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THE SCOOP

on fruits and nuts in Stanislaus County

Can Alternative Rootstocks Overcome Replant Disease in Unfumigated, Second Generation Orchards?

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Although research is ongoing, we currently do not have a good soil test to determine when pre-plant soil fumigation will be economically beneficial to manage replant disease when replanting orchards into second-generation sites. We can (and should) sample for pathogenic nematodes (rootknot, ring, and root lesion), which will tell us if pre-plant fumigation is important to protect new trees from these microscopic, parasitic worms. However, most of the replant problems we see in second-generation orchards are often caused by Prunus replant disease (PRD), not nematodes. Replant disease is a poorly understood soilborne disease complex that suppresses early growth and cumulative yield in replanted almond and other stone fruit orchards. PRD is associated with poor health of the trees' fine roots and often results in non-uniformity of unfumigated orchards. Although the exact cause of PRD is still inadequately described, it is generally associated with several species of plant-parasitic fungi and oomycetes (such as species of Pythium and Phytophthora). The severity of the disease varies greatly among orchards, but it is observed most commonly on loam, sandy loam, and sand soil textures in California.

Preplant soil fumigation has generally managed replant problems well in most cases, but soil fumigants are increasingly regulated and expensive. Telone II has become a popular fumigant for nematode control but many growers find themselves unable to use Telone II due to township cap limits. In general, chloropicrin, with or without Telone, has been shown to garner better growth responses in replanted orchards than Telone II alone because it is more effective against fungal and bacterial pathogens. Because chloropicrin is less effective against nematodes, mixtures of Telone II and chloropicrin have become popular (i.e., Telone C35).

Until there is a reliable test to determine whether replant disease will seriously affect a new, second-generation orchard, my suggestion is to fumigate. This is based on the results of many UC trials comparing fumigated and unfumigated soils, combined with personal experience observing uneven growth in most unfumigated second generation orchards. This includes all soil types, from the Whitney & Rocklin sandy loams on the far east side of Stanislaus County to the clay loam soils on the west side.

Unfortunately, it is not difficult to imagine a time when regulations and costs will make the use of soil fumigants impractical in California. In 2014, we initiated a trial to see if rotating away from Nemaguard to an alternative rootstock might help with replant disease. The trial is located north of Modesto in a third-generation orchard growing in an excellent Hanford sandy loam soil irrigated with high

In this issue…

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The Scoop on Fruits and Nuts in Stanislaus County is a combined effort of UC Cooperative Extension Farm Advisors Roger Duncan, Kari Arnold, and Jhalendra Rijal and covers topics on all tree and vine crops and associated pest management.

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-quality Modesto Irrigation District water. After harvest in 2014, a peach orchard on Nemaguard rootstock was removed, and the site was prepared to replant into almonds. Parts of future tree rows were strip fumigated with Telone C35 at a rate of 46.5 gallons per acre, while other areas were left unfumigated. In January 2015, Nonpareil almond trees, on five rootstocks, were planted in fumigated or unfumigated soil. The rootstocks we tested were Viking, Hansen 536, Empyrean 1, Rootpac R, and Nemaguard. Nematodes, tree growth, and yield were all monitored for six years.

Through the 6th leaf, fumigation has generally improved yield for trees on Nemaguard, Viking, and Rootpac R by a few hundred pounds per acre, although differences were not always statistically significant. Yield differences between fumigated and unfumigated trees are smaller than expected for this site but should still cover the cost of fumigation if the trend continues. Trees on Hansen and Empyrean 1 rootstocks have performed as well in unfumigated soil, as in soil fumigated with Telone C35.

Rootstock choice had a substantially larger impact on tree performance and yield than fumigation in this trial. For example, trees on Empyrean 1 rootstock, growing in unfumigated soil, have outyielded trees on Nemaguard growing in fumigated soil, by 2084 pounds per acre so far. Hansen trees in unfumigated soil have outyielded Nemaguard trees planted into fumigated soil by 1733 pounds. Trees on Rootpac R are substantially smaller than trees on Nemaguard, whether fumigated or not and have yielded roughly half of those on Nemaguard.

Take home messages from this trial:

- Rootstock has made a much larger impact on tree performance and profitability than fumigation with Telone C35.
- The superior performance of Hansen and Empyrean in unfumigated soil concurs with earlier trials by Dr. Greg Browne.
- Although trees on Hansen have performed very well in this trial, Hansen trees in unfumigated soil are supporting larger numbers of ring nematodes (data not shown) and may be more susceptible to bacterial canker. It is very risky to plant a peach x almond hybrid rootstock such as Hansen in soil that will support ring nematodes without preplant fumigation.
- Trees on Rootpac R are substantially smaller than Nemaguard in sandy loam soils (but not so much in heavy soil), regardless of fumigation. Rootpac R is probably not best suited for sandy or sandy loam soils.

Thank you to Tony Rodin and Brian Dugo for their cooperation in this trial.

Table 1. Cumulative Yield Through the 6th Leaf of Nonpareil Almond on Five Rootstocks Growing in Unfumigated Soil or Soil Fumigated with Telone C35.

	Yield (lb / acre)				
	3rd leaf 2017	4th leaf 2018	5th leaf 2019*	6th leaf 2020	Cumulative Yield
Empyrean 1	629	2407	1136	3469	7641 a
Empyrean 1 + C35	672	2293	1041	3074	7080 a
Hansen	551	2209	1044	3486	7290 a
Hansen + C35	511	1926	1081	3592	7110 a
Viking	438	1353	846	2708	5345 b
Viking + C35	511	1386	859	2831	5587 b
Nemaguard	345	1414	680	2673	5112 b
Nemaguard + C35	454	1616	682	2805	5557 b
Rootpac R	247	475	343	1395	2460 c
Rootpac R + C35	443	785	398	1303	2929 c

*2019 yield was substantially impacted by bacterial blast in all rootstocks. Bacterial blast is caused by invasion of buds or flowers by Pseudomonas syringae bacteria following sub-freezing temperatures and then warm rain. Rootstock does not generally affect bacterial blast severity.

Pulling the Trigger for the Start of Irrigation in the Spring: Too Much Too Soon for Walnuts?

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Walnuts are generally regarded as very sensitive to water stress. Severe stress and defoliation can occur when irrigation is reduced in the summer or discontinued entirely for harvest. Since walnuts depend on stored soil moisture during this time, growers were historically advised to start irrigation early in the spring to save deep soil moisture 'in the bank' for use later in the season. However, research findings in a Red Bluff, Ca. walnut orchard have seriously challenged this conventional wisdom. In fact, trees that were given an early start of irrigation (late April) showed more water stress at harvest than trees that were given a delayed start of irrigation (late May/early June). Surprisingly, this occurred even though the delayed start trees received substantially less water (about 28 inches throughout the growing season) than the early start trees (about 38 inches). The Red Bluff orchard is on a deep silt-loam/fine sandy-loam soil. However, similar results are being found in one Stanislaus County orchard on heavier clay soil and one orchard in western Tehama County on stratified soils with gravelly subsoils and much lower water holding capacity.

Using the right tool:

In many commercial orchards, in-season tree water stress is monitored by measuring midday stem water potential (SWP) using a pressure chamber (a.k.a. "pressure bomb," see sacvalleyorchards.com/manuals). This same tool could be used, specifically, to decide when to start irrigation in the spring with the appropriate information on this subject. As a starting point, there is a reference level of SWP that is expected for a fully irrigated (non-stressed) walnut tree, which is called the "Baseline" SWP. For more information about baseline SWP and how to obtain this value for a particular location, day, and time, we suggest the following websites:

Baseline and advanced interpretation explained: sacvalleyorchards.com/manuals/stem-water-potential/using-baseline-swp-for-precise-interpretation/

Baseline values calculated for you at: informatics.plantsciences.ucdavis.edu/Brooke_Jacobs/index.php

Using the tool to trigger the start of irrigation:

We began testing in 2014 in a 9-year-old commercial Chandler/Paradox orchard planted at 18 x 28 ft. (86 trees per acre) on a deep, well-drained silt-loam/fine sandy-loam soil near Red Bluff, Ca.The test continued through 2019. The design of the experiment was simple: we compared control trees given 100% irrigation (see below) starting about 30 days after leafout; to trees that were not irrigated until a trigger level of SWP was reached. We tested five trigger levels for the start of irrigation: a grower control (typically starting irrigation while the trees were still near baseline SWP), or 1, 2, 3, or 4 bars drier than baseline SWP.

We divided the field into 4 row X 11 tree plots and had five individual plots for each trigger level. In total, the test consisted of 12.5 acres. Starting after leafout (about the third week of April), we measured the SWP of 2 middle trees in each plot, every three or four days. When the average of those trees reached the trigger on two consecutive dates, we opened the sprinkler control valves to the tree rows in that plot. From then on, the plot was irrigated whenever the control plots and the rest of the orchard were irrigated.

Initial results in 2014:

We expected that a 1 or 2 bar trigger might cause mild water stress with minimal effect on the trees, but the 3 or 4 bar triggers would show some detrimental effects. However, we were not sure how long of a delay would result from waiting to start irrigation using any of these trigger levels. We were also unsure if trees with late triggers would always be 'behind' in their water needs and would experience severe water stress at harvest because we could not apply a 'catch up' irrigation to any of the delayed trees. In 2014, the 1 bar trigger occurred about the same time as the grower control, but much to our surprise, waiting for the 2-bar trigger gave 1 - 2 months of delay (depending on the plot), with the 3 and 4 bar triggers giving slightly longer delays (Table 1).

Longer delays also resulted in less irrigation. In 2014, the control trees received 100% of calculated evapotranspiration (ET, see anrcatalog.ucanr.edu/pdf/8533.pdf), whereas the 1 through 4 bar trees

SWP trigger for the first irrigation	2014 (ET-in season rain = 38")			
	Irrigation start date	Irrigation applied	% of ET-rain	Yield (pounds/ acre dry in-shell)
At or near baseline (control)	April 26	38"	100%	3690
1 bar below baseline	April 26	34"	89%	3700
2 bars below baseline	May 28-June 18	30"	79%	3440
3 bars below baseline	June 2-June 13	25"	66%	3420
4 bars below baseline	June 2-June 13	25"	66%	3360

Table 1. Irrigation start dates, seasonal irrigation applied (in inches and as the equivalent percent of irrigation requirement, calculated from ET minus in-season rainfall), and crop yield, for each of the irrigation treatments imposed in the first year of the study (2014).

ranged from 89% to 66% of this value, respectively (Table 1). There were some negative effects on crop yield, with the 4-bar trigger reducing yield by about 10% (Table 1), but there were also some positive signs. For instance, at harvest in October, the 2, 3, and 4 bar triggers had a healthier canopy appearance than the controls. This matched our SWP measurements, which indicated that the delayed trees were less stressed than the controls (Table 2). This was the most surprising result from the first year of the study: during the delay period (May, June), the longer delays were associated with more stressed (more negative) SWP values, as expected, with the controls being closest to the baseline. However, by harvest, the opposite was the case with the controls being furthest from the baseline (Table 2).

SWP trigger for the first irrigation	Measured SWP in	
	May-June (Baseline = -4.4)	October (Baseline = -4.3)
At or near baseline (control)	-5.2	-5.8
1 bar below baseline	-5.2	-4.9
2 bars below baseline	-5.9	-4.6
3 bars below baseline	-6.7	-4.2
4 bars below baseline	-7	-5.7

Table 2. Average SWP measured in May and June 2014, when irrigation was being delayed in most of the treatments, and average SWP in October around harvest (October 17, 2014). Also shown are the baseline SWP values for the same time periods.

Trial results for 2015-2018:

Due to the overall improved appearance of trees in the delayed plots at harvest compared to the controls, the grower's standard (control) irrigation start time in the entire orchard, including our control plots, was gradually delayed each year after 2014. Water applications in the orchard and the control plots became substantially less than 100% of the seasonal irrigation need (Table 3). Yields also generally improved across treatments compared to 2014, even though canopy size as measured by

SWP trigger for the first irrigation	Average 2015-2018 (ET-rain: 38.06")					
	Irrigation start date (days after leafout)	Inches irrigation (%ET-R)	yield (pounds/acre dry inshell)	% edible yield	Relative Value	Relative crop value (% of control)
At or near baseline (control)	Late April/Early May (25-35)	24.4 (63%)	5360	45.1	89.6	4840 (100%)
1 bar below baseline	Mid to late May (45-60)	22.5 (58%)	5230	45.5	90.9	4760 (98%)
2 bars below baseline	Early to mid-June (60-75)	20.7 (54%)	5000	45.1	90.2	4540 (94%)
3 bars below baseline	Mid to late June	16.9 (44%)	5080	45.9	91.3	4660 (96%)
4 bars below baseline	Late June to early Judly (85-95)	18.3 (47%)	4940	45.9	91.3	4530 (94%)

Table 3. Average irrigation start date (and equivalent days after leafout), seasonal irrigation applied in inches (and equivalent percent of the seasonal irrigation requirement, as in Table 1), yield, percent edible yield, relative value, and crop relative value (and equivalent percent of the control treatment). Relative value is an index combining the two main economic drivers of walnut value (percent edible yield and kernel color), and crop relative value is Yield x Relative value.

midsummer ground shaded area has remained stable at 86%. Even with the changes over time that occurred in the control trees, delays associated with a 1 to 4 bar trigger showed small but consistent improvements in percent edible yield and relative value as well as substantial savings in water (Table 3). There were also indications of small but consistent increases in nut load. However, since nut load is determined by many factors, ongoing research in additional orchards is being conducted to determine if this effect is consistent.

Soil moisture storage & possible implication for root health:

The soil in this location is a deep, well-drained silt-loam/fine sandy-loam, and soil moisture measurements have indicated that the trees in this orchard have access to at least 10 feet of stored soil moisture. In most years, rainfall is also sufficient to refill this soil profile. Hence, using the pressure chamber to determine when to start irrigating has enabled the grower to take maximum advantage of this soil moisture resource, potentially improving soil aeration and overall root health. This may be one of the reasons the delayed trees appeared healthier and less stressed around harvest compared to the controls. Answering this question with greater confidence will require more research focused on the root system.

Taking the delay of irrigation with SWP practice beyond Red Bluff:

It is also important to test the delayed irrigation approach on different soil types. Because this project was conducted in a relatively high rainfall area in the Sacramento Valley, extending these dramatic results to other areas within the state with differing rainfall and soils should be done with caution. We currently have two different trials underway to further test the merits of delaying the start of irrigation in walnut. A second site in Stanislaus County on heavier clay soil and a third trial in western Tehama County on stratified soils, with gravelly subsoils and much lower water holding capacity. Both trials are a smaller-scale version of the Red Bluff trial.

In a Stanislaus orchard consisting of Chandler on Vlach, results after three years suggest that similar benefits of delaying the first irrigation may be possible in this higher clay content soil site. Some ailing trees have shown partial recovery in the delay treatment, indicating the possibility of too much water being applied too early (Figure 1). Yield at the Stanislaus site was not affected when irrigation was withheld until readings of 2 bars drier than baseline.

After two years, results from the western Tehama County test on soils with lower water-holding capacity and soil layers that may restrict root depth suggest there may still be some benefit of delaying irrigation in terms of less tree stress at harvest, reduced water costs, and improved edible kernel. However, because of the lower water holding capacity of the soils, the delay may only be about one to two weeks with water savings of about four inches.

A key feature of using SWP to manage irrigation is that it provides growers with an orchard-specific measure of tree water stress and hence, allows them to safely take advantage of the existing soil moisture resource, regardless of soil depth, type, and quantity of the stored soil moisture. Using SWP to delay the start of irrigation resulted in healthier-looking, less water-stressed trees at harvest, challenging the conventional wisdom that an early start to irrigation is beneficial because it allows the saving of deep soil moisture 'in the bank' for use later in the season. Quite possibly, keeping this savings account too full in the spring may cause more problems than it solves.

The benefits of waiting to irrigate in spring until trees read 2 to 3 bars drier than the baseline despite the stark differences between these three sites is a powerful testament to the value of using the pressure chamber. Once growers use the pressure chamber to trigger the start of irrigation, they can continue to trigger irrigations throughout the season by waiting for SWP readings of 2 to 3 bars drier than the fully watered baseline.

Baseline and other information for interpreting SWP readings at: sacvalleyorchards.com/manuals/stem-water-potential/pressure-chamber-advanced-interpretation-in-walnut/

These trials are also challenging the conventional wisdom that we must irrigate to keep up with ET to have healthy and high-yielding walnut orchards (figure 2). Stay tuned as these two new trials continue to add to our collection of experiences.

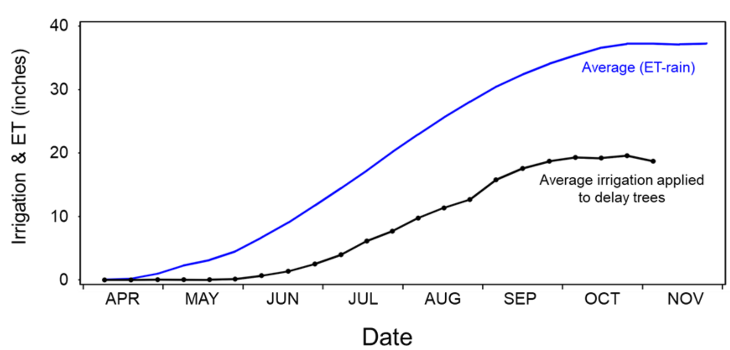

Figure 2. Summary of average orchard water requirement (ET-rain) and applied irrigation for all delayed irrigation tests to date (2014 – 2020). Daily CIMIS values for orchard water requirements were calculated beginning on April 1, based on current walnut crop coefficients, for each site and year, and averaged. Irrigation applied to all delayed treatments for each site and year were averaged for 10 day periods over the same seasons.

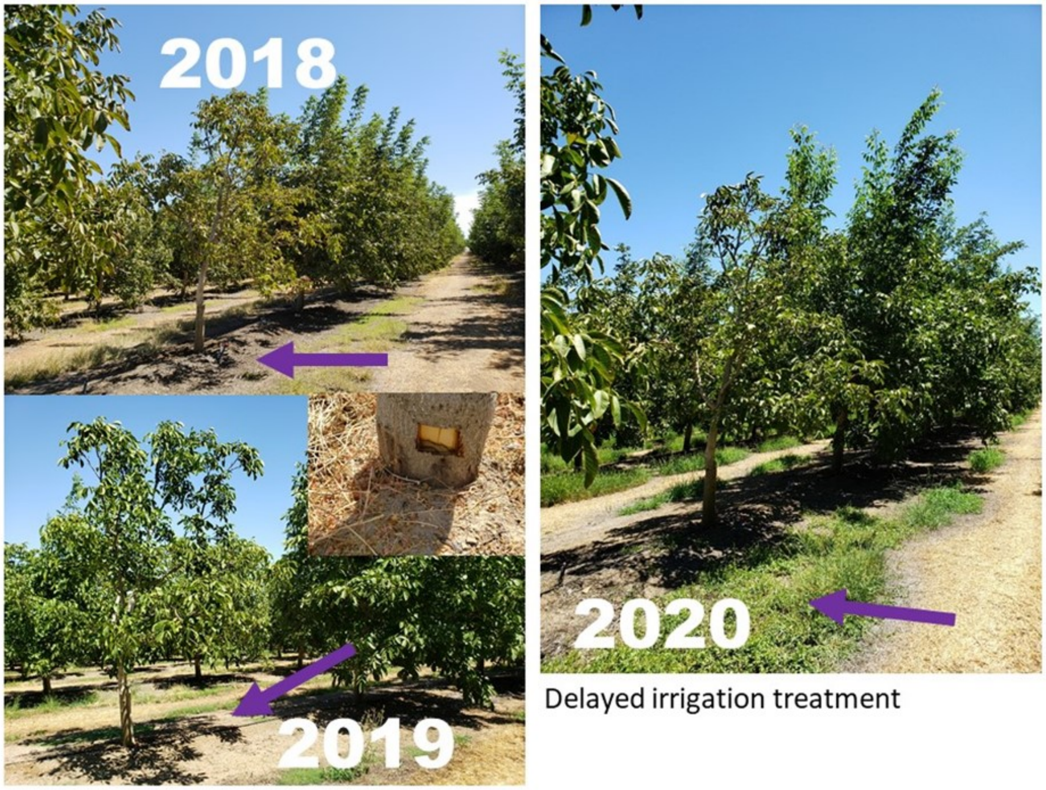

Figure 1. An ailing tree at the Stanislaus site in 2018 showed signs of deterioration. Although the trunk was somewhat sunken at the soil line and necrosis was forming under the bark (center photo), samples were collected multiple times, but no *Phytophthora spp.* were isolated/found. This tree happened to be included in the delay irrigation treatment and during the passing of three years appears to be recovering, specifically showing greater shade under the tree canopy at midday since the beginning of the trial in 2018 (photos by K. Arnold).

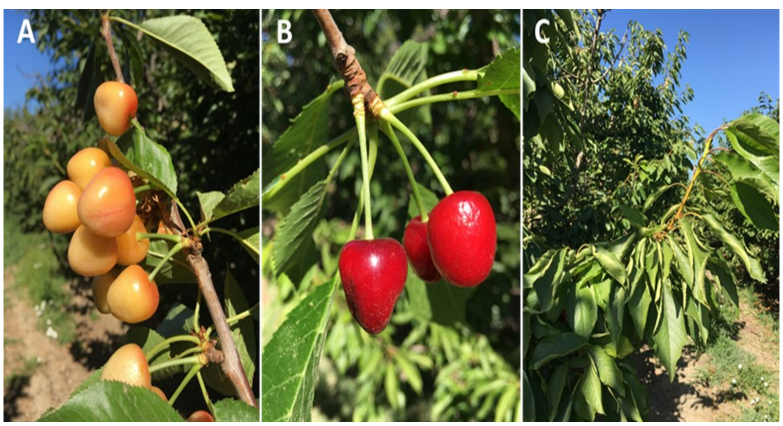

Fig. 2. Symptoms of X-disease phytoplasma in sweet cherry, **A** and **B.** Small, light colored and misshapen fruit with short stems, **C.** Small, pale-green leaves with "wavy" margins.

Fig. 3. Symptoms of cherry crinkle leaf and deep suture: Small, pointed fruit and distorted leaves.

Fig. 4. Symptoms of pits and grooves at the graft union in cherry wood on Mahaleb rootstock caused by X-disease phytoplasma.

Report of Cherry X-Disease Phytoplasma in the Northern San Joaquin Valley

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Survey

In June of 2020, my UC colleagues visited a large cherry orchard with a severe outbreak of cherry buckskin disease, also known as Western X disease phytoplasma. The orchard is 20 years old and roughly 50 percent of trees showed symptoms meaning much of the fruit is unmarketable. For new growers and PCAs, we provide this review summarizing details of this disease. Infected cherry trees are the most important source of inoculum for the spread of the disease in California. We are working closely with growers and PCAs providing information on symptoms, scouting, sampling and best management practices (see below) to slow the spread of the disease.

Background

Western X disease is caused by a phytoplasma that is spread by leafhoppers. There were major outbreaks in most cherry growing regions in CA as early as 1970. Historically this issue was mitigated through regional cooperation and abatement programs devised by joint research and outreach effort by UC, UCCE, and USDA researchers and the cherry industry to identify the causal agent, vectors, and successful management strategies. Today, we can see the results of diligent management efforts over the past few decades: although it is still present in some places, it is rarely encountered and no longer the threat it once was to the cherry industry.

Cherry X disease Symptoms

Symptoms of X-disease phytoplasma on sweet cherry trees depend on the rootstock. Cherries on Mahaleb rootstock develop different symptoms than cherries on Colt and Mazzard. On Mazzard or Colt, infection reduces fruit size and quality. Fruits from X-disease infected trees generally have a bitter taste, are small, and color up later (if at all) than fruit on healthy limbs and trees. The fruit is more pointed and has a shorter stem than normal fruit (Fig. 2A and B). They are unmarketable. Fruit symptoms of buckskin disease can be confused with those of cherry crinkle leaf and deep suture (Fig. 3).

The best time to scout for trees with such symptoms is in the week or two prior to harvest. Leaves are often smaller than normal with "wavy" margins (Fig. 2C), but these symptoms can have other causes and are not a good diagnostic indicator. Foliage symptoms are not obvious in early infection years. Only a single branch may show symptoms the first year after infection with more branches exhibiting symptoms in subsequent years, which can make disease diagnosis difficult at earlier stages of the infection. Trees decline over a period of several years. Symptoms may progress as follows:

- Early infection (Year 1): small fruit may be restricted to one branch or cluster, fruit color may develop normally or individual pale fruit may be observed.
- Middle infection (Years 2-3): small fruit observed on multiple or all limbs, and poor color development is pronounced.
- Terminal infection (Years 3-5), characterized by reduced fruit yield, and dieback of limbs.

Until trees die, they are a potential source of infection for other trees.

On Mahaleb rootstock, trees die either late in the season after becoming infected, or early in the following season. Symptoms may look like Phytophthora crown and root rot, Armillaria root rot, or rodent damage. Leaves are of normal size, but develop a yellow hue, turning bronze to dead as the season progresses. Trees exhibit a sudden decline as a result of a hypersensitive reaction at the graft union. Fruit symptoms do not develop on Mahaleb-rooted trees. In high-worked trees on Mahaleb, only infected scaffold branches develop these symptoms. Another diagnostic feature that can sometimes be seen is a pitting and grooving of wood – somewhat resembling a zipper – under the bark at the graft union. This symptom is different from pits, which develop in the wood of cherry stem pitting infected trees (Fig. 4).

Causal Organism: Western X Phytoplasma

Western X is not a virus. It is a special type of bacteria called a phytoplasma. The Western X phytoplasma lives and multiplies in phloem cells in the tree's vascular system, affecting movement of nutrients. Once a tree is infected, the pathogen multiplies and spreads through the phloem to other parts of the tree. The phytoplasma may cease to replicate or die in the aerial parts of the tree as it goes dormant in winter; surviving phytoplasma overwinters in the roots (except for Mahaleb rootstock which is resistant to the phytoplasma). The aerial portions of the tree become re-infected in the spring, as the phytoplasma moves up through the phloem of the tree.

Transmission

Vector: Leafhoppers

The most significant source of infection in cherry orchards is the tree-to-tree spread of the phytoplasma by insect vectors. The only known vectors of the X-disease phytoplasma are phloem-feeding species of leafhoppers. The most important vectors of buckskin in cherry in California are:

The cherry leafhopper (Flor's leafhopper, *Fieberiella florii*). It thrives on cherries (favored host) and some other woody plants. This leafhopper is the predominant vector responsible for spreading the phytoplasma from tree to tree within orchards.

The mountain leafhopper, *Colladonus montanus,* lives on herbaceous plants and weeds and occasionally feeds on cherries. Mountain leafhopper flies long distances and is thought to be responsible for introducing buckskin disease into cherry orchards from outside rather than spreading it among trees within orchards.

In Sierra foothill orchards, the leafhopper, *Scaphytopius acutus*, also appears to be an important vector.

Management Guidelines

Until it dies, a cherry tree that contracts the phytoplasma will remain infected for the rest of its life. Control of this disease requires a community effort because leafhoppers spread it from orchard to orchard. X-disease phytoplasma is still present but generally at low levels in local cherry orchards. Successful management requires a multi-pronged approach. Research in the 1980s and 1990s showed that these must be in combination for effective long-term suppression:

- ***Annual surveys:*** Each year, prior to harvest, systematically inspect orchards on Colt, Mazzard, Gisela, Krymsk or Maxma rootstock for fruit symptoms. For orchards on Mahaleb rootstock, be vigilant throughout the growing season for trees showing leaf symptoms. Examine the graft union of suspect trees for zipper-like grooving and pitting. If X-disease is suspected on any trees, it is possible to confirm a diagnosis further by collecting and submitting samples to a laboratory for a test. If this appears somewhat complicated, you can contact your local UCCE farm advisor or your PCA for help.
- ***Identify and remove diseased trees:*** Remove infected trees following postharvest treatment for leafhoppers. Infected cherry trees are the most important source of inoculum for the spread of the disease. On high grafted Mahaleb rootstocks, remove the diseased scaffold branches by sawing off below the graft union and then top-work if desired with clean scion wood. Low-grafted trees on Mahaleb or other susceptible cherry rootstocks should be completely removed. On Mazzard and Colt, removing symptomatic branches does not eliminate the phytoplasma since it is in the root system.
- ***Monitor and manage leafhopper vectors:*** If you have the disease in your own or a nearby orchard, implement a spray program. Between harvest time and leaf fall, leafhopper populations and X-disease phytoplasma concentration in the tree are higher than at other times. See sections of UC IPM on Cherry Leafhopper and Mountain Leafhopper for more information about postharvest treatment of the orchard for leafhopper vectors. Rotate leafhopper products when populations are present and try to maintain an effective insecticide residue in the orchard from July through October. A spray schedule could be every three to four weeks starting after harvest through late October.
- ***Control alternative hosts for phytoplasma and the leafhoppers:*** Several weed species act as an alternative host for phytoplasmas and leafhoppers; these are mainly clovers, dandelion and curly dock, and they should be removed from the orchard floor.

Exploring Navel Orangeworm Monitoring Tools for Almond Orchards Under Mating Disruption

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Background

Navel orangeworm (NOW), *Amyelois transitella* is the primary pest of almonds and pistachios, and a significant pest of walnuts in California. NOW females lay eggs on hull-split nuts in which young larvae bore into and cause direct damage to the nutmeat. Additionally, damaged nuts are highly susceptible to mold fungus, *Aspergillus* spp. that can produce carcinogenic aflatoxin. A comprehensive IPM approach that combines various monitoring and control measures is essential for navel orangeworm management. Recent studies have demonstrated that synthetic pheromone-based mating disruption could effectively be integrated into navel orangeworm management programs to reduce damage by this pest in nut crops. For monitoring purposes, the oviposition bait-based egg trap has been used to monitor egg-laying activity in nut orchards since the 1980's. After the discovery of the NOW pheromone and its commercial production, the use of pheromone lure has become a regular practice in nut orchards across the Central Valley. However, the pheromone trap is not effective in tracking NOW adult activities in mating disrupted orchards as synthetic pheromones from mating disruption products impair the male moth's ability to find females or the pheromone lure. In the last couple of years, new types and formulations of attractants such as oviposition baits, a naturally occurring phenolic compound — phenyl propionate (PPO), and host-derived ovipositional attractants are being used to monitor NOW adults in nut orchards, including almonds. In this article, we present the results of multiple studies conducted to examine the efficacy of commercially available attractants in capturing NOW adults in almond orchards, with or without a mating disruption program, and discuss the potential implications of these newer attractants in monitoring navel orangeworm as a part of the NOW IPM program.

Study Design

We conducted trapping studies in seven almond orchard sites in the Modesto and Fresno area. This represented the upper and lower SJV in the 2020 field season. In upper SJV, attractants were tested in three sites (60-90 acres) located in Stanislaus County. In each site, we had two plots (with commercial mating disruption, and without mating disruption - grower standard) of the same commercial planting, with a separation distance of ~400 ft. between the plots. In the mating disruption plot, navel orangeworm mating disruption dispensers (CIDETRAK NOW MESO; Trece, Inc.) were used at the rate of 20 dispensers/acre. Commercially available attractant types used in the study consisted of pheromone lure (Pheromone), two sources of phenyl propionate lure (PPO1; PPO2), the combination of PPO lures with pheromone lures (PPO1+pheromone; PPO1+pheromone), and ground pistachio-based Peterson bait (ovipositional bait - Ovibait). The orange delta trap was used for pheromone lure, while the white wing trap with sticky liners was used for the rest of the attractants. The attractants were deployed inside the traps following the manufacturer's directions, and four traps of each attractant were installed in two tree rows separated by five rows (approx. 100 ft) around the center 5-10 acres of individual plots. Traps were checked and serviced weekly for 20 weeks from May through mid-September.

In the lower SJV study conducted in Fresno County, three attractants (Pheromone, PPO1, Ovibait) were used, and all white wing traps were deployed in 160 acre almond orchard sites. The 40-acre quarters of these were used as experimental plots, with mating disruption or alternative treatments applied to the central 30 acres of these plots. All traps were at least 400 ft. from the edge of the orchard. The pheromone and ovibait traps were one tree apart because they attract different sexes at different times of night, and previous data indicate that there is no interaction between these trap types. PPO1 was used by itself and was 120 ft. away from the pheromone and ovibait traps. The wing traps were prepared by bending the wire to clip on and off the bottom half containing the trap liner. The ovibait traps were prepared with both the top and bottom about two and a half inches apart instead of the one-inch separation used for wing traps for pheromones. The wing traps with PPO1, also used the wider separation. Traps were checked weekly from April to September.

Results

Cumulative trap counts from mating disruption or grower standard plots of all three sites in the upper SJV or four sites in the lower SJV were combined for statistical analyses. In the upper SJV, traps that consisted of pheromone alone or the combination of pheromone and PPO1 or PPO2 caught significantly higher numbers of moth than Ovibait, PPO1, or PPO2 ~~used~~ traps in grower standard plots (Table 1). In mating disruption, the highest moth catch was recorded in PPO1+ pheromone traps. PPO2+ pheromone or Ovibait caught fewer moths than PPO1+ pheromone traps but higher than the rest of the treatments (Table 1). Pheromone alone traps resulted in significantly lower catch than the traps mentioned earlier under mating disruption (Table 1).

Attractant type	Grower Standard	Mating Disruption
	Mean ± SE	Mean ± SE
Ovibait	12 ± 2.2 bc	12 ± 1.5 ab
Pheromone	83 ± 17 a	3.4 ± 1.6 d
PPO1 + pheromone	64 ± 14 a	28 ± 7.6 a
PPO2 + pheromone	79 ± 12 a	12 ± 3.7 bc
PPO1	9 ± 2.6 bc	7.9 ± 3.0 cd
PPO2	5.3 ± 1.7 c	4.8 ± 1.6 d

Table 1. Cumulative numbers of navel orangeworm per trap for various attractants in almond orchards in upper San Joaquin Valley.
**Numbers following the same letters within the column are not statistically different.*

In the southern SJV, in grower standard plots, though treatments were not significantly different regarding total moth catch, a higher number of moth were caught in PPO1 and pheromone traps, respectively (Table 2). In the plots under mating disruption; however, PPO1 and Ovibait caught significantly higher numbers of moths than the pheromone traps (Table 2).

Although we present combined numbers in tables and used cumulative counts for statistical analysis, NOW adult activities across attractant types in all 14 plots across seven sites were highly variable (Figs. 1 & 2). It

Attractant type	Grower Standard	Mating Disruption
	Mean ± SE	Mean ± SE
Ovibait	23 ± 2.5 a	24 ± 4.0 a
Pheromone	43 ± 6.0 a	5 ± 1.6 b
PPO1	84 ± 16.7 a	59 ± 8.4 a

Table 2. Cumulative numbers of navel orangeworm per trap for various attractants in almond orchards in lower San Joaquin Valley.
**Numbers following the same letters within the column are not statistically different*

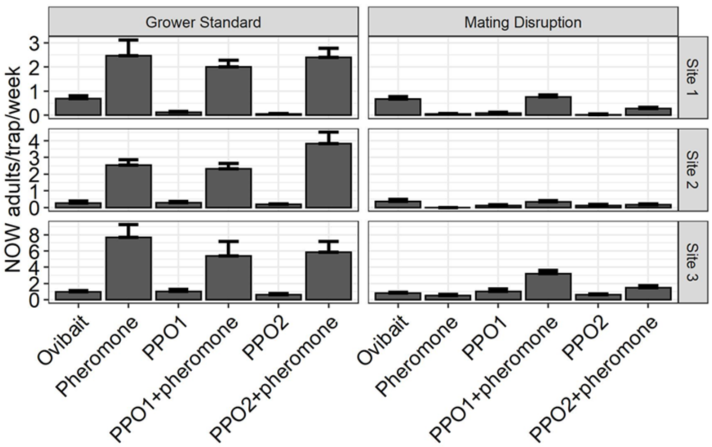

Fig. 1. Average weekly navel orangeworm adults/trap captured in various attractant types in almond orchards in upper San Joaquin Valley

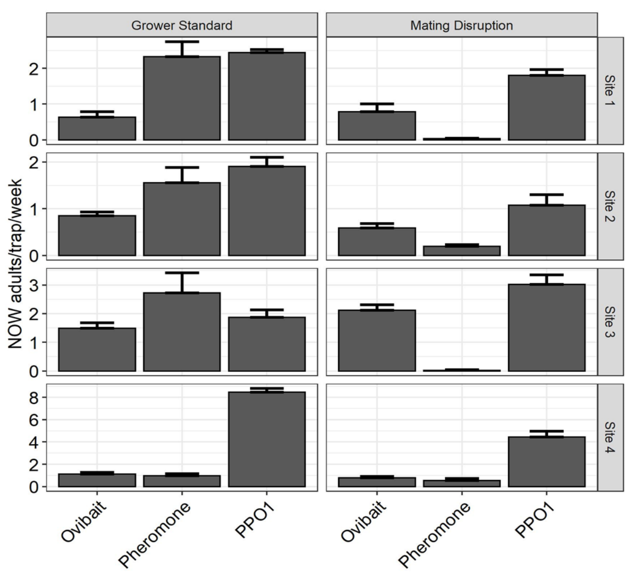

Fig. 2. Average weekly navel orangeworm adults/trap captured in various attractant types in almond orchards in upper San Joaquin Valley

is important to understand the orchard and population factors that can play an essential role in trap efficiency.

Summary

Our study indicated that the trap with PPO combined with pheromone lures shows excellent promise to use in orchards with or without mating disruption to monitor the navel orangeworm population. Also, the efficacy of

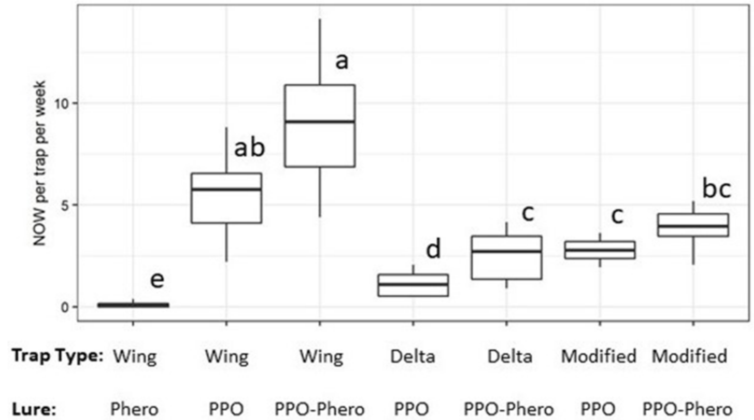

Fig. 3. Performance of different types of traps and lure combinations tested for capturing orangeworm adults in lower San Joaquin Valley. (Source: Burks et. Al 2020)

PPO seems to be different among orchards under varying levels of infestation. For example, PPO alone may provide a reasonable estimation of adult activity if the navel orangeworm population in the area is consistently moderate or high (e.g., lower SJV sites; Fig. 2). Under relatively low NOW pressure (e.g., sites 2 & 3 of upper SJV; Fig. 1), the combined use of PPO with pheromone seems to be critical. The selection of attractant type can depend on the purpose of the monitoring. If the monitoring is aimed at tracking the flights, PPO combined with pheromone lures seems to be the best choice. In contrast, if the monitoring is focused on navel orangeworm female moth activity, which is a better predictor of nut damage, the use of ovibait trap counts can be a valuable decision support tool for NOW pest management. (Rosenheim et al. 2017; *Ref:* J. Econ. Entomol. 110: 2692–2698; doi: 10.1093/jee/tox226). Additionally, although delta traps are easier to use and preferred traps among pest control professionals, the rate of capture in delta traps, even the modified delta trap in which a rectangular cut covering approximately half of the surface area of the delta trap 'roof' was made for better air flow, showed poor performance compared to the wing traps for both PPO (with/without pheromone) and Ovibait attractants (Burks et al., 2020; *Ref:* J. Econ. Entomol. 113: 1270-1278; doi: 10.1093/jee/toz363; Fig. 3).

The type of attractants that can effectively be used to track navel oranageworm flights in various field conditions and population levels is still a moving target. However, for information we generated so far, the use of PPO + pheromone lure in wing traps seems to be the best option to track navel orangeworm flights In conclusion, the type of attractants that can effectively be used to track navel oranageworm flights in various field conditions and population levels is still a moving target. However, for information we generated so far, the use of PPO + pheromone lure in wing traps seems to be the best option to track navel orangeworm flights in almond orchards under mating disruption. We will continue to explore and refine various monitoring tools that can help growers and pest control advisors implement IPM practices in nut crops.

Acknowledgments
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One more thing...

2021 Tree and Vine
IPM Update Breakfast Meetings

We have continued our twice monthly Tree & Vine IPM breakfast meetings this spring, although we are still meeting via Zoom due to COVID restrictions. Meetings are held on the first and third Wednesday, from 7:00 to 8:00 am, during March through June. One hour of pest management continuing education credits are offered at each meeting. Our June 16 meeting will include one hour of laws and regulations. **Click here to register.** Although we will discuss current pest management issues as they pop up through the spring, discussions will focus on the following topics:

May 5:	Cherry buckskin disease	Speaker: Dr. Mohamad Nouri
May 19:	Anerobic soil disinfestation	Speaker: Dr. Greg Browne
June 2:	Mite control	Speaker: David Haviland
June 16:	Recent regulatory changes	Speaker: Kamal Bagri, Agricultural Commissioner

UC Nitrogen Management Course

Are you interested in learning more about Nitrogen Management? Are you a Certified Crop Advisor seeking Continuing Education Units and/or preparing for the new California Nitrogen Specialty Exam? Has your grower clientele asked you if you are eligible to sign off on a Nitrogen Management Plan?

Click here to register!
Last day to register: July 31, 2021

In case you missed it...

2021 San Joaquin Valley Almond Day

Sponsored by the University of California Cooperative Extension

The 2021 San Joaquin Valley Almond Day was held online January 14. **For a recording of the talks, click here**. Topics covered include: Care of young trees during establishment, Nitrogen considerations in replanted orchards following whole orchard recycling, Effects of close tree spacing over 20 years, Field evaluation of almond rootstocks, Effects of compost on tree performance over five years, Implementing best management practices for nitrogen fertilization in almonds, Hull rot management, The new invasive peach rootknot nematode, The resurgence of Phytophthora diseases in Kern County, Findings from a statewide grower survey on NOW management, and Monitoring and management of plant and stink bugs in almonds.

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In This Issue:

- Can Alternative Rootstocks Overcome Replant Disease in Unfumigated, Second Generation Orchards?
- Pulling the Trigger for the Start of Irrigation in the Spring: Too Much Too Soon for Walnuts?
- Cherry X-Disease
- Exploring Naval Orangeworm

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