Preliminary results on the potential long-term cost-effectiveness of spraying insecticides for Asian citrus psyllids and rogueing huanglongbing-infected citrus trees in California

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Issue

Citrus greening disease, or huanglongbing (HLB), has inflicted significant damage on citrus production across Florida and Texas. This disease, caused by the phloem-organized bacterium *Candidatus* Liberibacter asiaticus (*C*Las) and vectored by the Asian citrus psyllid (ACP), leads to nutrient deficiency in infected trees with decreased fruit yield and quality. Upon HLB infection, the disease swiftly spreads throughout the tree (Farnsworth et al. 2014), producing unripened fruit before the trees die from the disease.

Florida's struggle with HLB serves as a stark example of the potential harm this disease poses to citrus growers who have not been affected yet. The spread of HLB in Florida incurred an estimated cost of $4.5 billion to the state's economy between 2007 and 2011 (Alvarez et al. 2016; Farnsworth et al. 2014; Hodges and Spreen 2012). Florida's citrus value in 2022 fell to around $585 million (USDA-NASS 2023b). Annual production decreased by 8 million tons between 2004 and 2020 (Simnett and Kramer 2020). As of 2022-2023, Florida orange production was down to approximately 720,000 tons (CPDPP 2023).

In California, the incidence of residential *C*Las+ ACP and HLB+ trees have been escalating rapidly. ACP was initially detected in residential trees in San Diego County in 2008 and is established throughout southern California in both residential and commercial citrus groves (Byrne et al. 2018; Hoddle 2012). Counties in California with identified HLB+ infections include San Diego, Riverside, Los Angeles, San Bernardino, Orange, and most recently, Ventura. None of these infections have occurred in commercial groves. According to the CDFA, the number of identified HLB+ trees reached 8,431 as of August 16, 2024.[1] In July 2023, the number of infected trees was 5,708 (Johnston et al. 2023), a concerning rate of transmission among residential trees of nearly 48% in just over a year. These results

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[1]Source: https://maps.cdfa.ca.gov/WeeklyACPMaps/HLBWeb/HLB_Treatments.pdf

come on the heels of two CLas+ ACP being found in commercial groves in two different southern California counties (CPDPP 2020; CPDPP 2022). These events motivate our efforts to identify effective HLB management practices for California and elsewhere as there is still no known cure for HLB.

As noted, California has not yet experienced a HLB tree infection in a commercial grove. To prevent such infections, many growers spray insecticides to control the ACP populations. The California Department of Food and Agriculture conducts surveys and trapping to monitor for ACP as well as releases taramixia (parasitic wasps) to control ACP populations, and outreach, among other practices, to help in the battle to control the spread of HLB. Another possible option is removing infected trees (rogueing) once a symptomatic tree is identified. The experience with HLB in Florida and Texas with implementing a three-pronged approach of tree removal (rogueing), insecticide spraying and re-planting with HLB-free trees may suggest otherwise (Graham et al. 2020). Moreover, Li et al. (2020) express that rogueing is not cost-effective in Florida. These negative outcomes may be due to production of processing oranges rather than fresh market fruit, which brings a much lower price, or as suggested by Yuan et al. (2021), the approach lacked region-wide implementation. It is worth noting that California primarily produces citrus for the fresh fruit market (USDA-NASS 2023b) and thus may see different outcomes when spraying and rogueing.

In this research note, we evaluate spraying of insecticides to control ACP and rogueing HLB-infected trees to observe their potential effect on preventing and managing HLB in a newly planted California Navel orange grove that sells to the fresh market over a 20-year lifespan. This is a sufficient time frame to see the effects of HLB on the productive and profitable lifespan of the grove and evaluate how cost-effective this practice is relative to taking no action and to only spraying to control ACP and ultimately HLB. Utilizing a simulation model, we assessed the impact of rogueing at the frequency of 105 days and the HLB tree removal threshold of 40% (given the results seen in Jewell et al. (2024)) with spraying at efficacies of 90%, 80%, and 70% on Navel orange production. Our analysis indicates that implementing rogue and spray practices together generates ACP and HLB management synergies, increasing yields. However, the cost of doing both more than offsets the synergy gains, resulting in lower profits than spraying alone. We evaluate separate rogueing and insecticide spraying approaches in other research notes, which can be found at `https://www.csus.edu/faculty/k/kaplanj/researchnotes/`.

Methods

We use a budget approach to estimate the effects of HLB on Navel orange production for a representative California grove and potential benefits from alternative ACP insecticide spraying and rogueing strategies to reduce HLB effects. Data from UCCE cost and returns studies (O'Connell et al. 2015; Kallsen et al. 2021) and California County Agricultural Commissioner Reports (USDA-NASS 2023a) are used to derive costs, prices, and yield conditions for Navel orange production for a representative newly planted grove in southern California. Table 1 lists the costs for producing California Navel oranges. Spraying cost is constructed from Kallsen et al. (2021). Monitoring and tree removal costs are also list in Table 1. Monitoring cost is based on the time to survey an acre multiplied by the labor wage rate. Tree removal costs are derived from Singerman et al. (2022). Table 2 provides the prices per box and maximum boxes per acre derived from California County Agricultural Commissioner Reports (USDA-NASS 2023a) that are used in the analysis.[2]

Cultural cost year 1	$7,756.43/acre
Cultural cost year 2	$1,789.04/acre
Cultural cost year 3	$2,066.17/acre
Cultural cost year 4	$3,198.23/acre
Cultural cost year 5	$4,590.30/acre
Cultural cost year 6+	$7,859.15/acre
Spraying cost	$0.246/tree
Monitoring cost	$6/acre/survey
Tree removal cost	$3/tree

Table 1: Cultural, insecticide spray, and rogueing costs

	$/Box	Boxes/acre
Low	6	541
Average	13.5	836
High	21	1,176

Table 2: Price per 37.5 lb box and average annual maximum yield (boxes) per acre

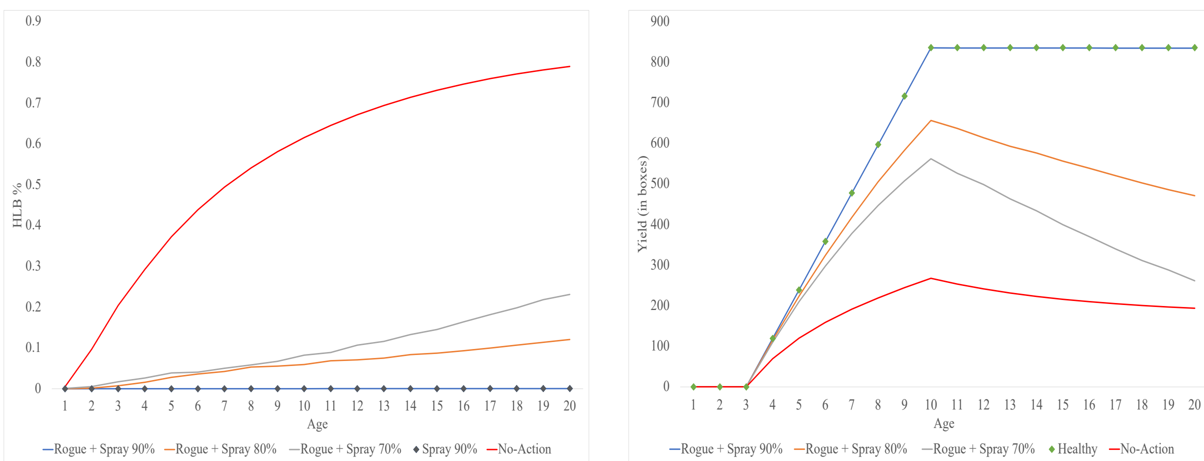
An agent-based model adapted from Lee et al. (2015) and (Haynes et al. 2021) simulates citrus flushes, ACP, and HLB spread in a newly planted Navel orange grove. Simulated data is required

[2]The maximum yield values underestimate the yield when a grove is established since the data captures production for establishing and established acreage.

given HLB has not been found in citrus groves in California nor can it be released into the field to measure its spread or treatment effectiveness. The simulation model generated HLB severity data across scenarios involving various efficacy rates of insecticides (90%, 80%, and 70%) with rogueing at a monitoring frequency of 105 days and a HLB removal threshold of 40%. This rogueing strategy was selected since it generated the greatest cumulative profits among alternative rogueing strategies evaluated in Jewell et al. (2024). Figure 1 shows the average annual HLB severity for the rogue and spray scenarios, and no action over a 20-year time frame, and the yield per acre for these scenarios and for a healthy grove.

To estimate healthy (uninfected) yield in each year for each scenario, we use a weighted-average of the yield per acre for data from the California County Agricultural Commissioner Reports (USDA-NASS 2023a) as the average maximum yield per acre shown in Table 2 and the age-yield profile reported in the UCCE cost and returns studies (O'Connell et al. 2015; Kallsen et al. 2021). For the infected grove over the timeframe, a yield factor, estimated by Bassanezi et al. (2011), is multiplied by the healthy yield in a given year and then applied to the remaining trees in the infected grove in that year and then across the different grove ages.

We use a weighted-average of Navel orange prices from the California County Agricultural Commissioner Reports (USDA-NASS 2023a) to derive the average price per 37.5 lb box. We also consider the lower and upper bounds for the 95% confidence levels for low and high price scenarios, respectively. For the simulated citrus grove, we assume there are 110 trees per acre. We use the estimated age-yield profiles in Figure 1b to calculate profits for the healthy groves, infected groves where no action is taken to control HLB, and infected groves where rogue and spray scenarios are adopted over a 20-year lifespan as this is sufficient time to observe the effects of HLB spread and effectiveness of the combined practice scenarios on yields and grove profits. We compare cumulative profits across the different scenarios relative to no action and spraying alone, and highlight when cumulative profit become positive and how long the grove remains profitable as HLB spreads.



(a) HLB severity (%trees in grove infected) by grove age for a representative California Navel orange grove infected with HLB when no HLB action is taken or the grower applies ACP insecticide spray at varying efficacy rates and surveys for HLB-infected trees every 105 days and removing HLB-infected trees if HLB severity exceeds 40% threshold. HLB severity for the 90% efficacy rate scenarios is shown for comparison.

(b) Yield per acre (maximum 836 boxes/acre/year) by grove age for a representative California Navel orange grove that is HLB-free (Healthy), or infected with HLB and no HLB action is taken or the grower applies ACP insecticide spray at varying efficacy rates and surveys for HLB-infected trees every 105 days and removing HLB-infected trees if HLB severity exceeds 40% threshold.

Figure 1: HLB severity and yield (boxes/acre/year) for representative California Navel orange groves that are HLB-free, infected but no HLB action is taken, and infected and varying ACP insecticide spray efficacy rates are applied along with surveys for HLB- infected trees every 105 days and removal of HLB- infected trees when HLB severity exceeds 40% threshold.

Findings

When combining rogue and spray practices, the highest efficacy spray at 90% with rogueing at a frequency of 105 days and 40% removal threshold produced the earliest profits Table 3 shows the first year cumulative profits are positive. Price per 37.5 lb. box and the maximum number of boxes produced were influential on profits. The highest price of $21 and mature yield of 1,176 boxes maintained the best outcome for HLB citrus production. Overall, rogueing and spraying done together were not as profitable as spraying alone (Table 4).

	$13.5/box 1,176 boxes/acre	$21/box 836 boxes/acre	$21/box 1,176 boxes/acre
Rogue & Spray 90%	year 10	year 9	year 8
Rogue & Spray 80%	year 12	year 10	year 8
Rogue & Spray 70%	-	year 13	year 9

Table 3: Grove age when cumulative profits are greater than zero for the first time for a healthy grove, an HLB infected grove (No Action), and HLB infected groves where the three different spray efficacies and rogueing every 105 days and removing HLB-infected trees if HLB exceeds the 40% threshold are adopted throughout the 20-year simulated time frame. Scenarios not shown did not generate positive profits at any age except for the healthy grove scenarios but are not listed.

	$13.5/box 1176 boxes/acre	$21/box 836 boxes/acre	$21/box 1176 boxes/acre
Healthy	$84,976.58	$108,496.58	$208,456.58
Rogue	-	$8,156.06	$67,535.58
Spray 90%	$84,234.62	$107,733.37	$207,603.09
Spray 80%	$26,627.80	$44,030.60	$117,992.48
Spray 70%	-	$12,157.82	$73,157.09
Rogue & Spray 90%	$83,815.32	$107,313.85	$207,182.60
Rogue & Spray 80%	$19,769.23	$36,493.19	$107,570.03
Rogue & Spray 70%	-	-$3,755.54	$50,958.72

Table 4: Cumulative profits per acre over a 20-year time frame for a representative California Navel orange grove when rogueing at the frequencies of 105 days and HLB severity tree removal threshold of 40%, spraying at efficacies of 90%, 80%, and 70%, and the combined practice of rogueing at 105 days and 40% removal threshold and spraying. Scenarios not shown did not generate positive profits at any age except for the healthy grove scenarios but are not listed.

Rogueing at a frequency of 105 days and a removal threshold of 40% and spraying insecticide with a 90% efficacy rate was the most effective among the rogue and spray scenarios. This scenario produced positive cumulative profits in year 8 for the high price per box of $21 and yield of 1,176 boxes per acre (Table 3). Cumulative profits reach $207,182.60 (Table 4.). The first year cumulative profits are positive are shown in Table 3. Positive annual profits remain for the 70%, 80% and 90% rogue and spray scenarios until year 19, 20, and 20, respectively.

For the high price per box of $21 and average yield of 836 boxes per acre, this combined scenario made positive profits in year 9 and cumulative profits of $107,313.85 (Table 3). These price and yield scenarios for rogueing with spraying at 90% continued to generate positive profits throughout the 20-year simulation as did the rogue and spraying at 80% scenario for this price-yield combination. The 70% scenario had positive annual profits until year 15. As we can see in Table 4, the combined practice of rogueing and spraying at 80% and 90% spray efficacy rates produced better results than only rogueing with a 105 day monitoring frequency and a 40% HLB severity tree removal threshold but, as noted, did not do as well as spraying only.

Key Insight

- Although rogueing and spraying is cost-effective relative to taking no action, spraying outperforms rogueing and spraying scenarios, and rogueing alone.
- Growers are not able to select efficacy rates but rather face uncertainty given the influence of environmental factors and pest resistance, among others factors, on efficacy rates. This uncertainty occurs whether rogueing happens or not and as such spraying still dominates rogue and spray scenarios, and rogueing alone.
- Ultimately, profitability depends heavily on spray efficacy rates, prices, and yields. Only when prices and yields are at or above average do we see positive profit outcomes, suggesting that unless alternative management practices are identified, there are likely to be harsh consequences when HLB reaches commercial groves in California.

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