Sacramento Valley Walnut News

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In This Issue

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Orchard Management Considerations: Budbreak through Early Summer

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APRIL

- ✓ Stay on top of your **blight sprays**, especially if we continue to have wet conditions. See the article in this newsletter for new tools to control blight and manage resistance.
- ✓ Limbs that have been killed by **Bot canker** are easy to identify between budbreak and full leaf expansion, but wait to prune deadwood until rain is no longer forecast. If timing Bot treatment based on the Leaf Wetness Model, watch for storms that bring ≥ ¼ inch of rain and temperatures ≥ 50°F. The Leaf Wetness Model can be found at: sacvalleyorchards.com/walnuts/diseases-walnuts/the-latest-on-managing-bot-canker-and-blight-in-walnut-2016-research-updates/
- ✓ **Codling moth** traps should have been put out by mid-March to establish the first flight biofix (typically between mid-March and mid- April), begin tracking degree days, and evaluate pest pressure. Refer to the article in this newsletter for a summary of codling moth management.
- ✓ Consider putting out **navel orangeworm (NOW)** pheromone traps for adult males and traps baited with ground pistachio meal for adult females.
- ✓ Monitor for **scale crawlers** by putting out double-sided sticky tape in mid-April if scale has been a problem and you didn't treat for scale during the dormant season.
- ✓ For varieties susceptible to pistillate flower abscission (PFA) (especially Tulare or Serr), apply first ReTain® spray at 30 to 40% pistillate (female) flower bloom. The percent PFA and rate of bloom determines if a second spray is needed. ReTain® cannot be applied within 2 days of a copper application. PFA often occurs in years when trees have a heavy catkin load and pollen shedding overlaps with pistillate bloom.
- ✓ Apply **Foliar Zinc** (if needed, based on leaf sample analysis or symptoms) when shoots are 6 to 10 inches long, when zinc can be easily absorbed through the leaf surface. If the deficiency is severe, additional sprays can be applied two more times every 2 to 3 weeks.
- ✓ Perform **irrigation system maintenance** now, before irrigation is necessary and system problems could cause tree stress. Check for broken or clogged filters and emitters. See http://micromaintain.ucanr.edu/ for more tips on maintaining micro-irrigation systems.

MAY

- ✓ Continue monitoring **codling moth** traps to confirm 1B flight activity and determine treatment thresholds and timings (more detail in article herein).
- ✓ **Aphid** sampling should begin this month and continue throughout spring and summer. Collect 5 first sub-terminal leaflets (one back from the last leaflet) from 10 trees, checking the top surface for dusky-veined aphids and the underside for walnut aphids. Make treatment decisions following guidelines at http://ipm.ucanr.edu/PMG/r881300511.html.
- ✓ Apply the first round of **nitrogen fertilizer** in May, not before. Walnut trees only use stored nitrogen the first month after leaf-out, meaning N applied before May will likely be leached by rain and/or irrigation. Walnut tree nitrogen use is fairly steady over the growing season. Evenly dividing nitrogen application in 3 to 4 doses between May and the end of August will improve N uptake compared to 1 to 2 applications. If heavy rains continue into May, remember that nitrate-based fertilizers can quickly leach through soils.
- ✓ Survey **weeds** to see which weeds were not controlled by fall or winter treatment. The UC Weed ID Tool at http://weedid.wisc.edu/ca/weedid.php can help with identification. Also see Herbicide Chart in this newsletter.
- ✓ **Before you start irrigating,** consider plant water stress (stem water potential) measurements and soil moisture sensor readings. Recent research in the Sacramento Valley has found irrigation can be delayed until June in some years, saving water and pumping costs without negative impacts to yield, size or quality. See the article in this newsletter for more information.
- ✓ **Root activity** begins about one month after leafing (May for Chandler). It is critical that roots get oxygen to function. Cold or moving water has more oxygen than warm or stagnant water. If orchards are flooded from excessive runoff or seepage as in 2017, trees are more likely to survive if the water is kept moving by pumping or trenching.

JUNE

- ✓ Hang **Walnut Husk Fly** traps by June 1. Yellow sticky traps charged with an ammonium carbonate lure work best. Check traps 2 to 3 times per week and treat based on detection of eggs in trapped females, overall trap catch numbers, or the first flies caught depending on spray material used, husk fly population, and previous damage. For more details on treatment decision-making, see http://www.sacvalleyorchards.com/walnuts/insects-mites-walnuts/walnut-husk-fly-biology-monitoring-and-spray-timing/.
- ✓ Keep monitoring **codling moth** traps, to determine when the second biofix occurs. Use trap catches, dropped nut evaluation, canopy counts, and orchard history to determine need to treat (more detail in article herein).
- ✓ Look for **spider mites** and their predators on the leaflets already being examined for aphids. Examine an additional 5 leaflets from higher branches for a total of 10 leaflets from 10 trees. Monitor weekly through August. Treatment guidelines based on spider mite and predator presence, as well as organophosphate or pyrethroid use can be found at http://ipm.ucanr.edu/PMG/r881400111.html.
- ✓ If applying only one fungicide spray for **Bot canker**, a mid-June to mid-July spray timing significantly reduced blighted shoots compared with a no spray treatment. Prune out dead branches to reduce inoculum now that threat of rain has passed.

2019 IPM Breakfast Meetings

Join Area IPM and Farm Advisors to discuss current pest management and production issues. We will largely focus on orchard crops (but everything is on the table for discussion!). These meetings are open to all interested growers, consultants, PCAs, CCAs, and related industry.

Meetings will be held the **second** Friday of each month (8:00-9:30am ***note new start time***) from March through October and will cover a wide range of timely pest and orchard management topics. Meeting locations will be rotated throughout the Sacramento Valley each month. Please contact Emily Symmes to request topics or bring your questions to the meeting!

2019 meeting dates:

- April 12th, 2019 (Yuba-Sutter-Colusa Counties): Dancing Tomato Café, Yuba City
- August 9th, 2019 (Yuba-Sutter-Colusa Counties): Field Meeting, Location TBA

Additional details will be posted on the events page at sacvalleyorchards.com

RSVPs required at (530) 538-7201 or ejsymmes@ucanr.edu

DPR and CCA Continuing Education hours requested

Industry Partners: Sponsorships for venue and refreshment costs are welcome and appreciated. If you would like to sponsor one or more of these meetings, please contact Emily Symmes to inquire.

Walnut Blight Management in 2019

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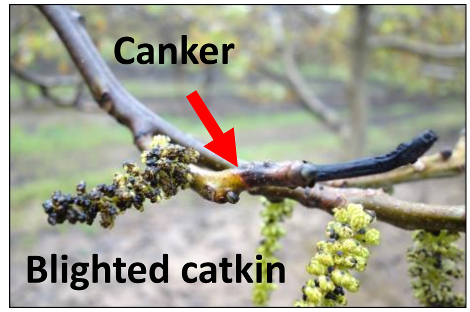
Dani Lightle, UCCE Farm Advisor Glenn, Butte and Tehama Counties
Janine Hasey, UCCE Farm Advisor Sutter-Yuba Counties

Walnut Blight Disease Cycle

Walnut blight is caused by the bacterial pathogen *Xanthomonas arboricola* pv. *juglandis* (*Xaj*). This devastating bacterium can overwinter in between scales of healthy buds, "waiting" to be rain-splashed onto the developing flowers and leaves. Twig cankers are another overwintering mechanism that can supply inoculum for primary infection (see photos 1, 2, & 3). Bud infections can result in bud death, and fruit infections sometimes lead to peduncle infections that do not dehisce from twigs. These infections can develop into twig cankers during the growing season, and they represent another mechanism of survival by the pathogen from one season to the next. In a recent study, healthy buds next to twig cankers harbored significantly more bacterial cells than buds not adjacent to twig cankers. This indicates that twig cankers are a source of inoculum for contaminating healthy buds. Under wet conditions, these cankers can ooze out bacterial cells that can be disseminated to surrounding tissue including healthy buds, flowers, and fruit. These disseminated bacterial cells can then live epiphytically (remain on the surface) or infect green tissues.





Photos 1, 2, & 3: Walnut blight twig cankers on 'Ivanhoe' (Left and center) and 'Howard' limbs (Photos 1 & 2 by Janine Hasey and photo 3 by J. E. Adaskaveg).

At the beginning of the growing season as buds and shoots grow, the epiphytic pathogen can be carried out from between the bud scales onto the new growth. Catkin and pistillate flower infections can arise from primary inoculum in healthy buds or cankers. Fruit infections that arise from the stylar end are classified as "end blight" due to the most common symptom being sunken black lesions at the flower end of the nut (photo 4). This type of infection is characteristic of a primary infection resulting from infection at the stylar end of the female flower. If wet, rainy, conducive conditions for disease exist, twig cankers can also be primary inoculum sources for catkin and pistillate flower, as well as fruit infections. Newly blighted tissues (male and female flowers, fruit with "end blight") can serve as secondary sources of inoculum. "Side blight" is a typical symptom of secondary infections (photo 5). End blight infections will typically kill the developing kernel resulting in a dropped nut, whereas secondary side blight infections, if they occur later in the season or after the nut is fully formed, do not typically result in a dropped walnut but may predispose the nut to worm damage or result in off-graded kernels.


Photos 4 & 5: Walnut fruit with "end blight" and "side blight", respectively. (Photos by J. E. Adaskaveg and H. Forster)

For attempting to predict or forecast walnut blight, utilizing orchard history, bud monitoring and Xanthocast are the three methods (Table 1). All methods have advantages and disadvantages and should be used as information to guide the grower/PCA decision-making process for implementing a preventative management program.

Table 1. Forecasting and Predicting Walnut Blight Risk

Method	**How it works**	**Notes:**
Orchard history	Previous June, survey 10 trees for infected nuts: < 50 nuts – low risk 50-150 nuts – high risk >150 nuts – high risk	High disease levels generally mean high bud populations and presence of twig cankers
Bud monitoring	Dormant buds are plated on agar and colony formation counted. See: sacvalleyorchards.com/walnuts/diseases/walnut-blight-bud-sampling/	Need positive identification of bacterial species; twig cankers can also be inoculum source; orchard can quickly go from low-risk to high-risk depending on favorable weather conditions

Xanthocast	Mathematical model using leaf wetness and temperature for forecasting the disease and timing re-treatment intervals	www.agtelemetry.com Values should be combined with information from orchard history and bud monitoring

Disease management

Kasugamycin (tradename Kasumin) was registered in 2018 for managing walnut blight and bacterial diseases of some other crops. Kasugamycin is a unique bactericide because it is not used in animal or human medicine. Environmental monitoring studies have shown that it does not select for human bacterial pathogen resistance with uses in plant agriculture. Furthermore, kasugamycin has its own FRAC Code 24 or mode of action that is different from other registered plant agricultural bactericides. Kasugamycin meets new toxicology standards for pollinating insects (e.g., honey bees), and it has a low animal toxicity with a "Caution" rating and a 12-hour re-entry time on the label. Still, as with any cautionary pesticide, mixers and applicators need to have standard personal protective equipment (PPE) when handling the bactericide. Thus, the three most effective conventional bactericides now available are copper, mancozeb, and the newly registered kasugamycin. Ratings for these and biological materials can be found at ipm.ucanr.edu/PDF/PMG/fungicideefficacytiming.pdf.

Copper is classified as FRAC Code M1 for the first element historically used for fungal and bacterial disease control. Copper affects many physiological pathways in plant pathogens and is classified as having a multi-site (M) mode of action. Not many bactericides have been developed for managing plant bacterial diseases, and fewer have been registered. Thus, there has been a great dependency on copper. Unfortunately, after many years of usage, bacterial pathogens such as the walnut blight pathogen *Xaj*, have developed resistance to copper. This is a direct result of overuse of one active ingredient (i.e., copper) and being limited with the lack of bactericides available to apply modern approaches to resistance management such as rotating between active ingredients with different modes of action and limiting the total number of applications of any one mode of action per season as part of following resistance management best practices (see "RULES" on pg. 9 of ipm.ucanr.edu/PDF/PMG/fungicideefficacytiming.pdf). Over-usage of any one active ingredient can create other environmental issues including possible soil and water contamination, as well as potential crop phytotoxicity especially in perennial crop systems.

To overcome copper resistance, copper-maneb (e.g., Manex) mixtures were first identified for use on walnut in 1992 and emergency registrations ensued until the full registration was obtained for the related compound mancozeb in 2014. Because copper resistance had already developed, this selection pressure for copper is maintained, and resistance levels are increasing from 50 ppm to over 100 ppm MCE even when mancozeb is used in the mixture. In effect, resistance management is not being effectively practiced since copper-resistance already exists and the use of mancozeb (M3) is selecting for resistant strains of the bacterial pathogen to the mancozeb mode of action. Without different modes of action to put into a rotation, resistance to mancozeb is inevitable unless new modes of action are registered that can be used in rotation with copper-mancozeb treatments.

Kasugamycin was identified, developed, and registered for the purpose of resistance management, reducing over-usage of any one mode of action, and sustaining the walnut industry of California. The bactericide has a unique mode of action and should be used in combination with copper or mancozeb. When kasugamycin is used in combination with mancozeb, good resistance management is being practiced since resistance has not been found in *Xaj* populations to either mancozeb or kasugamycin.

Kasugamycin Use on Walnuts

Kasugamycin is labeled as Kasumin for managing walnut blight and some of the label restrictions and guidelines are shown in Table 2. Applications should be initiated when conditions favor disease development. This is the same timing as for copper-mancozeb. In orchards with a history of the disease and when high rainfall is forecasted, applications should be initiated at 20-40% catkin expansion. Under moderate/low disease pressure (i.e., low rainfall forecasts and minimal dews), applications should start at 20% prayer stage (leaflets unfolding, before expansion), and at 40 % prayer stage when disease pressure is very low. These stages correspond to pistillate flower emergence.

Table 2. Label Restrictions[1] on Kasugamycin use in walnut orchards	
Minimum re-application interval	7 to 10 days
Pre-harvest interval	100 days (mid-late June, depending on walnut harvest date)
Application rate	64 fl. oz./ac in 100 gal water/ac (ground applications). Avoid applications using reduced rate of Kasugamycin
Applications per season	Current label: 2 applications / season (= 128 fl. oz. product)
Consecutive applications	2 consecutive applications allowed without rotating to another mode of action
Tank adjuvants	**Ok to use:** stickers **Avoid:** spreaders and penetrants
Alternate row applications	**Prohibited** to prevent selection of resistant isolates of *Xaj* Reduced spray volumes may be utilized for small trees provided that the volume of water is sufficient to provide good coverage of treated foliage
Presence of animals or animal waste products	**Prohibited** where animal waste/manure fertilizer applied or grazing is practiced to prevent selection of non-target, human-pathogen bacteria
[1] These are only some example restrictions in Kasugamycin use, always consult the pesticide label.	

The best way to use the bactericide is in combination with mancozeb or copper. Kasugamycin-mancozeb mixtures applied in our research trials were often the most effective of all treatments evaluated. Sample application management strategies for a two-, four- or five-spray rotational program are shown in Table 3. Suggested programs include a re-application interval of 7 to 10 days. The reason for this re-application interval is that most non-metal bactericides have a short residual life of a few days to a week or two and that Kasumin is locally systemic or translaminar and thus, is less likely to be re-distributed. Having copper-mancozeb last in the rotation will also provide the longest lasting residuals of both active ingredients. Furthermore, with new growth increasing the canopy volume weekly in the spring as walnut trees come out of dormancy, multiple and frequent applications are necessary for most cultivars flowering and fruiting in potentially high rainfall periods.

Table 3. Example Blight Management Rotation Programs[1]					
2-spray program	Kasugamycin/mancozeb	Copper/mancozeb			
4-spray program	Copper/ mancozeb	Kasugamycin/ mancozeb	Kasugamycin/ copper	Copper/ mancozeb	
5-spray program	Copper/ mancozeb	Kasugamycin/ mancozeb	Copper/ mancozeb	Copper/ Kasugamycin	Copper/ mancozeb
[1]Sample rotation programs; other programs incorporating material rotation are also acceptable. These example rotation programs do NOT constitute a recommendation.					

Kasugamycin and resistance

Resistance is a relative term indicating a change in sensitivity to an inhibitory compound. A moderately high minimal inhibitory concentration (MIC) for a bactericide does not mean that the pathogen is resistant. We have conducted baseline studies with kasugamycin, kasugamycin-copper, and kasugamycin-mancozeb for *Xaj* with MIC values of 20, 8.3, 5.3 ppm, respectively (the lower the value, the more toxic the chemical or chemical mixture). This was done before the bactericide was registered in California to determine any change in sensitivity after registration and commercial usage can be assessed. To date, resistance has not been found and isolates evaluated are all within the baseline distributions. Still, if resistance management strategies are not employed, there is a risk for selecting for pathogen resistance to kasugamycin. This is the reason why we developed the mixture-rotation programs suggested above.

Host Resistance
Cooperative research on walnut blight between UC Riverside and the UC Davis breeding program has led to several ways to evaluate new genotypes for blight resistance. The standard way is using natural incidence of walnut blight on trees that are old enough to have developed enough fruit that can be evaluated. This takes four to five years. Another method is to inoculate fruit, allowing susceptibility data to be collected regardless of rainfall events. Still, we have to use fruit for this assay and thus, the timeline for obtaining information on host susceptibility is not shortened. The third approach we are using for evaluating new genotypes for blight resistance is to inoculate buds at the beginning of the season and determine if the buds can support a pathogen population until the end of the season. Results show that many of the genotypes that support a high bud population also have a high incidence of fruit infections. Still, there are a few genotypes that do not support a bud population, and yet have high disease. These genotypes may have other ways for the pathogen to survive, such as cankers. Genotypes with traits that both restrict survival of the pathogen in their buds and have low fruit disease can be further advanced in a breeding program.

Conclusions
The integration of bactericides with different modes of action, application strategies of rotations of mixtures of bactericides with different modes of action, and forecasting tools such as XanthoCast (agtelemetry.com) should provide the stewardship necessary for having the tools available for managing walnut blight for years to come. The anticipation with the Kasumin registration is to provide resistance management and prevent or reduce the risk of resistance to copper-mancozeb while new approaches can be developed and integrated to protect kasugamycin and mancozeb from further resistance selection in pathogen populations. The industry needs new bactericides and several new modes of action are under development and in the process of registration. Walnut blight is the most serious disease impacting growers in California and multiple tools like kasugamycin, copper, and mancozeb need to be available to maintain a successful industry.

Revisiting Your Codling Moth IPM Program in a Lean Crop Year

Emily J. Symmes, Sacramento Valley Area IPM Advisor
University of California Cooperative Extension and Statewide IPM Program

The foundations of Integrated Pest Management (IPM) are rooted in economics. Simply put, IPM theory provides a basis for decision-support, with the goal of balancing or exceeding crop yield, quality, and plant health targets with pest management inputs (costs). Putting a well-established IPM program in use can help you address the following questions: Is treatment warranted (i.e., cost-effective) based on the pest population present? What are my best options and timings for treating economically-damaging populations? Particularly in years where crop prices are relatively low, taking this approach has the potential to save cost inputs by reducing the overall number of sprays needed to protect the crop, and by making wise decisions when it comes to the types of management tactics or materials used to minimize damage.

In walnuts, we are fortunate that one of the key pests, codling moth, has a very well-established and validated IPM program. The keys to this program are the predictable phenology and degree day development models and treatment thresholds (based on orchard history and in-season trap and damage counts during each flight). In addition, codling moth can be effectively managed using a number of methods (individually or in combination), including conventional pesticides and mating disruption. Bear in mind also that a good codling moth management program that minimizes early- and mid-season damage has been shown to effectively reduce harvest damage by navel orangeworm.

Begin the season by hanging codling moth traps, typically by mid-March. Although we have had an unusually wet and cold winter to date, we are entering a warmer and drier stretch beginning this second full week of March. The trees and insects will begin responding to this more typical spring-like weather soon! Place delta or wing traps containing codlemone (codling moth pheromone, 1X or L2) lures in the tree canopy. In or near mating disruption orchards, consider also using traps baited with combination lures containing codlemone + pear ester plant volatile (CMDA), as pheromone-only trap captures may be shut down or significantly reduced if mating disruption pheromone plumes are active in the orchard.

Check traps twice weekly to determine first flight biofix in your orchard(s), which is the first date that moths are consistently caught in traps and sunset temperatures are above 62°F. Trap checks can be reduced to once weekly once biofix is established, but you may want to check more often throughout the season during peak flights, key treatment timing periods, and when anticipating subsequent biofixes. Once you know your first flight biofix date, you can begin tracking degree day accumulations to inform treatment timings and predict the onset of subsequent flights. Degree day models are essentially mathematical models that pair the known developmental requirements (heat units) for a specific pest developing in a specific crop with actual heat units accumulated each day (maximum and minimum temperatures). The degree day calculator for codling moth in walnuts can be found at: http://ipm.ucanr.edu/calludt.cgi/DDMODEL?MODEL=CM&CROP=walnuts. Choose the CIMIS station nearest your orchard, or upload site-specific data from your orchard if you have an in-field temperature station.

Typical degree day accumulations for first flight peaks and subsequent flights are shown in Table 1. Note that there is a range of degree days for each flight prediction – always confirm population cycles with in-field trap activity. For example, the second flight biofix averages 1060 DDs after the first biofix, but can vary, so you would set second biofix *in your orchard* as the date trap counts begin to consistently increase again after the first flight within a range of 800 to 1300 accumulated DDs. Additionally, in many years and most valley locations, a third flight will be apparent, but we don't always observe a significant fourth flight in the Sacramento Valley. Codling moth typically enter diapause by late August, however, if 650 or more DDs have accumulated between the third flight peak and the third week of August, the fourth flight may emerge in late August and September.

Table 1. Degree day model predictions for codling moth in walnut.

Flight	Degree Day Model Predictions
First flight biofix	First date moths captured on consecutive trap checks AND Sunset temperatures above 62°F
1A peak	Typically 300 DD after first biofix
1B peak	Typically 600 to 700 DD after first biofix
Second flight biofix	800 to 1300 (average 1060) DD after first biofix
Third flight biofix	1100 to 1200 DD after second biofix
Fourth flight biofix*	Approximately 1200 DD after third biofix *Does not occur every year in every location.

Determining the need to treat is based on orchard history, in-season trap catches, and in-season damage evaluations (dropped nuts and canopy counts), depending on the flight. Table 2 summarizes the current UC IPM Program Pest Management Guidelines suggested treatment thresholds. Once you have determined the need to treat your codling moth population, the mode of action and residual performance of the selected insecticide will inform the most effective application timing. Optimal treatment timings are included on the product labels for each material, and are detailed in the UC IPM guidelines at: https://www2.ipm.ucanr.edu/agriculture/walnut/codling-moth/#TABLE1. The primary insecticide modes of action most commonly used for codling moth in recent years are pyrethroids, organophosphates (use becoming less common), insect growth regulators (e.g., Intrepid®), and diamides (e.g., Altacor®). Typically, IGRs and diamide materials are applied slightly ahead of typical pyrethroid and OP treatment timings (50 to 100 DDs earlier).

Table 2. Population assessment (monitoring) practices during each flight and suggested treatment thresholds for codling moth in walnut.

Population Assessment	Treatment Threshold
First Flight	
Previous season damage < 3% ***AND*** **< 2 moths/trap/night (1X)**	**Delay treatment to 1B or 2nd flight**
Previous season damage > 3% ***OR*** **> 2 moths/trap/night (1X)**	**CONSIDER TREATING both 1A & 1B**
Second Flight	
Canopy counts **(if 1B peak evident)**	**< 2% infestation NO TREATMENT WARRANTED**
	> 3% infestation CONSIDER TREATING **(short residual material)**
	> 5% infestation CONSIDER TREATING **(long residual material)**
Nut drop **(if 1B peak not evident)**	**≤ 4 CM-dropped nuts NO TREATMENT WARRANTED**
	4 – 24 CM-dropped nuts CONSIDER TREATING **(short residual material)**
	> 24 CM-dropped nuts CONSIDER TREATING **(long residual material)**
Third & Fourth Flights	
Canopy counts	**< 2% NO TREATMENT WARRANTED**

Mating disruption is a proven population and damage reduction alternative (or addition) to conventional insecticide approaches for codling moth. Certainly in "lean price" years, adopting a new strategy that may be more costly to implement may not be on your radar. However, consider mating disruption a longer-term investment relative to your annual pesticide program and the benefits it may provide your operation over the course of several years. In many cases, codling moth mating disruption programs can effectively reduce or completely eliminate the need for supplemental insecticide sprays. In addition, with increased regulation targeting the use of some of our historically-relied upon (and cheap!) insecticides, multi-spray programs dependent on more costly, newer generation materials may end up costing you the same amount over the course of the season (taking into account materials, as well as labor and application costs). If you have been successfully implementing mating disruption in recent years, my advice would be to "stay the course." The value of mating disruption (and your investment) is likely increasing year after year.

Take advantage of the well-established IPM guidelines for codling moth, and look to maximize your returns by reducing inputs while maintaining yield and quality.

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. In particular, severe stress and defoliation can occur when irrigation is reduced or discontinued entirely for harvest. Since walnuts depend on stored soil moisture during this time, growers are often advised to start irrigation early in the spring in order 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 despite the fact that the delayed start trees received substantially less water (about 28 inches over the course of the growing season) than the early start trees (about 38 inches).

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 http://fruitsandnuts.ucdavis.edu/pressure_chamber/). This same tool could be used to decide when to start irrigation in the spring, but there was no 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:

http://informatics.plantsciences.ucdavis.edu/Brooke_Jacobs/index.php

http://www.sacvalleyorchards.com/manuals/stem-water-potential/using-baseline-swp-for-precise-interpretation/

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 (86.4 trees per acre) on a deep, well-drained silt-loam/fine sandy-loam soil near Red Bluff, CA. The test continued through 2018 and may extend to 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 which 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 below (more stressed than) baseline SWP.

We divided the field into 4 row X 11 tree plots and had 5 individual plots for each trigger level. 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, and when the average of those trees reached the trigger on 2 consecutive dates, we opened the irrigation 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 was irrigated.

Initial results in 2014:

We expected that 1 or 2 bar trigger might cause mild water stress with minimal effect on the trees, but that the 3 or 4 bars triggers would show some detrimental effects. However, we were not sure how long of a delay would result by waiting to start irrigation using any of these trigger levels. We were also not sure if trees with late triggers would always be 'behind' in their water needs, and would experience severe water stress at harvest, because we couldn't apply a 'catch up' irrigation to any of the trees that were delayed. 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 <u>months</u> 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 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 actually 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).

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, has gradually been delayed each year since 2014. Water applications in the orchard and the control plots are now substantially less than 100% of the seasonal irrigation need (Table 3). Yields have also generally improved across treatments compared to 2014, even though canopy size, as measured by midsummer ground shaded area, has remained stable at 86%. Even with the changes over time that have occurred in the control trees, delays associated with a 1 to 4 bar trigger have shown small but consistent improvements in percent edible yield and relative value, and a substantial savings in water (Table 3). There are also indications of small but consistent increases in nut load, but since nut load is determined by many factors, more data will be needed 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" 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. At the same time, allowing the trees to use stored soil moisture in the spring may improve soil aeration and overall root health. This may be one of the reasons why the delayed trees appeared healthier and were less stressed around harvest compared to the controls. Answering this question 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 in the state with differing rainfall and soils should be done with caution. We currently have a second site in Stanislaus County with a smaller scale version of this trial, and results after one year suggest that similar benefits of delaying the first irrigation may be possible in this higher clay content soil site. 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 the quantity of 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. Apparently, keeping this savings account too full in the spring may cause more problems than it solves.

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).

SWP trigger for the first irrigation	2014 (ET-in season rain = 38")			
	Irrigation start date	Irrigation applied	% of ET-rain	Yield (pounds/acre dry inshell)
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 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.

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 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.

SWP Trigger for the first irrigation	Average 2015-2018 (ET-rain: 38.6")					
	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 (75-85)	16.9 (44%)	5080	45.9	91.3	4660 (96%)
4 bars below baseline	Late June to early July(85-95)	18.3 (47%)	4940	45.9	91.3	4530 (94%)

Tree and Vine Crop Herbicide Chart – Updated (2019)

Here's the most updated tree and vine crop herbicide chart organized by Brad Hanson, UCCE Weed Science Specialist. Remember that rotating and/or mixing herbicides with different modes of action (MOAs) is critical to good weed management, particularly with herbicide-resistant populations. Notes: R = registered, N = Not registered, NB = registered only for Non-Bearing. Always check the herbicide label before use.

Herbicide Registration on California Tree and Vine Crops -*(updated March 2019 - UC Weed Science)*

	Herbicide-Common Name *(example trade name)*	Site of Action Group[1]	Almond	Pecan	Pistachio	Walnut	Apple	Pear	Apricot	Cherry	Nectarine	Peach	Plum / Prune	Avocado	Citrus	Date	Fig	Grape	Kiwi	Olive	Pomegranate
			----- tree nut -------				- pome -		---------stone fruit ---------												
Preemergence	**dichlobenil** *(Casoron)*	L / 20	N	N	N	N	R	R	N	R	N	N	N	N	N	N	N	R	N	N	N
	diuron *(Karmex, Diurex)*	C2 / 7	N	R	N	R	R	R	N	N	N	R	N	N	R	N	N	R	N	R	N
	EPTC *(Eptam)*	N / 8	R	N	N	R	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N
	flazasulfuron *(Mission)*	B / 2	R	N	R	R	N	N	N	N	N	N	N	N	R	N	N	R	N	N	N
	flumioxazin *(Chateau)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	NB	NB	N	NB	R	N	R	R
	indaziflam *(Alion)*	L / 29	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	N
	isoxaben *(Trellis)*	L / 21	R	R	R	R	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	NB	R	NB	NB	NB
	mesotrione *(Broadworks)*	F2/27	R	R	R	R	N	N	N	N	R	N	R	N	R	N	N	N	N	N	N
	napropamide *(Devrinol)*	K3 / 15	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N	N
	norflurazon *(Solicam)*	F1 / 12	R	R	N	R	R	R	R	R	R	R	R	R	R	N	N	R	N	N	N
	oryzalin *(Surflan)*	K1 / 3	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	oxyfluorfen *(Goal, GoalTender)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	NB	R	R	R	R	R	R
	pendimethalin *(Prowl H2O)*	K1 / 3	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	R
	penoxsulam *(Pindar GT)*	B / 2	R	R	R	R	N	N	N	R	R	R	R	N	N	N	N	N	N	R	R
	pronamide *(Kerb)*	K1 / 3	N	N	N	N	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	rimsulfuron *(Matrix)*	B / 2	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	sulfentrazone *(Zeus)*	E / 14	N	N	R	R	N	N	N	N	N	N	N	N	R	N	N	R	N	N	N
	simazine *(Princep, Caliber 90)*	C1 / 5	R	R	N	R	R	R	N	R[2]	R	R	N	R	R	N	N	R	N	R	N
	trifluralin *(Treflan)*	K1 / 3	R	R	N	R	N	N	R	N	R	R	R	N	R	N	N	R	N	N	N
Postemergence	**carfentrazone** *(Shark EW)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	clethodim *(SelectMax)*	A / 1	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	R	N	N	NB	N	NB	N
	2,4-D *(Clean-crop, Orchard Master)*	O / 4	R	R	R	R	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	diquat *(Diquat)*	D / 22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
	fluazifop-p-butyl *(Fusilade)*	A / 1	NB	R	NB	NB	NB	NB	R	R	R	R	R	NB	R	NB	NB	R	N	NB	NB
	glyphosate *(Roundup)*	G / 9	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	glufosinate *(Rely 280)*	H / 10	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	N
	halosulfuron *(Sandea)*	B / 2	N	R	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	paraquat *(Gramoxone)*	D / 22	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	pelargonic acid *(Scythe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N
	pyraflufen *(Venue)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	R	R	R	R
	saflufenacil *(Treevix)*	E / 14	R	N	R	R	R	R	N	N	N	N	N	N	R	N	N	N	N	R	R
	sethoxydim *(Poast)*	A / 1	R	R	R	R	R	R	R	R	R	R	NB	NB	R	NB	NB	R	N	NB	NB
Organic	**Caprilic/Capric acid** *(Suppress)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	N	R
	ammoniated fatty acids *(Final-San-O)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	d-limionene *(AvengerAG)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	Ammonium nanoate *(Axxe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	N

Notes: R = Registered, N = Not registered, NB = nonbearing. This chart is intended as a general guide only. Always consult a current label before using any herbicide as labels change frequently and often contain special restrictions regarding use of a company's product.

[1] Herbicide site of action designations are according to the Herbicide Resistance Action Committee (letters) and the Weed Science Society of America (number) systems. NC = no accepted site of action classification; these contact herbicides are general membrane disruptors.