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Impacts of Irrigation on Citrus

in the Lower Rio Grande Valley

Citrus is an important irrigated crop for South Texas. Grown on 27,000 acres primarily in the Lower Rio Grande Valley, the citrus crop has been subject to freezes, market conditions and urbanization since 1950. About 71 percent of the citrus area is planted with grapefruit and 29 percent with oranges. Texas grapefruit varieties are 72 percent Rio Red, 17 percent Ruby Red, 11 percent Henderson/Ray and 1 percent other varieties. The oranges are 59 percent Early, 28 percent Navel and 13 percent Valencias.

In the Lower Rio Grande Valley, reduced water supplies are a challenge to growers because citrus requires 35 to 48 inches of water each year and rainfall supplies only 22 to 26 inches.

Citrus growers in the Valley can increase fruit quality and production by scheduling irrigation according to soil moisture levels and crop needs and by using irrigation methods that are appropriate for local conditions.

Agronomic Characteristics of Citrus

To manage irrigation properly, growers need to have a good understanding of how the soil type affects citrus growth. Citrus trees start bearing fruit from the third year after planting, but economic breakeven is usually delayed until the eighth year.

Citrus trees flower in February and March, but less than 6 percent of the flowers produce mature fruits. Fruits mature in 7 to 12 months after flowering, depending on such factors as the variety and water availability. Harvest in the Lower Rio Grande Valley starts in late September or October and ends in May or June.

During maturation, the amount of acid in the fruit decreases while sugar and aromatic substances increase, improving fruit quality. Because low temperatures increase the concentration of sugars within the fruit, many Valley growers do not begin harvest until after the first winter cold spell.

The color of the fruit is not an indicator of fruit maturity. Fruit is usually harvested "green," depending on market demand and price. Postharvest treatments can enhance ripening.

Citrus trees need a period of rest or reduced growth to flower. In the subtropics, cool winters induce flowering, but without sufficient chilling, flowering can be induced by water deficits. In the Valley, this chilling period generally occurs from November to January (Fig. 1) when temperatures and rainfall decrease.

Juan Enciso,
Julian W. Sauls,
Robert P. Wiedenfeld
and Shad D. Nelson

Associate Professor and Irrigation Engineering Specialist;
Professor and Extension Horticulturist;
Professor, Department of Soil and Crop Sciences;
Associate Professor of Horticulture,
The Texas A&M System

Citrus Yield and Water Use

Fruit yield is highly affected by the amount of water received in both current and previous growing seasons. When the plants do not get enough water, growth is slowed, young fruits fall and the mature fruit lacks sugar and quality. Also, vegetative growth is reduced, limiting the number of new fruit-bearing branches. The roots and leaves do not develop properly, which affects the number and size of the fruit and accentuates alternate bearing, which is high production one year followed by lower production the next year.

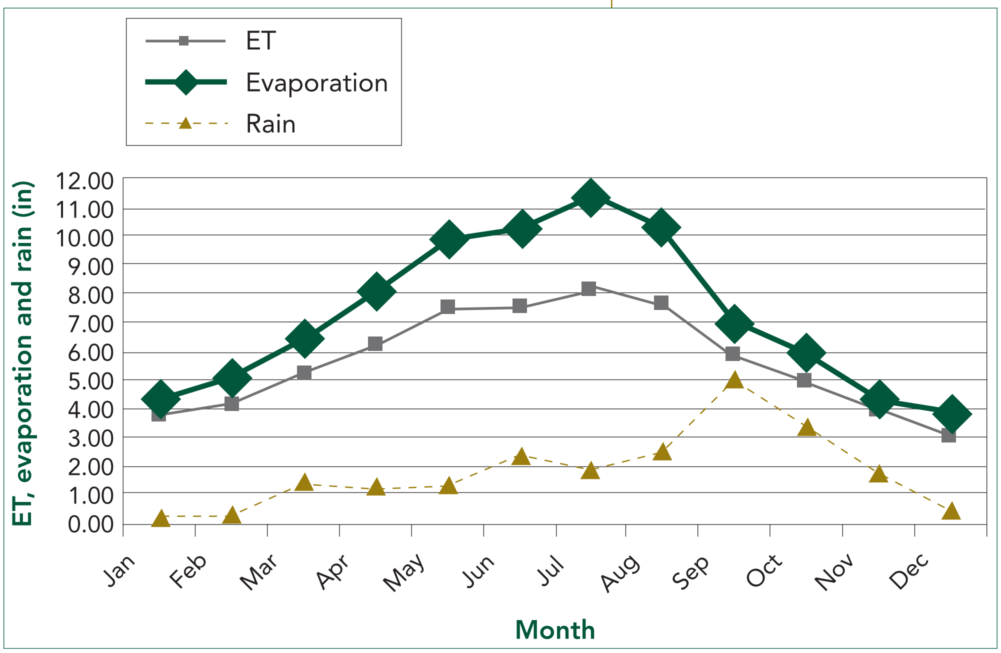

Figure 1. Average monthly evapotranspiration (ET), evaporation and rainfall between 1995 and 2003 in the Lower Rio Grande Valley.

Adequate water amounts are especially important during flowering and fruit set to achieve good production. Yield is reduced when water deficits of more than 33 percent occur during bloom, fruit set and rapid vegetative growth in the spring; deficits of 66 percent can be tolerated during the summer, fall and winter. Therefore, water stress should be avoided from February to June but can be somewhat tolerated from June through January.

According to research in 1986 by the Food and Agriculture Organization of the United Nations, good yields of citrus are:

- Oranges: 400 to 550 fruits per tree per year, corresponding to 10.1 to 16.1 tons per acre per year.
- Grapefruit: 300 to 400 fruits per tree per year, corresponding to 16.2 to 24.3 tons per acre per year.
- Lemons: 12.1 tons to 18.2 tons per acre per year.
- Mandarin: 8.1 tons to 12.1 tons per acre per year.

Local conditions affect yields. The Texas AgriLife Extension Service reported typical yields for three management levels in the Valley for an orchard density of 115 to 120 trees per acre (Table 1).

Table 1. Tons of citrus produced per acre under three levels of management in the Lower Rio Grande Valley. Sauls, 2005.

	Grapefruit			Early Oranges			Valencia		
Age (years)	Fair	Average	Very good	Fair	Average	Very good	Fair	Average	Very good
3	1	3	6	1	2	4	1	2	3
4	3	6	10	2	5	7	2	3	4
5	5	9	14	4	7	11	3	4	7
6	7	14	19	5	10	13	4	7	10
7	8	18	23	7	13	16	5	9	13
8	10	20	26	8	15	19	6	11	15
9	11	22	27	9	17	22	7	13	17
10+	12	23	28	10	18	24	8	14	18

Water is the most limiting factor for crop production. A close relationship between production and water applied is called water use efficiency. The Food and Agriculture Organization reported that water use efficiency for citrus is 428 to 1,070 pounds per acre-inch with a fruit moisture content of about 85 percent.

Impact of Water Requirements and Irrigation Scheduling

Depending on weather conditions and ground cover, citrus requires from 35 to 48 inches of water per year; grapefruit requires more water than do oranges, lemons or limes.

Water is removed from a crop by evapotranspiration (ET), which is the removal of water that evaporates or transpires from the plants and from the underlying soil. In the Valley, more water is lost through this process than is gained through annual rainfall. This means that supplemental irrigation is needed for citrus crops in the Valley.

A formula has been devised to estimate the amount of water needed by a particular crop under specific local conditions. The formula uses the rate of evapotranspiration from a standard "reference" crop, such as grass that is actively growing. This is called the reference evapotranspiration (ET_{ref}).

To calculate the evapotranspiration from a specific crop such as citrus, multiply the reference evapotranspiration (ET_{ref}) by the crop coefficient (Kc). Crop coefficients for citrus are shown in Table 2. The crop coefficient varies according to the crop's growth stage. The reference evapo-

Table 2. Citrus crop coefficients.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
No ground cover												
70% canopy	0.65	0.65	0.65	0.65	0.60	0.60	0.60	0.60	0.65	0.65	0.65	0.65
50% canopy	0.60	0.60	0.60	0.60	0.55	0.55	0.55	0.55	0.60	0.60	0.60	0.60
20% canopy	0.45	0.45	0.45	0.45	0.40	0.40	0.40	0.40	0.50	0.50	0.50	0.50
Ground cover or weeds												
70% canopy	0.75	0.75	0.75	0.75	0.70	0.70	0.70	0.70	0.75	0.75	0.75	0.75
50% canopy	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
20% canopy	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.85	0.85	0.85	0.85
Locally developed crop coefficients												
70% canopy	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6

Table 3. Crop water requirements considering an average of 9 years of data (1995–2003) and using local crop coefficients in the Lower Rio Grande Valley.

Month	ET_{ref} (inches)	Kc citrus	ETc citrus (inches)	Rain (inches)	ETc – Rain (inches)
Jan	3.4	0.6	2.1	0.2	1.9
Feb	3.7	0.6	2.2	0.4	1.8
Mar	5.0	0.7	3.5	1.5	2.0
Apr	5.9	0.7	4.1	1.3	2.8
May	7.1	0.7	5.0	1.3	3.7
June	7.2	0.7	5.0	2.4	2.6
July	7.8	0.7	5.5	1.9	3.6
Aug	7.5	0.7	5.2	2.5	2.7
Sep	5.8	0.7	4.1	5.0	0.0
Oct	4.9	0.7	3.4	3.4	0.0
Nov	3.8	0.6	2.3	1.8	0.5
Dec	3.1	0.6	1.9	0.4	1.5
TOTAL	65.3		43.8	22.1	23.1

transpiration varies throughout the year. Figure 1 shows the rainfall and evaporation during an average year in the Lower Rio Grande Valley.

If the soil has a ground cover such as grass or weeds, more water will be lost through evapotranspiration than that lost from bare soil, and the crop coefficient will rise (Table 2). Citrus in orchards with full grass cover can use 45 percent to 105 percent more water than can citrus in bare soil. The crop coefficients are slightly lower at mid-season than at the beginning and end of the season because the plants' stomata, or pores, close during periods of peak evapotranspiration (Table 2).

Table 3 lists irrigation guidelines for citrus that are based on average conditions for 9 years in the Lower Rio Grande Valley. In an average year in the Valley, citrus crops with 70 percent canopy and ground cover require about 44 inches of water; about half this amount is supplied by rainfall.

Irrigation Scheduling

To schedule effective irrigation, producers must know the properties of the soil and the amount of water stored in it. A balance sheet approach similar to a check register can be used to keep track of the amounts added through rainfall and irrigation and removed through crop water use or evapotranspiration. Depletion percentages can be measured directly or estimated. Both methods require information about a crop's rooting depth and the soil's moisture holding capacity.

Table 4. Properties of soils in the Lower Rio Grande Valley.

Soil series	Soil horizons (inches)	Available water capacity (inches/inches)	Water available in the top 4 ft (inches/4 feet)
Lyford sandy clay loam	0–11 11–48	0.18–0.24 0.16–0.21	8.6–11.5
Raymondville clay loam	0–15 15–65	0.12–0.18 0.10–0.18	5.8–8.6
Willacy fine sandy loam	0–74	0.14–0.18	6.7–8.6
Hidalgo sandy clay loam	0–28 28–80	0.08–0.17 0.08–0.20	3.8–8.2
Rio Grande silty loam	0–63	0.15–0.24	7.2–11.5

Citrus roots can extend to 6 feet and, in some cases, as much as 30 feet. Roots extract most of the water in the first 2 feet; they grow better in sandy soils that have less clay. Studies conducted in Spain found that citrus takes from 60 percent to 80 percent of its water from the upper 20 inches of the soil.

Table 4 shows the water-holding capacities for the top 4 feet of different soils in the Lower Rio Grande Valley. Water availability varies with soil depth. For example, the Hidalgo sandy clay loam soil can hold up to 0.17 inches of water per inch of soil to a depth of 28 inches; it can hold up to 0.20 inches of water per inch of soil between depths of 28 and 80 inches. The same soil can hold between 3.8 and 8.2 inches of water in 4 feet of soil.

Producers in the Lower Rio Grande Valley use various sensors to measure soil-moisture depletion levels. The most commonly used are granular matrix sensors, such as Watermark® soil moisture sensors from Spectrum Technologies, Inc., of Plainfield, Ill.; capacitance probes such as ECH$_2$O® probes from Decagon Devices, Inc., of Pullman, Wash., and EnviroSCAN® soil moisture sensors from Sentek Sensor Technologies, Australia.

During 2004, two Valley farmers installed EnviroSCAN sensors, which relayed soil moisture information through a modem to the Internet. After the sensors scanned the soil to a depth of 4 feet, the growers could monitor the soil water levels, enabling them to manage their drip and micro-irrigation systems more precisely.

These technologies are being evaluated and offer good potential for practical use. The cost of these devices varies dramatically, with Watermark sensors at the low end and EnviroSCAN at the high end.

Other new technologies are less useful for growers. Neutron probes and time domain reflectometry instruments are used to measure the volume of water in the soil. These instruments have been used only for irrigation research in the Lower Rio Grande Valley. They are impractical for most growers because they usually require calibration and are expensive and complicated to operate. Also, neutron probes require radiation licensing and radiation monitoring for safety.

However, growers throughout the Valley have used sensors to measure soil moisture tension. As soil moisture tension rises, plants have more difficulty extracting water. Tools such as tensiometers and Watermark sensors are relatively inexpensive.

Watermark sensors can measure a wider tension range (up to 200 centibars) than can tensiometers, which read only to 60 centibars. Centibars measure the tension in which the water is held by the soil. The higher the tension reading, the drier the soil. Inexpensive sensors such as Watermark can be installed at different depths and in different locations to test soil variability.

Because moisture availability includes the effects of soil texture, the readings need not be adjusted for soil type; however, the readings can be affected by soil salinity. Tension measurements tend to remain low for extended periods as plants absorb water from the soil, then rise rapidly as available moisture levels drop.

Irrigation becomes necessary when soil moisture tension in the root zone reaches between 30 and 60 centibars. The Watermark sensor has been observed to be slow, sometimes taking about 12 hours to show from dry to wet.

Another potential problem can be caused by the placement of the sensor in relation to the trunk of the tree and the irrigation emitter. Start irrigation when it is not yet completely dry to allow some time for the sensor to catch up and avoid tree stress.

To reliably measure conditions in the orchard, install the soil water sensors in several locations and at different depths, and record the sensor measurements regularly. The responsiveness of the Watermark sensors can vary, depending on the irrigation method used. These sensors respond faster to flood irrigation than to drip or microjet spray irrigation practices.

The management allowable depletion is the deficit point at which irrigation should be triggered. In citrus, irrigation can be triggered when the crop depletes about 55 percent to 60 percent of the soil water stored in the root zone. For example, for a Hidalgo sandy clay loam soil with water-holding capacity of 8.2 inches and a management allowable depletion of 60 percent, irrigation is needed at the point when 4.9 inches (8.2 x 0.6 = 4.9 in) has been used.

Table 5 shows the corresponding number of irrigations needed for a sandy clay loam in Hidalgo County with holding capacities of 8.2 inches and 60 percent allowable depletion.

Citrus growers in the Lower Rio Grande Valley commonly flood irrigate from five to seven times per year. However, the number of irrigations will be affected by the weather, soil type and water availability.

The balance sheet approach assumes that a plant can equally access all available moisture between saturation and permanent wilting point. This is an accurate assumption when soils are wet. However, as soil dries, plants have more difficulty extracting water, which decreases growth rates.

Salinity and Crop Production

Salinity is measured in millimhos per centimeter. Water from the Rio Grande has moderate salinity, ranging between 1.0 to 1.65 mmhos/cm (700 to 1,200 parts per million, or ppm). At Rio Grande City, the salinity is less than 1.2 mmhos/cm, with the highest values of 1.2 mmhos/cm occurring between April and June. The levels drop below 1.0 mmhos/cm (700 ppm) during the rest of the year.

Downstream, salinity levels increase: At the Mercedes Irrigation District, salinity ranges from 1.0 to 1.5 mmhos/cm, reaching 1.6 mmhos/cm during part of November.

Good soil drainage minimizes the effects of salinity. Heavy, slow-draining soils are poor for citrus production. To help the salt leach from the soil and improve drainage, some Lower Rio Grande Valley producers practice deep chiseling between citrus rows.

Bad drainage also can cause the accumulation of sodium or other salts including boron and chlorine. Citrus is sensitive to boron concentrations of 0.3 to 1.0 parts per million.

Citrus yields drop by 10 percent when soil salinity increases to 2.3. The soil salinity is measured by extracting water from a soil saturated paste. At higher soil salinity levels, the yields drop even more: by 25 percent at the 3.3 salinity level, 50 percent at the 4.8 level and 100 percent at 8 mmhos/cm.

Saline irrigation water also reduces citrus yields by 10 percent at 1.6 mmhos/cm.

Irrigation for Freeze Protection

Citrus trees grow best when the temperature is 73.4 degrees F to 86 degrees F (23 to 30 degrees C). Growth

Table 5. Number of irrigations for citrus with 70 percent canopy in a Hidalgo sandy clay loam soil with 60 percent management allowable depletion and holding capacity of 8.2 inches in 4 feet of soil depth.

Month	ET citrus – Rain (inches)	Number of Irrigations
Jan	1.9	0
Feb	1.8	0
Mar	2.0	1
Apr	2.8	0
May	3.7	1
June	2.6	1
July	3.6	0
Aug	2.7	1
Sep	0.0	1
Oct	0.0	0
Nov	0.5	0
Dec	1.5	0
TOTAL	23.1	5

Figure 2. Traditional irrigation with sloping borders and earth canals. One of the main problems of earth ditches is that they can break, spilling water out of the area to irrigate.

slows in temperatures above 100.4 degrees F (38 degrees C) and below 55.4 degrees F (13 degrees C). Active root growth occurs when soil temperatures are higher than 53.6 degrees F (12 degrees C).

Most citrus species tolerate light frost for short periods only and can be injured by temperatures of 26.6 degrees F (-3 degrees C) over several hours. Temperatures of 17.6 degrees F (-8 degrees C) cause branches to wither, and 14 degrees F (-10 degrees C) generally kills the tree.

Flowers and young fruits, which are particularly sensitive to frost, are shed after very short periods of temperatures slightly below freezing. Dormant trees are less susceptible to cold injury. Strong wind causes flowers and young fruits fall to easily; provide windbreaks when necessary.

Microsprinklers can protect young trees during freezing nights, especially when water is continuously applied to the lower part of the trunk, because as water freezes, heat is released. When the application rate is high enough, the freezing water will maintain the trunk, the bud union and lower branches at temperatures near freezing.

To protect trees using microsprinklers, place the sprinklers 1 to 2.5 feet from the trunks in the upwind side of the trees. Place insulating tree wraps around the trunks of young trees to slow the rate of temperature decline and protect the trunks; use the wraps in combination with sprinkler irrigation.

A microsprinkler irrigation rate of 20 gallons per hour is more effective for cold protection. Turn on the water before the temperature reaches 32 degrees F (0 degrees C), making sure the microsprinkler is placed correctly.

Continue running the microsprinkler all night during the freeze. Evaporative cooling will cause greater damage if the irrigation system fails when the temperature is below freezing. Therefore, do not to turn on the system if the pumping system is unreliable. The system can be stopped once temperatures rise above 33.8 degrees F (1 degrees C).

Irrigation Practices in the Lower Rio Grande Valley

Historically, producers in the Valley have used flood irrigation to water citrus crops. An extensive network of canals and large-diameter underground pipelines use gravity flow to deliver large volumes of water from the Rio Grande to fields over short periods of time.

Because the Valley generally slopes toward the northeast, away from the river, little pumping is necessary except to lift the water from the river to the canals. Present water restrictions are causing interest in more efficient irrigation technologies.

Properly managed flood irrigation can be efficient. During delivery, losses occur because of evaporation and leaks in canals and pipelines. Irrigation canals that are unlined earthen ditches allow water to seep out. Lining canals and using pipe to deliver water can reduce these losses and provide better control of the irrigation.

The most common irrigation method for citrus on the farm is flood irrigation with graded borders (Fig. 2). To irrigate efficiently with flood irrigation, level the land to the appropriate grade before establishing the orchard and control water applications with valves or structures (Fig. 3). Citrus groves that are bordered and properly graded do not produce runoff.

To distribute water faster and more efficiently, install alfalfa or orchard valves at different locations in the orchard use gated or flexible pipes. Build permanent borders every two rows, with an irrigation valve between each pair (Fig. 3). Temporary borders may be single or double row, depending on the grower's preferences.

For better control and faster irrigation, build one border per row of trees. The border edge is about 1 foot high. To reduce the irrigated area, place temporary borders along one side of the rows of young trees. This method, called strip flooding or narrow-border flood, allows faster water advancement (Fig. 4).

A farmer can receive 1,346 gallons of water per minute or more to irrigate a field of 40 acres. One "head" of water per outlet is equivalent to 3 cubic feet per second, or 1,346 gallons per minute.

Weed control methods affect the choice of irrigation method. Permanent borders need trunk-to-trunk herbicidal weed control, while temporary border irrigation requires tillage to control weeds in the row middles.

In both cases, apply the herbicides beneath the tree canopies. Use herbicides or tillage implements to control weeds in the row middles of orchards that are irrigated with microsprayer or drip irrigation systems.

Figure 3. Border irrigation with alfalfa (orchard) valves. Each valve covers one border with two rows of trees.

Figure 4. Using a narrow-border flood can conserve more water than can traditional flood practices in the orchard.

Figure 5. Irrigation of citrus crops with drip irrigation. The top photo shows two drip lines per tree row and weeds that are climbing the tree. The bottom photo shows an implement used to apply herbicide close to the tree to control weeds.

In deciding when to irrigate, producers also must consider the need to order water several days in advance and the wait for the water delivery. Depending on the location and the irrigation district, a reservoir may be needed to store water for frequent irrigations using microsprinkler irrigation or drip irrigation systems.

Improving Citrus Irrigation Efficiency

Periods of drought have reduced some water allocations in the Lower Rio Grande Valley. Pressurized irrigation systems can be used to increase production per unit of water applied and to maintain orchards during droughts.

These pressurized systems have one or more emitters at each tree, which allows for the uniform injection of fertilizers and some agrochemicals. This improves plant nutrition and increases productivity per unit of water applied, partly compensating for the higher initial cost of the system and the variable costs such as energy and maintenance. The most common pressurized systems are drip and micro-irrigation.

Drip Irrigation Systems

On Lower Rio Grande Valley farms with drip irrigation systems, the most common method is to run the drip lines parallel to the tree rows. Young orchards can be irrigated with a single line per row, but older trees require two lines—one on each side of the row—because they need more water (Fig. 5).

The initial system design must allow for the additional line of emitters to ensure that enough water can be supplied to both lines in the future. The drip emitters are generally spaced every 3 feet and apply about 1 gallon per hour per emitter.

Drip irrigation systems require filtration to prevent emitter clogging. Many farms have settling ponds, where sediments and small particles from the pumped canal water can settle out. The water is then filtered before entering the irrigation lines.

A drip irrigation system can save water because it wets only about 33 percent to 50 percent of the surface area. In addition, a drip system can apply fertilizer quickly, efficiently and uniformly.

Weed control in the wetted area can be difficult because frequent irrigations cause the herbicides to leach below the soil surface, where they are needed. Vines growing into and covering the tree are a serious problem. A good herbicide program is especially vital with these systems, and growers should include less soluble herbicides in the weed control program. Fortunately, some herbicides with reduced solubility can be applied through the irrigation system, placing the herbicide where it is most needed.

Micro-irrigation and Microsprayer Irrigation Systems

A microsprinkler has moving parts, and it sprays one or two streams of water as it rotates. Its deflectors move as they are hit by the water being sprayed. In contrast, microsprayers have no moving parts; the water is deflected into several discrete streams as it is sprayed out. In the Valley, moving parts have a tendency to clog when fine, wind-blown soil particles accumulate on the emitter.

Microsprayers are connected to a polyethylene lateral line through a micro-tube, often referred to as "spaghetti tubing," and are held in place by a plastic stake. They can apply from 3 to 30 gallons of water per hour; the higher the flow rate and pressure, the larger the wetted diameter (Fig. 6). However, large orchards may need to be subdivided into two or more zones and irrigated separately.

Microsprayer irrigation sprays a fan of water over the soil. The microsprayer can wet a diameter of 12 to 18 feet depending on the tree skirt. The spray or mist is produced by a flat spreader and a small orifice operating at high pressure.

Popular microsprinklers can apply 24 to 28 gallons per hour at a pressure of about 30 psi. These devices contain a deflector which allows water flow to be concentrated around young trees to a diameter of about 8 feet. Without the deflector the wetted diameter can be up to 22 feet to irrigate larger trees.

Figure 6. Microsprinkler irrigation.

Summary

The choice of irrigation technology and scheduling method depends on economic considerations as well as the location, situation and preferences of each grower. Producers should also seek input from their irrigation district about the feasibility of installing a particular system in their fields.

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