An Assessment of Yellow Sticky Card Traps as Indicators of the Abundance of Adult *Diaphorina citri* (Hemiptera: Psyllidae) in Citrus

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ABSTRACT Yellow sticky card traps were assessed as a tool for estimating absolute densities of adult *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) in citrus. Weekly trapping was conducted in young and mature trees with traps deployed directly in trees, one trap per tree. In addition, a comparison was made between one and three traps per tree in the mature trees. Solar radiation was positively correlated with numbers of adults trapped per week in both groups of trees. Air temperature was positively correlated with captures of adults in the mature trees. The value of traps as indicators of absolute densities of adults was therefore reduced by changes in sunlight and temperature. Captures of adults were not reduced by rain. A positive correlation was found for data from the young trees between trap captures of adults and maximum daily wind speed. Significant correlations were found between numbers of adults on leaves and traps. However, little confidence could be placed on individual predictions of adult densities on leaves based on numbers of adults on traps. Increasing the number of traps per tree from one to three did not improve individual estimates, although detection of adults in trees was improved using three traps when adult population levels were low. A better quantitative relationship between adults on traps and leaves might have been determined if greater sample sizes had been used to estimate densities. Regardless, day-to-day differences in sunlight and air temperature will influence numbers of adults captured on traps, thus reducing the value of traps as indicators of absolute densities.

KEY WORDS citrus greening disease, huanglongbing, psyllid

The Asian psyllid *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) is an important pest of citrus in Florida, primarily because it is a vector of "*Candidatus* Liberibacter asiaticus" (Halbert and Manjunath 2004). This and other species of "*Ca.* Liberibacter" are phloem-limited, nonculturable bacteria responsible for citrus greening disease (huanglongbing) (Halbert and Manjunath 2004, Hung et al. 2004). Citrus greening is considered to be one of the world's most serious diseases of citrus, as trees infected by this devastating disease may only live a few years during which time they decline in productivity and produce misshapen, inedible fruit (Bové 2006). *D. citri* was first found in Florida during June 1998 (Tsai and Liu 2000) and is now established throughout the state's citrus-growing regions (Michaud 2004). Citrus greening was found in southern Florida during late August 2005 (Bové 2006). Citrus growers in Florida are adopting aggressive insecticide programs for psyllid control as a key management component for citrus greening (Rogers 2008).

Population levels of *D. citri* in citrus trees can be estimated to time insecticide sprays or to compare population levels among different groups of trees – for example, trees treated with different insecticides for psyllid control. Relative density estimates may sometimes suffice, but absolute estimates of population levels of *D. citri* may sometimes be desired as in epidemiological studies on the transmission and spread of citrus greening disease. Several methods of estimating infestation levels of *D. citri* in citrus can be used. Citrus trees can be visually inspected to estimate absolute densities of eggs, nymphs and adults on flush (Dharajothi et al. 1989, Setamou et al. 2008). The relative abundance of adult *D. citri* in citrus can be estimated using yellow sticky card traps (Aubert and Quilici 1988, Aubert and Hua 1990, Hall et al. 2007) or by a tap-sampling procedure (Hall et al. 2007).

Yellow sticky traps have been shown to be effective for gauging population trends of *D. citri* over time in citrus (Hall et al. 2008), but to what extent numbers of adults captured on traps reflect absolute densities in trees was not known. A number of factors extrinsic and intrinsic to adult *D. citri* could influence numbers

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captured on traps, reducing the value of trapping data as an indicator of densities. The extent to which sunlight, temperature, wind or rain influence captures of adults on traps is not known. However, Aubert and Hua (1990) reported that flight or jumping activities by *D. citri* were sometimes more pronounced on windless, warm, sunny afternoons, which could increase captures of adults on traps.

The objectives of research presented here were to investigate the influence of temperature, sunlight, rain and wind on trap captures of adult *D. citri* and to assess the relationship between numbers of adults captured on traps and densities of adults on mature leaves.

Materials and Methods

Yellow (a bright yellow hue similar to S-G-390 by Behr Process Corp., Santa Ana, CA) sticky card traps (7.62 by 12.7 cm, sticky on both sides, Great Lakes IPM, Vestaburg, MI) were used in the studies presented here. Traps were suspended 1–1.5 m above ground near the outside of the canopy from a branch by using a twist tie. We punched a hole near the upper edge of each trap to hang the traps. Traps were deployed and replaced weekly.

One Trap per Tree. The relationship between trap captures of adult *D. citri* and densities of adults on leaves was assessed using data collected during 2005 and 2006 at two citrus groves, one grove in Saint Lucie County and one grove in Indian River County. The data were originally used by Hall et al. (2008) to characterize population densities and phenology of *D. citri* at the two locations, and these authors present a detailed description of the study sites. Briefly, the Saint Lucie County grove was located at a USDA–ARS research farm near Fort Pierce, FL. The block contained 'Marsh' grapefruit (*Citrus paradisi* Macf.) trees (2.5 yr old, ≈1.3 m tall) on the rootstock 'Sun Chu Sha' mandarin (*C. reticulata* Blanco). Sampling was initiated during early January 2005 and continued until July 2006. The Indian River County grove contained 'Temple' orange [*C. reticulata* Blanco × *C. sinensis* (L.) Osbeck] trees (36 yr old, ≈3.4 m tall) on the rootstock 'Cleopatra mandarin' (*C. reshni* Hort. ex Tan.). Sampling was initiated during early January 2005 and continued until the end of December 2006. Yellow sticky traps were placed in 10 trees randomly selected at each study location. In addition, on each day that traps were deployed and retrieved, adult psyllid counts were made on random pairs of mature leaves (including the stem between the leaves) in each tree, 10 pairs per tree in the young trees and 20 pairs per tree in the mature trees. The 10 or 20 leaf pairs were randomly chosen around the outer tree canopy 1–2 m above ground. The number of adults on each pair of leaves was counted without disturbing the leaves. The mean number of adults per pair of mature leaves per tree was calculated each week based on counts from both the beginning and end of each trapping period.

The influence of several environmental factors on captures of adult *D. citri* on traps was investigated. Air temperature data (hourly readings) were obtained at each location using a data logger (WatchDog model 100, Spectrum Technologies, Inc., Plainfield, IL) hung inside a tree canopy close to the trunk. Daily rainfall data for the young trees was obtained 3 km from the study site at a rain gauge operated by the University of Florida's Florida Automated Weather Network (FAWN). Daily rainfall data for the mature trees were obtained 0.4 km from the study site at a rain gauge operated by the Florida Research Center for Agricultural Sustainability. Hourly data on solar radiation (average Watts per square meter at 2 m) and wind (kilometers per hour at 10 m) obtained from the FAWN weather station were used for both study locations. The FAWN station was located 26 km from the mature tree study site. Mean, maximum and minimum air temperatures; mean solar radiation; and mean and maximum wind speed were determined for each trapping day using hourly data during daylight hours, and these were averaged for each weekly trapping period. Analyses with these particular environmental factors were restricted to daylight hours because previous research indicated adults are active primarily during the day (Aubert and Hua 1990, Wenninger and Hall 2008). Total rainfall was recorded for each weekly trapping period. Correlations (Pearson correlation coefficients) were then investigated between these environmental variables and numbers of adult *D. citri* captured per trap per week.

Relative variation (SEM/mean × 100) (Legg and Moon 1994) was used to gauge the precision of estimates of mean numbers of adult *D. citri* per pair of mature leaves based on sampling 10 (for the young trees) or 20 (for the mature trees) pairs of mature leaves per tree in each of ten trees. Relative variation also was used to gauge the precision of estimates of mean numbers of adults per trap per week (one trap per tree on each of 10 trees).

The quantitative relationship between trap captures of adult psyllids and population levels of adult psyllids on mature leaves in each group of trees was analyzed using simple linear regressions of 1) mean number of psyllids per pair of leaves per tree on number of psyllids per trap per week for the same tree, and 2) mean number of psyllids per pair of leaves over all trees per week on mean number of psyllids per trap per tree per week. The mean number of adults per pair of mature leaves used in the analyses was the average observed on the first and last days of each trapping period.

One versus Three Traps per Tree. A comparison of captures of adult *D. citri* on yellow sticky traps by using one versus three traps per tree was conducted at the Indian River County grove described above. Five pairs of trees at different locations within the block were selected. For each pair of trees, one yellow sticky trap was deployed in one tree and three traps were deployed in the other tree. For trees with three traps, these were spaced uniformly around the canopy. The traps were deployed and retrieved from the same trees on a weekly schedule. Sampling was initiated in January 2005 and concluded in January 2007. Mean ± SEM numbers of male, female and total adult *D. citri* captured per tree per week were calculated for trees with one trap. For trees with three traps, mean numbers of male, female and total adults captured among the three traps in each tree were

Table 1. Results of correlation analyses between mean number of adult *D. citri* per trap per wk and various environmental variables[a]

Variable	Mean (SEM) per trapping period	Correlation (Prob > r) with trap captures
Young tree study site (N = 77 trapping periods)		
Solar radiation (avg Watts per m^2 at 2 m)	462 (9)	0.31 (0.01)
Mean daily air temp (°C)	25.9 (0.4)	0.13 (0.27)
Max daily air temp (°C)	31.9 (0.4)	0.07 (0.53)
Min. daily air temp (°C)	16.7 (0.5)	0.19 (0.09)
Solar radiation × mean daily temp	12,605 (224)	0.26 (0.02)
Solar radiation × max daily temp	14,818 (379)	0.25 (0.03)
Total rainfall (cm)	2.3 (0.4)	0.15 (0.18)
Avg. daily wind (km/h))	25.2 (0.5)	−0.13 (0.25)
Avg. max daily wind (km/h)	75.1 (3.3)	0.50 (<0.0001)
Mature tree study site (N = 102 trapping periods)		
Solar radiation (avg Watts per m^2 at 2 m)	464 (8)	0.22 (0.03)
Mean daily air temp (°C)	26.5 (0.4)	0.22 (0.03)
Max daily air temp (°C)	33.2 (0.4)	0.29 (0.003)
Min. daily air temp (°C)	16.5 (0.6)	0.16 (0.12)
Solar radiation × mean daily temp	12,458 (340)	0.26 (0.01)
Solar radiation × max daily temp	15,621 (404)	0.29 (0.004)
Total rainfall (cm)	2.3 (0.3)	0.07 (0.50)
Avg. daily wind (km/h))	24.9 (0.5)	–0.20 (0.05)
Avg. max daily wind (km/h)	64.8 (2.8)	–0.03 (0.79)

[a] All environmental data were collected each day from 0800 to 1800 hours, except rainfall, which was total rainfall during each weekly trapping period. Wind and solar radiation data were collected 3 km from the young tree site and 26 km from the mature tree site.

calculated, and these were used to calculate the overall mean ± SEM numbers per tree per week. This facilitated comparisons of means per tree between trees with one or three traps. Paired sample *t*-tests were conducted over all trapping periods to compare mean numbers of adults per trap per tree according to one or three traps per tree. Each week, the percentage of trees in which at least one adult *D. citri* was captured on a trap was calculated. A paired *t*-test was conducted over all trapping periods to compare percentages of trees identified by traps as being infested.

In addition to weekly trap counts of adults, adult counts were made weekly on a pair of mature leaves as described above, 20 pairs of leaves per tree. The 20 leaf pairs were randomly chosen around the outer tree canopy 1–2 m above ground. Regression analyses were conducted between mean number of adults per pair of mature leaves and mean number of adults per trap per tree, and the results of these regressions were used to compare one versus three traps per tree as indicators of absolute adult densities. The mean number of adults per pair of mature leaves used in the regression analyses was the average observed on the first and last days of each trapping period.

Statistical Analyses. Correlation analyses were conducted using PROC CORR (SAS Institute 2003) (α = 0.05). Paired *t*-tests were conducted using PROC TTEST (SAS Institute 2003) (α = 0.05). Regression analyses were conducted using PROC GLM (SAS Institute 2003), and comparisons between regression slopes were made using 95% confidence intervals.

Results

One Trap per Tree. Means ± SEM of 5.5 ± 0.8 and 9.8 ± 2.0 adults per wk were captured on traps in the young and mature trees, respectively. The maximum observed number of adults per single trap was 78 in the young trees and 361 in the mature trees. The maximum observed mean number of adults per trap per sample period (n = 10 trees) was 28 ± 6 in the young trees and 157 ± 31in the mature trees. Means ± SEM of 0.06 ± 0.01 and 0.05 ± 0.01 adults per pair of mature leaves were observed in the young and mature trees, respectively. The maximum observed mean number of adults per pair of leaves per tree was 1.2 ± 0.5 in the young trees and 2.5 ± 0.7 in the mature trees. The largest observed number of adults per pair of leaves was six in the young trees and 13 in the mature trees.

Numbers of adults captured on traps in the young trees were positively correlated with solar radiation but not with air temperature, rainfall, or average daily wind speed (Table 1). Captures of adults were positively correlated with the combined effects of sunlight and air temperature but less so than with solar radiation alone. A significant, positive correlation was found for data from the young trees between captures of adults and maximum daily wind speed. In the mature trees, numbers of adults captured were positively correlated with solar radiation (solar radiation data 26 km from the study site) and air temperature (mean and maximum), but they were not correlated with rain. A higher correlation was found between trap captures and the combined effect of increases in sunlight and mean daily air temperature than between trap captures and either environmental factor alone. Captures of adults in the mature trees were not correlated with maximum daily wind (wind data 26 km from the study site). A weak, negative correlation was found between numbers of adults trapped and average daily wind speed. Solar radiation and rainfall were negatively correlated at the young tree site ($r = -0.33$, $Pr > r = 0.004$). These variables were not correlated at the mature tree site ($r = -0.14$, $Pr > r = 0.15$).

Relative variation (RV) associated with estimates of the mean number of adult *D. citri* per pair of mature

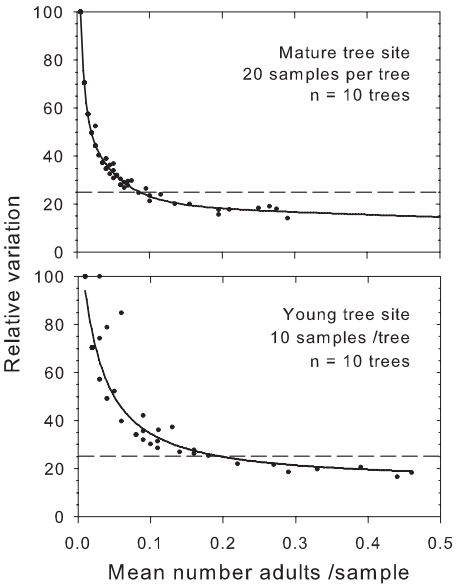

Fig. 1. Sampling precision based on relative variation (SEM/mean × 100) associated with mean estimates of the number of adult *D. citri* per pair of mature leaves in a group of mature citrus trees and a group of young citrus trees.

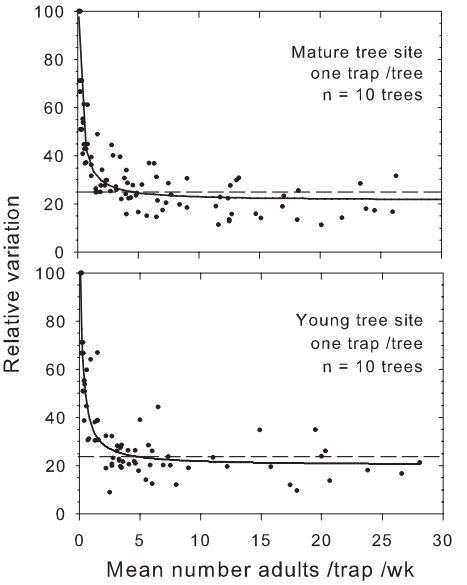

Fig. 2. Sampling precision based on relative variation (SEM/mean × 100) associated with mean estimates of the number of adult *D. citri* per yellow sticky trap per week in a group of mature citrus trees and a group of young citrus trees.

leaves increased as mean density decreased (Fig. 1). Observed RV values for data from the mature trees ranged from 11% at a mean density of 1.0 adult per sample to 100% at a mean density of 0.005 adults per sample. In the young trees, RV values ranged from 16% at a mean of 0.44 adults per sample to 100% at means of <0.03 per sample. The mean ± SEM RV value was 50.4 ± 3.2% for samples taken in the mature trees and 53.5 ± 3.7% for samples taken in the young trees. In the mature trees, a sample size of 20 leaf pairs per tree from ten trees yielded estimates with a mean RV value of 25% or less when mean adult densities per sample averaged 0.08 or more. In the young trees, a sample size of ten leaf pairs per tree from ten trees yielded a mean RV value of 25% or less when mean densities per sample averaged 0.18 or more.

RV values associated with estimates of the mean number of adults per trap per week increased as mean density per trap decreased (Fig. 2). In the mature trees, observed RV values ranged from 11% for a sample period that averaged 20 adults per trap to 100% or more for sample periods when fewer than a mean of 0.2 adults were present per trap. The mean ± SEM RV value was 35.1 ± 2.2% for trap samples in the mature trees and 34.7 ± 2.4% for trap samples taken in the young trees. One trap per tree in each of 10 trees yielded mean estimates per trap with average RV values of 25% or less at mean densities per trap of 4.0 or more in the mature trees and of 4.7 or more in the young trees.

Regression analyses (Table 2) indicated that a significant relationship existed between absolute infestation levels of *D. citri* on mature leaves in a citrus tree and the number of adults captured per week in the same tree for data from both the young and mature trees. The slope of the regression equation differed significantly between the young and mature trees. When data on numbers of adult *D. citri* on traps and leaves were averaged over the 10 trees sampled each week, statistical significance increased in the relationship between absolute infestation levels of *D. citri* on mature leaves and mean numbers of adults per trap per tree per week (Table 2; Fig. 3). The slope of the regression equation differed significantly between the young and mature trees. Note that data in Fig. 3 are truncated well below the maximum numbers of adults per trap or per pair of mature leaves observed. The figures were truncated to emphasize the relationship between numbers of adults on traps and leaves at small to moderate absolute densities, which was obscured in the figures when the range of the y and x axes were extended to include all data points. In total, 37 data values for the mature trees and nine data values for the young trees fell outside the range of Fig. 3.

One versus Three Traps per Tree. Means ± SEM of 8.4 ± 0.9 and 7.5 ± 0.6 adult *D. citri* per trap per tree were captured on traps in trees with one and three traps, respectively. There was no significant difference between these means ($t = 1.2$, $Pr > t = 0.23$, 507 df). Over all trapping periods in trees with one trap, means ranged from 0.0 to 110 adults per trap per tree. Over all trapping periods in trees with three traps, means ranged from 0.1 to 69 adults per trap per tree. There was no significant difference ($t = 1.34$, $Pr > t = 0.18$, 507 df) between trees with one and three traps with respect to mean number of males per tree per week (4.5 ± 0.5 and 3.9 ± 0.3, respectively). Also, there was no significant difference ($t = 1.49$, $Pr > t = 0.41$, 505 df) between trees with one and three traps with re-

Table 2. Results of regression analyses between mean number of adult *D. citri* per pair of mature leaves (Y) and number (per individual tree) or mean number (per 10 trees) of adults per trap per week (X)

	F	Pr > F	r^2	df	Regression equation	Slope SEM
Young tree study site, one trap per tree						
Individual trees	352.2	<0.0001	0.32	757	Y = 0.0217 + 0.0071X	0.0004
Means per 10 trees	147.8	<0.0001	0.53[a]	76	Y = 0.0104X	0.0009
Mature tree study site, one trap per tree						
Individual trees	936.7	<0.0001	0.48	1,009	Y = 0.0188 + 0.0033X	0.0001
Means per 10 trees	546.5	<0.0001	0.81[a]	101	Y = 0.0045X	0.0002
Mature tree study site, mean no. per 10 trees						
One trap per tree	318.6	<0.0001	0.70[a]	101	Y = 0.0051X	0.0003
Three traps per tree	127.4	<0.0001	0.56	100	Y = 0.0149 + 0.0046X	0.0004

[a] Corrected for the mean.

spect to mean number of females per tree per week (3.9 ± 0.4 and 3.5 ± 0.3, respectively).

Although no significant differences in numbers of adults trapped were found between trees with one and three traps over all trapping periods, a significant difference was found when the data analyses were restricted to sample periods when means of ≤1.5 adults per trap per tree were captured: greater numbers of adult *D. citri* were collected in trees with three traps (t = −4.39, Pr > t = <0.0001, 387 df). No significant difference was found between one and three traps per tree for trapping periods when means of >1.5 adults per trap per tree were captured (t = 1.73, Pr > t = 0.08, 503 df). Adult *D. citri* were detected each week in an average of 71.2% of the trees with one trap and 89.6% of the trees with three traps. These percentages were significantly different (t = −8.24, Pr > t = <0.0001, 101 df).

Means ± SEM of 0.05 ± 0.009 and 0.05 ± 0.007 adult *D. citri* per pair of mature leaves per tree were observed in trees with one and three traps, respectively. There was no significant difference between these means. The maximum observed mean number of adults per pair of mature leaves was 0.58 in trees with one trap and 0.44 in trees with three traps.

Regression analyses (Table 2) indicated that a significant relationship existed between absolute densities of *D. citri* on mature leaves and mean numbers of adults captured per trap per week by using either one or three traps per tree (Fig. 4). There was no signif-

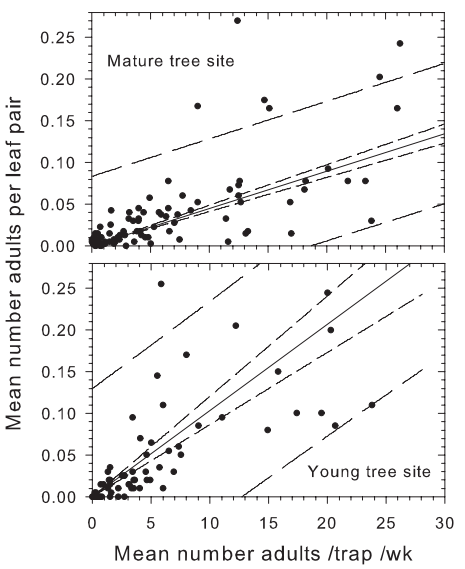

Fig. 3. Relationship between infestation densities of adult *D. citri* (number per pair of mature leaves) and weekly trap captures of adults by using yellow sticky traps. The upper graph presents data from a group of mature trees (10 trees, 20 leaf pairs per tree, one trap per tree, n = 102 trapping periods) and the lower graph presents data from a group of young trees (10 trees, 10 leaf pairs per tree, one trap per tree, n = 77 trapping periods). In each graph, the solid line is the mean prediction, short-dash lines are 95% limits for mean predictions, and the outer long-dash lines are the 95% limits for individual predictions. Consult Table 2 for details of the analyses.

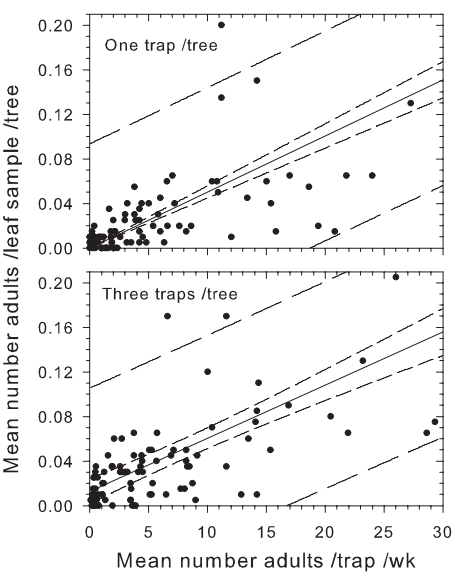

Fig. 4. Relationship between infestation densities of adult *D. citri* (number per pair of mature leaves) and weekly trap captures of adults using one or three yellow sticky traps per tree. The data are from a group of mature trees (five pairs of trees, 20 leaf pairs per tree, one or three traps per tree, n = 101 trapping periods). In each graph, the solid line is the mean prediction, short-dash lines are 95% limits for mean predictions, and the outer long-dash lines are the 95% limits for individual predictions. Consult Table 2 for details of the analyses.

icant difference between the slopes of the two regression equations The correlation coefficient associated with these regressions was larger for data from one trap per tree than for data from three traps per tree. For the same reasons presented earlier for Fig. 3, data in Fig. 4 for both one and three traps per tree are truncated well below the observed maximum numbers of adults per trap or per pair of mature leaves. A total of nine data values associated with one trap per tree and six data values associated with three traps per tree fell outside the range of Fig. 4.

Discussion

Yellow sticky card traps have been shown to have value in detecting adult *D. citri* in citrus (Hall et al. 2007). Numbers of adults captured at yellow sticky traps have been shown useful for gauging adult population densities over time (Hall et al. 2008). However, the research presented here indicated that there are drawbacks to trying to estimate population levels of adults in citrus by using yellow sticky traps.

Sunlight positively influenced captures of adults on traps in the young trees and probably in the mature trees. Therefore, where a trap is placed in a tree could influence how many adults are captured if some locations receive more sunlight than others, and day-to-day differences in sunlight would affect numbers of adults trapped. In addition to sunlight, air temperatures positively influenced numbers of adults captured on traps in the mature trees. These results indicated that the value of yellow sticky traps as indicators of absolute densities of adults is reduced by changes in both sunlight and air temperature. These results support observations by Aubert and Hua (1990) that indicated adult flight and jumping activities by *D. citri* are more pronounced on warm, sunny days. Although at one study site solar radiation and rainfall were negatively correlated (as expected due to cloud cover associated with rain), rainfall by itself was not related to numbers of adults trapped on yellow sticky traps at either study site. A weak but significant negative correlation between captures of adults on traps and average daily wind was found for trapping data from the mature trees, but no correlation was found for trapping data from the young trees. Although Aubert and Hua (1990) reported that adult *D. citri* were sometimes more active under windless conditions, the results of the study indicated that wind plays a minor role in reducing captures of adults. In fact, a fairly strong, positive correlation was found for data from the young trees between captures of adults and maximum daily wind speed. The reason why captures of adults and maximum wind speed were correlated in the young trees and not in the mature trees was not known. Perhaps adults in young trees are more prone to being dislodged by strong winds that disturb the trees and that trap captures of adults subsequently increase either accidentally or as dislodged adults return to a tree. Larger trees may be disturbed less by wind, and wind speed may be reduced within the larger canopies of mature trees. It remained possible that no correlation was found between numbers of adults on traps and wind speed in the older trees because the wind data were collected 26 km from the study site and thus may not have been representative of the study site. This data caveat for the mature tree study site also applied to solar radiation.

D. citri is an important citrus pest because it transmits the pathogen responsible for citrus greening disease. Intensive psyllid management is advocated throughout the year to reduce incidence and spread of the disease (Rogers 2008). Therefore, in gauging the effectiveness of psyllid suppression program, methods of estimating infestation levels of the psyllid should focus on low densities. Southwood (1978) suggests a sampling plan that provides a relative variation value of 25% or less is often sufficiently precise, although for research purposes a value of 10% or less may be desired. Relative variation associated with the sampling methods used in this study to estimate absolute densities of adults on leaves averaged 25% or less at mean densities of 0.08 or more per sample in the mature trees (20 samples per tree from 10 trees) and at mean densities of 0.19 or more per sample in the young trees (10 samples per tree from 10 trees). However, relative variation increased above 25% as infestation levels decreased below these densities. With respect to trap samples, relative variation associated with mean number of adults per trap averaged 25% or less at mean densities of about four or more per trap but increased above 25% at lower mean numbers.

Significant correlations were found between mean numbers of adult *D. citri* captured on sticky traps and mean numbers of adults on mature leaves. Correlations between numbers of adults on traps and numbers on leaves were considerably higher for data averaged over all trees per sample period than for data from individual trees, thus only data averaged over all trees are presented graphically. Mean predictions of absolute numbers of adults on leaves from numbers on traps were reasonably precise. However, even for data averaged over all trees, regression analyses indicated that little confidence could be placed on an individual density prediction. This was attributed in part to the sample sizes used to estimate absolute densities of adults on leaves when densities were low. Greater sampling precision in estimates of numbers of adults on leaves might have been achieved had larger numbers of leaf samples been sampled or if an individual sample had consisted of more than two mature leaves. Also, increasing the number of trees with traps might have improved the precision of estimates at low absolute densities. Increasing the number of traps per tree from one to three significantly improved the detection of adults in a tree when adult populations were low, but using three traps per tree did not significantly improve individual estimates of the absolute density of adults present.

Regardless of how many traps are deployed per tree and how many trees with traps are studied across a sample area, day-to-day differences in sunlight and air temperature will influence to some extent numbers of adults captured on traps. There may be other factors that influence psyllid activity and consequently trap captures. For example, movement by adult psyllids to and within

trees—and consequently numbers captured on traps—might be influenced by the presence or absence of flush, the only growth stage of citrus leaves on which *D. citri* oviposit and immatures develop (Catling 1970, Hall and Albrigo 2007). Trap captures of the pear psylla, *Cacopsylla pyricola* (Foerster), have been shown to be positively influenced by population densities of this psyllid (Horton and Lewis 1997). Numbers of *D. citri* captured on traps might be similarly influenced. Using yellow sticky traps to estimate absolute densities of adult *D. citri* in citrus is further complicated by the fact that the quantitative relationship between numbers of adults captured on traps and absolute densities on leaves differed between the young and mature trees studied. At the same absolute density of adults, greater numbers of adults were captured on traps in the mature trees compared with young trees. This might be a consequence of differences in light intensity within small and large tree canopies that affect the attraction of adults to traps.

The positive and negative aspects of using yellow sticky traps to estimate densities of adult *D. citri* are similar to those associated with *C. pyricola* (Horton 1994, Horton and Lewis 1997). Horton and Lewis (1997) reported that sticky traps are useful for *C. pyricola* management decisions but that sticky trap counts of *C. pyricola* often had a large behavioral or activity component that obscured density effects. For more precise estimates of absolute density of adult *C. pyricola*, beat tray sampling is preferred (Horton and Lewis 1997). A similar beat tray sampling procedure has been shown effective for detecting adult *D. citri* in citrus (Hall et al. 2007), and the value of this method for estimating absolute densities could be explored.

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