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Young Orchard Handbook

INTRODUCTION

This publication provides an overview of recent research and information to assistant in the management of young almond and walnut orchards. Proper management of an orchard in the first five years of its life will help optimize orchard health, growth and yield over the life of the orchard. This text is by no means exhaustive, and is meant as an introductory resource for understanding management steps to take in young orchards. Additional resources to consult for more detailed information are provided at the end of each section.

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Irrigating Young Orchards

Katherine Jarvis-Shean & Allan Fulton

Proper irrigation management for young orchards is critical for managing tree growth in the early (non-bearing) years of the orchard's life. Under-irrigating or over-irrigating can affect tree health and vigor, orchard uniformity, years to full production potential and the total costs to develop an orchard. When the tree and its root system are small, there is a greater chance of applying water and fertilizers outside of the root zone, an inefficient use of water, fertilizer and the energy to move them. Too much water can lead to added pruning and weed control.

Proper irrigation management may be one of the most complicated, dynamic aspects of young orchard management. As trees grow, their canopy size and water needs change, not just from year to year, but also within a season. Plus, as trees grow, so do their root systems, meaning they can capture water from a larger volume of soil.

Figure 1. Drip emitters irrigating outside of the root zone (left) and over the root zone (right).

Knowing how much to irrigate and when requires knowing how much water an irrigation system applies, how much water soils can hold, and how much water trees are using, then refilling that storage when it is used. This requires six steps.

1) Know the water application rate of your irrigation system
2) Figure out how much water your soil can store
3) Note how much water the orchard is using
4) Calculate the maximum allowable time between irrigation
5) Estimate how long the system will take to refill tree water use
6) Confirm irrigation schedule is on track with soil moisture or crop water stress measurements

STEPS OF IRRIGATION SCHEDULING

Step 1) Know the Water Application Rate of Your Irrigation System

Because of the variety of irrigation systems and designs, it is important to know the water application rate of each irrigation system. Usually, the water application rate is specified on system design blueprints when the system is installed. Drip systems generally range from 0.01 to 0.05 inch per hour, partial coverage microsprinklers 0.03 to 0.08 inches per hour and full coverage rotator minisprinklers or impact sprinklers 0.04 to over 0.10 inches per hour.

If you don't have the output from the system installer, you can calculate the average water application rate by knowing how many trees are planted per acre, how many emitters irrigate each tree, and how many gallons each drip or micro-sprinkler emitter puts out per hour when the system is at its recommended pressure.

For Example, a 26' x 14' almond planting has 120 trees per acre. If such a planting has one microsprinkler emitter per tree putting out 8 gallons per hour, that system applies 960 gallons per acre (120 trees x 1 tree/emitter x 8 gallons per hour, See Worksheet Example at end of text). There are 27,154 gallons per acre-inch of water, so 960 gal/ac equates to 0.035 acre-inches per hour (960 gal/ac per hour ÷ 27,154 gal/ac-in=0.035 ac-in/hr, See Worksheet Example).

Irrigation managers should generally be alert to the irrigation distribution uniformity of the system. However, irrigation distribution is usually quite high in young orchards with new irrigation systems. Non-uniform application of water becomes more of an issue as the system ages (over 10 years old) and accrues wear and tear.

Step 2) Figure Out How Much Water Your Soil Can Store

How much water the soil can store and make available to the young trees depends on the soil texture and the development of the root system. Finer texture clay soils can hold more water than sandier soils. Newly planted trees will initially have a very small root zone until the tree and root system grow.

The availability of the water to the trees declines as the soil becomes drier. There is always some water in the soil that is being held so tightly by the soil that plants can never access it. Trees take up water more easily when soil moisture content is higher in the root zone. Thus, when figuring out irrigation scheduling, we deal with Available Soil Moisture, not total soil moisture.

Trees trying to grow in soil with too little available water will be over-stressed, grow inconsistently and will be slower to come into production. In severe cases, young trees can die from water stress. In production agriculture, to avoid tree stress, we do not want plants using more than 50% of available soil moisture (50% ASM). These numbers are given in inches of water available in a foot of soil in Table 1.

An additional complication with young trees is the changing size of the root zone. Table 1 tells 50% ASM per foot of soil. But how many feet of soil are young tree roots exploring? This depends on the size of the tree at planting, growing condition and the vigor of the tree and rootstock. Generally speaking, 1st leaf trees have half a foot to 3 feet of root zone (smaller for potted trees, larger for bare root), 2nd leaf trees have about 2-4 feet of root zone and 3rd leaf trees have about 3-5 feet of root zone. Calculating how much water your soil can store and make available to the tree combines 50% ASM with root depth.

For Example, a March planted bare root almond tree may only have one foot of root depth by June 1st. Such an orchard in a sandy loam soil would have 0.7 inches of stored water to use before tree stress (0.7 inches per foot x 1 foot = 0.7"). A vigorously growing 3rd leaf orchard in July likely has four feet of root zone. Such an orchard on a sandy loam soil would have 2.8 inches of store water to use before tree stress (0.7 inches per foot x 4 feet = 2.8").

Table 1. 50% Available Soil Moisture (ASM) by soil texture.

Soil Texture	50% ASM (inches water/ft soil)
Gravelly, loamy sand	0.4
Sandy loam	0.7
Fine sandy loam	0.9
Loam	1.0
Silt loam	1.1
Clay loam	1.0

Step 3) Note How Much Water the Orchard Is Using

Now we have an estimate of water storage within the root zone. If we think of our soils as a water holding tank, now that we know the size of our tank, we need to think about how quickly it gets drawn down. That will lead us to how often we need to refill it to avoid stressing the trees. We call how much water is being used "evapotranspiration" or ETc. This combines evaporation from the soil and transpiration by the tree. This increases over the growing season for fully grown trees as temperatures increase, but it also increases over the growing season for young trees as the canopy size increases. Examining the tables, we see ETc peaks in July every year, and increases as trees grow from one year to the next.

Tables 1 and 2 shows estimated ETc values for young almond and walnut orchards based on research in the San Joaquin Valley and Tehama County, respectively. Numbers are given for estimated monthly and average daily use. The almond use estimates are for an orchard with some vegetation in the row middles. The 1st and 2nd leaf walnut estimates are for minimal vegetation in the orchard middles. The 3rd and 4th leaf walnut estimates include resident vegetation mowed in the middles. Thus, for an orchard with vegetation in the row middles, the 1st and 2nd leaf walnut numbers may be a little low. For an orchard without vegetation in the middles, the 3rd and 4th leaf numbers may be a little high.

The numbers given are averages from many seasons and locations and should be used as guidelines, not an exact recipe. True ETc in an orchard may be slightly lower or higher if temperatures are below or above average, if tree growth is slower than in an average orchard, or if orchard floor vegetation is managed differently.

Step 4) Calculate the Maximum Allowable Time Between Irrigation

Exactly how often to irrigate is based on many management considerations, such as timing of water availability, use of pumps and wells by other blocks and peak energy rate times. However the first step in determining how often to irrigate is to determine the maximum amount of time that can pass between irrigations before trees become stressed. This is based on soil water storage (Step 2) and tree water use (Step 3).

To find how many days it takes for the whole 50% ASM storage to be used, look at the approximate daily water use from Table 2 or 3 and use the "How Much Water Your Soil Can Store" calculation (Step 2) based on soil type and root depth. Water contributions from rain fall should also be considered, especially in the spring and early summer when rain events can be significant. Assuming there has been no recent rainfall, to find how often irrigation is required to avoid stress, divide the 50% ASM x rootzone by the daily water use.

For Example, in June a 1st leaf almond orchard on sandy loam with 1 foot of root zone needs to be irrigated about every 8 days (0.7" stored water ÷ 0.08" per day = 8.75 days). A 3rd leaf almond orchard with 4 feet of root zone on a sandy loam in July would need to be irrigated about every 12 days (2.8" stored water ÷ 0.22" per day = 12 days).

These calculations give the *maximum* amount of time that should pass between irrigation events. However, they do not tell you exactly how often to irrigate. That decision may be made based on other management considerations, such as peak energy rate times. You may want to irrigate once per week. If you are considering this route, make sure that the maximum amount of time that can pass between irrigations is not more than 7 days, otherwise trees will become stressed. To avoid tree stress with greater certainty, irrigating smaller amounts twice a week is a safer practice.

Step 5) Estimate How Long the Irrigation System Will Take to Refill Tree Water Use

We've answered how often to irrigate, but what about how long to irrigate? This depends on your irrigation system, including what percent of the orchard area is being wetted by these emitters. This last criteria is different from a mature orchard because young orchards generally rely on drip irrigation or microsprinklers with caps to temporarily restrict the water, focusing water in a smaller area.

Two 1 gallon drip emitters wet approximate 2% of the orchard (including some lateral subbing). Four 1 gallon drip emitters per tree, on the other hand, spread over approximately 15% of the orchard, once that water subs out from where it is applied. A microsprinkler with a cap restricting the spray radius might limit the wetted area to 8 to 10% of the orchard. The cap is temporary and will be removed in about a year after the tree has grown and established and expanding root system.

For Example, if we were dealing with 8 gallon per hour sprinklers spreading that water over 100% of the orchard, that'd equate to 0.035 inches of water per hour across the orchard. However, microsprinkler caps concentrate that water in a smaller area, meaning that 8% wetted area is actually getting 0.44 inches of water per hour, while the rest of the field gets zero water (0.035"/hr ÷ 0.08=0.44"/hr).

Table 2. Young Almond Orchard ETc

Almonds						
Month	1st Leaf		2nd Leaf		3rd Leaf	
	inches/month	inches/day	inches/month	inches/day	inches/month	inches/day
February	0.31	0.01	0.56	0.02	0.77	0.03
March	0.77	0.02	1.41	0.05	1.92	0.06
April	1.39	0.05	2.55	0.09	3.48	0.12
May	2.14	0.07	3.93	0.13	5.36	0.17
June	2.51	0.08	4.6	0.15	6.27	0.21
July	2.69	0.09	4.93	0.16	6.72	0.22
August	2.4	0.08	4.39	0.14	5.99	0.19
September	1.76	0.06	3.23	0.11	4.41	0.15
October	1.05	0.03	1.92	0.06	2.62	0.08
Total	15.69		28.76		39.22	

Table 3. Young Walnut Orchard ETc

Walnuts						
Month	1st Leaf		2nd Leaf		3rd Leaf	
	inches/month	inches/day	inches/month	inches/day	inches/month	inches/day
April	0.4	0.01	0.9	0.03	1.6	0.05
May	1.5	0.05	2.4	0.08	4.9	0.16
June	2.3	0.08	3.5	0.12	6.6	0.22
July	3.9	0.13	5.6	0.18	9.7	0.31
August	3.4	0.11	4.6	0.15	7.6	0.25
September	2.1	0.07	2.9	0.10	5.2	0.17
October	1	0.03	1.4	0.05	2.9	0.09
Total	14.6		21.3		38.5	

It is important to think about what percent of the area is being covered by the irrigation system because concentrating water means that the soil in that area of the orchard will fill up more quickly than if the water were spread over the whole orchard.

How long to irrigate depends on how much time has passed since the last irrigation, daily tree water use and if there has been any rainfall events that contributed towards refilling the water used by the tree. First, you'll want to calculate water use since the last irrigation. This is the amount that needs refilling. Then you'll subtract water already supplied by rain. Then you'll divide by the amount of water applied by your system per hour.

For Example, take a 1st leaf walnut orchard with one foot of root depth on a sandy loam in June. If it has been 4 days since the last irrigation, those trees have used 0.32" of water (0.08" x 4 days). This is the starting point for how much water needs to be refilled. Say a small rainstorm that passed in those 4 days and dropped 0.1" of rain. In that case, 0.1" of the 0.32" has already been refilled. Only 0.22" needs to be refilled with irrigation. How long does the irrigation system need to be run to refill that 0.22"? If we are working with the 8 gal/hr capped sprinklers above, the irrigation only needs to be run for half an hour to refill the 0.22" (0.22" ÷ 0.44"/hr = 0.5 hours).

Say instead we are dealing with a 3rd leaf almond orchard with four feet of root depth on a sandy loam in July. If it has been 7 days since the last irrigation, those trees have used 1.54" of water (0.22" x 7 days). If there were no rain events in those 7 days to help refill the soil moisture, it would all need to come from irrigation. If the system has 8 gal/hr microsprinklers with the caps *removed* (water spread over most of the orchard floor, 0.035 inches/hour), the irrigation needs to be run for 44 hours to refill the 1.54" used (1.54" ÷ 0.035"/hr = 44 hrs). For root health, it is inadvisable to run irrigation sets longer than 24 hours. Thus it would be best to split those 44 hours over 2-3 sets, and not wait so long between irrigations in this hot, peak ET time of year.

Step 6) Confirm irrigation schedule is on track with soil moisture or crop water stress measurements

There are a number of different technologies available to monitor soil moisture or crop stress to verify trees are not being over- or under-irrigated following the above irrigation scheduling approach. These include tensiometers, resistance blocks, dielectric sensors, neutron probes and pressure chambers. More information on these technologies and their use can be found in the ANR publication "Monitoring Soil Moisture for Irrigation Water Management" (see resource list below).

CONCLUSION

Irrigation scheduling for young orchards is complex. Not only are the demands of the tree constantly changing. The root zone, and thus amount of soil from which the tree can take up water is constantly changing as well. With all these moving parts, it can be easy to over- or under-irrigate an orchard, setting back growth and potentially endangering root health. By knowing the application rate of your irrigation system, the water holding capacity of your soil type and the water use of the trees, you can figure out the maximum amount of time that can pass between irrigations. Waiting longer than this period will make trees water-stressed. Knowing how frequently you want to irrigate based on other management limitation, system application rate, time elapsed since the last irrigation, and tree water use, you can figure out how long to run your system to backfill water use.

ADDITIONAL RESOURCES:

"Irrigation Tools for Developing Orchards" cetehama.ucanr.edu/files/165587.pdf

"Irrigating Young Trees" sacvalleyorchards.com/walnuts/irrigation-walnuts/irrigating-young-trees

"Potted Tree Irrigation" sacvalleyorchards.com/almonds/irrigation/potted-tree-irrigation-after-planting-getting-the-first-year-right

WORKSHEET EXAMPLE

APPLICATIONS OF IRRIGATION SCHEDULING STEPS AND EQUATIONS

Step 1) Know the Water Application Rate of Your Irrigation System

You'll Need:

- ☐ Number of drip or microspinkler emitters per tree
- ☐ Trees per acre
- ☐ Gallons per hour for each emitter
- ☐ Gallons per acre-inch of water (27,154 gal/ac-in)

Equation: Emitters per tree x Trees per ac x Gal per hr ÷ Gal per ac-in = Inches applied per hour

Example: Orchard Design and Irrigation System Information

- ✓ 1 minisprinkler emitter per tree
- ✓ 120 trees per acre
- ✓ 8 gph flow rate at recommended operating pressure

Calculations:

$$\frac{1\ emitter}{tree} \times \frac{120\ trees}{acre} \times \frac{8\ \frac{gal}{hr}}{emitter} \div 27{,}154\ gal\ per\ acre\ inch\ = \frac{1 \times 120 \times 8}{27{,}154} = 0.035\ \frac{acre\ inches}{hour}$$

Step 2) Figure Out How Much Water Your Soil Can Store

You'll Need:

- ☐ Inches of water storage per foot of soil – Based on soil type and 50% ASM from Table 1
- ☐ Root depth: 1st leaf ≈ <1 to 3', 2nd leaf ≈ 2 to 4', 3rd leaf ≈ 3 to 5'

Equation: Inches/foot water storage x feet of root zone = inches stored water to use before tree stress

Example A: Sandy loam, 1st leaf bare root almond trees

Calculations A:

$$\frac{0.7\ inches\ of\ water}{foot\ of\ soil} \times 1\ foot\ of\ root\ depth = 0.7 \times 1 = 0.7\ inches\ of\ water\ until\ tree\ stress$$

Example B: Sandy loam, 3rd leaf, vigorously growing almond trees

Calculations B:

$$\frac{0.7\ inches\ of\ water}{foot\ of\ soil} \times 4\ feet\ of\ root\ depth = 0.7 \times 4 = 2.8\ inches\ of\ water\ until\ tree\ stress$$

Step 3) Note How Much Water the Orchard Is Using

You'll Need:

- ☐ ETc value from Table 2 or 3, based on tree age and month

Example A: 1st leaf bare root almond trees irrigating on June 1st

$$\frac{0.08\ inches\ of\ water}{day}$$

Example B: 3rd leaf, vigorous growing almond trees irrigating on July 1st

$$\frac{0.22\ inches\ of\ water}{day}$$

Step 4) Calculate the Maximum Allowable Time Between Irrigation

You'll Need

- ☐ Soil Water Storage (from Step 2)
- ☐ Daily Tree Water Use (from Step 3)

Equation: Soil moisture storage x Daily tree water use = Maximum days between irrigation

Example A: Sandy loam, 1st leaf bare root almond trees irrigating on June 1st

Calculations A:

$$0.7\ inches\ soil\ water\ storage \div \frac{0.08\ inches\ of\ water}{day} = \frac{0.7}{0.08} = 8.75 \approx 9\ days\ max\ between\ irrigations$$

Example B: Sandy loam, 3rd leaf, vigorous growing almond trees irrigating on July 1st

Calculations B:

$$2.8\ inches\ soil\ water\ storage \div \frac{0.22\ inches\ of\ water}{day} = \frac{2.8}{0.22} = 12.7 \approx 13\ days\ max\ between\ irrigations$$

Step 5) Estimate How Long the Irrigation System Will Take to Refill Tree Water Use

You'll Need

- ☐ Inches applied per hour (from Step 1)
- ☐ Percent of orchard wetted by emitters
  - Drip: 2 x 1 gallons per hour = 2%
  - 4 x 1 gallons per hour = 15%
  - Microsprinkler with cap: 1 x 8 gallons per hour = 8%
- ☐ Daily Tree Water Use (from Step 3)
- ☐ Days since last irrigation
- ☐ Rainfall since last irrigation

Equations: (a) Inches applied per hour ÷ percent wetted area = inches per hour in wetted area
(b) Daily ETc x days since last irrigations = water used since last irrigation
(c) Water used – Rainfall since last irrigation = water to refill
(d) Water to refill – inches per hour in wetted area = hours to refill use

Example A: Sandy loam, 1st leaf bare root almond trees irrigating on June 1st, microsprinklers with cap, 4 days since last irrigation, 0.1" rainfall

Calculations A:

(a)

$$\frac{0.035\ acre\ inches}{hour} \div 8\%\ wetted\ area = \frac{0.035}{0.08} = \frac{0.44\ inches\ of\ water\ applied\ to\ wetted\ area}{hour}$$

(b)

$$\frac{0.08\ inches\ of\ water}{day} \times 4\ days\ since\ last\ irrigation = 0.08 \times 4 = 0.32\ inches\ water\ used$$

(c)

$$0.32\ inches\ water\ used - 0.1\ inches\ of\ rainfall = 0.32 - 0.1 = 0.22\ inches\ water\ to\ refill$$

(d)

$$0.22\ inches\ water\ to\ refill \div \frac{0.44\ inches\ applied\ to\ wetted\ area}{hour} = \frac{0.22}{0.44} = 0.5\ hour\ run\ to\ refill\ use$$

Step 5 continued) Estimate How Long the Irrigation System Will Take to Refill Tree Water Use

Example B: Sandy loam, 3rd leaf vigorous growing almond trees irrigating on July 1st, microsprinkler without caps (100% coverage), 7 days since last irrigation, no rainfall

Calculations B:

(a) $$\frac{0.035\ \textit{acre inches}}{\textit{hour}} \div 100\%\ \textit{wetted area} = \frac{0.035}{1.00} = \frac{0.035\ \textit{inches of water applied to wetted area}}{\textit{hour}}$$

(b) $$\frac{0.22\ \textit{inches of water}}{\textit{day}} \times 7\ \textit{days since last irrigation} = 0.22 \times 7 = 1.54\ \textit{inches water used}$$

(c) $$1.54\ \textit{inches water used} - 0.0\ \textit{inches of rainfall} = 1.54 - 0.0 = 1.54\ \textit{inches water to refill}$$

(d) $$1.54\ \textit{inches water to refill} \div \frac{0.035\ \textit{inches applied to wetted area}}{\textit{hour}} = \frac{1.54}{0.035} = 44\ \textit{hour run to refill use}$$

WORKSHEET EXAMPLE A SUMMARY Sandy loam, 1st leaf bare root almond trees irrigating on June 1st, microsprinklers with cap, 4 days since last irrigation, 0.1” rainfall	
Step 1) Water Application Rate of Irrigation System	0.035 acre-inches per hour
Step 2) Soil Water Storage	0.7 inches before stress
Step 3) Orchard Water Use	0.08 inches per day
Step 4) Maximum Allowable Time Between Irrigation	9 days
Step 5) How Long to Refill Orchard Water Use	0.5 hours to refill 4 days use

WORKSHEET EXAMPLE B SUMMARY Sandy loam, 3rd leaf vigorous growing almond trees irrigating on July 1st, microsprinkler without caps (100% coverage), 7 days since last irrigation, no rainfall	
Step 1) Water Application Rate of Irrigation System	0.035 acre-inches per hour
Step 2) Soil Water Storage	2.8 inches before stress
Step 3) Orchard Water Use	0.22 inches per day
Step 4) Maximum Allowable Time Between Irrigation	13 days
Step 5) How Long to Refill Orchard Water Use	44 hours* to refill 7 days use

**44 hours is longer than the 24 hour maximum recommended for root health. Would be preferable to irrigate for shorter durations every 3-4 days instead of waiting 7 days between irrigations.*

Fertilizing Young Almond and Walnut Orchards

Katherine Jarvis-Shean and David Doll

WHY FERTILIZE YOUNG TREES

Trees need nutrients to support the growth of vegetative tissue (trunk, roots, branches, leaves) and reproductive tissue (nuts, hulls, etc.). In the first few years of growth, trees generally are growing more vegetative tissue than reproductive tissue. All trees have a certain potential for growth based on cultivar, rootstock, climate, irrigation, and other growing condition. Nutrient deficiency can mean that the growth potential is not met, leading to smaller, stunted trees with weaker growth.

On the other side of the coin, too much fertilizer can have a negative effect. If grossly over-applied, toxicity could occur and kill tender tissues. More common, however, is fertilizer rates that lead to excessive vigor, which is indicated by lanky growth and too much space between buds. This interferes with future canopy branching structure and crop load bearing capacity (Figure 1). In nutrient management, it is essential to provide what is needed by the tree at the right time, without negatively impacting growth or canopy structure.

WHAT TYPE OF FERTILIZER TO APPLY

The three major nutrients for plant growth are nitrogen, phosphorus and potassium. Of these, nitrogen is the primary concern for young trees. This nutrient is critical for leaf growth and development of plant proteins. If too little is available leaves will be smaller in size, off-green in color, and overall growth will be stunted. In excess, leaves will be dark green, and vigor will be high. Potassium and phosphorous are required for woody tissue development. These nutrients rarely have been observed to cause toxicities, and deficiencies are not common in non-bearing trees.

Figure 1. Overloading young trees with nitrogen can result in lanky growth, interfering with future canopy structure and limb strength. Photo: D Doll

There are many different potential sources of nitrogen. So which one should be used? The basic answer is "***Nitrogen is nitrogen***," meaning no matter what form of nitrogen is applied, it will all be transformed in the soil into a form that can be used by the tree. Two trials in Merced County illustrate this point. The trials compared tree growth when the same amount of nitrogen was applied as ammonium sulfate, calcium nitrate, slow release fertilizer or triple 15 (contains nitrogen as ammonium and urea). One of the two trials also added a calcium-potassium-nitrate blend and potassium nitrate to the comparison. The seasonal growth in the first year, measured as trunk circumference, was equivalent for all sources of fertilizer (Figure 2). Seasonal growth was slightly lower for calcium nitrate in one location, and it is thought to be due to the high leaching potential from the fertilizer source and irrigation system used.

We can learn from these trials that all forms of nitrogen can *potentially* support tree growth equally well. But there are other reasons to pick one fertilizer over another when looking for a source of nitrogen. These include:

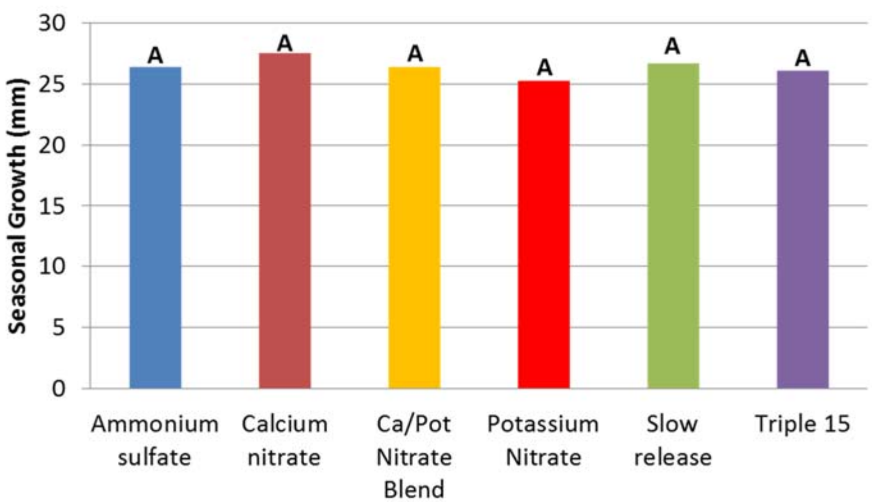

Figure 2. Nitrogen source did not impact tree growth. Fig: D Doll

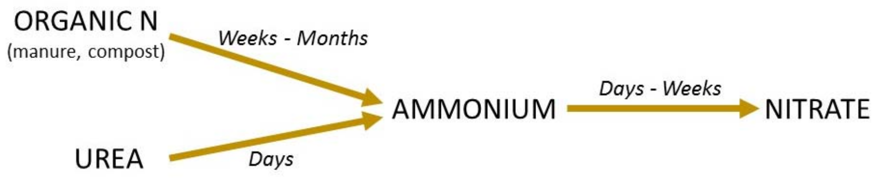

Figure 3. How different forms of nitrogen fertilizer transform in warm, moist soils. Adapted from UC ANR Almond Production Manual.

When will the nitrogen be available to the tree?

Almonds and walnuts largely take up nitrogen as nitrate. In agricultural soils, soil microbes can eventually transform all forms of nitrogen into nitrate (Figure 3). Organic nitrogen, such as nitrogen found in manure or compost, and urea, both transform into ammonium, over a matter of days to months in warm, moist soils, depending on environmental conditions and soil microbe populations. Ammonium is turned into nitrate in a matter of days to weeks. Table 1 shows the nitrogen form contained in many common fertilizers. Fertilizer selection should ensure that some nitrate is available within the active root zone over the whole growing season, either by supplying nitrate directly, or applying another form of nitrogen and allowing time for that nitrogen to be transformed into nitrate.

Controlled release fertilizers (CRFs) are an excellent technology if fertilizer is being hand applied to small orchards. CRFs are polymer coated granular fertilizers that utilize urea or other nitrogen sources. The polymer coating protects the nitrogen from soil processes until released. Release of nitrogen occurs by diffusion, and is affected by soil temperature. The use of CRFs helps increase nitrogen use efficiency by maintaining nitrogen within the root zone of the tree and by limiting the amount of nitrogen available at any given time. This reduces the risk of over-applying nitrogen and the corresponding risks of toxicity and overly vigorous growth.

Furthermore, it can lead to labor savings as trial work has shown that one large application of CRF containing the entire season's fertilizer amount provided the same growth response as six smaller split applications of other nitrogen sources. The increase in efficiency and labor reduction often offsets the increase in cost of CRF.

How will nitrogen move through the soil?

Some fertilizers move through the soil more rapidly than others. When comparing ammonium, urea, and nitrate, nitrate moves through the soil the fastest. This is due to its negative charge. If applying a nitrate-based fertilizer, care must be taken with irrigations and water management in order to keep the nitrogen within the root zone. Ammonium and urea, being positively charged, are less likely to be leached and may be suitable in California conditions to be applied in the late spring due to inconsistent rain events. Since all forms of nitrogen can eventually be transformed to nitrate, leaching is a concern no matter what form of nitrogen is used. Table 1 shows the leaching potential of many commonly used fertilizers.

How will the fertilizer affect soil pH and micronutrient availability

The process of changing ammonium to nitrate lowers the pH of the soil, so both ammonium and urea will reduce soil pH. Calcium nitrate can increase soil pH. High soil pH (above 7.5) greatly limits the solubility of zinc, iron, copper and manganese. Thus, if the soil pH is already above 7.5, ammonium or urea-based fertilizers (see Table 1) may help with long-term changes to soil pH, and increased availability of some micronutrients. Some fertilizers, like N-pHuric, have acids along with nitrogen, to lower the pH of soils much more rapidly than ammonium or urea can alone.

Table 1. Attributes of different nitrogen-based fertilizers. Adapted from UC ANR Almond Production Manual.

Fertilizer	Nitrogen (%)	Urea	Ammonium	Nitrate	Leaching Potential	Soil Acidifier	Comments
Ammonium Nitrate	34%		✓	✓	Medium	Medium	Nitrate N immediately available. Ammonium N half delayed.
Ammonium sulfate	21%		✓		Low	High	Source of sulfur
Calcium ammonium nitrate (CAN-17)	17%		✓	✓	Medium	Medium	
Calcium nitrate	16%				High	No	Source of calcium
Urea	45%	✓		✓	Low	Low	
Urea Ammonium Nitrate (UN-32)	32%	✓	✓	✓	Medium	Medium	Nitrate N immediately available. Remainder of N delayed.

HOW MUCH FERTILIZER TO APPLY

Once the source of nitrogen has been identified, the next question is how much to apply. It is important to keep in mind that young tree roots are sensitive to chemical burning when hit with too much nitrogen at one time. If this occurs, it will show above-ground as burned leaves and branch tips with shepherd's hook structure (Figure 4). It is particularly easy to burn trees with liquid fertilizers like UN32 or CAN17. A good rule of thumb is to never apply more than one ounce of nitrogen at a time to a one year old tree, and no more than two ounces at a time for two year old trees.

How can the amount of N in a fertilizer be determined? Table 1 shows the nitrogen content of different fertilizers by percent weight ("Nitrogen %"). Use this to find the amount of nitrogen in a pound of fertilizer. For example, ammonium nitrate is 34% nitrogen. With some quick multiplication we can figure out that one pound (16 oz) of ammonium nitrate contains 5.4 oz of nitrogen: 16 oz x 0.34 = 5.4 oz

Figure 4. Shepherd's hook and burned leaves resulting from nitrogen burn to young roots.

Before buying fertilizer for a non-bearing orchards, don't forget that there may already be nitrogen in your irrigation water and soils. If using groundwater, there is a good chance that nitrogen is being applied due to contamination with nitrate-nitrogen. For example, for every acre-inch of irrigation water, at 5 ppm NO_3-N, you are applying just over a pound of nitrogen per acre. That is nitrogen that does not need to be applied as fertilizer and contaminated N removed from the groundwater.

Table 2. Nitrogen available for plant use from irrigation water.

Reported as NO_3-Nitrogen (Nitrate Nitrogen) (ppm or mg/l)				
Acre- Inches	Pounds of Nitrogen in Water			
	1 ppm	5 ppm	10 ppm	15 ppm
1	0.2	1.1	2.3	3.4
6	1.4	6.8	13.5	20.3
12	2.7	13.5	27.0	40.5
Reported as NO_3 (Nitrate) (ppm or mg/l)				
Acre- Inches	Pounds of Nitrogen in Water			
	1 ppm	5 ppm	10 ppm	15 ppm
1	0.05	0.3	0.5	0.8
6	0.3	1.5	3.1	4.6
12	0.6	3.1	6.1	9.2

There may be a high amount of residual nitrogen in the orchard soil. Every orchard is different in terms of the nutrients in the soil when the orchard was planted. Soil samples prior to the first fertilization can provide an estimate of how much nitrogen and other nutrients are present within the soil. The analysis can then be used to determine pounds of nitrogen available to the trees. For example, 5 ppm NO_3-N in the soil equates to 20 lbs of nitrogen in the first foot of soil, where the majority of young root growth will occur. To find the amount of nitrogen in the *first 12 inches* of soil depth, simply multiply NO_3-N (in ppm) x 4. Because tree roots are not exploring the whole soil area in their first year of growth, an estimate then needs to be made of the percent of an acre that young tree roots are exploring in order to estimate the nitrogen in the soil that young tree roots can access and use.

ALMOND FERTILIZER NEEDS

A trial in Merced County applied different rates of nitrogen in one year old trees and measured the growth response. Based on trunk diameter and tissue samples the study showed that applying between 3-4 oz per tree during the first growing season resulted in optimum growth. Applying more than 4 oz per tree provided no additional growth benefit. Nitrogen applications were divided into six applications over the course of the season. These findings are in line with previous research that was conducted at Nickel's Field Estate Trust near Arbuckle, CA. Generally, smaller, more frequent dose of fertilizer are more efficient, particularly with young trees with small root zones.

Applying 3-4 oz N per tree works in the first year when there is no crop on the tree. In the second year, some nitrogen may be needed for the crop along with nitrogen for the vegetative growth. For 2nd leaf through 4th leaf, apply about 3-4 oz N per tree (about 25-30 lbs N per acre, depending on spacing) for new growth, then add another 85 lbs N for every 1,000 lbs harvested. Keep in mind that crop removal is roughly 68 lbs of nitrogen per 1,000 kernel pounds, but due to inefficiencies in application, 85 lbs should be applied to replace the removed 68 pounds. Once yields are above 2,000 lbs, simply apply 85 lbs N for every 1,000 lbs of crop. There is enough nitrogen at that rate to cover crop needs and moderate tree growth.

Table 3. Nitrogen Rate Summary

N Application Rate		
Tree Age	Almonds	Walnuts
Year 1	3-4 oz/tree	3-4 oz/tree
Year 2	3-4 oz/tree + 85 lbs/1,000 lbs nuts	6-8 oz/tree
Year 3	3-4 oz/tree ac + 85 lbs/1,000 lbs nuts	6-8 oz/tree
Year 4	25-30 lbs/ac + 85 lbs/1,000 lbs nuts	6-8 oz/tree + 36 lbs/ton nuts
Year 5	85 lbs/1,000 lbs nuts	6-8 oz/tree + 36 lbs/ton nuts

WALNUTS FERTILIZER NEEDS

There have not been any trials on fertilizing young trees in California. Based on decades of experience, however, farm advisors suggest rates very similar to what was found in the almond trials for first year trees – 3-4 oz N per tree over the growing season. Depending on conditions, much, if not all, of the first year nitrogen needs can be met by nitrogen already in the soil or nitrogen applied in the groundwater. Walnuts do not set fruit as early as almonds, so the N need of nuts does not come into play until usually the fourth year at the earliest. In the second year and third year, rates of N should be doubled with 6-8 oz of N per tree over the course of the season. For 4th and 5th leaf, consider about 6-8 oz of N per tree, plus 36 lbs lb per ton of harvested nuts. Keep in mind that crop removal is roughly 29 lbs of nitrogen per 1,000 pounds in-shell nuts, but due to inefficiencies in application, 36 lbs should be applied to replace the removed 29 pounds.

ADDITIONAL RESOURCES:

"Fertilizing Young Almond Trees: A Few Tips"
thealmonddoctor.com/2011/03/25/fertilizing-young-almond-trees-a-few-tips/

"Fertilizing Young Almond Trees: Be Careful"
thealmonddoctor.com/2010/03/15/fertilizing-one-year-old-trees-be-careful/

"Young Tree Nitrogen Presentation" (video)
thealmonddoctor.com/2015/03/29/young-tree-nitrogen-fertilization-presentation/

California Dept of Food and Agriculture Fertilizer Guidelines
apps.cdfa.ca.gov/frep/docs/Guidelines.html

Training and Pruning Young Almond and Walnut Trees

Katherine Jarvis-Shean & Bruce Lampinen

INTRODUCTION

The primary goal of both training and pruning is to create and maintain a tree that will produce optimal yields and facilitate cultural practices. In the first years the tree is trained to a structure that will support future crop weight and allow for cultural practices, while minimizing cuts which could decrease early yields.

After tree structure has been established, pruning primarily facilitates cultural practices like spraying and harvesting, and removes dead and diseased wood. In the past, pruning has been viewed as a way to invigorate tree growth. Numerous long-term trials have shown minimally pruned trees (pruned for cultural practices and disease control) yield as well or better than more heavily pruned trees.

When using pruning shears be sure shears are sharp. Never allow pruning shears to touch soil, because this can lead to the spread of soil borne diseases, such as crown gall. To cut, place the hook of the shears on the top of the limb and cut upward, with the blade close to the trunk or branch. When using a chain saw, cut at the branch collar to minimize the wound size and promote healing. In typical California conditions, wound dressings on pruning cuts are not necessary.

HOW PRUNING WORKS

Pruning changes where growth occurs by changing the hormone and resource balance. The response to pruning will depend on whether cuts are made during the dormant or growing season, and whether the cut is a thinning or heading cut. However, all pruning is dwarfing because you are cutting nutrients and carbohydrates out of the tree and removing leaves that could supply carbohydrates for new growth.

Dormant pruning creates vigorous regrowth in the spring from the area where the pruning cut was made. When wood is removed, carbohydrate and nutrient reserves in the trunk and roots are divided among fewer growing points the following spring. The heavier the pruning, the greater the localized regrowth.

Pruning in the summer instead of the dormant season will reduce the amount of regrowth that will occur at the pruning point. Summer pruning removes carbohydrate-producing leaves before they can send carbohydrates and nutrients to reserves.

The two different types of pruning cuts – thinning and heading cuts – produce different growth responses and should be done with different goals in mind. Thinning cuts direct growth in a particular area, and/or removing dead or diseased wood. Make a thinning cut at the branch collar, at the point of origin from the parent limb (Figure 1).

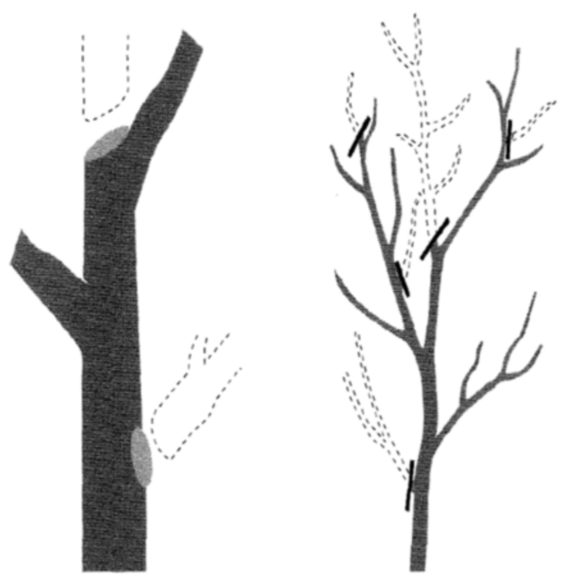

Figure 1. Thinning cuts at the limb's point of origin redirect growth.

Heading cuts create a concentrated area of several vigorous shoots where one large shoot or branch was headed back. To make a heading cut, remove the terminal portion of an existing branch. (Figure 2).

TRAINING YOUNG ALMOND TREES

Training young trees needs to address attributes and risks of a given site including soil, wind, rainstorms, tree spacing, and variety and rootstock selection. Training becomes more important the larger the tree (i.e. with more vigorous cultivars or rootstocks, wider spacing, etc.), because tree architecture needs to be able to support more crop per scaffold.

At Planting and During the First Growing Season

Top trees at three feet when they are first planted. This leaves enough trunk space for future shaking and to vertically stagger future scaffolds. For minimal scaffold selection (see below), consider topping 6-12” higher. During the season, remove cross limbs, rootstock suckers, and watersprouts that are too low to be scaffolds. Otherwise, just let the tree grow.

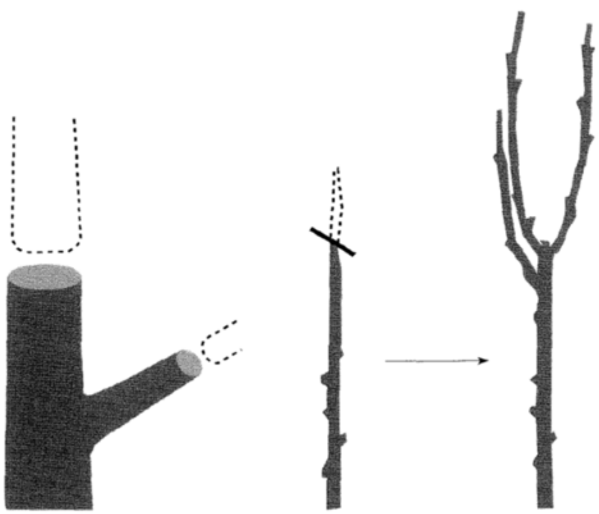

Figure 2. Heading cuts at the terminal portion of a branch results in concentrated vigorous regrowth.

First Dormant Pruning

Scaffold Selection

The goal of scaffold selection is to encourage strong, well-anchored scaffolds that won’t break or split from the trunk in future years. Branches selected to remain on the tree are called “primary scaffolds”. Branches picked next year arising from these primaries are “secondary scaffolds”.

First, remove branches that cross the middle or have very narrow or wide attachments. Then select scaffolds from the remaining branches. Keep in mind angle, orientation and spacing of the branches. Once the best scaffolds are picked, remove all competing potential scaffold branches. Leave short lateral branches coming off the scaffolds.

For maximizing attachment strength and load-bearing capacity, the ideal angle where a scaffold attaches to the trunk is 45° from the vertical and the horizontal. Branches at too narrow of an angle (less than 30°from the vertical) will develop included bark, preventing strong attachment leading to increased likelihood of breakage. Branches wider than 70° from the vertical may not support heavy crop weight.

Scaffold orientation should be evenly distributed to balance future crop load around the tree. Select a strong branch on the north side of the tree to help balance typical growth toward the sun on the south side. Where possible, select a strong branch in the direction of the prevailing wind to help fill out that portion of the canopy.

Even spacing of scaffolds around the tree gives scaffolds room to attach to the trunk and balance the crop weight. The goal is 3-4 scaffolds spaced 90-120° apart when viewed from above, 3-6” apart up and down the trunk.

Many growers have moved to 4-5 primary scaffolds. Trials in Stanislaus and Butte Counties compared 3 primary scaffolds to 4-6 primary scaffolds. After 15 years, there has been no cumulative difference in yield. Three scaffolds with minimal pruning after the first year filled in the canopy space in the Stanislaus trial just as quickly as 4-6 scaffolds.

Scaffold Pruning

Once primary scaffolds have been selected and other branches have been pruned out, it is time to prune the selected scaffolds, to stimulate side branches in the next season for secondary scaffold selection.

Make heading cuts on the scaffolds at 42-48” from the trunk. Ideally, this will be 1-2’ below the branch tip, cutting off the concentrated area of buds, which otherwise creates heavy, bushy growth. Pruning branches shorter than this sacrifices early yields for the sake of orchard uniformity. Leaving limbs unpruned can produce long limbs prone to breakage, bending and blow-over.

Second Dormant Pruning

The goal of the second dormant pruning is to continue to shape the structure of tree up and out to create strong architecture and fill the available space with canopy as quickly as possible. First, remove crossing branches, central water sprouts, and branches that would become an unwanted primary scaffold if not removed. Then select secondary scaffolds from the remaining branches.

Selection of secondary scaffolds and removal of overly vigorous watersprouts reduces corrective pruning needs later in the life of the orchard without significantly affecting yield. Select two to three vertically well-spaced secondary scaffolds per primary scaffold. The branches should be vigorous, growing up and out, and evenly spaced around the canopy.

TRAINING YOUNG WALNUT TREES

At Planting and During the First Growing Season

Traditionally, trees have been topped at three feet when first planted to encourage vigorous local growth to increase options for scaffold selection the following year. Recent work suggests this heading at planting may not be necessary. A trial in Colusa County with Chandler trees compared trees that were not headed at planting nor pruned thereafter with trees that were headed at planting and minimally pruned in the following season. There was no statistical cumulative yield difference found between the unheaded, unpruned and the minimally pruned trees by the orchard’s 6th leaf (Figure 4).

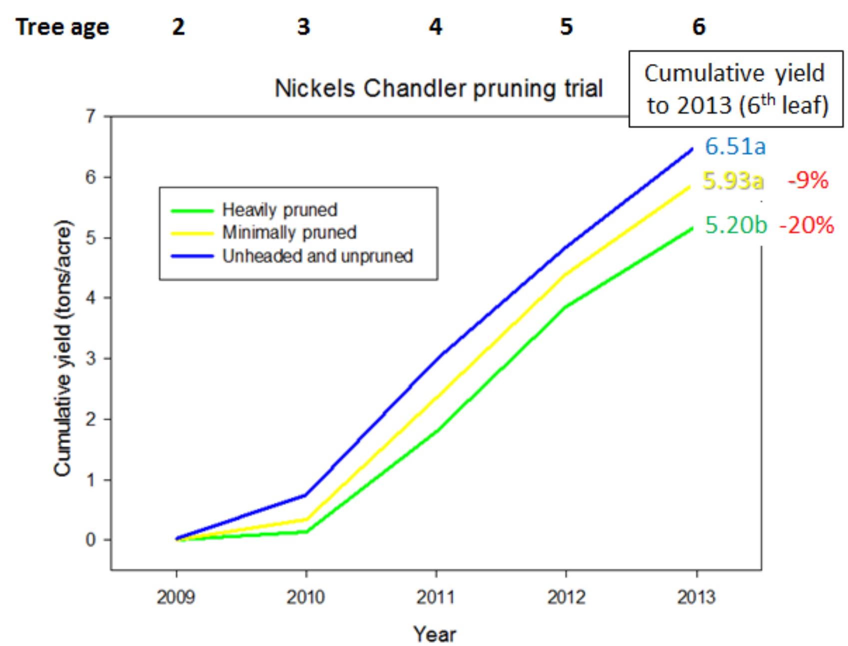

Figure 4. Unheaded, unpruned trees yielded as well as headed, minimally pruned trees.

First Dormant Pruning

For both minimal pruning and no pruning (headed but unpruned), grow a central leader in the first season after planting. After the first year of growth, removal all branches from the trunk except a single central leader. This includes removing neck buds at the trunk (Figure 5). These spurs are weakly attached to the trunk and will likely split off the trunk if allowed to grow and bear weight. For minimally pruned trees, after the first season head the tree back to 6-8 feet. This provides room for the shaker head when branching occurs below this .

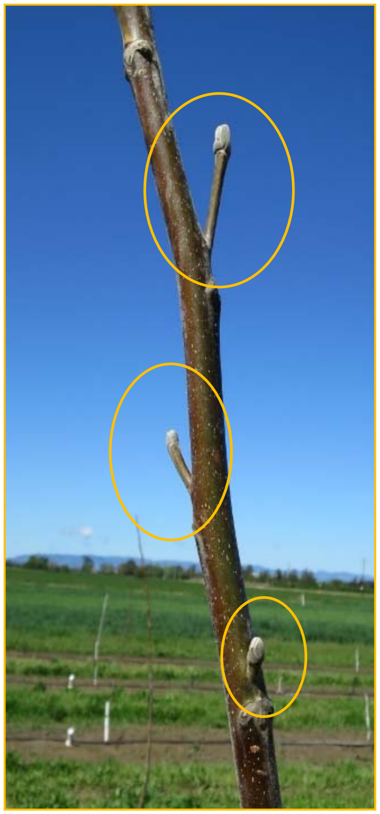

Figure 5. Neck buds (circled) should be removed during first dormant pruning.

Second Dormant Pruning

With the unheaded-unpruned approach, there is no scaffold selection, only elimination of branches that are likely to break or interfere with harvest. A trial in Colusa County with Howards compared no pruning after scaffold selection with the traditional pruning approach of removing approximately one-third of the previous year's growth every year. Over seven seasons, trees that were not pruned after scaffold selection yielded as well as trees that were pruned every year (figure 6).

Unpruned trees (in the headed trial and the unheaded trial) also showed decreased probability of limb breakage because crop load was distributed among more branches. Unpruned and minimally pruned trees also naturally develop flatter branch angles coming off the trunk, which allows light to penetrate deeper into the canopy. Lower light penetration from heavier pruning treatments in trials showed a host of quality problems, including yellow, bronze or black pellicles, nut shrivel and peewee nuts.

After the second season's growth, remove forks with branch angles of less than 20 degrees off the trunk. Also, remove all growth below four feet at the trunk to give future clearance for the shaker head.

After that point, for unpruned trees no additional cuts are made, except to allow orchard access and to cut out diseased or dead wood. For minimally pruned trees, pick 5-6 main scaffolds, including the central leader branch that is most towards the center of the tree. Head these main scaffolds, removing ¼ of the previous year's growth.

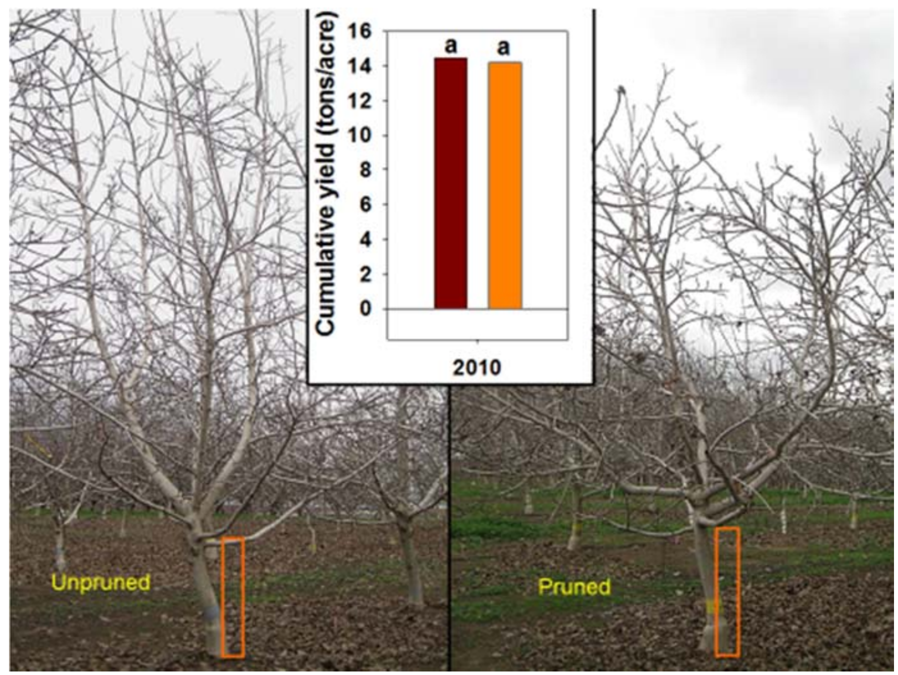

Figure 6. No difference in yield between pruned and unpruned trees. Howards at Nickels, here after 6th leaf

PRUNING MATURE ALMOND & WALNUT TREES

By the third dormant season, the architecture of the tree is largely established. Transition to minimal maintenance pruning to facilitate cultural practices, such as canopy spray coverage, orchard machinery entry and scaffold shaking, and to remove diseased or dead wood.

There are important reasons to do some pruning, as mentioned above, but maintaining yield is not one of them. Almond trials in Colusa and Stanislaus Counties have found that over 18 years and 16 years, respectively, trees which were not pruned after the first or second year of scaffold selection showed no difference in cumulative yield, and often had higher yields early on, compared to traditionally pruned trees. Figure 7 provides a summary of the approaches presented above and the different activities involved.

ADDITIONAL RESOURCES:

"Training Young Walnut Trees"
sacvalleyorchards.com/walnuts/horticulture-walnuts/training-young-walnut-trees-minimum-pruning-vs-no-pruning-compared
"Pruning 1st & 2nd Leaf Almonds"
thealmonddoctor.com/2009/11/23/pruning-first-and-second-leaf-almonds

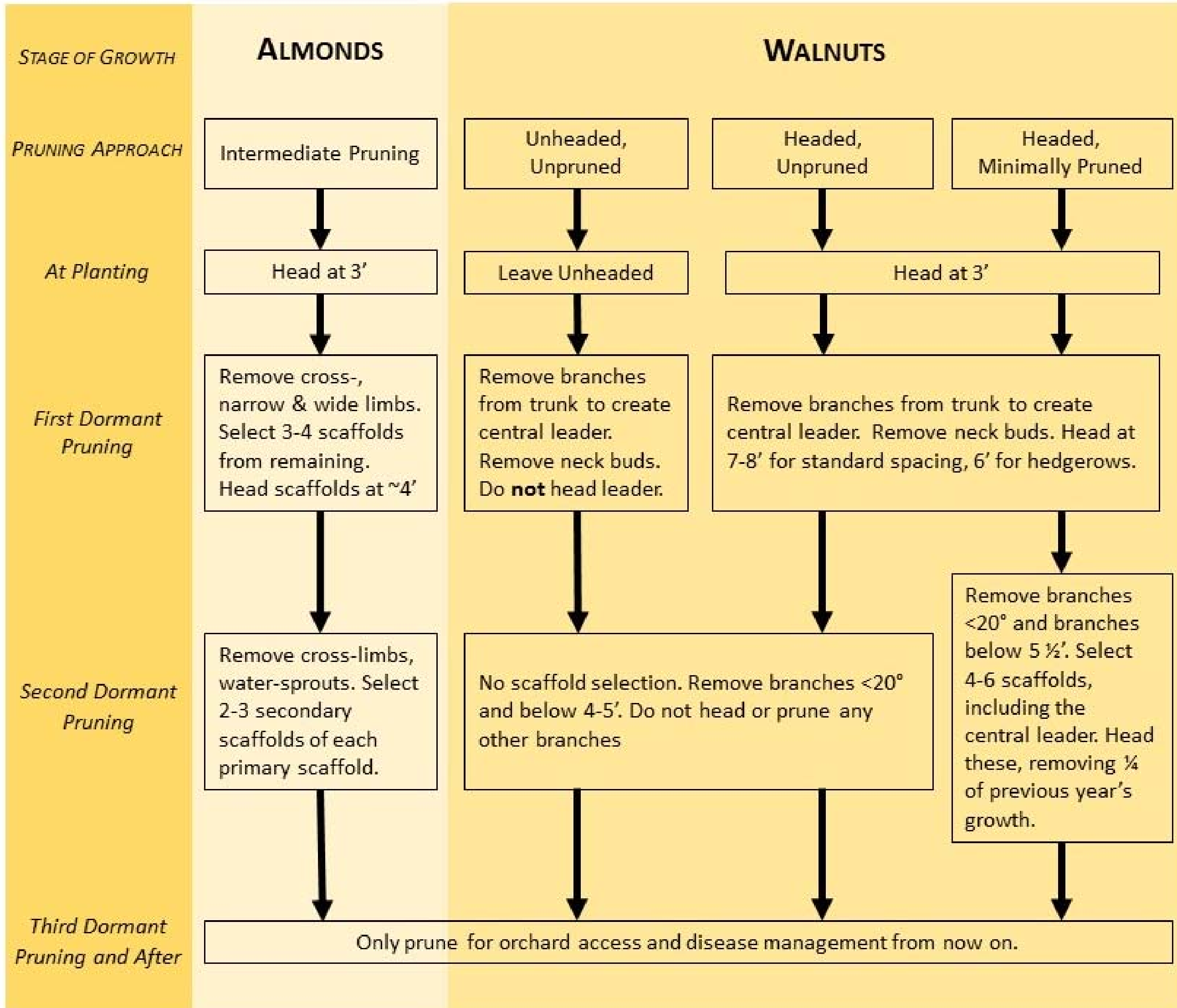

Figure 7. Steps for different training approaches at different growth stages of almonds and walnuts.

Weed Management for Young Orchards

Katherine Jarvis-Shean & Brad Hanson

Weeds in young orchards compete with trees for orchard resources – sunlight, water and nutrients, setting back growth and yield. Weeds can also create cover for vertebrate pests which can then damage tree trunks (Figure 1) and irrigation systems. For these reasons, weed control is important for young orchards.

There are a number of challenges in weed management in young orchards. Young trees often are more susceptible to herbicide damage. A number of different annual grasses and broadleaves need to be controlled. There are fewer herbicides available for use in young orchard, compared with mature trees. Several weed species are beginning to show resistance and/or tolerance towards herbicides that have previously been main-stays of weed management.

Figure 1. Vertebrates can damage young tree in orchards with too many weeds

Figure 2. Weeds can outcompete trees for sunlight, water and nutrients.

There are keys to effective weed control that are true no matter how old your trees. First, the weed problem must be correctly identified. UC Davis's weed identification website is a useful tool for this step: weedid.wisc.edu/ca/weedid.php. Next, registered herbicide(s) with activity on your weed spectrum must be selected. Finally, the material must be applied properly, at the appropriate growth stage with well-calibrated equipment.

PRECAUTIONS WITH YOUNG ORCHARD WEED MANAGEMENT

Remember that tree crops are not resistant to herbicides. Crop safety is usually achieved by placement; we avoid injuring trees by placing herbicides below the foliage and green tissues but above the root zone. Knowing this, there are a few important things to keep in mind:

- Green trunk wood is often still susceptible to contact herbicides. Leave cartons on tree trunks for the first two years after planting or until the trunk diameter gets too large.
- Branches on young trees are lower and more likely to get hit by drift. Be extra cautious with windy conditions, spray rig height, nozzle angles, and nozzle selection.
- After planting, tree roots are shallow and soil is still settling, which means soil-applied herbicide can settle or run into loosely packed pockets or cracks. Make sure soil is settled before applying herbicides and manage water carefully to avoid moving herbicides too deeply into the soil.

OPTIONS FOR WEED CONTROL IN YOUNG ORCHARDS

Young orchards do have the advantage of starting from scratch. If perennial weeds such as bindweed are a big problem on a site to be planted with an orchard, take corrective action early. As much as possible, control weeds before planting, but be wary of residual action of herbicides that might impact trees at planting. If you are planning on mounding the soil for tree rows, be sure that it does not closely follow herbicide application, to avoid concentrating herbicide-loaded topsoil in the mound. As much as possible, avoid mixing surface soil with herbicide into tree holes at planting. In an orchard replant situation, it may be advisable to reduce rates or eliminate altogether the use of residual herbicides in the last season of the old orchard to minimize the risk for the new orchard.

There are a number of herbicides registered for use with nut trees two years old or younger. Reliable, long-term weed control depends on using herbicides with different modes of action in tank mix or in sequence and targeting different life stages. Pre-emergent herbicides are applied before weed seeds germinate and prevent weed seedlings from establishing. Post-emergent herbicides work on weeds that have already germinated and emerged. However, these herbicides are most effective when weeds are small and young (Figure 3). There is no perfect rule of thumb for how small is small enough, but generally weeds should be less than 3 inches in height and diameter for herbicides to be effective.

Table 1 shows a list of herbicides that, at last check, can be used on tree crop orchards. Always check the labels for any product you may consider using. Not all products are labeled on all tree crops, and this chart may become out-of-date. Label information can be found on websites such as Agrian (agrian.com/labelcenter/results.cfm) or CDMS (cdms.net/Label-Database).

Figure 3. Herbicide was ineffective on hairy fleabane because weeds were too large and old.

AVOIDING RESISTANCE

The key to avoiding or minimizing problems with herbicide-resistant weeds is varying your weed management approach. Many growers rely heavily on glyphosate because it is affordable and can provide good post-emergent weed control. However, by using the same product and mode of action to kill weeds, we are selecting for herbicide resistance. To avoid this, add different modes of action or tank mixes to your herbicide program. Table 1 shows the mode of action for many different herbicides. By using herbicides with different modes of action within-season and from one season to the next, you attack weeds from many different angles, making it hard for one resistance gene or one particular weed to thrive and build up a population.

Table 1. Herbicides that may be options for use on young orchards. Always check label information to confirm appropriate usage.

	Herbicide	Example Trade Name	Site of Action	Notes
PRE-Emergent	EPTC	Eptam	N / 8	For well-established
	flumioxazin	Chateau	E / 14	1 year needs carton
	indaziflam	Alion	L / 29	1 year
	isoxaben	Trellis	L / 21	
	norflurazon	Solicam	F1 / 12	18 months
	oxyfluorfen	Goal	E / 14	
	pendimethalin	Prowl	K1 / 3	
	oryzalin	Surflan	K1 / 3	
	penoxsulam	PindarGT	B / 2	9 or 15 months
	rimsulfuron	Matrix	B / 2	Established 1 season
POST-Emergent	carfentrazone	Shark	E / 14	Not OK on green bark
	clethodim	Select	A / 1	Non-bearing only
	2,4-D	Dri-Clean	O / 4	1 year
	diquat	Diquat	D /22	Non-bearing only
	fluazifop-p-butyl	Fusilade	A / 1	Non-bearing label in some crops
	glyphosate	RoundUp	G / 9	
	glufosinate	Rely 280	H / 10	Not OK on green bark
	paraquat	Gramoxone SL	D /22	Not OK on green bark
	pyraflufen	Venue	E / 14	Not OK on green bark
	saflufenacil	Treevix	E / 14	Not OK on green bark
	sethoxydim	Poast	A / 1	

ADDITIONAL RESOURCES:

UC Davis Weed Resource and Information Center: wric.ucdavis.edu/

UC Weed Blog ucanr.edu/blogs/UCDWeedScience/index.cfm?tagname=orchards%20and%20vineyards

UC Davis Weed Identification Tool: weedid.wisc.edu/ca/

UC Herbicide Damage Symptoms ID Tool: herbicidesymptoms.ipm.ucanr.edu/

Weed Section on crop-specific pages on UC IPM: www.ipm.ucdavis.edu/PMG/crops-agriculture.html

"Orchard Floor Management" (Ch 28) in the Almond Production Manual and "Vegetation Management" (Ch 26) in the Walnut Production Manual: anrcatalog.ucanr.edu/Details.aspx?itemNo=3364

Vertebrate Management in Young Orchards

Katherine Jarvis-Shean, Roger Baldwin & Brianna Vinsonhaler

INTRODUCTION

Feeding on the roots, crown and trunk of a young tree by burrowing vertebratepests (i.e. pocket gophers, voles, ground squirrels) irreparably interferes with the movement of water and nutrients (Figure 1). Girdled trees will likely be weak and under-perform their potential. Above-ground damage can impact the tree canopy or the orchard infrastructure. Deer remove leaves, the carbohydrate making factories of the tree, resulting in less energy for new growth. Irrigation line damage by rodents, jackrabbits and coyotes can result in not enough (or too much) water getting to young tree roots.

These issues can be avoided or minimized if vertebrate pests are monitored and managed. Because orchard ground has usually been ripped before planting, young orchards may start with an advantage of very low-to-no burrowing vertebrate pests. Monitoring and quick action is critical to maintain that advantage. Be sure to consult local, state and federal regulations and read all pesticide labels before employing any of the techniques discussed here.

IDENTIFYING AND UNDERSTANDING TARGET PESTS

Probably the most frequently encountered and most damaging pests in young orchards are pocket gophers (*Thomomys bottae*), especially in almond orchards, but California ground squirrels (*Otospermophilus beecheyi* and *O. douglassi*), meadow voles (*Microtus californicus*), jackrabbits (*Lepus californicus*), deer (*Odocoileus hemionus*) and coyotes (*Canis latrans*) are also common. Knowing when vertebrate pests are active and breeding and what they eat can help inform their management.

Figure 1. Almond tree girdled by gophers feeding on crown and trunk. (Photo: D. Lightle)

Burrowing Vertebrate Pest (Rodents)

Pocket gophers often feed on herbaceous, nitrogen-fixing plants and plants with long, fleshy taproots, but will also eat tree crowns and roots. Cover crops can increase in-orchard gopher populations that will then feed on tree crown and roots when the cover crop dries or is mowed. Pocket gopher presence can be identified by the horseshoe shaped tunnel entrance mounds (Figure 2). They are rarely seen above ground. Gophers live alone in a burrow system, except when breeding and when raising young. Gopher breeding can be year-round but peaks in early spring and late fall. Females will have 1 to 2 litters per year, each averaging five young. After the young mature they will move out and create their own burrow. Tunnels are 6 to 18 inches below the surface.

The ground squirrel is a burrowing pest that causes significant problems in bearing orchards because they feed on nuts and fruits. In non-bearing orchards, they sometimes feed on bark and roots. They also can gnaw on drip lines. Ground squirrels live in colonies underground. Burrow entrances are about 4” wide, with most tunnels 2-3 feet below the soil surface (Figure 2). Squirrels will hibernate over winter and start emerging from late January into February. Typically, in the spring they feed on green grasses and forbs, then switch to seeds, grains and nuts in the summer. They will travel up to 100 yards from the burrow for food. The females typically will have their litter in February or March with an average of eight young.

Meadow voles, also called meadow mice, are a concern for young almond orchards but they usually avoid feeding on walnut rootstock. Voles create small burrow systems with an opening averaging 1.5 inches in diameter. In contrast to pocket gopher burrow entrances, vole burrow systems are open. However, pocket gopher burrow entrances sometimes appear open when shallow feeder hole plugs cave in. Vole burrow systems can be distinguished from gopher feeding holes by characteristic connecting runways through vegetation or over bare ground (Figure 2). Young trees girdling generally starts at the soil line and can move up to around 6 inches in height. Voles are active year-round, day and night. Breeding can be year-round. Females will produce several litters in a year with peaks in the spring and fall.

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Figure 2. Burrow system entrances for pocket gophers, ground squirrels and meadow voles. (Photos: UC ANR)

Figure 3. Jackrabbit bark gnawing. (Photo: UC ANR)

Above-Ground Vertebrates

Jackrabbits can gnaw the bark off of young tree trunks (Figure 3). This scratching will be higher than what voles generally cause. Jackrabbits also eat buds and young foliage within their reach and occasionally chew on irrigation lines. Jackrabbits may seek refuge under brush or in sparsely vegetated cover, often on orchard margins, moving in to feed in the early morning and early evening. Damage will occur more often in winter and early spring.

Large vertebrate pests like deer and coyotes don't live in the orchard. They often come into orchards from nearby foothills, riparian areas or wild lands. Deer often browse orchard leaves (Figure 4), feeding mostly at night. Coyotes often chew on irrigation lines, causing substantial localized damage when present.

EFFECTIVE CONTROL OPTIONS FOR VERTEBRATES PESTS

Approaches for the management of vertebrate pest include habitat modification, trapping, rodenticides and burrow fumigation. Because populations adapt to different strategies, employ multiple techniques over the life of an orchard. The most appropriate approaches for a given operation depend on funds and supplies, labor, orchard scale and pest population size. Figure 5 illustrates this point. It shows sample calculations for costs of gopher control. Fumigation by aluminum phosphide is the cheapest approach for limited applications, but because traps are re-usable, after a few days of trapping, the cost to catch each gopher is less with traps than with aluminum phosphide. The PERC machine requires a significant upfront investment, but can make economic sense when managing multiple orchards.

Burrowing Vertebrate Pest (Rodents)

Habitat modification is the first step to minimize vertebrate pest build up. Removal of large brush piles and debris reduces habitat for ground squirrels and jackrabbits. Limiting orchard floor vegetation growth can help limit build up of pocket gophers, voles and jackrabbits, but must be weighed against the advantages of cover cropping. The risk of vole damage is significantly reduced by strip weed control 3 feet from the tree trunks.

To proactively minimize rodent build-up before significant damage occurs:

- *Watch the perimeter*. Monitor for and manage populations on the orchard periphery before they can move in and establish themselves in the orchard interior.
- *Focus efforts ahead of breeding spikes*. Reducing the parent population means reducing potential off-spring. For gophers, trap in the late winter and early spring. For ground squirrels, focus on late winter through early spring.

Figure 4. Deer browsing damage. (Photo: UC ANR)

Trapping is highly effective for controlling gophers and moderately effective for ground squirrels. It is not

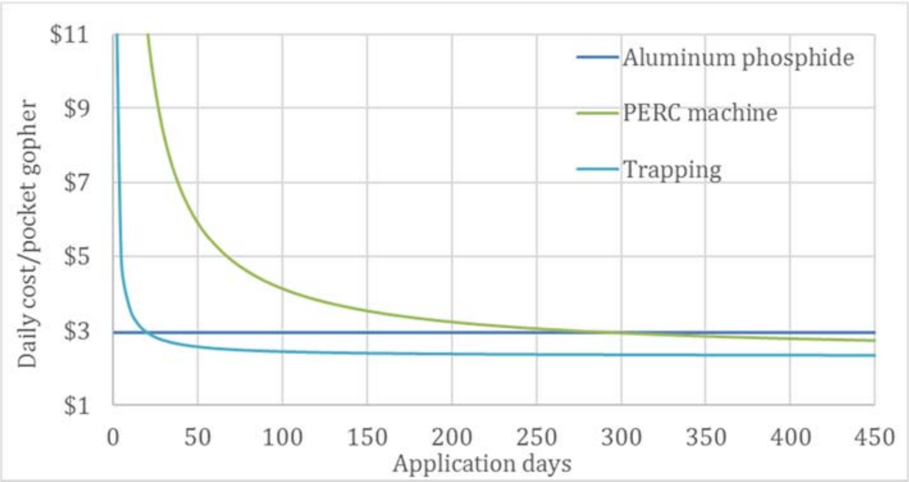

Figure 5. Comparison of cost per killed gopher over days using different techniques. (Image: R. Baldwin)

usually practical for vole control because populations are often too numerous. Though trapping can be time-consuming, the cost is generally offset by the effectiveness. Research has found ways to reduce time spent deploying and checking each trap, and increase effectiveness.

- *Trap ahead of breeding spikes*.
- *Set traps in active burrows*. Look for darker, freshly disturb soil.
- *Use the most effective trap*. For gopher management, head-to-head research found the Gophinator, available online, caught more gophers than the more widely used Macabee trap (Figure 6). This appeared to be because the Gophinator out-performed the Macabee with mid-sized and larger gophers. Modifications can be made to Macabees to catch a wider range of sizes.
- *Don't spend time covering trap holes*. Trials found covering trap holes slightly increased gopher trap efficiency in spring and summer, but did not increase the number of gophers captured per day given the increased amount of time spent setting and checking covered traps (Figure 6). Covering traps had no impact on capture rate or efficiency in fall.
- *Acclimate ground squirrels to traps before setting them*. Live-capture wire traps work best if prebaited for a few days before setting the trigger mechanism. Live-captured animals must be euthanized humanely via shooting or carbon dioxide gas. Body gripping traps, such as the Conibear 110, at the entrance of burrow systems are also commonly used for ground squirrels. Traps must be checked daily according to the California Department of Fish and Game Code.
- *Don't worry about scent with pocket gophers.* Wearing gloves to avoid transferring human scent to the trap has not been found to effect trap catch rates.
- *Wait one to two weeks between trapping efforts.* It can be a week or more between gopher mounding events. A little waiting will make the gophers you missed the first time easier to find the second time.

Rodenticides can be used by inserting into tunnel systems, spot placing, broadcasting or within bait stations, depending on the target pest's burrowing and feeding habits and applicable regulations.

First-generation anticoagulants (e.g. chlorophacinone, diphacinone) can be used to manage ground squirrels, voles, jackrabbits, and pocket gophers, although they are often not very effective against gophers. First-generation anticoagulants require multiple feedings to work; as such, multiple applications are required. Anticoagulant bait can be highly effective against ground squirrels, especially for large populations, and especially when used in the late spring and early summer, as their diet is shifting away from vegetation and before tree nuts are available to eat. Bait stations are the most common form of bait delivery in orchard systems. Spot treatments may be more economical for smaller populations but cannot be used within an orchard during the growing season.

The acute toxin zinc phosphide can be effective against ground squirrels and voles as well. It is applied via spot treatment or broadcast application, but again, it cannot be used within the orchard during the growing season. Strychnine is by far the most effective rodenticide for pocket gopher control, but it has become less available in recent years. Application is made through direct placement into the burrow system via hand application, an all-in-one probe and bait dispenser, or through a tractor-drawn burrow builder. Pocket gophers can become resistant to strychnine if it is used repeatedly as the only management tactic. All rodenticides are considered restricted-use products when used in production agriculture settings.

Burrow fumigation is another management option. Fumigants must stay in the burrow system to be effective, so proper soil moisture and no soil cracking are critical. Fumigants are generally not effective against voles because their tunnels are to shallow. Nor are they effective against ground squirrels when they are hibernating because they seal off entrances to their nesting chambers.

There are several fumigant options which have varying degrees of efficacy. Aluminum phosphide is effective in controlling ground squirrels and pocket gophers. Pellets or tablets dropped into burrows react with moisture in the burrow to create a toxic gas. For ground squirrels, burrow fumigation is most effective around 3 weeks after the first emergence from the burrow (late winter to early spring, depending on location), before the females have their litter.

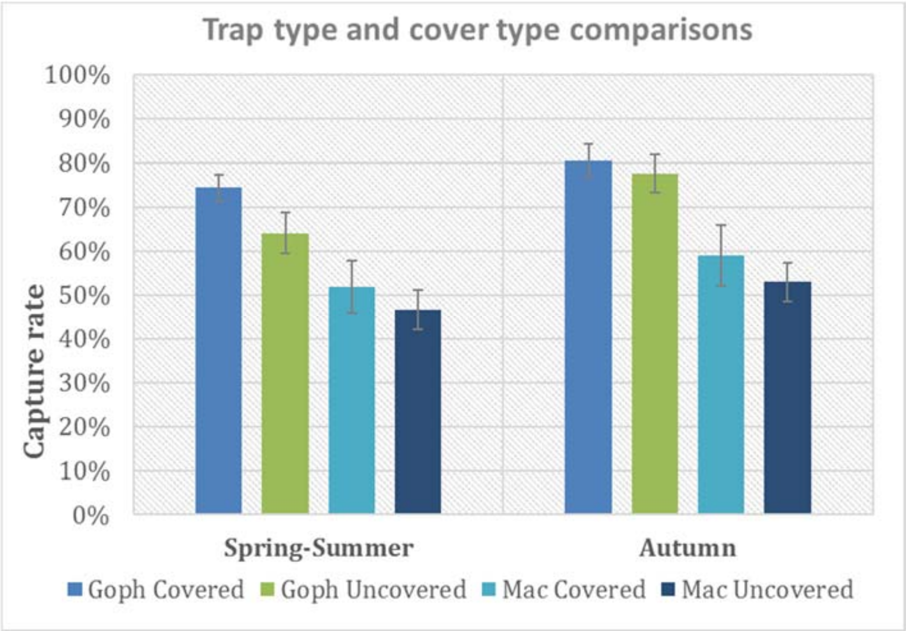

Figure 6. Comparison of gopher captures using Gophinator and Macabee traps, covered and uncovered, at different times of year. (Image: R. Baldwin)

Gas cartridges are not very effective against gophers because they seal off their tunnel when they detect smoke and gas. Gas cartridges have been effective against ground squirrels.

Carbon monoxide-generating machines such as the Pressurized Exhaust Rodent Controller (PERC) inject pressurized carbon monoxide exhaust into the burrow system which asphyxiates the pest. Research has shown the PERC machine to be moderately to highly effective against ground squirrels but only moderately effective for pocket gophers. Lower effectiveness and higher costs may potentially be offset by the speed at which acreage can be treated, especially for large orchards or high pest populations.

Above Ground Vertebrates

Habitat modification for deer and coyotes is highly impractical because the animals are capable of traveling long distances and do not live inside the orchard.

Exclusion by fencing is the most effective management tool for above-ground vertebrate pests, but is very expensive. Near foothills or riparian habitats deer herd size and associated damage are often significant enough to warrant the expense. When managing jackrabbits and voles it can be effective to use trunk guards in a young orchard. For jackrabbits they need to reach at least 2.5 feet above ground for the trees protection. Trunk guards are far more effective against voles when placed at least 6 inches underground to ensure that they do not burrow under the device, thereby allowing access to the tree trunk from the inside of the trunk guard.

Chemical repellents work in some situations for jackrabbits and deer. Repellents typically involve the use of a product that elicits an unpleasant taste, a pain response, or a frightening odor. They are most effective when alternative food options are available. Treating all trees in an orchard with a repellent may be cost prohibitive, but treating trees on field edges regularly invaded by jackrabbits or deer can provide temporary relief from browsing damage.

Frightening devices that use flashing lights or loud noises are generally effective against deer or coyotes for only a few days.

Lethal removal via shooting is possible for coyotes, deer, and jackrabbits. No special permitting is needed to remove jackrabbits or coyotes by the owner or tenant, or employee thereof. However, a depredation permit from the California Department of Fish and Wildlife is required to remove deer. Such permits are difficult to obtain given their status as a game animal.

CONCLUSION

Vertebrate pests can cause significant damage in young orchards. Gophers are the most common concern, but depending on orchard surrounding’s, ground squirrels, meadow voles, jackrabbits, deer and coyotes can also cause problems. Ripping the orchard before planting, early and consistent monitoring and management of invading burrowing pests, and, where necessary, large vertebrate exclusion will help ensure healthy, vigorous and uniform young orchard development.

ADDITIONAL RESOURCES:

Ground squirrel best management practices. groundsquirrelbmp.com

Vertebrates section of Integrated Pest Management for Almonds
anrcatalog.ucanr.edu/Details.aspx?itemNo=3308

Vertebrates section of Integrated Pest Management for Walnuts
anrcatalog.ucanr.edu/Details.aspx?itemNo=3270

Vertebrate Pest Control Handbook
vpcrac.org/about/vertebrate-pest-handbook

Vertebrate Management in Young Orchards (Presentation Video)
youtube.com/edit?o=U&video_id=g-3lcV6MFlQ

How to Trap Pocket Gophers in an Orchard (In-Field How-To Video)
youtu.be/iDW0l6eeG0M

Pests and Diseases in Young Orchards

Katherine Jarvis-Shean & Dani Lightle

INTRODUCTION

Because trees in young orchards have not yet set a commercial sized crop, the primary pests and diseases to be concerned with are those that interfere with the architecture, strength, growth and long-term health of the tree, rather than those that infect or feed on nuts. The primary pests are moths or borer insects that interfere with the growth of scaffold branches, or the function and strength of trunk and scaffold wood. Diseases include fungi and bacteria that kill branches and scaffolds, or stunt or kill trees by weakening their root systems.

This section is meant to outline preventative actions to avoid the pest and disease problems discussed, and help identify pests and diseases if they do occur in a young orchard. However, pesticide treatment will not be discussed in detail, because the rapid changes to available products, new chemistries, allowable use and other regulations could quickly make such details incorrect once this handbook is published. For more information about treating particular pests and diseases, see http://ipm.ucanr.edu/PMG/selectnewpest.almonds.html for almonds and http://ipm.ucanr.edu/PMG/selectnewpest.walnuts.html for walnuts.

BRANCH AND TRUNK PESTS

Larvae from two different moth species are a concern in young almond orchards. In the spring, these larvae will bore into or near the tip of the shoot, killing the growing point of the branch. Watch for this tip dieback, called "shoot strikes" (Figure1). If you see shoot strikes, follow up by cutting the shoot lengthwise and looking for

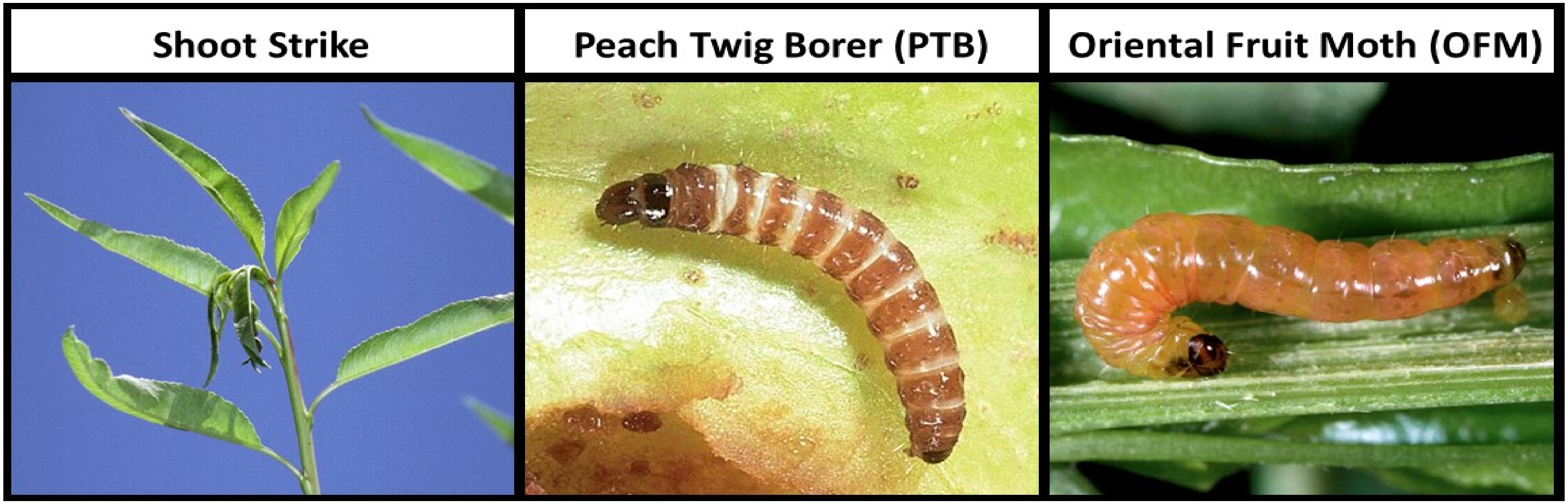

Figure 1. Shoot strike to look when monitoring and PTB & OFM larvae that may be found inside.

Figure 2. American plum borer frass near a pruning wound in a young almond tree. Photo: UC ANR

larvae. Peach twig borer (PTB) (*Anarsia lineatella*) have a dark body and black head. Oriental fruit moth (OFM) (*Grapholita molestra*) larvae are white or pink with a brown head. Scout for shoot strikes the first April after planting. Consider a May spray if you have more than 4 shoot strikes per tree. This threshold could be more or less based on the abundance of growth and scaffold options. PTB strikes generally occur earlier in the growing season but the damage looks similar so it is better to identify the larvae than to rely on the timing of damage (Figure 1).

Wood borers generally cause problems in young orchards when they bore into wood that has already been damaged by sunburn or shaker barking. Larvae tunnel and feed beneath the bark, further damaging wood, and may provide an entry point for infection by fungi like *Botryosphaeria* and *Ceratocystis*.

In almonds, the primary tree borers are Prune limb borer (*Bondia comonana*) and American plum borer (*Euzophera semifuneralis*). Monitor young almond orchards in the spring and summer for small piles of reddish orange frass (larva excrement) left by the borers and amber gumming produced by the tree in response to wounding (Figure 2). Look especially near pruning wounds and in scaffold crotches, as well as around graft unions, crown galls or shaker damage. Minor damage will typically callus and heal over, however if populations are deemed heavy enough, spray treatments are available.

In walnuts, the primary tree borer is the Pacific flatheaded borer (*Chrysobothris mali*). It is rare for Pacific flatheaded borers to attack healthy trees. To prevent injury that would encourage borer attacks, paint walnut trees shortly after planting with diluted white interior latex paint (usually 50% paint, 50% water). Any part of the trunk that is not shielded by a tree guard should be painted. Spraying pesticides for Pacific flatheaded borer is not recommended.

BRANCH AND TRUNK DISEASES

A number of pathogens that can cause cankers to grow on the branches of young trees. A canker is a patch of dead wood that was killed by a fungus or bacteria. Branch cankers are especially undesirable in a young tree because they can kill whole scaffolds, and even grow down into the trunk, delaying peak productivity or shortening the tree’s lifespan. Branches with cankers may have yellow, small or dead leaves, sunken or shriveled wood and, in almonds, gum balls or running sap called “gummosis”. For one of these diseases to take hold, three things must be present – the susceptible host (the tree), the disease inoculum (bacteria or fungus), and environmental conditions that allow successful infection of the disease.

Fungi that commonly cause cankers on almonds include Botryosphaeria, Ceratocystis, Eutypa, and Phytophthora. The primary bacteria that can cause branch cankers is bacterial canker (Pseudomonas syringae), particularly in sandy soils with ring nematodes and replant situations. Verticillium wilt might be confused with a branch canker initially because it generally only kills one or two branches on a tree, but it is actually caused by a soil borne fungus.

Figure 3. Gum balls on almond trunk often indicate band canker. Photo: UC

Verticillium wilt can be distinguished by discolored vascular tissue when examining a cross-section of the branch.

In young walnuts, branch cankers are rare. Botryosphaeria canker will sometimes infect walnut pruning wounds on young trees, especially if the new orchard is near a source of inoculum, like an old, infected orchard or a riparian area.

Branch cankers may occur when pruning cuts are wet from rain or irrigation and exposed to fungal spores or bacteria before they can heal. To avoid branch cankers, keep irrigation water off tree trunks and limbs and time pruning cuts so they heal before rain event, especially in orchards that are adjacent to significant inoculum loads (i.e. lots of bacteria or spores), such as older diseased orchards, riparian areas, old wood lots or roads lined with unhealthy ornamental trees. There are trials underway to test sprays and paints to apply to pruning wounds to prevent infection. Traditional pruning paint does not increase wound healing and is not recommended.

Pathogens can also infect healthy tissue through wind cracks. This is more common in almonds than walnuts. Space scaffolds up and down the trunk to avoid weak attachment points that may cause scaffolds to split from the trunk. Tying trees can reduce such cracks and wind breakage. Care must be taken to pick the right rope that will not dig into and girdle the secondary scaffold branches.

Trunk cankers are rare in young orchards. Almond can be infected with band canker (Botryosphaeriaecaea), which causes gummosis on the trunk, usually in bands of sap gum balls (Figure 3). The fungus generally gets into the tissue through growth cracks in vigorous 3rd to 6th leaf trees. The odds of getting band canker may be reduced by managing water and nitrogen to discourage overly vigorous growth, and by keeping water off tree trunks.

ROOT PESTS

Nematodes are the main pest that can decrease the vigor of young almond and walnut trees. The three major species of concern for almonds and walnuts are root knot (*Meloidogyne spp*.), root lesion (*Pratylenchus vulnus*) and ring (*Mesocriconema xenoplax*) (Figure 4). Above-ground, the tree will be somewhat stunted and may look mildly stressed. Soil and root samples can then diagnose if nematodes may be contributing to lack of vigor. Prevalence of the different species varies by region, location, soil type and previous plantings on the site.

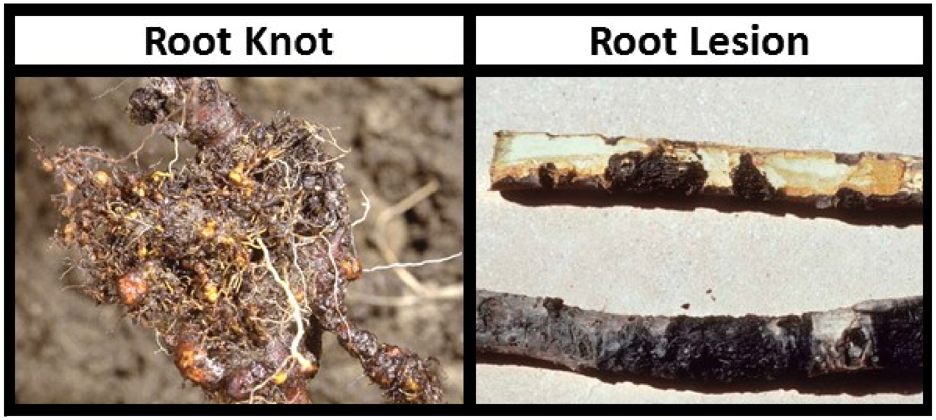

Figure 4. Root knot nematode damage on peach rootstock and root lesion nematode damage on walnut rootstock. Photos: UC ANR

Pre-plant nematode sampling, site preparation (fallowing the field or fumigation) and appropriate rootstock selection are the most reliable steps to avoid nematode damage. Once trees are planted, treatment options are limited. Pesticides are labeled for killing nematodes in planted orchards, however, in UC research trials, population decreases using these products were inconsistent.

CROWN & ROOT DISEASES

Crown gall, Armillaria root rot and Phytophthora are the main root diseases that can hinder or halt the growth of a young orchard. Root diseases often take many years to severely infect and kill root or crown tissue, so symptoms of these infections may not be noticed until the 3rd or 4th leaf of an orchard's life. Depending on the extent of the infection and tree decline, in a young orchard it is sometimes more efficient to remove and replant a tree than treat it.

Crown gall is caused by a bacterium (*Agrobacterium tumefaciens*) that enters wounds, causing galls that interfere with the movement of water and nutrients. Infection of the "crown" (on the trunk near the soil line) is more common in walnut (Figure 5), while roots are more typically infected in almonds.

Figure 5. Crown gall at the base of walnut.

Preventative actions to avoid infection can include removing old roots from the previous orchard, soil fumigation, purchasing trees from a reputable nursery, dipping or spraying roots at planting with a biological control agent like Galltrol A®, and avoiding root injury. If walnut crowns become infected, removing galls is very labor intensive. It requires excavating the soil to expose the galls (generally done with compressed air), flaming or applying bacteriocide to the gall margins to kill any remaining bacteria, and leaving the wound uncovered for at least a year.

Armillaria root rot (oak root fungus) (*Armillaria mellea*) is caused when a fungus spreads from dead tree roots into healthy trees. Follow appropriate site preparation practices, including thorough removal of old roots. If planting into a known Armillaria site, select a rootstock with resistance to Armillaria. If trees become infected with Armillaria, remove the tree and all roots as quickly as possible, as well as surrounding healthy trees (these roots may also be infected), to slow spread to nearby healthy tree roots.

Phytophthora are water-borne pathogens similar to a fungus that cause crown and root rots (Figure 6). Crown rot can be found by removing the bark at the crown and looking for dark cankers. Site preparation to encourage good soil drainage and irrigation system design to allow irrigation sets of 24 hours or less, with time for soil to dry between sets, will decrease the likelihood of this disease. If trees are identified as being infected with *Phytophthora*, re-evaluate your water management practices to reduce saturated soil conditions and consider adjusting irrigation application to minimize water pooling around the trunk. Preventative treatment options are available, but should not be relied upon without also following good water management practices.

CONCLUSION

Pest and disease management in young orchards is important to establish the desired tree architecture, ensure early growth, and protect the long-term health of the tree. Monitoring for and managing insects that bore into shoot tips, scaffolds and trunks are key to above-ground early pest management. Timing pruning to avoid rain events, managing tree vigor and avoiding wetting tree trunks can decrease likelihood of above-ground disease infection. Root pests and diseases are best prevented with proper site preparation, rootstock selection and water management.

ADDITIONAL RESOURCES:

Almonds http://ipm.ucanr.edu/PMG/selectnewpest.almonds.html
Walnuts http://ipm.ucanr.edu/PMG/selectnewpest.walnuts.html

Figure 7. This almond tree first yellowed, then collapsed from *Phytophthora* infection. Photo: UC ANR