The Impact of Tolerant Varieties on Managing Citrus Greening Disease

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Introduction

- The Florida citrus industry has been significantly impacted by Huanglongbing (HLB), a disease that first appeared in 2005 and has since spread rapidly, infecting approximately 80% of the citrus trees in the state. The industry has faced substantial declines in acreage and yields due to HLB. (Singerman and Useche 2019;Spreen and Zansler 2016)
- HLB is a bacterial disease spread by the Asian citrus psyllid, which damages tree roots and blocks nutrient movement, resulting in stunted growth and reduced fruit quality (Graca 1991). Various management strategies, including insecticide treatments, nutritional programs, and removal of diseased trees, have been implemented to combat HLB. However, these strategies are costly, can lead to pest resistance, and are often less effective due to the latency period of the disease.
- Long-term solutions to HLB focus on the development of resistant varieties. While no HLB-resistant varieties are currently available, ongoing research and significant investments by federal and state governments, industry, and the scientific community aim to develop such varieties. Promising research includes findings on citrus-related plants with significant resistance and genetic engineering techniques to create HLB-resistant varieties, offering hope for the future of the Florida citrus industry.

Research question

This paper models grower behavior in managing HLB with the option of adopting resistant/tolerant varieties.

Simulation

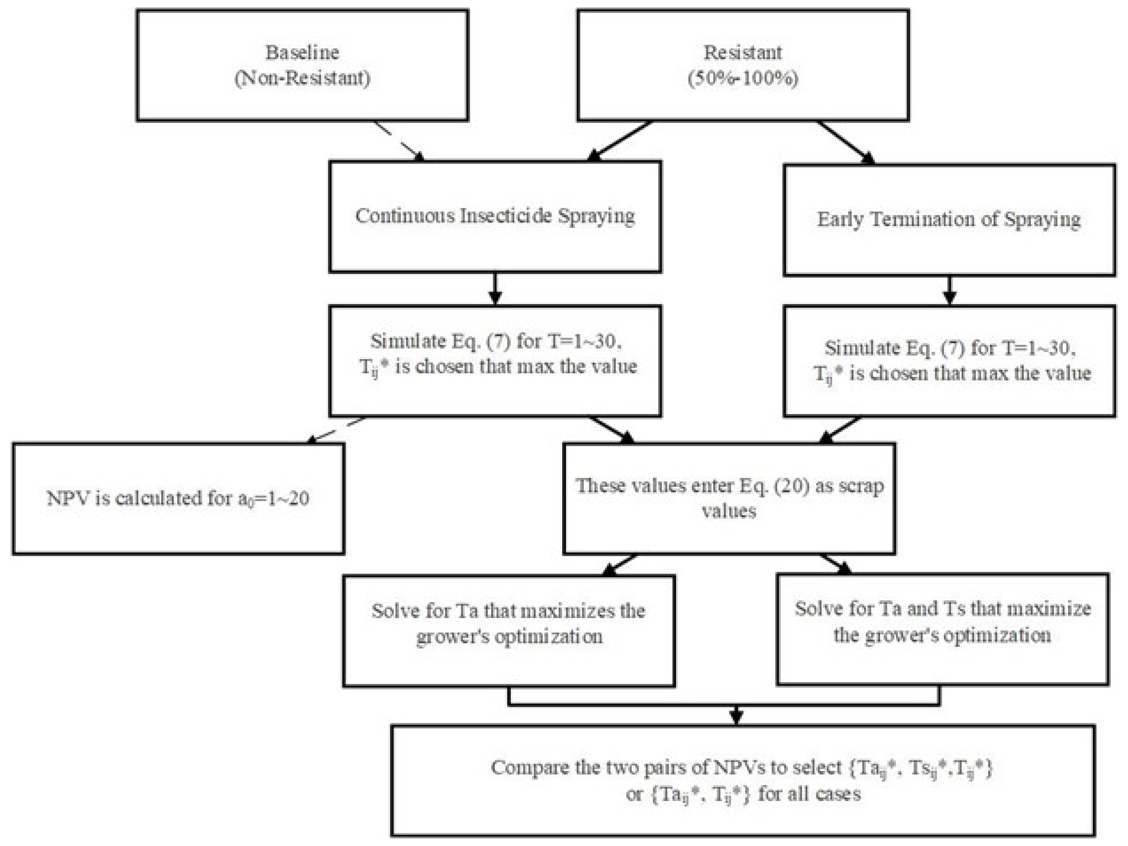

Figure 1. Simulation Steps

- The simulation begins by solving for the optimal rotation length in a baseline scenario where no resistant variety is developed, considering insecticides and nutritional programs.
- Next, two scenarios with resistant varieties are considered: one with continued insecticide use and one without, across six resistance levels (50% to 100%).
- The optimization process calculates the net present value (NPV) of infinite rotations under different rotation lengths (1 to 30 years).
- The optimal timings for replanting with resistant varieties (T_a) and halting insecticide spraying during the initial rotation (T_S) are calculated. If it is optimal to continue spraying, only the replanting time is established.
- Two grove densities (220 and 303 trees per acre) and 16 disease classes are considered. The goal is to determine the optimal timing for adopting resistant varieties and ceasing insect control, balancing costs and benefits under different scenarios.

Model

The grower's maximization problem becomes:

$$\max_{T_{a_{ij}}, T_{S_{ij}}} \left\{ \sum_{t=0}^{T_{a_{ij}}} \left(p_j \sum_a \sum_d (\text{Yield} \circ \text{Trees}_t(a,d)) - C_I I_i - C_M \right) - C_{R_i} \right\} \frac{1}{(1+r)^t} + \varphi_{ij}(T_{a_{ij}}, T_{ij}, \text{PV}_{ij}, C_{R_i}) \quad (1)$$

Subject to:

$$N_{(t+1)} - N_t = \beta N_t \left(1 - \frac{N_t}{K}\right) - \gamma N_t I_t + \overline{N} \quad (2)$$

$$Z_{(t+1)} = ac\left(\frac{X_t + Y_t}{D}\right) N_{t+1} + \delta \overline{N} \quad (3)$$

$$X_{(t+1)} - X_t = abZ_t(D - X_t - Y_t) - abZ_{(t-l)}(D - X_{(t-l)} - Y_{(t-l)}) \quad (4)$$

$$Y_{(t+1)} - Y_t = abZ_{(t-l)}(D - X_{(t-l)} - Y_{(t-l)}) \quad (5)$$

$$T_{S_{ij}} \leq T_{a_{ij}} \quad (6)$$

- where p_j is the price received per unit output.
- $\sum_a \sum_d (\text{Yield} \circ \text{Trees}_t(a,d))$, represents the total yield per acre.
- Trees_t (a,d) is a matrix that represents the number of trees at each age and disease class for a grower in year t.
- The grower will incur costs of the insecticide spraying, C_I, maintenance costs, C_M, the cost of replanting, C_{R_i}.
- The grower chooses simultaneously when to adopt the resistant cultivar, $T_{a_{ij}}$, and when to stop the insect control program to manage the insect population, $T_{S_{ij}}$.
- Equation (21) represents insect population growth.
- Equation (22) represents disease acquisition.
- Equations (23) and (24) represent the HLB progression among citrus trees.

Results

- The option of tolerant/resistant varieties leads to a divergence in psyllid control. As the cultivar's efficacy improves, more growers find it optimal to cease psyllid spraying before the rotation ends.
- Immediate adoption of these cultivars is suboptimal due to zero yields from replanting and high replanting costs.
- Figure 2 indicates gains from adopting these varieties increase with both the starting age of the grove and the efficacy.

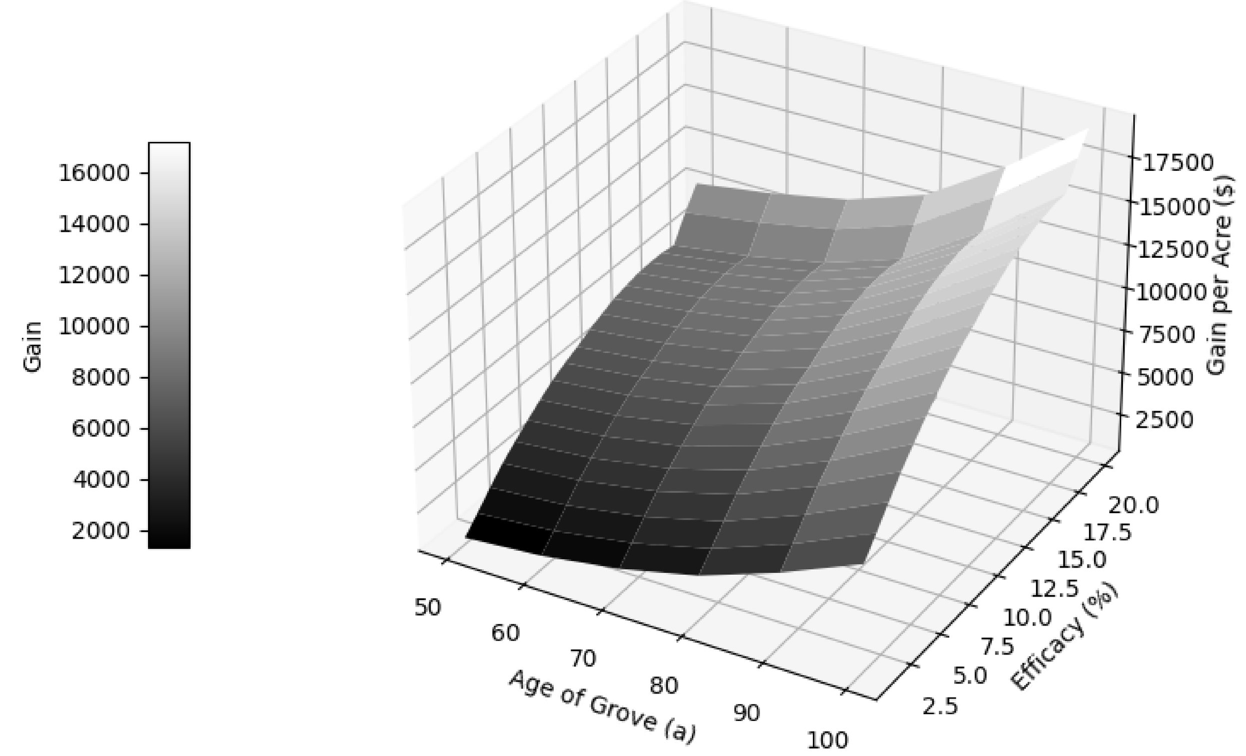

Figure 2. Gain per acre from resistant varieties by starting age of grove and cultivar efficacy at 220 trees/acre under the price scenario of \$1.59/lb solids.

Discussion

- This work creates an economically optimal management regimen for managing HLB with the option of tolerant/resistant varieties.
- The introduction of these varieties provides long-term benefits but creates short-term challenges, leading to divergence in grower practices and potential externalities that could continue disease progression regionally, despite the availability of these cultivars.
- Policymakers play a crucial role in emphasizing collective strategies during the transition to these varieties.

References

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