Topics in Subtropics Newsletter

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News from the Subtropical Tree Crop Farm Advisors in California

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Phytophthora Diseases Associated with Citrus in California

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There are at least four species of *Phytophthora* species associated with citrus in California and all species can cause various symptoms in citrus. The three ‘diseases’ in citrus caused by these fungal-like pathogens are; Phytophthora Root Rot, Phytophthora Brown Rot of citrus fruits both pre-and post-harvest, and Phytophthora gummosis, which causes a canker at the lower area of the tree usually at or around the soil line. These organisms are active within the field essentially all year long so one tree could possibly have all three disease symptoms at one time but this is usually not the situation. These pathogens are also ubiquitous within the soils of CA citrus groves so keeping an eye out for these diseases is essential to help manage these citrus issues.

Phytophthora Root Rot: This disease can affect young to mature trees and is often associated with groves that do not have good drainage such as high clay soils. So, if you’re working in a field with this situation, it is important to look for symptoms of this disease but the disease can also occur in lighter soils as well. Trees that are infected with this disease will often show yellowing leaves and sometimes thinning of the canopy (Fig 1). If you suspect that your tree has this disease, you can dig up roots to evaluate them because this pathogen mostly infects the feeder roots below the soil line. Figure 2 shows what a healthy root system looks like as well as a root system infected by the pathogen.

Fig 1. Yellowing and thinning of citrus canopy due to *Phytophthora* infection.

(left) Figure 2. Healthy root system of a citrus plant and a root system infected with *Phytophthora* showing decay of the feeder root system (right).

Brown Rot: This disease is associated with mostly mature fruits. The symptoms can be seen in the field, primarily on low lying fruit because the spores of the pathogen can get dispersed with water and wind and move from the soil to the low-lying fruit in the tree (Fig 3). Therefore, it is recommended to ‘skirt’ the tree so that there is no low-lying fruit to get infected. Brown rot can also occur after the fruit is picked (not showing symptoms) so it is also a post-harvest issue as well.

Fig 3. Brown rot symptoms of *Phytophthora* on a lemon fruit.

Gummosis: This disease is usually only seen around the soil line to a foot or so above the soil line but could produce a larger canker higher up the trunk (Fig 4). The disease is recognizable because once infected, the tree starts to produce compounds to combat the infection which results in oozing of sap and sometimes a white crust appearance as well.

Figure 4. Gummosis symptoms on lower trunk of a citrus tree. Note that the scion is more susceptible than the rootstock because most growers use *Phytophthora* tolerant rootstocks.

If a grower has a field that has had a history of various *Phytophthora* issues, there is the possibility to do a pre-plant fumigation using metam sodium or chloropicrin. If a grove becomes infected after planting, the most common methods of control are the use of chemicals usually applied through the drip lines. The most common products are Aliette, Ridomil Gold , and Prophyt. In the last several years, another product (Orondis) has been developed to control *Phytophthora* diseases which many growers have been using and have been satisfied with the level of control. Micronutrient sprays that contain phosphite may also help to control these diseases because this molecule stimulates a systemic induced resistance response in the plants that helps the plant fight off infections. The new compounds will provide good control when used in a rotation to avoid resistance, as has happened with many older products. There are additional products that have also been studied in recent years which may even add more products in the future to help control these diseases and may help to avoid resistance in the populations if rotations are used (https://apsjournals.apsnet.org/doi/10.1094/PDIS-07-18-1152-RE).
More details on phytophthora and its control can be found at the UC IPM website; https://www2.ipm.ucanr.edu/agriculture/citrus/?src=redirect2refresh.

Is it Root Rot, Or? The 12 Signs of ARR

Ben Faber, Ventura/Santa Barbara Counties

It's been drought, high winds, a freeze in late March and the trees are flowering and never look good this time of year. In fact some trees really looked awful, is it avocado root rot? A common question was how to figure out whether the tree was diseased with *Phytophthora cinnamomi* or just stressed. Drought is also compounded and confused by salt accumulation, which is a reflection of how water is being managed. It might be the right amount, but not timed correctly. Too much at one time means the water goes beyond the shallow root system, too little at an irrigation and the salts contained in the water start being taken up by the roots. These "extra" salts need to be leached; otherwise, they actually compete with the tree for soil water. By "extra", these are the salts like sodium and chloride that can be harmful to the tree, rather than the nutrient salts that are necessary for tree growth, but will also be leached when trying to achieve a balance by removing the harmful salts.

So there are several steps to follow to figure out a generally stressed tree from a root-rotted tree. If the tree is stressed, eventually though, it quite likely can lead to root rot.   Looking at wilted leaves is an indication of a stressed root system which is common with a lack of water, but can happen when the roots are soaked for too long from rain, a leaky irrigation system or sediment accumulation that can occur with flooding. Wilting is also one of the first symptoms of root rot, because there are not sufficient roots to keep up with the tree's water demand.

Step I. Wilting

Wilting is going to be the first step in alerting you to a soil/root/water problem, but it is just the first alert and there are more steps to a field diagnosis. The steps take on three different parts of the tree:

First, look at the canopy overall and then more closely in the canopy

Then, look AT the ground

Then, look IN the ground

If you look at the tree from a distance and the canopy is thinning
with dieback (staghorning)

Step 2: Thinning canopy.

This means that it is something that has been going on for a longer time that just to cause the leaves to flag (wilt)

And when you look more closely, the leaves are small, yellow, have tip burn and there are lots of flowers

Steps 3, 4, 5: Small, yellow leaves; tip burn; profuse flowering

This again means that it's something that just didn't happen with a missed irrigation or two, or a stopped up emitter. Something has been going on for maybe more than a season.

And if there is fruit, if it is sunburned which means it probably isn't saleable, it means there isn't enough canopy to protect income

Step 6: Small, sunburned fruit

Now you definitely know there is a problem with the roots. The roots mirror the canopy. When they go wrong, they canopy goes wrong. All these thinning symptoms in the canopy, also means the root system is thinning. Also, when the canopy goes wrong, the roots have problems. When the canopy can't feed the root system, it is less able to fend off disease, if that is the cause of the thinning canopy problem. At this point, it's not definitive that it is root rot causing the problem, but a sad canopy can lead eventually to a root rot problem because of lack of energy generated in the canopy.

The next step is to look **AT** the ground surface and see if there's natural leaf mulch. If the tree lacks energy to produce leaves, there won't be any leaf drop and now leaf accumulation. These should be leaves in various stages of brown, indicating they have been there for a while. This mulch protects the roots from drying out and also produces an environment hostile to the root rot organism. No leaves to feed the fungi and bacteria that compete and destroy Phytophthora; eventually Phytophthora will come to dominate the system. No energy to produce leaves; no canopy to protect leaf mulch from wind? And, then the wind blows the leaves away. On hillsides, gravity can act against mulch creation and also exposes trees to more wind, but a healthy tree can create its own mulch in harsh hillside environments.

Step 7: No natural leaf mulch

With a sick canopy and no natural leaf mulch, this is the time to think there is something seriously wrong. There is something wrong with the water uptake in this tree. Either a lack of water or a lack of roots. Is it the timing, amount or distribution of the water? These are all issues that can be corrected if there is sufficient water to do so. Maybe the soil is too wet? It could be asphyxiation. Lack of air. That can be corrected by identifying the cause of the lack of air or too much water.

Step 8: Asphyxiation

But if the soil is not too wet, when you apply water, does the tree perk up? Give it a couple of days. This could always have been the problem. Does the water come on? Is a valve shut down? Is the system not working? Is there poor water distribution. This infrastructure problem is common in hillsides irrigation with cheap parts that are easily damaged by coyotes, rabbits, and pickers.

Step 9: Turn on the water

But if the tree does not or has not responded to applied water, then start digging. It's time to look **IN** the ground. This is something that should be done on a regular basis just to see how those roots are doing, anyway.

And when you start digging, there's no roots

Step 10: NO roots

Or only big roots

Step 11: Only big roots

And, if you do find any little roots, they are blackened and brittle

Step 12: dead root tips

And you have applied water and the tree doesn't perk up, then the tree probably has Avocado Root Rot disease caused by *Phytophthora cinnamomi.*

*T*here can be other reasons, for a tree collapse like this, like a gas pipe leak, gopher activity in young trees, a chemical/fertilizer spill. Probably other things that kill roots, but a field diagnosis like this process can pretty much identify the problem as root rot. It can then be verified by a lab test to make sure. However, there are times of the year and disease conditions when a test will come back negative and it might be necessary to retest with another sample at another time of year.

Most groves that have been in the ground for many years and have been harvested by outside commercial crews quite likely have the root rot organism present in the orchard. The lack of disease is because the stress that brings on disease is lacking – water management, frost/heat damage, flooding, too much rain, too much fruit, pruning, etc. – anything that predisposes the tree to infection. It is when several stresses are present that the trees start declining, and if identified soon enough can be corrected and the decline stopped and reversed.

New irrigation tools and strategies may assist avocado growers in Southern California to enhance resource-use efficiency, water quality, and economic gains

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California accounts for the majority of U.S. avocado production. Avocado is primarily grown in Southern and Central California, typically in regions tempered by coastal climates with fine or course sandy loam soils. These regions face uncertain water supplies, mandatory reductions of water use, and the rising cost of water, while efficient use of irrigation water is one of the highest conservation priorities.

Fig. 1. A high-density avocado experimental orchard in Escondido, CA.

Avocado is a sub-tropical rainforest tree and therefore, careful water management is critical for its high yields of good quality fruit. Currently, the industry's concern is how to increase production, while decreasing the cost of water and mitigating the impacts of drought and climate change. Developing more accurate estimates of crop water use and more effective irrigation scheduling may have a significant impact on water quality and quantity issue. This knowledge could possibly affect the economic sustainability of avocado production. Data on water use by avocado orchards in the California production systems is limited, and the lack of information hinders the achievement of efficient water and nutrient management.

This avocado irrigation study funded by USDA-CDFA Specialty Crop block grant intends to acquire relevant information on crop water consumption and crop coefficients, optimal irrigation water management, and to assist growers in employing adaptive tools that support profitable and sustainable avocado production; and improve water quality. A combination of field experiments, case studies, and a robust outreach program are planned to develop and disseminate information and tools to growers and stakeholders.

Fig. 2. Ground view of a flux tower/monitoring station in an avocado orchard in Irvine.

The field experiments are being conducted at the six mature avocado orchards selected in Irvine, Escondido, and Temecula areas. The experimental orchards have different plant density, row orientation, canopy features, soil types and conditions, climate, and water qualities that can provide a good representation of avocado production systems in the region. A flux tower was set up in each of the experimental sites to measure actual evapotranspiration (crop water consumption) on a continuous 30-minute basis. The flux tower contains a combination of surface renewal and eddy covariance equipment that continuously measures high frequency data for the energy balance analysis. Monitoring soil moisture, soil salinity, plant water status, canopy reflectance and features, and fruit yield and quality are being carried out, as well.

Fig.3. A near look from the top of a flux tower demonstrates Net Radiometer sensor and two fine Thermocouple sensors, and an area of the experimental orchard in Temecula.

Improved irrigation scheduling and irrigation system operation are cost-effective tools to address longstanding water challenges in southern California. It allows avocado growers to achieve the maximum return per unit water used and full economic gains. It is expected that the tools and information developed by this study will enable more efficient resource-use irrigation management and long-term sustainability in avocado production.

All avocado growers can help contribute to this by effort by participating in our industry survey of grove management found at: https://surveys.ucanr.edu/survey.cfm?surveynumber=36053

Why Not Replace Hass with GEM?

Mary Lu Arpaia and Ben Faber

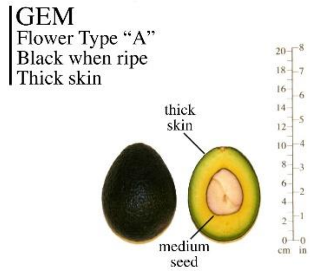
In 2021, on average for all sizes picked during an 11-week period in spring and early summer, the GEM variety returned as much or more than Hass (John Cornell, Pers. Comm.). Given that it is somewhat more productive, and possibly more heat and cold resistant than Hass, why not move the industry to this variety? Here is some discussion topics around this issue.

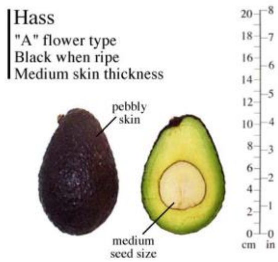
GEM is a variety that fits nicely in the short term as a supplement to Hass. Long term, based on grower experience it could be a Hass replacement, but if this was to occur, it would be many years from now since we need to grow acreage and market acceptance. We also do not ever want to replace Hass. It has such great eating quality and shelf life especially when harvested at optimum maturity. Maybe in the long-term we will find the optimum growing environments for Hass and focus their production there so that we maintain the premium for CA produced fruit. The beauty of GEM is that we also can market the fruit as something unique since there is no GEM fruit that can be shipped into the US from any other producing country except Chile. This gives us the opportunity to optimize the CA brand knowing that there is no competition from anyone else, since Chile has very limited production at this time.

The GEM from work done at USDA has different sensory qualities than Hass. Most significantly, Bethany Hausch who did a postdoc at USDA found that consistently with Ventura grown GEM vs Hass from the same orchard, GEM had a great deal more oleic acid content in the fruit (https://pubs.acs.org/doi/10.1021/acs.jafc.0c05917?ref=pdf). The eating quality assessed by both a trained panel and consumer panel show differences (https://pubmed.ncbi.nlm.nih.gov/34383297/). The study also shows the increasing acceptability of GEM over the harvest season and that the sensory descriptors used for Hass can be applied to GEM, as well. In all, good news for the GEM variety.

The Gem does have a later maturation curve at the front end of the season. The later dates are due partially to the fact that the minimum maturity for GEM is higher than for Hass. On the back end of the season, it is my belief (M.A) from looking at postharvest issues and seed germination characteristics that the fruit can easily held until roughly the end of the Hass season. Later would greatly be influenced by environmental conditions. In hot dry conditions such as Fallbrook, holding GEM fruit later than Hass would not be recommended. Perhaps further up north along the coast where summer conditions are not so extreme, they could be held longer than Hass. We have seen much higher dry matter readings from GEM as the season progresses. Hass normally plateaus around 35/36% dry matter. It is not uncommon to see 40%+ in GEM. These fruit are very oily. Some people really like them this way. The two papers referenced above do not reflect this tendency since the project ended in July when the cooperator wanted to finish their harvest of Hass.

This UC/USDA collaborative research group is particularly interested in following up on oil composition differences that were detected between Hass and GEM. In CA, we are focused on fresh fruit, but the hope is that we can also develop a specialty crop oil industry much like the olive oil industry. To this end, the hope is to start an oil project this fall and submit a proposal to the CDFA Specialty Crop Grant Program to further fund work on this. If any growers are interested in this idea, let Mary Lu know because letters of support will be very helpful when we apply. We are fortunate to now have in our research group, Dr. Claudia Asensio who has a lengthy background in oil (olive oil and essential oils) and brings the necessary skill set to pursue this project. We have also establishing research collaboration with Dr. Selena Wang at UC Davis who is working on defining industry standards for avocado oil.





How grower beliefs influence the efficacy of area-wide coordinated management of Asian citrus psyllids and Huanglongbing in California

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Concern about Huanglongbing (HLB) was heightened in the summer of 2020 when CDFA announced the discovery of the first *C*las-positive Asian citrus psyllid (ACP) in a commercial citrus grove in southern California (CPDPP 2020). HLB cost Florida an estimated $4.5 billion dollars in less than a decade, and decreased production by 8 million tons per year (Alvarez et al. 2016, Farnsworth et al. 2016, Hodges et al. 2012, Simnett et al. 2020). A lack of cooperation or presence of significant hurdles to cooperation are seen as leading factors in the decline in Florida citrus production and acreage (Alvarez et al. 2016; Farnsworth et al. 2014; Hodges et al. 2012; Simnett et al. 2020; Singerman et al. 2020). Thus, it is important to understand what factors may hinder cooperative HLB control in California to avoid a similar fate. Given the geographic scale of HLB and how scientific information can be difficult to find and understand, growers often must rely on personal beliefs when deciding how to respond to HLB (Gent et al. 2013). These widely varying beliefs have a documented effect on participation in coordinated control activities (Garcia-Figuera et al. 2021b, Milne et al. 2018, Singerman et al. 2019). We also surveyed growers here and California (Haynes et al. 2021) and found these effects persist. These past findings confirm the assumptions about beliefs that our analysis rests upon and provides the basis for an examination of how these beliefs affect HLB control decisions and ultimately grove profitability.

Due to limited data availability, we capture the epidemiological-economic interactions by utilizing an agent-based model (ABM) that uses a bottom-up approach to characterizing a combined human nature system, such as ACP, HLB, and citrus production, based on known behaviors. To do so, we use the ABM described in Lee et al. (2015) that characterizes the spread of HLB by ACP within a single grove as a basis for a localized area of citrus production involving 9 growers managing separate plots in a 3x3 grid. This expansion is sufficient to capture the interaction between growers and ACP controls across groves in each potential connectivity between adjacent groves. We relied on University of California Cooperative Extension Cost and Return Study by Kallsen et al. (2021) to parameterize the economic model. Each grower was limited in their actions to 3 choices: No ACP spraying, Spray insecticides to control ACP on their own schedule, or Area-wide coordinated ACP insecticide spraying within a small window around the dates recommended by the California Department of Food and Agriculture.[1] Growers who choose spray on my own time do so within a larger windows around those same dates. We first examined how these different choices affect yield. Figure 1 shows the decline in yield over a five-year period. Representative growers who did not control ACP experience significantly larger declines in yield than those who engage in either type of spraying. Between the growers who spray, those who choose spray on their own time do slightly worse than those who choose coordinated spraying. For all spraying growers, yield decline is slowed significantly when 100% of their neighbors are participating in coordinated spraying.

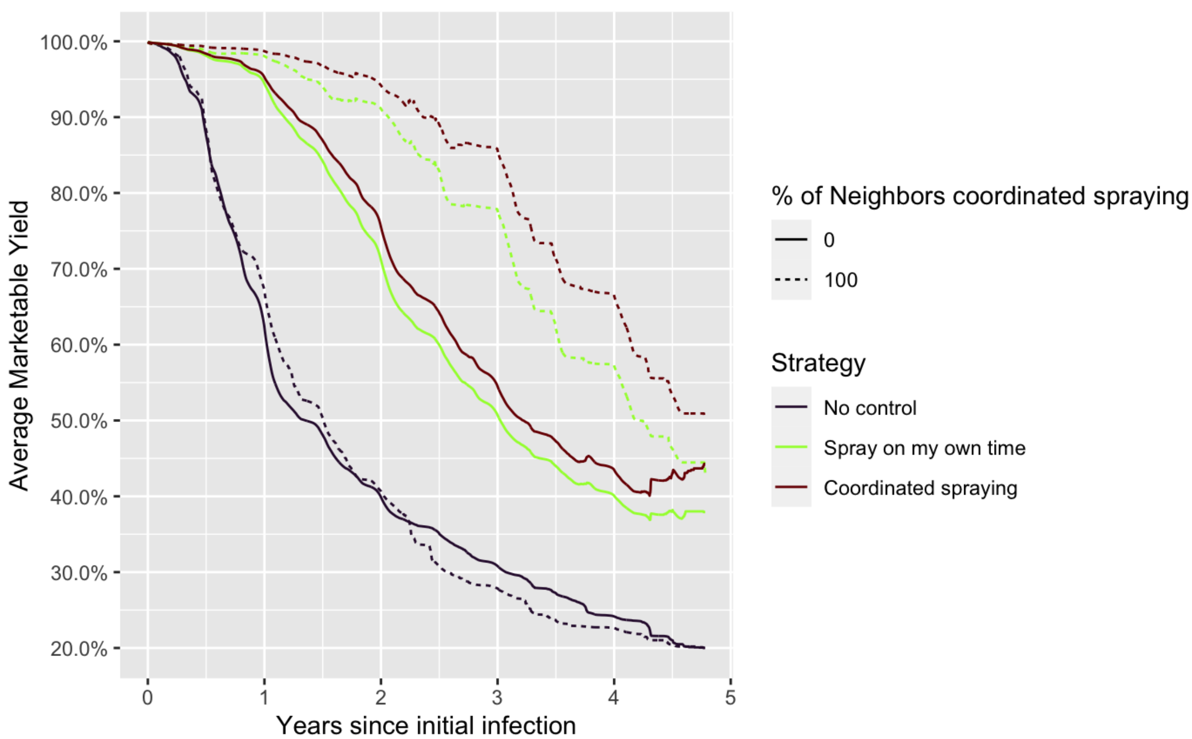

Figure 1 – Average yield decline for each strategy (No control, Spray on own time, Coordinated spraying) over a 5 year timespan based on agent-based model simulation data.

To examine how grower beliefs in their neighbors' participation in area-wide coordinated spraying and trust in information provided by extension personnel about the spread of HLB, we varied each belief from zero to 100% where zero represents a belief that no neighbor will participate in area-wide coordinated spraying or no confidence in extension personnel and 100% reflects a belief that all neighbors will participate in area-wide coordinated spraying and complete confidence in extension personnel. Figure 2 shows average yield declines experienced across different values for these beliefs. In the lower right section of the graph, we observe growers with high trust in extension personnel and low belief in neighbors. These growers experience lower yield declines than those in the upper left section, who have a high

[1] For detail dates, see https://citrusinsider.org/psyllid-and-disease-control/treatments/treatment-schedules-by-region/.

belief in their neighbors and low trust in extension personnel. These results are our primary takeaways, and can be summarized in two points:

1) Growers who have more trust in extension personnel are more aware of the risk of HLB and are more likely to participate in coordinated control activities.
2) Growers with a high belief in their neighbors expect to receive less benefit from control activities since their neighbors are already controlling the disease.

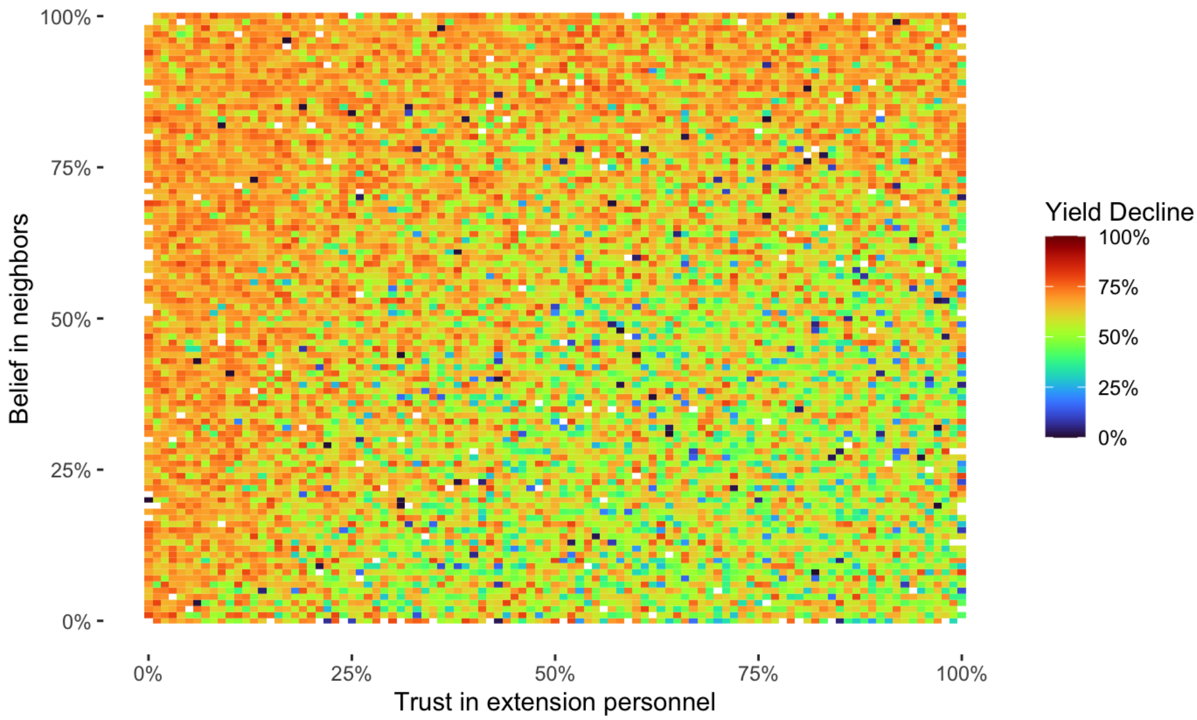

Figure 2 – Heat map of average percent yield decline by grower beliefs about neighbors' coordinated spray behavior (0 = belief no neighbors participate in area-wide coordinated spraying, 100% = belief all participate) and trust (confidence) in extension personnel about HLB infection likelihood (0 = no trust to 100% = complete trust).

Growers who do not participate in HLB control experienced yield declines of 25-30% more than those who did. As such, it is critical for anyone attempting to coordinate cooperative HLB control to consider the beliefs that the growers in their local area hold. Unfortunately, scarcely any of our simulated growers kept HLB to a level low enough to be profitable based on current cost and return figures in Kallsen et al. (2021). Spraying, even when coordinated well, is not able to keep HLB from making citrus production unprofitable. These findings lead us to suggest that future research consider the economic potential of other HLB control strategies that can supplement or replace spraying, such as rogueing, biocontrols, root and tree health promoting strategies, among others, and provide greater resilience to HLB.

Lastly, we have created a companion web tool that allows growers, researchers, and other industry stakeholders alike to interact with the model and develop an intuition for the results. In the coming year, we will be incorporating existing and emerging technologies to reduce the risk of HLB spread here in California as well as other citrus producing regions throughout the world. Those interested in searching the site can connect using the link or QR Code provided below. The site also includes links to key related references and our research notes about our survey of growers and use of the ABM to evaluate the roles risk perceptions, a grower's beliefs about other growers' participation in area-wide coordinated ACP insecticide spraying, and trust in extension information in controlling the spread of HLB.

HLB Grower Webtool

https://www.csus.edu/faculty/k/kaplanj/economic_tools/hlbtool.html

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Topics in Subtropics

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