

Irrigating Sorghum in South and South Central Texas

Charles Stichler and Guy Fipps*

“WATER IS ALL we sell in agriculture.” Whether the enterprise is corn, cattle, cauliflower, cotton, or grain sorghum, water is essential for its production and the single most important aspect of production that determines yield.

Grain sorghum is a tropically adapted plant that can survive under drought and adverse conditions. Because of its ability to survive in unfavorable conditions, sorghum is often relegated to poor soils and poor management.

However, to be profitable, a sorghum crop needs sufficient water at critical points in its development. Therefore it is vital that growers manage irrigation properly. If grain sorghum is managed well, it will produce profitable, high yields.

Growth and development

Like other grains, the ultimate purpose of a sorghum plant is to produce seeds. Seed production is a singular event — the plant’s root, leaf and stem development are all directed toward this outcome.

Because yield is determined by both the number and weight of seeds, it is vital for growers to understand the plant processes that affect seed development. One such process is photosynthesis, in which green plant tissues take carbon dioxide from the air, water and nutrients from the soil and energy from sunlight and convert them into sugars or carbohydrates. The products of photosynthesis are also called photosynthates.

The more active, functioning leaves a plant has, the more photosynthates it will produce, and thus the greater its yield potential. To increase yield potential, growers need to take management steps that support leaf development, maximize photosynthesis and limit water loss.

A critical component of the photosynthesis process is water. Water can be said to be part of a plant’s circulatory system — water moves throughout the plant, carrying with it plant minerals, nutrients and plant chemicals such as enzymes, proteins, sugars and carbohydrates. Water evaporates from the leaf and is replaced with water from the soil in a process called transpiration.

A sorghum plant gets more than 75 percent of its water and nutrients from the top 3 feet of soil. Plants can use about 50 percent of the total available water without undergoing stress.

The availability of water is the key factor to consider when deciding on row spacing and plant population. Moisture dictates yield goals, which in turn dictate seeding rates and spacing. For irrigated production, growers should aim for between 70,000 and 80,000 established plants per acre; for dryland production, the total should be 50,000 to 60,000

*Associate Professor and Extension Agronomist, and Professor and Extension Irrigation Engineer, The Texas A&M University System

established plants per acre. (For more information, refer to B-6048, *Irrigated and Dryland Sorghum Production*.)

Yields will be reduced if the plants are too crowded. The more plants that are established, the more water the crop will use. If too many are planted, much of the soil moisture will be used before the reproductive stage begins, rendering the plants unable to produce seeds.

Research has been conducted at Texas Tech University on the amount of water per acre required by sorghum. The studies have shown that sorghum at pre-bloom uses 8 to 10 inches of water per acre and that each additional inch will produce 385 to 400 pounds of grain.

For a grain yield of 7,000 pounds per acre, total water use — from both soil and plant evaporation — is about 28 inches of water per acre. However, water use varies greatly in sorghum, depending on the final yield, the maturity of the hybrid, planting date and weather conditions. For this reason, prior to planting, the soil profile should be filled to 24 inches deep if a grower desires a maximum yield.

Water needs at different growth stages

Water needs for sorghum vary according to the different plant stages — different amounts are used in the seedling development phase, the rapid growth and development stage, and the bloom to harvest phase (Fig. 1).

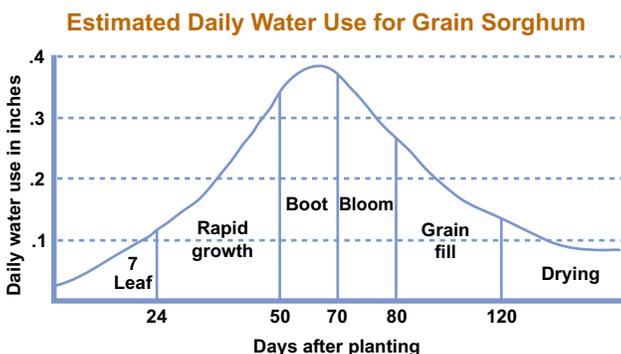


Figure 1. Water needs for sorghum rise sharply at the rapid growth stage, peak during the boot stage and then drop off afterward.

Seedling development

The seedling development stage begins at germination and ends at about 26 days after planting,

when the plants have five to six mature (fully expanded) leaves. This early-growth stage does not directly affect the number of seeds produced, but it does set the direction of development.

Although water management is not critical during the seedling development period, minor stress does affect future growth, plant size and yield potential.

During the seedling stage when the soil is not shaded, more moisture is lost through soil evaporation than by transpiration from leaves. To minimize moisture losses from the soil, it is important that you adopt water-conserving practices, such as:

- Residue management
- Conservation tillage
- Narrow-row spacing
- Good weed control, and
- Proper planting date for rapid canopy establishment

Rapid growth and early reproductive phase

The need for water is extremely critical during the rapid growth stage and before the reproductive stage. If the plants are water stressed during the rapid growth stage, it does not matter what steps a grower takes afterward — the number of flowers has already been determined and yield will be reduced.

After seedling development, water needs begin to increase as the leaves enlarge and expand. Because leaves are the part of the plant that collect energy from the sun, growers should adopt production practices (such as those listed above) that encourage early leaf development.

About 40 days after planting, the total number of leaves has been determined and one-third of the total leaf area has developed. During this period, the growing point changes from vegetative to reproductive, and the seed panicle begins to form inside the stalk.

During the next 30 to 35 days, the immature leaves continue to grow and the number of ovules that will develop into seed are formed until the flag leaf (final leaf) emerges and the plant begins to boot. The size of the panicle and number of seeds are determined between day 35 and 65 by adequate water, fertility and photosynthate production. Root formation is completed and the panicle (head) is

visible in the bottom of the plant inside the stalk.

The demand for water is extremely critical during this stage because the potential head size has already been determined before head exertion begins. The goal is to limit moisture stress during the rapid growth phase so that a robust plant structure and full panicle have been produced.

Growers should not wait too long to irrigate, else production will suffer. Water use will be about 0.2 to 0.3 inch per acre per day. Up to bloom, sorghum will use about 8 to 10 inches and any moisture stress during this period will reduce the yield potential.

Bloom to harvest (reproductive stage)

In the next stage, the plant develops from bloom to physiological maturity, which is when the seeds are fully developed and no further weight is added. This phase requires about 45 days to complete. Sorghum blooms over a 5- to 9-day period. During this time, the proteins and photosynthates that are produced and stored in the leaves are moved into the developing grain.

During the period just before bloom and until early grain fill, sorghum will use about 0.35 inch of water per day, declining to 0.1 inch a day when the grain is dry. Anything that reduces leaf function — such as leaf loss, water or nutrient stress, or disease or insect damage — will eventually reduce yield.

Growers should time the final irrigation to carry the crop from the last irrigation to black layer, or physiological maturity. Any additional irrigation just before and after this point is wasted. From physiological maturity until harvest, the crop is just drying down. By harvest, the plant will have absorbed about 35 pounds of nitrogen and 11 pounds of phosphate for each 1,000 pounds of grain and stover produced. After the initial 8 to 10 inches of water to reach bloom, each additional 1 inch of water will produce 350 to 425 pounds of grain, bringing the total to 28 inches of water for a 7,000-pound yield.

Furrow irrigation

Furrow irrigation is best timed according to the plants' stage of growth. Furrow irrigation is not as exact as is sprinkler irrigation. If furrow irrigation is managed well, most water applications will be about 3 to 4 inches per irrigation.

A good guide is to apply irrigations at key growth stages if there is no rain and additional soil moisture is needed:

1. If the soil profile is full at planting, the stored soil moisture should supply the water requirements until the first irrigation at the reproductive stage.
2. The onset of the reproductive stage is 30 days after planting. One 4-inch irrigation will last the 25 days until flag leaf.
3. At flag leaf or boot stage, two 3-inch irrigations about 2 weeks apart will last until soft dough in the grain fill period.
4. The last irrigation will maximize yield, but is generally not economical and does not pay for the water. One 3- or 4 inch-irrigation is needed at soft dough to complete grain fill, which takes about 45 days from bloom to reach black layer.

Using this schedule, the appropriate amount of irrigation water will be applied during each growing period if rainfall is not received. If those amounts are totaled for the entire growing period, the amount need by the crop will approximate the following:

$$\begin{aligned} &6 - 8 \text{ inches} && \text{rainfall or pre-irrigation to fill} \\ &&& \text{the soil profile if totally dry} \\ &+ 4 \text{ inches} && \text{30 days after planting} \\ &+ 6 \text{ inches} && \text{in two 3-inch irrigations at flag} \\ &&& \text{leaf or boot stage} \\ &+ 3 \text{ inches} && \text{at soft dough} \\ &= 19 - 21 \text{ inches} && \text{of total water} \end{aligned}$$

The 19 to 21 inches is the amount of water needed to produce a crop without stress. The total amount needed will vary somewhat, depending on weather conditions such as heat, low humidity, cloud cover and wind.

How much replacement water is needed?

The amount of water a crop uses is known as evapotranspiration (ET), which is the water lost through a combination of two processes: evaporation, which is the water removed from the soil, and transpiration, which is the water removed from the plant leaves. The amount (in inches) of water used by a crop in a day is called daily ET.

ET varies by weather conditions (such as wind, humidity, temperature, cloud cover or solar radiation) and by plant characteristics (such as canopy

closure). Because it is related to the leaf surface area, smaller plants transpire less than do larger plants, and ET is lower.

Growers can minimize evaporation from the soil by:

- Spacing the plants equally in narrow rows. Narrow-row crop production reduces the amount of bare soil, which loses more moisture through evaporation than do shady and mulched soil surfaces.
- Leaving crop residues, which can reduce soil evaporation by 1 to 3 inches during the season.

Irrigation scheduling based on potential evapotranspiration

Researchers have developed a simple way for growers to calculate the water requirements of their crops. First, the water requirements of a standard plant were developed to use as a reference. That plant's water requirements are referred to as **PET** (potential evapotranspiration).

Growers can now use PET to calculate the estimated water needs of their crops. To determine the amount of water being used by their crop, growers multiply the PET by the crop coefficient (Kc) for the specific crop being grown and for that crop's growth stage. For sorghum, the crop coefficients in the North High Plains are listed by stage of growth in Table 1. Researchers at the Uvalde Research and Extension Center are working to determine the sorghum crop coefficients for South Texas.

PET can be obtained for different parts of the state on the Internet at <http://texaset.tamu.edu/> where weather stations across much of south Texas will give producers weather information to calculate PET for a day or several days.

Please note that the dates listed are provided only as a general guide, as crop growth rate is affected by many factors, including location, variety, current weather and soil moisture conditions.

How to Use PET

To calculate the water requirements of your crop, multiply the PET by the crop coefficient using the following equation:

$$PET \times Kc = \text{Crop water requirements}$$

PET is the sum of daily PET over the period of interest, such as the 3-day or weekly total.

Table 1. Sorghum crop coefficients in the North High Plains.

Growth Stage ¹	Crop Coefficient (Kc)	Days After Planting ²
Seeding	0.40	3 - 4
Emergence	0.40	5 - 8
3-leaf	0.55	19 - 24
4-leaf	0.60	28 - 33
5-leaf	0.70	32 - 37
GPD	0.80	35 - 40
Flag	0.95	52 - 58
Boot	1.10	57 - 61
Heading	1.10	60 - 65
Flower	1.00	68 - 75
Soft dough	0.95	85 - 95
Hard dough	0.90	95 - 100
Black layer	0.85	110 - 120
Harvest	0.00	125 - 140

¹Sorghum will bloom at different times, depending on location, planting date and maturity of the variety.

²The days after planting are for a medium-early to medium-late variety.

Kc is the crop coefficient for the current stage of crop growth.

Example 1: The 5-day PET total is 1.32 inches. Your sorghum is in the "heading" growth stage. What are the water requirements? (Note: From Table 10, the "heading" crop coefficient is 1.10.)

$$1.32 \text{ inches} \times 1.10 = 1.45 \text{ inches}$$

Thus, to irrigate the sorghum adequately during this period, apply 1.45 inches to replace the water used by the sorghum in the past 5 days.

Adjusting for irrigation system efficiency

If your irrigation system is inefficient, you may need to compensate for it by increasing the amount of water you irrigate. See Table 2 for the typical efficiency ranges of on-farm irrigation systems. To adjust for irrigation system efficiency, use the following equation:

$$PET \times Kc = \text{Eff} = \text{Irrigation water requirements}$$

Eff is the overall efficiency of the irrigation system.

Example 2: You are irrigating with a low-pressure center pivot. You estimate that your overall system efficiency is 85 percent. What are the irrigation water requirements for the sorghum in Example 1?

$$1.32 \text{ inches} \times 1.10 = 0.85 = 1.71 \text{ inches}$$

You will need to irrigate 1.71 inches to meet the plants' water requirements for that period.

Table 2. Typical overall on-farm efficiencies for various types of irrigation systems.

System	Overall Efficiency
<u>Surface</u>	<u>0.50 - 0.80</u>
Common	0.50
Land leveling and water volume per row meeting design standards	0.70 - 0.80
Surge	0.60 - 0.90 ¹
<u>Sprinkler</u>	<u>0.55 - 0.75²</u>
Center Pivot	0.55 - 0.90 ²
LEPA	0.90 - 0.95
Drip/Trickle	0.80 - 0.90 ³

¹Surge has been found to increase efficiencies 8 to 28% over non-surge furrow systems.

²Higher efficiencies are for low wind conditions.

³Trickle systems are typically designed at 80 to 90% efficiency.

Adjusting for rainfall and soil moisture

Rainfall reduces the amount of irrigation water needed to meet plant requirements. However, not all rainfall can be used by plants and crops. Some of the rainfall will be lost to evaporation from the top 2 to 3 inches of soil, runoff and deep percolation (water moving below the root zone), depending on such factors as soil type and slope, soil moisture levels and the duration and intensity of rainfall.

In irrigation scheduling, the term *effective rainfall* refers to the part of the rainfall that can be used by

plants — the part that infiltrates into and is stored in the root zone. Growers must estimate the effective rainfall for each field and for each rainfall. Generally, do not record rainfall of less than 1/4 inch because it evaporates so quickly. Then subtract the amount of effective rainfall from the irrigation requirement determined with Equation 1 or 2.

You may use soil moisture monitoring devices to determine soil moisture levels and the date to restart irrigations after rains. For more information on this procedure, see Texas Cooperative Extension publications B-1670, *Soil Moisture Management*, and B-1610, *Soil Moisture Monitoring*.

Common mistakes

Growers need to avoid these common mistakes affecting water usage:

- **Waiting too long to put on the first irrigation.** The head begins to form about 35 days after planting. If the plant is stressed during this period, the number of seeds per head will be reduced.
- **Irrigating too late.** Do not irrigate after the hard dough stage. Also do not irrigate after the plants have reached physiological maturity, which is 45 days after flowering or at black layer. After that point, the individual seed's "umbilical cord" is sealed off and stops functioning. It will not gain any more weight after this event, which occurs at about 30 percent moisture.
- **Over-planting.** For irrigated production, do not exceed 70,000 to 80,000 established plants per acre; dryland production should not exceed 50,000 to 60,000 established plants per acre. Over-planting reduces head size, increases the chance of charcoal rot and lodging, increases plant competition, and increases water use with little increase in yield.

Proper irrigation management is critical for profitable yields. If you pay attention to timely and adequate irrigation, you can keep costs to a minimum while maximizing production.

Produced by Agricultural Communications, The Texas A&M University System
Extension publications can be found on the Web at: <http://tcebookstore.org>

Educational programs of Texas Cooperative Extension are open to all people without regard to race, color, sex, disability, religion, age or national origin.

Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Chester P. Fehlis, Director, Texas Cooperative Extension, The Texas A&M University System.

2.5M, New