Thresholds for Vector Control and Compatibility with Beneficial Fauna in Citrus with High Incidence of Huanglongbing

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Abstract

Huanglongbing (HLB) or citrus greening disease is vectored by the Asian citrus psyllid (ACP), *Diaphorina citri* Kuwayama. Vector control is considered a basic component of HLB management even in a high disease incidence scenario. Such control is mostly chemically oriented. However, overuse of insecticides would increase costs and be incompatible with biological control. Establishment of economic thresholds for psyllid control under different price scenarios would optimize returns on investment. A 3-year experiment is being conducted in a commercial orange block with high HLB incidence. Experimental design is RCB with 4 treatments and 4 replicates: (1) calendar applications, (2) insecticide applications according to a threshold of 0.2 psyllids/stem tap sample, (3) applications according to a 0.7 threshold and (4) no insecticide. Vector populations are monitored biweekly by tap sampling. Differences in vector abundance among treatments are being correlated to fruit yields. Consequences of each vector control strategy on beneficial arthropod fauna are also being evaluated, as well as potential negative impacts on biological control. After two years, a significant yield increase was observed with the calendar treatment, but so far, justification for the additional costs would require higher than actual juice prices scenarios. ACP management strategies based on nominal thresholds are so far more profitable. Negative impacts of calendar sprays on biological control of mites and leafminers have been observed.

Keywords: Asian citrus psyllid, greening disease, citrus, natural enemies, economic viability

INTRODUCTION

Huanglongbing (HLB) or citrus greening is considered one of the world's most devastating citrus diseases with no known cure (Bové, 2006). Disease management is largely dependent on control of the Asian citrus psyllid (ACP) vector, *Diaphorina citri* Kuwayama (Qureshi and Stansly, 2008, 2010). As a result, insecticide use has greatly intensified with concomitant risks to biological control processes already observed in the citrus agroecosystem. Consequent reduction of biotic mortality to populations of ACP and other pests could require even more frequent insecticide applications and induce secondary pest outbreaks (Zhang and Swinton, 2009). Recent studies and grower experience has indicated that productivity of HLB-infected trees can be maintained by a combination of foliar nutrient remediation programs aimed at mitigating nutritional deficiencies caused by HLB, and vector suppression to reduce reinoculation of the causal bacteria (Stansly et al., 2013). However, the degree of vector suppression required to maintain economic viability of process oranges has yet to be determined. The goal of this research is therefore to establish economic thresholds under different juice price scenarios that optimize returns on investment when a nutrient remediation program is applied in groves with high-moderate incidence of HLB. Loss of biological control services is considered as an indirect cost. Results from this study will provide growers and consultants with information necessary to make critical decisions pertaining to pest management strategies.

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MATERIALS AND METHODS

Experimental Design

A 3-year study was initiated on summer 2010 in a commercial sweet orange grove under standard cultural practices located in Hendry County (southwest Florida) and with an estimated initial HLB infection level of 98% of the trees. Four different ACP management strategies were tested in a randomized complete block design with four replicates: (1) calendar applications, (2) ACP sprays based on a nominal threshold of 0.2 adults per stem tap, (3) ACP sprays based on a threshold of 0.7 adults per tap, and (4) no insecticides to control ACP. Treatments, (3) and (2) received one or two sprays, respectively, during tree dormancy in winter (Qureshi and Stansly, 2010) without considering any threshold.

ACP Insecticide Applications

An insecticide program was design to try to maintain ACP numbers as close to zero as possible in treatment (1) considering potential impacts on beneficial fauna, secondary pests and resistance risks. Insecticide sprays were conducted on a monthly basis and eight different insecticide groups were used and rotated throughout the season. Broad-spectrum insecticides were restricted to the ‘dormant’ season or just before when natural enemies’ presence and activity was expected to be reduced whereas more selective insecticides were used during the main growing season (Table 1). The cost of each application was estimated for further economic analyses.

Sampling

ACP populations were monitored every two weeks by 40 stem tap samples per plot. Spiders (*Araneae*), arboreal ants (*Hymenoptera*: *Formicidae*, *Pseudomyrmecinae*), ladybeetles (*Coleoptera*: *Coccinellidae*) and lacewings (*Neuroptera*) were also monitored by stem tap to calculate cumulative numbers over the season and used as an indication of. Differences on natural enemies’ cumulative numbers among treatments were used to indicate impact of ACP insecticide sprays on beneficial fauna.

Total yields per plot were recorded during the harvest in November 2010, just after initiating the experiment to serve as a baseline with which to compare subsequent harvests, and in November 2011. Increments in yield from 2010 to 2011 among treatments were compared. Before 2011 harvest, fruit samples consisting of approximately 15 kg of randomly collected fruits from each replicate of each treatment were taken for juice quality analysis. Samples were sent to the University of Florida citrus quality laboratory in Lake Alfred, FL. Juice was de-aerated under vacuum for 2-3 minutes and soluble solids content measured by hydrometer.

Economic Study

A preliminary economic study was conducted to determine if yield increments obtained compared to the untreated control covered costs of the insecticide applications. The following cost-benefit equation was used to this goal:

$$\text{ACP insecticide application costs} = \Delta \text{ yields} \times \text{juice price}$$

After estimating the applications costs of each treatment and the yields increments resulting from them, the juice price that balance the two sides of the equation was calculated and compared to the Florida market prices during that season. Profitability among treatments was compared.

Table 1. Insecticides calendar program followed in the calendar treatment (1) and in the two nominal threshold treatments, 0.2 ACP adults per stem tap (2) and 0.7 ACP adults per tap (3) when their nominal thresholds are reached. Active ingredients, applications rates and applications costs are included.

Date	Active ingredient (product name)	Rate per acre	Price ($)	Mineral oil	Insecticide* ($)	Mineral oil* ($)	Appl.* costs	Total* ($)	Treatments sprayed
January	Fenpropathrin (Danitol 2.4 EC)	0.58 L/ha	650/L	***	24.7	0	59.5	84.2	(1), (2), (3)
March	Diflubenzuron (Micromite 80WGS)	438 g/ha	35/kg	10%	73.4	13.1	59.5	146.0	(1)
April	Carbaryl (Sevin XLR Plus)	7.02 L/ha	113/L	***	55.6	0	59.5	115.1	(1)
May	Spinetoram (Delegate WG)	315 g/ha	184/L	5%	72.4	57.6	59.5	189.5	(1)
June	Imidacloprid (Admire Pro)	315 g/ha	73/g	3.50%	28.7	40.3	59.5	128.5	(1)
July	Abamectine (Agri-Mek SC)	0.26 L/ha	908/L	2%	16.3	23.0	59.5	98.8	(1)
August	Malathion (Gowan Malathion 8F)	2.92 L/ha	189/L	***	38.5	0	59.5	98.0	(1)
September	Fenpropathrin (Danitol 2.4 EC)	0.58 L/ha	605/L	***	55.6	0	59.5	115.1	(1)
October	Spirotetramat (Movento MPC)	1.171 L/ha	1438/L	2%	117.4	23.0	59.5	199.9	(1)
November	Carbaryl (Sevin XLR Plus)	7.02 L/ha	113/L	***	55.6	0	59.5	115.1	(1)
December	Phosmet (Imidan 70-W)	1122 g/ha	4.3/L	***	23.47	0	59.5	82.97	(1), (2)
Annual costs:								$1372.9	

*Costs are given per hectare.

Statistical Analysis

Cumulative numbers of ACP, beneficial arthropods and yield increments were compared among treatments using general mixed models where treatment was considered as fixed factor and block as random factor. Data were log-transformed when normality and homocedasticity assumptions were not met.

RESULTS

Significant reduction of *D. citri* adults in response to insecticide treatment was observed (*F*=8.36; df=3, 9; *P*=0.0057), with lower ACP cumulative numbers on trees receiving monthly insecticide applications (Fig. 1).

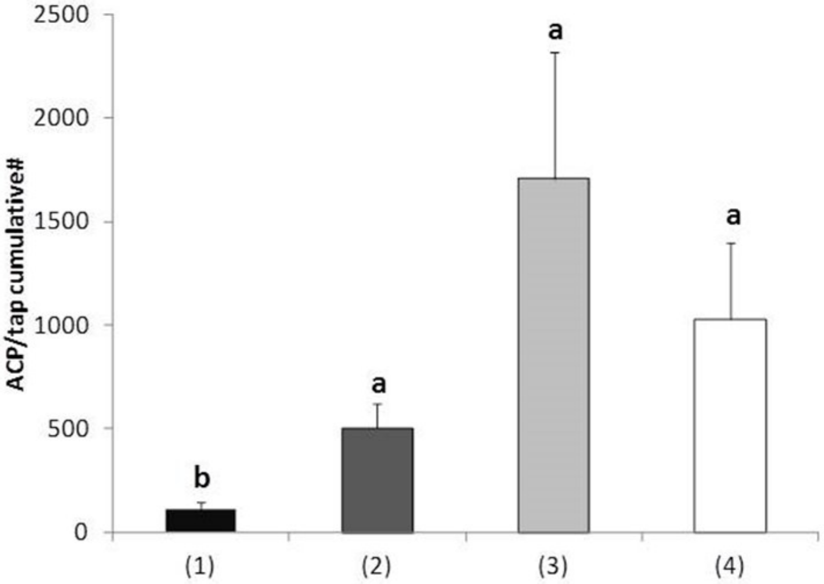

Fig. 1. ACP cumulative numbers from October 2010 to November 2011 obtained by stem tap sampling in the four treatments evaluated: (1) calendar applications, (2) insecticide applications according to a nominal threshold of 0.2 ACP adults per stem tap, (3) insecticide applications according to a nominal threshold of 0.7 ACP adults per stem tap and (4) no ACP insecticide applications. Different letters indicate significant differences among treatments (LS Means: *P*<0.05).

Spiders, arboreal ants and ladybeetle populations were negatively affected by monthly insecticide applications (*F*=3.05; df=3, 25; *P*=0.0473, *F*=5.23; df=3, 25; *P*= 0.0061 and *F*=5.13; df=3, 25; *P*=0.0067, respectively) whereas no significant effect was found on lacewings (*F*=0.62; df=3, 25; *P*=0.6061) (Fig. 2).

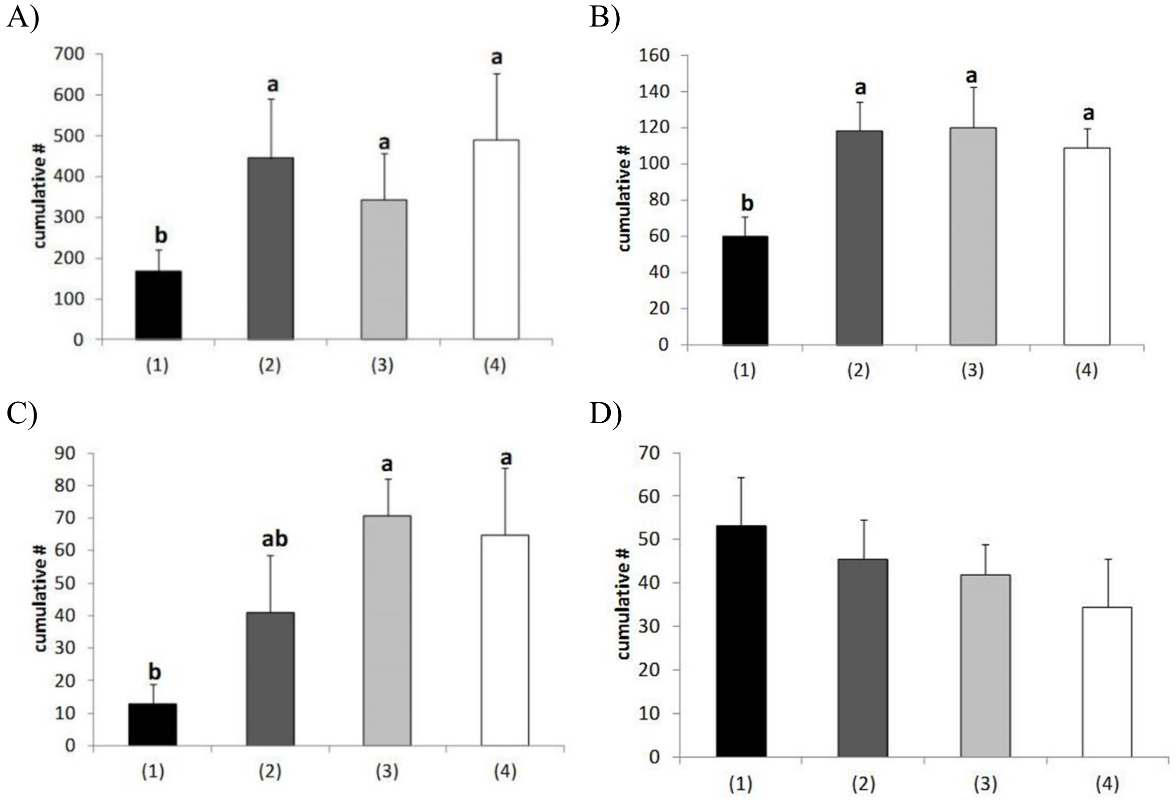

Fig. 2. Beneficial arthropod cumulative numbers from October 2010 to November 2011 obtained by stem tap sampling in the four treatments evaluated: (1) calendar applications, (2) insecticide applications according to a nominal threshold of 0.2 ACP adults per stem tap, (3) insecticide applications according to a nominal threshold of 0.7 ACP adults per stem tap and (4) no ACP insecticide applications. Different letters indicate significant differences among treatments (LS Means: $P<0.05$). A) Arboreal ants (*Hymenoptera*: *Formicidae*, *Pseudomyrmecinae*), B) Spiders (*Araneae*), C) Lady beetles (*Coleoptera*: *Coccinellidae*) and D) Net-winged insects (*Neuroptera*).

Yield increments from 2010 to 2011 were significantly greater from trees receiving monthly sprays compared to the untreated control receiving no insecticide applications (LS Means: $t=3.18$; df=9; $P=0.0112$). No significant differences were found among the other treatments (Fig. 3).

Total additional costs of the calendar treatment (1) were estimated at $1372.9 per hectare and year (Table 1). The yield increments due to calendar sprays were estimated in 3985.6 kg per hectare. An estimated increment of 0.0697 kg of solids per kg of fruit was obtained from trees receiving this treatment. However, the price necessary to pay for the additional costs of the calendar treatment would then be $4.88/kg or $0.34 per kg of fruit. Additional costs of the 0.2 threshold treatment (2) were estimated at $167.1 per ha and year. Given estimated yield increments of $878.3 per hectare, a juice price of $2.72 per kg solids or $0.19 per kg of fruit would be needed to pay for the extra costs of treatment (2). Additional costs of the 0.7 threshold treatment (3) were estimated in $84.2 per hectare and year resulting in yield increments of $423.5 per hectare. The juice price that would pay for the additional costs of treatment (3) was calculated to be $2.84 per kg solids or $0.20 per kg of fruit.

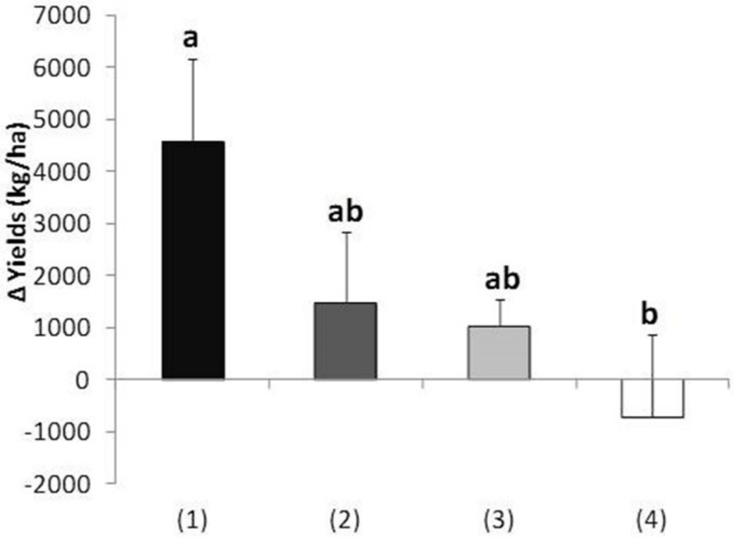

Fig. 3. Yield increments in harvest from 2010, considered as a preliminary situation, to 2011 in the four treatments evaluated: (1) calendar applications, (2) insecticide applications according to a nominal threshold of 0.2 ACP adults per stem tap, (3) insecticide applications according to a nominal threshold of 0.7 ACP adults per stem tap and (4) no ACP insecticide applications. Different letters indicate significant differences among treatments (LS Means: $P<0.05$).

CONCLUSIONS

Regular application of insecticides to control ACP significantly suppressed the vector population but also reduced numbers of beneficial ladybeetles, spiders and ants. Services provided by natural enemies toward reducing ACP populations as well as to control other important pests occurring in Florida citrus agroecosystem cannot be dismissed (McCoy, 1985; Michaud, 2004; Qureshi and Stansly, 2009). Thus, insecticide sprays may exact a cost through negative effects on beneficial fauna addition to product and application costs. However, long term effects from loss of beneficial fauna on control of ACP and secondary pests are yet to be determined.

Two years were sufficient to demonstrate positive effects of insecticidal control on yields in a high HLB incidence citrus orchard receiving supplemental applications of foliar nutrients, confirming results from a previous study (Stansly et al., 2013). However a citrus juice price of $4.88 per kg solid would have been necessary to pay for the additional cost of the monthly spray program used here, well above market prices in 2011 that ranged between $3.79 and $4.67 per kg solids. Juice prices that would pay additional costs when nominal thresholds of 0.2 and 0.7 ACP adults per stem tap were used ($2.72 and $2.84 per kg solid), were below market prices in 2011. According to these results both treatments would be economically profitable especially the 0.2 threshold level.

Our preliminary results indicate that direct and indirect costs of monthly insecticide applications for ACP control are not justified by expected profits, given current market conditions. There is thus a need to optimize profits by eliminating ineffective sprays during the growing season. The economic feasibility of thresholds will depend on the frequency and efficacy of sprays necessary to maintain pest densities under those values that in turn will depend on ACP populations and their capacity to recover after a spray. This study was conducted in a scenario of low pest densities in which only one or two winter sprays, depending on the treatment, were required to keep ACP numbers below the nominal thresholds. Future results will help adjust spray frequency to vector densities necessary for maintaining profitability under different cost-benefit scenarios.

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