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DEVELOPING AND EVALUATING TRAPS FOR MONITORING *SCIRTOTHRIPS DORSALIS* (THYSANOPTERA: THRIPIDAE)

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ABSTRACT

Scirtothrips dorsalis (Hood) (Thysanoptera: Thripidae) is a recently identified invasive pest to the Caribbean and poses a significant threat to agriculture and trade in the region. Methods are needed to detect the presence and to monitor populations of this pest so that it can be effectively managed. Three different CC trap base colors (blue, yellow, and white) with or without dichlorvos as a killing agent, and a newly developed and named the Blue-D trap were studied in Taiwan and St. Vincent for attraction and capture of *S. dorsalis*. In lemons in Taiwan, mean numbers of *S. dorsalis* caught in Blue-D traps were greater compared with dichlorvos cube modified CC traps. In St. Vincent chili pepper plantings, the Blue-D traps caught more *Thrips palmi* (Karny), *Frankliniella* sp., and *Microcephalothrips abdominalis* (Crawford) than dichlorvos cube modified CC traps. More *Frankliniella intonsa* (Trybom), *Megalurothrips usitatus* (Bagnall), *T. palmi*, *Frankliniella* sp., and *M. abdominalis* were caught in blue and white base CC traps than yellow base CC traps. Average captures per CC trap per week were 0.07 and 0.02-0.09 *S. dorsalis* in Taiwan and St. Vincent, respectively. There were no differences in *S. dorsalis* captures in white, blue, or yellow base CC traps. The average weekly *S. dorsalis* catch for yellow sticky card traps was 19.8. CC traps can be used for detection of *S. dorsali* and collecting intact *S. dorsalis* for taxonomic and genetic determinations when a few of the species are found in a large commercial production area. Yellow sticky traps can be used for monitoring *S. dorsalis* populations. A combination detecting system of visual observation, yellow sticky traps, and CC traps may be an effective *S. dorsalis* population detecting and monitoring system.

Key Words: *Scirtothrips dorsalis*, *Frankliniella occidentalis*, *Thrips palmi*, CC traps, Caribbean area

RESUMEN

Scirtothrips dorsalis (Hood) (Thysanoptera: Thripidae) es una plaga invasora recien identificada en el Caribe y representa una amenaza significativa a la agricultura y comercio de la región. Es necesario desarrollar métodos para detectar la presencia de esta plaga y realizar un monitoreo de su poblacion para lograr un manejo mas eficaz. Trampas de CC de tres colores diferentes (azul, amarilla, y blanca) con o sin el pesticida dichlorvos como agente para matar, y una trampa recién desarrollada y nombrada 'Blue-D' fueron estudiadas en Taiwan y St. Vincent para ver su habilidad para atraer y capturar *S. dorsalis*. En limones en Taiwan, el promedio del número de *S. dorsalis* capturados en las trampas de Blue-D fue mas alto comparado con las trampas de CC cubicas modificadas con dichlorvos. En siembras del chile verde en St. Vincent, la trampa de Blue-D capturo mas *Thrips palmi* (Karny), *Frankliniella* sp., y *Microcephalothrips abdominalis* (Crawford) que la trampa de CC cubica modificada con dichlorvos. Habian un mayor número de *Frankliniella intonsa* (Trybom), *Megalurothrips usitatus* (Bagnall), *T. palmi*, *Frankliniella* sp. y *M. abdominalis* capturadas en trampas de CC con la base de color azul o blanco que en las trampas con la base amarilla. El promedio de los *S. dorsalis* capturados en las trampas de CC por semana fue 0.07 y 0.02-0.09 en Taiwan y St. Vincent, respectivemente. No hubo ninguna diferencia en el número de *S. dorsalis* capturados en trampas de CC con la base de color blanco, azul o amarilla. El promedio semanal de los *S. dorsalis* capturados con trampas de tarjetas pegajosas amarillas fue 19.8. Se puede usar las trampas de CC para detectar la presencia de *S. dorsalis* y recolectar especimenes de *S. dorsalis* intactos para su identificación taxonómica y genética cuando solamente se encuentran pocos especies en las áreas grandes de producción comercial. Se puede usar las trampas amarillas pegajosas para realizar un monitoreo de la población de *S. dor-*

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salis. Un sistema de detección que combine la observación visual, las trampas amarillas pegajosas, y las trampas de CC puede ser efectivo para detectar y realizar monitoreos de poblaciones de *S. dorsalis*.

Scirtothrips dorsalis (Hood) was described in 1916 as a new species collected from castor bean and chili plants in Coimbatore, Southern India (Hood 1919). *S. dorsalis* are polyphagous pests that are widespread in habitat ranging from temperate to tropical climate regions in Pakistan, Japan, and Australia (Mound & Palmer 1981). Primary hosts are onion, cashew nut, tea, chili, cotton, tomato, mango, tobacco, and castor bean. The insect has been reported by the Animal Plant Health Inspection Service (APHIS) as one of the thirteen most important pest species that could become a serious threat to United States (US) agricultural crops if it becomes established in the country (USDA-APHIS 2004). The Florida Nurserymen and Growers Association (FNGA) also consider *S. dorsalis* as an exotic pest with high potential to damage their industry if it becomes established in the state (FNGA 2003). Since 1984, USDA-APHIS inspectors at various US ports of entry have reported finding live *S. dorsalis* a total of 89 times from imported plant materials of 48 plant taxa (USDA 2003). On July 6, 2003, a Plant Protection and Quarantine (PPQ) officer in Miami, FL intercepted live *S. dorsalis* on chili peppers shipped from St. Vincent, a Caribbean island nation (Skarlinsky 2003). Subsequently, surveys of St. Vincent and St. Lucia confirmed the presence of *S. dorsalis* on both islands (Ciomperlik & Seal 2004). Thrips samples collected from both islands were catalogued and submitted to the USDA-Agricultural Research Service (ARS) Systematic Entomology Laboratory, Beltsville, MD, and the Australian Commonwealth Scientific & Industrial Research Organization (CSIRO) Entomology Laboratory, Canberra, Australia.

A pest risk assessment by Venette & Davis (2004) indicates that the potential geographic distribution of *S. dorsalis* in the U.S. ranges from the northeastern Atlantic area to Minnesota in the northern latitudes and to Texas in the south. Meissner et al. (2005) indicates that permanent establishment would likely be limited to southern and West Coast states. The species also seems capable of spreading throughout the entire Caribbean region. So far, it has become established on the Caribbean islands of St. Lucia, St. Vincent (Ciomperlik & Seal 2004), and Trinidad (USDA Offshore Pest Information System 2004).

Current survey, detection, and monitoring methods for *S. dorsalis* are laborious and require significant manpower and technical training. Most species in the genus *Scirtothrips* are pale in color, minute, and must be cleared and slide mounted for species identification. In addition, the genus is confused taxonomically. The names *Heliothrips minutissimus* (Bagnall), *Anaphothrips andreae* (Karny), *Scirtothrips padmae* (Ramakrishna), and *S. fragaiae* (Girault) appear in the literature but are now considered to be synonyms of *S. dorsalis* (Mound & Palmer 1981). Ongoing research and development methods that incorporate Polymerase Chain Reaction-Restriction Fragment Length Polymorphism (RFLP-PCR) genetic techniques (Toda & Komazaki 2002) are being conducted to explore the ribosomal ITS2 DNA regions that can be used to rapidly distinguish between thrips species. These methods require that individual insect samples be whole and undamaged, free of foreign contaminating substances, and preferably without contaminant DNA. Based on these requirements, sticky traps often used for thrips detection and monitoring are unsuitable.

To obtain specimens for taxonomic and genetic studies, terminal leaf samples can be collected in ziplock bags and washed with ethanol to obtain full intact specimens (Ciomperlik & Seal 2004). The plastic cup trap (named CC trap) (Fig. 1) also collects intact *S. dorsalis* specimens. It can be installed in a commercial production area where the pest has been found or suspected and serviced periodically for long periods of time. The CC trap was designed and validated for monitoring sweetpotato whitefly, *Bemisia tabaci* (Gennadius) B-biotype, populations. Trap design was based on the sweetpotato whitefly attraction to the color yellow, flight patterns approaching plants, and landing behavior (Chu et al. 1995; Chu & Henne-

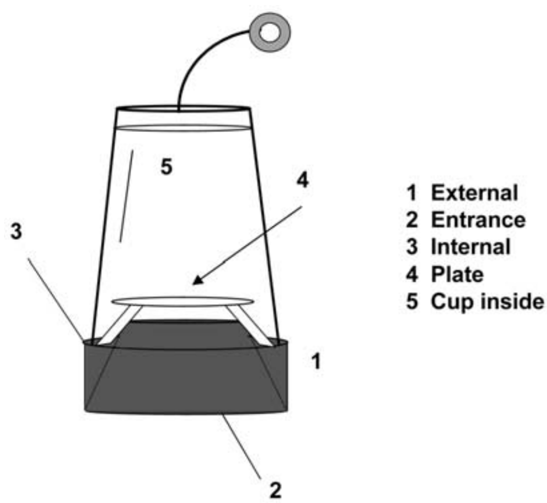

Fig. 1. CC trap with number trap surface identifications.

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berry 1998). The white base CC traps caught more *S. dorsalis* and *Thrips palmi* (Karny) in a peanut field in India in 1996 than yellow base traps (Chu et al. 2000). To extend the usefulness of the CC traps for detection and monitoring *S. dorsalis*, *T. palmi*, and other thrip species under Caribbean island conditions, we are studying different methods to increase trap efficacy.

White, yellow, and blue colors have been reported attractive to *S. dorsalis*, *T. palmi*, or *F. occidentalis* (Beavers et al. 1971; Gillespie & Vernon 1990; Cho et al. 1995; Tsuchiya et al. 1995; Chu et al. 2000; Hoddle et al. 2002; Chen et al. 2004). Chu et al. (2005) have modified CC whitefly traps for detecting and monitoring western flower thrips.

Objectives of the current study were (1) to evaluate CC thrip trap modification with a killing agent and a specimen preservative, (2) to evaluate a modification of a commercially available dichlorvos strip package for use as a thrips trap, named the Blue-D trap in this report, and (3) to evaluate sticky card traps.

Materials and Methods

Comparison of CC and Blue-D traps

The study was conducted in commercial farms with randomized complete block designs with 15 and five replicates in Taiwan and St. Vincent, respectively. Treatments were re-randomized weekly in St. Vincent, but not in Taiwan. The four CC trap treatments in Taiwan were trap base colors (white, blue, and yellow with a 1 cm^2 dichlorvos cube and 15 ml, 10% ethylene glycol) and the Blue-D trap. In St.Vincent, the three trap base colors with or without dichlorvos cube and with or without ethylene glycol made a total of 12 treatments. Blue-D trap was the 13th treatment. The dichlorvos cubes in CC traps were not replaced during the experimental periods. The ethylene glycol treatment was used to preserve thrip specimens. The CC traps were serviced weekly, disassembled in the field, rinsed with 20 ml 85% ethanol to dislodge insects that were retained in the trap bases, and stored in labeled glass vials for identification in the laboratory.

The Blue-D traps were Hot Shot® No-Pest® Strip dispensers (United Industry Corp., St. Louis, Mo.) fitted with plastic bags attached to the dispenser bottoms for collecting dead insects. Vertically oriented blue plastic strips (two 2.5-cm wide strips spaced at 2.5 cm apart) were attached inside the front and back surfaces of the dichlorvos dispensers packages (Fig. 2). The Blue-D traps were replaced weekly.

Experiment 1. Taiwan (dry season). The experiment was conducted in a 0.6-ha lemon (*Citrus limon* L., cv. Eureka) orchard for eight weeks from 26 November 2004 to 30 January 2005 in Neipu, Taiwan. The traps were suspended in trees 1.9 m above the ground.

Fig. 2. Dichlorvos dispenser modification with blue stripe and sample collecting bag placed in the top canopy of a lemon tree in Neipu, Pingtung County, Taiwan.

Experiment 2. St. Vincent (wet season). The experiment was conducted about one mile inland from Caribbean sea in Georgetown, St. Vincent Island in two (~0.2 ha each) geographically separated chili pepper (*Capsicum chinense* L.) fields. Plants were set 1 m within and between row spacings in both fields. Plants in one field were Scotch Bonnet variety and in the other field the West Indies Red variety. Traps were placed 1 m apart on wooden stakes placed within the plant rows. The trap bases were located about 22 cm below the tallest plant terminals. The experiment was conducted for six weeks from 14 October to 29 November, 2004.

Experiment 3. St. Vincent (dry season). The experiment was conducted in two Scotch Bonnet variety (~0.2 ha each) fields, as described in Experiment 2. The experiment was conducted for six weeks from 23 March to 4 May, 2005.

All thrips in the samples were identified and counted. *Scirtothrips dorsalis* was readily separated from the other species by the small size (0.7-1.0 mm), pale yellow color, and the presence of microtrichia extending along the median area of the abdominal sternites (Hoddle & Mound 2003). The remaining species were separated from each other

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by characters found in Nakahara's key to Thripidae (unpublished). Representative individuals of each thrips species were slide mounted to confirm the species identity. Voucher specimens from St. Vincent were deposited in the USDA-ARS Systematic Entomology Laboratory and in the St. Vincent Ministry of Agriculture and Fisheries.

Seasonal Weather during the Wet and Dry Seasons in St. Vincent, 2004-2005

Daily rainfall data and air temperatures during both seasons were obtained from weather station records housed at Rabacca Field Station in Georgetown, St. Vincent. The weather station was located about 0.4 km from the experimental chili pepper fields. CC trap captures were examined in relation to average rainfall and temperature in the wet and dry seasons.

Comparison of Sticky Card Trap Colors (Dry Season)

Experiment 4. The experiment was conducted during the dry season in 2005 in the same commercial pepper fields in St. Vincent described for Experiment 3. The thrips trap captures compared sticky card traps with the CC and Blue-D trap captures. The sticky card traps were 10.0 by 10.5 cm in size. White sticky card traps were constructed by coating both sides with brush-on Tanglefoot® formula (Tanglefoot Co., Grand Rapids, MI). Blue sticky card traps of the same dimensions were Takitrap® obtained commercially (Oecos Ltd., Kimpton, Hertfordshire, England). Yellow sticky card traps also of the same dimensions were custom made commercially (Olson Products, Medina, OH). The sticky card traps were placed in chili pepper rows 1 m apart. Traps were oriented vertically with wire loops attached to 25 cm long wooden stakes. Traps were placed 5-10 cm above the plant terminals.

Statistical Analysis

Numbers of thrips caught were averaged over sampling periods for each experiment. Data were analyzed by *t*-tests, ANOVA orthogonal comparisons, or three factor factorial analysis (Anonymous 1989). Means were separated by Tukey's HSD.

Results

Experiment 1. Comparison of CC and Blue-D traps in Taiwan (dry season). Blue-D traps caught more *S. dorsalis* than the CC traps ($F = 4.8$, $df = 1, 58$, $P = 0.034$). Mean captures for *F. intonsa* or *T. hawaiiensis* (Morgan) for the two trap types were not statistically different (Table 1). Catches of *S. dorsalis* by the three different color CC trap bases were not significantly different. White base CC traps caught more *T. hawaiiensis* ($F = 14.5$, $df = 2, 28$, $P = <0.001$), and blue base CC traps caught more *M. usitatus* ($F = 49.0$, $df = 2, 28$, $P = <0.001$) compared with other trap base colors. White and blue base CC traps caught more *F. intonsa* ($F = 7.3$, $df = 2, 28$, $P = 0.028$) compared with yellow base CC traps. The four thrips species are considered economic pests in Taiwan (Chang 1995).

Experiment 2. Comparison of CC and Blue-D traps in St. Vincent (wet season). Blue-D traps caught more *T. palmi*, *Frankliniella* sp., and *M. abdominalis* than CC traps ($F = 42.4 – 99.2$, $df = 1, 58$, $P = <0.001$). Mean captures of *S. dorsalis* for the two trap types were not significantly different. Captures of *S. dorsalis* in CC traps for different trap base colors were not significantly different. Blue and white base CC traps caught more *T. palmi*

TABLE 1. SEASONAL MEANS (±SE) THRIPS CAUGHT IN A LEMON ORCHARD IN NEIPU, TAIWAN, DRY SEASON, 26 NOVEMBER 2004 TO 30 JANUARY 2005 (EXPERIMENT 1).

	Mean numbers/trap/week			
	S. dorsalis	*F. intonsa*	*T. hawaiiensis*	*M. usitatus*
Trap type				
Blue-D[a]	0.34 ± 0.20 a[c]	0.50 ± 0.33 a	1.78 ± 1.39 a	0.44 ± 0.17 a
CC traps	0.07 ± 0.02 b	0.11 ± 0.02 a	0.36 ± 0.05 a	0.76 ± 0.17 a
F, *P*	4.8, 0.034	3.9, 0.053	3.0, 0.089	3.0, 0.089
CC trap (base color)				
White[b]	0.10 ± 0.03 a	0.10 ± 0.02 ab	0.63 ± 0.09 a	0.18 ± 0.04 b
Blue	0.02 ± 0.01 a	0.20 ± 0.05 a	0.28 ± 0.06 b	2.07 ± 0.28 a
Yellow	0.09 ± 0.04 a	0.03 ± 0.01 b	0.18 ± 0.04 b	0.03 ± 0.03 b
F, *P*	3.7, 0.047	7.3, 0.028	14.5, <0.001	49.0, <0.001

[a]Dichlorvos dispenser plus blue stripes (Blue-D).
[b]CC-trap base color with dichlorvos killing agent and ethylene glycol preservative.
[c]Means in a column not followed by the same letter are significantly different by orthogonal comparison for Blue-D vs. CC traps, $df = 1, 58$ and by Tukey's HSD for CC traps, $df = 2, 28$.

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and *Frankliniella* sp. (F = 4.1 and 5.3, df = 2, 44, P = 0.024 and 0.009, respectively) than yellow base CC traps. Blue base CC traps caught more *M. abdominalis* than white and yellow base CC traps (F = 99.2, df = 2, 44, P = 0.003). Dichlorvos cubes in CC traps increased captures of all thrips species (F = 6.0 – 20.6, df = 1, 44, P = 0.018 – <0.001) except *S. dorsalis*. Ethylene glycol in the CC trap bases had no effect on trap catch numbers. However, thrips captured in ethylene glycol equipped traps were well preserved, with less damage to antennae and less desiccation than traps without ethylene glycol.

There were significant treatment interactions for CC trap base colors and dichlorvos treatments for *T. palmi* trap catches (F = 6.6, df = 2, 44, P = 0.003), but not for the three other thrips species (Table 2). Thrips captures for the ethylene glycol treatment, or the interactions with CC trap base color and dichlorvos were not significantly different.

Frankliniella sp. captures were identified by Systematic Entomology Laboratory as *Frankliniella cephalica* (Crawford) and *Frankliniella insularis* (Franklin).

Experiment 3. Comparison of CC and Blue-D traps in St. Vincent (dry season). Mean numbers of *T. palmi*, *Frankliniella* sp., and *M. abdominalis* caught in Blue-D traps were greater compared with CC traps (F = 8.2 – 10.4, df = 1, 58, P = 0.002 – 0.006). Mean captures of *S. dorsali* were not significantly different for the two trap types (Table 3). dichlorvos cubes in CC traps increased captures of all four thrips species (F = 8.6 – 72.2, df = 1, 44, P = 0.005 – <0.001). On average, blue and white base CC traps caught more *T. palmi*, *Frankliniella* sp., and *M. abdominalis* than yellow base CC traps (F = 9.5 – 16.7, df = 2, 44, P = 0.002 – <0.001). The addition of ethylene glycol in traps resulted in greater captures of *S. dorsalis*, *Frankliniella* sp., and *M. abdominalis* (F = 7.4 – 10.5, df = 1, 44, P = 0.009 – 0.002), than the mean captures of *T. palmi*. Blue and white base CC traps with ethylene glycol caught more *Frankliniella* sp. (F = 4.0, df = 2, 44, P = 0.024), but not the other three thrips species. There were no significant differences in thrips captures for other treatment interactions.

TABLE 2. SEASONAL MEANS (±SE) OF THRIPS CAUGHT IN TRAPS IN COMMERCIAL CHILI PEPPER FIELDS, GEORGETOWN, ST. VINCENT, WET SEASON, 14 OCTOBER TO 29 NOVEMBER (EXPERIMENT 2.)

	Mean numbers/trap/week			
	S. dorsalis	*T. palmi*	*Frankliniella* sp.	*Microcephalothrips abdominalis*
Trap type				
Blue-D[a]	0.00 ± 0.00 a[b]	0.47 ± 0.16 a	0.71 ± 0.17 a	0.82 ± 0.10 a
CC traps	0.02 ± 0.01 a	0.08 ± 0.01 b	0.11 ± 0.03 b	0.15 ± 0.02 b
F, *P*	1.3, 0.259	42.4, < 0.001	48.9, < 0.001,	99.2, < 0.001
CC trap (base color)				
White	0.02 ± 0.01 a	0.09 ± 0.03 a	0.10 ± 0.03 ab	0.11 ± 0.04 b
Blue	0.03 ± 0.01 a	0.10 ± 0.03 a	0.20 ± 0.06 a	0.24 ± 0.04 a
Yellow	0.02 ± 0.01 a	0.03 ± 0.01 b	0.03 ± 0.02 b	0.09 ± 0.03 b
F, *P*	<0.1, None	4.1, 0.024	5.3, 0.009	6.9, 0.003
Dichlorvos in CC traps				
Yes	0.02 ± 0.01 a	0.12 ± 0.02 a	0.17 ± 0.05 a	0.22 ± 0.03 a
No	0.03 ± 0.01 a	0.03 ± 0.01 b	0.06 ± 0.02 b	0.07 ± 0.02 b
F, *P*	0.2, None	17.5, < 0.001	6.0, 0.018	20.6, < 0.001
Base-dichlorvos				
White-yes	0.02 ± 0.01 a	0.17 ± 0.05 a	0.13 ± 0.05 a	0.15 ± 0.06 a
White-no	0.02 ± 0.02 a	0.02 ± 0.01 b	0.08 ± 0.04 a	0.07 ± 0.03 a
Blue-yes	0.02 ± 0.01 a	0.18 ± 0.03 a	0.32 ± 0.11 a	0.36 ± 0.05 a
Blue-no	0.03 ± 0.01 a	0.03 ± 0.02 b	0.09 ± 0.04 a	0.11 ± 0.04 a
Yellow-yes	0.02 ± 0.01 a	0.02 ± 0.02 b	0.06 ± 0.04 a	0.16 ± 0.04 a
Yellow-no	0.03 ± 0.01 a	0.04 ± 0.01 a	0.00 ± 0.00 a	0.03 ± 0.01 a
F, *P*	<0.1, None	6.6, 0.003	1.6, 0.214	2.3, 0.108

[a]Dichlorvos dispenser plus blue stripes (Blue-D).
[b]Means in a column of the same variable not followed by the same letter are significantly different by orthogonal comparison for Blue-D vs. CC traps, and df = 1, 58, and by Tukey's HSD for CC traps, and df = 1 or 2, 44. Means of three way interactions were not significantly different. Ethylene glycol treatments and other interactions were not statistically different.

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TABLE 3. SEASONAL MEANS (±SE) OF THRIPS CAUGHT IN COMMERCIAL CHILI PEPPER FIELDS, GEORGETOWN, ST. VINCENT, DRY SEASON, 23 MARCH TO 4 MAY 2005 (EXPERIMENT 3).

	Mean numbers/trap/week			
	S. dorsalis	*T. palmi*	*Frankliniella* sp.	*Microcephalothrips abdominalis*
Trap type				
Blue-D[a]	0.05 ± 0.03 a[b]	1.06 ± 0.33 a	0.21 ± 0.09 a	0.33 ± 0.06 a
CC trap	0.09 ± 0.02 a	0.49 ± 0.08 b	0.08 ± 0.02 b	0.17 ± 0.03 b
F, *P*	0.7, None	10.4, 0.002	8.7, 0.005	8.2, 0.006
CC trap (base color)				
White	0.06 ± 0.02 a	0.53 ± 0.13 a	0.08 ± 0.02 ab	0.16 ± 0.04 ab
Blue	0.13 ± 0.04 a	0.78 ± 0.16 a	0.14 ± 0.04 a	0.25 ± 0.06 a
Yellow	0.08 ± 0.02 a	0.17 ± 0.04 b	0.02 ± 0.01 b	0.10 ± 0.03 b
F, *P*	2.3, 0.111	16.7, <0.001	9.5, <0.001	7.2, 0.002
Dichlorvos in CC traps				
Yes	0.13 ± 0.03 a	0.82 ± 0.12 a	0.14 ± 0.03 a	0.31 ± 0.04 a
No	0.05 ± 0.01 b	0.17 ± 0.03 b	0.02 ± 0.01 b	0.04 ± 0.01 b
F, *P*	8.6, 0.005	55.3, <0.001	33.9, <0.001	72.2, <0.001
Base-dichlorvos				
White-yes	0.08 ± 0.04 b	0.89 ± 0.18 b	0.13 ± 0.03 b	0.28 ± 0.06 b
White-no	0.04 ± 0.02 b	0.18 ± 0.07 c	0.03 ± 0.02 bc	0.03 ± 0.03 c
Blue-yes	0.23 ± 0.06 a	1.35 ± 0.19 a	0.26 ± 0.06 a	0.46 ± 0.07 a
Blue-no	0.03 ± 0.01 b	0.22 ± 0.06 c	0.02 ± 0.01 c	0.04 ± 0.03 c
Yellow-yes	0.08 ± 0.02 b	0.22 ± 0.06 c	0.04 ± 0.02 bc	0.18 ± 0.05 bc
Yellow-no	0.08 ± 0.03 b	0.12 ± 0.04 c	0.01 ± 0.01 c	0.03 ± 0.01 c
F, *P*	4.6, 0.015	11.7, <0.001	8.3, 0.001	6.4, 0.004
Ethylene glycol in CC traps				
Yes	0.13 ± 0.02 a	0.51 ± 0.09 a	0.11 ± 0.03 a	0.22 ± 0.04 a
No	0.05 ± 0.02 b	0.48 ± 0.12 a	0.05 ± 0.02 b	0.12 ± 0.04 b
F, *P*	7.5, 0.009	0.2, None	7.4, 0.009	10.5, 0.002
Base-ethylene glycol				
White-yes	0.10 ± 0.04 a	0.57 ± 0.15 a	0.10 ± 0.03 ab	0.24 ± 0.07 a
White-no	0.03 ± 0.02 a	0.50 ± 0.21 a	0.06 ± 0.03 b	0.08 ± 0.03 a
Blue-yes	0.15 ± 0.05 a	0.74 ± 0.21 a	0.21 ± 0.07 a	0.27 ± 0.08 a
Blue-no	0.11 ± 0.05 a	0.83 ± 0.26 a	0.07 ± 0.03 b	0.23 ± 0.09 a
Yellow-yes	0.13 ± 0.02 a	0.23 ± 0.06 a	0.02 ± 0.01 b	0.16 ± 0.05 a
Yellow-no	0.03 ± 0.01 a	0.11 ± 0.04 a	0.03 ± 0.02 b	0.05 ± 0.02 a
F, *P*	0.4, None	0.5, None	4.0, 0.024	1.4, 0.239

[a]Dichlorvos dispenser plus blue stripes (Blue-D).
[b]Means in a column of the same variable not followed by the same letter are significantly different by orthogonal comparison for Blue-D vs. CC traps, and *df* = 1, 58, and by Tukey's HSD for CC traps, and *df* = 1 or 2, 44. Means of three way interactions were not significantly different. Ethylene glycol treatments and other interactions were not statistically different.

Seasonal Weather Effects on CC Trap Catches during the Wet and Dry Seasons in St. Vincent, 2004-2005

CC trap captures were 4.5 and 6.1 fold greater for *S. dorsalis* and *T. palmi*, respectively, during the dry season compared with the wet season. Rainfall averaged 1.1 mm per day during the dry season and 18.0 mm per day during the wet season (Table 4). Air temperatures in the dry season was 1.3°C higher compared with the wet season.

Experiment 4. Comparison of Sticky Card Trap Colors (Dry Season). Significantly more *S. dorsalis* were caught on yellow sticky card traps compared with blue sticky card traps. Yellow and blue sticky card traps caught more *S. dorsalis* than white sticky card traps (Table 5). More *T. palmi*, *Frankliniella* sp. and *M. abdominalis* were caught on blue sticky card traps compared with white and yellow sticky card traps.

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TABLE 4. SEASONAL MEAN (±SE) RAINFALL, AIR TEMPERATURE, AND CC TRAP CAPTURES OF THRIPS SPECIES DURING THE WET AND DRY SEASONS IN ST. VINCENT, 2004-2005.

					Mean numbers/trap/week[a]			
Season	Mean mm/day	Rainfall total (mm)	Rainy days total	Air temperature °C	*S. dorsalis*	*T. palmi*	*Frankliniella* sp.	*Microcephalothrips abdominalis*
Wet (W)	18.2 ± 4.8	855.1	34/47	28.4 ± 0.03	0.02 ± 0.00 b	0.08 ± 0.01 b	0.11 ± 0.03 a	0.15 ± 0.02 a
Dry (D)	1.1 ± 0.4	48.1	10/43	29.7 ± 0.01	0.09 ± 0.01 a	0.49 ± 0.09 a	0.08 ± 0.01 a	0.17 ± 0.02 a
t, *P*					57.8, <0.001	22.3, 0.002	0.8, None	0.6, None
D/W ratio	0.58	0.47	0.23	1.05	4.5	6.1	1.4	1.1

[a]Means in a column followed by the same letter are not significantly different by *t*–test, *df* = 1.

DISCUSSION

Blue-D traps caught more *S. dorsalis* than the CC traps in Taiwan, but approximately equal numbers in St. Vincent. Similarly, Blue-D traps consistently caught more of the other three thrips species in the study compared with the CC trap. Overall, the addition of dichlorvos cubes increased CC trap captures of *S. dorsalis* in St. Vincent. The blue base CC trap with dichlorvos cubes caught more *S. dorsalis* than the other treatment combinations only during the dry season in St. Vincent. Unfortunately, previous trap studies conducted in India on *S. dorsalis* did not include blue base CC trap comparisons with white and yellow base traps (Chu et al. 2000). The addition of ethylene glycol to CC traps increased trap catches of *S. dorsalis* and *M. abdominalis* during the dry season in St. Vincent. The addition of ethylene glycol resulted in better preserved specimens for taxonomic and genetic studies.

Numbers of *S. dorsalis* captured in CC traps with dichlorvos were low in both Taiwan and St. Vincent. We reported earlier that blue sticky card traps caught more *F. occidentalis* in a broccoli field than yellow sticky card traps (Chen et al. 2004). Blue sticky card traps also captured greater numbers of *T. palmi*, *Frankliniella* sp., and *M. abdominalis* than yellow or white traps in the current studies. Our results from St. Vincent indicate that yellow sticky card traps were more attractive to *S. dorsalis* than white or blue sticky card traps. Similarly, Hoddle et al. (2003) reported that *Scirtothrips perseae* (Nakahara) was more attracted to yellow than white or blue sticky card traps.

The Blue-D trap did not consistently capture greater numbers of *S. dorsalis* than CC traps. Its potential toxicity in the environment is of concern. Although the CC trap captures fewer *S. dorsalis*, the quality of the captured specimens is high. They are easily recovered from the trap and stored in ethanol for later taxonomic and genetic analysis. Yellow sticky traps capture more thrips than the CC traps but they also capture a large number of non-target insects. In addition, thrips that are captured on the sticky trap are not easily removed and stored for later studies. Sticky traps seem to be less labor intensive, require less component assembly and therefore less expertise in trap placement than the CC traps.

Seal et al. (2005) have determined from direct plant sampling that economic damage to chili peppers by *S. dorsalis* occurs at densities of 0.5 to 2 individuals (larvae or adults) per terminal leaf. This sampling method requires nine samples per 24-48 m^2 area in order to achieve the 90% precision level. This method may be too labor intensive to use in large scale survey and detection efforts. Alternatively, visual observation

TABLE 5. SEASONAL MEANS (±SE) OF THRIPS CAUGHT ON WHITE, BLUE, AND YELLOW STICKY CARD TRAPS IN COMMERCIAL CHILI PEPPER FIELDS, GEORGETOWN, ST. VINCENT, DRY SEASON, 23 MARCH TO 4 MAY 2005 (EXPERIMENT 4).

	Mean numbers/trap/week[a]			
Sticky trap color	*S. dorsalis*	*T. palmi*	*Frankliniella* sp.	*Microcephalothrips* sp.
White	1.41 ± 0.11 b	8.04 ± 1.45 b	2.08 ± 0.34 b	4.39 ± 0.57 b
Blue	3.72 ± 0.37 b	27.11 ± 2.20 a	8.75 ± 0.85 a	21.40 ± 1.79 a
Yellow	14.10 ± 1.06 a	7.38 ± 0.62 b	1.73 ± 0.18 b	4.30 ± 0.45 b
F, *P*	111.4, <0.001	57.411.7, <0.001	50.0, <0.001	77.6, <0.001

[a]Means in a column not followed by the same letter are significantly different by Tukey's HSD, and *df* = 2 or 18.

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for plant damage symptoms like curled, deformed, or yellow leaves coupled with placing sticky card traps can be utilized as a preliminary detection tool. Positive detections would then be followed by direct plant sampling to capture large number of individual specimens for taxonomic verification. APHIS guidelines for survey are based on the principle of finding one *S. dorsalis* in a suspected area. The guidelines suggest 2,280 CC traps for initial survey that will be placed in one square mile areas for detecting *S. dorsalis* (USDA-aphis, 2004). If one or more *S. dorsalis* is found the second phase of survey the survey area will be expanded to the eight surrounding square miles. The presence of a single *S. dorsalis* in the second survey will lead to an expansion of the survey area to 80 surrounding square miles for the third phase of survey. Results of our studies estimate that CC traps would catch 46 and 205 for wet and dry seasons, respectively. These would translate to the captures of 46 and 205 *S. dorsalis* in CC traps for the initial survey, 148 and 666 for the second survey, and 1069 and 4813 for third phase of survey during wet and dry seasons, respectively, in St. Vincent.

Current methods employed for detection of *S. dorsalis* are inefficient as demonstrated in the present report. Studies of *S. dorsalis* behavior, including the development of attractants and pheromones as potential lures, are being conducted to develop more efficient trap systems for detection and monitoring of this insect pest.

During preparation of this manuscript, *S. dorsalis* was detected on roses in Palm Beach, FL and in multiple retail garden centers on hot pepper seedlings by the Florida Department of Agriculture and Consumer Services (FDACS) (Wayne Dixon, pers. comm.). Further surveys of retail garden centers in the Lower Rio Grande Valley of Texas likewise revealed the presence of this new invasive species on hot pepper seedlings (M. Ciomperlik, unpublished data). Specimens were confirmed as *Scirtothrips dorsalis* by the USDA ARS Systematic Entomology Laboratory. The current distribution of *S. dorsalis* in the Caribbean is limited to a few islands. It has recently invaded the US, and is expected to spread over time through agricultural trade and tourism (Venette & Davis 2004; Meissner et al. 2005). These observations also indicate an alarming potential for rapid spread of this pest thrip species through interstate movement of ornamentals and plant seedlings in the US. The potential impact of this thrips on agriculture in the United States alone has been estimated at approximately \$3.6 to \$6.0 billion a year (Lynn Garrett, USDA APHIS PPQ CPHST, pers. comm.). Effective survey and detection methods are needed to monitor the spread, and manage populations, of *S. dorsalis* both in the Caribbean and the US.

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