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AVOCADO WATER RELATIONS

Don Gustafson

Avocado growing requires a basic understanding of soils, plants and water. For the grower to be successful in avocado production it is important to remember some basic facts. 1) The avocado is sensitive 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, which is a function of texture, structure and depth. 4) The soil in which the trees are growing should be moist at all times, but not saturated. 5) It is just as important to know when to turn the water off as when to turn it on.

Rainfall is inadequate in California, and the distribution pattern is erratic and unfavorable, so irrigation is necessary for growing avocados commercially. Irrigation is required 8-12 months a year, depending on the rainfall season. Irrigation may be necessary in areas with distinct rainy seasons in which large amounts of rain falls in a relatively short period of time. 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.

Basic Irrigation Principles

Soil as a Reservoir

The soil serves as a moisture reservoir (3). 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 spaces are present, but because the larger pore spaces in sands either never fill or are drained rapidly.

The larger pores in soil can be emptied by downward drainage but moisture is held more securely in the smaller pores. As plants use and deplete the moisture from the pores, a greater suction is required to draw water from the soil particles. Available soil moisture is ultimately depleted to such a point that there is not enough to supply the plant's needs, so it wilts. Irrigation should, therefore, be scheduled well in advance of wilting symptoms.

Irrigating refills the pore spaces, as 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. Too much water added at one time where restricted subsoil occurs will actually damage roots and provide a favorable environment for root diseases. It is important to know how wet the subsoil becomes and what happens to excess water.

Soil depth 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.

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How Trees Use Water

Just how much and at what rate trees will use water depends on weather and total leaf surface area. Trees will use or transpire more water on a hot day than on a cool one. Transpiration, the rate at which water is given off through the leaves, is affected by: 1) temperature, 2) humidity, 3) wind and 4) leaf surface area. High temperature and low humidity in combination with windy weather can quickly desiccate the foliage due to high transpiration. A densely foliated tree will use more water than a sparsely foliated one and a large tree more than a small one.

How to Irrigate

Irrigating according to set dates or at fixed intervals is not a good practice. If water is available only at fixed intervals or on certain dates, be sure the intervals are short enough to provide for peak-use periods of hot, dry weather. Adjustments should be made in the amount of water applied per irrigation to avoid excessive application at other times.

The directions for a single irrigation are simple. Apply sufficient water to wet the portion of soil which approaches dryness. The surface 5-15 cm 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 60 cm. The soil at lower depths may still contain much available moisture.

An irrigation is necessary if judgment and experience indicate the soil is relatively dry. Irrigation is to correct 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 12-24 hours or more after an irrigation.

In California during the peak water use period, May to October, avocado trees require water frequently, every 5-10 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 60 cm. Every 6 weeks during the summer irrigation period extra water should be applied for leaching the salts from the root zone. This can be from half again as much to twice the amount of the usual irrigation application. Total water use for a year is approximately 35-50 ha-cm for mature trees. This allows for about a 20% salt-leaching faction.

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% efficient. Unavoidable losses always occur, but the irrigator can minimize these losses.

Deep percolation—or water that goes below the root zone—is a common loss. Water going below the root area is not recovered. An actual check of penetration during the 2 or 3 days after an irrigation is suggested. One advantage to deep watering is that the excess water leaches accumulated salts from the root zone, which is especially important when highly saline water is used for irrigation and under saline soil conditions.

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. Greater 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 for weed control with respect to soil moisture depends on the degree of competition, cost of control and the cost and availability of water.

Special Problems

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

Drainage Problems

Any subsurface 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 accumulate in the lower sections as free subsurface water causing wet soil conditions. The results arc restricted root activity and conditions favoring root rot organisms, particularly *Phytophthora.*

Avoid such drainage problems by applying water carefully. Furrows or ditches help remove surface water and prevent waterlogging. Occasionally, tile drains are used to remove subsurface free water.

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 slope, below the surface but on top of the subsoil, causing surface seepage at lower levels for several days.

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: 1) reduce weed competition for available soil moisture; 2) apply a mulch on soil surface to reduce evaporation losses; 3) decrease the area of soil surface wetted at each irrigation, if practical; and 4) use drip or other low-volume irrigation where practicable.

Soil Salinity

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 application, timing of irrigation and using less saline water where possible. Colorado River water is used in San Diego County on avocado trees, the analysis of which is shown in Table 1.

Table 1. Analysis of Colorado River Water, June 30, 1975.

Constituents	mg/l
Silica	7.90
Iron	0.05
Calcium	84.00
Magnesium	30.50
Sodium	107.00
Potassium	5.00
Carbonate	0.00
Bicarbonate	144.00
Sulfate	309.00
Chloride	92.00
Nitrate	0.30
Boron	0.15
Fluoride	0.40
Total dissolved solids	708.00
Total hardness as $CaCO_3$	335.00
Total alkalinity as $CaCO_3$	118.00
Free Carbon Dioxide	2.00
Hydrogen ion concentration (pH)	8.10
Electrical conductivity	1,110.00

Source: Thirty-seventh Annual Report of the metropolitan Water district of Southern California, 1975.

Tipburn, due to an accumulation of salts—mainly chloride and sodium—is thought to be affected by a number of factors such as: 1) soil differences, 2) varietal differences (rootstock and/or scion), 3) inadequate amounts of water and 4) methods of water application. Total salinity does not seem to be as important as accumulation of individual ions such as Cl and Na.

Chlorides in the soil are highest during the fall or winter (in California) after an irrigation season has been completed. The percentage of Cl^- in the leaves will also be highest during this period. Chlorides move readily with water; therefore, leaching is the only effective method of removing them from the root zone. Irrigation and amounts should be increased with increasing Cl^- concentrations. About 80-90% of the avocado roots are in the upper 60 cm of soil, so it is important to have this area as low in Cl^- and Na^+ as possible. Maintaining a moist condition in the upper60 cm at all times maintains Cl in a more dilute state, which is not as deleterious to the plant as is the higher concentration which exists when the soil is dry. A good flushing of the soil every 4-6 weeks should be done through the application of additional water. The amount used is usually 1.5-2 times the normal irrigation application.

Irrigation during the fall months (September to November) is very important in California since soil Cl^- is highest and the climatic conditions are usually hot, dry, sunny 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 fruit loss. Desiccating winds occur in other parts of the world and affects growers in a similar manner as in California.

Avocado trees seem to have an affinity for Cl^-. The undesirable effect of Cl^- injury is to reduce the bearing leaf surface by causing early droppage of foliage and thereby lessening fruit production potential. Chloride injury dues not usually become evident until concentrations in the leaves are sufficient to cause cells to die, as manifested by leaf tipburn. It is not known if Cl^- 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 salt, and yet tipburn occurred again the following year. This might indicate the possibility of carryover of Cl^- in the tree.

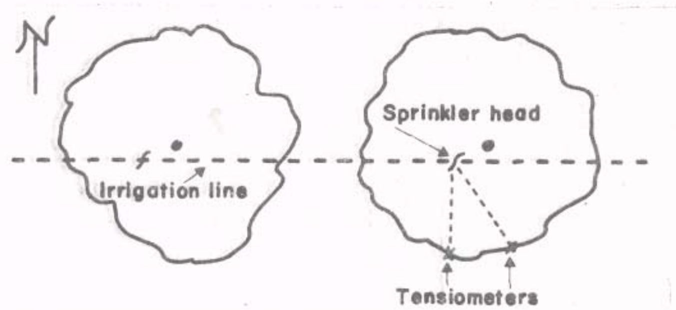


Fig. 1. Diagram showing the placement of tensiometers in relation to sprinkler heads, tree canopy and direction.

Determination of Water Needs

Tensiometers

The tensiometer is an instrument which measures soil suction (1). 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 a column of water in the tube which is shown on the dial of the gauge. Most gauges are calibrated in centibars, from 0, indicating the wet condition, to 100. Readings above 80 are not reliable. Colored distilled water 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 so that if the soil within an orchard varies from a sandy type to a clay type, 1 set of instruments should be in the sandy soil, 1 set in the clay soil and another set in the soil which combines these 2 types. The most desirable position is just under the dripline on the south side of the tree since the most active roots are near the dripline and the south side of the tree usually dries out first (Fig. 1).

Each station should include 2 instruments approximately 20 cm apart at depths of 30 and 60 cm. Where water accumulation is a problem, an instrument could be placed at a depth of 20 cm to 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.) The instruments should never be placed on a direct line from the sprinkler, but each instrument should "see" the sprinkler head (Fig. 1).

Installation and Service. Tensiometer installation is very important. The ceramic cup must be in good contact with the soil. A small soil tube can be used to make the holes, but if its diameter is larger than the tensiometer body, back-filling with loose soil and packing it around the instrument is necessary.

The colored, distilled water should be added to the instrument after it is in place. Once the tube is full, the air must be removed. A vacuum pump can be used with some instruments to remove the air.

Tensiometers must be serviced periodically to assure proper operation. This consists of keeping the instrument full of water and removing air from it. It is useful to read the gauge often to be sure changes in soil moisture are being reported. Servicing should be done every 2-3 weeks to assure proper functioning.

Readings. A reading should be made daily after the initial installation to determine if the instruments are operating properly. Readings need be taken only 2-3 times a week once it is known that the instruments are functioning. 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 cause an inaccurate reading. Uniform distribution of water is very important to avocado trees, especially if tensiometers are being used as a guide to an irrigation program.

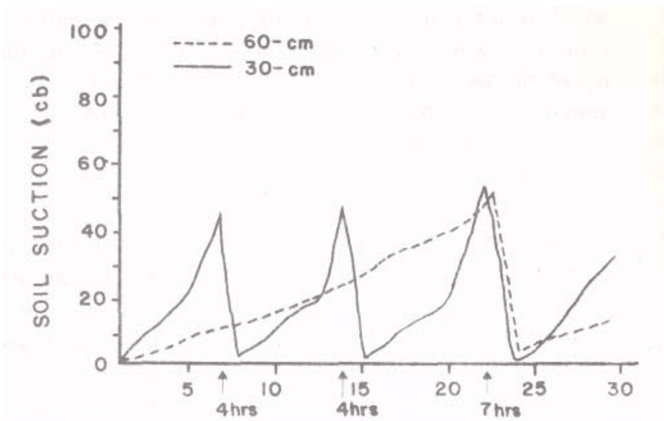
Charts. Readings from all tensiometers in the orchard should be plotted on charts, as they are used to determine irrigation frequency and amount. It is important to realize that it is not so much a particular reading but the rate at which readings are changing that guides the need to irrigate. Studying charts, a grower can predict 2-3 days in advance when an irrigation is needed.

It will be noted in Fig. 2 that each irrigation was based on the rate of change measured by the 30-cm instrument. The readings reached 20 cb in approximately 5 days and rapidly climbed to 40-50 cb in the next 2 days. It is this rate of change during periods of peak water use that is important and gives a good guide to when to irrigate. The 60-cm instrument showed sufficient moisture for about 3 weeks, so a deep irrigation was not needed until the third or fourth irrigation. The rate of climb of a 90-cm instrument at this station would be even less than the 60-cm one, probably not reaching much over 25 cb in most cases. The reason for this pattern of tensiometer readings is the distribution of the root system, with the most active roots being located in the upper 30-45 cm of soil.

Evapotranspiration

Evapotranspiration is the sum of transpiration from the plant and evaporation 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, expressed as cm or ha-cm. Under practical conditions, the total amount of water lost by transpiration and evaporation are combined. The 2 are not independent. Transpiration may be influenced by evaporation from soil, which is influenced by the amount of crop canopy existing and availability of soil moisture near the soil surface.

Consumptive use is practically identical with evapotranspiration, but differs by the inclusion of water retained in the plant tissue. However, the maximum amount of water in the plant generally represents less than 1.0% of the total water evaporated during a crop season.



July

Fig. 2. Typical tensiometer chart for July showing soil suction at depths of 30 and 60 cm. Irrigation was applied for the limes indicated at the arrows.

Irrigation water requirement is the quantity of water, exclusive of precipitation, required to maintain the desired soil moisture level and salinity level in some areas during the crop season, usually expressed as cm or ha-cm for a given period of time.

Evapotranspiration results in the transfer of sail-free water to the atmosphere, thereby concentrating the salts 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, climate and soil conditions, as the 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 affecting evapotranspiration but soil and air temperature, humidity, rainfall and wind also influence it. Soil factors affecting evapotranspiration are amount of available soil moisture in the root zone, soil temperature and salt concentration.

High salt concentration in the soil can kill a plant. Lesser concentrations reduce evapotranspiration as a factor of reduced growth rate of the plant due to the effects of the salts on foot functioning.

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 top growth and thus indirectly limit the transpiration rate. A plant can obtain water with relative case when soil moisture is near field capacity, but it becomes more difficult as soil moisture approaches the wilting point (5).

Measurements from an avocado drip irrigation project conducted in San Diego County, California, show the greatest water-use period is the third quarter of the year July, August and September. Rainfall in that part of California is from November to April, with most rainfall in normal years coining in December, January and February. Daily evapotranspiration rate for the summer months average 7.5 mm compared to 2.5 mm during the winter months.

Irrigation Systems

Basin irrigation is desirable only for young trees with water being applied from a water truck. Basins are usually broken down after the first season. Many growers in California install a permanent irrigation system using a stationary spitter for the first 2 or 3 years in conjunction with basin irrigation.

Spitters

Spitters are stationary-type heads emitting a spray directed at the tree. The amount of area covered depends upon the spitter design. It comes in 1/4, 1/2, 3/4 and full circle design. The amount of water discharged is determined by the size of the opening in the spitter head. Discharge rates are about 3-4 liters/min. Spitters are used during the first 3 years to reduce the amount of water applied as compared to a rotating sprinkler.

Sprinklers

The basic permanent sprinkler system is the same as for tin spitter system with the only difference being the head itself—the sprinkler head has a rotating nozzle which sprinkles water over the orchard. 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 savings in labor. Proper planning of a sprinkler system cannot be over stressed. There should be even distribution of water to all sprinklers and each sprinkler should give a good distribution pattern. The system should apply water at a rate the soil can absorb without runoff.

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

Drip/Trickle

The newest development in the field of irrigation is drip/trickle irrigation (4). It was introduced experimentally into California in the late 1960's for use in avocado orchards planted on steep slopes. It is the frequent, slow application of water to soil through emitters that are located at selected points along water delivery lines. Most emitters are placed on the ground, but they can be buried at shallow depths for protection.

The volume of soil wetted by drip irrigation usually is much less than wetted by other irrigation methods. It may be only 10% of the soil in the root zone for newly planted crops. Researchers and experienced operators believe that at least 33% of the soil in the root zone under mature crops must be wetted and that crop performance improves as the wetted volume increases to 60% or higher. The volume of soil wetted depends on soil characteristics, irrigation operation time and the number of emitters used. The number of emitters may range from less than 1 emitter per plant for row crops to 8 or more emitters placed in-line or around large trees.

The number 1 problem with drip irrigation is the clogging of lines and emitters by particles of mineral or organic matter, but other problems exist. Some soils may not have sufficient infiltration capacity to absorb the water. Salts tend to concentrate near the soil surface and constitute a potential hazard. Rodents have chewed the plastic pipe when it is exposed on the surface of the ground.

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 the land be relatively flat.

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.

Tables 2 through 7 summarize costs for various methods of irrigation and individual cost studies for the different types of systems used in avocado orchards.

Summary

Irrigation of avocado trees is very difficult and should be given first priority in the cultural program of an orchard. Careful consideration should be given to application of water, both in the amount and timing. Water quality should be known. If the amount of Cl~ exceeds 100 ppm, 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 irrigation, but during and between irrigations. Time spent on evaluation of an irrigation program, using every means to improve the program, will pay dividends in the long run.

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Table 2. Summary of costs for various methods of irrigation.

	Flood		Wheel line sprinkler	Circular sprinkler	Hand move sprinkler	Drip	Furrow	Hose drag	Permanent set sprinkler
	District water	Well water							
Time 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 3. Cost study for hand-move sprinkler irrigation system.

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[z]	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' @ $0.40	1.20
- sprinkler 4%	9.00
Total operating cost	$102.75
Overhead	61.85
Total irrigation cost	$164.60

[z] $HP = \frac{600 x 250}{3960 x 0.65} = \frac{150{,}000}{2{,}574} = 58.3 = 75$

Table 4. Cost study for furrow irrigation.

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Leveling	200	-	16.00	4.00	20.00
Well	100	5.00	4.00	2.00	11.00
Pump 40 HP, 1,000 gpm[z]	75	3.75	3.00	1.50	8.25
Return flow	25	1.25	1.00	0.50	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' @ $3.15	1.75
Total operating cost	$147.75
Overhead	42.00
Total irrigation cost	$189.75

[z] $HP = \frac{1000 x 100}{3960 x 0.65} = \frac{100{,}000}{2{,}574} = 38.8 = 40$

Table 5. Cost study for drag hose irrigation system.

		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[z]	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 for 3.0' @ $6.85	20.55
Repairs - well and pump 3.0' @ $0.40	1.20
- sprinkler 5%	18.00
Total operating cost	$111.75
Overhead	92.45
Total irrigation cost	$204.20

[z] $HP = \frac{600 x 250}{3960 x 0.65} = \frac{150{,}000}{2{,}574} = 58.3 = 75$

Table 6. Cost study for drip irrigation.

		Annual Cost			
Investment	Per Acre	Depreciation	Interest	Taxes, etc.	Total
Well	100	5.00	4.00	2.00	11.00
Pump 25 HP, 300 gpm[z]	80	4.00	3.20	1.60	8.80
Sprinklers	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 - well and pump 2.0' @ $0.40	0.80
- drip system @ 4%	20.00
Total operating cost	$66.15
Overhead	99.00
Total irrigation cost	$165.95

[z] $HP = \frac{300 x 200}{3960 x 0.65} = \frac{60{,}000}{2{,}574} = 23.3 = 25$

Table 7. Cost study for permanent set 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[z]	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 cost	Per Acre
Labor 8 hours @ 0.5 hours = 4 hours @$4.50 (including fringes)	$18.00
Power for 30' @ $6.85	20.55
Repairs - well and pump 3.0' @ $0.40	1.20
- sprinklers 3%	33.00
Total operating cost	$72.75
Overhead	146.85
Total irrigation cost	$219.60

[z] $HP = \frac{600x250}{3960x0.65} = \frac{150,000}{2,574} = 58.3 = 75$