The economic potential of oxytetracycline and Asian citrus psyllid insecticide spraying to control Huanglongbing in a California citrus grove

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May 14, 2025

Research Note 2025-1

Key Insight

- Spraying insecticides at high efficacy rates is most effective at slowing the spread of HLB and providing positive profits over the 20 year simulation, as long as price and yield are at or above average.
- Prices and yields play a key role due to fluctuations from harvest to harvest, the best strategy for growers is to spray insecticides for ACP before HLB detection and then, after it is detected, growers are recommended to use OTC trunk injections along with spraying.

This research was partially supported with funds from USDA NIFA SCRI grant 2019-70016-29066 and 2020-70029-33202.

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Issue

Citrus greening, also known as Huanglongbing (HLB), poses a substantial challenge to global citrus production, endangering both its sustainability and economic feasibility. HLB is a disease transmitted by the Asian citrus psyllid (ACP), which introduces the bacterium *Candidatus* Liberibacter asiaticus (*C*Las) into citrus trees, resulting in fruit drop, reduced yield and quality, and eventual tree mortality. This disease has been the cause of significant economic losses in major citrus producing countries, such as Brazil, China, and the United States. In Brazil, approximately 55.5 million sweet orange trees infected with HLB were eradicated from 2005-2019 (Bassanezi et al. 2020). Also, the economic losses in orange production in the Paranavaí region of Brazil were \$39.2 million USD from 2011 to 2013 (Costa et al. 2021). In China, where HLB originated, the top-producing Jiangxi Province lost 25% of its groves from 2012 to 2018, including the destruction of 100 million commercially grown citrus trees reported in Asia (Djeddour et al. 2021). In the United States, Florida has been the most affected by HLB, with annual economic losses exceeding \$1 billion USD and an approximate annual job loss of 5000. Florida citrus production has declined 92% between 2003 and 2023 from 300 million boxes to less than 20 million boxes. In Texas, HLB has been detected in 26% of commercial groves and 40% of residential sites since its first appearance in 2012 (National Plant Network 2023). Meanwhile, California, where HLB has only been detected in residential groves, faces an imminent threat. Counties such as San Diego, Riverside, Los Angeles, San Bernardino, Orange, and Ventura have identified HLB+ infections in 9,999 residential citrus trees, up from 5,708 in July 2023 (Johnston et al. 2023; CPDPP 2025) - an increase of approximately 75% in under two years.[1] The rate of infection underscores the urgency for California citrus growers to identify the economic effectiveness of current and emerging management practices at stemming the damage from HLB.

To mitigate this threat and manage ACP populations, coordinated spraying efforts are recommended. Qureshi and Stansly (2010, 2014) have shown that spraying with high efficacies can help prevent and manage ACP and HLB progression in citrus groves. Furthermore, trunk injection of the antibiotic oxytetracycline (OTC), in conjunction with foliar spraying, has shown potential to reduce yield losses in infected trees. OTC was first administered as a pesticide for use in peach groves in 1974 (Batuman et al. 2024). OTC suppresses the *C*Las infection in citrus trees, significantly reducing premature fruit drop, and mitigating the yield and quality reduction associated with HLB infection. Previous studies (Hu and Wang 2016; Archer et al. 2023; Castellano-Hinojosa et al. 2024) found that OTC trunk injections in HLB-infected citrus trees can increase yields by 12.96% to 32.33% over untreated HLB-infected trees, depending on injection characteristics and tree diameter.

In this research note, we use a bioeconomic agent-based model (ABM) to evaluate the effect of insecticide spraying, OTC trunk injections and the combination of insecticide spraying and OTC in a representative newly planted California Navel orange grove that sells to the fresh market over a 20-yaer lifespan. We assess the impact of three OTC effectiveness rates (32.33%, 23.90%, and 12.96%) and spray efficacy rates (90%, 80%, and 70%) on HLB severity and on profits.[2] We selected these effectiveness and efficacy ranges based on recent research and past observations for modeling purposes, although growers cannot necessarily select an efficacy rate given environmental conditions and pest resistance to insecticides. We consider rogueing (tree removal) and 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 prevention and mitigation strategies to reduce HLB economic losses. Data from UCCE cost and return studies (O'Connell et al. 2015; Kallsen et al. 2021) and California County Agricultural Commissioner Reports (USDA-NASS 2023) are used to derive costs, prices, and yield conditions for production for a representative newly planted grove in southern California. Prices and yields were extracted for Fresno, Kern, and Tulare coun-

[1] As of 05/09/2025. Source: `https://maps.cdfa.ca.gov/WeeklyACPMaps/HLBWeb/HLB_Treatments.pdf`

[2] We do not illustrate the 90% scenarios given, at this rate, the results are nearly identical to those for a healthy grove because HLB severity is very close to zero throughout the 20-year period. The same result occurs when OTC is used in conjunction wth spraying because, when insecticide spraying is this effective, the minimum HLB severity threshold to start OTC injections, discussed below, is not reached and OTC is never used.

ties, the largest producers of Navel oranges in the state. Table 1 lists the costs used to derive grove profits. Table 2 provides the prices per box and maximum boxes per acre used in the analysis.

An ABM adapted from Lee et al. (2015) and Flowers et al. (2021) simulates citrus flushes, ACP, and HLB spread in a newly planted Navel orange grove. Simulated data is required given HLB has not been found in commercial 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 across the range of spraying efficacy rate scenarios. We presume OTC does not affect the spread of HLB but instead reduces the negative effects from the disease.

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
OTC trunk injection cost	\$1.94/tree
Insecticide spray cost	\$0.25/tree

Table 1: Cultural costs, Oxytetracycline (OTC) trunk injection costs, and spray costs used in economic analysis of OTC and insecticide spraying for Asian Citrus Pysllid to manage HLB.

	\$/Box	Boxes/acre
Low	7.4	541
Average	15.5	836
High	23.3	1,176

Table 2: Price per box and maximum boxes per acre of Navel oranges that are used in the economic analysis of Oxytetracycline and insecticide spraying for Asian Citrus Pysllid to manage HLB.

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 2023) as the average maximum yield per acre[3] shown in Table 2 along with 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, a yield factor that varies over time, estimated by (Bassanezi et al. 2011), is multiplied by the healthy yield in a given year and then applied to the number of trees in the infected grove in that year and then across the different grove ages. To incorporate OTC trunk injections, we multiply the infected yield by (1 + OTC effectiveness value) when HLB severity is above 15% to account for a lack of early HLB detection capabilities. See Figures 1 through 4 for the HLB severity, spray yield estimates, OTC effects in yield estimates, and the spraying with OTC yield estimates, respectively. Moreover, we assume there are 110 trees per acre.

We use the constructed age-yield profiles to estimate the profits for the OTC and spraying scenarios over 20 years. We evaluate and compare cumulative profits for the different strategies across the price and maximum yield ranges to see how the practices, prices, and yields affect when the grove turns a positive cumulative profit and how large are those profits after 20 years of production.

[3]This underestimates the yield when a grove is established since the values shown in Table 2 contain yields for all bearing acre, young and old.

Figure 1: HLB severity for a representative Navel orange grove in California for no action and 80% and 70% Asian citrus psyllid insecticide efficacy rates.

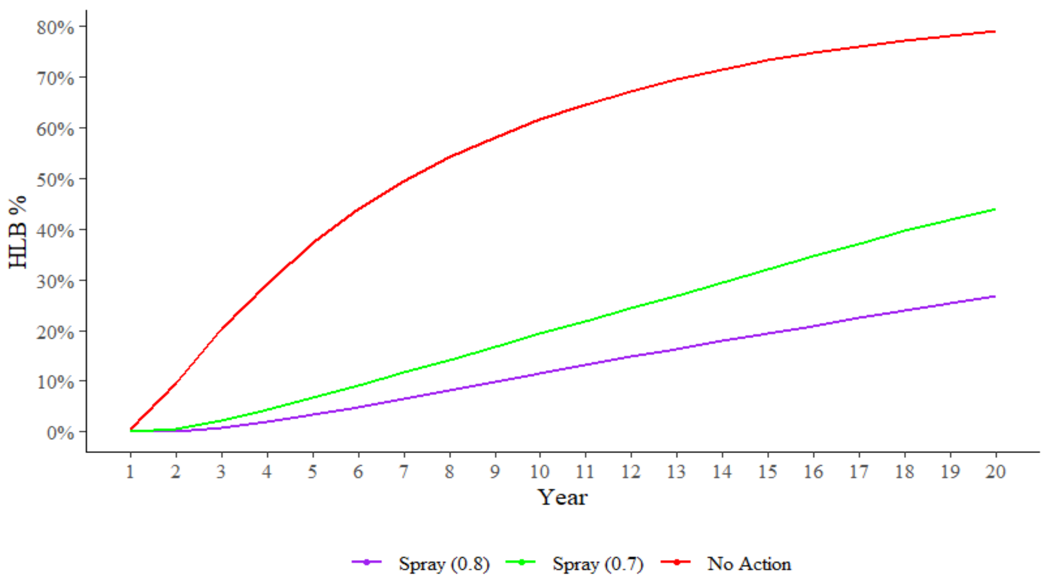


Figure 2: Average yield (37.5 lb boxes per acre) for a healthy grove, an infected grove with no action, and two infected groves that spray for ACP with 70% and 80% efficacy rates

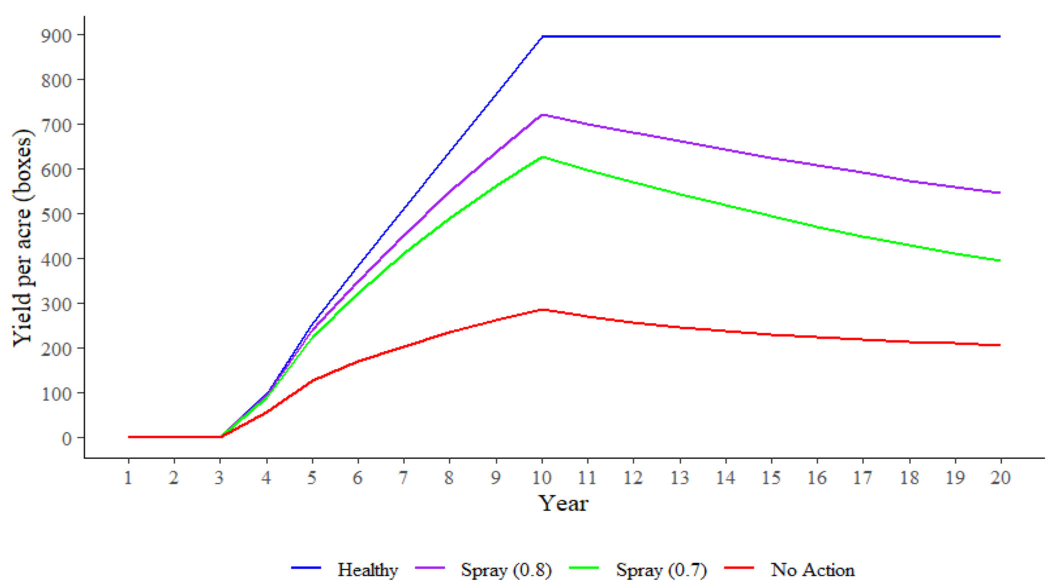


Figure 3: Average yields (37.5 lb boxes per acre) when OTC trunk injection treatments are administered.

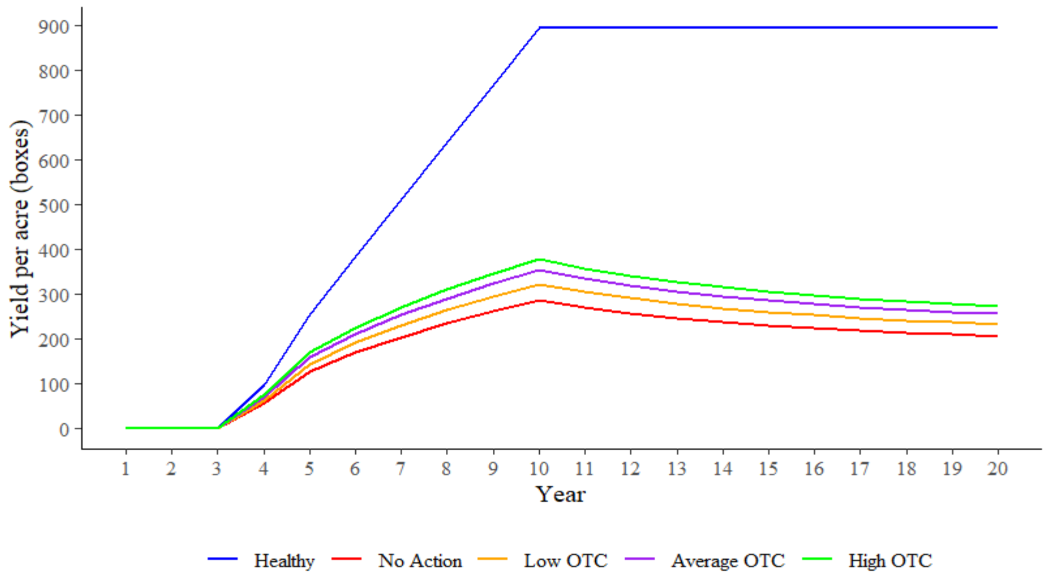
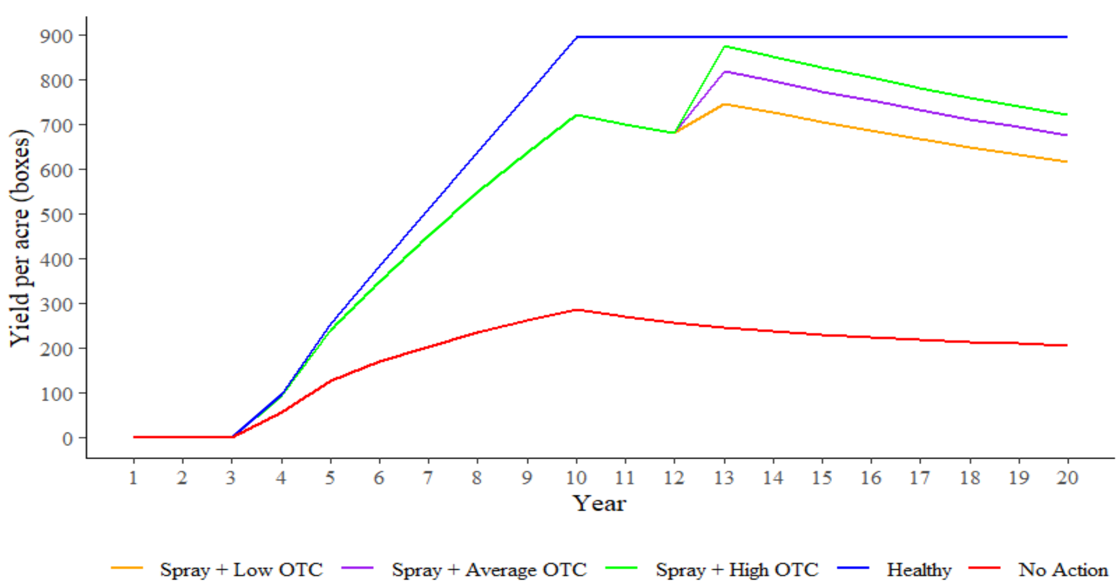


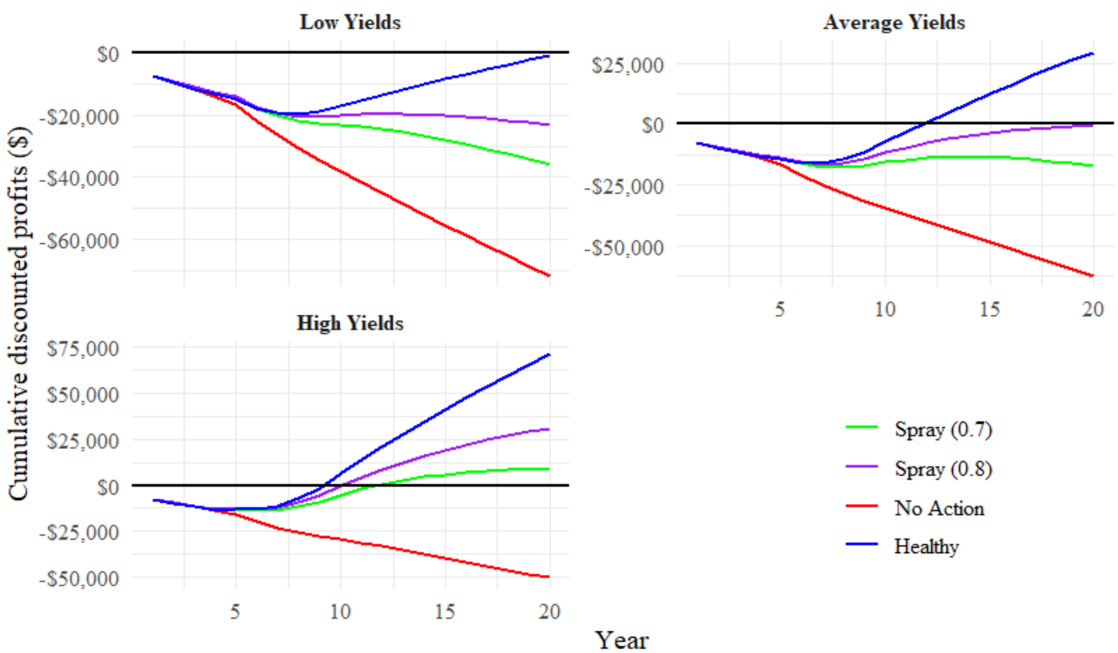
Figure 4: Average yields (37.5 lb boxes per acre) when both spraying and OTC trunk injections treatments are administered, and the insecticide has an 80% spraying efficacy rate



Findings

Figures 5 through 8 show the effects of the different strategies on cumulative discounted profits.[4,5] We see that when prices and yields are at or above their average values, spraying exclusively and spraying combined with OTC trunk injections strategies are profitable at varying OTC effectiveness percentages and insecticide efficacy rates with the spraying and OTC simulations generating greater profits than spraying alone (except for the 90% efficacy rate scenario). OTC is only profitable when price and yield are well above average and OTC effectiveness is at or above average (see Figure 8). Moreover, when insecticide efficacy is 90%, spraying is preferred as profits are highest and HLB levels are so low that OTC is never an option. However, spray efficacy depends on outside factors, such as environmental and climatic conditions. Given that uncertainty, and synergies between spraying and OTC use seen in these results suggest that spraying insecticides for ACP control before HLB is detected in the grove is preferred to taking no action before detection and, once detected, OTC trunk injections and continued spraying are preferred, except in the rare case when prices and yields are well above average and OTC effectiveness is at or above average levels. When prices, yield, and OTC effectiveness are at their average values and insecticide efficacy is 80%, cumulative profits are $10,626 per acre over the 20-year period. When price, yield, and OTC effectiveness are at their upper values and insecticide efficacy is 80%, cumulative profits are $124,936 per acre over the 20-year period.

Figure 5: Cumulative discounted profits for average prices ($15.53) when spraying at different efficacies.



[4] We use a 3% discount rate over the 20-year period.

[5] Also, recall that the 90% insecticide efficacy rate is not shown but would be nearly identical to the healthy grove results less the cost of spraying.

Figure 6: Cumulative discounted profits for high prices ($23.29) when spraying at different insecticide efficacy rates

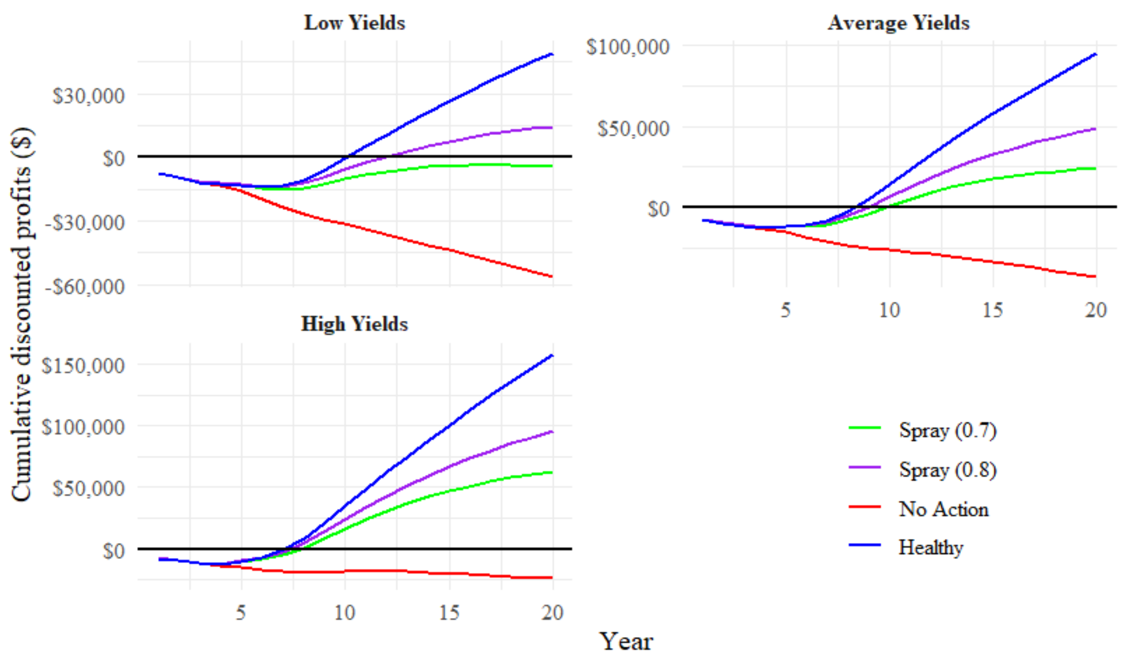


Figure 7: Cumulative discounted profits of spraying at an 80% insecticide efficacy rate and use of OTC trunk injections, when price per box is average ($15.53).

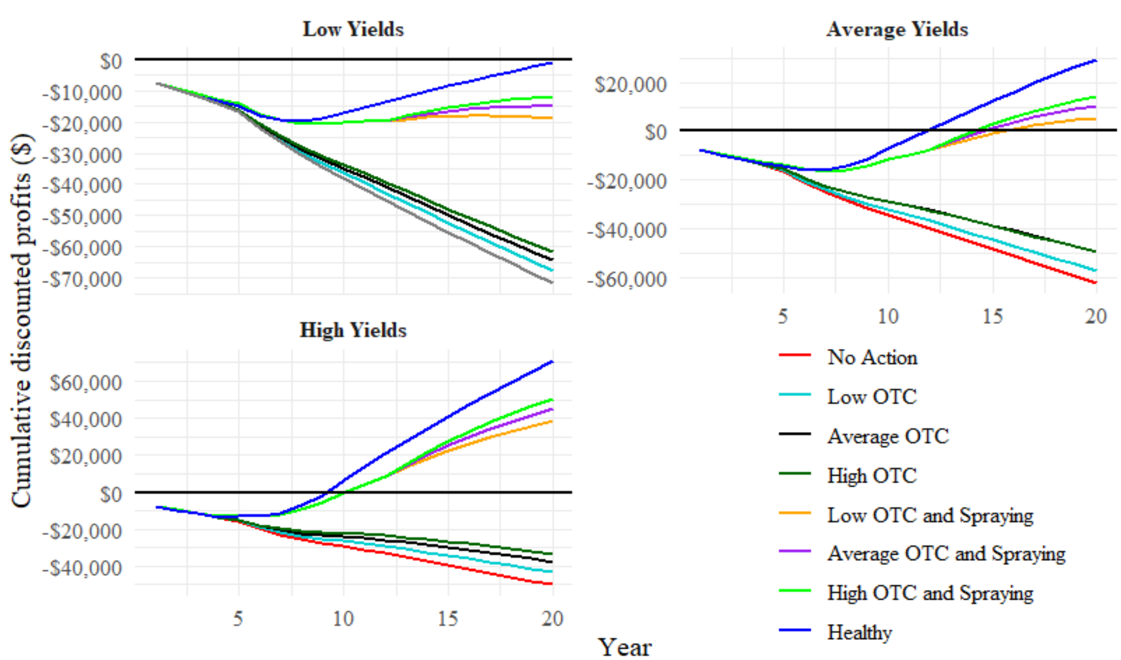


Figure 8: Cumulative discounted profits of spraying at an 80% insecticide efficacy rate and use of OTC trunk injections, when price per box is average ($23.29).

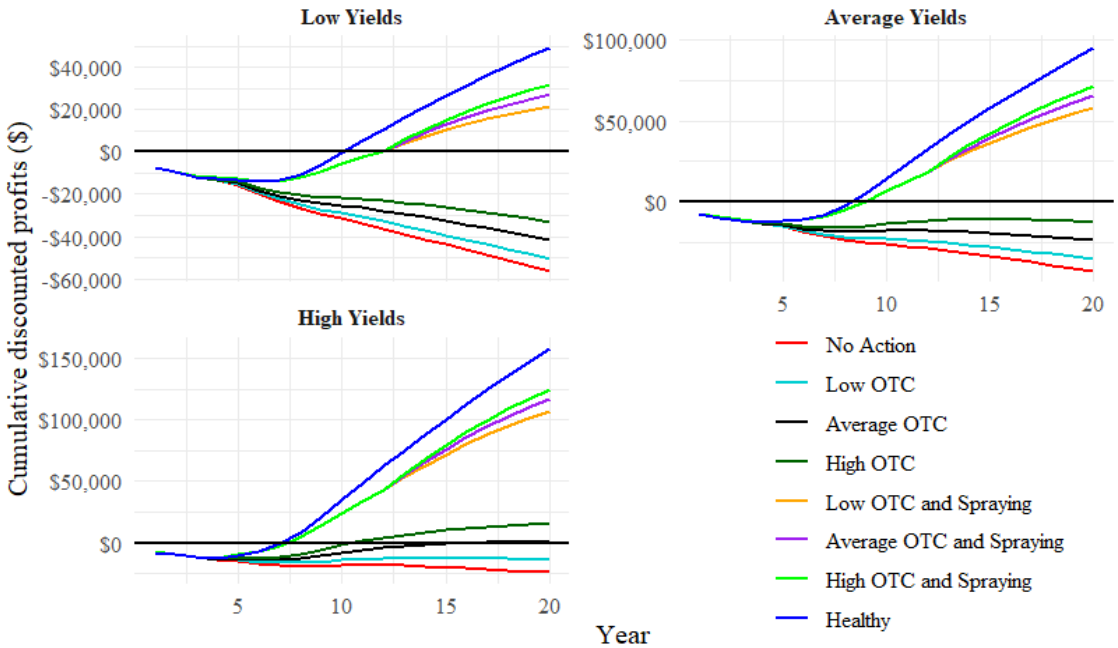


Table 3 presents the first year when cumulative discounted profits are above zero for the scenarios that are profitable. We observe that positive cumulative profits are seen between 8 and 17 years, across spray and spray plus OTC trunk injection scenarios after first planting when prices and yields are at or above average values. These first profitable years differ from a healthy grove under the same prices and yields by 0 to 9 years.

	Low Yields		Average Yields		High Yields	
	$15.53/box	**$23.29/box**	**$15.53/box**	**$23.29/box**	**$15.53/box**	**$23.29/box**
Healthy	-	year 11	year 12	year 9	year 10	year 8
Spray 70%	-	-	-	year 10	year 12	year 8
Spray 80%	-	year 12	-	year 9	year 11	year 8
OTC 23.89%	-	-	-	-	-	year 17
OTC 32.33%	-	-	-	-	-	year 11
Spraying (0.7) + OTC 12.96%	-	year 14	-	year 10	year 11	year 8
Spraying (0.7) + OTC 23.89%	-	year 12	-	year 10	year 11	year 8
Spraying (0.7) + OTC 32.33%	-	year 12	year 15	year 10	year 11	year 8
Spraying (0.8) + OTC 12.96%	-	year 12	year 16	year 9	year 11	year 8
Spraying (0.8) + OTC 23.89%	-	year 12	year 15	year 9	year 11	year 8
Spraying (0.8) + OTC 32.33%	-	year 12	year 15	year 9	year 11	year 8

Table 3: First year of positive cumulative discounted profits under different spraying and OTC scenarios with positive cumulative profits in year 20.

References

Archer, L., F. Kunwar, S.and Alferez, O. Batuman, and U. Albrecht (2023). Trunk injection of Oxytetracycline for Huanglongbing management in mature grapefruit and sweet orange trees. *Phytopathology, 113(6)*. 1010-1021.

Bassanezi, R. B., S. A. Lopes, M. P. de Miranda, N. A. Wulff, H. X. L. Volpe, and A. J. Ayres (2020). Overview of citrus huanglongbing spread and management strategies in Brazil. *Tropical*

Plant Pathology, 45. 251-264.

Bassanezi, R. B., L. H. Montesino, M. C. G. Gasparoto, A. Bergamin Filho, and L. Amorim (2011). Yield loss caused by huanglongbing in different sweet orange cultivars in São Paulo, Brazil. *130*(4), 577–586.

Batuman, O., K. Britt-Ugartemendia, S. Kunwar, S. Yilmaz, L. Fessler, A. Redondo, and T. Wade (2024). The use and impact of antibiotics in plant agriculture: A review. *Phytopathology®, 114(5)*. 885-909.

Castellano-Hinojosa, A., J. González-López, M. B. D. Tardivo, C., J. de Freitas, S. L. Strauss, and U. Albrecht (2024). Trunk injection of Oxytetracycline improves plant performance and alters the active bark and rhizosphere microbiomes in Huanglongbing-affected citrus trees. *Biology and Fertility of Soils, 60(4)*. 563-576.

Costa, G. V. D., C. S. V. J. Neves, R. B. Bassanezi, R. P. Leite, and T. S. Telles (2021). Economic impact of Huanglongbing on orange production. *Revista Brasileira de Fruticultura, 43(3)*. e-472.

CPDPP (2025). *HLB Quarantine and Treatment Areas*. CPDPP. https://maps.cdfa.ca.gov/WeeklyACPMaps/HLBWeb/HLB_Treatments.pdf.

Djeddour, D., C. Pratt, K. Constantine, I. Rwomushana, and R. Day (2021). The Asian Citrus Greening Disease (Huanglongbing): evidence note on invasiveness and potential economic impacts for East Africa.

Flowers, A., A. Singh, and J. D. Kaplan (2021). An agent based model of ACP/HLB in California citrus-preliminary results on the effects of insecticide and coordination on the spread of HLB. *California State University, Department of Economics Research Note 2021-2*.

Hu, J. and N. Wang (2016). Evaluation of the spatiotemporal dynamics of Oxytetracycline and its control effect against citrus Huanglongbing via trunk injection. *Phytopathology 106*(12), 1495–1503.

Johnston, E., J. Kaplan, and A. Singh (2023). Potential economic consequences from Huanglongbing (aka citrus greening disease) in California commercial citrus: Results for Valencia orange production. *California State University, Department of Economics, Research Note 2023-4*.

Kallsen, C. E., G. W. Douhan, K. Jetter, D. Stewart, and D. A. Sumner (2021). *Sample Costs to Establish an Orchard and Produce Oranges*. UC Davis Department of Agricultural and Resource Economics. https://coststudyfiles.ucdavis.edu/uploads/pub/2021/08/12/2021orangessjvsouth.pdf.

Lee, J. A., S. E. Halbert, W. O. Dawson, C. J. Robertson, J. E. Keesling, and B. H. Singer (2015). Asymptomatic spread of Huanglongbing and implications for disease control. *Proceedings of the National Academy of Sciences 112*(24), 7605–7610.

National Plant Network (2023). *Citrus Threat of HLB*. Retrieved [January 15, 2025].

O'Connell, N. V., C. E. Kallsen, K. Klonsky, and K. P. Tumber (2015). *Sample Costs to Establish an Orchard and Produce Oranges*. UC Davis Department of Agricultural and Resource Economics. https://coststudyfiles.ucdavis.edu/uploads/cs_public/19/d4/19d4f1bb-408a-443e-a759-36fd53a2948f/oranges_vs_2015.pdf.

Qureshi, J. A., B. C. Kostyk, and P. A. Stansly (2014). Insecticidal suppression of Asian Citrus Psyllid *Diaphorina citri* (hemiptera: Liviidae) vector of Huanglongbing pathogens. *PLOS ONE 9*(12), e112331.

Qureshi, J. A. and P. A. Stansly (2010). Dormant season foliar sprays of broad-spectrum insecticides: An effective component of integrated management for *Diaphorina citri* (hemiptera: Psyllidae) in citrus orchards. *Crop Protection 29*(8), 860–866.

USDA-NASS (2023). *County Agricultural Commissioner Annual Report*. USDA-NASS. https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/index.php/.