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Management of Drip Irrigation Systems on Tree Crops

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Introduction

It has been 12 years since the author initiated a drip irrigation project on a commercial avocado orchard in northern San Diego County. The purpose of this test was to compare drip irrigation with the conventional fixed head sprinkler and rotating head sprinkler systems. Two reasons for initiating the project were: (1) the high cost of imported water, with costs ranging between $200-$400 an acre foot, and (2) because of the steep hillside plantings of avocado orchards. In southern California, irrigation is a "way of life," since rainfall cannot be depended upon. Rainfall occurs between the months of October—November to the first of March, with the bulk of the rain occurring in December, January, and February.

In 1969, when the project was started, there were very few acres of drip irrigation installed. In twelve years, the drip irrigation philosophy of irrigation has grown from a few experimental acres to a thriving industry, which has become a viable part of the overall irrigation industry in the United States and worldwide.

After proving that the drip irrigation concept can be used on tree crops, it was determined that other crops could utilize this system. Today, there is no crop that has not tried the drip irrigation system. In most cases, the system has worked. Growers have experienced considerable savings in water, and with some crops an increase in yield.

Drip irrigation is more sophisticated than other types of irrigation systems. With this increased sophistication, there is a greater need for better water and irrigation system management. In working with growers that have installed drip irrigation systems, either in newly planted orchards or in converted older groves, the success of the system depended upon management of the system and the installation of a good irrigation system.

Management

Management of a drip irrigation system begins before the system is installed. There are a number of factors to consider, and they are: (1) water source, which includes both the quality and quantity, (2) soil type, (3) climatic conditions, (4) labor availability, and (5) selecting the system that will do the best possible job. Another factor that enters into the decision on what type of system to use, and how to manage it, would be the type of irrigation dictated by the location of the orchard. Will the system be supplemental to a large amount of rainfall occurring in a short period of time? Will it be a year-around type of irrigation such as we need in California? Or will it be a combination of irrigation plus good rainfall?

The amount of rainfall the area receives, and the rainfall pattern, will dictate to a great extent the type of system needed.

An important consideration when a decision about drip irrigation is to be made is the personality of the grower. Is the grower a hard worker, doing much of his own work, or has he turned the operation of his orchard over to a farm manager or a farm management company? The sophistication of the drip irrigation system requires the interest and dedication of time and effort by the grower to assure the system is operating at its maximum potential.

Factors in Detail

Water. Water is the most important factor to consider when deciding on the type of irrigation system to use. The water source must be known, such as wells, rivers, canals, reservoirs, or water districts. The amount of water is critical and must be determined before the system can be designed. Quality of the water is very important, especially in areas where salinity is a problem. Many waters throughout the country have become more saline. The toxicity of certain elements such as sodium, chloride, boron, and sulfate to particular plants must be determined or known. The management of a system will be determined by the quality and quantity of water. The cost of water ranges from a few dollars an acre foot in some parts of the country to as high as $400 an acre foot, which is the predicted cost in the near future for water in San Diego County. Ninety-five percent of the water used in San Diego County is imported and is used by agriculture, industry, and residents. The cost of water makes it even more important to reduce wasted water to a minimum, even to a zero factor.

The research project on drip irrigation with avocados has provided necessary information regarding the plants' requirement for water on a daily basis. This is an absolute necessity with all tree crops, if a good water program is to be followed. The secret to the success of drip irrigation is the daily replacement of water consumed by the plant. A detailed study of an individual grower's water situation is absolutely required, if a good irrigation management program is to be realized.

Soils. Knowledge of the soil in which trees are to be planted, or are grown, is the next important factor in the management of an irrigation program. The texture of the soil should be known to a depth of 3 or 4 feet. The deeper the rooting system of the plant, the more important it is to know what the soil profile is to the depth of the rooting. The grower and/or the irrigation designer should know whether the soil is sandy, silt, or of a clay type. Each of these types of soil, or the mixture of these sand, silt, and clay particles will govern how a system is designed. The sandier the soil, the less lateral movement is obtained, requiring the emitters being placed closer together. A clay soil will have good lateral movement, so emitters can be placed farther apart on the line. A clay soil, likewise, will hold more water than a sandy soil, and the scheduling of the irrigations will be different. For instance, a sandy soil may require daily application of water, provided that the soil has a certain amount of lateral movement and does not stove-pipe or channel directly under the emitters. If the soil has no lateral movement, then an alternative irrigation system should be considered. On the other hand, a clay soil will hold more moisture; so a 2-3 day interval between irrigations is possible. The structure of the soil must be known in order to irrigate the trees adequately. The soil must be measured for shallowness, the presence of hardpans, clay streaks, rock layers, and sand layers. Variations in soil structure will influence root development, tree growth, production, and the ability of a system to wet the soil uniformly.

Growers should have a soil map made of their property, whether it is one acre or five thousand acres. The soil map should be done by a competent soil scientist. Soil cores should be taken throughout the property to determine the texture and the structure of the soil in each section of the orchard. If the soil has a series name, the name should be applied to the soil map for quick identification.

Climate. Climatic conditions within the orchard should be considered. Climate affects the evapo-transpiration and governs the amount of moisture required by the plant and the frequency of applying moisture. The factors to consider throughout the year are heat, wind, humidity, and sunlight. In California, during the months of September to December, there is an east wind condition called Santa Ana winds. When the winds occur in September, they are devastating. Temperatures can rise to 115 degrees to 120 degrees F, wind velocity reaches 35 to 50 miles per hours, the humidity drops to between 5% and 15% with absolutely clear and brilliant sunlight. This condition is the ultimate in affecting water loss from trees. Under these extreme conditions, experience has shown that trees wilt between 2 and 4 o'clock in the afternoon, even though the soil moisture is at field capacity or higher. The transpiration rate is so great that the plant cannot maintain the uptake of moisture to compensate for the water loss. It is during these times that a great demand is placed upon the system. Avocados and citrus trees use upward of 40 gallons per day per tree, but during a Santa Ana wind, the demand could be as high as 60 gallons per day per tree. Many orchards are planted on hillsides, and subject to winds from all directions. In the fall, it is from the east; in the winter, from the north; and in the summertime, the prevailing winds are from the west and southwest. The summer winds blowing in from the ocean reach velocities of 10 to 20 miles per hour, and blow from 11 o'clock in the morning until 6 or 7 in the evening. Even though these winds are not extremely strong, they are steady and cause an increase in transpiration. In some locations this wind will cause a 10 to 20 percent additional irrigation requirement to compensate for the extra water loss.

Labor. Labor must be considered when deciding on the type of irrigation system to be installed, as well as how the system is managed. Availability of labor, the quality of the labor, the dependability of labor, and whether it will be a full time or part-time labor force must be known. The more sophisticated the irrigation system, the more experienced and intelligent the worker must be to provide good maintenance and operation of the system.

Labor is considerably reduced when the drip system is automated. Labor will be involved in checking filters and cleaning them periodically. If a sand filter is used, then back flushing must be done on a regular basis. The pressure gauges should be read daily to be sure the system is operating at the proper pressure. Hoses and emitters should be checked frequently for any type of coyote or rodent damage. Once or twice a year, each dripper should be checked for proper discharge by measuring the outflow and determining whether or not there is any type of plugging in the lines. Fertilizer materials must be placed in the fertilizer tank on a weekly basis, as well as checking for any clogging of the system through the use of these materials. Clogging is the number one problem with drip irrigation and, therefore, the man in charge should be constantly on the lookout for this problem.

Equipment. The drip irrigation system consists of many parts. The different pieces of equipment are described as follows:

EMITTERS

Emitters, which control water flow from lateral lines into the soil, vary in type from porous-wall (line source) units to complicated mechanical or passageway (point source) units. Emitters will decrease the pressure from the inside to the outside of the lateral, thus allowing the water to emerge as drops. This may be done by small holes, larger holes in series, long passageways, vortex chambers, discs, steel balls, manual adjustment, or other mechanical means to reduce water flow into the soil. Some emitters maintain steady flow at different pressures by changing the length or cross-section of passageway. Rate of flow usually is fixed at from 1/2 to 2 gallons per hour (gph); 1 gph is most common. Some emitters have manually adjusted rates; some are reported to be self-cleaning, and some flush automatically.

LATERAL LINES

Emitters are connected to or are a part of the lateral lines, which usually are plastic and of small diameter (three-eighths to ^{3}A inch). These Lines may go long distances because flows are low. Lateral lines generally are one per tree row and one for each crop row or pair of rows and should be installed as near level as possible, particularly for systems using pressures of less than 10 pounds per square inch (psi).

MAIN LINES

Main lines, which are usually plastic and buried, convey water from the head to the lateral lines. Size of main lines depends upon number of laterals and flow of water to them.

THE HEAD

The head is the control station where water is measured, filtered or screened, treated, and regulated as to pressure and timing of application.

METERS

Water is generally measured onto a field with meters. Some meters automatically turn off when the desired amount of water has been applied.

FILTERS AND SCREENS

Generally, water used for drip irrigation must be cleaner than drinking water. To accomplish this, various types of sand filters or cartridge filters and screens of 100 to 200 mesh are used individually or in combination. The sand filter usually has manual or automatic backflushing devices for cleaning. The cartridge filter is changed when dirty, and screens are usually cleaned manually.

INJECTORS

Injectors are used to apply fertilizer, algaecides, and other materials into the Unes. These may be piston-type power injectors or Venturi-type that create a pressure drop across an orifice to suck material for treatment from a tank.

PRESSURE REGULATORS

Most systems require some pressure regulation — a brass or plastic mechanical pressure regulator usually is used. Pressures for different emitters vary from 2 or 3 psi to 30 or 40 psi. Emitters operate best at design pressure.

CLOCKS

Special clocks are geared to provide timed water applications ranging from 5 minutes to 24 hours for any predetermined number of days. The clocks, which are powered by electric lines, batteries, or water, actuate control valves that turn water on and off as needed.

The design of a system is important because no two orchard sites are alike. Due to Santa Ana type winds in the fall, there will be an added demand on the system for increased water supply. It is, therefore, important to design the basic system to deliver 60 gallons per day per tree. In California, when an irrigation system is installed it is designed as if it were going to be used as a sprinkler system. There is a real advantage to this, and that is, if a grower wants to sell his property he may have difficulty selling to someone who is not in favor of drip. Therefore, for a few hundred dollars per acre more the design and installation of an irrigation system that will accommodate any type of sprinkler system will be much better than if it was designed for just one type of irrigation system. Because of the rapid development of new equipment and new ideas in irrigation technology it is, therefore, even more important to have a system that can accommodate any new equipment coming on the market. It is felt that the 60 gallons per day requirement is sufficient to take care of any emergency arising from adverse climatic conditions.

Equipment Operation and Maintenance

Fertilizer materials are required by tree crops for proper growth and fruit production, regardless of where they are grown in the country. The usual elements required are nitrogen, phosphorus, potassium, and zinc.

Fertilization through a Drip-Trickle Irrigation System

Following is a chart giving the amounts of various nitrogen fertilizers to apply monthly to each tree. This amount is the accumulative total for the month but can be divided into weekly or bi-monthly applications. If fertilization was stopped in November, begin the fertilizer program in January or February.

TABLE 1.

POUNDS OF MATERIAL PER TREE PER MONTH

Tree Age	Urea	Ammonium Nitrate (33% N)	Calcium Nitrate (15% N)
1	.028	.038	.086
2	.056	.076	.072
3	.092	.126	.287
4	.139	.189	.431
5	.278	.379	.862

Table 1 gives an outline of the three most common nitrogenous fertilizer materials used in avocado and citrus orchards, and the amounts per month for each year of age of the tree. These materials can be injected directly into drip-irrigation systems through the use of a fertilizer tank and a Venturi- type injection unit. Phosphorus and potassium can likewise be applied through the irrigation system. With the use of high calcium Colorado River water, phosphorus materials, dry or liquid, must be acidified to prevent a precipitate of calcium phosphate from clogging the entire system.

Fertilizer materials are injected weekly beginning in January and extending into October. There is no need to apply fertilizer during the winter months of November and December.

Irrigation schedules will vary with soil type, orchard location, wind conditions, and type of system. Daily water application is the secret to good results with drip irrigation. Night irrigations are preferable to daylight hours. Reasons for this are: (1) increased pressure in irrigation lines and (2) less water loss due to evaporation. One alternative to daily, or every other day application of water and fertilizer, is dependent upon the climate, the time of year of irrigation, and the soil type. These three factors influence water utilization by the plant. If the soil is clay having a relatively high water holding capacity, an every two to three day schedule can be instituted.

Water measurements must be made so the proper amount of water is applied to the trees. Tensiometers have been the most popular water measuring device. The tensiometer is an instrument for measuring available water in the soil. It is placed in the most concentrated root system of the plant at the drip line. The instruments are placed in pairs. Avocado being a shallow-rooted plant, tensiometers are placed at 12 and 24 inch depths and set about 8 inches apart. For citrus, because of the deeper rooting habit of the plant, instruments are placed at 18 inches and 36 inches.

Experience has shown that with a daily irrigation program, it is recommended to keep the level of soil moisture below 20 centibars.

Another method of measuring water use is the Class A evaporative pan. The pan is placed in the orchard in an area most typical of the climate. The large pan is filled with water. Measurements are made daily to determine the amount of water evaporated.

Salinity control, where high saline waters are used, is of prime importance. Drip irrigation makes it possible to irrigate with saline waters. Daily applications of water results in a high soil water regime that maintains the salt in a dilute state. Extra water is needed to leach accumulated salts below the root-zone and to the outer edges of the wetting pattern. About 20% additional water is required to satisfactorily control salinity. The management of an irrigation system becomes very important when it involves salinity control. One of the most critical factors of drip irrigation is the extremely high concentration of salts that accumulates in the first three inches of the soil. At the end of an irrigation season, salts have accumulated in the surface soil and in the root-zone. If the first rains are not heavy, severe leaf damage can take place if the irrigation system is not operating on a daily basis. If the first rain is only an inch or less, then drip irrigation must be continued as if no rain had fallen. A rule of thumb followed by avocado growers is that, until three inches of rain has fallen from one or two successive storms during a short period, the irrigation system should not be turned off.

Filtration is the key to proper operation of drip irrigation systems. Filtration can be done either through the use of separate sand filters and double screen filters of 150 or 180 mesh, or the combination of the two. Depending on the amount of debris, dirt, sand, and algae in the water. The degree of filtration will depend on the water source. If water comes from wells, rivers, lakes, canals, or reservoirs, filtration is an absolute must. The water must be treated with chlorine prior to delivery into the system.

In San Diego County, and other areas of southern California, the Metropolitan Water District delivers Colorado River water through hundreds of miles of open concrete ditches, tunnels, and siphons. When the water enters the county, the County Water Authority puts it into a closed system and adds chlorine.

Filters must be serviced regularly. Sand filters must be back flushed every 12 hours either manually or automatically. Screen filters should be removed from the container and washed off at least once a week if good filtration is to be accomplished.

Weeds around emitters must be controlled. Weed oil or some herbicides registered for use with particular tree crops will be a more satisfactory way of controlling weeds. Because of the hose and emitters lying upon the surface of the ground, hoeing or mowing could cause damage to the tubes. Weeds will compete for moisture; and, in areas of short water supply and high cost, this is one source of competition that should be eliminated.

To help retain moisture in the soil after an irrigation, and to reduce the amount of weeds growing in and around the area of the root-zone of the tree, a mulching material should be used. Materials used include manures of all types, sawdust, wood chips, straw, or other organic matter. Not only does the mulch help retain the moisture in the soil, it prevents the soil from cracking, drying out, reduces weeds, and improves the tilth of the soil.

Emitter Checks

Emitters should be checked regularly for proper operation and discharge rate. This is done usually once every three to six months when the system is new, and maybe once every 6 to 9 months after the system has been proven free of problems. Plugging or clogging is one of the more serious problems in drip systems because of the small orifice in each emitter. Plugging can be caused by algae, dirt, sand, pieces of plant material, shavings from the installation of the plastic pipe, and roots that grow into emitters through the orifice.

Rodent damage should be checked for daily. Damage consists of hoses that have been chewed, puncturing holes in the tubing or actually tearing the pipe apart. Coyotes are particularly troublesome. Baby coyotes like to use the hose as teething rings. Rodent-damaged pipe and emitters must be replaced. If this is not done on a daily basis, considerable water is lost and many trees will not receive adequate water.

Water savings can be realized with drip irrigation. In the six-year test on avocados, a 65-75% water savings was obtained with drip compared to sprinkle irrigation. A 50% water saving was recorded on six-year old trees. It is estimated that a 25% water savings would be possible on a fully mature orchard, where there was a full canopy of leaves and no weeds. This represents the amount of water lost through evaporation during a sprinkler application, and that which evaporates from the ground or leaf surface after the sprinklers have been turned off.

Crops. In the four worldwide drip irrigation surveys conducted by the author, it was reported that practically every known commercial agriculture crop grown has been irrigated by drip irrigation on an experimental basis and/or commercial basis. Tree crops have adapted well to drip irrigation and the success of the system is the result of a good irrigation system design and good management.

Future. The future of drip irrigation appears to be bright. Fully automated systems, computerized systems, and innovative pieces of equipment are being developed and used to enhance the efficiency of drip irrigation systems. There is no question that water can be saved. A better crop can be grown. In some crops, there is an increase in yield. Quality of the fruit or vegetable is as good, if not better, than under conventional irrigation systems.

It is anticipated that new systems, new equipment, and new ideas will further the development of drip irrigation.

Regardless of what type of equipment comes on the market, the most important factor contributing to the effectiveness and efficiency of a drip irrigation system is **good management.**