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Texas Agricultural Extension Service

Crop Water Management for the High Plains

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Water Use Efficiency

In areas where water supply is limited or expensive, such as the Texas High Plains, it is economically important for farmers to attain high water use efficiency as well as high yields. Water use efficiency values can be calculated in several ways and should be clearly defined to avoid misinterpretation. Water use efficiency for a crop and irrigation system can be expressed as crop yield (pounds) per unit of water applied to or actually used by the crop (acre-inches).

Seasonal water use efficiency (SWUE) either for dryland or irrigated crops is usually calculated as follows:

$$\text{SWUE (lbs/ac-in)} = \frac{\text{Crop Yield, lbs/ac}}{\text{Seasonal Water Use (ET), inches}}$$

The seasonal water use, or evapotranspiration (ET), takes into account the seasonal rainfall from crop planting to maturity, runoff from rainfall, irrigation water application, irrigation water runoff, and the change in soil water storage in the crop root zone. Seasonal water use (ET) is primarily dependent on climatic factors and type of crop. For most crops, there is a linear relationship between ET and yield. Thus the highest yield usually occurs at the highest seasonal water use.

Values of SWUE are normally much lower for dryland than for irrigated crop production on the High Plains because the yields are much lower. Seasonal water use efficiency is improved by soil management factors that increase yield (e.g., soil fertility) and prevent water waste (e.g., control of weeds, tailwater losses or deep percolation). Some other useful practices that improve soil moisture storage, ET and yield include furrow diking, conservation tillage, and chiseling to reduce hardpan effects.

Irrigation water use efficiency (IWUE) is the additional crop yield that results from irrigation divided by the amount of irrigation water applied, as follows:

$$\text{IWUE (lbs/ac-in)} = \frac{\text{(Irrigated Crop Yield} - \text{Dryland Yield), lbs/ac}}{\text{Irrigation Water Applied, inches}}$$

Irrigation water use efficiency provides a useful index for comparing results from alternative irrigation systems and water management methods for specific crops and regions. Peak crop yields may occur at higher levels of irrigation than are required to obtain high water use efficiencies. IWUE values should be considered for areas where full season irrigation is not possible or is economically infeasible. Seasonal water use patterns and critical application periods for crops should be observed in attempting to attain high irrigation water use efficiencies.

Rainfall Patterns

Annual rainfall ranges from 12 to 22 inches across the Texas High Plains, and on the average about two-thirds of this occurs just before or during the summer growing season. However, average monthly rainfall data can be misleading because large variations occur. Therefore percent probability that a certain rainfall amount will occur is a better way of assessing risk.

Dryland crops should be grown during periods of high rainfall probabilities to allow more of the rainfall to be used for evapotranspiration.

The amount of monthly precipitation that has been exceeded in 75, 50 and 25 percent of the 104 years of record for Amarillo is shown in Figure 1. This rainfall probability chart shows large variations between the average and median values and between the wettest and the driest 25 percent of the years.

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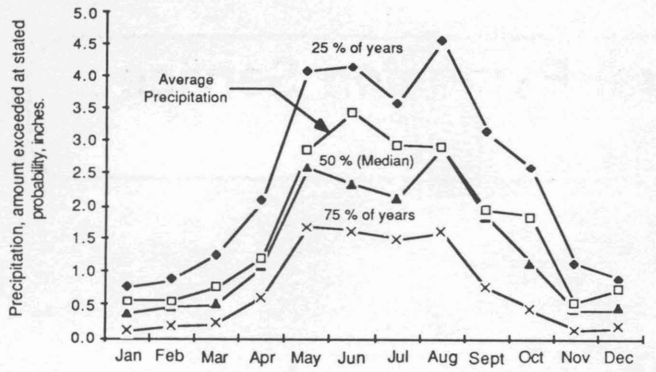

Figure 1. Average precipitation and amount exceeded in 25, 50 and 75 percent of years at Amarillo, TX, based on 104 years of data (Stewart et al., 1984).

The probability of receiving more than nine selected precipitation amounts ranging from 0.01 to 10 inches within periods of 1 week, 2 weeks, 3 weeks and 1 month across the state has been determined and is available in a Texas Agricultural Experiment Station publication (Dugas, 1983). The number of consecutive days without daily precipitation above 0.0, 0.1 and 0.4 inches, with probability levels of 90, 50 and 10 percent, was also determined.

For example, the data for Lubbock shows that between April 26 and September 19 there is a 50 percent chance that a dry spell will be ended within 6 to 13 days by precipitation of 0.4 inches or more. Similar data for Amarillo has established this time period at 6 to 17 days. Between mid-October and mid-March, consecutive periods of more than 1 or 2 months without 0.4 inches or more of daily precipitation should be expected in at least 50 percent of the years.

Crop Water Requirements and Water Use Efficiencies

The four main crops produced in the High Plains—**sorghum, corn, wheat** and **cotton**—have been the subject of water management research and demonstrations in Texas for several decades. Experimental results for yield and water use efficiency have varied, but many common water management principles have emerged and are receiving widespread application by farmers. Limited irrigation is now being widely practiced on drought tolerant crops to take advantage of expected rainfall, which includes a 30-day period of fairly reliable rainfall from mid-May through mid-June. This late-spring rainfall normally coincides with sorghum and cotton planting and typically follows corn planting.

Sorghum

Sorghum has good ability to adjust to water stress. Sorghum requires 13 to 24 inches of seasonal water use (evapotranspiration) from precipitation, stored soil moisture and irrigation to achieve grain yields of 3,000 to 6,700 pounds per acre. Dryland sorghum yields an average of about 1,600 pounds per acre, although yields of up to 3,000 pounds per acre are not uncommon during high rainfall years.

Preplant irrigation is often not needed, and moreover may be inefficiently applied especially when using conventional graded furrow irrigation systems. The same amount of water may be more efficiently used if applied at later stages of crop growth. Conservation tillage can reduce the need for preplant irrigation of sorghum through improved soil moisture storage.

Irrigations should be timed to avoid water stress during periods of peak water use (boot, heading and flowering stages) to achieve reasonably good yields and maximum irrigation water use efficiency. Peak water use rate is about 0.30 inches per day. Two well-timed seasonal irrigations of 4 inches per application or the equivalent are adequate in normal years for good yields of medium maturity hybrids. Saving irrigation water by withholding a 4-inch irrigation reduces sorghum grain yields by only about 10 percent during the early 6- to 8-leaf stage but by almost 50 percent if withheld at the heading and bloom stage.

Irrigation water use efficiencies may reach 400 to 500 pounds of sorghum grain per acre-inch with limited but well-timed irrigations as compared to about 200 to 250 pounds per acre-inch with adequate full-season irrigation.

Corn

Corn is much more sensitive to water stress than sorghum, wheat or cotton. Corn is planted earlier than sorghum which typically allows more efficient use of the May-June wet season than sorghum. However, the early planting date required for corn increases the need for preplant irrigation for stand establishment. The total seasonal water use (ET) to achieve any corn grain yield is about 13 inches.

At Bushland, corn yields with adequate irrigation averaged 8,650 pounds per acre, which was 22.5 percent higher than for sorghum under similar conditions. Seasonal ET's for corn peak yields are around 28 to 32 inches per year. Peak ET rates are 0.3 to 0.4 inches per day, depending upon weather conditions.

Preplant irrigation is often necessary. Then three or four seasonal irrigations of 4 inches each are essential for high corn yields in most years in the Texas High Plains. Drought seasons require one or two additional irrigations.

Irrigation water use efficiency values are usually 250 to 450 pounds of corn per acre-inch with adequate irrigation. However, peak IWUE values of 500 pounds per acre-inch or more have been obtained with limited irrigation in good rainfall seasons. Center pivot irrigation allows frequent irrigations of 1 to 1.5 inches during peak water use periods on corn.

Moisture stress caused by low soil water availability or hot, dry conditions during the flowering stage (which includes tasseling, silking and pollination) can severely restrict corn yield.

Reduced irrigation of corn has generally resulted in significant yield decreases. Planned water deficits into the stress range are not recommended and may only be feasible on soils with moderate to high water storage and during the early vegetative or grain ripening stages. Reduced acreage, rather than reduced irrigation, offers the best way to adjust corn irrigation to limited water supplies.

Wheat

Winter wheat is a major drought-tolerant crop that grows vegetatively during the normal dry period from fall to early spring and develops grain during a period of increasing spring rainfall. Wheat is normally planted around October 1 and requires available soil moisture from irrigation or precipitation for germination and early growth. Wheat should also receive perhaps one late fall irrigation followed by two to three spring irrigations for high grain yields. One additional early irrigation (together with additional applied fertilizer) is usually needed for early planted wheat that is grazed and also managed for grain production. Seasonal water use is around 26 to 28 inches for wheat (grain only) yielding 4,700 to 5,800 pounds per acre, or 85 to 100 bushels per acre.

The highest wheat yield response to irrigation usually occurs during jointing and boot stages. These stages also coincide with a period of relatively low probability of rainfall, during which irrigation water use efficiencies of about 230 pounds of grain per acre-inch have been realized from a 4-inch irrigation. Spring irrigations totaling 4 to 12 inches have resulted in good irrigation water use efficiencies of above 170 pounds of grain per acre-inch. The least efficient irrigation is during grain filling, which normally is associated with increased rainfall, resulting in IWUE values of less than 115 pounds per acre-inch. Short wheat varieties in recent tests have exhibited 50 percent higher irrigation water use efficiency values than tall wheat varieties in earlier tests. Wheat yields have been increased in some experiments using no-till, limited tillage, or furrow diking as compared to conventional tillage.

Cotton

Cotton is a drought-tolerant long-season crop that lends itself to limited irrigation despite a somewhat complicated pattern of water use, deficits and application. Cotton is the major irrigated crop on the Texas High Plains and is second to wheat in dryland production acreage. Widespread cotton production under limited irrigation has a major impact on the state's water budget.

Early fruit set is important in cotton production. However, the production, placement and retention of fruiting sites are sensitive to soil water availability.

Under dryland conditions, expected lint yields are in the range of 250 to 300 pounds per acre. Cotton requires more than 13 inches of seasonal water use to produce appreciable lint yields. Expected average yields with 50 percent probability of occurrence are 450 to 475 pounds lint per acre. Maximum yields occur at about 27 inches of seasonal water use. High levels of water application can decrease lint yield by causing excessive vegetative development and fall immaturity. A preplant irrigation of 4 inches is usually advantageous especially if spring rainfall is not adequate, but heavier preplant irrigations are not warranted.

Cotton has the ability to overcome moisture stress at most growth stages if water becomes available and low temperatures do not limit growth. The most critical period for irrigation is early to mid-bloom. If water is available, a second irrigation should be applied at peak to late bloom. The irrigation cut-off date for cotton is mid- to late-August. For irrigated cotton, yield results generally favor narrow-row planting with high plant populations. Land leveling on slopes of 0.5 percent or greater has increased yields by more than 100 pounds lint per acre for both furrow irrigated and dryland cotton.

Irrigation water use efficiencies for cotton have ranged from as little as 20 to 30 pounds per acre-inch for full irrigation to as high as 80 to 100 pounds per acre-inch for two well-timed furrow irrigations (applied at preplant and peak bloom) in some experiments. A reasonable target for limited furrow irrigation appears to be 50 pounds per acre-inch. Cotton irrigated with the LEPA (low energy precision application) system and drip systems produced around 90 pounds lint per acre-inch in research plots.

Systems and Practices

Numerous water management systems and practices have been tested and placed in use to improve water management for both dryland and irrigated crops in the Texas High Plains. The type of soil can greatly affect decisions regarding systems, cultural practices, water application rates and timing. It is important for farmers and their professional advisors to carefully examine the applicability of each method for a given farm.

Practices and systems that should be considered for irrigation water management on field row crops, cereal crops and vegetables on the Texas High Plains are listed in Table 1. These practices are summarized according to precipitation harvesting (including tillage and cultural practices), irrigation systems and methods, and irrigation scheduling techniques. The relative importance or applicability of each practice is rated as high (H), medium (M), low (L) or not applicable (blank). The ratings can vary greatly depending upon type of crop and general soil texture. The information in the table can furnish a useful perspective in considering various practices for possible adoption.

Table 1. Guide to Recommended Irrigation Water Management Methods for Texas High Plains.

Recommended Water Management Practices	Field Row Crops (Cotton, Sorghum, Corn)			Cereal Crops (Wheat, Barley, etc.)			Vegetables		
	Soil Type[1]			Soil Type			Soil Type		
	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy
1. Precipitation Harvesting									
a. Soil Modification									
(1) Furrow Diking	M[2]	H	H				M	H	H
(2) Chiseling	L	H	H						
(3) Terracing Steep Slopes	M	L	L		M	M			
b. Cultural Practices									
(1) Crop Rotation	M	M	M	L	L	L	M	M	M
(2) Conservation Tillage/ Residue Management	M	H	H	M	H	H			
(3) Weed Control	H	H	H	H	H	H	H	H	H
c. Controlled Soil Moisture									
(1) Soil Moisture Sensing or Measurement	M	M	M	M	M	M	H	H	H
(2) Restricted Late & Early Season Irrigation	H	H	H						
(3) Utilization of Rainfall Probability Data	M	M	M	M	M	M			
2. Irrigation Methods									
a. Furrow Irrigation									
(1) Alternate Row Irrigation		H	H						
(2) Surge Flow		H	M		L	L		M	M
(3) Tail Water Recycle	L	M	H	L	M	H	L	M	H
b. LEPA (Linear & Center Pivot Configuration)									
(1) Alternate Row Watering	H	H	H						
(2) Furrow Diking	H	H	H				H	H	H
(3) Chemigation Capability	H	H	H	H	H	H	H	H	H
3. Irrigation Scheduling									
a. ET Accounting	H	H	H	H	H	H	H	H	H
b. Soil Moisture Sensing or Measurement	H	H	H	H	H	H	H	H	H
c. Water Balance Calculation	H	H	H	H	H	H	H	H	H
d. Crop Modeling	M	M	M	L	L	L	M	M	M

[1] Soil type: Light textured—sands; medium textured—fine sandy loams and loams; heavy textured—clay loams and clays.

[2]Code:

H = Highly important practice L = Low importance
M = Moderately important Blank = Not applicable

References

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