Subtropical Plant Science 57:16-22. 2005.

Irrigation of Citrus in Texas - A Review

Juan Enciso[1], Julian Sauls[2], Bob Wiedenfeld[3] and Shad Nelson[4]

Texas A&M University Research & Extension Center, Weslaco
Texas A&M University Kingsville Citrus Center, Weslaco

ABSTRACT

One of the challenges of producers in the Lower Rio Grande Valley (LRGV) is decreasing water supplies since citrus requires about 33-48 inches of water annually but only 22-26 inches can be supplied by rainfall. This paper reports citrus yields for different management levels and relations between water applied and citrus productivity and quality. It also reviews methodologies used in the LRGV to schedule irrigation such as the use of soil water monitoring devices and reviews some locally generated crop coefficients to estimate citrus water requirements. This paper also describes current irrigation practices in the LRGV and methods to improve irrigation efficiency. The paper identified research needs such as the determination of crop coefficients for the region and the optimum placement of soil water sensors. Another research need identified is the economical comparison between irrigation methods such as drip, microirrigation and flood irrigation.

RESUMEN

Uno de los retos para los productores del Bajo Valle del Rio Grande (BVRG) es la escacez de fuentes de agua. Los cítricos requieren de 33-48 pulgadas de agua anualmente y en promedio la lluvia anual en la región es de 22-26 pulgadas. En este artículo reportamos el rendimiento, productividad y calidad de los cítricos bajo diferentes formas de manejo y cantidad de agua de riego aplicada. También reportamos el uso d medidores de humedad en el suelo usados para determinar los calendarios e riego en el BVRG. Asi como también revisamos coeficientes de cultivo generados en el área que sirven para estimar los requerimentos de aqua en cítricos. Metodos más eficients de irrigación son discutidos bajo la luz de las prácticas actuales de riego en la región. En este artículo también se reporta la necesidad de determinar los coeficientes de cultivo en la región y el uso apropiado de los sensores de humedad. También se identifico la necesidad de investigaciones económicas que comparen los diferentes métados de irrigación como son el riego por goteo, microirrigación y por inundación.

Citrus is an important irrigated crop for the LRGV of Texas grown about 27,000 acres. The citrus industry has been changing due to freezes, market conditions and urbanization since 1950. About 71 percent of the citrus area is planted with grapefruit and 29 percent with oranges (da Graca and Sauls, 2005). The percentage of Texas grapefruit varieties is split into 72 percent Rio Red, 16 percent Ruby Red, 11 percent Henderson/Ray and 1 percent other varieties. Oranges are split into 59 percent early, 28 percent navel and 13 percent Valencias.

One of the challenges for producers in the LRGV is decreasing water supplies since citrus requires about 33-48 inches of water annually, but only about 22-26 inches can be supplied by rainfall. Several strategies have been proposed to conserve water and at the same time increase citrus production and quality. The objectives of this paper are to review and describe current irrigation practices in Texas, review previous citrus irrigation research, and identify future research needs.

Agronomic Characteristics of Citrus. A good understanding of the agronomic characteristics of citrus growth is important for managing irrigation. Sauls (2005a) reports citrus yield data for trees of different ages and three levels of management in the Lower Rio Grande Valley for an orchard density of 115 to 120 trees per acre, derived from information developed by the TAMU-K Citrus Center. Citrus trees start bearing fruit beginning in the third year after planting, but economic breakeven is usually not until the eighth year.

Citrus trees flower in spring (February-March), but fewer than 6 percent of flowers produce mature fruits. Fruits take from 7 to 12 months to mature, depending on variety and on several other factors including water availability. Harvest starts in late September to October and lasts into May or June. During maturation, the amount of acid decreases while sugar and aromatic substances increase. The fruit has higher quality when sugar content is high (Wiegand et al., 1982; Doorenbos and Kassam, 1986; Smajstrla et al., 1986). The color of the fruit is not an indicator of fruit maturity.

---

[1] Assistant Professor and Irrigation Engineer Specialist, BAEN Depatrment, Texas A&M University
[2] Professor and Extension Horticulturalist
[3] Professor of Soil Science
[4] Assistant Professor of Agronomy, Agronomy and Resource Sciences, Texas A&M University Kingsville Citrus Center

Table 1. Citrus produced under three levels of management in the LRGV (Sauls, 2005a).

	Grapefruit			Early Oranges			Valencia oranges		
Age	Fair	Avg.	Very good	Fair	Avg.	Very good	Fair	Avg.	Very good
yrs	---------- tons / acre ----------								
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

A period of rest or reduced growth is needed to induce flowering. In the subtropics, cool winter temperatures induce flowering, but in the absence of sufficient chilling, flowering can be induced by water deficits. This chilling period generally takes place during November to January. After induction, floral differentiation and initiation commences during favorable environmental conditions of temperature and soil moisture, after which flowering occurs. **Citrus Yield and Water Use** Production is highly affected by water applied. Current and previous growing season water deficits can affect citrus yield. When water is insufficient, growth is retarded, young fruits fall and fruits that mature are deficient in sugar and quality. Water deficits also affects future production by reducing vegetative growth, limiting the creation of new fruit bearing branches, impairs root and leaf development, and ultimately affects the number and size of the fruits and accentuates alternate bearing (Sauls, 2005b).

Water deficits should be especially avoided during flowering and fruit set to achieve good production (Doorenbos and Kassam, 1986; Wiegand and Swanson, 1982a, b). The deficit levels at which production is reduced have been studied in Florida by Koo (1963, 1978) who determined that water depletion greater than 33% of water available soil water content during periods of bloom, fruit set, and rapid vegetative growth in the spring could reduce yield; however, depletions of 66% could be tolerated during the summer, fall and winter months. Therefore, water stress should be avoided from February to June, and they can be tolerated from June through January.

According to Doorenbos and Kassam (1986), good yields of citrus are: orange - 400 to 550 fruits per tree per year corresponding to 10.1 to 16.1 tons/acre per year; grapefruit – 300 to 400 fruits per tree per year and 16.2 to 24.3 tons/acre per year; lemons from 12.1 to 18.2 tons/acre per year and mandarin from 8.1 to 12.1 tons/acre per year. Sauls (2005a) reported typical yields for three management levels in the LRGV (Table 1). Doorenbos and Kassam (1986) also mentioned that water use efficiency (production per unit of water applied) for citrus fruits is about 2 to 5 kg/m^3 (428 to 1070 lbs/ac-in) with a moisture content of about 85 percent, except for lime which contains about 70 percent moisture.

Impact of Water Requirements and Irrigation Scheduling. Depending on weather conditions and ground cover, citrus evapotranspiration (ET) requirements vary from 35 to 48 inches. Grapefruit has a greater water requirement than oranges, lemons or limes; however, the literature reports citrus crop coefficients without differentiating between them. Reference ET, defined as the water use of grass actively growing, is calculated based on temperature, humidity, wind speed and solar data gathered by automated weather stations. Reference ET is multiplied by a crop coefficient (Kc) to account for citrus evapotranspiration (Et citrus = Et reference * Kc). Variation of reference ET, rainfall, and evaporation during an average year is shown in Fig. 1 for the LRGV.

Table 2. Citrus crop coefficients recommended by Allen et al 1998.

	Jan	Feb	Mar	Apr	May	Jun	Jul	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

Reference ET is higher than annual rainfall during all months of the year, indicating that irrigation is needed to meet crop water requirements. The crop coefficient for citrus will be affected if the soil has ground cover like grass or weeds, which will increase citrus ET (Table 2). Table 2 also shows that the mid season crop coefficients are slightly lower than initial and ending values due to the effects of stomatal closure during periods of peak ET. The local crop coefficients reported on Table 2 were developed by Fipps (2002).

Smajstrla et al (1986) measured 45 to 105% higher annual citrus ET in orchards with full grass cover compared with those having bare soil. The effect of soil surface shading on ET has been cited by Castel et al. (1982), who reported ET reductions as ground shading caused by tree growth increased.

The percent canopy and conditions of ground cover will affect crop water requirements. Most of the crop coefficients have been determined in places like Arizona and Florida. There have not been any published data of crop coefficients in the Lower Rio Grande Valley. Irrigation guidelines for citrus have been developed based on average conditions for nine years of data, (Enciso and Wiedenfeld, 2005). Table 3 shows the crop water requirements for citrus with 70% canopy and ground cover for an average year is 44 inches and approximately half of this is supplied by rainfall as calculated by the Penman-Monteith equation and locally developed crop coefficients.

Table 3. Crop water requirements considering an average of nine years of data (1995-2003) and using local crop coefficients in the LRGV. (Enciso and Wiedenfeld, 2005).

Month	ET ref	Kc citrus	ET citrus	Rain	ETc – Rain
	in		in	in	in
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
Oct	4.9	0.7	3.4	3.4	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

Class A pan evaporation data correlates somewhat with plant water use. Enciso and Wiedenfeld (2005) developed coefficients to estimate reference ET from class A pan values (Table 4). The values estimated with reference ET generally differ slightly from the ones estimated using the pan "A" evaporimeter as it can be observed in Tables 3 and 4.

Irrigation Scheduling. Traditionally farmers in the LRGV have irrigated using experience and judgment based on visual observations of the plant and by feeling soil water conditions using the hand method and considering water availability. When farmers were questioned about what decisions they used, it is unclear what symptoms and conditions they were referring to. This management by experience has produced a tendency to over-irrigate when water is plenty and inexpensive and to adequately irrigate when there are water restrictions or drought conditions.

To effectively schedule irrigation, producers must know the properties of the soil and keep a record balance of water stored in the soil. A balance sheet approach (like a checkbook register) can be used to keep track of additions (through rainfall and irrigation) and removals (through crop water use or ET citrus) from a soil reservoir of a specific size. Depletion percentages can then either be measured directly or estimated. Both methods require information about a crop's rooting depth and the capacity of a particular soil to hold moisture.

Depending on soil type, citrus roots can extend as deep as 6 ft, but there are some cases in which roots extend deeper than 30 feet. Roots extract most of the water in the first two feet, and grow healthier in sandy soils with a lower percentage of clay (Wiedenfeld et al., 1982). Studies conducted in Spain by Castel et al (1987) found that citrus takes from 60 to 80% of its water from the upper 20 in. of the soil.

Table 5 shows 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, Hidalgo Sandy Clay Loam soil can hold 0.08 to 0.17 inches of water per inch of soil between soil depths of 0 and 28 inches; and between 0.08 to 0.20 inches of water per inch of soil between soil depths of 28 and 80 in. The same soil can hold between 3.8 to 8.2 inches of water in 4 ft of soil depth.

Table 4. Average monthly pan evaporation for nine years of data (1995-2003) at the Weslaco Research and Extension Center and coefficients used to estimate citrus evapotranspiration for pan evaporimeter Class "A". (Enciso and Wiedenfeld, 2005).

	Class A Pan Evaporimeter			
Month	inches	Kc	Kv	ET citrus
Jan	4.4	0.6	0.70	1.8
Feb	5.2	0.6	0.69	2.2
Mar	6.4	0.7	0.74	3.3
Apr	8.2	0.7	0.72	4.1
May	9.9	0.7	0.74	5.1
June	10.3	0.7	0.72	5.2
July	11.4	0.7	0.71	5.7
Aug	10.4	0.7	0.69	5.0
Sep	7.0	0.7	0.84	4.1
Oct	5.9	0.7	0.79	3.3
Nov	4.4	0.6	0.75	2.0
Dec	3.9	0.6	0.68	1.6
TOTAL	87.3			43.4

Producers in the LRGV have used several sensors to measure soil-moisture depletion levels. The most commonly used are granular mark sensors (Watermark). However, capacitance probes (EH2O probe and Enviroscan), although they are more expensive, have been adopted by some farmers recently. During

Table 5. Properties of soils in the Lower Rio Grande Valley.

Series	Soil horizons	Available water capacity	Water available in the top 4 ft.
	in	(in/in)	(in)
Lyford sandy clay Loam	0 – 11 11 – 48	.18 – .24 .16 – .21	8.6 – 11.5
Raymondville clay loam	0 – 15 15 – 65	.12 – .18 .10 – .18	5.8 – 8.6
Willacy fine sandy loam	0 – 74	.14 – .18	6.7 – 8.6
Hidalgo sandy clay loam	0 – 28 28– 80	.08 – .17 .08 – .20	3.8 – 8.2
Rio Grande silty loam	0 – 63	.15 – .24	7.2 – 11.5

2004, two farmers installed Enviroscan sensors which sent the information through a modem to the internet. The sensors scanned the soil to a depth of 4 ft. and they were able to observe the wet and dry soil levels to manage their drip and micro-irrigation systems more precisely. These technologies are being evaluated and offer good potential for practical use.

Neutron probes and time domain reflectometry (TDR) instruments measure actual volumetric moisture content. These instruments usually require calibration to relate data to available soil moisture. Such instruments are expensive and complicated to operate and have only been used for irrigation research in the LRGV.

Tensiometers and Watermark sensors measure the tension at which soils hold water; as a soil's tension numbers rise, plants have an increasingly difficult time extracting water. These tools are relatively inexpensive and have been used by growers of the Lower Rio Grande Valley (Fipps, 2002). However, Watermark sensors are preferred because they have the widest range of reading (0 to 200 centibars) compared with tensiometers that only read from 0 to 60 centibars. Centibars is a unit that measures the tension in which the water is held by the soil. The higher the tension, the drier the soil. The advantage of having inexpensive sensors like Watermark is that more can be installed at different depths and in different soil types especially when there is great soil variability.

Moisture availability estimations based on soil-moisture tension integrate the effects of soil texture so readings need not be adjusted for soil type, but can be biased by soil salinity. Typically, tension measurements will remain low for extended periods as plants remove available water from the soil then rise rapidly as available moisture levels approach lower limits. When soil moisture tension in root zones reaches between 30 and 60 centibars, it is usually time to irrigate. One of the problems of the Watermark sensors that has been observed in the Valley is its slow response, especially after irrigating. It can take about 12 hours to register from dry to wet. Another problem is in deciding the placement of the sensor in relation to the trunk of the tree and with the irrigation emitter. It is recommended to initiate irrigation when it is not dry to allow some time for the sensor to catch up and avoid tree stress.

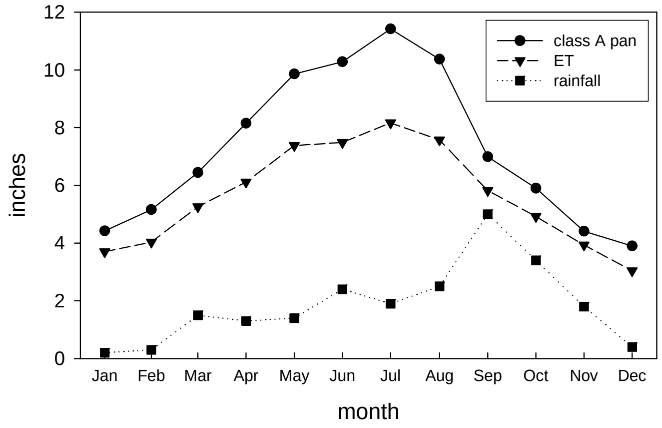

Figure 1. Average monthly class "A" pan evaporation, Pennman Monteith reference evapotranspiraion and rainfall from 1995 to 2003 at the Texas A&M University Center at Weslaco.

Table 6. Number of irrigation for citrus with 70% canopy in a Hidalgo sandy clay loam soil with 50% MAD and holding capacity of 8.2 inches in 4 ft of soil depth. (Available moisture = 4.1 in.)

Month	ET_{citrus} – Rain	Number of Irrigations
	(in)	
Jan	1.9	0
Feb	1.8	1
Mar	2.0	1
Apr	2.8	0
May	3.7	1
June	2.6	1
July	3.6	1
Aug	2.7	1
Sep	0	0
Oct	0	0
Nov	0.5	1
Dec	1.5	0
TOTAL	23.1	7

In order to reliably measure conditions in the orchard, producers need to install soil water sensors in several locations and at different depths, then regularly go into their orchard to record sensor measurements.

Irrigation is generally triggered when the citrus crop depletes about 55 to 60 percent of the soil water stored in the root zone (Sauls, 2005b). This point is called the management allowable depletion (MAD). For example, for a Hidalgo Sandy Clay Loam soil with water-holding capacity of 8.2 in. and a MAD of 50 percent, irrigation is needed at the point that 4.1 in. (8.2*0.5 = 4.1 in) has been used. Table 6 shows the corresponding number of irrigations needed for this soil for those soil conditions.

It is common to apply between 5 and 7 irrigation per year for citrus irrigated with flood irrigation in the LRGV, however the number of irrigation will be highly affected by the weather, soil type and water availability. The balance sheet approach assumes that a plant can access equally all available moisture between saturation and wilting point. Researchers have shown such assumptions to be accurate for wet soils. However, as a soil dries, plants have increasing difficulty in extracting water, and their growth rates decline well before soil moisture reaches the wilting point (Allen et al., 1998).

Salinity and Crop Production. Citrus is sensitive to high salt concentration in the soil. Citrus yield decreases 10% when soil salinity increases to 2.3, 25% at 3.3, 50% at 4.8 and 100% at 8 mmhos/cm (Ayers and Westcot, 1976). Citrus yields can be reduced by saline irrigation water by 10% at 1.6, 25% at 2.2, and 50% at 3.3 mmhos/cm.

Water from the Rio Grande has moderate salinity, ranging between 1.0 to 1.65 mmhos/cm (700 to 1200 ppm). At Rio Grande City, the salinity is less than 1.2 mmhos/cm with the highest values observed between April and June (1.0 to 1.2 mmhos/cm), and dropping below 1.0 (700 ppm) during the rest of the year. Salinity increases downstream. At the Mercedes Irrigation District, salinity ranges from 1 to 1.5 mmhos/cm, occasionally reaching 1.6 mmhos/cm during some days in November (IBWC, 2002).

Salinity is minimized in soils with good drainage. Heavy soils are not good for citrus production due to their slow drainage. Some farmers in the Lower Rio Grande Valley have practiced deep chiseling between citrus rows in their farms in order to enhance salt leaching and improve drainage in the soil profile. Bad drainage can create other problems such as the accumulation of sodium or other salts such as boron, chlorides, and sodium. Citrus is sensitive to boron concentrations of 0.3-1.0 ppm.

Irrigation for Freeze Protection. The optimum mean daily temperature for citrus tree growth is 23 to 30°C. Growth is markedly reduced above 38°C and below 13°C. Active root growth occurs when soil temperatures are higher than 12°C. Most citrus species tolerate light frost for short periods only. Leaf injury is caused by temperatures of -3°C occurring over several hours. Temperatures of -8°C cause branches to wither and -10°C generally kills the tree entirely. Flowers and young fruits are particularly sensitive to frost and are shed after very short periods of temperatures slightly below 0°C. Dormant trees are less susceptible to cold injury. Strong wind is harmful to citrus trees because flowers and young fruits fall easily; windbreaks should be provided when necessary (Doorenbos and Kassam, 1986). Microsprinklers can protect young trees during freezing nights, especially the lower part of the trunk, when water is applied continuously, because water freezes and heat is released. When the application rate is high enough, the freezing water will maintain the trunk, bud union and lower braches at a temperature near 0°C. Boman (2002) recommends placing the sprinkler 1 to 2.5 feet from the trunk on the upwind side of the tree. This author also mentions that insulating tree wraps placed around the trunk of young trees slows the rate of temperature fall and allows trunk protection, so he recommends the use wraps for young trees in combination with sprinkler irrigation. According to Boman (2002) microsprinkler irrigation is more effective for cold protection when high volumes of water are used, which can be accomplished with microsprinklers applying 20 gallons per hour. The water should be turned on before the temperature reaches 0°C, so the placement of the thermometer is very important. The microsprinkler should be kept running all night during the freeze. If the irrigation systems fails when the temperature is below freezing more damage can be caused due to evaporative cooling. Therefore, it is important not to turn on the system if the pumping system is unreliable. The system can be stopped once temperatures are above 1 °C.

Current Irrigation Practices in the Lower Rio Grande Valley. Historically, producers in Texas's Lower Rio Grande Valley have used flood to irrigate their citrus crops. An extensive network of canals and large-diameter underground pipelines deliver large volumes of water from the Rio Grande River to fields, primarily by gravity flow, over short periods of time according to a rotational scheme. Because the Valley generally slopes toward the northeast, away from the river, little pumping is necessary except to lift the water from the river. At present, water restrictions generate increasing interest in using more efficient irrigation technologies.

Flood irrigation can be efficient when properly managed. At the delivery system level, losses occur due to evaporation and leaks caused by the age and condition of canals and pipelines. For example, many irrigation canals are unlined earthen ditches which allow water to seep into their banks. Obviously, water lost to evaporation or leakage is not available to irrigate producers' crops. The lining of canals and the use of pipe to convey and deliver water significantly improve efficiencies by reducing infiltration and evaporation losses.

At the farm level, the most common irrigation method for citrus is flood irrigation with graded (sloping) borders. In a few orchards, water is generally conducted within the farm with earth ditches and water is banked and blocked with canvas or plastics. The ditch is cut to deliver water to the border or water is taken from the ditch with siphon tubes.

With flood irrigation it is important to level the land to the appropriate grade before establishing the orchard and to have valves or structures to control water applications to irrigate efficiently. Citrus groves that are bordered, and are properly graded don't produce runoff.

Alfalfa or orchard valves at different points within the orchard are helpful to adapt gated or flexible pipes (poly-pipe) and distribute water faster into the field and with high efficiencies. Permanent borders are generally located every two rows with an irrigation valve between each pair. Temporary borders may be single or double row depending on the grower preferences.

It is preferable to have one row of trees per border with a height of around one foot to have a better control of irrigation and to irrigate faster. A modification of the flood irrigation is to reduce the irrigated area by placement of temporary borders along either side of the tree rows. This method is called strip flooding, and it allows advance water faster.

One head of water will irrigate a field of 40 ac in size. "One head" of water per outlet is equivalent to 3 cfs or 1346 gallons per minute.

Weed control methods affect preference for an irrigation method. Permanent borders should be accompanied by trunk-to-trunk herbicidal weed control, while temporary border irrigation requires the use of tillage implements to control weeds in the row middles. In both cases, herbicides are applied for weed control beneath the tree canopies. Weed control in the row middles of orchards with micro sprayer or drip irrigation systems may be with herbicides or by tillage.

In deciding when to irrigate, producers also must consider non agronomic factors, including the need to order water several days in advance and the fact that they may have to take turns with other growers to receive water. Depending on location and the particular irrigation district, some microirrigation or drip irrigation systems may require the construction of a reservoir in which to store water for irrigation.

Ultimately, when choices must be made, the grower will allocate scarce resources in such a manner as to produce the greatest return.

Improving Citrus Irrigation Efficiency. Periods of drought have caused reduced water allocations for some irrigation districts in the LRGV. Citrus farmers have considered pressurized irrigation systems as a way to increase production per unit of water applied and as a way to maintain orchards during these drought periods. The fact that pressurized systems have one or more emitters at each tree allows the injection of fertilizers (and some agrochemicals) with high uniformity, thereby enhancing plant nutrition increasing productivity per unit of water applied. This partly compensates for higher initial cost ($750 to $1500 per acre) of the system and the variable costs such as energy (electricity or diesel), and maintenance. The most common pressurized systems are drip and micro-irrigation.

Drip Irrigation Systems. There are several farms in the LRGV with drip irrigation systems. The most common configuration is drip-lines parallel to the tree rows. Young orchards can be adequately irrigated with a single line per row, but older trees require two lines—one on either side of the row. The initial system design must accommodate the need for the additional line of emitters in order to assure that enough water can be supplied to both lines in the future. The drip emitters are generally spaced every 3 ft and apply about 1 gallon/hour per emitter.

Drip irrigation systems require filtration to prevent emitter clogging. Since the water is pumped from the canal, many farms have a settling pond where sediments and small particles settle out. The water is pumped through the filters before entering the irrigation lines.

Considering that only part of the soil surface area is wetted (normally 33 to 50%), considerable water is saved with this irrigation system. Another advantage with these systems is that fertilizer is applied in very uniform rates in a short time just at the root system where trees use it (Wutscher, 1975).

A common problem that farmers face with drip irrigation is weed control in the wetted area. With drip irrigation, the only herbicides that can be applied are pre-emergence. A common problem is to maintain the herbicide close to the surface. Generally, most weeds germinate in the top 1 to 2 inches of soil depth and frequent irrigation leach the applied herbicides below 2 inches where they are needed. Vines that can grow into and cover the tree are a serious problem. Microirrigation can offer the best alternative for weed control, because post emergence herbicides can be used.

Micro-irrigation and Micro-Sprayer Irrigation Systems. A microsprinkler has moving parts, spraying one or sometimes two streams of water as it rotates. The microsprinkler with movable parts consist of deflectors that move as they are hit by water exiting the orifice. Microsprayers basically have no moving parts and the water is deflected into several discrete streams as it emerges from the emitter. Valley farmers prefer microsprayers because moving parts have a tendency to malfunction when fine, wind-blown soil particles accumulate on the emitter.

Microsprayers generally are connected to a polyethylene lateral line through a micro-tube, often referred to as "spaghetti tubing". They are commonly 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. However, pumping capacity may dictate that large orchards be subdivided into two or more zones to be irrigated separately.

Microsprayer irrigation sprays water over the soil. The micro-sprayer produces tiny droplets and can wet a diameter of 12 to 18 feet depending on the tree skirt configuration. Its spray or mist is produced by a flat spreader and a small orifice operating at pressures between 25 and 43 pounds per square inch (psi).

Microsprinkler / microspayer irrigation systems usually utilize one emitter per tree and have been used also for frost protection when they can deliver at least 16 gpm per emitter.

Summary. A literature review was conducted to determine what irrigation practices and studies have been conducted for citrus production in the Lower Rio Grande Valley. This review reports citrus regional yields and water requirements for the Valley from several years of observation. Although estimated citrus water requirements have been reported in the literature, there is a need to obtain more information about citrus crop coefficients to estimate ET more accurately and thus schedule irrigation using weather stations. This study also found that there is a big acceptance of soil moisture monitoring sensors to estimate citrus water requirements among Valley farmers. However, there is no information about the optimum depth and location for placing the sensors, and the optimum management allowable depletions for these sensors, and reports that indicated their performance. Micro-irrigation and drip irrigation systems have seen limited use in the Valley, and although farmers recognize their benefits in conserving water and injecting fertilizers through the system, there are no studies that report comparisons in yields per unit of water and net return under different irrigation methods.

CITRUS IRRIGATION REFERENCES

Ayers, R.S. and D.W. Westcot. 1976. "Water Quality for Agriculture". Food and Agriculture Organization (FAO) of the United Nations, Irrigation and Drainage Paper No. 29, Rome, Italy, 1976.

Allen, R.G., L.S. Pereira, D. Raes and M. Smith. 1998. Crop evapotranspiration - guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56. Rome.

Boman, B.J. 2002. Water and Florida Citrus: Use Regulation, Irrigation, Systems, and Management. University of Florida. Institute of Food and Agricultural Sciences. 603 p.

Castel, J. R., I. Bautista, C. Ramos, and G. Cruz. 1987. Evapotranspiration and irrigation efficiency of mature orange orchards in "Valencia" (Spain). Irrigation and Drainage Systems 3:205:217.

da Graca J.V. and J.W. Sauls. 2005. Texas Citriculture – Past and Present. Texas A&M University-Kingsville Citrus Center. http://primera.tamu.edu/kcchome/webpages/texascitriculture.htm

Doorenbos, J. and A.H. Kassam. 1986. "Yield Response to Water". Food and Agriculture Organization (FAO) of the United Nations, Irrigation and Drainage Paper No. 33, Rome, Italy.

Enciso, J. M. and B. Wiedenfeld. 2005. "Irrigation guidelines based on historical weather data in the Lower Rio Grande Valley of Texas". Agric. Water Manage. 76:1-7.

Fipps.G. 2002 Citrus Water Management. http://apache.tamu.edu/texaset/rioqueen/charts/Web%20Charts/310%20S.htm

Koo, R.C.J. 1963. Effects of frequency of irrigation on yield of orange and grapefruit. Proc. Fla. State Hort. Soc. 71:1-5.

Koo, R.C.J. 1978. Response of densely planted "Hamlin" orange on two rootstocks to low volume irrigation. Proc. Fla. State Hort. Soc. 91-8-10.

International Boundary and Water Commission United States and Mexico (IBWC). 2002. Flow of the Rio Grande and Related Data From Elephant Butte Dam, New Mexico to the Gulf of Mexico. Water Bulletin Number 72. 135 p.

Sauls, 2005a. Citrus Orchard Establishment. Texas Coop. Ext., Texas A&M Univ. Sys., College Station. http://aggie-horticulture.tamu.edu/citrus/L2306.htm

Sauls, 2005b. Citrus Water Management. Texas Coop. Ext., Texas A&M Univ. Sys., College Station. http://aggie-horticulture.tamu.edu/citrus/water/L2307.htm

Smajstrla, A.G., L.R. Parsons, F.S. Zazueta, G. Vellidis, and K. Aribi. 1986. Water use and growth of young citrus trees. Paper No. 86-2069. Am Soc. Agric. Eng., St. Joseph, MI.

Wiedenfeld, R.P., C.G. Lyons., R.E. Rouse. 1982. Effects of Soil Texture on Citrus Root Development and Tree Vigor. J. Rio Grande Valley Hort. Society. 35:65-72.

Wiegand, C.L. and W.A. Swanson. 1982a. Citrus Responses to Irrigation: I. Irrigation Requirements; Daily, Monthly, and Annual Evapotranspiration Amounts; and Water Management Recommendations. J. Rio Grande Valley Hort. Society. 35:73-85.

Wiegand, C.L. and W.A. Swanson. 1982b. Citrus Responses to Irrigation: II. Fruit Yield, Size and Number. J. Rio Grande Valley Hort. Society. 35:87-94

Wiegand, C.L., W.A. Swanson., and R.R. Cruise. 1982. Marrs, Valencia and Ruby Red Juice Quality as Affected by Irrigation plus Rainfall. J. Rio Grande Valley Hort. Society. 35:109-120.

Wutscher, H.K., A. Peynado, and H. Hill. 1975. Effect of Drip and Flood Irrigation on Mineral Nutrition of Young Grapefruit Trees. J. Rio Grande Valley Hort. Society. 29: 17-24.