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A COMPARISON OF TRAPS AND STEM TAP SAMPLING FOR MONITORING ADULT ASIAN CITRUS PSYLLID (HEMIPTERA: PSYLLIDAE) IN CITRUS

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ABSTRACT

Studies were conducted at 2 different field sites to compare yellow sticky card traps, blue sticky card traps, Multi-Lure traps, and CC traps (red, blue, black, white, yellow, and dark green bases) for monitoring adult Asian citrus psyllid, *Diaphorina citri* Kuwayama, in citrus. The Multi-Lure and CC traps were charged with either ethylene glycol or a dichlorvos kill strip to kill psyllids entering the trap. We also investigated a stem tapping method for monitoring adult *D. citri*. Yellow sticky card traps captured significantly more adults than blue sticky card traps over a 4-week period in one study but not the other. Over all sample weeks, each of these traps captured significantly greater numbers of adults than any of the other traps. Yellow and blue sticky traps were equally effective in detecting the presence of adults in trees given the infestation levels present at the 2 study sites. The CC and Multi-Lure traps captured so few adult psyllids and provided such poor detection of trees infested by adults that they appeared to have no value for monitoring *D. citri*. Tap sampling was easy to conduct and provided relatively good detection of trees infested by adults given the infestation levels present at the 2 groves. An advantage to stem tap sampling over sticky trap sampling is that tap sampling provides information on the presence and relative abundance of adult *D. citri* during a single visit to a block of trees while sticky trap sampling requires 2 visits. Research to develop standard protocols for sticky trap and stem tap sampling for adult *D. citri* in citrus would be advantageous.

Key Words: trapping, sampling, sticky traps, Multi-Lure, CC trap

RESUMEN

Se realizaron estudios en dos campos diferentes para comparar las trampas de tarjetas pegajosas del color amarillo, trampas de tarjetas pegajosas de color azul, trampas "Multi-lure" y trampas "CC" (con bases de color rojo, azul, negro, blanco, amarillo y verde oscuro) para el monitoreo de adultos del psílido Asiático de los cítricos, *Diaphorina citri* Kuwayama en cítricos. Las trampas Multi-Lure y CC fueron cargadas con un "kill strip" (una plancha para matar) que contenia ya sea etilenglicol o diclorovos para matar los psílidos que entraban a las trampas. También, investigamos un método de trampa de pegado al tallo para el monitoreo de los adultos de *D. citri*. Las trampas de tarjetas pegajosas de color amarillo capturaron significativamente más adultos que las trampas de tarjetas pegajosas de color azul durante el periodo de 4 semanas en uno de los estudios pero no en el otro. En todas las semanas de muestreo, cada una de estas trampas amarillas capturaron significativamente un número mayor de adultos que cualquiera de las otras trampas. Las trampas pegajosas de los colores amarillo y azul fueron igualmente efectivas en detectar la presencia de adultos en árboles teniendo en cuenta el nivel de infestación presente en los dos sitios del estudio. Las trampas de "CC" y "Multi-lure" capturaron muy pocos adultos de psílidos y proveyeron una detección tan pobre de árboles infestados que pareciera indicar que no tienen ningún valor para realizar un monitoreo de *D. citri*. El muestreo de pega a los tallos fue fácil de realizar y proveyó una detección relativamente buena de árboles infestados por adultos teniendo en cuenta el nivel de infestación presente en los 2 huertos. Una ventaja del muestreo de pega de tallos sobre el muestreo usando trampas pegajosas es que el muestreo de pega de tallos provee información sobre la presencia y la abundancia relativa de los adultos de *D. citri* durante una sola visita al bloque de árboles mientas que el muestreo usando trampas pegajosas requiere 2 visitas más. Investigaciones para desarrollar protocolos estandardizados para el muestreo de adultos de *D. citri* usando trampas pegajosas y de pega de tallos de los cítricos serian de gran provecho.

The Asian citrus psyllid, *Diaphorina citri* Kuwayama, was first discovered in Florida during Jun 1998 (Tsai et al. 2000), and it subsequently dispersed throughout the state (Michaud 2004). *D. citri* has a wide host range within the plant family Rutaceae, including citrus and citrus rela-

tives such as orange jasmine, *Murraya paniculata* (L.) Jack (Halbert & Manjunath 2004). Mature citrus plants fed upon by *D. citri* can sustain damage to growing shoots, while young plants can suffer death during high psyllid populations (Aubert 1987; Michaud 2004). Additionally, *D. citri* vectors the causative bacterial agents (*Candidatus* Liberibacter asiaticus, *C.* L. africanus, and *C.* L. americanus) of citrus greening disease (huanglongbing), one of the world's most serious diseases of citrus (McClean & Schwartz 1970; Bové 2006). Trees infected by this devastating disease may only live 5 to 8 years, during which time they produce misshapen, inedible, and unmarketable fruit (Bové 2006). Halbert & Manjunath (2004) provide a comprehensive overview of citrus greening disease and *D. citri* biology. Citrus greening was discovered in southern Florida during late Aug 2005 and has since been detected at a number of locations across the state's citrus growing region (FDACS 2006). This sets the stage for the spread of the disease into other citrus-producing areas in North America.

A simple and efficient sampling procedure for *D. citri* is vital to the development of a successful IPM program aimed at controlling citrus greening disease. The presence and relative abundance of adult *D. citri* in a planting of citrus or orange jasmine can be determined by counting adults on plant samples (Tsai et al. 2000; Tsai et al. 2002). Adults can be observed by tapping an infested branch with a stick, which promotes adults to drop onto a surface (e.g., a board or pan) held beneath the branch. A similar stem-tapping method has been shown useful for monitoring pear psylla, *Cacopsylla pyricola* (Foerster) in pear (Horton & Lewis 1997). Sticky traps can be used to detect and gauge the relative abundance of *D. citri* (Aubert & Quilici 1988; Aubert & Hua 1990). Preliminary research by Quilici & Trahais (1990) and Aubert & Hua (1990) indicated *D. citri* was more attracted to yellows than other colors, but specific information on the attractiveness of other colors was not presented. Working with sticky traps hung 50 cm above the canopy of an orange jasmine planting, Aubert & Hua (1990) tested sticky Rebell traps (similar to those marketed by Great Lakes IPM, Vestaburg, MI) that were uniformly Saturn yellow, bright yellow, orange yellow, brown yellow, black or white in color and traps that were checkered brown-yellow and bright yellow. These authors did not clarify the difference between Saturn and bright yellow. Brown-yellow colored traps performed best during cloudy weather conditions, while bright yellow functioned best during sunny conditions (Aubert & Hua 1990). A plastic cup trap referred to as the CC trap (named after C. Chu who developed the trap) has been shown to be useful for monitoring thrips, whiteflies and leafhoppers (Chu et al. 2000; Chu et al. 2006), and unidentified adult psyllids have occasionally been caught in these traps in St. Vincent (M. Ciomperlik, unpublished). The Multi-Lure trap (Better World Manufacturing, Inc., Fresno, CA) has been useful in citrus for monitoring fruit flies (Diptera: Tephritidae) (Hall et al. 2005), but its efficacy for monitoring adult *D. citri* is not known.

Although published information indicated yellow to be the most attractive color to adult *D. citri* (Aubert & Hua 1990), quantitative data on the relative attractiveness of blue sticky cards were lacking. Therefore, the purpose of the research presented here was to compare the efficacy of yellow and blue sticky traps, the Multi-Lure trap, and the CC trap along with a stem tapping technique for monitoring adult *D. citri* in citrus.

Materials and Methods

The following traps were compared with respect to numbers of adult *D. citri* trapped weekly: yellow sticky cards, blue sticky cards, Multi-Lure trap (clear top with standard yellow and white base), and 6 CC traps (clear top with a blue, yellow, white, dark green, black, or red base). The yellow sticky cards (7.62 × 12.7 cm) (a bright yellow hue similar to S-G-390 by Behr Process Corp., Santa Ana, CA), blue sticky cards (trimmed to 7.62 × 12.7 cm) (hue similar to 550B-6 by Behr Process Corp.), and Multi-Lure traps were obtained from Great Lakes IPM (Vestaburg, MI). The CC traps were supplied by the Pest Detection Diagnostics and Management Laboratory, Edinburg, TX (USDA, APHIS, Plant Protection and Quarantine, Center for Plant Health Science and Technology). Information on the spectral reflectance of the CC trap colors is provided by Chu et al. (2000). The colors of the CC trap bases were similar to the following Behr Process Corp. hues: blue 3C-20; yellow 310B-6; and red S-G-170. The dark green CC trap base was a hue similar to green 07GG 08/244 by Glidden (Cleveland, OH).

Experiment 1

The study was conducted in a USDA-ARS grove near Ft. Pierce in St. Lucie County, Florida. The block of trees chosen for the study contained 'Hamlin' orange trees (*Citrus sinensis* L.) (4 yr old, ~2 m tall, row spacing 8 m, tree spacing 3 m). No systemic or foliar hard insecticides were applied prior to the study during 2006 or during the course of the study. Each trap was hung near the exterior of a tree canopy about 1.5 m above ground, 1 type of trap per tree. Sixteen trees along each of 5 rows (replications) were randomly assigned one of the traps. Each row consisted of 21 to 40 trees. The test followed a randomized complete block design with 5 replications. The traps were deployed on May 11, 2006, and checked weekly for 4 weeks. At the beginning of

each week, the traps along each row were re-randomized. One set of CC and Multi-Lure traps was charged with 15 mL of a 50% pre-mixed solution of ethylene glycol and water (Super Tech antifreeze, Bentonville, AR) as an entrapment and preservative fluid for adult psyllids, and one set was charged with Hercon Vaportape (10% dichlorvos, 0.229 g ai/cm^2, 2.54 × 4.5-cm strip) (obtained from Great Lakes IPM, Inc., Vestaburg, MI) as a toxicant to kill adults entering a trap. A hole at the center of the top of each CC trap allowed a string to be attached to hang the trap from a branch. No kick plates (Chu et al. 2006) were used with the CC traps in this experiment. Sticky cards were suspended from branches near the outer edge of the canopy with a twist tie. When the CC and Multi-Lure traps were checked for psyllids, all the contents from the traps were emptied into vials and transported to a laboratory. The number of psyllid adults per trap was tabulated weekly. New sticky card traps were deployed each week. The CC and Multi-Lure traps were washed with soap and water each week before they were redeployed in the field.

Data on number of adults per trap per week were analyzed by a multi-observation (measurements over time) analysis of variance, and Tukey's studentized range (honestly significant difference, HSD) was used to determine significant differences ($\alpha = 0.05$) among traps. Prior to these analyses, Levene's test was used to verify homogeneity of variances ($\alpha = 0.05$), and the data were log-transformed where appropriate. The percentage of trees in which adult *D. citri* was detected with each type of trap was computed each week. An analysis of variance over all weeks was conducted on percentage detection (on arcsine square-root-transformed data where appropriate based on Levene's test), and Tukey's studentized range (HSD) was used to determine significant differences ($\alpha = 0.05$) among traps. All analyses of variance were conducted in PROC GLM (SAS Institute, 2002) with the Levene and Tukey options.

In addition to trapping psyllids, adult *D. citri* were monitored with stem tap samples in the same trees in which the above traps were deployed. This allowed a measure of adult abundance in each tree based on both trap and tap samples. A white metal pan (20.32 × 20.32 × 10.16 cm; length, width, and depth, respectively) was held several cm under a haphazardly-chosen branch (1.0-1.5 m above ground), and a polyvinyl chloride (PVC) pipe (0.6 m length, 1.27 cm i.d., 2.13 cm o.d.) was used to tap the branch 3 times. All adult psyllids falling in the pan were counted. Tap sampling was conducted on May 11 when the above traps were deployed and at the end of each week when traps were checked for adult psyllids. The mean number of adult *D. citri* per tap sample was computed for each tree from samples taken at the beginning and end of each sample week. Data were subjected to analyses of variance, and Tukey's studentized range (HSD) was used to investigate for significant differences ($\alpha = 0.05$) in numbers of adults per tap sample among trees assigned the different trap types and to evaluate dispersion of adults among trees. Prior to these analyses, Levene's test was used to verify homogeneity of variances ($\alpha = 0.05$), and the data were log-transformed where appropriate. For trees assigned to each trap type, the percentage of trees in which adult *D. citri* was detected each week with tap sampling was computed. An analysis of variance over all weeks was conducted among trees assigned each type of trap on the percentage of trees in which adult *D. citri* were detected by tap sampling (on arcsine square-root-transformed data where appropriate based on Levene's test). Tukey's studentized range (HSD) was used to determine significant differences ($\alpha = 0.05$) among trees assigned each type of trap with respect to the percentage infested based on tap sampling. All analyses of variance were conducted in PROC GLM (SAS Institute, 2002) with the Levene and Tukey options.

Experiment 2

A second study was conducted near Vero Beach in Indian River County, Florida in a block of 'Temple' orange trees [*C. reticulate* Blanco × *C. sinensis* (L.) Osbeck] (36 yr old, ~3.4 m tall, row spacing 9 m, tree spacing 5 m). No systemic or foliar hard pesticides were applied prior to the study during 2006 or during the course of the study. An application of a nutritional spray including 470 oil (71 L per ha) was applied ~1 h before the traps were placed in the field during the first week of the study. However, the intent of the experiment was to judge relative numbers of adult *D. citri* collected at traps and during tap sampling, not to assess the effects of the treatment against the psyllid. This study was similar to Experiment 1 in all respects except each of the 5 replicates consisted of 3 rows of trees (21 to 26 trees per replicate), and a yellow CC trap with a kick plate (Chu et al. 2006) and charged with ethylene glycol was added to the study. This study was initiated Jun 29, 2006, and ran for 4 weeks.

Results

Experiment 1

Heterogeneity in variances was detected in numbers of adult *D. citri* per trap per week for data over all sample weeks ($F = 3.39$, $Pr > F = <0.0001$, 15 *df*) and for data from week 3 ($F = 2.70$, $Pr > F = 0.0030$, 15 *df*) (analyses on other weeks not presented). Heterogeneity was detected in mean numbers of adults captured from week-to-week for data from blue sticky card traps ($F =$

3.30, Pr > *F* = 0.05, 3 *df*) but not for data from yellow sticky card traps (*F* = 1.76, Pr > *F* = 0.20, 3 *df*) (analyses on other traps not presented). Variances were homogeneous with respect to numbers of adults per stem tap sample for data over all sample weeks (*F* = 0.92, Pr > *F* = 0.54, 15 *df*) and for data from week-to-week (*F* = 0.78, Pr > *F* = 0.52, 3 *df*). Data analyses on percentages of trees in which adult *D. citri* were detected with traps and stem tap sampling indicated heterogeneity in variances associated with traps (*F* = 3.32, Pr > *F* = 0.001, 15 *df*) but not tap sampling (*F* = 1.47, Pr > *F* = 0.16, 15 *df*).

There was no significant difference over the 4-week study with respect to numbers of adults captured at yellow and blue sticky card traps (Table 1, *F* = 4.73, Pr > *F* < 0.0001, 318 *df*). Each of these sticky card traps captured significantly more adult *D. citri* than any of the other traps. There were no significant differences from week-to-week in captures of adults at yellow sticky traps (*F* = 1.67, Pr > *F* = 0.21, 19 *df*) or blue sticky traps (*F* = 1.60, Pr > *F* = 0.23, 19 *df*) (data for other traps not presented). Low numbers of adults were captured in the CC and Multi-Lure traps, and there were no significant differences among any of these traps with respect to numbers of adults captured. There was no evidence of any difference with respect to charging CC and Multi-Lure traps with ethylene glycol or dichlorvos strips. Means ± SEM of 1.6 ± 0.1, 1.2 ± 0.1, 1.1 ± 0.1, and 1.3 ± 0.1 adults per stem tap sample were observed across all trees during sample weeks 1, 2, 3 and 4, respectively. There were no significant differences among these weekly means (*F* = 1.45, Pr > *F* = 0.22, 39 *df*). Means of 1.6 ± 0.4, 1.0 ± 0.3, 0.7 ± 0.4 and 0.9 ± 0.2 adults per tap sample were observed in trees with yellow sticky traps during weeks 1, 2, 3 and 4, respectively, and means of 2.4 ± 0.7, 1.0 ± 0.3, 2.1 ± 0.5 and 0.6 ± 0.2 adults per tap sample were observed in trees with blue sticky traps during the same respective weeks. Mean numbers of adults per tap sample did not differ significantly from week-to-week in trees with yellow sticky traps (*F* = 1.67, Pr > *F* = 0.21, 19 *df*) nor in trees with blue sticky traps (*F* = 2.55, Pr > *F* =0.09, 19 *df*) (analyses for tap samples taken in trees with other trap types not presented). No significant differences (*F* = 1.07, Pr > *F* = 0.34, 319 *df*) were observed in mean numbers of adult psyllids per tap sample among trees assigned the different types of traps (Table 1). Adult *D. citri* were collected on yellow and blue sticky card traps in every tree sampled (Table 2). Percentage detection of trees infested by adults with the other trap types ranged from 10 to 40% (no significant differences).

TABLE 1. NUMBER OF ADULT *DIAPHORINA CITRI* COLLECTED WEEKLY AT DIFFERENT TRAPS AND DURING WEEKLY TAP SAMPLING IN 'HAMLIN' ORANGE TREES.[a]

	Mean number (SEM) adults per trap per tree[b]					Mean number (SEM) per tap sample per tree[c]
Type of trap in tree[d]	Week 1	Week 2	Week 3[e]	Week 4	Overall[e]	Overall
Yellow sticky card	9.2 (2.4) a	10.8 (4.3) a	3.6 (1.4) a	5.2 (0.9) a	7.2 (1.4) a	1.1 (0.2) a
Blue sticky card	6.2 (0.6) a	6.0 (1.3) ab	4.2 (1.4) a	2.8 (0.7) a	4.8 (0.6) a	1.5 (0.3) a
Yellow CC EG	0.4 (0.4) b	0.8 (0.6) bc	0.6 (0.2) b	0.4 (0.4) b	0.6 (0.2) b	1.0 (0.2) a
Multi-Lure DC	0.8 (0.4) b	1.0 (0.5) bc	0.2 (0.2) b	0.2 (0.2) b	0.6 (0.2) b	1.0 (0.2) a
Blue CC DC	0.6 (0.4) b	1.0 (0.3) bc	0.2 (0.2) b	0.0 (0.0) b	0.5 (0.2) b	1.5 (0.2) a
Red CC EG	0.8 (0.4) b	0.6 (0.2) bc	0.2 (0.2) b	0.0 (0.0) b	0.4 (0.1) b	1.3 (0.3) a
Green CC DC	0.6 (0.2) b	1.0 (0.5) bc	0.0 (0.0) b	0.0 (0.0) b	0.4 (0.2) b	1.1 (0.1) a
Green CC EG	0.6 (0.6) b	0.2 (0.2) c	0.2 (0.2) b	0.0 (0.0) b	0.3 (0.2) b	1.4 (0.2) a
Black CC DC	0.0 (0.0) b	0.2 (0.2) c	0.6 (0.2) b	0.2 (0.2) b	0.3 (0.1) b	1.2 (0.2) a
Black CC EG	0.2 (0.2) b	0.0 (0.0) c	0.0 (0.0) b	0.4 (0.2) b	0.2 (0.1) b	1.2 (0.2) a
White CC EG	0.4 (0.4) b	0.4 (0.2) bc	0.0 (0.0) b	0.0 (0.0) b	0.2 (0.1) b	1.5 (0.2) a
White CC DC	0.0 (0.0) b	0.4 (0.2) bc	0.0 (0.0) b	0.2 (0.2) b	0.2 (0.1) b	1.6 (0.2) a
Yellow CC DC	0.2 (0.2) b	0.2 (0.2) c	0.0 (0.0) b	0.2 (0.2) b	0.2 (0.1) b	1.3 (0.2) a
Red CC DC	0.2 (0.2) b	0.4 (0.4) bc	0.0 (0.0) b	0.0 (0.0) b	0.2 (0.1) b	1.3 (0.2) a
Blue CC EG	0.2 (0.2) b	0.2 (0.2) c	0.0 (0.0) b	0.0 (0.0) b	0.1 (0.1) b	1.3 (0.2) a
Multi-Lure EG	0.2 (0.2) b	0.0 (0.0) c	0.2 (0.2) b	0.0 (0.0) b	0.1 (0.1) b	1.2 (0.2) a

[a]Means in the same column followed by the same letter are not significantly different (α = 0.05), Tukey's test.

[b]For traps—1 trap per tree, 16 trees with traps per replication, 5 replications. Tap sampling was conducted weekly in each tree with a trap.

[c]Weekly mean number of adult *D. citri* observed in tap samples taken in the trees assigned to each specific type of trap.

[d]CC = CC trap; CC and Multi-Lure traps were charged with either EG (ethylene glycol) (15 ml of a 50% solution) or DC (dichlorvos kill strip).

[e]Analyses on log-transformed data, raw means presented.

TABLE 2. PERCENTAGE OF 'HAMLIN' ORANGE TREES IN WHICH ADULT *DIAPHORINA CITRI* WERE DETECTED WITH TRAPS AND STEM TAP SAMPLES.[a]

Type of trap in tree[c]	Mean (SEM) percentage trees in which adults were detected[b]	
	Traps[d]	Tap samples[e]
Yellow sticky card	100.0 (0.0) a	80.0 (8.2) a
Blue sticky card	100.0 (0.0) a	90.0 (5.8) a
Multi-Lure DC	40.0 (4.2) b	80.0 (8.2) a
Yellow CC EG	35.0 (9.6) b	80.0 (8.2) a
Blue CC DC	35.0 (17.1) b	100.0 (0.0) a
Red CC EG	35.0 (15.0) b	85.0 (5.0) a
Green CC DC	30.0 (17.3) b	100.0 (0.0) a
Black CC EG	25.0 (12.6) b	100.0 (0.0) a
Green CC EG	15.0 (5.0) b	85.0 (9.6) a
Black CC DC	15.0 (9.6) b	90.0 (10.0) a
White CC EG	15.0 (9.6) b	95.0 (5.0) a
White CC DC	15.0 (9.6) b	95.0 (5.0) a
Yellow CC DC	15.0 (5.0) b	85.0 (9.6) a
Red CC DC	10.0 (5.8) b	90.0 (10.0) a
Blue CC EG	10.0 (5.8) b	85.0 (9.6) a
Multi-Lure EG	10.0 (5.8) b	80.0 (11.5) a

[a]For traps—1 trap per tree, 16 trees with traps per replication, 5 replications. Tap sampling was conducted weekly in each tree with a trap.

[b]Means in the same column followed by the same letter are not significantly different ($\alpha = 0.05$), Tukey's test.

[c]CC = CC trap; CC and Multi-Lure traps were charged with either EG (ethylene glycol) (15 ml of a 50% solution) or DC (dichlorvos kill strip).

[d]Analyses on arcsine square-root transformed percentages (raw percentages presented).

[e]Percentage of trees in which adult *D. citri* were detected in tap samples taken in the trees assigned to each specific type of trap.

Overall, tap sampling indicated 88.8% of the trees studied were infested by adults. There were no significant differences among trees with each type of trap with respect to the percentage identified as being infested by tap sampling (Table 2). Stem tap samples failed to detect a small percentage of infested trees that were identified as being infested by yellow and blue sticky traps.

Experiment 2

Heterogeneity in variances was detected in numbers of adult *D. citri* per trap per week for data over all sample weeks ($F = 4.12$, $Pr > F = <0.0001$, 16 *df*) and for data from each of the 4 weeks separately (analyses on individual weeks not presented). Heterogeneity was detected in mean numbers of adults captured from week-to-week for data from both blue ($F = 44.19$, $Pr > F = <0.0001$, 3 *df*) and yellow sticky traps ($F = 8.73$, $Pr > F = 0.001$, 3 *df*) (analyses on other traps not presented). Variances were homogeneous with respect to numbers of adults per stem tap sample for data over all sample weeks ($F = 0.72$, $Pr > F = 0.77$, 16 *df*) and for data from week-to-week ($F = 0.3.1$, $Pr > F = 0.06$, 3 *df*). Data analyses on percentages of trees in which adult *D. citri* were detected indicated no heterogeneity in variances associated with either traps ($F = 0.86$, $Pr > F = 0.61$, 16 *df*) or tap sampling ($F = 1.56$, $Pr > F = 0.12$, 16 *df*).

Yellow sticky card traps captured significantly more adult *D. citri* over the 4-week study than blue sticky card traps, and each of these traps captured significantly more adult *D. citri* over the 4-week study than any of the other traps (Table 3, $F = 2.78$, $Pr > F < 0.0001$, 338 *df*). There were no significant differences in numbers of adults collected each week at yellow and blue sticky traps. One blue sticky card trap was found to be missing when the traps were checked on Jul 20. There were no significant differences from week-to-week in captures of adults at blue sticky traps ($F = 2.14$, $Pr > F = 0.13$, 18 *df*), but significantly greater numbers of adults were collected at yellow sticky traps during weeks 1 and 4 than during weeks 2 and 3 ($F = 3.97$, $Pr > F = 0.02$, 19 *df*) (data for other traps not presented). Numbers of adults captured at the CC and Multi-Lure traps were consistently low, and there were no significant differences among any of these traps with respect to numbers of adults captured. There was no evidence of any difference with respect to charging CC and Multi-Lure traps with ethylene glycol or dichlorvos strips. Means of 2.36 ± 0.2, 1.2 ± 0.1, 0.8 ± 0.1, and 2.2 ± 0.3 adults per stem tap sample were observed across all trees during sample weeks 1, 2, 3 and 4, respectively, and significant differences were found between these weekly means ($F = 2.55$, $Pr > F = 0.03$, 39 *df*). Means of 2.2 ± 0.3, 0.5 ± 0.2, 0.9 ± 0.3 and 2.2 ± 1.0 adults per tap sample were observed in trees with yellow sticky traps during weeks 1, 2, 3 and 4, respectively, and means of 2.9 ± 0.7, 1.1 ± 0.4, 1.6 ± 0.9 and 2.1 ± 0.8 adults per tap sample were observed in trees with blue sticky traps during the same respective weeks. Week-to-week means varied significantly for data from trees with yellow sticky traps ($F = 4.38$, $Pr > F = 0.02$, 19 *df*) but not for data from trees with blue sticky traps ($F = 2.11$, $Pr > F = 0.14$, 18 *df*) (analyses for tap samples taken in trees with other trap types not presented). No significant differences (overall $F = 1.35$, $Pr > F = 0.04$, 339 *df*; main effect trap $F = 0.40$, $Pr > F = 0.98$, 16 *df*) were observed in mean numbers of adult psyllids per tap sample among trees assigned the different types of traps (Table 3). Adult *D. citri* were collected on yellow and blue sticky card traps in 95 and 85%, respectively, of the trees sampled (Table 4). Percentage detection of trees infested by adults with the other trap types ranged from 15 to 50% (no significant differences). Overall, tap sampling indicated 81.5% of the trees studied were infested during the study. There were no significant differences among trees

TABLE 3. NUMBER OF ADULT *DIAPHORINA CITRI* COLLECTED WEEKLY AT DIFFERENT TRAPS AND DURING WEEKLY TAP SAMPLING IN 'TEMPLE' ORANGE TREES.[a]

	Mean number (SEM) per trap per tree[b]					Mean number (SEM) per tap sample per tree[c]
Type of trap in tree[d]	Week 1	Week 2	Week 3	Week 4	Overall	Overall
Yellow sticky card	20.6 (4.7) a	5.8 (2.9) a	4.0 (1.6) a	29.0 (13.7) a	14.8 (4.2) a	1.5 (0.3) a
Blue sticky card	10.3 (4.2) ab	4.0 (1.9) ab	2.8 (1.2) ab	5.0 (0.8) ab	5.3 (1.6) b	1.9 (0.4) a
Yellow CC KP EG	3.2 (1.2) bc	0.2 (0.2) c	0.4 (0.2) bc	2.4 (2.2) bc	1.6 (0.6) c	1.6 (0.4) a
Yellow CC EG	1.8 (0.6) cd	0.6 (0.4) bc	0.2 (0.2) bc	1.6 (1.6) c	1.1 (0.4) c	1.7 (0.3) a
Multi-Lure DC	0.8 (0.2) cd	0.4 (0.2) c	0.2 (0.2) bc	1.6 (0.8) bc	0.8 (0.2) c	1.4 (0.2) a
White CC EG	1.0 (0.6) cd	0.2 (0.2) c	0.8 (0.6) bc	0.2 (0.2) c	0.6 (0.2) c	1.8 (0.3) a
Blue CC EG	1.6 (0.6) cd	0.2 (0.2) c	0.2 (0.2) bc	0.2 (0.2) c	0.6 (0.2) c	1.5 (0.4) a
Green CC DC	0.6 (0.4) cd	0.4 (0.2) c	0.2 (0.2) bc	0.8 (0.5) c	0.5 (0.2) c	1.8 (0.5) a
Multi-Lure EG	0.8 (0.2) cd	0.4 (0.2) c	0.2 (0.2) bc	0.4 (0.2) c	0.5 (0.1) c	1.3 (0.3) a
Black CC EG	1.4 (0.9) cd	0.0 (0.0) c	0.2 (0.2) bc	0.2 (0.2) c	0.5 (0.2) c	1.4 (0.3) a
Red CC EG	0.6 (0.4) cd	0.2 (0.2) c	0.2 (0.2) bc	0.4 (0.2) c	0.4 (0.1) c	1.7 (0.4) a
Green CC EG	0.2 (0.2) d	0.8 (0.4) bc	0.0 (0.0) c	0.2 (0.2) c	0.3 (0.1) c	1.4 (0.3) a
Yellow CC DC	0.6 (0.2) cd	0.2 (0.2) c	0.2 (0.2) bc	0.0 (0.0) c	0.3 (0.1) c	1.4 (0.3) a
White CC DC	0.0(0.0) d	0.4 (0.2) c	0.0 (0.0) c	0.6 (0.4) c	0.3 (0.1) c	1.7 (0.7) a
Blue CC DC	0.4 (0.4) cd	0.0 (0.0) c	0.0 (0.0) c	0.6 (0.4) c	0.3 (.01) c	1.7 (0.4) a
Black CC DC	0.6 (0.2) cd	0.0 (0.0) c	0.0 (0.0) c	0.4 (0.4) c	0.3 (0.1) c	2.0 (0.4) a
Red CC DC	0.2 (0.2) d	0.2 (0.2) c	0.0 (0.0) c	0.2 (0.2) c	0.2 (0.1) c	2.0 (0.4) a

[a]Means in the same column followed by the same letter are not significantly different ($\alpha = 0.05$), Tukey's test.
[b]For traps—1 trap per tree, 17 trees with traps per replication, 5 replications. Tap sampling was conducted weekly in each tree with a trap. Analyses on log-transformed data, raw means presented.
[c]Weekly mean number of adult *D. citri* observed in stem tap samples taken in the trees assigned to each specific type of trap.
[d]CC = CC trap; KP = kickplate atached; CC and Multi-Lure traps were charged with either EG (ethylene glycol) (15 ml of a 50% solution) or DC (dichlorvos kill strip).

with traps with respect to the percentage identified as being infested by tap sampling (Table 4). Stem tap samples failed to detect a small percentage of infested trees that were identified as being infested by yellow sticky traps. Blue sticky traps failed to identify a small percentage of trees that were identified as being infested by tap sampling.

DISCUSSION

Numerically greater numbers of adult *D. citri* were usually captured each week with yellow sticky card traps than blue sticky card traps, but statistical differences in numbers captured were only found during the second study across all 4 weeks of the study. Significant differences over all study weeks during the first study and during the individual weeks of each study might have been found had we used more than 5 replications of each type of trap. Previous studies indicated yellow sticky traps capture more adult *D. citri* than sticky traps of other colors, and traps of a bright yellow hue captured more adults than traps of a brown yellow hue under sunny conditions (Aubert & Hua 1990). We did not investigate the occurrence of clouds during our studies, but sunlight may have contributed to increased captures of adults at yellow sticky traps during some weeks. Yellow and blue sticky traps were equally effective in detecting the presence of adult *D. citri* in trees given the infestation levels present. The CC and Multi-Lure traps studied captured so few adult psyllids and provided numerically such low levels of percentage detection of trees infested by adults that they appeared to have no value for monitoring *D. citri*. Additional advantages for sticky cards to detect psyllids were that they were inexpensive, readily available, and relatively easy to work with.

Significant fluctuations from week-to-week were observed in numbers of adult *D. citri* collected at yellow sticky traps during the second study, and these fluctuations were reflected in stem tap samples across all trees with traps. We attributed these fluctuations to suppression of psyllids by the spray oil treatment. By the fourth week, developing nymphs had matured to adults, thus contributing to the increased adult population. No significant fluctuations from week-to-week were observed in numbers of adults captured at blue sticky traps during the second study. Reasons were unknown why increased numbers of adult *D. citri* were observed at the end of the second study both at yellow sticky traps and during tap sampling but not at blue sticky traps. These differences may have been related to

TABLE 4. PERCENTAGE OF 'TEMPLE' ORANGE TREES IN WHICH ADULT *DIAPHORINA CITRI* WERE DETECTED WITH TRAPS AND STEM TAP SAMPLES.[a]

Type of trap in tree[c]	Mean (SEM) percentage trees in which adults were detected[b]	
	Traps	Tap samples[d]
Yellow sticky card	95.0 (5.0) a	85.0 (5.0) a
Blue sticky card	85.0 (9.6) ab	95.0 (5.0) a
Yellow CC KP EG	50.0 (17.3) abc	75.0 (15.0) a
Multi-Lure DC	50.0 (12.9) abc	80.0 (11.5) a
Yellow CC EG	40.0 (14.1) bc	80.0 (8.2) a
Multi-Lure EG	45.0 (12.6) bc	75.0 (9.6) a
Blue CC EG	35.0 (15.0) c	70.0 (19.1) a
Green CC DC	35.0 (5.0) c	85.0 (15.0) a
White CC EG	30.0 (5.8) c	85.0 (9.6) a
Red CC EG	30.0 (5.8) c	75.0 (15.0) a
Black CC EG	25.0 (12.6) c	80.0 (8.2) a
Green CC EG	25.0 (12.6) c	75.0 (12.6) a
Yellow CC DC	25.0 (12.6) c	85.0 (9.6) a
White CC DC	20.0 (11.5) c	90.0 (5.8) a
Blue CC DC	20.0 (9.6) c	75.0 (15.0) a
Black CC DC	20.0 (14.1) c	85.0 (15.0) a
Red CC DC	15.0 (5.0) c	90.0 (5.8) a

[a]For traps—1 trap per tree, 17 trees with traps per replication, 5 replications. Tap sampling was conducted weekly in each tree with a trap.

[b]Means in the same column followed by the same letter are not significantly different ($\alpha = 0.05$), Tukey's test.

[c]CC = CC trap; KP = kickplate atached; CC and Multi-Lure traps were charged with either EG (ethylene glycol) (15 ml of a 50% solution) or DC (dichlorvos kill strip).

[d]Percentage of trees in which adult *D. citri* were detected in tap samples taken in the trees assigned to each specific type of trap.

sunlight or other environmental factors that affect the attractancy of the yellow traps more than blue traps. Additionally, adults may actually be less attracted to blue traps but subject to being accidentally captured at these traps during their movement within trees, as supported by the fact that the blue sticky traps caught similar numbers of adults at each study site. However, it remained possible that significant differences might have been found from week-to-week in numbers of adult *D. citri* on blue sticky traps had we studied more than 5 blue traps each week.

We observed some non-target insect species on both yellow and blue sticky traps but did not identify or quantify these. Various species of Diptera including the love bug, *Plecia nearctica* Hardy, have sometimes been captured in large numbers on yellow sticky card traps during other trapping studies in citrus (D. G. Hall, unpublished). The presence of other insects on sticky traps can interfere with finding and counting adult *D. citri* on the traps and may also interfere with captures of *D. citri*. Whether blue traps might have less impact on non-target insects in citrus than yellow traps remains to be investigated. Other researchers have reported that color influences captures of non-target insects. For example, Knight & Miliczky (2003) reported that the choice of trap color affected numbers of honeybee (*Aphis mellifera* L.) and non-target muscoid flies captured at sticky delta traps used to monitor codling moth (*Cydia pomonella* L.).

Our traps were hung directly in citrus trees. Other researchers working with *D. citri* have placed sticky traps on poles near plants or suspended them above plants (Aubert & Hua 1990). Where traps are placed in a citrus tree or grove may affect their relative efficiency for monitoring adult *D. citri* as well as other insects. This was demonstrated by Dowell & Cherry (1981), who reported that the location of sticky traps in citrus trees affected captures of parasitoids and predators of citrus blackfly, *Aleurocanthus woglumi* (Ashmead). Research to establish guidelines for using sticky traps to detect and monitor adult *D. citri*, including numbers of traps to operate and how these traps should be allocated within trees and across an area of trees, would be beneficial to both growers and researchers.

Stem tap sampling was easy to conduct and provided relatively good detection of trees infested by adults, at least at the infestation levels present at the 2 groves. Data from tap sampling indicated adult psyllids were uniformly dispersed among the trees studied, supporting the conclusion that differences in numbers of adults collected at the various types of traps were due to differences in trap efficiency. An obstacle to stem tap sampling was defining the force at which a branch should be hit. Also, some adults flew before falling to the pan, and it was sometimes difficult to count all adults in the pan before they took flight. Although week-to-week fluctuations in mean numbers of adult *D. citri* per tap sample followed the same trend in trees with yellow and blue sticky traps during the second study, differences were only significant for data from trees with the yellow traps. Larger numbers of trees and tap samples per tree may be required for mean estimates with less variability than were obtained with a sample size of 1 tap sample per week in 5 trees. Overall, however, the stem tap sampling method appeared to provide a good relative measure of the presence and abundance of adult *D. citri* and might be improved by placing a cloth (e.g., see Horton & Lewis 1997) or sticky card in the pan. An advantage to stem tap sampling over sticky trap sampling is that tap sampling provides information on the presence and relative abundance of adult *D. citri* during a single visit to a block of trees. Sticky trap sampling requires 2 visits to a block of trees with a period of time between visits (7 d in our study). Captures of non-target insects was less an issue with stem tap sampling to monitor adults than sticky trap sam-

pling. Research to develop formal protocols for tap sampling would be advantageous. Of interest would be optimum numbers of tap samples to take across an area of trees and how these samples should be allocated within and among trees. The ultimate decision of whether to use sticky traps or stem tap sampling for adult *D. citri* in citrus may depend on the intent of sampling and cost. If one is simply interested in whether or not adults are present in trees, stem tap sampling may be preferable, at least at the infestation densities of adults observed during these studies.

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