A survey of insect populations in *Capsicum chinense* L. plantings in Georgetown, St. Vincent, using modified CC traps[1,2]

Matthew Ciomperlik[3], Chang-Chi Chu[4], Jason Carlson[3], Marcus Richards[5] and Thomas J. Henneberry[4]

J. Agric. Univ. P.R. 93(3-4):207-221 (2009)

ABSTRACT

The insect populations in hot pepper, *Capsicum chinense* L. (Solanaceae), were surveyed in Georgetown, St. Vincent, during the 2004 wet and 2005 dry seasons. Modified white, blue, and yellow CC traps were used to capture insects in the plantings. Overall, 69 insect families were captured, 41 of which were captured during both the wet and dry seasons. During the wet season, the greatest numbers of individuals captured were from the Cecidomyiidae, Chironomidae, Chloropidae, Chrysomelidae, Cicadellidae, and Drosophilidae families. During the dry season, the greatest numbers of individuals captured were from Chrysomelidae and Cicadellidae families. The addition of dichlorvos as a killing agent and propylene glycol as an insect preservative to the CC traps increased the number and diversity of insects caught. Additionally, propylene glycol helped to preserve the specimens for taxonomic and genetic determinations. CC traps with yellow bases attracted more insect families than traps with white or blue bases. However, CC traps with blue bases caught more Lonchaeidae during both the wet and dry seasons, and more Tachinidae during the dry season. CC traps with white or yellow trap bases were equally attractive to insects in the families Aleyrodidae, Drosophilidae, Lauxaniidae, and Otitidae.

Key words: CC trap, color attraction, dichlorvos, propylene glycol, St. Vincent, insect families

RESUMEN

Catastro de poblaciones de insectos en siembras de *Capsicum chinense* L. en Georgetown, San Vicente, usando trampas CC modificadas

Las poblaciones de insectos en el ají picante, *Capsicum chinense* L., se monitorearon en Georgetown, San Vicente, durante la época de lluvia de 2004 y la de sequía de 2005. Se usaron las trampas CC modificadas, blancas, azules y amarillas, para capturar insectos en las siembras. Se capturaron 69 familias de insectos; 41 de éstas se capturaron durante ambas épocas, la de lluvia y la de sequía. Durante la época de lluvia, el mayor número de indivi-

[1]Manuscript submitted to Editorial Board 24 March 2008.

[2]The authors thank Juan M. Rodríguez for his technical assistance and Carolyn Cohen, USDA APHIS International Services, for her support for the study.

[3]USDA, APHIS, PPQ, CPHST Mission Laboratory, Edinburg, TX 78541.

[4]Retired, USDA, ARS Western Cotton Research Laboratory, Phoenix, AZ 85040.

[5]Ministry of Agriculture and Fisheries, St. Vincent and the Grenadines, Kingstown, St. Vincent, W.I.

duos capturados pertenecía a las familias Cecidomyiidae, Chironomidae, Chloropidae, Chrysomelidae, Cicadellidae y Drosophilidae. Durante la época de sequía, el mayor número de individuos capturados pertenecía a las familias Cicadellidae y Chrysomelidae. El número y la diversidad de los insectos capturados aumentaron al añadir dichlorvos como un agente exterminador y glicol de propileno como agente preservativo a las trampas CC. Además, el glicol de propileno ayudó a preservar los especímenes para las determinaciones taxonómicas y genéticas. Las trampas CC con bases amarillas atrajeron más familias de insectos que las trampas con bases blancas o azules. Sin embargo, las trampas CC con bases azules capturaron más Lonchaeidae durante ambas épocas, de lluvia y sequía, y más Tachinidae durante la época de sequía. Las trampas CC con bases blancas o amarillas resultaron igualmente atractivas a los insectos en las familias Aleyrodidae, Drosophilidae, Lauxaniidae y Otitidae.

Palabras clave: Trampas CC, atracción a color, dichlorvos, glicol de propileno, San Vicente, familias de insectos

INTRODUCTION

The CC trap has been used extensively to monitor sweet potato whitefly populations (Chu and Henneberry, 1998; Chu et al., 2000, Chu et al., 2001; Chu et al., 2007). This trap consists of three components: a clear plastic trap top to admit light for adult orientation into the trap, a clear deflector plate to reduce the escape of trapped adults, and a colored trap base with an opening to allow entry of insects. The trap is easy to use, reusable, and has no sticky materials, pheromones, nor baits as attractants. The trap bases can be made in different colors for attraction of different insects, yet the ability of the trap to capture different types of insects remains largely unknown. The trap has been tested in a number of crops to date; however, it has been evaluated for efficacy only with a few different insect species. The CC trap has been shown to readily capture western flower thrips, *Frankliniella occidentalis* Pergrante; onion thrips, *Thrips tabaci* Lindeman (Liu and Chu, 2004); leafhoppers, *Empoasca* spp. and *Asymmetresca* spp. (Karut et al., 2005); and the insect parasitoid *Eretmocerus eremicus* Rose and Zolnerowich (Hoelmer et al., 1998).

During the evaluation of CC traps with different modifications for detection and monitoring of chilli thrips, *Scirtothrips dorsalis* Hood (Chu et al., 2006), we recorded other families of insects caught in the traps during 2004 and 2005 in plantings of hot pepper, *Capsicum chinense* L., on St. Vincent. Specific objectives of the study were 1) to inventory insect families on St. Vincent in hot pepper; and 2) to measure trap capture efficiency for insect families when white, blue, and yellow colored CC trap bases were used; and 3) to determine whether additions of a killing agent and/or a preservative increased trap captures of insects.

MATERIALS AND METHODS

The studies were conducted in 2004 and 2005 on two commercial farms in Georgetown, St. Vincent, West Indies, by using a randomized complete block design with five replicates (Chu et al., 2006). The test plots (~ 0.2 ha each) were located with approximately 1.5 km separation between plots. On both farms, hot pepper plants (*Capsicum chinense*) were separated by 1 m within rows and 1 m between rows.

The treatments consisted of trap base color with or without a 1-cm^2 cube of the killing agent dichlorvos (United Industries Corp., St. Louis, MO)[6], or with or without 15 ml of 10% propylene glycol as a preservative agent (Sierra antifreeze/coolant, Old World Industries, Northbrook, IL) (Figure 1). The dichlorvos cube was suspended at the top of the trap by bending a paperclip, passing it through the top of the trap, and piercing the cube to the portion of the paperclip inside of the trap. The propylene glycol solution was added by inverting the trap, pouring in 15 ml of the solution, and re-inverting the trap prior to placement in the field. The trap deflector plate (Figure 1, part B) was not included in this study to facilitate the addition of both the dichlorvos cube and the propylene glycol solution. The CC traps were placed on wooden stakes and spaced 1 m apart within hot pepper rows with the trap bases positioned collectively about 22 cm below the tallest plant terminals.

The treatments were 1) white base, 2) white base with dichlorvos, 3) white base with propylene glycol, 4) blue base, 5) blue base with dichlorvos, 6) blue base with propylene glycol, 7) yellow base, 8) yellow base with dichlorvos, and 9) yellow base with propylene glycol. Weekly, trap placement within the fields was re-randomized, and dichlorvos cubes and the preservative propylene glycol were replaced in treatment traps. Sample collection was accomplished by weekly disassembling the traps in the field and rinsing them with 20 ml of 85% ethanol to dislodge insects from the trap bases. The insects suspended in ethanol were poured into labeled 8-dram glass vials and stored for later identification in the laboratory.

Traps were in operation for six weeks during the wet season from 14 October to 29 November 2004, and during the dry season from 23 March to 4 May 2005. Weather data, including air temperature and relative humidity, were recorded on an hourly basis by a HOBO Pro Series H8 data logger (Onset Computer Corp., Bourne, MA). Rainfall was recorded with a Digital Tipping Bucket Rain Gauge (Spectrum Technologies, Plainfield, IL). All insects in the samples were identified by using

[6]Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials nor is this mention a statement of preference over other equipment or materials.

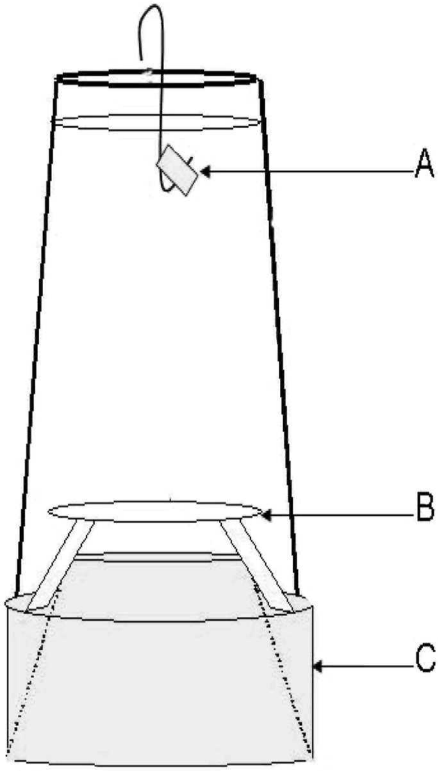

FIGURE 1. Schematic drawing of CC trap used in the hot pepper field studies on St. Vincent. Part A is a paperclip bent to attach the trap to a suspended stake, and to the 1-cm^2 dichlorvos cube simultaneously; part B is the removable deflector plate; and part C is the trap base bottom available in multiple single colors.

the characters described in Borror et al. (1989), and then sorted by families and counted. Based on wet or dry season, only the number of insects per family that showed differences in capture rates among trap treatments (base color, base color with dichlorvos, and base color with propylene glycol) are reported here for space considerations.

Statistical Analysis

The data collected were heterogeneous and not normally distributed as required by ANOVA; therefore, we decided to transform the data using Log(Y+1) prior to the analysis. ANOVA were performed using a three factor factorial analysis (Anonymous, 1989) and means were separated by using Tukey's HSD (Tukey, 1953). Here we report only the main effects: trap base color, dichlorvos, and propylene glycol, excluding two-way and three-way interactions for space considerations.

RESULTS

Insect Families

A total of more than 22,000 insect specimens, comprising 61 and 48 families were caught in CC traps during the 2004 wet and 2005 dry seasons, respectively (Table 1). Forty-one families were caught during both the wet and dry seasons. A total of 69 different insect families were captured during this study.

Trap Base Colors

In the 2004 wet season, the mean number of individuals per family from Chalcidae, Chironomidae, Chloropidae, Chrysomelidae, Cicadellidae, Drosophilidae, Empididae, and Phoridae families were significantly greater for yellow base traps than for blue or white (Table 2). Significantly greater mean numbers of insects from Lauxaniidae and Otitidae families were caught in yellow base traps than in blue base traps. The mean number of insects from the Lonchaeidae family caught

TABLE 1.—*The insect families caught in CC traps at Georgetown, St. Vincent, in 2004 wet season and 2005 dry season.*

Agromyzidae*	Coccinelidae*†	Isotomidae*	Saldidae*†
Aleyrodidae*†	Colletidae*	Lampyridae*	Sarcophagidae*
Anisopodidae*	Cucujidae*	Lauxaniidae*†	Scathophagidae†
Aphelinidae*†	Culicidae*	Lepismatidae*†	Sciaridae*†
Aphididae*†	Curculionidae*	Lonchaeidae*†	Signiphoridae†
Apidae*	Delphacidae*†	Lygaeidae*	Staphylinidae*†
Asteiidae*	Dolichopodidae*†	Miridae†	Tachinidae*†
Blaberidae*†	Drosophilidae*†	Muscidae*†	Tanagostomatididae†
Bostrichidae*†	Elateridae†	Mycetophilidae*†	Tenebrionidae*†
Braconidae*†	Empididae*†	Mymaridae*	Tephritidae*
Callophoridae*†	Entomobryidae*†	Neelidae*†	Termitidae*†
Cecidomyiidae*†	Ephydridae*	Otitidae*†	Tingidae*†
Chalcidae*†	Eulophidae†	Pentatomidae*	Tipulidae*
Chamaemyiidae*	Eurytomidae*†	Phoridae*†	Trichogrammatidae†
Chironomidae*†	Formicidae*†	Poduridae*†	Zorotypidae*
Chloropidae*†	Halictidae*†	Psychodidae*†	
Chrysomelidae*†	Heleomyzidae*	Psyllidae*†	
Cicadellidae*†	Ichneumonidae†	Pteromalidae*	

*and † denote CC trap captures of insect families for wet (2004) and dry (2005) seasons, respectively.

TABLE 2.—*Mean (±SE) number of individuals per family captured in CC traps with different colored trap bases at Georgetown, St. Vincent, 2004 – wet season.*

	No./ week × 100						
	Agromyzidae	Braconidae	Cecidomyiidae	Chalcidae	Chironomidae	Chloropidae	Chrysomelidae
Color[1]							
White	2.9 ± 1.4 a[2]	0.68 ± 0.6 a	173.4 ± 20.0 a	4.2 ± 1.4 b	119.3 ± 15.8 b	675.0 ± 109.0 b	166.50 ± 20.88 b
Blue	2.9 ± 1.4 a	1.6 ± 0.9 a	176.8 ± 22.2 a	7.3 ± 2.2 b	124.5 ± 12.8 b	221.8 ± 40.1 c	66.33 ± 14.46 c
Yellow	2.3 ± 1.4 a	0.0 ± 0.0 a	205.8 ± 22.6 a	17.1 ± 3.5 a	159.8 ± 18.3 a	1,638.4 ± 292.1 a	367.25 ± 43.42 a
Dich[1]							
Yes	3.1 ± 1.2 a	0.8 ± 0.5 a	211.3 ± 11.7 a	12.4 ± 2.5 a	153.6 ± 11.5 a	876.5 ± 166.7 a	252.11 ± 31.82 a
No	2.3 ± 1.0 a	0.7 ± 0.5 a	159.4 ± 21.1 b	6.7 ± 1.9 b	115.5 ± 13.9 b	813.7 ± 198.4 a	149.74 ± 31.39 b
PG[1]							
Yes	4.9 ± 1.3 a	1.4 ± 0.7 a	241.9 ± 14.3 a	11.3 ± 2.7 a	182.1 ± 10.7a	1,042.3 ± 169.7 a	266.39 ± 33.25 a
No	1.8 ± 0.9 b	0.0 ± 0.0 b	128.8 ± 14.2 b	7.7 ± 1.8 a	86.9 ± 8.9 b	647.8 ± 189.0 b	133.7 ± 27.8 b
	Cicadellidae	Dolichopodidae	Drosophilidae	Empididae	Formicidae	Lauxaniidae	Lonchaeidae
Color[1]							
White	216.50 ± 20.96 b	14.83 ± 3.81 a	169.17 ± 29.50 b	22.17 ± 6.39 b	61.67 ± 9.58 a	18.33 ± 3.56 ab	5.75 ± 1.76 b
Blue	85.33 ± 7.00 c	28.17 ± 5.02 a	101.92 ± 18.78 c	5.17 ± 2.01 b	57.00 ± 10.09 a	8.75 ± 2.74 b	24.50 ± 4.79 a
Yellow	331.58 ± 29.13 a	18.08 ± 4.08 a	249.83 ± 35.79 a	65.08 ± 12.73 a	74.17 ± 11.67 a	27.50 ± 4.36 a	6.33 ± 2.62 b
Dich[1]							
Yes	268.44 ± 28.27 a	21.22 ± 3.42 a	220.72 ± 22.41 a	49.33 ± 9.95 a	91.11 ± 8.57 a	24.72 ± 3.33 a	13.17 ± 3.20 a
No	153.83 ± 16.01 b	19.50 ± 3.89 a	126.56 ± 26.28 b	12.28 ± 3.40 b	37.44 ± 4.95 b	11.67 ± 2.67 b	11.22 ± 3.05 a
PG[1]							
Yes	232.83 ± 25.41 a	216.50 ± 24.34 a	28.89 ± 4.24 a	39.06 ± 9.34 a	70.06 ± 6.01 a	26.11 ± 3.24 a	17.94 ± 3.79 a
No	189.44 ± 24.57 b	30.78 ± 25.03 b	11.83 ± 1.97 b	22.55 ± 6.51 b	58.50 ± 10.45 b	10.28 ± 2.52 b	6.44 ± 1.72 b

[1]Base color: Denotes CC trap base; Dich = Dichlorvos; PG = Propylene glycol.

[2]Means within columns not followed by the same letter are significantly different by Tukey's HSD test, $P = 0.05$ and df = 2, 1, 1, and 44 for base color, dichlorvos, propylene glycol (PG), and error, respectively. Data were logarithmic transformed before ANOVA.

TABLE 2.—*(Continued) Mean (±SE) number of individuals per family captured in CC traps with different colored trap bases at Georgetown, St. Vincent, 2004 – wet season.*

	No./ week × 100						
	Muscidae	Otitidae	Phoridae	Poduridae	Psychodidae	Sciaridae	Tachinidae
Color[1]							
White	6.50 ± 2.22 a	40.75 ± 8.61 ab	49.17 ± 6.63 b	0.58 ± 0.58 a	20.83 ± 5.62 a	11.33 ± 2.67 a	1.67 ± 0.76 a
Blue	1.83 ± 1.05 a	23.75 ± 4.41 b	36.83 ± 6.83 b	1.58 ± 0.88 a	12.50 ± 2.53 a	14.25 ± 3.74 a	3.75 ± 1.54 a
Yellow	6.67 ± 1.55 a	71.17 ± 16.46 a	81.92 ± 12.02 a	4.09 ± 2.12 a	22.50 ± 4.76 a	18.58 ± 3.45 a	2.50 ± 1.22 a
Dich[1]							
Yes	7.00 ± 1.53 a	52.28 ± 11.12 a	70.17 ± 7.70 a	1.83 ± 0.95 a	17.78 ± 2.49 a	21.33 ± 2.92 a	3.61 ± 1.11 a
No	3.00 ± 1.19 b	38.17 ± 7.66 a	41.78 ± 7.38 b	2.33 ± 1.30 a	19.44 ± 4.65 a	8.11 ± 1.88 b	1.67 ± 0.84 a
PG[1]							
Yes	6.55 ± 1.66 a	57.50 ± 6.64 a	70.22 ± 6.78 a	2.61 ± 1.31 a	25.56 ± 4.32 a	20.89 ± 2.74 a	3.33 ± 1.17 a
No	3.44 ± 1.05 a	32.94 ± 11.46 b	41.72 ± 8.23 b	1.56 ± 0.92 a	11.67 ± 2.42 b	8.55 ± 2.22 b	1.94 ± 0.77 a

[1]Base color: Denotes CC trap base; Dich = Dichlorvos; PG = Propylene glycol.

[2]Means within columns not followed by the same letter are significantly different by Tukey's HSD test, $P = 0.05$ and df = 2, 1, 1, and 44 for base color, dichlorvos, propylene glycol (PG), and error, respectively. Data were logarithmic transformed before ANOVA.

in blue base traps was significantly greater than the number in white and yellow base traps. There were no significant differences in the mean number of individuals captured from the Agromyzidae, Braconidae, Cecidomyiidae, Dolichopodidae, Formicidae, Muscidae, Poduridae, Psychodidae, Sciaridae, or Tachinidae families caught in traps with different base colors.

During the 2005 dry season, the mean number of insects caught in yellow base traps from the Chrysomelidae, Cicadellidae, Coccinellidae, Elateridae, Empididae, and Tanagostomatididae families were significantly greater than in white or blue base traps (Table 3). Significantly greater mean numbers of insects from Aleyrodidae, Drosophilidae, and Otitidae families were caught in yellow base traps than in blue base, but not so in white base traps. The mean numbers of insects caught were significantly greater in blue base traps for Lonchaeidae and Tachinidae families than in white and yellow base traps. There were no significant differences in mean numbers of insects caught based on trap base colors for Aphididae, Bostrichidae, Cecidomyiidae, Chironomidae, Chloropidae, Formicidae, and Halictidae families (Table 3).

Dichlorvos effect

In the 2004 wet season, significantly greater numbers of insects were caught in dichlorvos-equipped traps from Cecidomyiidae, Chalcidae, Chironomidae, Chrysomelidae, Cicadellidae, Drosophilidae, Empididae, Formicidae, Lauxaniidae, Muscidae, Phoridae, and Sciaridae families than in traps without dichlorvos (Table 2). There were no significant differences in the number of insects caught in traps with or without dichlorvos for Agromyzidae, Braconidae, Chloropidae, Dolichopodidae, Lonchaeidae, Otitidae, Poduridae, Psychodidae, or Tachinidae families (Table 2).

For the 2005 dry season, insect catches of Chrysomelidae, Cicadellidae, Coccinellidae, Elateridae, Empididae, Formicidae, and Tachinidae families were significantly greater in traps with dichlorvos than in traps without dichlorvos (Table 3). A significantly greater number of insects from the Chironomidae family were caught in traps without dichlorvos. There were no significant differences in insect catches of Aleyrodidae, Aphididae, Bostrichidae, Cecidomyiidae, Drosophilidae, Lonchaeidae, Otitidae, and Tanagostomatididae families in traps with or without dichlorvos (Table 3).

Propylene Glycol Effect

In the 2004 wet season, the numbers of insects from Agromyzidae, Braconidae, Cecidomyiidae, Chironomidae, Chloropidae, Chrysomel-

TABLE 3.—*Mean (±SE) number of individuals per family captured in CC traps with different colored trap bases at Georgetown, St. Vincent, 2004 – dry season.*

	No./ week × 100						
	Aleyrodidae	Aphididae	Bostrichidae	Cecidomyiidae	Chironomidae	Chloropidae	Chrysomelidae
Color[1]							
White	25.94 ± 3.21 ab[2]	7.81 ± 1.69 a	0.00 ± 0.00 a	19.06 ± 3.25 a	15.00 ± 2.95 a	8.44 ± 2.09 a	162.50 ± 25.97 b
Blue	19.06 ± 2.46 b	5.31 ± 1.38 a	15.63 ± 6.21 a	13.75 ± 2.29 a	14.38 ± 2.57 a	35.63 ± 23.61 a	75.00 ± 10.44 c
Yellow	37.50 ± 5.07 a	7.50 ± 1.85 a	3.13 ± 3.13 a	18.13 ± 3.57 a	18.75 ± 2.83 a	69.38 ± 58.27 a	335.94 ± 51.47 a
Dich[1]							
Yes	30.83 ± 3.63 a	7.71 ± 1.49 a	8.33 ± 3.95 a	17.50 ± 2.37 a	12.71 ± 1.86 b	66.67 ± 41.33 a	258.54 ± 32.07 a
No	24.17 ± 2.90 a	6.04 ± 1.18 a	4.17 ± 2.90 a	16.46 ± 2.69 a	19.38 ± 2.50 a	8.96 ± 2.48 a	147.71 ± 23.10 b
PG[1]							
Yes	30.83 ± 3.74 a	10.63 ± 1.24 a	10.43 ± 4.33 a	23.33 ± 2.71 a	19.58 ± 2.30 a	700.00 ± 41.21 a	268.75 ± 30.10 a
No	24.17 ± 2.76 a	3.13 ± 1.07 b	2.08 ± 2.08 b	10.63 ± 1.65 b	12.50 ± 2.08 b	5.63 ± 1.21 b	137.50 ± 23.89 b

	Cicadellidae	Coccinellidae	Drosophilidae	Elateridae	Empididae	Formicidae	Halictidae
Color[1]							
White	212.81 ± 24.71 b	1.25 ± 0.57 b	12.50 ± 2.80 a	1.88 ± 0.92 b	5.00 ± 1.61 b	59.38 ± 7.91 a	3.44 ± 1.15 a
Blue	63.44 ± 8.56 c	2.50 ± 0.95 b	6.66 ± 2.17 b	2.81 ± 0.96 b	0.63 ± 0.43 b	73.13 ± 12.68 a	2.19 ± 1.14 a
Yellow	933.13 ± 38.16 a	5.63 ± 1.69 a	20.94 ± 3.85 a	21.56 ± 6.32 a	17.50 ± 4.83 a	57.50 ± 7.58 a	1.56 ± 0.62 a
Dich[1]							
Yes	223.54 ± 31.28 a	5.21 ± 1.08 a	15.42 ± 2.96 a	13.96 ± 4.55 a	11.88 ± 3.22 a	73.96 ± 4.92 a	3.13 ± 0.83 a
No	158.75 ± 35.49 b	1.04 ± 0.74 b	11.46 ± 2.28 a	3.54 ± 1.15 b	3.54 ± 1.84 b	52.71 ± 9.69 b	1.67 ± 0.79 a
PG[1]							
Yes	301.25 ± 35.51 a	4.58 ± 1.27 a	18.96 ± 2.99 a	9.38 ± 2.24 a	10.00 ± 3.17 a	89.79 ± 5.91 a	4.17 ± 1.10 a
No	81.04 ± 14.59 b	1.67 ± 0.51 b	7.92 ± 1.80 b	8.13 ± 4.34 a	5.42 ± 2.13 a	36.88 ± 6.54 b	0.63 ± 0.35 b

[1] Base color = Denotes CC trap base; Dich = Dichlorvos; PG = Propylene glycol.

[2]Means within columns not followed by the same letter are significantly different by Tukey's HSD test, $P = 0.05$ and df = 2, 1, 1, and 44 for base color, dichlorvos, propylene glycol (PG), and error, respectively. Data were logarithmic transformed before ANOVA.

TABLE 3.—*(Continued) Mean (±SE) number of individuals per family captured in CC traps with different colored trap bases at Georgetown, St. Vincent, 2004 – dry season.*

	No./ week × 100				
	Lonchaeidae	Muscidae	Otitidae	Tachinidae	Tanagostomatididae
Color[1]					
White	9.06 ± 1.78 b	3.44 ± 1.15 a	25.63 ± 4.75 a	1.25 ± 0.57 b	3.13 ± 1.16 b
Blue	21.25 ± 3.49 a	1.88 ± 1.02 a	6.25 ± 2.03 b	2.81 ± 1.06 a	1.56 ± 0.77 b
Yellow	2.81 ± 1.06 c	2.81 ± 0.96 a	18.44 ± 3.94 a	0.31 ± 0.31 b	9.69 ± 1.95 a
Dich[1]					
Yes	11.25 ± 2.04 a	3.13 ± 0.98 a	19.17 ± 2.71 a	2.50 ± 0.77 a	4.38 ± 1.28 a
No	10.83 ± 2.66 a	2.29 ± 0.70 a	14.38 ± 3.89 a	0.42 ± 0.29 b	5.21 ± 1.31 a
PG[1]					
Yes	15.00 ± 2.62 a	3.96 ± 0.97 a	26.25 ± 3.72 a	1.88 ± 0.61 a	6.67 ± 1.56 a
No	7.08 ± 1.82 b	1.46 ± 0.65 b	7.29 ± 1.67 b	1.04 ± 0.61 a	2.92 ± 0.83 b

[1] Base color = Denotes CC trap base; Dich = Dichlorvos; PG = Propylene glycol.

[2]Means within columns not followed by the same letter are significantly different by Tukey's HSD test, $P = 0.05$ and df = 2, 1, 1, and 44 for base color, dichlorvos, propylene glycol (PG), and error, respectively. Data were logarithmic transformed before ANOVA.

idae, Cicadellidae, Dolichopodidae, Drosophilidae, Empididae, Formicidae, Lauxaniidae, Lonchaeidae, Otitidae, Phoridae, Psychodidae, and Sciaridae families caught in traps with propylene glycol were significantly greater than in traps without propylene glycol (Table 2). There were no significant differences in the number of insects from Chalcidae, Muscidae, Poduridae, and Tachinidae families caught in traps with or without propylene glycol.

During the 2005 dry season, the numbers of insects from Aphididae, Bostrichidae, Cecidomyiidae, Chironomidae, Chloropidae, Chrysomelidae, Cicadellidae, Coccinellidae, Drosophilidae, Formicidae, Halictidae, Lonchaeidae, Muscidae, Otitidae, and Tanagostomatididae families captured in traps with propylene glycol were significantly greater than in traps without propylene glycol (Table 3). There were no significant differences in the number of insects from Aleyrodidae, Elateridae, Empididae, and Tachinidae families caught in traps with or without propylene glycol.

DISCUSSION

The CC traps caught a total of 69 insect families during this study, with 41 of the families caught during both the wet and dry seasons. Chu et al. (2006) also reported catches of several species of Thripidae in St. Vincent hot peppers. The mean air temperatures were 28.4 and 29.7 °C, respectively, for the wet and dry seasons during this study, and there were 34 and 10 rainy days with rainfall totaling 855.1 and 48.1 mm for the wet and dry seasons, respectively. On average, there were 25.2 and 4.8 mm of rainfall on each rainy day for the wet and dry seasons, respectively. More insect families were caught in traps during the wet season than during the dry season, thus indicating that the wet season was probably more conducive than the dry season for the growth and development of insect populations, presumably because more weed and plant hosts were available during that time period.

Color attraction is an innate characteristic of many insect species. It is well known that yellow is attractive to *Trialeurodes vaporarorium* Westwood (Lloyd, 1921) and *Bemisia* sp. (Mound, 1962); olive fruit flies, *Dacus oleae* Gmelin (Economopoulos, 1986), *Vespula pensylvanica* Saussure (Chang, 1988); and whitefly parasitoids *Eretmocerus* sp. (Hoelmer et al., 1998). Other insect species attracted to yellow are *Bombus* spp. (Gross and Carpenter, 1991); *Chaetocnema publicaria* Melsheimer (Adams and Los, 1986); *Liriomyza sativae* Blanchard (Affeldt et al., 1983); *Frankliniella occidentalis* Pergande (Cho et al., 1995); and cereal aphid sp. (De Barro, 1991). Gaum and Giliomee (1994) reported that *T. vaporariorum* responded more positively to yellow with a peak reflectance at 600 nm. *Frankliniella occidentalis*, in contrast, showed a greater attraction response to bright blue sticky traps with a peak reflectance at 460 nm. Blackmer et al. (1995) reported that 76% of *B. tabaci* adults responded to a visual wavelength stimulus at 550 nm in a flight chamber. Numerous other reports also indicate that thrips are attracted to blue as well as white (Bradley and Mayer, 1994; Brodsgaard, 1993; Matteson and Terry, 1992; Yudin et al., 1987). Vernon and Gillespie (1995) found that yellow-colored traps placed in front of violet or blue backgrounds caught significantly more thrips than yellow traps in front of yellow backgrounds. In this study trap catches indicate that yellow trap base color appears to be more attractive to Aleyrodidae, Chalcidae, Chironomidae, Chloropidae, Chrysomelidae, Cicadellidae, Coccinellidae, Drosophilidae, Elateridae, Empididae, Lauxaniidae, Otitidae, Phoridae, and Tanagostomatididae than the white and blue colors. In previous studies Chu et al. (2006) found that blue base traps captured more *Frankliniella* sp. and *Megalurothrips* sp. (Thripidae) than yellow or white base traps. In the current study, this was also the case for Lonchaeidae and Tachinidae. White and yellow trap bases appear to be equally attractive to Aleyrodidae, Drosophilidae, Lauxaniidae, and Otitidae. The differences in trap captures of various families of insects here are most likely due to differences in color attraction. This information may be useful in providing preliminary determination of color attraction for specific insect families for future studies.

The increase of trap catches due to dichlorvos for Cecidomyiidae, Chalcidae, Chironomidae, Chrysomelidae, Cicadellidae, Coccinellidae, Drosophilidae, Elateridae, Empididae, Formicidae, Lauxaniidae, Muscidae, Phoridae, Sciaridae, and Tachinidae is similar to our earlier report on the greater numbers of thrips found in traps equipped with dichlorvos (Chu et al., 2005; 2006). This finding suggests that insects were able to escape the trap without the presence of the dichlorvos killing agent. In this study, we did not include the clear plastic circular deflector plate (Figure 1, part B) in order to simplify the trap loading process. Further studies that include the deflector plate may help determine whether the addition of the deflector plate and/or the addition of dichlorvos is required to maximize insect captures in the traps.

Ethylene glycol has been shown as a good short- and long-term storage medium for preserving insect specimens for future DNA analysis (Dillon et al., 1996). In this study, propylene glycol was used instead of ethylene glycol because it has been determined to be less toxic to mammals. Propylene glycol in the CC traps resulted in not only better preservation of insect specimens for taxonomic and genetic studies, but it also increased trap catches of Agromyzidae, Aphididae, Braconidae, Cecidomyiidae, Chironomidae, Chironomidae, Chloropidae, Chrysomelidae, Cicadellidae, Coccinellidae, Dolichopodidae, Drosophilidae, Empididae, Formicidae, Halictidae, Lauxaniidae, Lonchaeidae, Muscidae, Otitidae, Phoridae, Psychodidae, Sciaridae, and Tanagostomatididae. Also in previous studies, we found that propylene glycol resulted in increased weekly trap catches of thrips including: *S. dorsalis, Thrips palmi, Frankliniella* spp. and *Microcephalothrips abdominalis* during the dry season on St. Vincent (Chu et al., 2006). It is not known at this time why the use of propylene glycol increased the trap catches of these species, but we suspect that it ensnared insects and prevented their escape from the traps. Thomas et al. (2001) showed that propylene glycol significantly increased trap captures and improved preservation of *Anastrepha* fruit flies, suggesting that the propylene glycol or possibly some breakdown product may have been acting as an attractant. Given the diversity of insect families and the increased trap efficacy in this study, we do not believe that propylene glycol was acting as an attractant.

Direct plant sampling is an option often used to assess insect populations and densities. However, this method is laborious, time consuming, and subject to error because insects leave the plants when disturbed. For monitoring insect populations, sticky traps are also widely used, but are difficult to use because of the sticky coating, and they often become clogged with debris other than insects plus wind-blown dirt. This study shows that a very diverse set of insect families may be captured in the CC trap although the numbers captured may be low. Different color bases might be employed to gather information of color preferences of insects. The addition of dichlorvos and propylene glycol increased trap captures over those without the chemicals, and the insects captured were preserved well enough to allow further morphological and DNA analysis. Further studies incorporating the use of pheromones in CC traps may yield useful information on the interactions of color and pheromone attraction of specific insect species. The CC trap is an inexpensive, re-useable trap that can be readily modified for color by interchanging the trap base; thus it should be considered as another potential monitoring tool in integrated pest management programs.

LITERATURE CITED

Adams, R. G. and L. M. Los, 1986. Monitoring adult corn flea beetles (Coleoptera: Chrysomelidae) in sweet corn fields with color sticky traps. *Environ. Entomol.* 15:867-873.

Affeldt, H. A., R. W. Thimijan, F. F. Smith and R. E. Webb, 1983. Response of greenhouse whitefly (Homoptera: Aleyrodidae) and the vegetable leafminer (Diptera: Agromyzidae) to photospectra. *J. Econ. Entomol.* 76:1405-1409.

Anonymous, 1989. MSTATC. A microcomputer program for the design, management, and analysis of agronomic research experiments. Michigan State Univ.

Blackmer, J. L., D. N. Byrne and Z. Tu, 1995. Behavioral, morphological, and physical traits associated with migratory *Bemisia tabaci* (Homoptera: Aleyrodidae). *J. Insect Behavior* 8:251-267.

Borror, D. J., C. A. Triplehorn and N. F. Johnson, 1989. An introduction to the study of insects. Saunders College Publishing, Philadelphia, PA.

Bradley, S. J. and D. F. Mayer, 1994. Evaluation of monitoring methods for western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae), during the blossom period of 'Granny Smith' apples. *J. Entomol. Soc. of British Columbia* 91: 63-68.

Brodsgaard, H. F., 1993. Coloured sticky traps for thrips (Thysanoptera: Thripidae) monitoring on glasshouse cucumbers. Bulletin OILB-SROP 16:19-22.

Chang, V., 1988. Toxic baiting of the western yellowjacket (Hymenoptera: Vespidae) in Hawaii. *J. Econ. Entomol.* 81:228-235.

Cho, K., C. S. Eckel, J. F. Walgenbach and G. G. Kennedy, 1995. Comparison of colored sticky traps for monitoring thrips populations (Thysanoptera: Thripidae) in staked tomato fields. *J. Entomol. Sci.* 30:176-190.

Chu, C. C. and T. J. Henneberry, 1998. Arthropod management: development of a new whitefly trap. *J. Cotton Science* 2:104-109.

Chu, C. C., P. J. Printer Jr., T. J. Henneberry, K. Umeda, E. T. Natwick, Y. Wei, V. R. Reddy and M. Shrepatis, 2000. Use of CC traps with different trap base colors for silverleaf whiteflies (Homoptera: Aleyrodidae), thrips (Thysanoptera: Thripidae), and leafhoppers (Homoptera: Cicadellidae). *J. Econ. Entomol.* 93:1329-1337.

Chu, C. C., T. J. Henneberry, E. T. Natwick, D. Ritter, S. L. Birdsall, 2001. Efficacy of CC traps and seasonal activity of adult *Bemisia argentifolii* (Homoptera: Aleyrodidae) in Imperial and Palo Verde Valleys, California. *J. Econ. Entomol.* 94: 47-54.

Chu, C. C., M. A. Ciomperlik, T. Y. Chen, S. Tuck, P. Alexander and T. J. Henneberry, 2005. Variations in CC trap catches of thrips associated with different colors with or without dichlorvos cubes, pp. 1173-1175. *In*: P. Dugger and D. Richter (Eds.) Proc. Belt. Cotton Conf., New Orleans, LA.

Chu, C. C., M. A. Ciomperlik, N. T. Chang, M. Richards and T. J. Henneberry, 2006. Developing and evaluating traps for monitoring *Scirtothrips dorsalis* (Thysanoptera: Thripidae). *Florida Entomol.* 89:47-55.

Chu, C., E. Barnes, E. T. Natwick, T. Chen, D. Ritter and T. J. Henneberry, 2007. Trap catches of the sweetpotato whitefly (Homoptera: Aleyrodidae) in the Imperial Valley, California, from 1996 to 2002. *Insect Science* 14:165-170.

De Barro, P. J., 1991. Attractiveness of four colours of traps to cereal aphids (Hemiptera: Aphididae) in south Australia. *J. Aust. Ent. Soc.* 30:263-264.

Dillon, N., A. D. Austin and E. Bartowsky, 1996. Comparison of preservation techniques for DNA extraction from hymenopterous insects. *Insect Mol. Biol.* 5:21-24.

Economopoulos, A. P., 1986. Evaluation of color and food-odor trapping methods in the olive fruit fly. *In* M. Mangel et al. (Eds), NATO Adv Study Inst Service, Pest Control Operations and Systems Analysis in Fruit Fly Management 11:115, Springer-Verlag, Berlin, W. Germany.

Gaum, W. G. and J. H. Giliomee, 1994. Preference of western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae), and greenhouse whitefly, *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae), for differently coloured sticky traps. *J. Southern African Soc. Hort. Sci.* 4:39-41.

Gross, H. R. and J. E. Carpenter, 1991. Role of the fall armyworm (Lepidoptera: Noctuidae) pheromone and other factors in the capture of bumblebees (Hymenoptera: Aphidae) by universal moth trap. *Environ. Entomol.* 20:377-381.

Hoelmer, K. A., W. J. Roltsch, C. C. Chu and T. J. Henneberry, 1998. Selectivity of whitefly traps in cotton for *Eretmocerus eremicus* (Hymenoptera: Aphelinidae), a native parasitoid of *Bemisia argentifolii* (Homoptera: Aleyrodidae). *Environ. Entomol.* 27:1039-1044.

Karut, K., C. C. Chu, T. J. Henneberry and C. Kazak, 2005. Determination of seasonal activity of the sweetpotato whitefly (Homoptera: Aleyrodidae) and leafhoppers (Homoptera: Cicadellidae) by plastic cup traps on the Çukurova Plain, Turkey. *Plant Protect. Science* 41, 8-13.

Liu, T. X. and C. C. Chu, 2004. Comparison of absolute estimates of *Thrips tabaci* (Thysanoptera: Thripidae) with field visual counting and sticky traps in onion fields in south Texas. *Southwest. Entomol.* 29:83-89.

Lloyd, L., 1921. Notes on a colour tropism of *Asterichiton (Aleyurodes) vaporariorum*, Westwood. *Bull. Entomol. Res.* 12:355-359.

Matteson, N. A. and L. I. Terry, 1992. Response to color by male and female *Frankliniella occidentalis* during swarming and non-swarming behavior. *Ent. Exp. Appl.* 2:187-201.

Mound, L. A., 1962. Studies on the olfaction and colour sensitivity of *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae). *Ent. Exp. Appl.* 5:99-104.

Thomas, D. B., T. C. Holler, R. R. Heath, E. J. Salinas and A. L. Moses, 2001. Trap-lure combinations for surveillance of *Anastrepha* fruit flies (Diptera: Tephritidae). *Florida Entomol.* 84:344-351.

Tukey, J. W., 1953. The problem of multiple comparisons. Unpublished manuscript, Princeton University.

Vernon, R. S. and D. R. Gillespie, 1995. Influence of trap shape, size, and background color on captures of *Frankliniella occidentalis* (Thysanoptera: Thripidae) in a cucumber greenhouse. *J. Econ. Entomol.* 88:288-293.

Yudin, L. S., W. C. Mitchell and J. J. Cho, 1987. Color preference of thrips (Thysanoptera: Thripidae) with reference to aphids (Homoptera: Aphididae) and leafminers in Hawaiian lettuce farms. *J. Econ. Entomol.* 80:51-55.