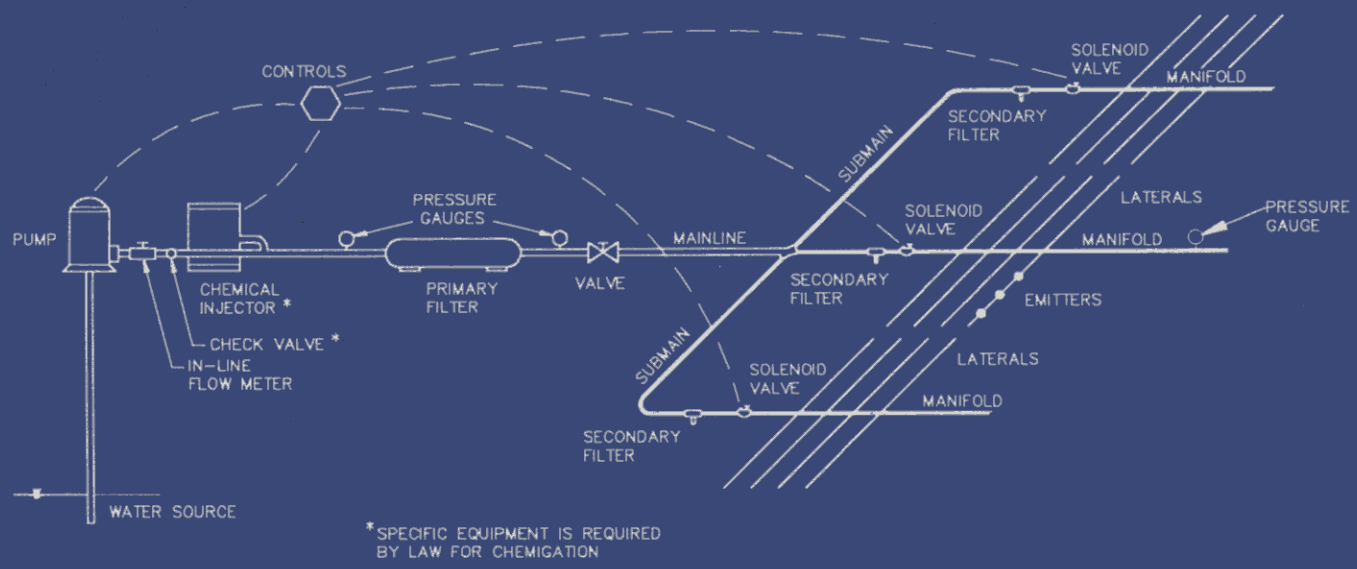
B-1663

Texas Agricultural Extension Service

Planning and Operating Orchard Drip Irrigation Systems



Components of a typical drip irrigation system.

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PLANNING AND OPERATING ORCHARD DRIP IRRIGATION SYSTEMS

Leon New and Guy Fipps*

Drip irrigation allows precise application of water to plant roots. Small amounts of water are applied frequently to replace that withdrawn by the plant and lost by evaporation or deep seepage. Thus, soil moisture in the area around the plant is maintained at a uniform level throughout the growing period. This increases growth and production potential since plants are not subjected to wet and dry cycles which normally occur with other irrigation methods.

Drip irrigation simplifies irrigation procedures, minimizes distribution and evaporation losses and may reduce labor requirements. Less of the total soil surface area is wet with drip than with sprinkler and furrow systems. This significantly reduces the amount of water required for irrigation and simplifies weed control. The irrigation system can be automatically controlled with a time clock and/or soil moisture sensors and automatic valves, thereby maintaining optimal soil moisture with minimum labor. Drip irrigation is used more often for orchard crops than for field crops, primarily because the spacing between emitters and laterals is greater. This lowers system costs per acre.

DRIP IRRIGATION SYSTEM LAYOUT

Water is distributed to individual trees through a pipeline system which should be carefully planned for the specific site, orchard size and shape, land slope, tree spacing and water requirements. The system should provide reasonably uniform pressure at all emitters, require minimum material and achieve maximum operating convenience.

Components of a typical drip irrigation system are illustrated in Figure 1. The *pipeline* is composed of a main line which carries water to manifolds and laterals. Water flow is regulated using *manual* or *automatic valves*. *Pressure gauges* are located at critical points and are used to ensure proper system operating pressure. A *filter system* is installed in the main line so that all water is filtered. Injection of fertilizers and other chemicals into the irrigation water often causes minerals to precipitate. Thus, the *fertilizer injector equipment* should be installed upstream from the filter so that precipitates will be filtered. An *anti-siphon unit* consisting of a *check valve* and a *vacuum breaker* is installed in the main line between the pump and fertilizer injector to prevent backflow of fertilizers or other chemicals back into the water source in the event that the irrigation pump stops during injection. Note that specific chemigation equipment is required by federal regulations. These requirements are covered in Texas Agricultural Extension Service publication B-1652, "Chemigation Workbook."

A lateral pipeline containing emitters is placed along each row of trees. In larger systems, the orchard may be divided into sections or blocks, with the laterals for each block connected to a separate manifold pipeline. The main line is normally connected at the center of the manifold as illustrated in Figure 1. However, topography may dictate placement of the connection at some other point. An *automatic pressure regulating valve* or a *manual globe type valve* with a pressure gauge is installed on the manifold side of the valve to allow for appropriate control of pressure in all blocks. Valves can be used to equalize pressure variations caused by elevation differences and friction losses, and to maintain sufficient minimum pressure throughout the system.

On moderate to steep slopes, laterals and tree rows generally should be across (or perpendicular to) the slope to help maintain more uniform pressure at the emitters. For slight, uniform slopes, proper water pressure in the laterals can sometimes be achieved by placing laterals along the direction of the slope to offset pressure loss caused by friction. Laterals which direct water flow up the slope should generally be avoided especially when low pressure emitters are used.

Water is released by emitters attached to the laterals near each tree. Application rates of emitters vary from 1/2 to 2 gallons per hour (gph), while micro-sprinklers may discharge up to 10 gph or sometimes more. Do not select an emitter which applies water faster than it can be absorbed by the soil. Most emitters can be installed underground. However, it is easier to adjust emitter location and to observe and clean clogged emitters when they are on the soil surface.

The size of main lines and manifolds should be carefully selected based on the water flow rate required by mature trees and on pipeline length. As a general rule, pipe sizes are selected so that velocity of flow is less than 5 feet per second to prevent excessive pressure loss and water hammer (Table 1). Polyvinyl chloride (PVC) pipe is generally used for the main and manifold pipelines.

Main and manifold pipelines are frequently installed underground with laterals on the surface, although laterals

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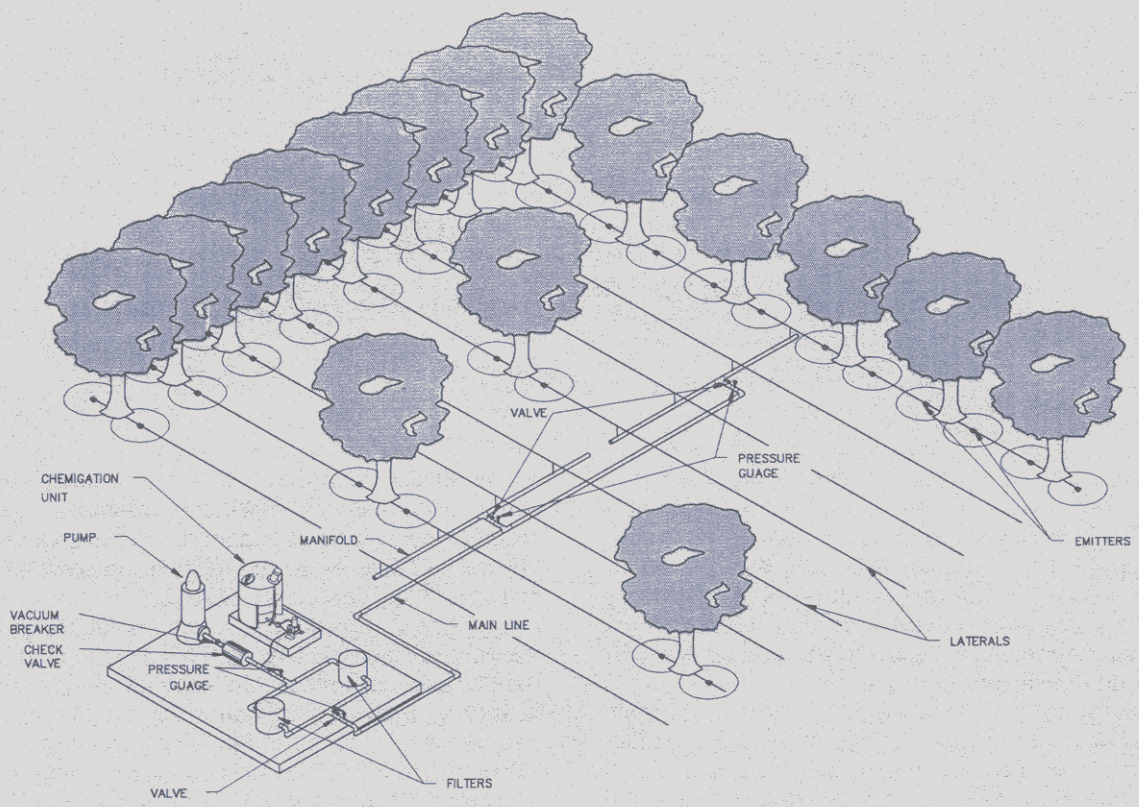

Figure 1. Components of a typical orchard drip system.

also may be underground. Underground pipelines last longer and do not interfere with field operations. Main and manifold pipelines are often set 18 to 24 inches below the surface, but site conditions may require other depths. Underground laterals are usually 12 to 15 inches below the surface, or below plow depth. Connection joints in underground pipelines should be checked for leaks before covering pipes with soil. The ditch may be partially backfilled as installation progresses, leaving only the connection joints exposed. It is best to cover underground pipelines when temperature is coolest, e.g., early morning.

Table 1. Approximate maximum flow rate (gallons per minute) in plastic pipe for drip irrigation.

Manifold and pipeline sizes and flow rates	
Size, inch	**GPM**
1	10
1 1/4	20
1 1/2	30
2	50

Filters

Clean water is essential for successful drip irrigation. Sand, silt, organic and other foreign material can easily clog small emitter openings. Select a filtration system according to the types and quantity of foreign material in the water and the emitter characteristics, as recommended by the manufacturer. A filter system in the main pipeline near the pump is more economical and much easier to maintain than several filters located throughout the irrigation system.

Filters with corrosion-resistant stainless steel or bronze screens are available. These are usually adequate when the irrigation water contains small amounts of sand only. Two or more filters can be connected in short, parallel manifold pipelines to increase filtering capacity. Backflushing capability can be provided with an appropriate arrangement of valves. Be sure that the mesh size of the filtering screen is appropriate for the particular emitter chosen.

Filters with multi-stage screens may be required when water contains moderate to large amounts of sand. If sand is an extreme problem, settling tanks or sand separators can be installed upstream from the filter to remove a large amount of sand and reduce the filter load. Dual or oversized filters also will handle extra heavy filter loads, but sand separators or settling tanks may be more economical.

Surface water such as rivers, canals and ponds frequently requires more filtration than water from wells. It may be necessary to have both a synthetic fiber or metal screen intake filter *and* a fine-mesh screen or sand filters on the discharge side of the pump. Settling basins may be needed if the water contains considerable algae. Sand (or media) filters are commonly used for surface water sources. These filters are expensive but are very effective and can be equipped for automatic flushing.

Equip filters with cleanout or flush valves so that trapped particles can be easily removed. Daily flushing is necessary when water contains moderate amounts of sand or other material. Screens will need periodic, thorough cleaning.

Pressure gauges installed on both sides of the filter provide an indication of filter clogging. A moderate to high pressure difference indicates the filter needs flushing or cleaning.

Lateral Pipelines

Lateral pipelines are usually flexible polyethylene or polybutylene pipe. Pipe sizes may be given by manufacturers in English or metric units (Note: 1 inch = 25.4 mm). Available sizes include 10mm, 13mm, 15mm, 16mm and 3/8 inch to 1 inch. Sizes most frequently used for lateral pipelines are 15mm, 16mm and 1/2 inch. Smaller sizes may be used for very short laterals and larger sizes for extra long laterals. Select a good quality polyethylene or polybutylene (or other plastic formulation) tubing manufactured specifically for drip irrigation systems. Be sure pipe, fittings and emitters are compatible. During installation, heat the end of the pipe in hot water if connections are extremely difficult.

The number of laterals required for each row of trees is determined primarily by tree size or spacing and emitter arrangement at the tree. For large trees such as pecans, one lateral for each row is normal when micro-sprinklers or tree loops are used. In-line or attached emitters are often used for smaller trees (peaches, apples, citrus). Two laterals of in-line emitters may be best for each row of mature pecan trees. Three laterals per row may be required for pecan trees spaced 50 feet apart.

Underground lateral pipelines last longer and do not interfere with cultural and harvesting operations. Place underground laterals approximately 12 inches deep or below plow and freeze depths. Position single lateral pipelines with in-line emitters 2 feet from the tree trunk. Where two emitter pipelines are used, locate each pipeline one-fourth of the row spacing on each side of the tree. Use emitter tubing to apply water within 12 inches of small trees.

Laterals placed on the surface should be "snaked" or left slightly loose along tree rows. In addition, leave 5 to 10 feet of extra pipe at each end so that lateral and emitter location can be easily adjusted. Extra lateral length is especially helpful when emitters are installed in-line. Flexible pipe also tends to "crawl" as it expands and contracts with temperature changes. Permissible lateral length is influenced by the diameter of the lateral, tree spacing, quantity of water delivered to each tree, type of emitter and land slope. Design lateral lines to not exceed the length, pressure loss and flow rates recommended by the manufacturer.

With properly designed drip systems there will be reasonably uniform water application by every emitter in the system. Many emitters are "pressure compensating," which means that their discharge rate varies little over a wide range of operating pressure. Other emitters discharge more water as pressure increases and less water as pressure decreases (Figure 2). Due to the difficulty of achieving absolutely uniform pressure throughout the system, most drip systems are designed for 90 percent uniformity. This means that the emitter with the lowest discharge rate will apply at least 90 percent as much water as the emitter with the highest discharge rate. Allowable pressure variation within the system or within a block in a large system can be determined with the pressure-discharge curve for the particular emitter selected. If a pressure-discharge curve is not available, an allowable pressure variation of no more than 20 percent is suggested as the design criterion.

Friction pressure loss in laterals can be determined using friction loss charts for the specific type of plastic pipe used. These charts are usually available from pipe manufacturers. Lateral diameter, length and flow rate are needed to determine the pressure loss caused by friction. Friction pressure loss in a lateral (or any pipeline containing at least 10 uniformly sized and spaced emitters along its length) is about 40 percent of that of a pipe with no emitters. This is sometimes refered to as the 40 percent rule. Multiply pressure loss calculated from friction charts by 0.40 to determine pressure loss in the proposed lateral. Compare the calculated pressure loss with the allowable pressure variation. If the calculated pressure loss is greater than the allowable variation, lateral length should be decreased or lateral pipeline diameter increased. Head in feet (such as elevation differences) can be converted to psi (pounds per square inch) by dividing by 2.31 (2.31 feet of water = 1 psi). Guidelines for lateral length and flow rate in 1/2-inch lines with emitters are given in Table 2.

Manifold Pipelines

In larger orchards, water may be supplied to a "block" of several laterals through a pipeline called a manifold. The manifold is usually connected to the main line at the midpoint of the manifold in order to provide more uniform pressure to all laterals in the system. The manifold can be of either polyethylene or polyvinyl chloride (pvc) pipe and is usually installed underground.

Plan manifold pipelines to provide as nearly equal pressure at each lateral as possible. A globe valve or an automatic pressure regulating valve is installed between the main line and manifold to allow for adjustment of pressure so that all laterals have approximately equal pressure. Install a pressure gauge immediately downstream from the globe valve to measure pressure at the midpoint of the manifold. Set the appropriate operating pressure by adjusting the globe valve. Maximum pressure loss in the manifold plus loss in the lateral should generally be less than 20 percent of the emitter operating pressure. Select manifold pipe size on the basis of water flow rate and the corresponding friction pressure loss. Recommended maximum flow rates for some pipe sizes are listed in Table 1. The 40 percent friction lost rule (see above) applies to manifold as well as laterals pipelines.

Table 2. Recommended maximum lateral lengths[1] for 1/2-inch plastic pipe with emitters for various flow rates in gallons per minute (GPM).

1/2 - inch laterals with emitters	
Flow rate, GPM	**Length, feet**
1.5	650
2.0	500
2.5	300
3.0	225

[1]Use manufacturer's recommendations when available.

Emitters

The term emitter is often used to refer to any drip irrigation water discharge oriface. Various types are available, including in-line and barbed types. With non-pressure compensating emitters, an increase in pressure increases the emitter discharge rate, while a decrease in pressure decreases the discharge rate (Figure 2). A pressure compensating emitter will discharge approximately the same amount of water under a wide range of pressures. Emitter manufacturers provide information on the relationship between pressure and water discharge for their emitters.

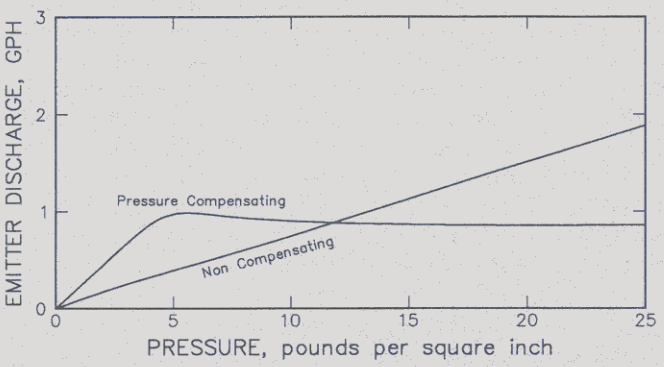

Figure 2. Typical relationships between emitter discharge and pressure for pressure compensating and non-compensating emitters.

Emitters are sometimes classified according to their design operating pressure, either low or high pressure. Low pressure emitters usually apply 1 to 2 gallons per hour at operating pressures of 2 to 8 psi (pounds per square inch), while high pressure emitters typically apply 1 gallon per hour at about 15 psi. The pressure-discharge curves in Figure 3 show that low pressure emitters apply more water at a given pressure than high pressure emitters. Do not use both high and low pressure emitters in the same drip irrigation system unless pressure-regulating devices are installed upstream from the low pressure emitters. High and low pressure emitters should not be used in the same lateral pipeline.

The water discharge rate of high pressure emitters is affected less by changes in land elevation within the orchard or friction pressure loss in the pipe than that of low pressure emitters. Laterals with low pressure emitters cannot be as long as laterals with high pressure emitters. All of these factors should be considered in selecting emitters and planning drip systems.

The number of emitters needed for each tree is influenced by water movement in the soil as well as the amount of water required by the tree. A soil that allows limited horizontal movement of water (sandy soil) requires more emitters with lower discharge rates than a soil that will allow greater lateral spreading (clay soil). The wetting pattern generally should cover at least 60 percent of the horizontal extent of the tree canopy and root zone. Diameter of the wetting pattern is affected by soil type, discharge rate and the duration of each irrigation period.

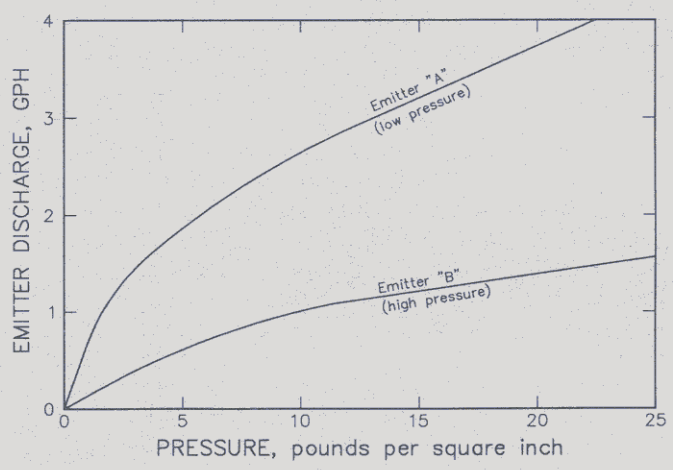

Figure 3. Pressure discharge relationship for low pressure emitter and high pressure emitter.

Emitter arrangement at each tree should be considered carefully to provide convenient orchard care, easy emitter maintenance and adequate irrigation. Typical emitter arrangements are shown in Figure 4. Emitters should be within 1 to 1.5 feet of the trunk of young, newly transplanted trees, but should be moved away from the trunk as the trees grow. Water quality is a factor in emitter location since salts tend to concentrate at the edges of the wet soil area (Figure 5). It may be necessary to locate emitters so that wet areas overlap at the tree trunk to prevent harmful accumulations of salt at or near the trunk.

Tree-loops are often used for large trees such as pecans, as shown in Figure 4a. The loop is connected to the underground lateral pipeline and circles the tree between the trunk and the canopy line. Tree loops are usually 1/2-inch or 3/8-inch polyethylene pipe, 6 to 10 feet long initially, and contain one or two emitters. Additional sections of pipe 8 to 12 feet long, containing one emitter, are connected to the initial loop as the tree grows and requires more water. Large pecan trees typically require tree loops with 6 to 10 or more emitters.

In-line emitter arrangements, as shown in Figure 4b, have been used satisfactorily for smaller trees such as citrus, peaches and apples. Two to four emitters are installed in the lateral so that wet areas slightly overlap in a line along the tree row. When laterals become too long to allow for the addition of emitters without excessive friction pressure loss, a dual-lateral arrangement, as shown in Figure 4c, may be used to supply additional water as the trees grow.

Emitter water discharge rates should be measured periodically using a graduated cylinder or other marked container. Graduated cylinders are frequently marked to measure volume in milliliters. Table 3 can be used to convert milliliters per minute to gallons per hour. Emitter discharge rate should be checked at several locations over the orchard to ensure adequate and uniform irrigation. Also check operating pressure at the ends of lateral lines at different locations. Pressure checks should be made immediately if emitter discharge rates are less than planned.

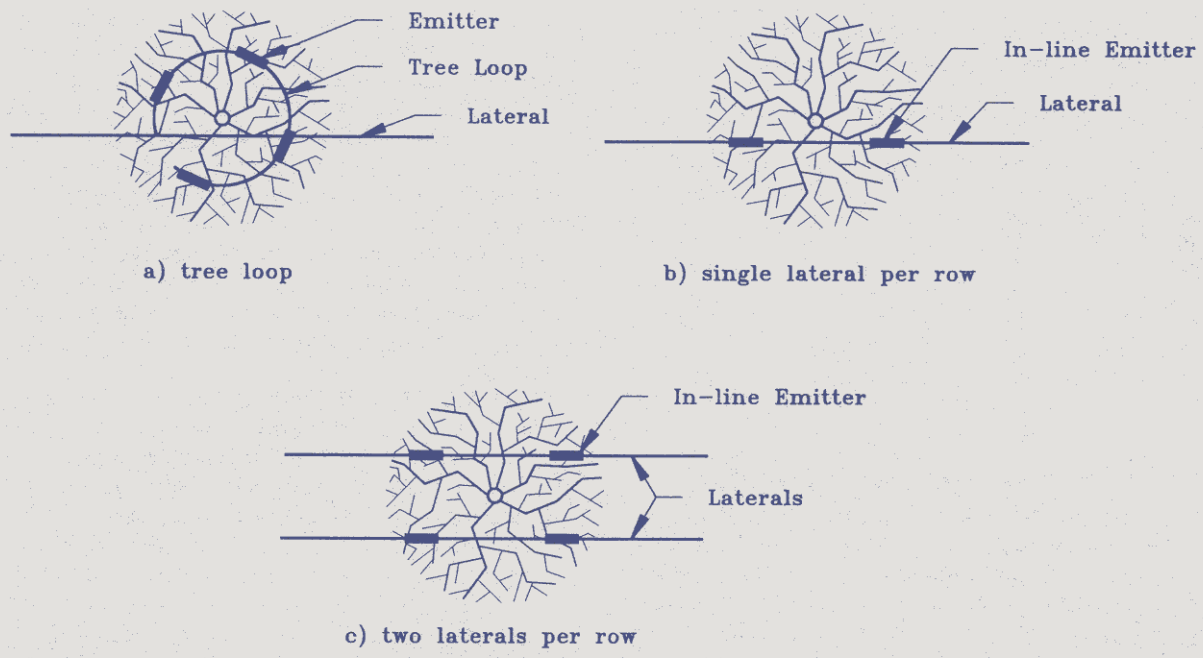

Figure 4. Typical emitter arrangements: (a) emitters installed in a tree loop, (b) single lateral with in-line emitters; and (c) double lateral with in-line emitters.

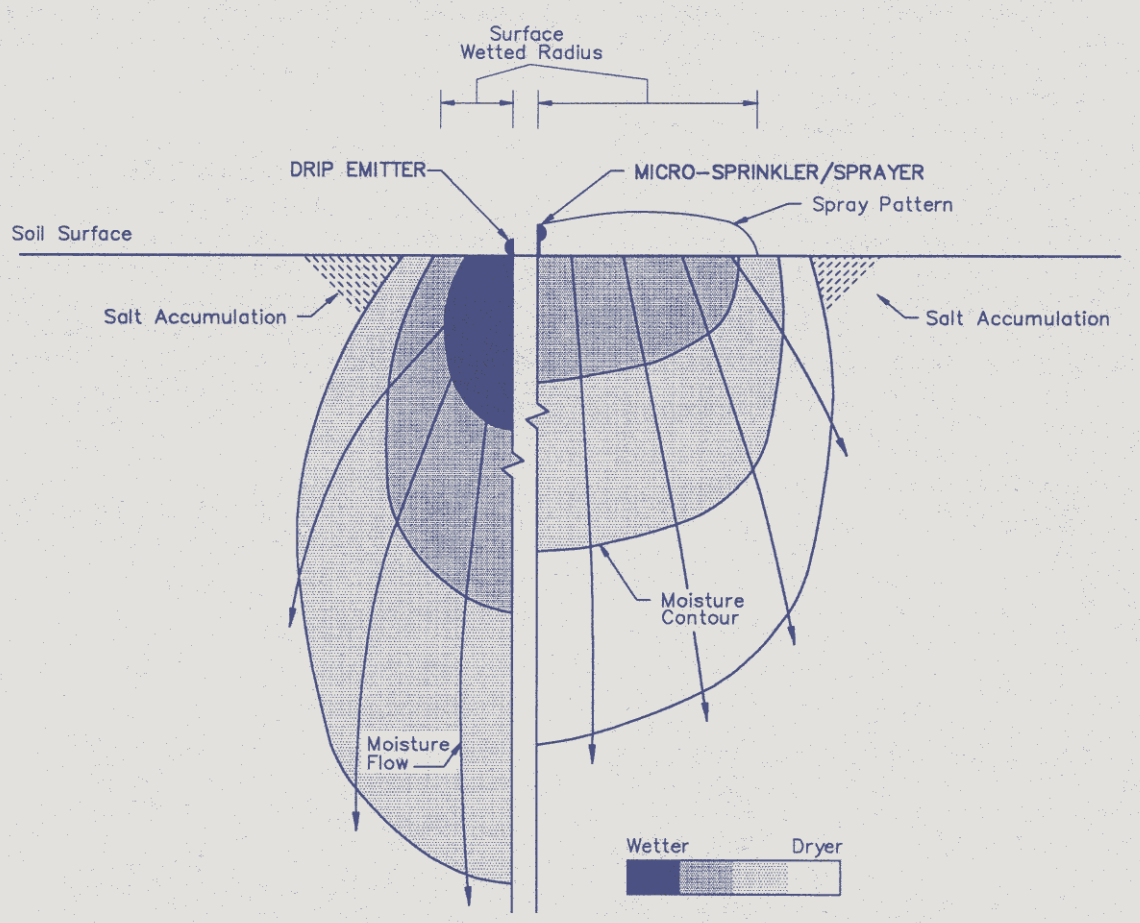

Figure 5. Typical wetting patterns of drip emitters and micro sprinklers.

Table 3. Conversion of flow rate in milliliters per minute (ml/min.) to gallons per hour (gph).

(milliliters/minute x .015852 = gallons per hour)

Flow rate (ml/min.)	GPH	Flow rate (ml/min.)	GPH
35	.55	70	1.11
40	.63	75	1.19
45	.71	80	1.27
50	.79	85	1.35
55	.87	90	1.43
60	.95	95	1.51
65	1.03	100	1.59

Micro-Sprinklers and Micro-Sprayers

Micro-sprinklers (with moving parts) and micro-sprayers (without moving parts) are sometimes preferred over drip emitters. With these devices, water is discharged into the air and travels some distance before contacting the soil surface. Micro-sprinklers and micro-sprayers usually have higher flow rates than drip emitters and wet larger soil surface areas in their circular or fan-shaped application patterns.

Figure 5 illustrates typical soil moisture distribution under a micro-sprinkler or sprayer as compared with a drip emitter. With drip emitters, small areas of nearly saturated soil may occur near the emitter as shown. Micro-sprinklers and sprayers spread water over a larger surface area and soil saturation is less likely to occur. Spreading water over larger soil surface areas is particularly advantageous on coarse, sandy soils (where water from a drip emitter moves very little laterally) and on fine-textured clay soils (where water from a drip emitter may puddle on the surface).

Micro-sprinklers and sprayers are available in a variety of application patterns from a full circle to fan-shaped or part-circle. Some of the application patterns available are shown in Figure 6. Some micro-sprinklers and sprayers have interchangable nozzles so that the spray pattern and discharge rate can be changed. Thus, a pattern which concentrates water near the tree can be used when the tree is small. As the tree grows and the root system expands, the application pattern can be changed to wet a larger soil surface area.

Water droplets traveling through the air from a micro-sprayer or sprinkler are subject to evaporation loss. In addition, greater evaporation loss from the soil surface will occur because a larger surface area is wet. Evaporation losses of 5 to 15 percent can be expected depending upon temperature, wind, humidity, system pressure and orifice size. Since a larger surface area is wet with micro-sprinklers and sprayers, increased weed germination and growth can be expected.

The *rate* of water flow to each tree will generally be four to ten times greater from micro-sprinklers or sprayers than from a drip system. Therefore, larger pipe sizes (except the main supply pipeline) will generally be required to obtain uniform water application over the orchard. Also, it may be necessary to divide the orchard into more blocks to route the water supply in sequence from block to block. Conversion of an existing drip system to a micro-sprayer or sprinkler system may result in unsatisfactory irrigation uniformity unless flow rate requirements and piping system hydraulics are adequately evaluated.

Since salts typically accumulate around the edges of the wet pattern (Figure 5), micro-sprinklers and sprayers may provide better control of soil salinity. However, drip emitters may be the better choice if the total salt content of the water is high, since the soil is maintained at a higher moisture content near the emitter.

IRRIGATION SYSTEM CAPACITY

Selection of the emitter and sizing of laterals and mainlines are based on a chosen or available system water capacity, usually expressed as GPM (gallons per minute). Pipelines that make up the irrigation system must be sized initially to provide the water required when the orchard is mature. For planning purposes, water requirements of

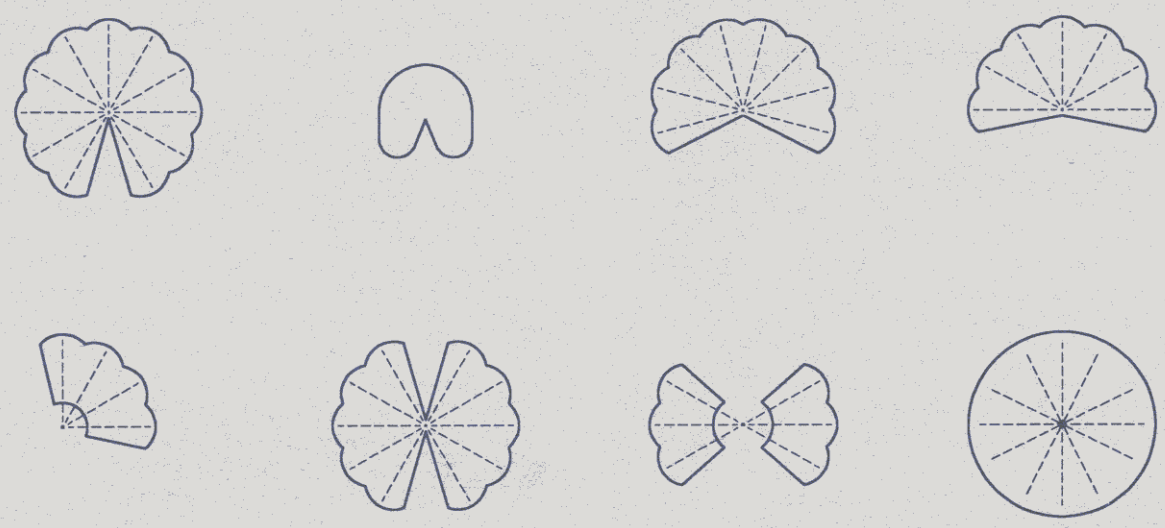

Figure 6. Typical application patterns of micro-sprinklers and sprinklers.

orchards can be estimated from National Weather Service Class A evaporation pan rates. Pan evaporation is influenced by such environmental factors as temperature, relative humidity and wind. Each of these factors also influences the amount of water that trees require.

Pan evaporation rates are related to tree water usage with a Water Use Factor (WUF). A WUF of 0.7, which means that the water use is 70% of the pan evaporation rate, has been used successfully in planning for orchard irrigation system capacity. However, experience with citrus orchards in the lower Rio Grande Valley has indicated different values for WUF, as given in Table 4.

Table 4. Water use factors (WUF) for trees for Equations 1 and 3.

Tree	WUF
Pecan	
average yearly	0.7
Citrus[1]	
June 1 - Aug 31	0.7
Nov 1 - Feb 15	0.5
remainder of year	0.6
Other	0.7

[1]Source: Dr. Julian Sauls, Texas Agricultural Extension Service, Weslaco. Citrus values are for the lower Rio Grande Valley.

The other factor used to estimate water requirements is the area covered by the plant canopy. In orchards the canopy area is based on the diameter of the circle formed by the tree drip line. The maximum potential size of the tree when mature should be used to calculate canopy diameter for determining irrigation system capacity and in sizing all irrigation pipelines. The canopy diameter of mature trees can be assumed to be equal to the tree spacing in the row. For example, the canopy of mature peach trees will be 18 feet in diameter when planted on a spacing of 18 feet by 24 feet. Pecan trees planted on a spacing of 35 feet by 35 feet will have a canopy diameter of 35 feet when mature.

The daily maximum water requirement for each tree can be projected using the formula:

Equation 1

$$Q = A \times E \times WUF \times 0.623$$

Where:
- Q = Daily water requirement in gallons.
- A = Area covered by plant canopy in square feet.
- E = Class A pan evaporation in inches per day.
- 0.623 = Constant (7.48 gallons/cubic foot divided by 12 inches/foot)
- WUF = water use factor (Table 4).

For trees, the area (A) in equation 1 is the area of a circle with a diameter equal to the diameter of the tree canopy, calculated by:

Equation 2

$$A = \frac{\pi D^2}{4}$$

Substituting this value for A in equation 1 and combining constant numerical values produces the following equation:

Equation 3

$$Q = D^2 \times E \times WUF \times 0.49$$

Where:
- Q = Daily water requirement in gallons per tree.
- D = Diameter of area within tree canopy in feet.
- E = Class A pan evaporation, inches per day in Table 5.
- WUF = water use factor (Table 4).

Equation 3 can be used to calculate the daily water requirement of trees or other single plants whose canopies cover a *circular* area.

Average daily Class A pan evaporation rates at various locations in Texas are given in Table 5. These rates are the daily averages for each month of the year. Select the daily evaporation rate at the nearest location or average the rates shown for two or three stations nearest the orchard location. Normally, the maximum daily evaporation for the year occurs in June, July or August. Use the maximum value to plan irrigation system water capacity. The value selected from Table 5 is the "E" value used in equations 1 and 3.

Table 6 shows the number of gallons of water required to supply a WUF of 0.7 of daily pan evaporation for trees with canopy diameters of 5 feet to 70 feet. For a WUF of 0.7, Tables 5 and 6 can be used directly to determine the daily water requirements in gallons. For example, the maximum average daily evaporation in San Antonio is 0.36 inch and occurs in the months of July and August.

Table 7 shows that 151 gallons of water per day will be required to supply a WUF of 0.7 of pan evaporation for a tree with a canopy 35 feet in diameter. Note that no allowance has been made for rainfall. Allowing for normal or expected rainfall often will temporarily reduce the total amount of water that must be supplied by the irrigation system to meet peak water usage. However, in the event of extended drought, the system should have insufficient capacity to maintain potential yields and prevent tree damage and loss.

Water Requirements of Pecan Trees

Researchers in the Southeast and Southwest have reported widely differing estimates of the water requirements of pecan trees. Experience in Texas has indicated that a mature pecan tree will use between 160 and 240 gallons per day during the peak water use period. Some research has indicated that for short periods during the nut-filling stage, water use increases to almost 100 percent of pan evaporation. Experience has shown that with systems designed at 0.7 pan evaporation, enough water usually can be stored in the root zone in advance (with proper soil moisture management) to supply the requirements of pecan trees during this maximum use period.

Table 5. Average class A pan evaporation at selected locations* (inches per day by months).

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Amarillo	.11	.15	.24	.32	.36	.44	42	.36	.32	.23	.13	.08
Angleton	.07	.09	.12	.16	.19	.22	.21	.20	.18	.14	.10	.07
Austin	.08	.11	.17	.20	.23	.28	.30	.31	.23	.17	.12	08
Balmorhea	.18	.20	.29	.36	.40	.44	.37	.37	.31	.22	.14	.13
Beaumont	.09	.10	.14	.18	.21	.23	.22	.22	.18	.15	.11	.08
Beeville	.10	.12	.18	.22	.25	.29	.30	.29	.23	.18	.13	.10
Big Spring	--	--	--	.31	.35	.41	.42	.39	.30	--	--	--
Buchanan Dam	.09	.12	.19	.24	.26	.35	.37	.37	.26	.20	.14	.09
Chillicothe	.09	.13	.20	.27	.30	.37	.39	.37	.27	.18	.12	.08
College Station	.08	.10	.15	.19	.22	.27	.28	.28	.22	.17	.12	.09
Dalhart	--	--	--	.28	.33	.38	.39	.35	.29	--	--	--
Del Rio	.11	.16	.24	.30	.33	.40	.44	.41	.31	.22	.15	.11
Denison Dam	.11	.13	.19	.26	.28	.37	.33	.33	.27	.20	.14	.09
Denton	.07	.10	.16	.20	.22	.29	.31	.31	.24	.17	.12	.08
Dilley	.09	.13	.20	.25	.27	.32	.35	.35	.26	.19	.12	.09
Dryden	.13	.20	.33	.42	.45	.52	.52	.50	.39	.24	.20	.15
Fort Stockton	.13	.17	.29	.36	.41	.48	.44	.40	.30	.23	.17	.13
Grandfalls	.10	.17	.29	.39	.42	.47	.44	.41	.30	.22	.15	.10
Iowa Park	.06	.09	.16	.21	.24	.30	.32	.31	.24	.17	.11	.06
Lake Kickapoo	--	.13	.21	.34	.35	.47	.41	.41	.33	.25	.17	.13
Laredo	.18	.22	.29	.37	.42	.49	.53	.50	.37	.27	.20	.14
Lubbock	.07	.12	.19	.27	.29	.35	.35	.32	.25	.17	.11	.07
Mansfield Dam	.08	.10	.16	.20	.24	.32	.34	.34	.25	.19	.13	.08
Nacogdoches	.06	.09	.12	.16	.18	.22	.23	.23	.19	.14	.09	.07
Possum Kingdom Dam	.12	.18	.22	.30	.31	.39	.43	.46	.32	.26	.14	.10
Prairie View	.13	.14	.18	.23	.26	.32	.30	.31	.24	.20	.14	.11
Red Bluff Dam	.12	.18	.29	.38	.44	.49	.44	.42	.34	.21	.15	.10
San Antonio	.10	.13	.18	.23	.26	.32	.36	.36	.28	.20	.13	.10
Sonora	.13	.17	.23	.31	.34	.42	.41	.40	.29	.23	.15	.11
Spur	.10	.13	.20	.26	.29	.36	.35	.32	.25	.19	.14	.10
Temple	.08	.11	.16	.20	.22	.28	.31	.31	.24	.18	.12	.09
Troup	.06	.10	.14	.18	.22	.28	.28	.28	.22	.16	.10	.07
Tyler (Lindale)	.07	.10	.15	.19	.22	.26	.27	.27	.21	.16	.1	.08
Weslaco	.10	.12	.17	.21	.23	.27	.28	.27	.20	.17	.14	.09
Winter Haven	.08	.11	.18	.22	.25	.31	.34	.33	.25	.18	.12	.08
Ysleta	.14	.17	.28	.43	.46	.51	.39	.35	.33	.22	.15	.08

*Adapted from Bulletin 787, "Water Evaporation Studies in Texas," Texas Agricultural Experiment Station - Texas Agricultural Extension Service, The Texas A&M University System.

For Chihuahua Desert conditions of west Texas, researchers have found that water consumption of pecan orchards can be coorelated to the trunk diameter and the number of trees planted per acre. For more information contact the Texas Agricultural Experiment Station in El Paso.

Capacity of Irrigation Water Source

Drip irrigation systems should be planned to deliver the eventual maximum daily water requirement in 1 day (24 hours) or less. The required supply of water is calculated by the number of emitters and the discharge rate of each emitter. Water needs for young orchards are low. One or two emitters will deliver sufficient water for each small tree. Emitters must be added as trees grow and require more water. Each additional emitter increases the amount of water that the irrigation well or other water source must supply.

The rate (in gallons per minute) that an irrigation well or other water supply source must deliver for each acre irrigated can be calcualted as follows:

Equation 4

$$\text{GPM/Acre} = \frac{\text{Number of trees per acre x flow rate (gph per tree)}}{\text{60 minutes per hour}}$$

In Table 7, the required water delivery rates calculated with equation 4 are listed for various hourly water application rates and tree spacings. Three to 6 gallons of water daily will usually supply the water requirement of a tree during the first and second year after planting. Thus, the irrigation system needs to be operated for only 3 to 6 hours a day or an equivalent amount of time per week during maximum water use months when one 1-gallon-per-hour emitter is used for each tree. However, as trees grow, additional water must be

Table 6. Gallons of water required per tree to supply 0.7 pan evaporation.

Average daily evaporation (inches)	Diameter of drip line of tree										
	5'	10'	15'	20'	25'	30'	35'	40'	50'	60'	70'
	Gallons of water per tree per day										
.10	0.9	3.4	8	14	21	31	42	55	86	123	168
.12	1.0	4.1	9	16	26	37	50	66	103	148	202
.14	1.2	4.8	11	19	30	43	59	77	120	173	236
.16	1.4	5.5	12	22	34	49	67	88	137	198	269
.18	1.5	6.2	14	25	39	55	76	99	154	222	303
.20	1.7	6.9	15	27	43	62	84	110	172	247	336
.22	1.9	7.5	17	30	47	68	92	121	189	272	370
.24	2.1	8.2	18	33	51	74	101	132	206	296	404
.26	2.2	8.9	20	36	56	80	109	143	223	321	437
.28	2.4	9.6	22	38	60	86	118	154	240	346	471
.30	2.6	10.3	23	41	64	92	126	164	257	370	505
.32	2.7	11.0	25	44	68	99	134	175	274	395	538
.34	2.9	11.7	26	47	73	105	143	186	292	420	572
.36	3.1	12.3	28	49	77	111	151	197	309	445	605
.38	3.3	13.0	29	52	81	117	160	208	326	469	639
.40	3.4	13.7	31	55	86	123	168	219	343	494	673
.42	3.6	14.4	32	58	90	129	176	230	360	519	706
.44	3.8	15.1	34	60	94	126	185	241	377	543	740
.46	3.9	15.8	35	63	98	142	193	252	394	568	773
.48	4.1	16.5	37	66	103	148	202	263	412	593	807
.50	4.3	17.1	39	68	107	154	210	274	429	617	841
.52	4.5	17.8	40	71	111	160	218	285	446	642	874
.54	4.6	18.5	42	74	116	167	227	296	463	337	908

Table 7. Required pumping rate in gallons per minute per acre.

$$\text{GPM/acre} = \frac{\text{Number of trees per acre x Gallons per hour per tree}}{\text{60 minutes per hour}}$$

Trees per acre	Gallons per hour per tree										
	0.50	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
27[a]	0.23	0.45	0.90	1.35	1.80	2.25	2.70	3.15	3.60	4.05	6.67
36[b]	0.30	0.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	
48[c]	0.40	0.80	1.60	2.40	3.20	4.00	4.80	5.60	6.40		
70[d]	0.59	1.17	2.34	3.51	4.68	5.85	7.00	8.17			
87[e]	0.73	1.45	2.90	4.36	5.81	7.26	8.70				
109[f]	0.91	1.82	3.63	5.45	7.27	9.08					
116[g]	0.97	1.94	3.87	5.81	7.74						
145[h]	1.21	2.42	4.80	7.25							

[a] 40' x 40' spacing
[b] 35' x 35' spacing
[c] 30' x 30' spacing
[d] 25' x 25' spacing
[e] 20' x 25' spacing
[f] 20' x 20' spacing
[g] 15' x 25' spacing
[h] 15' x 20' spacing

Examples

1. Trees are spaced 30 feet x 30 feet in a 100-acre orchard. The water requirement for mature trees is anticipated to be 8 gallons per hour per tree. How much water should the irrigation well deliver? *640 GPM* (6.4 GPM/Acre x 100 acres = 640 GPM).

2. With the same tree spacing and acreage (30 feet x 30 feet and 100 acres), what pumping rate is required to apply 1 gallon per hour per tree during the first year after transplanting? *80 GPM* (.80 GPM/Acre x 100 acres = 80).

3. How many acres of trees spaced 35 feet x 35 feet will a 50-GPM well irrigate when the peak water requirement is estimated to be 8 gallons per hour per tree? *10.4 Acres* (50 GPM divided by 4.8 GPM/Acre = 10.4 acres).

available to supply daily requirements.

FERTILIZER INJECTION

Dry fertilizer broadcast on the soil surface may not be effectively moved into the root zone because only a small area of soil is wet by drip emitters. However, fertilizer can be effectivly applied through the irrigation system and this method is recommended. Excellent injection equipment is available. Usually it can be connected into the main pipeline so that the fertilizer can be selectively routed to all trees in the orchard. To prevent emitter plugging, fertilizer must be injected upstream from the filter so that all undissolved fertilizer material and precipitates will be contained by the filter. Select an injector that operates properly on the electrical voltage, water pressure and water flow rate available in the orchard, and that has adequate capacity to apply the fertilizer needs of *mature* trees, since this equipment has a normally long lifetime.

Highly soluble nitrogen fertilizers such as potassiun nitrate, calcium nitrate, ammonium nitrate, ammonium polyphosphate and liquid uran and urea nitrogen can be applied by the drip irrigation system. First dissolve or mix dry fertilizer material in water to make the proper concentrate, making certain that all fertilizer is in solution. Liquid nitrogen such as uran and urea normally can be applied undiluted by the irrigation system. Check for formation of a precipitate that can clog the emitters and filter by mixing appropriate amounts of the fertilizer solution and irrigation water prior to injection. A precipitate is frequently formed when anhydrous ammonia is added to irrigation water. Other nitrogen fertilizers may also produce precipitates at high concentrations, especially with lower quality water.

Begin fertilizer injection when the irrigation system is applying water at the normal rate. Check the application rate by timing injection of a specific quantity of material. Complete injection before the irrigation cycle ends in order to move fertilizer out of the irrigation system and into the root zone. One to 3 hours may be required to move fertilizer material to trees at the ends of lateral pipelines, especially where only one emitter is used for each tree.

SALINITY MANAGEMENT

All water from streams and underground sources contains dissolved materials known chemically as salts. In many areas of Texas irrigation water does not contain enough salt to be injurious to plants. However, the application of irrigation water does add salt to the soil, where it will accumulate unless it is moved below the root zone by rainfall or excess irrigation water. When the amount of salt added exceeds the amount removed by leaching, salts may accumulate until the concentration in the soil solution becomes harmful to plants. High soil salinity interferes with the plants' ability to take up water. In addition, certain salts or ions can produce specific toxic effects. Water containing high levels of soduim requires special management since sodium affects soil structure and chemistry.

Irrigation water is considered poor quality when it contains moderate to large amounts of salt. Poor quality water often can be used more successfully with drip irrigation than with sprinkler or surface irrigation. Less total salt is added with drip irrigation since less water is applied. In addition, a uniformly high soil moisture level is maintained with drip irrigation, which makes more water available to trees and moves or leaches the salts below the root zone.

Even with good irrigation water management, salt will accumulate at the edges of the wet pattern as illustrated in Figure 5, and some artificial leaching (removal of salts from the root zone) may be required. Rainfall is normally adequate in the eastern, southern and central areas of the state to accomplish any required leaching of salts. The addition of extra irrigation water may be required in areas of low rainfall such as in western and High Plains locations. In most cases, operating the irrigation system when the water requirement of the trees is low can accomplish the required leaching. When irrigation water contains significant quantities of salt, an annual salinity analysis of soil samples from the root zone is advisable. Do not guess about water and soil salinity. Know your water quality by having it laboratory tested and manage it to prevent problems. This will ensure the long-term productivity of the orchard.

OPERATING DRIP IRRIGATION SYSTEMS

Continuous irrigation from early spring through the summer is not required. Orchard water requirements are influenced by tree size and growth stage as well as temperature, relative humidity and wind velocity. Ideal system operation applies just enough water to replace that used by the trees the previous day. Uniform soil moisture content is maintained and the volume of moistened soil neither increases nor decreases.

Estimate the daily operating time in hours by dividing the daily water requirement (as listed in Table 6) by the water application rate at each tree in gallons per hour:

Equation 5

$$\text{Daily operating time (hours)} = \frac{\text{Daily water requirement of each tree (gallons)}}{\text{Water application rate to each tree (gallons per hours)}}$$

The irrigation system is operated for shorter time periods early in the season; operating time increases as evaporation rates and tree use increase as shown in Table 5. When the operation time calculated with equation 5 exceeds 24 hours per day, additional emitters must be added for each tree.

In new plantings, one emitter often is used to supply the small quantity of water needed by each tree. As the trees grow, their increased water requirement is provided by longer daily operation until additional emitters are required. The drip system will have more capacity than needed during the first 3 to 4 years. Design capacity will be reached when enough emitters have been added to supply the amount of water needed by mature trees. Continuous operation will likely be required during months of maximum Class A pan evaporation.

Operate the system long enough (24, 48 or 72 hours) early in the season to supply enough water to "fill" the soil root zone. This is often done when applying fertilizer. Then

operate the system to replenish the amount of water removed by the trees. Also, operate the system 24 to 48 hours following tree planting to wet and settle soil around tree roots. Applying too much water during the season can hinder tree growth and damage roots by causing poor soil aeration, especially in heavy soils with slow water movement.

Irrigation time can be controlled manually, with time clocks or with moisture-sensing instruments which activate pump controls and automatic valves. Operate manually-controlled or set time clock-controlled systems to apply the required amount of water based on Class A pan evaporation (Table 5) or estimated water requirement. Inspect the orchard regularly to determine whether the daily irrigation time should be adjusted.

Soil moisture sensing instruments such as tensiometers and gypsum blocks can help in making irrigation management decisions. Install instruments to sense soil moisture at two depths, such as 12 and 36 inches. Use two or more sensing locations for each 20 acres of orchard unless tree size varies within smaller areas or soil types change significantly. Locate sensors about two-thirds from the center to the outer edge of the wetted pattern (Fig. 5). Irrigation is started when the tensiometer gauge reads between 20 and 40 centibars for most soils. However, the exact gauge reading can be determined by trial.

Drip irrigation systems can be completely automated with switching tensiometers which activate system controls to start and stop irrigation. Field experience with automatic systems is limited but promising. Automatic control is convenient and may conserve irrigation water by preventing over irrigation. However, all orchards, including those with automatic drip irrigation systems, should be inspected regularly and any necessary maintenance and adjustment of system operation performed promptly.

EMITTER CLOGGING CONTROL

The greatest potential problem, other than proper system design, for the operator of a drip irrigation system is emitter clogging. Water passages in emitters are very small, and can easily become clogged by minerals or organic matter. Clogging can reduce emission rates and cause non-uniform water distribution. This may cause stress to plants and limit production.

Contaminants are often present in irrigation water. Contaminants may be soil particles, living or dead organic materials, and scale from rusty pipes. In some cases, contaminants are trapped in the system during installation. These include insects, teflon tape, PVC pipe shavings, organic material and soil particles. Contaminants can grow, aggregate or precipitate in water as it stands in the lines or evaporates from emitters or orifices between irrigations. Iron oxide, manganese dioxide, calcium carbonate, algae and bacterial slimes can form in drip systems under certain circumstances.

The solution to clogging must be based on the nature of the particular problem. Emitter clogging can be divided into three groups: physical; biological; and chemical.

Physical clogging is caused by such substances as soil particles (sand and silt), plant material, pipe rust and debris. Physical clogging is prevented by selecting a filter system that is matched to the emitter orifice size and type.

Biological clogging is caused by the growth of algae, bacteria and slime, usually in the drip tubing (lateral lines). Selecting emitters with large orifices and black pipe may reduce clogging. In many cases chlorination is necessary. To treat biological clogging iniatially the system can be flushed with a chlorine concentration of 10 ppm for an hour. If necessary, concentrations are then increased gradually to about 50 ppm. If the water pH is high, acid may be injected to lower pH to 7 or below to reduce the concentration of chlorine needed. Some irrigators recommend routine injection of 1 to 2 ppm chlorine to control algae growth.

Fluid ounces of chlorine needed per 1000 gallons of water is calculated by the following equation:

Equation 6

$$\text{Ounces chlorine required per 1000 gallons water} = \frac{\text{ppm chlorine} \times 13.3}{\text{\% chlorine of source}}$$

Where:

a) chlorine in bleach is 5.25 percent (52,500 ppm) or 10 percent (100,000 ppm) (check label), and

b) chlorine content of calcium hypochlorite is 35 percent or 70 percent.

Chemical clogging is caused by the precipitation of calcium, magnesium, iron, fertilizer, etc., from the irrigation water. Determining the quality of the irrigation water by laboratory analysis is helpful in determining the potential for clogging and the most effective treatment. Table 8 lists concentrations of some elements which will lead to clogging problems. Sulfuric and hypochloric acids can be injected to lower the pH of water and reduce the amount of chemical precipitates. Regular acid treatments are usually necessary to clean emitter passages when concentrations of calcium or magnesium exceed 50 ppm or when water pH is greater than 8.0. Experimentation is the best method of determining the concentration of acid needed. First, acid is added to lower the pH to about 6.5. Expose emitters to this concentration for 30 minutes to 1 hour. More acid is then added as necessary until the pH is lowered to about 2.

Table 8. Recommended chemical treatments for selected conditions.

Water quality	Suggested treatment
Ca > 50 ppm Mg > 50 ppm	Hard water, caused by high concentrations of Ca or Mg, can reduce flow rates by the buildup of scales on pipe walls and emitters. Periodic injection of an HCl solution may be required throughout the season. Lower concentrations of Ca and Mg may require HCl treatment every 2 to 4 years.
Fe > 0.5 ppm S > 0.5 ppm	Iron, sulphur and other metal contaminants create an environment in water that is conducive to bacterial activity. Byproducts of bacteria in combination with the fine (less than 100-micron) suspended solids can cause system plugging. Bacterial activity can be controlled by chlorine injection and line flushing on a regular basis throughout the irrigation season. Bacterial activity is prevalent in concentrations of Fe and S over 0.5 ppm, but also occurs at lower concentration.

Source: British Columbia Ministry of Agriculture, "Water Treatment Guidelines for Trickle Irrigation," Engineering Reference Information R512.000, 1982.

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