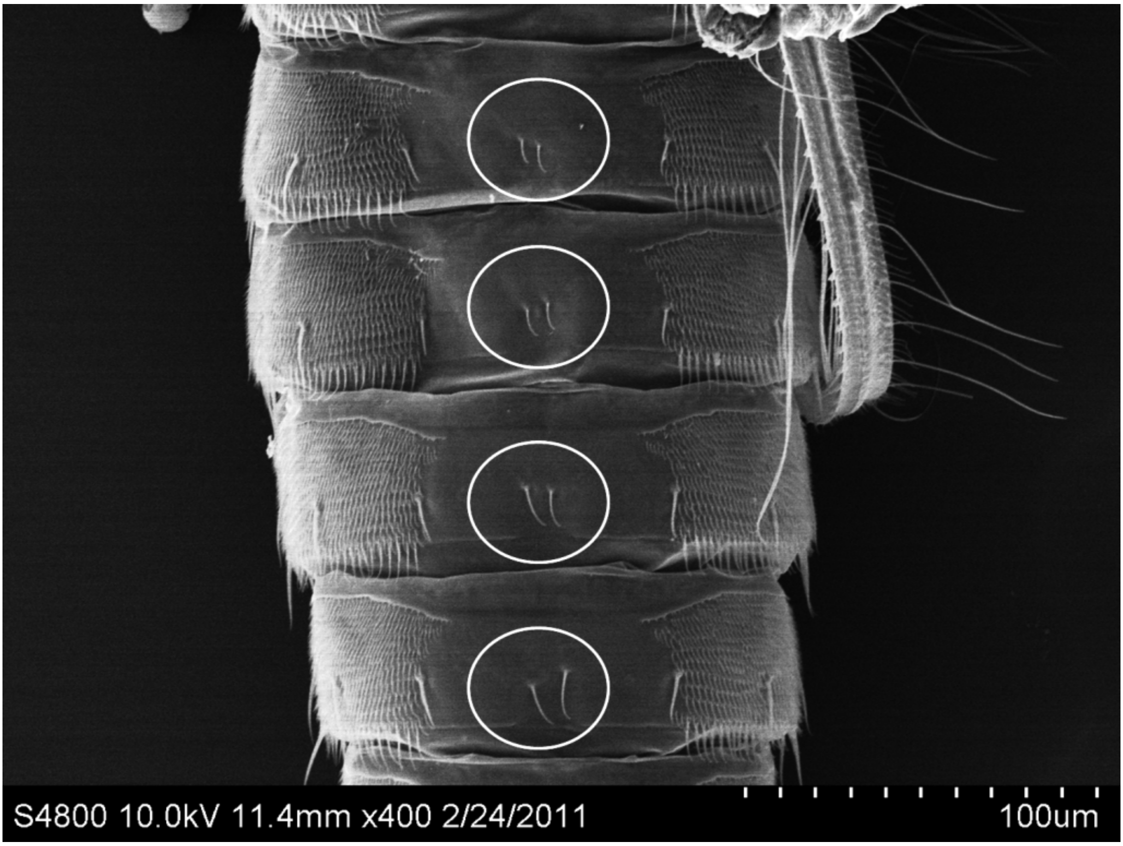

Fig. 7. Abdominal tergites III to VI of *S. dorsalis* present small setae medially situated close to each other.

cation tool with numerous advantages over traditional microscopy including: i) it has a large depth of field, which allows greater part of a specimen to be in focus at one time, ii) it has much higher resolution than light microscope and iii) because it uses electromagnetism instead of lenses, specimens can be magnified to much higher levels and the researcher has much more control in the degree of magnification of the specimen understudy (Schweitzer 2011). However, SEM's use in the taxonomic characterization of Thysanopterans has been is limited. High-resolution pictures of *S. dorsalis* using SEM technique will help research, regulatory and extension personnel to identify this pest with greater ease. SEM produced Figs. 2-9 provide information about all of the major identification characters of this pest. Two members of genus *Scirtothrips*, *S. aurantii* and *S. dorsalis* are unusual in having sternites covered with microtrichia (Hoddle & Mound 2003; Hoddle et al. 2009). Fig. 9 shows the band of microtrichia is continuous only across the posterior half of the *S. dorsalis* sternite, a feature that differentiates this pest not only from *S. surantii*, but insofar as is known, from all other species of *Scirtothrips*.

No major differences were observed in the body lengths of *S. dorsalis* adults recently collected from the 5 regions. Mean body lengths ranged from 0.85 mm (Negev population) to 0.98 mm (Florida population). The mean length of adults collected from New Delhi, India in 2008 was greater than that previously reported by Raizada (1976) (0.91 and 0.76 mm, respectively). The mean body length of the Florida (2009) population is 0.223 mm longer than that of the New Delhi (1976) population. Likewise, the mean antennal length of the Florida (2009) *S. dorsalis* is 0.026 mm longer than that of the New Delhi (1976) population. We speculate that these differences may be attributed to a possible role of the feeding and reproductive hosts in regulating body size of the pest.

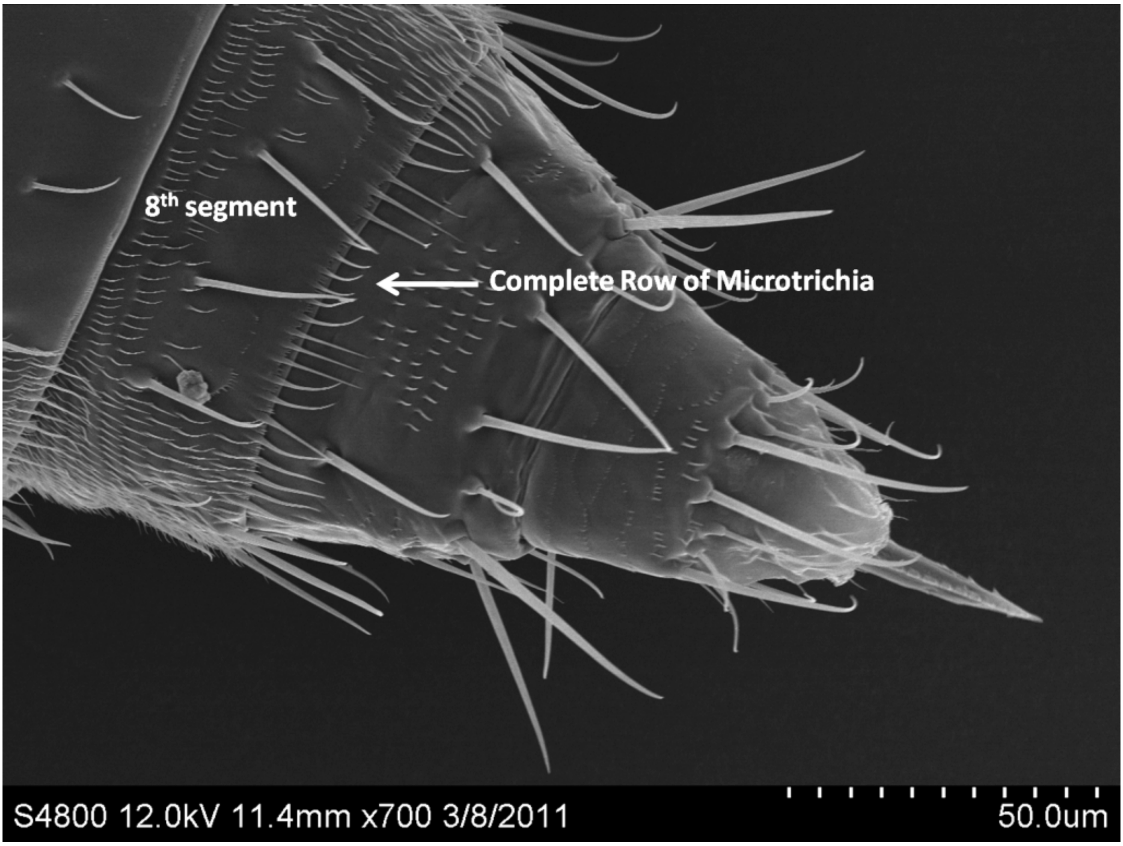

Fig. 8. The posteromarginal comb (row of microtrichia) on segment VIII is complete.

Insects are know to regulate their body size in response to the temperature surrounding them; which is associated with elevation and latitude (Blanckenhorn & Demont 2004; Tantowijoyoa & Hoffmann 2011). Studies suggest that there can be positive correlations between elevation and latitude on the one hand and body size on the other; and this is commonly observed (Smith et al. 2000). On the other hand, no correlation, or even a negative correlation, may be observed between sizes of body traits and elevation and latitude (Kubota et al. 2007; Hawkins & DeVries 1996). Variation in size can affect fitness traits like development and reproduction (Berger et al 2008; Tammaru et al. 2002), somatic and sexual growth (Blanckenhorn 2006; Fischer et al. 2003), thermoregulation (Bishop & Armbruster 1999) and dispersal ability (Gutierrez & Menendez 1997). At high temperatures, some populations of thrips species acquire a small and paler form, and at low temperatures, they tend to be large and dark in color. However, results from our present study did not show any significant impact of temperature on body size of *S. dorsalis* collected from the 5 regions, but we have no detailed information on temperatures during the times of collection.

According to Björkman et al. (2009) body size within certain taxonomic groups tends to increase with latitude (Bergmann clines), while in certain other groups insect body size decreases (converse Bergmann clines), and in yet others tends to stay relatively constant with latitude. In this study, the populations were from the following latitudes: St. Vincent, West Indies: 13.35 N; Homestead, Florida: 25.48 N; Delhi, India: 28.38 N; Negev, Israel: 34.67 N; and Shizouka, Japan: 36.00 N. On comparing the measurements of individuals from 5 regions, we found that the body length of *S. dorsalis* in these samples did not vary either directly or inversely with latitude (Table 2).

All of the specimens the recently collected at New Delhi, Florida, St. Vincent and Negev were reared on pepper, but not at Shizouka, which

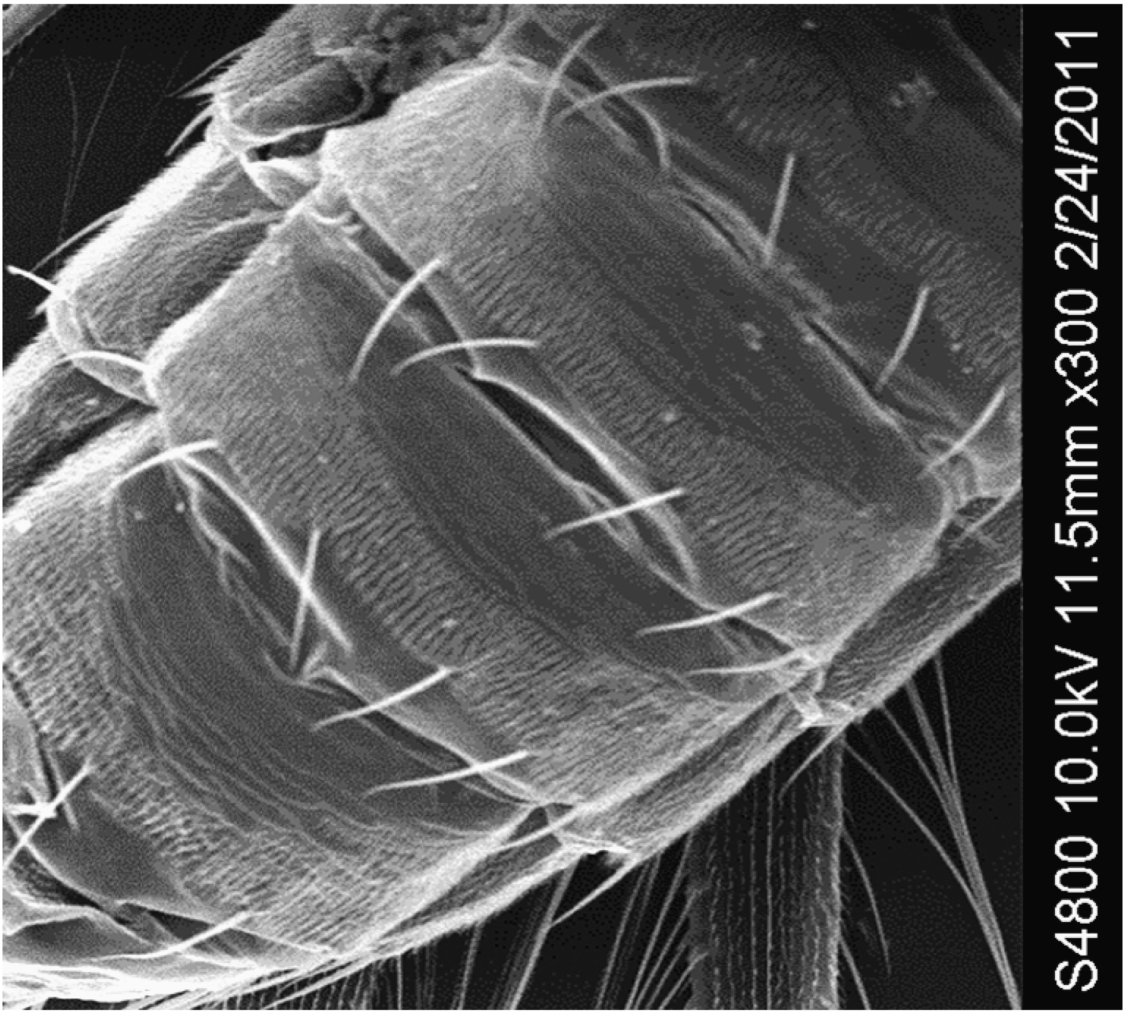

Fig. 9. Discal setae absent on sternites, posterior half of sternite presents a continuous band of microtrichia, but microtrichia are absent in the antero-medial region.

were reared on tea. Since tea was not a host plant of the other 4 populations sampled in this study, we could not determine if host plants directly affect morphology. Nevertheless, the Shizouka population differs significantly from the other populations by having a longer and wider mesothorax and metathorax and abdomen that is wider, which is an essential morphological character of females that allows them to produce more eggs and have high fecundity and greater fitness (Benitez et al. 2011). In a concurrent experiment conducted to determine the effect of host plant on the growth of *S. dorsalis*, the pest was reared under identical conditions at Homestead, Florida on 6 different hosts, i.e., 'Jalapeño' pepper (*Capsicum annuum* L.), 'Pod Squad' bean (*Phaseolus vulgaris* L.), 'Black Beauty' eggplant (*Solanum melongena* L.), 'Butternut' squash (*Cucurbita moschata* [ex Duchesne Lam.] Duchesne ex Poir.), 'Solar Set' tomato (*Solanum lycopersicum* L.) and 'Knockout' rose (*Rosa chinensis* Jacq.) (Seal et al. 2010). Body lengths and widths of different development stages (10 individuals each) were measured, and no significant differences in body size of this pest was observed when *S. dorsalis* was reared on these 6 different hosts indicating, that these host plant species did not differentially induce size alterations in *S. dorsalis*.

Table 2. Measurements of fourteen morphological characters from five different populations of *Scirtothrips dorsalis*.

Morphological Character	Morphological Character Mean (mm) ± SEM by Population (year collected)						
	India (1976)	New Delhi India (2008)	Florida (2009)	St. Vincent Island (2006)	Shizouka Japan (2009)	Negev Israel (2009)	ANOVA F, P value
Body L	0.757 ± 0.021	0.912 ± 0.025 a	0.980 ± 0.30 a	0.871 ± 0.015 a	0.873 ± 0.015 a	0.856 ± 0.029 a	0.49, 0.741
Antennal L	0.180 ± 0.001	0.198 ± 0.002 a	0.206 ± 0.005 a	0.196 ± 0.004 a	0.218 ± 0.005 a	0.182 ± 0.004 a	1.06, 0.387
Head L	0.066 ± 0.002	0.052 ± 0.004 a	0.054 ± 0.002 a	0.062 ± 0.002 a	0.060 ± 0.002 a	0.054 ± 0.002 a	2.47, 0.058
Head W	0.110 ± 0.002	0.120 ± 0.003 a	0.111 ± 0.001 a	0.120 ± 0.002 a	0.120 ± 0.002 a	0.122 ± 0.006 a	1.76, 0.153
Prothorax L	0.086 ± 0.002	0.086 ± 0.005 a	0.098 ± 0.003 a	0.088 ± 0.004 a	0.099 ± 0.003 a	0.098 ± 0.003 a	2.38, 0.656
Prothorax W	—	0.142 ± 0.003 a	0.141 ± 0.003 a	0.146 ± 0.003 a	0.147 ± 0.004 a	0.145 ± 0.003 a	0.59, 0.674
Mesothorax L	—	0.055 ± 0.004 ab	0.043 ± 0.001 b	0.048 ± 0.004 ab	0.056 ± 0.003 a	0.048 ± 0.002 ab	3.00, 0.028
Mesothorax W	—	0.164 ± 0.004 ab	0.149 ± 0.004 b	0.166 ± 0.008 ab	0.179 ± 0.006 a	0.153 ± 0.006 b	4.00, 0.007
Metathorax L	—	0.098 ± 0.003 bc	0.097 ± 0.002 c	0.108 ± 0.003 ab	0.112 ± 0.006 a	0.097 ± 0.004 c	3.44, 0.015
Metathorax W	—	0.166 ± 0.004 ab	0.160 ± 0.002 b	0.162 ± 0.004 b	0.181 ± 0.005 a	0.176 ± 0.006 ab	4.09, 0.006
Abdomen W	0.200 ± 0.004	0.192 ± 0.003 bc	0.193 ± 0.005 bc	0.182 ± 0.005 c	0.213 ± 0.005 a	0.207 ± 0.005 ab	6.38, 0.0004
Ovipositor L	0.150 ± 0.003	0.146 ± 0.003 a	0.140 ± 0.004 a	0.146 ± 0.004 a	0.139 ± 0.004 a	0.134 ± 0.005 a	1.36, 0.263
Forewing L	0.510 ± 0.016	0.514 ± 0.011 a	0.523 ± 0.012 a	0.512 ± 0.010 a	0.509 ± 0.012 a	0.513 ± 0.017 a	0.16, 0.956
Hind wing L	0.440 ± 0.012	0.458 ± 0.011 a	0.467 ± 0.011 a	0.460 ± 0.012 a	0.459 ± 0.013 a	0.461 ± 0.017 a	0.07, 0.990

All data were analyzed using analysis of variance (ANOVA) procedures with the exception of the India (1976) population previously reported by Raizada (1976). Means were separated using Tukey test at the 0.05 level of significance. Means followed by same letter within a row are not significantly different ($P \leq 0.05$).

TABLE 3. NUMBER OF TRAITS IN WHICH SIGNIFICANT QUANTITATIVE DIFFERENCES OCCURRED BETWEEN THE VARIOUS GEOGRAPHIC POPULATIONS OF *SCIRTOTHRIPS DORSALIS* WHEN COMPARED TWO AT ONE TIME, AND THE CORRESPONDING TRAITS THAT WERE QUANTITATIVELY DIFFERENT.

	India 2008	Florida 2009	St. Vincent 2006	Israel 2009	Japan 2009
India 2008	X	0	0	0	2 Metathorax L Abdomen W
Florida 2009	0	X	1 Metathorax L	0	5 Mesothorax L Mesothorax W Metathorax L Metathorax W Abdomen W
St. Vincent 2006	0	1 Metathorax L	X	2 Metathorax L Abdomen W	2 Metathorax W Abdomen W
Israel 2009	0	0	2 Metathorax L Abdomen W	X	Mesothorax W Metathorax L
Japan 2009	2 Metathorax L Abdomen W	5 Mesothorax L Mesothorax W Metathorax L Metathorax W Abdomen W	2 Metathorax W Abdomen W		2 Mesothorax W Metathorax L

The results from our study suggest that the Japan population may have diverged the most from the ancestral population in south Asia. We speculate that the Japan population is not ancestral to populations in the Americas or Israel. It seems possible that the population in India may be ancestral to the populations in the New World and Israel. This could have been facilitated by the extensive movement of people between India and Israel, and India and the Caribbean. In addition, Israel has commercial horticultural ventures in the Greater Antilles. Thus, movement of *S. dorsalis* from India to Israel and subsequently to the Caribbean cannot be ruled out. It would be interesting to determine whether there are substantial genetic or behavioral differences, and even barriers to reproduction, between the Shizouka and New Delhi populations as well as between the Shizouka and Florida populations.

We believe that by using the automontage system did not introduce inordinately large errors cause by failure to have each specimen perfectly within the horizontal plane. We repeated each measurement on 10 different individuals, and it is well known that small experimental errors tend to cancel each other. Morphometric analysis is an efficient tool that is being utilized for identification, determination of larval instar, and discrimination of cryptic species of several insect species including leaf miners, bees, beetles, and aphids, (Dale 1985; Ellis & Ellis 2008; Favret 2009; Shiao 2004; Tantowijoyoa & Hoffmann 2011), but is rarely used for thrips. This is because thrips body size, and color are known to be phenotypically plastic in response to changing environments, which can occur across both small and large spatial scales (Sakimura 1969; Murai & Toda 2001; Mound 2005). It may be important to collect live populations from different regions, rear them under identical environmental conditions in order to ascertain if the apparent stability of morphological traits has a genetic basis. Future research will concentrate on direct correlation of morphometric analyses with molecular analyses of cohorts to validate our hypothesis that the Japan population is not ancestral to populations in the 4 other regions.

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