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AVOCADO WATER RELATIONS

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INTRODUCTION

Avocado growing requires a basic understanding of soils, plants, and water. For the grower to be successful in the production of avocados, it is important to remember some basic facts. (1) The avocado is a sensitive crop to soils, to water, to climate, and to competing plants. (2) The use of water by avocado trees depends greatly on weather conditions. (3) Soils in which avocado trees are grown vary in their capacity to hold water, a function of texture, structure, and depth. (4) The soil in which the trees are growing should be moist at all times. It should not be in a saturated condition, nor should the soil be dry. (5) It is just as important to know when to turn the water off as to when to turn it on.

To grow avocados commercially in California, you must irrigate. In California where rainfall is inadequate in total and the distribution pattern erratic and unfavorable, irrigation is a way of life. Irrigation is accomplished from eight to twelve months a year, depending on the rainfall season. In other countries where large amounts of rain falls, but in a relatively short period of time, up to four months, this likewise will necessitate irrigation in the non-rain months of the year. Successful irrigation demands careful study of soil moisture and weather conditions to determine how much water trees need and when. This ability comes with experience and a knowledge of basic principles.

The avocado is an exacting plant. It cannot stand drought. Excessive moisture restricts root activity and favors root diseases. In many respects the irrigator controls the destiny of the avocado orchard.

Before studying particular problems of avocado irrigation, a review of the principles basic to all irrigation should be done.

BASIC IRRIGATION PRINCIPLES

Soil as a Reservoir

The soil serves as a moisture reservoir (1). Water is stored in the network of pore spaces that surround solid soil particles. Clay soils store more water per unit volume than sandy soils, not only because more air voids are present, but because the larger pore spaces in sands never fill or are drained.

Only the larger pores in soil can be emptied by downward drainage. In the smaller pores, moisture is held more securely. As plants use and deplete the moisture from the pores, a greater suction is required to draw water into the plant root. When the plant cannot draw water rapidly enough it wilts. Irrigation should, therefore, be scheduled well in advance of wilting symptoms.

Irrigating the soil refills the pore spaces. It is like refilling or "recharging" a reservoir. Enough water should be added at each irrigation to replace the water that has been used by plants. Water passing below the root zone is wasted. Where restricted subsoil occurs, too much water added at one time will actually damage roots and provide a favorable environment for root diseases. When irrigating, it is important to know how wet the subsoil becomes and what happens to excess water.

The depth of soil also affects the amount of water that plants can use. Shallow soils have less storage capacity than deep ones and need refilling at shorter intervals.

How Trees Use Water

Just how much, and at what rate, the trees will use water depends on weather and total area of leaf surface. Trees will use or "transpire" more water on a hot day than on a cool one.

Four things affect transpiration. The rate at which water is given off through the leaves increases with: (1) rising temperature, (2) lowering humidity, (3) windy weather—particularly when warm and dry—may desiccate and burn the foliage. The use of water during a summer month can total many times as much as in a winter month. Total water use is greater in the more interior, warmer districts than in the coastal districts. (4) The more leaves on a tree, the larger is the total leaf surface area and the greater will be the use of water. A densely foliated tree will use more water than a sparsely foliated one, and a large tree more than a small one. The water supply or irrigation program should be adequate to maintain good soil moisture conditions for the trees during the warmest and driest months.

Irrigating according to set dates or at fixed intervals is not a good practice. However, if you must take water at fixed intervals or on certain dates, make sure the summer intervals are short enough to provide for those "peak use" periods of hot, dry weather. At others times, you'll need to make adjustments in the amount of water applied per irrigation to avoid excessive application.

Soils vary in their capacity to store water. A clay soil can hold a given amount of water in a relatively small volume. More loam or sandy soil is required to store the same amount of water.

Water moves rapidly and essentially downward into sandy soil. Clay soils take water slowly and require more time for water to wet the soil to a given depth. Lateral movement is greatest in clay soils. Many avocado orchards are on sandy-loam soils.

How to Irrigate

The directions for a single irrigation are simple. Apply sufficient water to wet the portion of soil which approaches dryness. The surface two to six inches may dry out by evaporation, but otherwise the soil will become dry only in the areas of good root activity. Most root activity—and, therefore, water extraction—is often in the upper two feet. The soil at lower depths may still contain much available moisture.

On deep uniform soils there may be good root distribution into the third foot. With this deeper root system and water penetration, these soils will require recharging of the reservoir less frequently than shallow soils.

An irrigation is necessary if judgment and experience indicate the soil is relatively dry. Irrigating is done to make up for moisture deficiency, such as fertilizing makes up for a nutrient deficiency. The soil should be checked for moisture content at various depths.

Apply water only to dry soil. Addition of water to soil that is wet has caused more root damage than any other man-controlled practice. Remember, water will continue to move downward through the soil 12 to 24 hours or more after an irrigation.

The basic problem in avocado irrigation is to put water where it is needed. It is easy to state the problem, but the solution is not simple. The solution lies in devising the right type of irrigation system for the orchard—at the time you plan it and lay it out.

Irrigation Losses

The actual use of water by trees cannot account for all water applied. This means that irrigation is never 100 percent efficient. Unavoidable losses always occur. However, with care the irrigator can minimize these losses.

Deep percolation—or water that goes below the root zone—is one common loss. Water reaching below the root area is not recovered. If the soil is not well drained, trees may be injured by excessive use of water. An actual check of penetration during the two or three days after an irrigation is suggested. One advantage to deep watering is that the excess water leaches accumulated salts from the root zone. This is especially important when highly saline water is used for irrigating.

Runoff should not occur under sprinkler irrigation. If it does occur, the type of sprinkler, discharge rate, size of orifice, or sprinkler adjustments may be wrong.

Evaporation from soil accounts for some water loss. Often it can be minimized by leaving a thin layer of natural leaf mulch or by applying other mulching material.

Evaporation loss occurs where sprinklers are used because more of the ground surface and part of the leaf surfaces are wet during each irrigation.

Weed competition is one of the most important causes of moisture loss. The need or desirability of weed control depends on the degree of competition, cost of control, and the cost and availability of water. In healthy, mature orchards weeds may be controlled by weed-killing sprays, and mowing.

Special Problems

Special problems may confront the irrigator. Some of these are poor subsurface drainage, limited water supply, and salt accumulations.

Drainage Problems

Any sub-surface obstacle to water movement, such as a hardpan or clay layer, can present a drainage problem. The tendency is for water that cannot readily move into the substrata to move down and across the slope as free sub-surface water. The surplus water accumulates in the lower sections. The results are restricted root activity and conditions favoring root rot organisms, particularly Phytophthora root rot.

Avoid drainage problems due to irrigation by applying water carefully. Heavy winter rainfall can result in excessive sub-surface water where drainage is restricted. Furrows or ditches help remove surface water and prevent water logging. Occasionally, tile drains intercept subsurface flow as it moves down the slope.

A common condition on hillsides is the presence of a subsoil that is considerably less permeable than the topsoil. When rainfall is heavy or irrigation is excessive, more water moves through the topsoil than can move through the subsoil. The excess then moves down the slope, below the surface but on top of the subsoil.

Limited Water Supply

Reduced water supply is another special concern for some growers, usually in years of deficient rainfall. Suggested practices for a short water supply are:

- Reduce weed competition.
- Apply a mulch on soil surface to reduce evaporation losses.
- Decrease the area of soil surface wetted at each irrigation.
- Use drip irrigation where practicable.

GENERAL IRRIGATION SCHEDULE

In California during the peak water use period, May to October, avocado trees require water frequently, every five to ten days depending on soil depth, soil texture, age of trees, and climate. Water should be applied at each irrigation to a depth of at least two feet. Every six weeks during the summer irrigation period extra water should be applied for leaching the salts from the root zone. This can be from one-half again as much to twice the amount of the usual irrigation application. Total water use for a year is approximately 3-4 acre feet per acre for mature trees. This allows for about a 20 percent salt leaching faction.

THE SALINITY PROBLEM IN GROWING AVOCADOS

The salinity problem, resulting in leaf tipburn, plagues avocado growers worldwide (2). Salinity effects can be reduced by changes in irrigation systems, methods of water applications, timing of irrigation, and where possible, using less saline water.

Tipburn, due to an accumulation of salts—mainly chloride and sodium—is thought to be caused by a number of factors. (1) Accumulation of salts in the soil. (2) Soil differences. (3) Rootstock differences. (4) Varietal differences (rootstock and/or scion). (5) Inadequate amounts of water, and (6) Methods of water application.

Total salinity does not seem to be as important a factor as accumulation of individual ions, such as chloride and sodium. Chlorides in the soil are highest during the fall or winter (in California) after an irrigation season has been completed. The percentage of chloride in the leaves will likewise be highest during this period. Chlorides move readily with water, and, therefore, leaching is the only effective method of removing salts from the root zone. The higher the chloride content of irrigation water, the more frequent the irrigation should be and the more water should be used. The first 18 to 24 inches of soil should be moist at all times since 80 to 90 percent of the avocado roots are in the first two feet. It is, therefore, important to have this area as low in chlorides and sodium as possible. Maintaining a moist condition in the first two feet at all times, the chlorides are in a dilute state, which does not have the bad effect on the plant as if the soil were on the dry side. Every four to six weeks a good flushing of the soil should be done through the application of additional water. The amount is usually 1 1/2 to two times the normal frequent irrigation application. Irrigation during the fall months (in California, September to November) is very important since soil chlorides are highest, and the climatic conditions are usually hot, dry, bright sun, and windy. This combination places serious stress upon the trees. Having sufficient water available for the trees during this period will reduce the risk of damage to the tree and possible loss of fruit. East-blowing, desiccating winds occur in various parts of the world and effects growers of crops in a similar manner as to the situation in California. Colorado River water is used in San Diego County on avocado trees, and for the analysis of the water see Table 4.

Avocado trees seem to have an affinity for chlorides. The undesirable effect of chloride injury is to reduce the bearing leaf surface, resulting in early droppage of foliage and thereby lessening the potential of the tree to produce fruit. Chloride injury does not usually become evident until sufficient buildup in the leaves causes death in the cells and results in leaf tipburn. It is not known whether chlorides will accumulate in other parts of the tree. There have been cases where trees suffering extreme tipburn were given extra irrigations resulting in reduced accumulation of soil salts, and yet in the following year, the tip-burn was still evident on the leaves. This might indicate the possibility of carryover of chlorides in the tree.

DETERMINATION OF WATER NEEDS

Tensiometers

The tensiometer is an instrument which measures a property of soil water, namely soil suction (3). It measures the soil moisture condition and not the quantity of water. The instrument consists of a ceramic cup, a body (tube), a vacuum gauge, and a reservoir. Movement of moisture in and out of the ceramic cup causes tension on the column of water in the tube which is shown on the dial of the gauge. Most gauges are calibrated in centibars from zero to one hundred (0-100), the lower reading indicating the wet condition. Readings above eighty (80) are not reliable. A colored liquid is placed within the body of the instrument through the opening at the top of the reservoir. The whole system, except for the cup, should be air-tight.

Placement of Instrument

Placement of the tensiometer is very important. The stations located in an avocado orchard should be representative of the soil types present. In other words, if the soil within an orchard varies from a sandy type to a clay type, one set of instruments should be in the sandy soil, one set in the clay soil, and another set in the soil which combines these two types. The most desirable position for the instrument is on the south side of the tree, just under the dripline. The reason for this is that the most active roots are near the dripline and that the south side of the tree usually dries out first.

Each station should include two instruments, approximately eight inches apart, and placed at the twelve and twenty-four inch depths. In a spot where water accumulation is a problem, a thirty-six inch instrument could be placed as a check on the amount of water present at this depth. In San Diego County soils this is especially important; because when clay underlays a permeable top soil, there is always the possibility of avocado root rot getting a start. In placing the tensiometers, each instrument should "see" the sprinkler head (Figure 1). The instruments should never be placed on a direct line from the sprinkler.

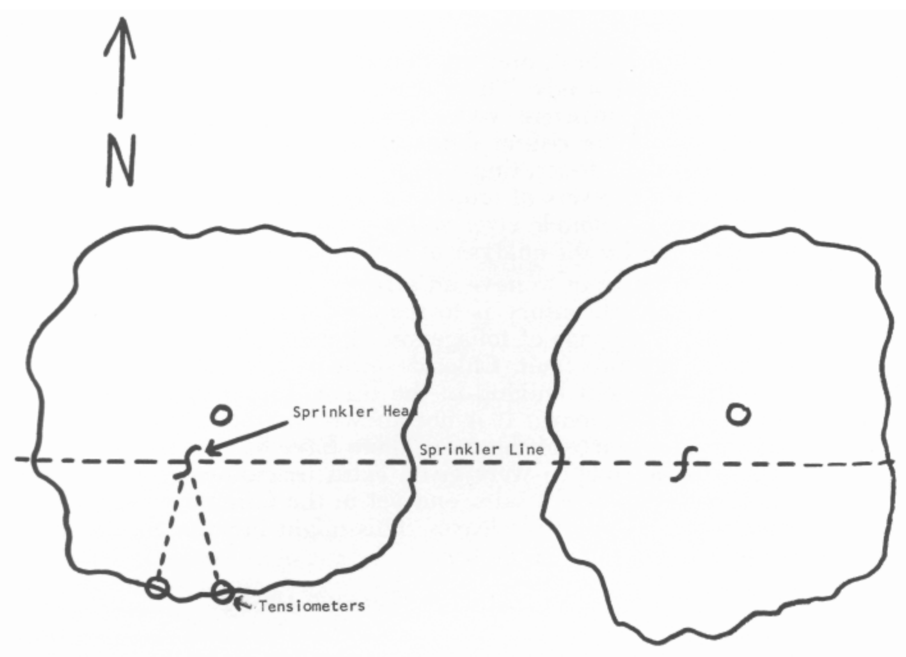

FIGURE 1. PLACEMENT OF TENSIOMETERS

Installation

Installation of tensiometers is also very important. The ceramic cup must be in good contact with the soil. If holes are dug with a small soil tube whose diameter is larger than the tensiometer body, then backfilling with loose soil and packing it around the instrument is necessary.

Service

Tensiometers must be serviced periodically to assure proper operation. This consists of: (1) Keeping the instrument full of water, (2) Removing air from the instrument, (3) Reading the gauge often to be sure changes in soil moisture are being reported.

After placing the instrument in the soil, the colored distilled water should be added to the instrument. Once the tube is full, the air must be removed. With some instruments, a vacuum pump can be used to remove the air. This procedure should be followed every two or three weeks to be sure the instrument is giving the proper reading.

Readings

Readings of the instruments should be made often. After the initial installation, a reading should be made daily to determine whether or not the instruments are operating properly. Once it is known that the instruments are functioning, readings need be made only two or three times a week. It is preferable to read the gauge at the same time each day, early morning being the best. The instruments should be checked periodically during irrigations to see that all obstacles are removed between the sprinkler and the instruments so a proper reading is obtained. A low hanging branch is enough to intercept the water and give an inaccurate reading. Uniform distribution of water is very important to avocado trees, and especially if tensiometers are being used as a guide to an irrigation program.

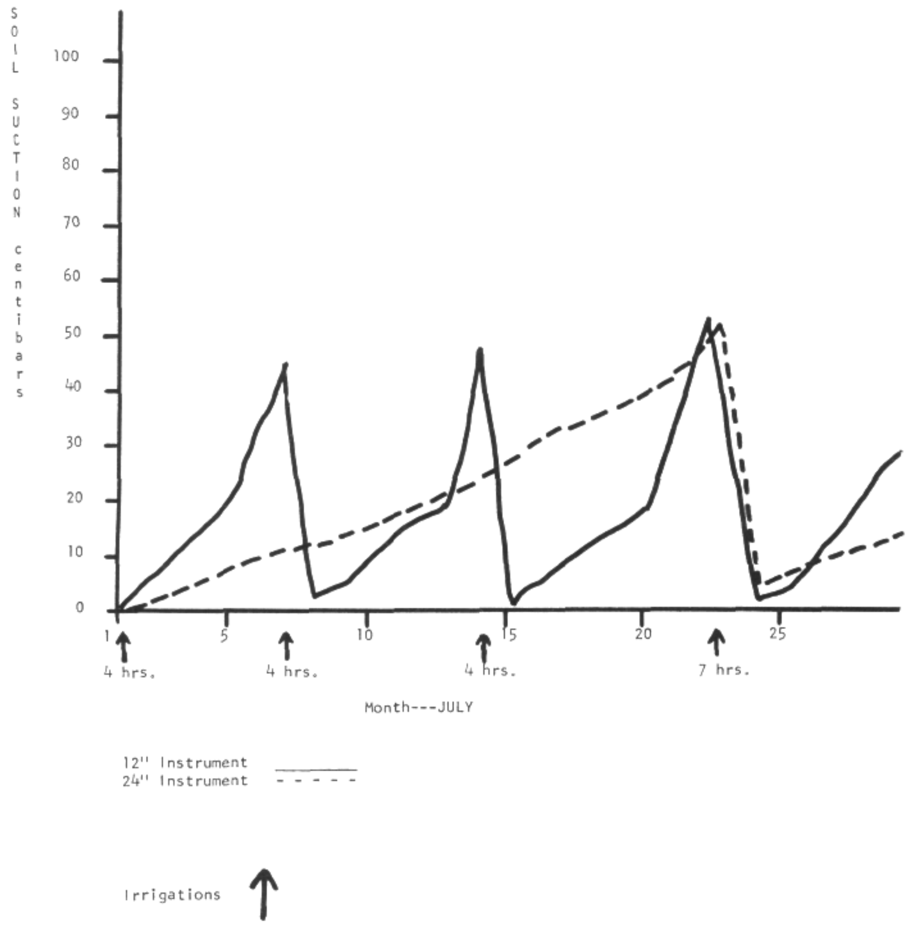

FIGURE 2. TENSIOMETER CHARTS

Charts

Charts should be kept on all instruments in the orchard. The chart is the key to how often an irrigation is needed and how much moisture is required. In evaluating the soil moisture condition from the readings on the chart, it is important to realize that it is not so much a particular reading at any one time but the rate at which readings are changing that guides the need to irrigation. Studying the charts, a grower can know two or three days in advance when an irrigation is needed. To obtain the maximum value of the use of tensiometers, the instruments should be read frequently, consistently, and the results plotted on a continuing chart (Figure 2). It will be noted that each irrigation was based on the rate of change on a twelve inch instrument. The twelve inch instrument reached twenty centibars (20) in approximately five days and the reading in the next two or three days rapidly climbs toward the forty (40) to fifty (50) centibar range. It is this rate of change during peak water use that is important and gives a good guide when to irrigate. The twenty-four inch instrument showed sufficient moisture so a deep irrigation was not needed until the third or fourth irrigation. If the thirty-six inch instrument had been placed in this station, the rate of climb would be even less than the twenty-four and in most cases would not reach much over twenty-five (25) centibars. The reason for this pattern is that the largest percentage of active roots are in the first two feet of soil with very little root activity below this level. Also, the Vista candy-loam soil and Fallbrook fine sandy-loam soil, which predominate in the avocado growing areas of San Diego County, are relatively coarse textured in the upper eighteen inches and therefore have a tendency to dry out faster because of a low water holding capacity and the activity of the root system of the avocado.

Evapotranspiration

"Evapotranspiration is the sum of transpiration and water evaporated from the soil, or exterior portions of the plants where water may have accumulated from irrigation, rainfall, dew, or oxidation from the interior of the plant." If the unit of time is small, evapotranspiration is expressed in acre inches per acre or depth in inches. For larger units of time, such as crop growing season, or a twelve-month period, evapotranspiration is expressed as acre feet per acre or depth in feet or inches.

"Consumptive use is, for all practical purposes, identical with evapotranspiration. It differs by the inclusion of water retained in the plant tissue. However, the maximum amount of water in the plant generally represents less than one percent of the total water evaporated during a crop season."

"Irrigation water requirement is the quantity of water, exclusive of precipitation, required to maintain the desired soil moisture and salinity level during the crop season." It is usually expressed as depth in inches or feet for a given period of time. Under practical conditions the total amount of water lost by transpiration and evaporation are combined. The two are not independent. Transpiration may be influenced by the evaporation from soil, and the evaporation from soil surface is influenced by the amount of crop canopy existing and availability of soil moisture near the soil surface.

Evapotranspiration results in the transfer of salt-free water to the atmosphere thereby concentrating the salts remaining in the soil solution. Maintenance of a favorable root environment requires the replenishment of soil moisture as it is used and the removal of salts that accumulate. Evapotranspiration data must be determined for specific crops, under specific water conditions, climate conditions, and the soil conditions.

Evapotranspiration rate is affected by the amount of leaf area on a crop, stage of the crop growth, climate, and soil. Solar radiation is the most important climatic factor effecting evapotranspiration. Soil and air temperature, humidity, rainfall, and wind are also other factors influencing evapotranspiration for a given crop. Soil factors effecting evapotranspiration are amount of available water in the root zone, temperature of the soil, and salt concentration.

High concentration of salts in the soil can kill a plant and stop transpiration entirely. In lesser amounts it makes the plant roots do more work in obtaining water, and reduces evapotranspiration in growth rates of the plant. It increases the irrigation requirement of an orchard because additional irrigation water in excess of that need for evapotranspiration must be applied to leach the salts from the root zone.

Soil temperature affects the viscosity of the water in the soil, the vapor pressure, and the ability of the roots to absorb water. Lack of adequate soil aeration will slow root and topgrowth and thus indirectly limit the transpiration rate. Evaporation from the soil is greater when the surface is wet, and only a partial cropcover exists then when the surface begins to dry. When the soil is near field capacity, the plant can obtain water with relative ease; but as the soil approaches the wilting point, it becomes more difficult for roots to obtain water for transpiration (4).

Measurements from the avocado drip irrigation project conducted in North San Diego County shows the greatest water use period is the third quarter of the year—July, August, and September. The rainfall pattern in this part of California is usually from November to April, with most rainfall in normal years coming in December, January, and February. Daily evapotranspiration rate for the summer months averaged 0.30 compared with average daily rate of 0.10 during the winter months.

IRRIGATION SYSTEMS

Basins

Irrigation with basins is desirable for young trees only, water being applied with a hose or a tankwagon. Many growers install a permanent irrigation system using a stationary spitter for the first two or three years in conjunction with basin irrigation. Basins are usually broken down after the first season.

Spitters

Spitters are stationary-type heads emitting a spray directed at the tree. The amount of area covered depends on the spitter design. It comes in quarter circle, half circle, three quarter, and full circle design. The amount of water discharged is determined by the size of the hole in the spitter head. Discharge rates range from eight-tenths of a gallon per minute to over one gallon per minute. Spitters are used during the first three years to reduce the amount of water applied as compared to a rotating sprinkler. Three reasons for not using sprinklers until the fourth or fifth year are: (1) wastes water, (2) increased weeds, and (3) high cost of water.

Sprinklers

With sprinkler irrigation, water is conveyed over the land in pipes and discharged through nozzles which sprinkle the water on the soil. The basic permanent system is the same as under the spitter irrigation. The only difference between spitter and rotating sprinkler is the head itself. Uniform penetration and better control of the irrigation water are possible with sprinkler systems. Systems properly installed and operated with care can result in excellent distribution of water, often with a considerable saving in labor. Proper planning of a sprinkler system cannot be stressed enough. Two important points are: (1) Be sure the length and size of pipe will ensure an even distribution of water to all sprinklers. (2) Be sure sprinklers give a good distribution pattern and discharge water at a rate the soil will absorb without runoff.

The grower who is not familiar with principles of governing water movement through pipes should obtain technical advice and assistance.

One real advantage of a sprinkler system is flexibility. Sprinklers can apply greater or smaller amounts of water in different areas or at different intervals. Operating advantages favor the underhead or under trees sprinkler system in preference to the overhead system where sprinklers are on tall risers and spray over the tops of the trees. The trend is towards permanent underhead sprinkler systems. They are convenient and require a minimum of time and labor to operate. Portable sprinkler systems are satisfactory, have a lower initial cost, but a higher labor cost in use.

Drip/Trickle

The newest development in the field of irrigation is called drip/trickle irrigation (5). It was introduced into California in the late 1960s to experiment in avocado orchards planted on steep hillside slopes.

What is Drip Irrigation?

Drip irrigation is the frequent, slow application of water to soil through mechanical devices called emitters that are located at selected points along water-delivery lines. (The importance of the words "frequent" and "slow" is explained later under "Operational Requirements.") Most emitters are placed on the ground, but they can be buried at shallow depths for protection. Water enters soil from the emitters, and most water movement to wet the soil between emitters occurs by capillarity beneath the soil's surface.

Less Soil is Wetted

The volume of soil wetted by drip irrigation usually is much less than that wetted by other irrigation methods. It may be only 10 percent of the soil in the root zone for newly planted crops. Researchers and experienced operators believe that at least 33 percent of the soil in the root zone under mature crops must be wetted, and that crop performance improves as the amount wetted increases to 60 percent or higher. The amount of soil wetted depends on soil characteristics, irrigation operation time, and the number of emitters used. This number ranges from less than one emitter per plant for row crops to eight or more emitters placed in-line or around large trees.

It's Different

Drip irrigation differs from conventional irrigation methods in many respects: The equipment used and its management with respect to irrigation scheduling and fertilization; the results obtained in terms of water use and plant response; and the effects of water and salt concentration and distribution in the soil

How Is It Done?

Drip irrigation is done by a system consisting of emitters, lateral lines, main lines, and a "head" or control station.

Equipment includes emitters, pipe lines, filters, regulators, fertilizing tanks, meters, clocks, timers, and injectors.

Advantages

Operating costs have been reduced, field operations easier, fertilizers can be injected at time of irrigating, pipe sizes can be smaller, soil moisture uniformity is improved.

Problems

The number one problem with drip irrigation is the clogging by particles of mineral or organic matter in the lines and emitters. Some soils may not have sufficient infiltration capacity to absorb the water. Salts tend to concentrate in soil surface and constitute a potential hazard, and rodents have chewed the plastic pipe when it is exposed on the surface of the ground.

Operational Requirements

Irrigation must be frequent. Water should be applied slowly. Application duration will vary with the age of the crop and the variety of crop. The amount of water applied should be based on measured or carefully observed soil-water conditions that reveal the balance between additions and withdrawals. Tensiometers are a good tool to use to determine the water schedule. Evaporation-transpiration data can be used in scheduling of irrigations. Filters and screens must be cleaned periodically, either by hand or built-in backflushing systems. Emitters should be checked visually frequently for correct flow as well as operations, and water pressure in the lines should be checked to determine whether or not the system is operating.

IRRIGATION SYSTEMS COSTS

There are several methods to apply irrigation water. As far as the avocado is concerned, there are the following types used: permanent set (spitter or sprinkler), drag hose, drip/trickle, and furrow. (6)

Permanent Set

Orchards and vineyards use permanent set irrigation systems primarily because of the high investment cost of these systems. Other crops do not use it.

Drag Hose

Experience indicates a high labor requirement in the use of the drag hose system even though the initial cost is less than the permanent set.

Drip/Trickle

This is the newest of the commercial irrigation systems in California. It is a frequent or daily application of water in the form of drops or small streams of water emitting from small diameter tubes or mechanical devices called emitters.

Furrow

Furrow irrigation is a variation of flood irrigation where water is confined in narrow furrows rather than wide border checks. Furrows may be either straight, zigzag, or contour. This type of irrigation can be used on almost all crops, but the requirement is that land be relatively flat. In some crops the requirement is .05 feet of grade per hundred feet because of germination problems, insect problems, harvest, rooting, etc. The only time furrow irrigation can be used on a hillside is if terracing of a slope results in a flat area for the furrow to be placed.

In Tables 1, 1A, 2, 2A, and 3, 3A you will find a summary for the costs for the various methods of irrigation as well as individual cost studies for the different types of systems used in avocado orchards. The two primary systems used are drip irrigation and permanent-set sprinklers. No hand-move sprinklers or furrow irrigation is practiced in San Diego County. There are some drag hose systems, but these are gradually being replaced with the drip or permanent. No overhead sprinkler systems are used anymore.

SUMMARY

Irrigation of avocado trees is very difficult. Irrigation should be given first priority on the culture program of an orchard. There is no substitute for a good irrigation program. Careful consideration should be given to the application of water, both in the amount and timing. Water quality should be known. If the amount of chlorides goes over 100 parts per million, be extremely careful in how the water is used. Proper operation of the irrigation system is also an important part of an efficient irrigation program. Periodic checks should be made for pressure changes in the line, improper operating heads, leaks, and any other factors which would affect the operation of the system. The system should be operating as perfectly as possible. This means constant attention, not only at the beginning and end of an irrigation run, but during it. Time spent on evaluation of an irrigation program, using every means to improve the program, will surely pay good dividends in the long run.

SUMMARY OF COSTS FOR VARIOUS METHODS OF IRRIGATION

	Flood		Wheel Line Sprinkler	Center Pivot Sprinkler	Hand Move Sprinkler	Drip	Furrow	Hose Drag	Permanent Set Sprinkler
	District Water	Well Water							
Times irrigated	6	6	8	8	8	-	6	8	8
Water applied-feet	3-4	3-4	3.0	3.0	3.0	2.0	3-4	3.0	3.0
Investment per acre	$475	$650	$520	$960	$460	$680	$400	$595	$1,335
Overhead per acre									
Depreciation	$ 13.75	$ 22.50	$ 40.25	$ 38.50	$ 34.25	$ 59.00	$ 10.00	$ 56.75	$ 66.75
Interest	27.00	34.00	20.80	56.80	18.40	27.20	24.00	23.80	53.40
Taxes, etc.	9.50	13.00	10.40	19.20	9.20	13.60	8.00	11.90	26.70
Total	$ 50.25	$ 69.50	$ 71.45	$114.50	$ 61.85	$ 99.80	$ 42.00	$ 92.45	$146.85
Operating cost per acre									
Irrigation preparation	$ 10.00	$ 10.00	$ -	$ -	$ -	$ -	$ 54.00	$ -	$ -
Labor	27.00	27.00	36.00	4.50	72.00	36.00	81.00	72.00	18.00
Power	-	11.00	20.55	25.35	20.55	9.35	11.00	20.55	20.55
Water	28.00	-	-	-	-	-	-	-	-
Repairs	2.10	3.50	12.60	12.15	10.20	20.80	1.75	19.20	34.20
Total operating	$ 67.10	$ 51.50	$ 69.15	$ 42.00	$102.75	$ 66.15	$147.75	$111.75	$ 72.75
Total cost	$117.35	$121.00	$140.60	$156.50	$164.60	$165.95	$189.75	$204.20	$219.60

TABLE 1

HAND MOVE SPRINKLERS

		Annual Cost			
Investment	Per Acre	Depreciation	Interest	Taxes, Etc.	Total
Well	$100	$ 5.00	$ 4.00	$2.00	$11.00
Pump 75 HP, 600 gpm 1/	135	6.75	5.40	2.70	14.85
Sprinklers	225	22.50	9.00	4.50	36.00
Total	$460	$34.25	$18.40	$9.20	$61.85

Operating cost	Per Acre
Labor 8x @ 2 hours = 16 hours @ $4.50 (including fringes)	$ 72.00
Power for 3.0' @ $6.85	20.55
Repairs - well and pump 3.0' @ $.40	1.20
- sprinkler 4%	9.00
Total operating cost	$102.75
Overhead	61.85
Total irrigation cost	$164.60

1/ $HP = \frac{600 \times 250}{3960 \times .65} = \frac{150,000}{2,574} = 58.3 = 75$

TABLE 1A

FURROW IRRIGATION

Investment	Per Acre	Depreci-ation	Interest	Taxes, Etc.	Total
		Annual Cost			
Leveling	$200		$16.00	$4.00	$20.00
Well	100	$ 5.00	4.00	2.00	11.00
Pump 40 HP, 1,000 gpm1/	75	3.75	3.00	1.50	8.25
Return flow	25	1.25	1.00	.50	2.75
Total	$400	$10.00	$24.00	$8.00	$42.00

Operating cost		Per Acre
Irrigation preparation:		
Ditch 6x @ $1.00	$ 6.00	
Furrow 4x @ $6.00	24.00	
Disk 4x @ $6.00	24.00	
Total preparation		$54.00
Labor 6x @ 3 hours = 18 hours @ $4.50 (including fringes)		81.00
Power for 3.5' @ $3.15		11.00
Repairs 3.5' @ $.50		1.75
Total operating cost		$147.75
Overhead		42.00
Total irrigation cost		$189.75

1/ $HP = \frac{1000 \times 100}{3960 \times .65} = \frac{100,000}{2574} = 38.8 \doteq 40$

TABLE 2

HOSE DRAG

Investment	Per Acre	Depreci-ation	Interest	Taxes, Etc.	Total
		Annual Cost			
Well	$100	$ 5.00	$ 4.00	$ 2.00	$11.00
Pump 75 HP, 600 gpm	135	6.75	5.40	2.70	14.85
Sprinklers	360	45.00	14.40	7.20	66.60
Total	$595	$56.75	$23.80	$11.90	$92.45

Operating cost	Per Acre
Labor 8x @ 2 hours = 16 hours @ $4.50 (including fringes)	$ 72.50
Power 3' @ $6.85	20.55
Repairs - well and pump 3.0' @ $.40	1.20
- sprinklers 5%	18.00
Total operating cost	$111.75
Overhead	92.45
Total irrigation cost	$204.20

1/ $HP = \frac{600 \times 250}{3960 \times .65} = \frac{150,000}{2574} = 58.3 = 75$

TABLE 2A

DRIP IRRIGATION

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, Etc.	Total
Well	$100	$ 5.00	$ 4.00	$ 2.00	$ 11.00
Pump 25 HP, 300 gpm 1/	80	4.00	3.20	1.60	8.80
Drip system	500	50.00	20.00	10.00	80.00
Total	680	59.00	27.20	13.60	99.80

Operating cost	Per Acre
Labor 8 hours @ $4.50 (including fringes)	$ 36.00
Power for 2.0' @ $4.67	9.35
Repairs - pump and well 2.0' @ $.40	.80
- drip system @ 4%	20.00
Total operating cost	$ 66.15
Overhead	99.00
Total irrigation cost	$165.95

1/ $HP = \frac{300 \times 200}{3960 \times .65} = \frac{60,000}{2,574} = 23.3 = 25$ hp

TABLE 3

PERMANENT SET SPRINKLERS

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, Etc.	Total
Well	$100	$ 5.00	$ 4.00	$ 2.00	$ 11.00
Pump 75 HP, 600 gpm 1/	135	6.75	5.40	2.70	14.85
Sprinklers	1,100	55.00	44.00	22.00	121.00
Total	$1,335	$66.75	$53.40	$26.70	$146.85

Operating costs	Per Acre
Labor 8x @ .5 hours = 4 hours @ $4.50 (including fringes)	$ 18.00
Power for 3' @ $6.85	20.55
Repairs - well and pump 3.0' @ $.40	1.20
- sprinklers 3%	33.00
Total operating cost	$ 72.75
Overhead	146.85
Total irrigation cost	$219.60

1/ $HP = \frac{600 \times 250}{3460 \times .65} = \frac{150,000}{2574} = 58.3 = 75$

TABLE 3A

TABLE 4. ANALYSIS OF COLORADO RIVER WATER*

Constituents	*June 30, 1975*	
Silica	7.9	mg/l
Iron	0.05	mg/l
Calcium	84	mg/l
Magnesium	30.5	mg/l
Sodium	107	mg/l
Potassium	5	mg/l
Carbonate	0	mg/l
Bicarbonate	144	mg/l
Sulfate	309	mg/l
Chloride	92	mg/l
Nitrate	0.3	mg/l
Boron	0.15	mg/l
Fluoride	0.4	mg/l
Total Dissolved Solids	708	mg/l
Total Hardness as $CaCO_3$	335	mg/l
Total Alkalinity as $CaCO_3$	118	mg/l
Free Carbon Dioxide	2	mg/l
Hydrogen Ion Concentration	8.1	
Electrical Conductivity	1,110	

* *From: 1975 Thirty-seventh Annual Report, The Metropolitan Water District of Southern California*

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