EXTENSION

Understanding Grain Sorghum Irrigation Requirements in Oklahoma

March 2021

Jason Warren
Soil and Water Conservation Extension Specialist

Sumit Sharma
Irrigation and Water Management Specialist

Josh Lofton
Cropping System Extension Specialist

Introduction

Grain sorghum is generally believed to be a drought-tolerant crop that is well suited for rainfed systems in limited rainfall environments. While this is true, grain sorghum can respond to irrigation. Additionally, integrating grain sorghum into irrigated systems allows for reduced water demand from reservoirs under certain circumstances. For example, prior efforts presented in current report CR-2173, Economic Viability of Grain Sorghum and Corn as a Function of Irrigation Capacity demonstrate the economic advantages of grain sorghum over corn when irrigation capacities fall below 4.2 gallons per minute per acre (GPM/acre). This analysis showed the reduced costs of growing grain sorghum compensates for the lower yield, if the price of grain sorghum was within 6% of the corn price. Furthermore, Table 3 in CR-2173 shows the resiliency of grain sorghum to the adverse weather conditions of the region when adequate irrigation can be supplied. The production season of 2011 provides an example of this, when Texas County experienced a historic drought, with the Goodwell Mesonet location receiving only 3.25 inches between the typical planting and harvest windows (May 1 through Sept. 1). The average yield for corn in the hybrid performance trial was 85 bushels per acre in contrast to 166 bushels per acre for grain sorghum. These yields were achieved with 21 inches and 10 inches of irrigation, respectively.

Unfortunately, due to suppressed prices for grain sorghum and the yield gap between grain sorghum and corn in optimal conditions, sorghum is seldom considered for irrigation. However, as demonstrated above, if irrigation capacity is limited, grain sorghum prices are high and/or drought conditions are prevalent, then grain sorghum can be a viable alternative for irrigated cropping systems in Oklahoma. This fact sheet will provide estimates of irrigation requirements as well as recommendations for managing irrigated grain sorghum to optimize productivity and efficiency.

How Much Irrigation Capacity is Needed?

Irrigation capacity is an important factor when considering the irrigation of any crop because it dictates how much water can be supplied to a cropping system. For instance, a well capacity of 600 GPM can supply 864,000 gallons per day (600 GPM x 60 minutes/hour x 24 hours/day), which is equivalent to 31.8 acre-inches per day. If this water is supplied to a 60-acre pivot, the maximum application per day is 0.53 inches per acre (31.8 acre-inches per 60 acres). However, if it is supplied to a 120-acre pivot, it provides only 0.27 inches per day. To optimize crop performance, the irrigation capacity must be sufficient to replace the soil water deficient during peak ET, which begins at boot stage for grain sorghum, with a subsequent decline in ET after full flower. The question of how much irrigation capacity is needed is further complicated by rainfall patterns as well as the atmospheric water demand, which dictates the ET of grain sorghum. Both rainfall and irrigation must be considered in the stored water budget, but the amount stored is dictated by the soil water holding capacity, which is influenced by soil texture. A detailed discussion of soil water-holding capacity and irrigation thresholds can be found in fact sheet BAE-1537, Understanding Soil Water Content and Thresholds for Irrigation Management. The remainder of this fact sheet will provides a discussion of sorghum ET and soil water deficits at five locations and two planting dates to provide perspective on potential irrigation capacity needs as well as total irrigation water requirements for grain sorghum.

Grain Sorghum Evapotranspiration

Evapotranspiration varies greatly across the state of Oklahoma. This is exacerbated by traditional rainfall patterns, which generally decrease when moving from east to west across the state. Planting date and hybrid maturity also can influence evapotranspiration. Therefore, the irrigation planner on Mesonet has been utilized to simulate ET for grain sorghum for 10 years at four locations and two planting dates. Figure 1 shows the average daily potential ET for grain sorghum planted on June 5 at Altus, Goodwell, Blackwell, Woodward and Fort Cobb. Figure 2 shows the average daily potential ET for April 15 planting at these same locations. Goodwell was not included because soil temperatures are seldom sufficient for germination on this date. These two planting dates were selected because, on average, they result in flowering occurring before (April) and after (June) the hottest weeks of summer. The potential ET presented in these graphs is the amount of water sorghum could use under ideal management with no water stress (water stress will reduce ET and crop growth).

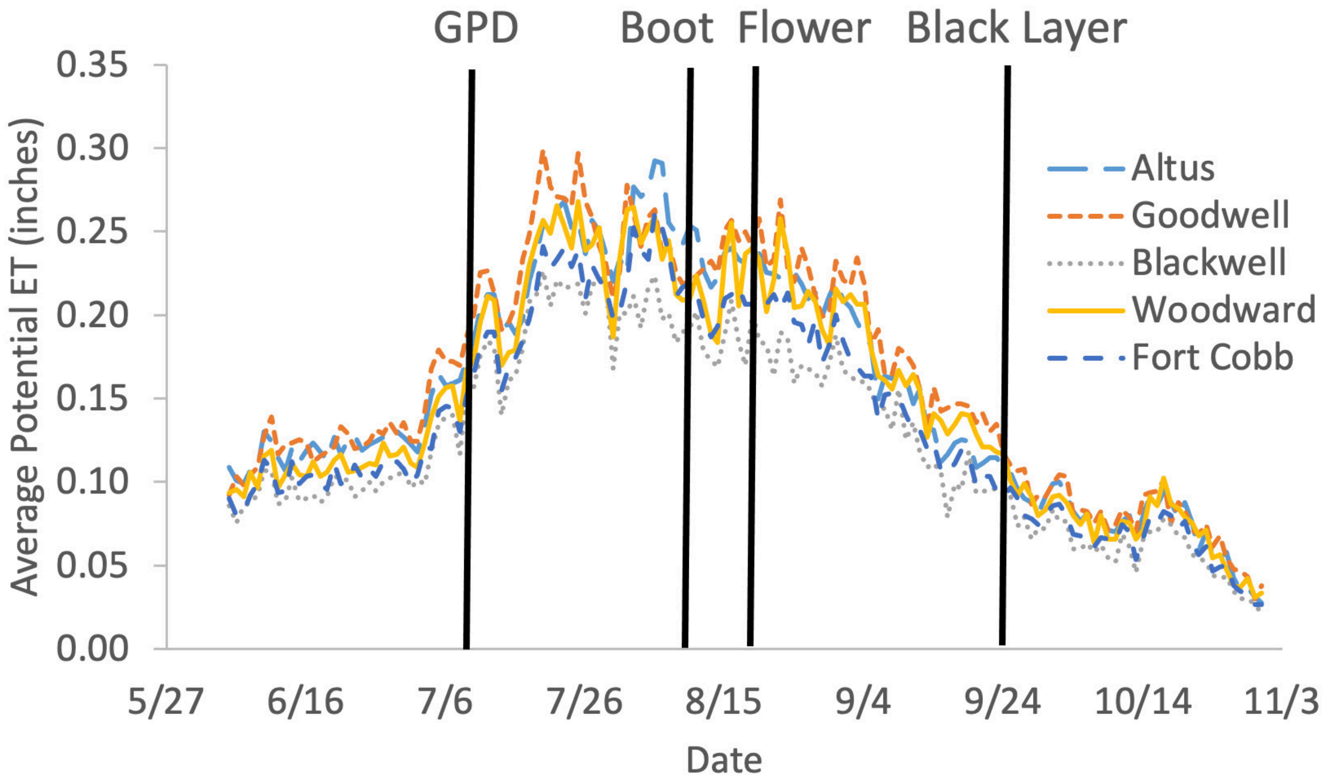

Figure 1. The 10-year average daily potential ET for Altus, Goodwell, Blackwell, Woodward and Fort Cobb when grain sorghum is planted June 5. The black lines show growing point differentiation (GPD), boot, flower and hard dough stages.

Figure 1 shows the ET prior to the growing point differentiation (GPD) ranges from 0.07 inches to 0.18 inches per day for grain sorghum planted in June. Also, peak ET occurs in July prior to boot stage and can be as high as 0.3 inches per day. As would be expected, Blackwell had the lowest ET, while Goodwell generally had the highest daily ET. Furthermore, as expected, the daily ET declines between boot and black layer. In Figure 2, the initial ET between planting on April 15 and GPD is generally lower as compared to a June planting. This is an important observation because most of the ET during the first 30 days to 45 days after planting is evaporation (E) from the soil surface. The high initial ET in June reflects a higher amount of unproductive E verses productive T. This is one reason why, when emergence can be achieved in April, improved irrigation water productivity (yield/inch of irrigation) can be achieved. As growth continues, ET increases to a peak as high as 0.33 inches per day at Altus and as low as 0.26 inches per day in Blackwell between GPD and flowering. In the April planting date scenario, daily ET declines is seen after flowering, despite the fact that the grain fill period occurs in July, which is typically associated with the highest atmospheric water demand due to high temperatures and low humidity. This occurs because after flowering, the crop canopy has a lower physiological demand for water, which offsets the greater atmospheric demand for water. The peak ET values in Figures 1 and 2 are important in understanding the potential irrigation capacity required to irrigate grain sorghum. Assuming no additional moisture is received through rainfall and soil moisture is depleted prior to peak ET, 700 gpm and 500 gpm, pumping capacity would be required to meet the peak ET in Goodwell and Blackwell, respectively. However, with proper management of soil profile moisture, these requirements for successful irrigation of grain sorghum can be dramatically lowered, especially if rainfall does occur.

Soil Water Deficit

A detailed assessment of average soil water deficits can provide more useful information than simply evaluating the average daily ET. The simplest analysis would be the difference between ET and rainfall during a growing season. Table 1 shows that planting in April actually increases potential ET as compared to June planting. However, the rainfall patterns associated with this earlier planting may decrease irrigation needs. This is especially true in Blackwell, where this data suggest that average seasonal rainfall is sufficient. It should be noted these simple averages do not account for the distribution of rainfall in the growing season, nor do they account for the variability from year to year. Nonetheless, they do suggest in loamy soils with substantial water-holding capacity, lower total irrigation requirements can be expected for April-planted grain sorghum at most locations, though a more detailed assessment is needed to validate this expectation.

Figures 3 and 4 shows the 10-year average cumulative rainfall and ET for April- and June-planted grain sorghum in Woodward, respectively. When the line representing rainfall is above the line representing ET, drainage can be expected, but when the rainfall line is below ET, a moisture deficit should be present. With April planting, a period of excessive to equal moisture can occur early in the season, but turns to a deficit following rapid water uptake associated with later growth stages. Less drainage is expected (based on Figure 4) with

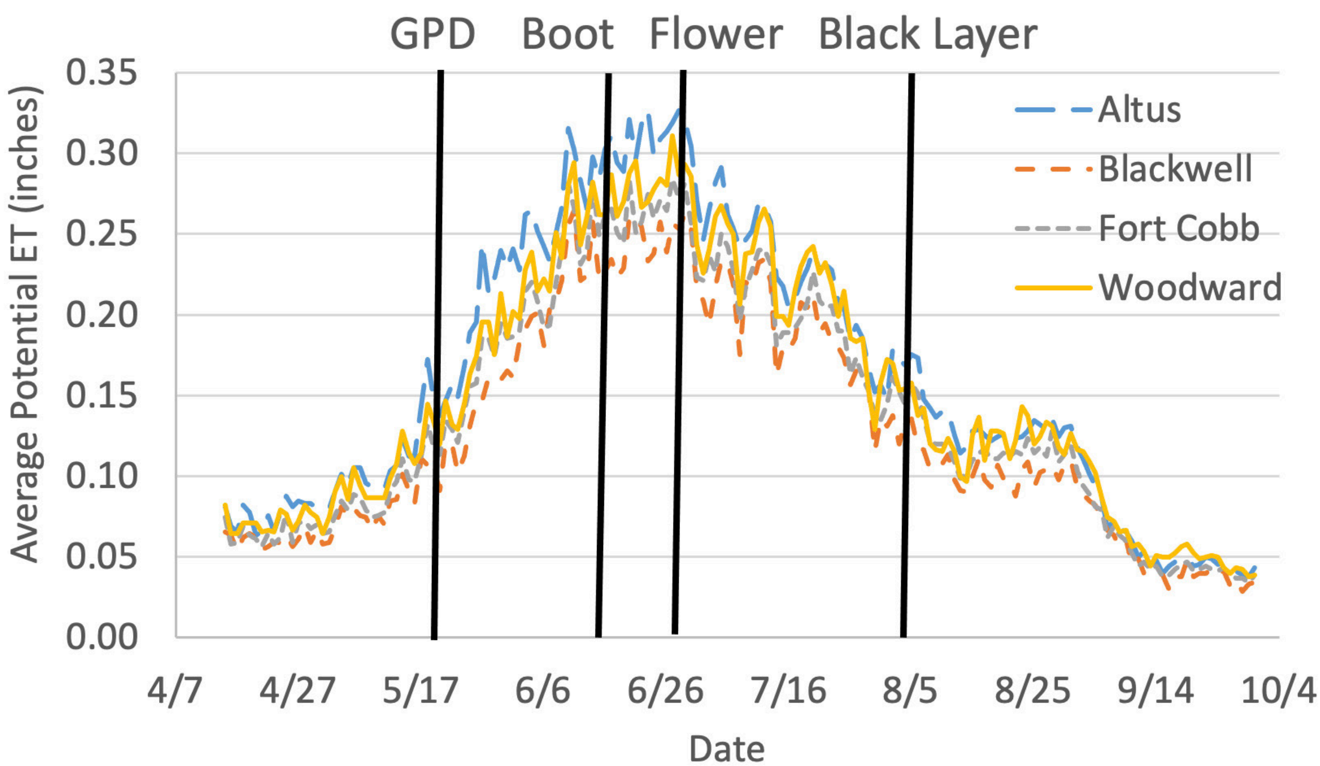

Figure 2. The 10-year average daily potential ET for Altus, Blackwell, Fort Cobb and Woodward when grain sorghum is planted on April 15. Goodwell was not included here because soil temperatures would not allow for germination with an April 15 planting. The black lines show growing point differentiation (GPD), boot, flower and hard dough stages.

June planting. Take the difference between the cumulative rain and ET, then subtract the drainage, the seasonal soil water budgets can be generated for each location and planting date. Figure 5 shows the soil water deficit for locations planted in April. The amounts of drainage were 1.8 inches, 4.9 inches, 5 inches and 1.1 inches for Altus, Blackwell, Fort Cobb and Woodward, respectively. Given a full profile at planting this calculated drainage would be lost from the profile. However, if the profile is not full at planting this drainage contributes to recharging the water content of the profile. Regardless, it is important to note this drainage when comparing the soil water deficits in Figures 5 and 6 to the simple differences between rainfall and ET presented in Table 1.

Table 1. The average cumulative potential ET and rainfall as determined from mesonet data between planting and black layer for grain sorghum planted on April 15th or June 5th. Goodwell is not included in April because soil temperatures would not allow for germination.

	April 15		*June 5*	
Location	*ET*	*Rain*	*ET*	*Rain*
		Inches		
Altus	22.1	11.9	20.4	9.5
Blackwell	17.6	17.1	16.7	13.1
Fort Cobb	19.1	15.7	18.1	11.3
Goodwell	NA	NA	21.3	8.2
Woodward	20.5	11.9	19.7	9.4

Figures 5 and 6 contain important information with regard to irrigation management. The average seasonal soil water deficit can be determined between planting and black layer (important for irrigated and rainfed systems). Also critical irrigation management information, such as potential first irrigation date and average irrigation demand during peak irrigation can be determined. The information is presented in Table 2, which shows that planting on June 5 reduces peak irrigation demand, but by no more than 0.03 inches per day at Altus, which is a difference of 70 gpm over a 125-acre pivot. Planting on June 5 reduced the average seasonal soil water deficit by as much as 1 inch at Blackwell, but resulted in an increase at Woodward of 0.9 inches. It is important to note this deficit should be viewed as the average maximum irrigation required because the soil can supply a significant portion of this water depending on its texture and the pre-season rainfall. These concepts are discussed in BAE-1537 Understanding Soil Water Content and Thresholds for Irrigation Management. Site-specific data can be found on the soils available water storage capacity at the NRCS Web Soil Survey website. Once the area of interest has been defined, select the 'Soil Data Explorer' tab and then 'Soil Properties and Qualities' tab.

The Importance of Stored Soil Water

Stored soil moisture is a very important component of any irrigation water budget and often the most challenging to

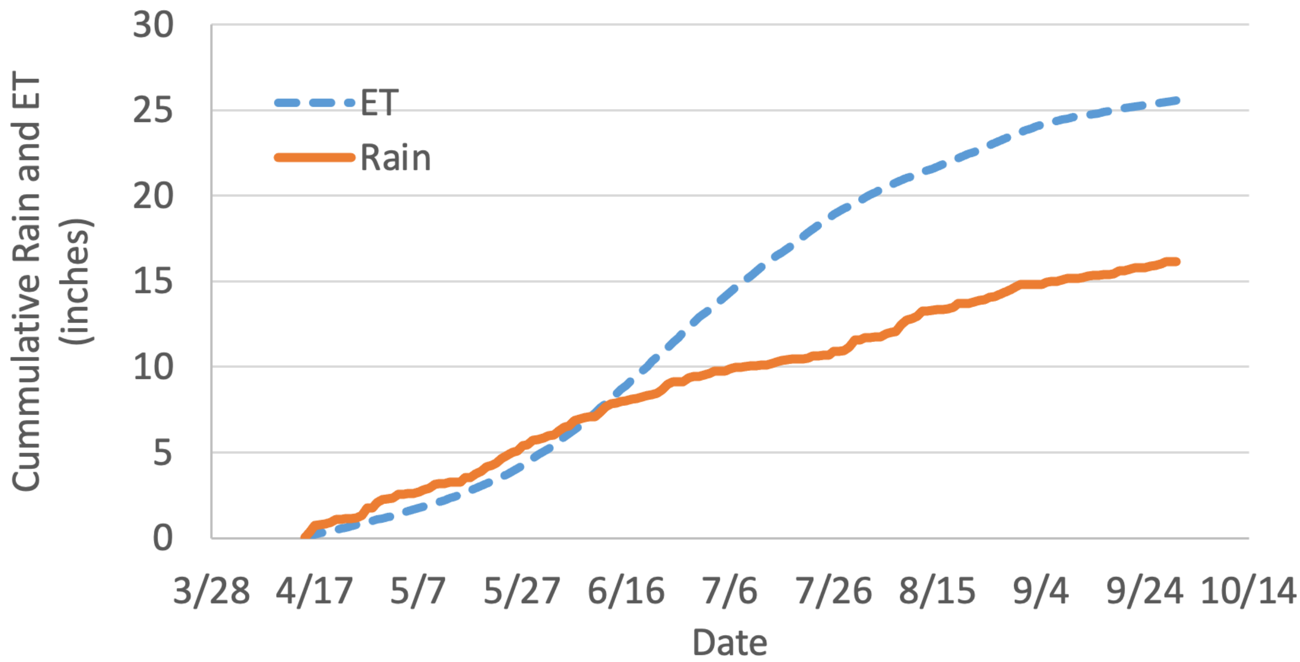

Figure 3. The 10-year average Cumulative Rainfall and ET for the grain sorghum growing season at Woodward when planted April 15.

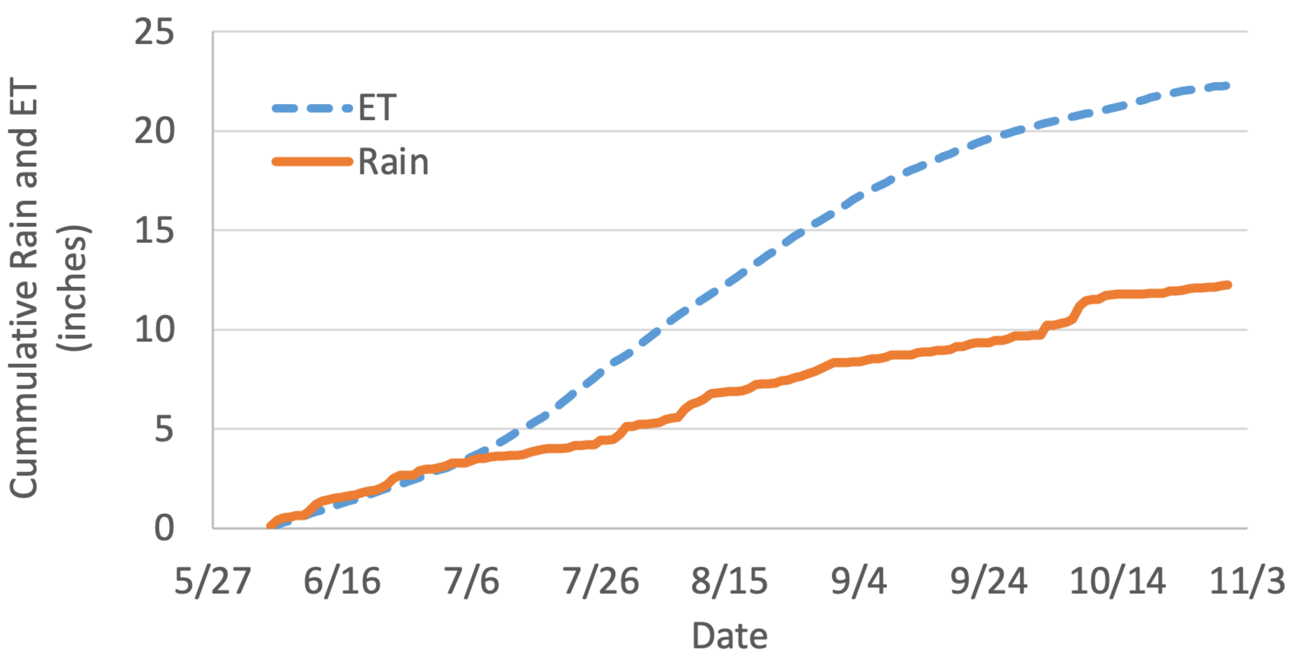

Figure 4. The 10-year average Cumulative Rainfall and ET for the grain sorghum growing season at Woodward when planted June 5.

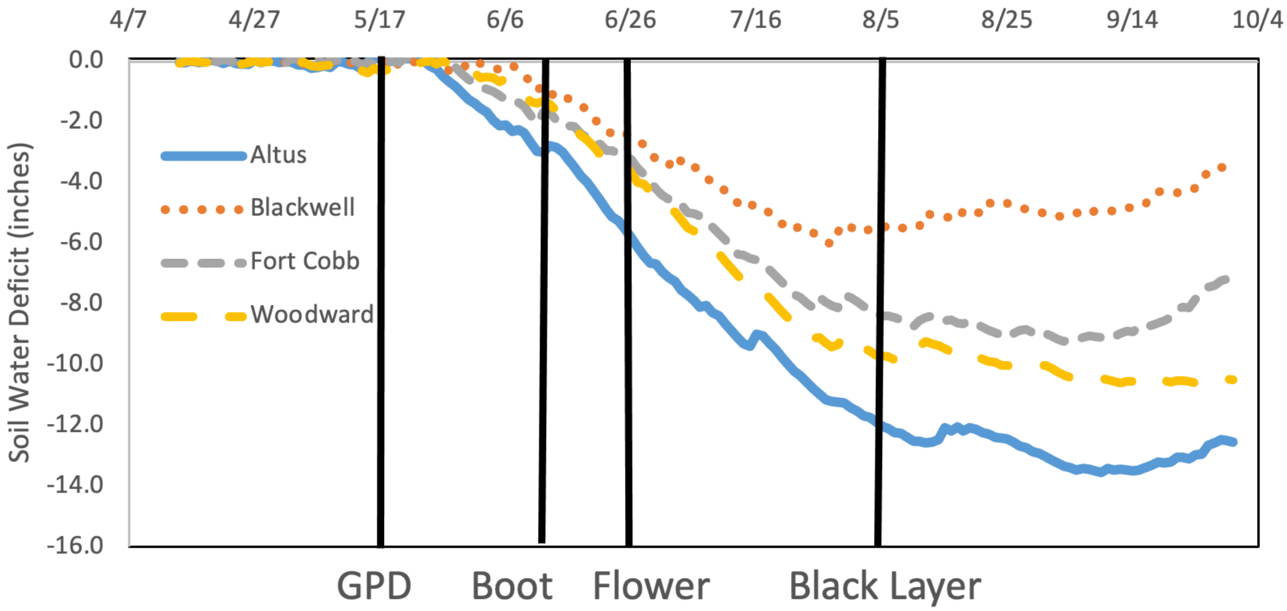

Figure 5. The average soil water deficit based on 10 years of rainfall and ET data for grain sorghum planted April 15 at Altus, Blackwell, Fort Cobb and Woodward.

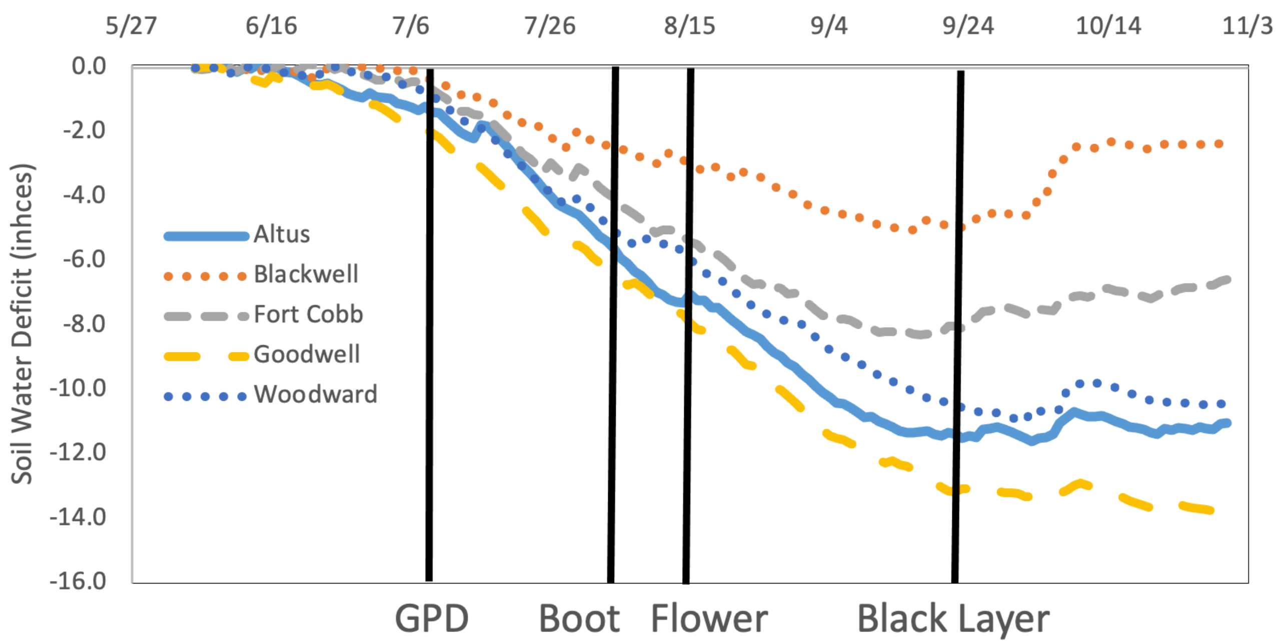

Figure 6. The average soil water deficit based on 10 years of rainfall and ET data for grain sorghum planted June 5 at Altus, Blackwell, Fort Cobb, Goodwell and Woodward.

Table 2. The average date when the soil water deficit first reaches 1 inch and irrigation initiation may be needed, the period of peak ET, peak irrigation demand and average soil water deficit between planting and black layer.

	April 15				*June 5*			
Location	*Initiation*	*Peak period*	*Peak irrigation inches/day*	*Soil deficit Inches*	*Initiation*	*Peak period*	*Peak irrigation inches/day*	*Soil deficit Inches*
Altus	5/30	6/16 to 6/30	0.26	12.0	7/3	7/16 to 7/30	0.23	11.4
Blackwell	6/11	6/16 to 6/30	0.13	5.9	7/18	7/16 to 7/30	0.12	4.9
Fort Cobb	6/4	6/24 to 7/7	0.17	8.4	7/11	7/16 to 7/30	0.16	8.3
Woodward	6/9	6/24 to 7/7	0.19	9.7	7/10	7/16 to 7/30	0.20	10.6
Goodwell					6/28	7/16 to 7/30	0.21	13.1

understand because of the spatial and temporal variability of a single field. This is why irrigation managers are encouraged to utilize soil moisture probes to monitor soil water. The contribution of stored soil water is evident when prior research on grain sorghum irrigation needs at Goodwell has been reviewed. Figure 7 shows the grain sorghum yield as a function of in-season irrigation applied over six site years using subsurface drip irrigation. When 9 inches or more irrigation is applied, the yields are more stable and range from 140 bushels per acre to 177 bushels per acre. When less than 9 inches is applied, the yields range from 92 bushels per acre to 162 bushels per acre. This data suggests that 9 inches of irrigation in combination with stored soil moisture (4 inches of allowable deficit) is sufficient to increase yield stability. The data also shows the year-to-year variability in response to irrigation is very high. Therefore, it is important to adjust irrigation applications based on in-season rainfall and ET estimates to optimize irrigation efficiency.

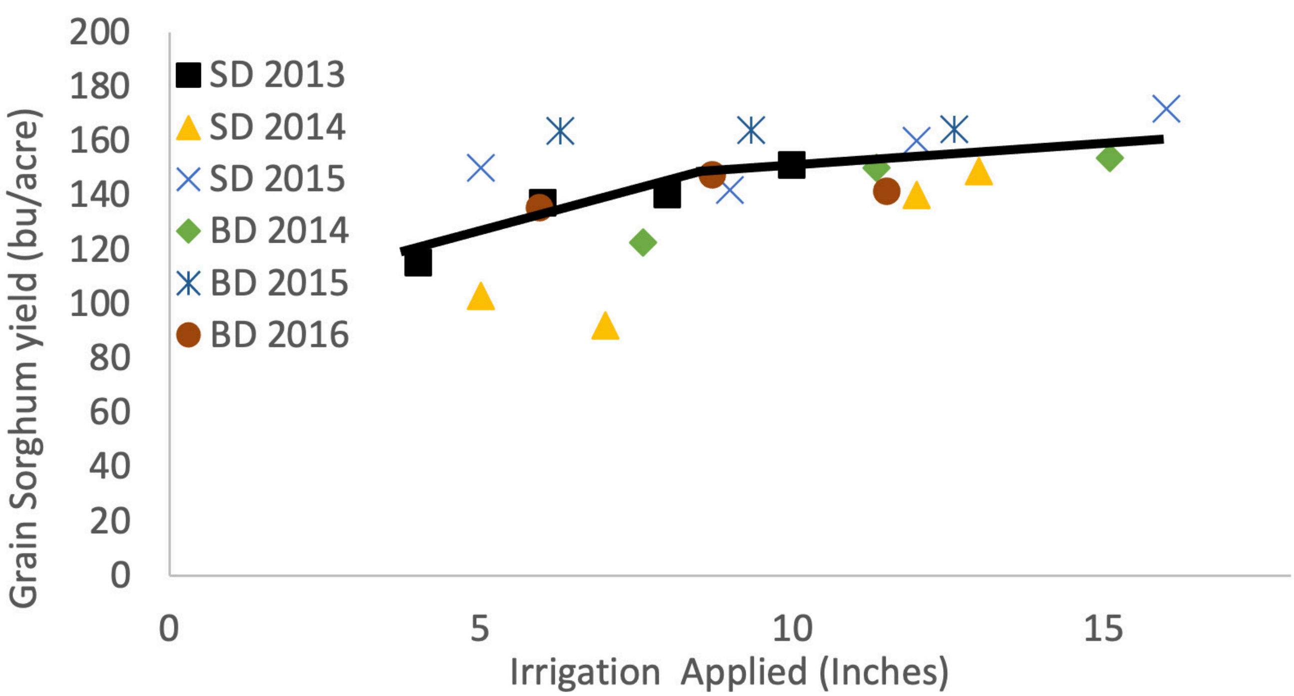

Figure 7. Grain sorghum yield response to irrigation rates applied in six site years using subsurface drip irrigation in Goodwell [SD, data from a study conducted on small SDI plots (100 feet by 10 feet) evaluating strategies to share limited water with corn; BD, data from a study conducted on large SDI plots (600 feet by 60 feet) to evaluate row orientation with only standard treatments presented].

Summary

Peak irrigation demand for grain sorghum, which determines irrigation capacity requirements, ranged from 0.12 inches to 0.26 inches per day in Blackwell and Altus, respectively. These are equivalent to 270 gpm and 590 gpm on 120 acres. A very limited impact of planting date on the irrigation water requirement was found. In general, the April-planted grain sorghum is expected to require higher capacity than the June-planted grain sorghum. This is because the June-planted crop closes canopy after the period of peak atmospheric water demand in late June/early July.

Despite similarities in the irrigation requirements between April and June planting, it is recommended to plant in April when time and soil temperatures permit. April planting gives better opportunity to take advantage of the spring rainfall, which reduces likelihood of summer drought, which causes adverse growing conditions. It is important to remember the values presented in this fact sheet are average values. In lower rainfall years or years with high ET demand, one must expect to depend more on stored soil moisture if irrigation capacities are below those presented in Table 2. If water stress is experienced, it is better for it to occur after flowering versus boot stage. Notice with April planting, peak ET occurs after boot stage at each location and with June planting, the peak ET period is prior to boot stage. Therefore, if irrigation is not sufficient to replace daily ET, the June planting is less resilient to low rainfall conditions because it would have a higher likelihood of depleting the profile to below the allowable deficit before the completion of the flowering stage. Furthermore, early planting reduces the likelihood of crop damage due to late-season pests and allows for more rapid dry down before the onset of fall weather.

The Oklahoma Cooperative Extension Service

WE ARE OKLAHOMA

The Cooperative Extension Service is the largest, most successful informal educational organization in the world. It is a nationwide system funded and guided by a partnership of federal, state, and local governments that delivers information to help people help themselves through the land-grant university system.

Extension carries out programs in the broad categories of agriculture, natural resources and environment; family and consumer sciences; 4-H and other youth; and community resource development. Extension staff members live and work among the people they serve to help stimulate and educate Americans to plan ahead and cope with their problems.

Some characteristics of the Cooperative Extension system are:

- The federal, state, and local governments cooperatively share in its financial support and program direction.
- It is administered by the land-grant university as designated by the state legislature through an Extension director.
- Extension programs are nonpolitical, objective, and research-based information.
- It provides practical, problem-oriented education for people of all ages. It is designated to take the knowledge of the university to those persons who do not or cannot participate in the formal classroom instruction of the university.
- It utilizes research from university, government, and other sources to help people make their own decisions.
- More than a million volunteers help multiply the impact of the Extension professional staff.
- It dispenses no funds to the public.
- It is not a regulatory agency, but it does inform people of regulations and of their options in meeting them.
- Local programs are developed and carried out in full recognition of national problems and goals.
- The Extension staff educates people through personal contacts, meetings, demonstrations, and the mass media.
- Extension has the built-in flexibility to adjust its programs and subject matter to meet new needs. Activities shift from year to year as citizen groups and Extension workers close to the problems advise changes.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Director of Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. This publication is printed and issued by Oklahoma State University as authorized by the Vice President for Agricultural Programs and has been prepared and distributed at a cost of 20 cents per copy. 03/2021 GH.