Irrigation and Nutrient Management of Young Orchards

Water Efficiency Technical Assistance Program

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Contents

Abstract:

In the Irrigation and Nutrient Management of Young Orchard handbook, we delve into the intricacies of irrigation and nutrient management strategies tailored specifically for young orchards, exploring key considerations, best practices, and the importance of proactive management in achieving optimal outcomes.

This guide focuses on the best irrigation and nutrient management practices for young orchards in the San Joaquin Valley. As the acreage of young orchards has expanded due to newly established plantings and the replacement of old, unproductive trees, it is crucial to address their sensitivity to water limitations. Growers often use calculated crop evapotranspiration for irrigation, but the crop coefficients are designed for mature, full-canopy orchards. The water use of young trees changes rapidly both from year to year and within a single season. Understanding the unique water requirements of young trees and implementing advanced irrigation strategies ensures healthy orchard development, optimal water use, and long-term productivity.

Young orchards have distinct nutrient requirements compared to mature orchards. During the initial growth stages, trees allocate significant energy toward root development and canopy establishment. Essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) are vital for promoting vigorous root growth, foliar expansion, and overall tree vitality. Additionally, micronutrients like iron (Fe), zinc (Zn), manganese (Mn), and boron (B) are critical for enzyme activation, photosynthesis, and overall metabolic processes.

Implementing best management practices for young orchard irrigation and nutrient management is essential for coping with recurring drought and complying with Irrigated Lands Regulatory Program (ILRP) and Sustainable Groundwater Management Act (SGMA) regulations. This handbook provides the necessary insights and practical guidance to help growers achieve these goals and enhance the productivity and sustainability of their young orchards.

Chapter 1: Principles of Irrigation Management in Orchards

Abdelmoneim Mohamed, UCCE Irrigation and Soils Advisor

Proper irrigation management during the early stages of orchard development is vital for the long-term health, growth, and productivity of the trees. Proper irrigation ensures that trees receive an adequate supply of water, which is crucial for photosynthesis, nutrient uptake, and overall vigor. Insufficient irrigation can lead to stunted growth, shallow root development, delayed production, and increased susceptibility to pests and diseases. On the other hand, over-irrigation can cause root suffocation, nutrient leaching, and waterlogging, which can also adversely affect tree health and productivity.

Crop water use changes drastically between early years and within the season. Good irrigation efficiency includes how well the irrigator matches water applications to crop water needs.

There are main three irrigation scheduling methods for orchards: irrigation scheduling based on soil, plant, and weather measurements.

Weather-based method:

Many growers are using calculated Evapotranspiration (ET_C) reports available through University of California Cooperative Extension county-based offices. This method is based on replacing the amount of water used by the crop since the last irrigation. ET_C is the losses from soil (evaporation) and canopy (transpiration) (Figure 1) and is calculated by multiplying reference crop ET_o and crop coefficient (K) [$ET_C = ET_o \times K_C$]. Studies have found that ET is linked to how much ground or canopy they cover. For example, crops with full canopy coverage, like alfalfa fields, have the highest ET rates, slightly lower than if there was just water sitting out in the open. Scientists have used this information to create a weather measurement system. When this system is set up in a grassy area that is well-watered, it can accurately estimate the maximum daily ET. This estimation, called ET_o, is reported daily by weather stations. K_C is the specific crop coefficient for a given stage of growth. There is a chance to over-irrigate using this method since K_c values are outdated and used for different management practices and different rootstocks than what we currently have. This can be avoided by using some sensors currently available in the market to measure actual ET in your orchard. We will discuss how to adjust ET reports for young trees. After that, you can use the following equations to calculate application rate, irrigation set time, and applied water:

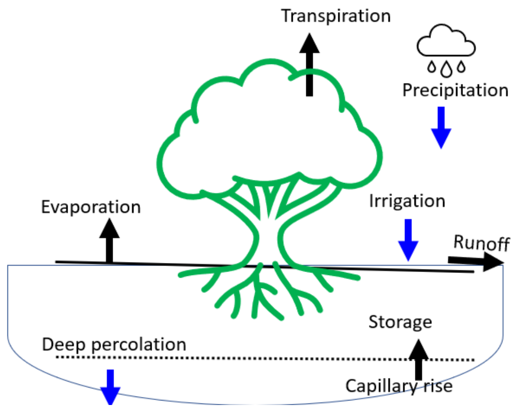


Figure 1: Evapotranspiration process and soil water balance

$$Microsprinkler\ system\ application\ rate\ (in/hr) = \frac{Avg\ tree\ flow\ rate\ (gph)}{Tree\ spacing\ (ft^2)} \times 1.6$$

$$Irrigation\ set\ time\ (hrs) = \frac{Crop\ water\ use\ (in/day)}{Application\ rate\ (in/hr)}$$

$$Applied\ water\ (in) = \frac{Pump\ flow\ rate\ (gpm) \times irrigation\ set\ time\ (\min)}{Irrigated\ orchard\ area\ (acre)\ \times 27{,}152}$$

These calculations need to be adjusted to the covered area by your irrigation system (Table 1).

Table 1: Percent of wetted area for different irrigation systems

Irrigation system	% of wetted area
Single line drip	20 – 30%
Double line drip	20 – 50%
Micro-sprinkler	30 – 60%

Plant-based method:

Plants have different ways to regulate the equilibrium between their water uptake and requirement. Consequently, the plant-based methods of irrigation scheduling are based on the assessment of one or multiple such mechanisms. Besides checking leaves by yourself for curl or wilt, there are many sensors available to detect plant water stress such as dendrometers, infrared radiometers, sap flow gauges, stomatal conductance porometers, leaf turgor probes and remotely sensed based tools. The sooner these sensors can detect water stress, the better they are in irrigation scheduling decision making. Out of the many plant-based irrigation scheduling sensors, the pressure chamber (Figure 2), which measures the tension of water within the plants, has shown its reliability as a physiological indicator of water stress in trees and vines. This method tells when to irrigate and to check on the other methods (weather and soil). Weather- and soil-based irrigation scheduling methods tell how much irrigation is required but you need to make assumptions about the root zone depth. Thus, plant-based methods can determine if those assumptions are accurate. Pressure chambers measure the force required in a plant for the water to get pulled from the soil up through the leaves. This can be done by covering the sample leaf with a foil-laminate bag for at least ten minutes, to reduce the measurements' error to 0.5 bar, before being removed from the tree. This measurement happens during midday because the water potential stays constant at its highest deficit for the day. Then while the leaf is in the aluminum bag inside the chamber, the pressure required to force water out of the stem is equal to the water potential and is given in metric units of pressure (bars). The drier the soil is, the more tension there is in the plant, thus requiring more pressure to force water out of the stem. Choosing a healthy and representative tree for your measurements is the key to accurately monitoring plant water stress. Select 3 or 4 side-by-side rows of uniformly growing trees in a representative area, then choose 3-4 trees for SWP measurements using a rational schedule (measure SWP in a different row each time).

Figure 2: The Pressure Chamber

Soil-based method:

The look and feel method of your soil used to be the most common field method to check soil moisture, but this method takes time and experience to train yourself and it is subjective especially when soil is dry or wet. There are many soil moisture sensors available in the market, sensors that can tell you when to irrigate (Tensiometers, Granular matrix Sensors). These sensors measure how strongly water is held by soil particles: the drier the soil, the higher the tension, and the more difficult it is for a plant to extract water. The reading provided by these sensors is in cb or kPa. On the other hand, some sensors tell you how much and when to irrigate (Neutron Probe, Resistance, Capacitance, Time Domain Reflectometry (TDR)). The Neutron Probe will give you the most correct answer while the others will give you a trend that is usable for irrigation scheduling.

When we talk about how much water soil can hold for plants, we use three terms. The first term is "field capacity" (FC). FC is the water that is left in the soil after most of it has drained away, usually about 3 to 4 days after watering. The second term is "permanent wilting point" (PWP). PWP is when the soil has so little water left that plants cannot take it up anymore. And the third term, "Total available water" (TAW), is the difference between field capacity and permanent wilting point, (Figure 3). TAW is the space required to manage your soil water depletion. Deciding how dry you are okay with the soil getting before irrigation, is called management allowable depletion (MAD) and is usually set around 50% (table 2). Depleting the soil water beyond this point will negatively impact plant growth and yield.

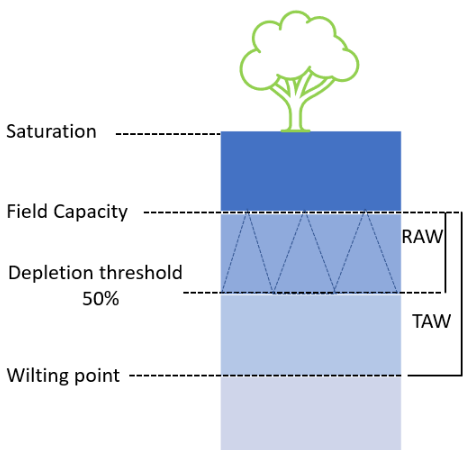


Figure 3: Soil-based irrigation scheduling

Table 2: Percent of allowable depletion for different tree crops

Crop	Allowable depletion (%) non-stress
Citrus	50
Apples, Cherries, Pears	50
Apricots, Peaches, Stone Fruit	50
Avocado	70
Kiwi	35
Olive	65
Walnut	50
Almond	40
Pistachio	40
Grapes	65

The type of soil you have affects how much water it can hold (table 3).

Table 3: Total available water for different soil textures

Soil texture	**Soil water content**			**TAW**
	SAT	FC	PWP	
	Vol%	Vol%	Vol%	in/ft
Sand	36	13	6	0.84
Loamy sand	38	16	8	0.96
Sandy loam	41	22	10	1.44
Loamy	46	31	15	1.92
Silt loam	46	33	13	2.4
Silt	43	33	9	2.88
Sandy clay loam	47	32	20	1.44
Clay loam	50	39	23	1.92
Silty clay loam	52	44	23	2.52
Sandy clay	50	39	27	1.44
Silty clay	54	50	32	2.16
Clay	55	54	39	1.8

Example: If you have 2nd leaf walnut in clay soil, then the available water at 50% = 1.8/2 = 0.9 in/ft. For 2 ft root zone = 0.9 × 2 = 1.8 inches of net irrigation requirement. Then, you must account for the irrigation system's efficiency. Gross irrigation requirements = net irrigation requirements/system application efficiency.

No irrigation scheduling method is perfect. Using just one irrigation scheduling method is still effective but using two is even better. However, combining all three methods is recommended, as it gives you more confidence in making informed and effective water management decisions.

Chapter 2: Principles of Nutrient Management in Orchards

Mae Culumber, UCCE Nut Crops Farm Advisor

There are 17 essential nutrients for plant growth. All are needed in different quantities: if any are deficient, plant development and production will be impaired. Nitrogen (N), phosphorus (P), and potassium (K) are considered the primary plant nutrients as these are needed in the greatest quantity and most commonly deficient. For tree crops, N is the nutrient of key importance as all living plant cells need it to synthesize amino acids into proteins and other compounds like chlorophyll, which are vital to plant growth and production. Nitrogen deficiencies make fewer flowers and therefore set a smaller crop, but excess N can also have detrimental effects, including symptoms of toxicity or a shift to more vegetative growth over fruitful production. As the most abundant cation in plant cells, K is nearly equally important as N. Adequate K levels are critical to maintaining stomatal conductance for water transport, the activation and regulation of enzymes, protein synthesis, and the rate of photosynthesis in plants. Deficiencies have been associated with increased sensitivity to drought stress, susceptibility to frost damage, and vulnerability to disease. Macro- and micronutrients are provided by the soil (or by foliar application), and all have a critical role in plant metabolism. The micronutrients needed in much smaller amounts (Zn, Cu, Fe, Mn, and B) are critical to many aspects of flowering, including pollen formation and fertilization, among many other functions.

Many factors influence soil nutrient availability to orchard crops including soil texture, organic matter content, pH, salinity, irrigation management, as well as fertilizer type, form, and application method. These aspects should be taken into consideration when developing an orchard nutrient management program. An effective nutrient management program also takes into consideration crop nutrient requirements and uptake patterns, and the ability to adjust plans based on information gained from soil and tissue nutrient analyses. Nutrient requirements for individual crops are dependent on the needs of the developing crop and growth demand. Most California N and K management plans are based on nutrient removal by the crop. The rates and timing of other macro- and micro-nutrients consider soil characteristics, cropping history, tissue analysis, and field observations. Updated information about N requirements for the developing crop can be found in Nitrogen concentrations in harvested plant parts – updated 02/2024.

Leaf nutrition

Tree tissue analyses are a useful tool for diagnosing nutritional problems and monitoring the fertilization program. Nutrient concentrations change through the growing season and within different parts of the plant. It is essential to follow plant tissue sampling guidelines for the specific orchard crop. These guidelines can be found in the 'Plant

Tissue and Sampling in Orchards and Vineyards " document located on the CDFA Frep Fertilization Guidelines webpage: Orchard_Tissue_Sampling.pdf

Table 4 Mid-summer leaf sample and fruit hull critical values for almond

	N %	P%	K %	BORON (HULL) PPM	ZN PPM
ADEQUATE	2.2 – 2.7	0.10 – 0.3	>1.4	80 – 150	>15
EXCESSIVE	>2.7		>1.6 – 1.8	>200	

Mid-summer tissue analyses are important for making determinations about end of season fertility management, and next season's nutrient management plan. Tests can also help determine if foliar applications are needed to rapidly correct deficiencies.

Annual N, P, K, and Zn fertility rates and timing: *Example rates for mature bearing almonds assuming a 2500 lb crop on sandy loam soils and 85% efficiency. The lb/ac values for N, K, and B are for the actual lb of nutrients, not fertilizer. Application amounts will vary depending on nutrient source.*

Table 5: Annual N, P, K and Zn rates and timing for bearing almonds

Season		Nitrogen	Potassium	Boron	Zinc
Spring (Early March thru Mid-May)	% annual budget	50%	20%		0-50%
	lb./ac	~100 lb. N	~37 lb. K	*If very deficient a 0.2 -0.4 lb. actual B /acre foliar at **pink bud**	Foliar 5 lb. zinc sulfate in 100 gallons /acre
Summer (Mid-May-Early June)	% annual budget	30%	30%		
	lb./ac nutrient	~60 lb. N	~56 lb. K KNO_3 (can be applied as foliar), K_2CO_3, KTS		
Post-harvest/dormancy	% annual budget	20%	50%	100%	50-100%

	lb./ac	~40 lb. if July tissue analysis < 2.5%	94 lb./ac banded 4-5 ft from tree trunks, sources: potassium sulfate (54% K_2O) or potassium chloride (63% K_2O), compost	Foliar 0.2 -0.4 lb. B /acre in 100 gallons *If very deficient combine foliar with a soil application: 2-4 lb. actual B/ac, or up to 1.5 lb./ac actual B through fertigation	Foliar 5 lb. zinc sulfate in 100 gallons /acre October

Nitrogen notes

- First application timing is soil dependent (sandy soils wait for leaf out; clay and loam soil can apply earlier)
- 80% should be delivered before hull-split, 20% in the post-harvest – Majority prior to kernel fill
- Frequent smaller applications are best
- Leaf Tissue Based Adjustment – If April N concentrations exceed 3.5%, it is likely that June fertilization can be omitted
- Concentrations above adequate levels may not increase yield but can increase fertilizer costs and hull rot

Potassium notes.

- Potassium is important for enzyme activation, photosynthesis, movement of sugars, synthesis of proteins and starch, and stomatal conductance in trees.
- 72 lb. of elemental potassium (K) for every 1000 kernel pounds is equivalent to 92 lb of potassium oxide (K_2O)
- Soils with lower exchange capacities need multiple smaller applications throughout the year.
- Heavier soils can apply large “slugs” of potassium chloride or potassium sulfate in the dormant period and small in-season doses if needed
- There are benefits and risks with in-season applications. Potassium nitrate is about 13% N and can be applied as a foliar spray or fertigated. Potassium carbonate can be used to help buffer acidic soils. Potassium thiosulfate acidifies the soil but commonly causes phytotoxicity when over-applied

Boron and Zinc notes

- Both Zn and B can be absorbed through the leaves, stored over winter, and moved to the buds for use at almond bloom.
- To correct a very B deficient orchard, a combination of foliar and soil applied B fertilizer may be needed.
- **Tank mixes of Zn and B:** Acidify the spray solution to pH 5 before adding zinc using an organic acid-based material (for example, Mixwell™ or Tri-Fol®) and not a phosphate buffer (will precipitate with zinc). Then add B.

Chapter 3: Water and Nutrient Management in Non-Bearing Walnuts

Abdelmoneim Z. Mohamed, UCCE irrigation and Soils Advisor

Walnut is currently grown on over 400 thousand acres in California with the majority of production concentrated in the Northern San Joaquin Valley (NSJV). The recurring droughts and climate change in California will likely increase the uncertainty in water supply to walnuts and other specialty crops. Good irrigation and nutrient management for young trees ensures healthier tree development, better resource utilization, and more resilient orchards in the face of climate change. Young walnut trees use less water than mature trees. Young walnuts have lower ET rates and grow rapidly within the season and from year to year. Among the irrigation scheduling methods discussed earlier, tree water status and soil moisture are more useful than ET reports in the first two months of planting. After that, ET reports need to be adjusted based on canopy size (discussed later). Stem water potential baselines are appropriate for both young and mature trees. You can use a pressure chamber to track and maintain the level of stem water potential between -4 to -8 bars from May to August, and then allow a bit more stress (-10 to -11 bars) to reduce late season shoot growth. This helps the green shoot tissue to mature into woody tissue, which can better handle cold temperatures during fall and winter (Fulton, A. 2013).

It is suggested to start irrigating first leaf trees using drip irrigation using two drippers, each one gallon per hour (gph), for each tree. This provides enough capacity to irrigate the newly planted trees adequately and precisely. This is cost effective when it comes to tight water allocation and weed competition. It is preferable to use button drip emitters that allow you to plug buttons when trees turn to third leaf. You may consider adding two to four 1-gph emitters in the mid-summer of the 1^{st} leaf or just prior the 2^{nd} leaf. In the 3^{rd} leaf, convert your irrigation system to micro-sprinkler. Another way is to customize a mini-sprinkler system by placing sprinklers close to the tree, within a few feet, and using caps to control the water spray area for the first two years. As the trees grow and their root systems develop, you can remove the caps and relocate the sprinklers further away.

When it comes to using ET reports for young walnuts, you can either use the historically developed ET_c, or % ET_C based on tree age or % midday canopy shading.

1) Historical ET_C

ET_c values were developed from research conducted in Tehama County to be used as a guideline (table 6). Site specific conditions need to be considered (weather, cultivars and rootstocks, irrigation system design, Orchard floor vegetation). You can note how rapidly water use changes within the season and from year to year.

Table 6: Historical ET values for young walnut

	1st		2nd		3rd	
	in/month	in/day	in/month	in/day	in/month	in/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	

2) Adjusting ET based on tree age as a function of mature tree ET

Consider the age of trees when deciding how much water they need, because water use rapidly increases in the first few years of planting. Table 7 provides a bi-weekly estimate of % ET based on tree age as a function of mature trees. Table 8 provides the percentage of ET_C that needs to be adjusted for young trees based on ET_C of mature trees. For example, if you have a weekly ET_C in a mature walnut orchard of 1.7 inch during first week of June then the 2nd leaf tree would require 1.7 x 0.5 = 0.85”

Table 7: Bi-weekly percent ET based on tree age as a function of mature trees

Date	1st leaf	2nd leaf	3rd leaf	4th leaf
Apr 1-15	15	35	70	100
Apr 16-30	20	40	75	100
May 1-15	25	45	85	100
May 16-31	30	45	90	100
June 1-15	30	50	95	100
June 16-30	35	50	95	100
July 1-15	40	55	100	100
July 16-31	40	60	100	100
Aug 1-15	45	60	100	100
Aug 16-31	45	60	100	100
Sept 1-15	40	55	100	100
Sept 16-30	40	55	100	100
Oct 1-15	35	50	100	100
Oct 16-31	30	45	100	100

Table 8: Adjusting ET based on tree age

Tree Age	Percent of ET_C or K_C for mature trees
1st leaf	30
2nd leaf	50
3rd leaf	85
4th leaf	100

3) Adjusting ET based on fraction (%) of midday canopy shaded area

After transplanting, the average PAR (measuring midday canopy photosynthetically active radiation interception) in orchards is 1%. Table 9 suggests ET_c changes 2% (41/20) per one percent reduction in canopy shaded area for trees smaller than 20 % midday shaded area. An estimated average canopy of 1% suggests a Kc adjustment of 2%. This means reducing the weekly crop ET report to 2%.

Table 9: Fraction of midday canopy shaded area as a percent of ETc for mature orchards

Fraction of midday canopy shaded area	% of ET_C for mature orchards
20	41
30	54
40	67
50	79
60	92
70	100

Example: If the weekly ET_C is 2.2" after considering system efficiency, then the adjusted ET = 2.2 x 0.02 = 0.044".

Several weeks after planting, the average PAR is 5%. Table 9 suggests ET_C changes 2.05% (41/20) per one percent reduction in canopy shaded area for trees smaller than 20% midday shaded area. An estimated average canopy of 5% suggests a Kc adjustment of 10%. This means reducing the weekly crop ET report to 2%.

Example: If the weekly ET_c is 1.7" after considering system efficiency, then the adjusted ET = 1.7 x 0.1 = 0.17". Gallons per week = [(0.17 x 27,154)/Trees per acre (90)] = 51 gal/week = 7 gal/day. If you have a drip irrigation system with 3gph, then irrigate in two sets of 9 hours every 3 to 4 days.

Nutrient Management of young walnuts

Fertilizer supply must match tree demand and root uptake and should be applied to the root zone. Fertilizer applications should be based on soil test recommendations and tree nutrient requirements, taking into account factors such as soil type, irrigation practices, and environmental conditions. Split applications of fertilizer throughout the growing season can help maintain steady nutrient availability and minimize the risk of nutrient leaching.

Nitrogen (N)

In the first year, nitrogen is the only nutrient that trees may need. N fertilization can be reduced or omitted in the first two seasons on fertile soils.

- **When**: Mid-spring and early summer
- **Type**: 1st leaf: It is recommended to use granular fertilizer, as the liquid fertilizer may burn roots as a result of high fertilizer concentration in the root zone. 2nd leaf: Liquid fertilizers (UN-32 or CAN-17)
- **Method**: Dry form or through fertigation
- **How much**: Table 10

When trees turn mature, you can use the Nitrogen Budget Worksheet

Table 10: Nitrogen requirements for young walnuts

Tree Age (season)	N application rate		
	(lbs/acre)	(lbs/tree)	(ox/tree)
First	10-20	0.2-0.3	2-5
Second	25-50	0.4-0.8	6-12
Third	50-100	0.8-1.5	12-25
Fourth	63-125	1-1.9	16-31
Fifth	75-150	1.2-2.3	18-37

Phosphorus (P_2O_5)

- **When**: During the dormant period in fall or winter
- **Type**: Triple superphosphate
- **Method**: Applying P fertilizer in 6-inch deep trenches is more effective than broadcast applications (Trenches should be 2 feet or more away from the trunk, depending on tree size, and within the irrigation wet zone) FREP.
- **How much**: For P fixing soils, applying 25 pounds of triple superphosphate per tree (11 pounds of P_2O_5) can alleviate phosphorus deficiency in trees aged 2 to 10 years for a minimum of 5 years.

Potassium (K_2O)

- **When**: During the fall to allow winter rains to move K into the root zone
- **Type**: Potassium chloride (KCl) or potassium sulfate (K_2SO_4)
- **Method**: Annual band of Potassium fertilizer on either side of the tree or supplied through fertigation
- **How much**: In most California soils, N is the only required fertilizer for newly planted trees. Potassium may be required for soils with very low K (Very sandy or K fixing soils). K deficient trees require a higher application rate (Annual band applications of 240 lb K_2O/acre have been recommended to K deficient trees grown on sandy soil. On heavier soils, up to 900 lb K_2O/acre may be required) FREP.

Chapter 4. Irrigation and Fertilization for Young Almonds

Cameron AT Zuber, Orchard Crops Farm Advisor

Appropriate irrigation management starts with determining when to begin irrigation at the start of the season. Once that is decided the amount needs to be determined, and then that amount is irrigated, checked, and repeated until the almonds enter dormancy.

Determining when to start

Almond trees are dormant during the fall and winter and do not require water. Once leaf emergence occurs in spring, the tree begins to transpire water from the soil. However, irrigation does not necessarily need to start at this time as seasonal precipitation has moistened the soil and normally can supply the water demands of the trees for a period.

How long this period lasts can be different each year, so it is best to determine when to start either using plant- or soil- based monitoring techniques.

Determining amount to irrigate

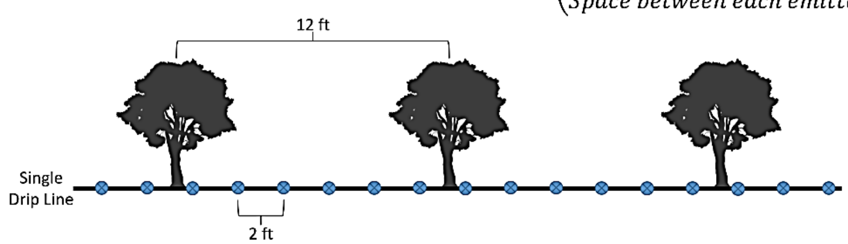
Determining how long to run the irrigation requires calculating the emitter output (e.g., gallons per hour) and water use (e.g., gallons) of a tree using equation:

Determining emitter output per tree can be easier, as one microsprinkler output can be assumed to be for one tree, or more difficult, as with in-line drip or solid set irrigation.

$$Hours\ run\ irrigation = \frac{Gallons\ per\ tree}{Emitter\ output\ per\ tree}$$

While the specifics of determining this cannot be discussed here, an example is provided in Figure 4.

$$Emitter\ output\ per\ tree = (One\ emitter's\ output)\left(\frac{Tree\ spacing}{Space\ between\ each\ emitter}\right)$$



$$6\ gallons/hour = (1\ gallon/hour)\left(\frac{12\ feet}{2\ feet}\right)$$

Figure 4. Equation (top) and example image (middle) and calculation (bottom) to calculate the emitter output for one tree with a single in-line drip irrigation system

To determine water use per tree, you can use the following calculation if using feet for row and tree spacing. If not using feet, then a different value for 0.623 needs to be determined:

$$Gallons\ per\ tree = (ET_C \times Portion\ Based\ on\ Tree\ Age) \times\ Row\ Spacing \times Tree\ Spacing \times 0.623$$

ET_C is the evapotranspiration for a mature crop. This can be calculated using an observed evapotranspiration (ET_o) from resources like a nearby CIMIS station and multiplying against an appropriate crop coefficient. Alternatively, various UC Cooperative Extension offices provide weekly reports of ET_C.

Young almond orchards use less water than mature almonds. As the ET_C is for a mature almond tree, the portion of this based off the younger tree age needs to be included. Rough approximations for the young almond portion of mature ET_C are in Table 11.

These calculations are a start as they can be further refined by including things like distribution uniformity, water hold capacity of the soil within the rootzone, measured light interception of canopy, or an allowable soil moisture depletion.

Table 11: Portion of mature almond evapotranspiration based on age of young almond orchard

Almond tree age (years)	Portion of ET_c of mature almond trees
1	0.40
2	0.55
3	0.75
4	0.90

Irrigate amount calculated

After calculations are performed, irrigate that amount. However, it is important to know that any method to determine irrigation has its caveats and should be checked with some sort of in-field monitoring.

Check amount was appropriate

There are many tools and methods available to monitor either plant water stress or soil moisture. Whichever one is picked normally provides lines on a graph or a subset of numbers on a given day. It can be a challenge to know how to use this information.

A way to use this information is to determine the range you wish to stay within. One end outside the range would be too wet and the other too dry. The value for these ends is based on the type of tool or method used to monitor irrigation, whether the soils in an orchard, the crop, the period within a growing season, and one's own comfort level.

For young almonds, there will be a transition between non-bearing and bearing, typically at year 3. When harvesting almonds the range for plant water stress or soil moisture can be more stressed or drier, respectively, leading up to harvest as an appropriate “dry down” period is needed for a consistent hull split which can result in a more consistent harvest.

Nutrients are needed in young almonds to support the growth of vegetation (i.e., wood and leaves). Once the tree becomes bearing, nutrients are needed both for supplying the baseline vegetative growth as well as for the harvestable crop.

While many nutrients and micronutrients are needed for healthy trees, nitrogen is the primary one of focus within agriculture. For nitrogen, considerations towards the type, amount, how often, and placement have variable importance for young almonds.

Type of nitrogen

To a plant in soil, nitrogen is nitrogen as non-available forms like urea or ammonium will be transformed to available forms like nitrate. However, how long this takes may be different. Availability can also be affected if certain materials are included in a fertilizer product that delays the release of nutrients to the soil, such as with slow-release fertilizers.

The types of fertilizer are more important when considering how they move through soil as some may move faster, or leach further past the rootzone, than other forms. Additionally, some fertilizer can affect the soil pH overtime. Soil pH can impact the solubility or availability of other nutrients in the soil. Of course, there is also cost as while nitrogen is nitrogen to the plant, that is not necessarily true to the wallet.

Amount of nitrogen

Guidelines for nitrogen amount can be seen in Table 12. The baseline is the amount needed to supply expected vegetative growth. If almonds are bearing a crop, then an additional amount should be included of 68 lb. of nitrogen for every 1000 lb. of almond kernels expected to be harvested per acre.

Table 12. Recommended nitrogen amount based on age of almond orchard. Source Nitrogen Best Management Practices.

Year	Nitrogen per acre (lb.)	
	Baseline	Additional
1	30	0
2	55	0*
3	65	68 per 1000 kernel lb.
4	55	68 per 1000 kernel lb.

** Some Year 2 almond orchards can have substantial yield. If so, follow Year 3 and 4 recommendations.*

These amounts can be refined based off of leaf nutrients from the prior year, amount of nitrogen in the soil, and amount of nitrogen in irrigation water. If nitrogen is present in irrigation water, a constant of 0.23 can be multiplied by the nitrate-nitrogen (NO_3-N) if in ppm. Conversion will calculate pounds of nitrogen per acre inch of water which can be subtracted from the total amount.

Additionally, these amounts do not account for other management practices that may affect nitrogen availability in the soil such as whole orchard recycling which can affect availability due to the higher carbon in the soil.

How often

Many smaller applications of nitrogen are preferred than applying large amounts less often. This avoids lanky growth which can create a weak canopy structure or "burning" the tree which reduces plant function.

Many smaller applications is often called "spoon feeding" and for young almonds it is best to apply no more than one oz of nitrogen per tree for any application including what is in the irrigation water. Start applying nitrogen when there is visible growth of new shoots and leaves.

Placement

"Right place" is a principle for nutrient management as a tree can only use nutrients if they are within the rootzone of the tree. While roots can "search out" nutrients in the soil, within agricultural normally it is best to apply where the roots are currently present.

Young almonds have smaller roots than older almonds; however, most irrigation systems are designed, and emitters placed, for the latter. This can result in the wetted area in the soil only marginally being within the rootzone of young trees (Figure 5). Applying liquid forms of fertilizer through irrigation can impact how much is available to the tree as the nitrogen will only go where the water goes.

This can be mitigated through granular applications (though there is a higher cost with labor), adjustments to the irrigation emitter placement, or timing of applications. Regardless of how placement should be accounted for with young trees.

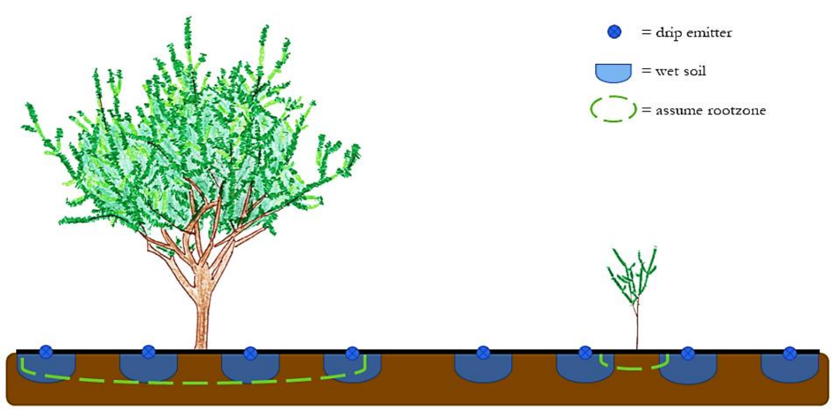


Figure 5. Conceptual images of rootzone (green-dashed polygon) of older (left) and younger (right) almond trees relative to wetted soil (blue polygon) from inline drip emitters (blue-circles). Original tree images from FREP.

Chapter 5: Irrigation Management of Young Pistachios

Tobias Oker, Soils and Irrigation Advisor

Pistachio acreage in California has been steadily increasing in recent years. A recent report by the Administrative Committee for Pistachios puts the bearing acreage of pistachio in California at about 461,000 acres, and the non-bearing acreage at about 144,000 acres. Generally, young pistachio trees are those of non-bearing age.

In California, pistachio is usually planted at row spacings of 20 to 22 feet and tree spacings of 15 to 20 feet. In ideal circumstances, the tree grows to cover most of this space by the time it reaches maturity. The amount of orchard space that the tree canopies shade at any given time is a critical component that goes into the estimation of how much water the trees need as they mature. For mature pistachio trees, the intermittent estimation of the crop water requirement (evapotranspiration) is relatively easier to determine due to the availability of research-developed water use curves (crop coefficients) for pistachio trees. Table 13 shows crop coefficients for mature trees in California. In the southern San Joaquin Valley, a mature pistachio tree requires about 46 inches of water every season, with a peak daily demand of about 0.34 inches per day during hottest summer days. Research has shown that the evapotranspiration of tree crops generally tends to reach its maximum by the time the orchard floor area shaded by the tree canopies is between 50% and 60%.

Table 12 Crop coefficients for mature pistachio trees

Date	Goldhamer (2005)	Zaccaria (2016 - 2019)	
		Coalinga	Hanford
15-Apr	0.07	0.52	0.36
30-Apr	0.43	0.86	0.59
15-May	0.68	0.94	0.8
31-May	0.93	0.91	0.82
15-Jun	1.09	0.94	0.89
30-Jun	1.17	1.05	0.88
15-Jul	1.19	1.04	0.91
31-Jul	1.19	1.03	0.85
15-Aug	1.19	0.97	0.89
31-Aug	1.12	0.96	0.87
15-Sep	0.99	0.92	0.82
30-Sep	0.87	0.81	0.79
15-Oct	0.67	0.78	0.65
31-Oct	0.5	0.58	0.58
15-Nov	0.35	0.41	0.48

There are no crop coefficients for young pistachios. Instead, young pistachio evapotranspiration is estimated by multiplying that of a mature tree by an adjustment factor. For example, the crop water demand of a first-leaf pistachio tree, on a peak evapotranspiration summer day is about 0.034 inches per day (i.e., mature pistachio of

0.34 in./day multiplied by an adjustment factor of 0.1). Adjustment factors for drip irrigated pistachio in the southern San Joaquin are given in Tables 14 and 15 below.

Table 13: Irrigation adjustment factors for drip irrigated pistachios

Age	1st leaf	2nd leaf	3rd leaf	4th leaf	5th leaf	6th leaf	7th leaf	8th leaf	9th leaf
Adjustment factor	0.1	0.2	0.3	0.4	0.52	0.65	0.78	0.9	1.0

Table 14: Irrigation adjustment factors for fanjet (micro-sprinkler) irrigated pistachios

Age	1st leaf	3rd leaf	5th leaf	7th leaf	8th leaf	9th leaf
Adjustment factor	0.4	0.52	0.65	0.78	0.9	1.0

A young pistachio tree spends most of its energy on vegetative growth. Its canopy is very small and only covers a small fraction of its assigned tree area, implying that it has a relatively small evaporative surface. To efficiently irrigate a young pistachio tree, it is important to ensure that water is directly applied to the area close to the base of the tree and is concentrated in the rootzone. This approach mitigates water and nutrient loss through deep percolation and/or evaporation. For young pistachios, button drippers (or devices that can concentrate water application close the tree) are recommended because they can be installed close to the tree. Button drippers usually have flow rates ranging from 0.5 to 2gph. To install a button dripper, the irrigation lateral is punctured to create a small hole which is then plugged with the emitter. For newly potted trees, the dripper should be positioned to apply water directly to the root ball for about 30 days. After the roots have grown into the surrounding soil, additional drippers can be installed. As the tree grows each year, additional button drippers are added onto the lateral. To promote root growth in young established trees, it is recommended that they are not frequently irrigated, as an imposition of mild stress conditions spurs roots to grow in search of water and nutrients. It is important to find out what type of soil is found in the orchard when determining an irrigation schedule. To aid irrigation management, it is recommended that growers utilize soil moisture probes and stem water potential monitoring devices. It is recommended that stem water potential values should often be maintained between -9 to -10 bars.

The performance of an irrigation system can also be limited by the general state of the “health” of the soil of an orchard site. For example, soils which are highly compacted and/or sodic significantly limit soil water infiltration, leading to water loss. Therefore, when establishing new orchards in “tough” soils, it may be beneficial to carry out some practices to improve the physical, chemical, and biological properties of the soil. This may involve actions like tilling to break soil crust, applying amendments to reduce salinity or sodicity, and adding organic matter.

Chapter 6: Water and Nutrient Management for Young Olive Orchards

Giulia Marino, CE Specialist in Orchard Systems, UC Davis

Young olive orchard evapotranspiration (ET)

Calculating crop evapotranspiration (ET_C) for young orchards is very challenging. The common procedure is to use the reference evapotranspiration (ET_o) from a public (or private) weather station, a crop coefficient (K_C) that refers to mature orchards and apply a correction coefficient (Kr):

$$ET_C = ET_o \times K_C \times k_r$$

The Kr is applied for any crop that has canopy cover (the percentage of ground shaded by the tree) below 60%. Selecting the K_C and the Kr brings a lot of uncertainty in the calculation of orchard water requirements. This is why it is always good practice to use calculated ET_C as a guideline to get quantification of water needs, but add some in-field monitoring tools, such as soil moisture and/or precise tree water status monitoring. In California, a K_C of 0.65 for hedgerow olive oil orchards and 0.75 for vase-shaped table olive orchards for the entire season is suggested. Ongoing trials from our research group indicate that Kc values in spring may be lower than the historically suggested ones.

Table 15: Crop Evapotranspiration (ET_C) for a Sacramento Valley hedgerow (spacing 12x6 ft) mature (shading 60% of the ground at midday) olive orchard

Month	ET_o (in)	K_C	ET_C (in)	ET_c (in/day)	Gall/tree/day
Apr	5.1	0.5	2.6	0.11	3.8
May	6.8	0.5	3.4	0.14	5.1
Jun	7.8	0.5	3.9	0.17	5.8
Jul	8.7	0.6	5.2	0.18	7.8
Aug	7.8	0.6	4.7	0.16	7.0
Sep	5.7	0.6	3.4	0.12	5.1
Oct	4.0	0.6	2.4	0.08	3.6
Nov	2.1	0.6	1.3	0.05	1.9
Total			26.8		

ET_o (Reference Evapotranspiration) accounts for climate differences and can be downloaded at CIMIS

Kr (Reduction coefficient): account for smaller trees with canopies shading less than 60% of the ground:

$$Kr = 2 \times fc$$

Fc (cover fraction) The fraction of ground shaded by olive trees at midday

For round shaped canopies:

$fc = (\pi \times D^2 \times N) \div 174{,}240$

D (ft) = average diameter of canopy

N = the number of trees per acre

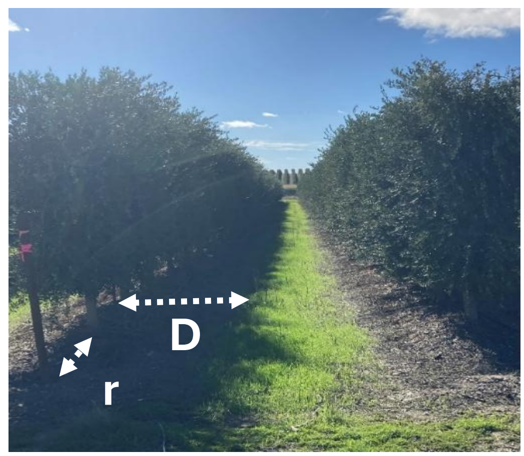
For hedgerow systems:

$fc = (N \times d \times r) \div 43{,}560$

N = number of trees per acre

D (ft) = average width of the canopy

r (ft) is the distance between trees



Water potential measurement in olive

The method for stem water potential measurement with the pressure chamber is similar in olive and other crops. One main difference is that the petiole of an olive leaf is very short, making the reading challenging. Instead of the leaf, a shoot with 1 to 3 pairs of mature leaves can be measured: the water will come out from the shoot and the reading will be easier to perform.

The stem water potential baseline: The baseline provides the midday stem water potential (SWP) values that a non-stressed olive tree (a tree with no limitation of soil water) would have. The baseline changes every day since it depends on how hot and dry the environment is. A non-stressed olive would have a SWP at midday of -11 bars on a cool spring day with 75 ºF and 35% of relative humidity. On a very hot and dry day in August (100 ºF and 25% RH), a non-stressed olive tree would show a SWP of -15 bars (Table 17).

Table 16: Baseline (bar) for olive. Adapted from Milliron et al. 2019.

Temperature (F)	Relative Humidity (%)								
	25%	30%	35%	40%	45%	50%	55%	60%	65%
70°	-11	-11	-11	-11	-11	-11	-11	-10	-10
75°	-12	-12	-12	-12	-11	-11	-11	-11	-10
80°	-13	-13	-12	-12	-12	-11	-11	-11	-11
85°	-13	-13	-13	-12	-12	-12	-12	-11	-11
90°	-14	-14	-14	-13	-13	-12	-12	-12	-11
95°	-15	-15	-15	-14	-14	-13	-13	-12	-12
100°	-16	-16	-15	-15	-14	-14	-13	-13	-12
105°	-18	-17	-16	-16	-15	-15	-14	-14	-13

Water stress thresholds

Olive trees can stand stem water potential way lower than most other species cultivated in California. If you are familiar with SWP measurement in walnut and almond, you will need to change your mind about olive. In general, mild stress occurs when SWP decreases below -15 bars, and medium stress occurs between -20 and -25 bars. Other crops will be severely stressed at this latter level and close stomata completely.

Fertilization in young olive

Fertilization and irrigation should be very frequent in the first year after planting since trees have a very small root system. Weekly to biweekly fertilization and more irrigation events per week are desirable, depending on soil type and environment. The objective is to promote fast growth: nutrient deficiency and water stress should be avoided, as well as over-irrigation and nitrogen over-fertilization.

First year: 4-8 doses of 4-8 grams of urea per plant, or 10g ammonium nitrate, alternating with 10g of potassium (or 10 calcium nitrate) per plant per week (or 15 days).
Foliar Zinc, Mn, Fe (alkalizes soil), and nitrogen based on leaf analysis (1 kg zinc sulfate, 1 kg mn sulfate, 5 kg urea in 1000 liters of water).

Recommended dosages for intensive mature orchard:

- Nitrogen: 150 kg/ha/year
- Phosphorous: 35 kg/ha/year
- Potassium: 200 kg/ha/year

Critical leaf levels

Nutrient		Deficiency	Sufficiency	Over-fertilization toxicity
N	%	< 1.4	1.5-2.0	
			> 1.2-1.3	
			1.4-1.8	***> 1.9***
P	%	0.05	0.1-0.3	
			< 0.13	
K	%	0.4	> 0.8	
			> 0.9	
Ca	%	0.30	> 1.0	
Mg	%	0.08	> 0.1	
Na				> 0.2
Fe	mg kg^{-1}		none	
Mn	mg kg^{-1}		> 20	
Zn	mg kg^{-1}		> 10	
			> 8	
B	mg kg^{-1}	14	19–150	185
Cu	mg kg^{-1}		> 4	
Cl	%			> 0.5

July sampling

Dag et al., 2023. Nutrition and Fertilization. In: The Olive Botany and Production. pp 374-414.

Chapter 7: Irrigation & Nutrient Management of Young Citrus Orchard

Charles Hillyer & Shawn Ashkan, Center for Irrigation Technology, California State University, Fresno

Irrigation Management

Citrus is a major crop in California. In 2022, California produced 62 percent of the total U.S. citrus fruit and contributed 78 percent of the total value of the U.S. citrus crop. The San Joaquin Valley, the primary citrus-producing region in California, had more than 210,000 acres dedicated to citrus production, as shown in the table for different counties (Table 18).

Table 178: San Joaquin Valley Citrus Production by Type and Acreage - 2022

Type and Count	Acres Standing in 2022		
	Bearing	Non-bearing	Total
Grapefruit			
Fresno	405	88	**493**
Kern	583	80	**662**
Tulare	1,330	366	**1,696**
Lemons			
Fresno	1,906	582	**2,488**
Kern	3,416	342	**3,758**
Tulare	8,367	1,625	**9,993**
Oranges, Navel			
Fresno	18,803	537	**19,340**
Kern	23,409	702	**24,110**
Kings	180	0	**180**
Madera	1,482	0	**1,482**
Tulare	62,875	1,805	**64,679**
Oranges, Valencia			
Fresno	1,955	108	**2,063**
Kern	3,666	216	**3,881**
Madera	753	0	**753**
Tulare	11,368	238	**11,606**
Pummelos & Hybrids			
Fresno	64	55	**119**
Tulare	790	143	**933**
Mandarins & Mandarin Hybrids			
Fresno	10,083	488	**10,571**
Kern	19,271	2,222	**21,493**
Madera	4,018	0	**4,018**
Stanislaus	223	0	**223**
Tulare	24,923	1,118	**26,041**
		TOTAL	**210,582**

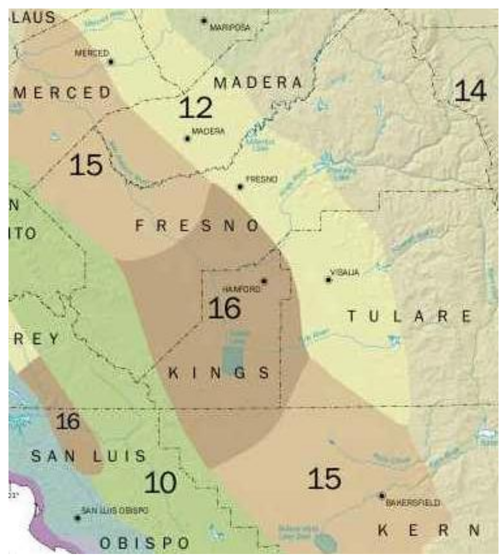


Figure 7: ETo Zones of citrus growing regions

Table 19: Monthly Average Reference Evapotranspiration by Et_o Zone (Inches/Month) - Citrus Growing Zones

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.4
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5

The Valley citrus production region is primarily located in the citrus belt on the Sierra hills and terraces in Tulare, Kern, Fresno, and Madera Counties. Regarding the reference evapotranspiration rates (ETo) or evaporative demands that chiefly determine the irrigation water requirements, this region is mainly located in ETo zones 12, 15, and 16, as categorized by the California Department of Water Resources and shown in Figure 7 and Table 19. Historically, the region has high evaporative demands in summer.

Crop evapotranspiration is commonly estimated by multiplying ETo by the crop coefficient (Kc). The Kc of mature citrus trees is about 0.65 to 0.70, while the Kc of young trees is a fraction of mature trees, depending on age and canopy cover, as shown in Figure 2.

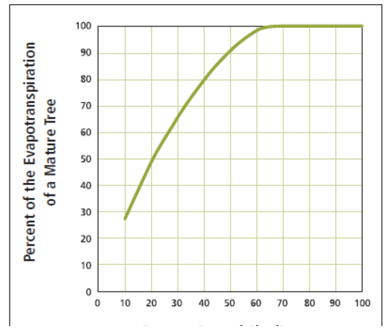


Figure 5- Percent ETc of young trees

Daily ETo values can be obtained from local CIMIS weather stations, and daily ETc for young citrus crops can be estimated using appropriate Kc values. The daily ETc can be used to estimate soil water deficit for irrigation scheduling using the following equation:

$$SWDi = SWDi - 1 + ETci + DPi - Ii - (P - RO)i$$

where
SWDi = Soil Water Deficit on the current day
SWDi-1 = Soil Water Deficit on the previous day
ETci = Crop evapotranspiration on the current day
DPi = Deep percolation on the current day
Ii = Net irrigation application on the current day
(P - RO)i = Precipitation less runoff on the current day

For verification and adjustment, soil moisture sensors should be used to measure soil water deficit (SWD).

Nutrient Management

Efficient irrigation must be complemented by optimal nutrient management, which includes regular soil and plant tissue analysis to determine nutrient requirements. Young citrus trees need balanced macronutrients (nitrogen, phosphorus, potassium) and micronutrients (zinc, boron, iron). Fertilizer applications should be scheduled based on soil and plant conditions, using methods like fertigation, soil application, or foliar spray. By ensuring these trees receive the right amount of water and nutrients, we can set a strong foundation for their future productivity and health.

The nutrient management plan begins with monitoring, including qualitative and quantitative assessments. Qualitative assessments involve visual observations of tree performance, looking for signs of nutrient deficiencies or excesses. Quantitative assessments require sending soil and tissue samples to a laboratory for detailed analysis.

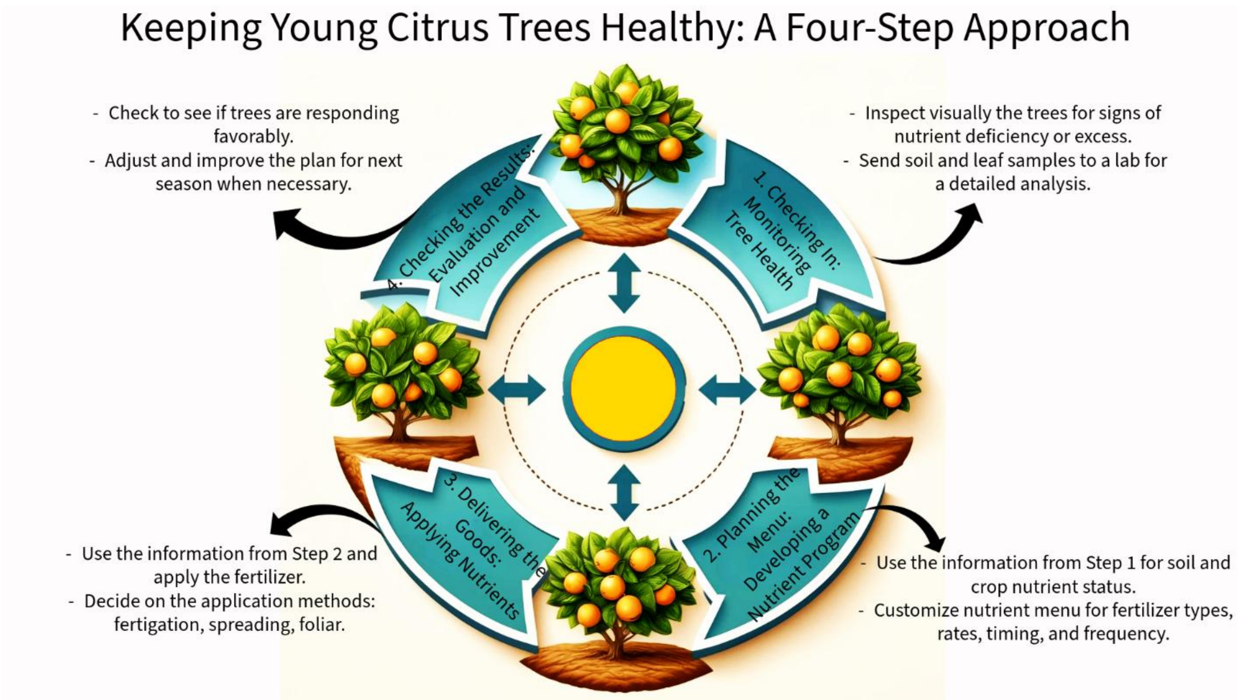


Table 20 shows the recommended fertilizer application rates for young citrus plants. The nitrogen application rates vary depending on the soil's nitrogen-supplying capacity. Leaf analyses are recommended to assess if the nitrogen application rates are sufficient. The University of California (UC) does not offer specific phosphorus and potassium fertilization guidelines for citrus orchards. Initial soil test analyses should guide phosphorus and potassium applications to young trees.

Table 20: Recommended Nitrogen, Phosphorous, and Potassium Application Rates

Tree Age (Years)	Application Rate (lb. N/Tree/Year)	Application Rate (lb. P_2O_5/Tree/Year)				Very Low K Availability (lb. K_2O/Tree/Year)
		Soil Test P				
		Very Low	Low	Medium	High/Very High	
1	0.13 – 0.25	0.15 – 0.30	0.11 – 0.23	0.08 – 0.15	0	0.15 – 0.30
2	0.25 – 0.50	0.30 – 0.60	0.23 – 0.45	0.15 – 0.30	0	0.30 – 0.60
3	0.50 – 0.75	0.45 – 0.90	0.34 – 0.68	0.23 – 0.45	0	0.45 – 0.90

Source: https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/Citrus.html

Our UCCE advisors and staff offer one-on-one technical assistance and training in irrigation and nutrient management in the San Joaquin Valley. This is free and available in English and Spanish.

If you are interested in learning more, please contact:

- **Moneim Mohamed** – UCCE Stanislaus, San Joaquin, and Merced Counties: amohamed@ucanr.edu
- **Mae Culumber** – UCCE Fresno County: cmculumber@ucanr.edu
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For more information on advanced irrigation techniques and resources, growers are encouraged to reach out to UC Cooperative Extension and participate in workshops focused on young orchard irrigation and nutrient management.

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