IRRIGATION SCHEDULING FOR WALNUTS

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Introduction

Specific research concerning the water requirements of walnuts grown in the San Joaquin Valley is being conducted. Existing data indicates walnuts are capable of using between 42 and 58 inches of water per season depending on orchard floor management, soil type, and weather. Taking into account an average irrigation efficiency of 70 percent (not uncommon), the actual water applied per acre would therefore be 60 to 83 inches! It could be said that irrigation is the single-most important factor to walnut orchard performance.

Unfortunately, many individuals assigned irrigation responsibilities are unknowledgeable about when irrigations should occur and how much water should be applied at a given time. This often results in excessive or insufficient soil moisture which can lower plant vigor, create conditions for roots to be attacked by serious fungal diseases, increase insect problems, affect nutrient uptake and lower, production and nut quality. As energy and water costs increase and profit margins narrow, farmers must realize the necessity of improved irrigation scheduling to obtain maximum yields for the lowest financial investment. Improved knowledge of irrigation timing can also be of great value in scheduling cultural and spray operations.

The University of California has several publications available through county-based Extension offices that are designed to assist walnut growers in better irrigation practices. Publication #21410 titled, "Walnut Orchard Management", is an excellent resource book that every walnut grower should have. Included in this 178 page book are three chapters on water use by trees and how to meet their requirement. Leaflet #21199 titled, "Basic Irrigation Scheduling", concisely explains the concepts of meeting plant water needs by use of weather information available in local newspapers and radio stations. Leaflet #21419 titled "The Water Budget Method - Irrigation Scheduling for Southern San Joaquin Valley Deciduous Orchards," provides step-by-step guidelines for evaluating your present irrigation practices. Leaflet #21259 titled, "Drip Irrigation Management", thoroughly discusses all aspects of this specific irrigation method. With a little effort, growers can learn to use this information to greatly improve irrigation effectiveness when compared to the less precise method of scheduling by the calendar that does not take into account the seasonal variations in rainfall and temperature. Irrigation scheduling using current weather data is referred to as the water budget procedure. Practical application of this method is the subject of this paper. A table showing the water used by walnuts every two weeks is also provided to assist growers in evaluating their present watering program. Statewide research and on-site evaluation of Walnut grower irrigation practices indicate that the general tendency is to over-irrigate in the spring and under-irrigate in the summer. The time between irrigations is often twice that necessary to avoid stressful walnuts that can affect tree health, yield and nut quality.

The Concept of ET

Water is lost from an orchard in two ways: direct evaporation from the soil surface, and transpiration, which is loss of water vapor from plant leaves. This combination of soil and plant water loss is called evapotranspiration or ET. ET is the amount of water actually used by the orchard. The intensity of solar radiation is the primary factor that determines the water use or ET of an orchard, although air temperature, relative humidity and wind also affect it.

Research has shown the ET of any crop to be related to the degree of ground cover or canopy. Crops having 100% canopy, such as an alfalfa field, possess the maximum ET rate which is slightly less than standing water completely exposed to the existing weather conditions. Scientists have used this fact to develop a weather measurement system which, when placed in a well-watered grass cover, accurately estimates the maximum daily ET. This value is reported daily by weather stations and many local newspapers. It is called ETo.

Orchards obviously vary in their percent canopy; using maximum ET values for a first year orchard would result in over-irrigation if no other vegetation is present such as an intercrop. This also appears to be true for declining walnut orchards whose root system is badly damaged; they do not use water at the same rate as healthy trees.

Research on the water use of several deciduous orchard species indicates maximum ET is attained when 50 to 60% of the ground is shaded at midday during the summer. This means a young orchard with light still falling onto the soil surface could consume as much water daily as an older orchard with complete shading. As illogical as it may seem, water research has repeatedly demonstrated this fact. Declining walnut orchards may use as much as 25-50% less water than a healthy orchard!

Growers irrigating orchards with less than 50% canopy must estimate what fraction of maximum ET represents their daily water use. If maximum potential ET occurs in orchards at 50% shaded ground area at midday, then assuming half potential maximum ET with a 25% canopy would be a fairly accurate estimation. Verification of grower ET estimates is best performed by direct soil moisture testing (soil auger) or through use of tensiometers or gypsum blocks that will be discussed later. Future research is planned to determine maximum ET adjustment factors (known as crop coefficients) for orchards at various stages of canopy development.

Field Capacity, Permanent Wilting Point and Available Water

Unlike drip irrigation that is designed to replenish the amount of water consumed by the orchard on a frequent basis, furrow or basin irrigation relies upon the soil to serve as a reservoir for water between applications. The ability of a soil to store water is dependent upon its texture. Due to different physical and chemical characteristics, fine textured soils hold more water than coarse textured soils. The capacity of a soil to hold water for plant use is defined by three terms. The first is field capacity (fc) which is simply the water remaining in the soil after most of the drainage has occurred 3 to 4 days after an irrigation. The second is permanent wilting point (pwp), defined as the writer content of the soil at which plants are unable to absorb it for their use. The third term, available water, is the difference between field capacity and permanent wilting point. This is the actual amount of water held by a soil for plant use. Table 1 gives the available water for various soil types in inches of water per foot of soil.

TABLE 1. AVAILABLE WATER FOR VARIOUS SOIL TYPES

	Available Moisture	
Type of Soil	range inches/foot	average inches/foot
Very coarse to coarse-textured sand	0.5 to 1.00	0.75
Moderately coarse-textured sandy loams and fine sandy loams	1.00 to 1.50	1.25
Medium texture-very fine sandy loams to silty clay loam	1.25 to 1.75	1.50
Fine and very fine texture–silty clay to clay	1.50 to 2.50	2.00
Pests and mucks	2.00 to 3.00	2.50

Steps to Better Irrigation Scheduling

After selecting the soil type or types that best represent your orchard, one can now take the following steps to better irrigation scheduling:

1. It is absolutely essential that walnut growers begin the season with deep soil moisture. Specifically, the 4 to 6 foot root zone must be near field capacity in order to adequately supply the walnut tree with water during the hottest summer months. In almost all orchards, in season irrigations never reach this depth since the water applied is being used at such a rapid rate. Further, attempting to replenish deep moisture during the growing season results in too much water applied at once. Excessive irrigation causes saturated soils and low oxygen in the upper root zone that destroys roots if this condition exists longer than about three days. Excessive irrigation in the spring can also develop root rot diseases such as Phytophthora. These problems can be avoided by applying a pre-season irrigation during late January or early February when soils typically take water best and are too cold for the spread of root diseases. Winter rainfall is not sufficient to replenish deep soil moisture. Walnut growers need to check the soil with an auger before assuming that the lower root zone is near field capacity. Appendix 2 can assist the grower in determining soil water content for various soil textures. Failure to begin the season with deep soil moisture will increase the probability of early orchard decline and decrease yield and quality. This is especially true of the Hartley variety that develops deep bark canker, a stress-related bacterial infection associated with water management.

2. Estimate the depth to which the orchard has a large number of roots. This varies from three to ten feet depending on soil characteristics. Under uniform well-drained soil conditions, walnuts will have the majority of their roots in the upper six feet. Shallow soils may only have an effective rooting depth of three or four feet. An accurate estimation of rooting depth is essential to determining how much water can be effectively stored in the soil for plant use. An excellent method for accomplishing this is backhoeing several sites in the orchard. Examination of these

sites will also provide valuable information on soil texture and the existence of compacted layers or hardpans limiting water intake rates. Knowing the rooting depth and soil textures of your orchard will allow you to apply sufficient water early in the season to the lowest portion of the root zone.

3. Determine how low you want the soil moisture to get prior to irrigating. This is known as allowable depletion and is often set at about 50% in orchards with good to excellent water intake rates. If available soil water is depleted beyond this level, plant growth and nut quality can be adversely affected depending upon the duration and degree of low moisture status. Assuming one had decided on a 50% depletion value, one would irrigate when half the available water had been used in the root zone. No single allowable depletion level can be recommended for all situations; consideration of rooting depth, soil texture and evaporative demand must be made. The allowable depletion used is highly dependent upon how well your soil takes water (infiltration rate). Soils with low infiltration will require more frequent irrigation and the use of a low depletion level since only small quantities of water can be applied per irrigation. A good rule of thumb is to allow only as much water to be used by your orchard as can be safely applied per irrigation. In many cases that is only three to four inches! Very few soils can accommodate a six-inch irrigation.

4. Using ET information adjusted for your percent canopy, monitor water loss to determine when to schedule irrigations. The necessity of monitoring daily ET can be avoided by knowing the average ET curve for a given region from data supplied by the local National Weather Bureau Office. Adjustments to the curve would be necessary in years of extremely hot or cool weather. Average ET information for clean cultivated and cover cropped walnut orchards is provided with this paper. Based on a 30-year average, the attached tables can assist growers in determining how much water use is occurring at any time during the season. ET values shown for a cover cropped orchard are for complete grass and not sparse cover.

5. Estimate your irrigation efficiency. Delivering water to the farm and applying it to the land involves losses which can be minimized, but they are difficult to eliminate. Figure 1 shows water received and potential losses at the farm level during and after irrigation.

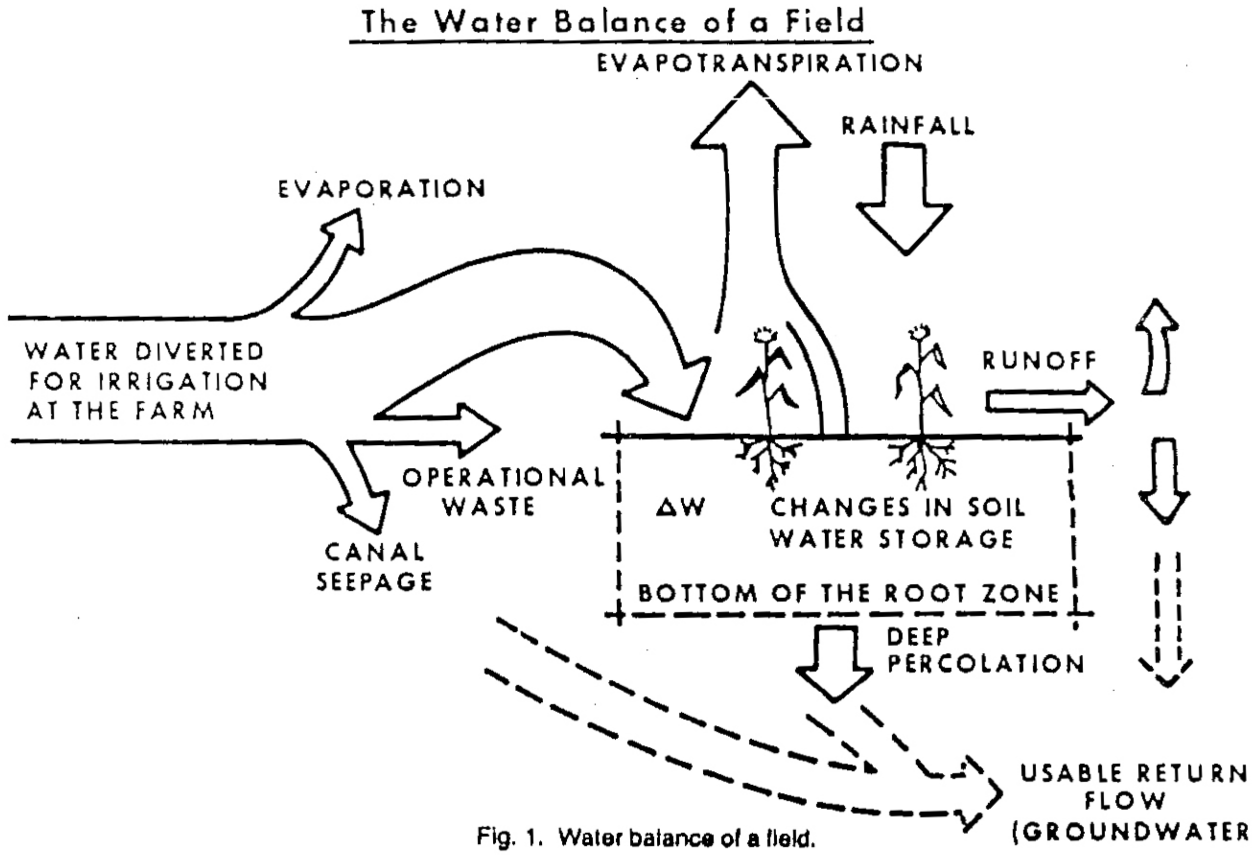

Fig. 1. Water balance of a field.

If losses are kept to a minimum, most of the applied water goes to meet the ET demand. Estimating irrigation system efficiency should include consideration of such factors as the length of the run, slope of the orchard floor, method of delivery and rate of runoff. Procedures for estimating irrigation efficiency of common irrigation methods - border strip, furrow, sprinkler and drip - have been established. Consult your local farm advisor or Soil Conservation Service office for information. Irrigation efficiency for a flood system could range between 50 and 80%. Additional water above that estimated to fill the soil reservoir must be applied to compensate for the various losses described. The total amount needed is simply determined by dividing the quantity necessary to fill the soil reservoir by the efficiency rating. Assuming an irrigation efficiency of 70% (.7), the amount of water that must be delivered to achieve an effective 4.0 inch irrigation would be:

$$\frac{4.0}{0.7} = 5.7 \text{ inches}$$

6. Apply at your local power company for a pump test. In most cases this is provided free of charge; it is an important factor for improving orchard irrigation. Most growers are surprised to find out the actual gallons per minute their well is supplying. Knowing actual pump capacity allows one to determine the time needed to apply the desired amount of water. A pump test will

also provide valuable information on pump efficiency, standing water depth, pumping water depth, and the per acre foot cost of water delivery.

Verification of Irrigation Efficiency

Three common methods exist for monitoring soil moisture. The simplest (and best) method of evaluation is direct soil sampling with an auger and assessing its water content by feel. Experienced growers have an excellent understanding of how soil acts at various moisture contents. Although time consuming, direct soil sampling can be a very effective and assuring means of determining the depth of irrigation and relative soil moisture levels. Used in conjunction with the basic irrigation scheduling procedure, growers can check that they are indeed applying the correct amount of irrigation water at the right time. Appendix 1 provides growers guidelines for determining soil texture based on feel and appearance. Appendix 2 serves as a guide for practical interpretation of available soil water for various soil textures.

A second method of monitoring soil moisture is the tensiometer. This instrument comes in various lengths that can be installed to soil depths correlating with the location of the root zone. As the soil is depleted of water from plant use, a porous cup in contact with the soil allows water to move from the sealed tensiometer into the soil. This creates a vacuum that is registered on a gauge located immediately above the soil surface. Tensiometers are most valuable when two or three are placed in a single location but at different depths in the root zone. This provides information about how rapidly the soil moisture is being depleted and whether the lower rooting area is beginning to dry out. Used in combination with the water budget, tensiometers can be helpful in evaluating soil water status. Due to their rather narrow tension range, tensiometers are better suited to light textured soils. In heavy soils, the instrument can read offscale when soil moisture is still quite adequate.

A third instrument used for soil-water measurement is the gypsum block. A small block of gypsum containing two wires is inserted at different depths in the root zone. Wires leading up to the soil surface are connected to a meter which measures the resistance created between the wires inserted in the block. The resistance values increase as the soil becomes drier. Gypsum blocks have a higher working range than tensiometers. However, for optimum value the readings should be correlated to specific soil water contents by calibration. Soil salinity will also affect the resistance reading. Used properly, they can be valuable in monitoring available soil water.

Irrigating Young Trees

Monitoring soil moisture can often be more critical in young trees than a mature orchard due to the greater potential for excessive soil water saturation leading to root disorders. The following are suggestions that, in the authors' opinion, reduce the potential for high tree loss during establishment.

1. Avoid flooding the entire soil surface as the means for watering in newly planted trees. This results in an excessively wet soil condition during a period when the lack of plant foliage prevents the tree from quickly changing its soil moisture environment. Late rains can further enhance conditions favoring root disease and tree death. Flooding trees in newly ripped soil is

particularly risky due to the greater volume of water absorbed by the fractured soil profile. If possible, hand water young trees with 3 to 5 gallons from a large tank moving behind the planting crew. Another alternative to surface flooding is placing a furrow 18 inches away from either side of the tree. This can be successfully used for the first year's irrigation. Additionally, it may enhance the irrigation efficiency and reduce the amount of weeds that need controlling.

2. Take action on perennial weed problems prior to planting. Repeated disking of Johnson and Bermuda grass during the summer is often sufficient control. Treflan applied prior to planting and immediately incorporated will provide excellent weed control and reduce the tree's competition for water, light and nutrients. Proper irrigation is difficult when weeds are absorbing as much water as the tree itself. Placement of Treflan treated soil into the planting hole should be avoided due to its suppressive effect or lateral root development.

EVAPOTRANSPIRATION (ET) FOR A "NORMAL YEAR"
Data based on a 30 year average

Location: San Joaquin Valley
Crop: Walnuts

CLEAN CULTIVATED
(Including sparse grass)

Leafing Date: Mar. 15
Harvest Date: Nov. 15

DATE	GRASS REF. ETo	CROP COEFFICIENT Kc	WATER USE ET (INCHES)	CUMULATIVE ET (INCHES)
Mar 16-31	2.08	.12	0.25	0.25
Apr 1-15	2.40	.53	1.27	1.52
Apr 16-30	2.70	.68	1.84	3.36
May 1-15	3.15	.79	2.49	5.85
May 16-31	3.84	.86	3.30	9.15
Jun 1-15	3.75	.93	3.49	12.64
Jun 16-30	3.90	1.00	3.90	16.54
Jul 1-15	4.05	1.14	4.62	21.16
Jul 16-31	4.16	1.14	4.74	25.90
Aug 1-15	3.60	1.14	4.10	30.00
Aug 16-31	3.52	1.14	4.01	34.01
Sep 1-15	2.85	1.08	3.08	37.09
Sep 16-30	2.40	.97	2.33	39.42
Oct 1-15	1.80	.88	1.58	41.00
Oct 16-31	1.44	.51	0.73	41.73
Nov 1-15	0.90	.28	0.25	41.98

COVER CROPPED ORCHARD
(Full grass cover)

Leafing Date: Mar. 15
Harvest Date: Nov. 15

DATE	GRASS REF. ETo	CROP COEFFICIENT Kc	WATER USE ET (INCHES)	CUMULATIVE ET (INCHES)
Mar 16-31	2.08	.85	1.77	1.77
Apr 1-15	2.40	.87	2.09	3.86
Apr 16-30	2.70	1.06	2.86	6.72
May 1-15	3.15	1.17	3.69	10.41
May 16-31	3.84	1.21	4.65	15.06
Jun 1-15	3.75	1.26	4.73	19.79
Jun 16-30	3.90	1.35	5.27	25.06
Jul 1-15	4.05	1.45	5.87	30.93
Jul 16-31	4.16	1.45	6.03	36.96
Aug 1-15	3.60	1.45	5.22	42.18
Aug 16-31	3.52	1.45	5.10	47.28
Sep 1-15	2.85	1.34	3.82	51.10
Sep 16-30	2.40	1.21	2.90	54.00
Oct 1-15	1.80	1.14	2.05	56.05
Oct 16-31	1.44	1.10	1.58	57.63
Nov 1-15	0.90	.94	0.85	58.48

APPENDIX 1

DETERMINING SOIL TEXTURE BASED ON FEEL AND APPEARANCE

SAND

Sand is loose and single grained. The individual grains can be seen or felt readily. Squeezed in the hand when dry, sand falls apart when pressure is released. Squeezed when moist, it forms a cast but crumbles when touched.

SANDY LOAM

A sandy loam is soil containing a high percentage of sand but having enough silt and clay to make it somewhat coherent. The individual sand grains can be readily seen and felt. Squeezed when dry, a sandy loam forms a cast that falls apart readily. If squeezed when moist, a cast can be formed that bears careful handling without breaking.

LOAM

A loam is soil having a relatively even mixture of different grades of sand, silt, and clay. It is mellow with a somewhat gritty feel but is fairly smooth and slightly plastic. Squeezed when dry, it forms a cast that bears careful handling, and the cast formed by squeezing the moist soil can be handled freely without breaking.

SILT LOAM

A silt loam is soil having a moderate amount of fine sand and only a small amount of clay; over half of the particles are of the size called silt. When dry, a silt loam appears cloddy but the lumps can be broken readily; when pulverized, it feels soft and floury. When wet, the soil runs together readily and puddles. Either dry or moist, it forms a cast that can be handled freely without breaking; when moistened and squeezed between thumb and finger, it does not ribbon but has a broken appearance.

CLAY LOAM

A clay loam is fine-textured soil that usually breaks into clods or lumps that are hard when dry. When the moist soil is pinched between the thumb and finger, it forms a thin ribbon that breaks readily, barely sustaining its own weight. The moist soil is plastic and forms a cast that bears much handling. When kneaded in the hand, it does not crumble readily but works into a heavy compact mass.

CLAY

A clay is fine-textured soil that usually forms very hard lumps or clods when dry and is very plastic and usually sticky when wet. When the moist soil is pinched out between the thumb and finger, it forms a long, flexible ribbon. Some clays very high in colloids are friable and lack plasticity at all conditions of moisture.

GUIDE FOR PRACTICAL INTERPRETATION OF AVAILABLE SOIL WATER FOR VARIOUS SOIL TEXTURES

Prepared by David A. Goldhamer, Extension Irrigation Specialist.
Adapted from SCS National Engineering Handbook, Chapter 15, 1964
and Israelsen et al, Irrigation Principles and Practices, 1980.

Available [1/] Water (%)	Feel or Appearance of Soil			
	Sand	**Sandy Loam**	**Loam/Silt Loam**	**Clay Loam/Clay**
Above field capacity	Free water appears when soil is bounced in hand.	Free water is released with kneading.	Free water can be squeezed out.	Puddles; free water forms on surface.
100 (Field capacity)	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand. (1.0)[2/]	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand (1.5)	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand. (2.0)	Upon squeezing no free water appears on soil but wet outline of ball is left on hand. (2.5)
75-100	Tends to stick together slightly sometimes forms a weak ball [3/] under pressure. (0.8 to 1.0)	Forms weak ball, breaks easily, will not slick. (1.2 to 1-5)	Forms a ball, is very pliable slicks readily if relatively high in clay. (1.5 to 2.0)	Easily ribbons out between fingers, has slick feeling. (1.9 to 2.5)
50-75	Appears to be dry, will not form a ball with pressure. (0.5 to 0.8)	Tends to ball under pressure but seldom holds together. (0.8 to 1.5)	Forms a ball some-what plastic, will sometimes slick slightly with pressure. (1.0 to 1.5)	Forms a ball, ribbons out between thumb and forefinger. (1.2 to 1.9)
25-50	Appears to be dry, will not form a ball with pressure. (0.2 to 0.5)	Appears to be dry, will not form a ball. (0.4 to 0.8)	Somewhat crumbly but holds together from pressure. (0.5 to 1.0)	Somewhat pliable, will ball under pressure. (0.6 to 1.2)
0-25 (0 is permanent wilting.)	Dry, loose, single-grained, flows through fingers. (0 to 0.2)	Dry, loose, flows through fingers. (0 to 0.4)	Powdery, dry, sometimes slightly crusted but easily broken down into powdery condition. (0 to 0.5)	Hard, baked, cracked, sometimes has loose crumbs on surface. (0 to 0.6)

[1/] Available water is defined as the difference between field capacity and permanent wilting point.
[2/] Numbers in parenthesis are available water contents expressed as inches of water per ft. of soil depth.
[3/] Ball is formed by squeezing a handful of soil very firmly.