Response of Irrigated Grain Sorghum to Planting Date and Density

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Introduction

Depletion of groundwater resources threatens irrigated agriculture in the Central and Southern High Plains of the Ogallala Aquifer region. In particular, the Texas and Oklahoma Panhandles are exhibiting considerable declines in groundwater levels and well capacities. The rate of depletion is usually considerably faster during drought periods, which are common in this region. In the Oklahoma Panhandle, for example, the rate of groundwater decline was 2.75 times larger during the drought of 2011-2015 compared to non-drought years (Khand et al., 2017). Under these conditions, grain sorghum becomes a more viable irrigated crop in this region since it is relatively drought tolerant and well suited to water-limited environments (Araya et al., 2018; Masasi et al., 2019). In addition, grain sorghum has comparable economic and nutrition values to corn (Warren et al., 2017). However, a major challenge to managing irrigated grain sorghum is optimizing the planting date and planting density to achieve maximum and stable yields (Baumhardt et al., 2006) and to maximize production economics (Conley & Wiebold, 2003). This factsheet provides the results of a simulation study that evaluated the response of grain sorghum yield to planting date and density in the Oklahoma Panhandle.

Methods

The study utilized the AquaCrop model (Steduto et al., 2012), which simulates crop water use, soil moisture, biomass, and yield in response to variable weather, soil, water, and field conditions. The model was first calibrated and validated using seven years of experimental data consisting of full and limited irrigated treatments that were collected at two sites: 1) the US Department of Agriculture, Agricultural Research Service Conservation and Production Research Laboratory near Bushland, TX; and 2) the Oklahoma Panhandle Research and Extension Center near Goodwell, OK (Masasi et al., 2019). Figure 1 shows a sorghum plot at the second site in Oklahoma Panhandle.

Figure 1. Experimental sorghum plot near Goodwell, Oklahoma.

The calibrated model was used to estimate the yield and irrigation requirement of nine different sorghum management strategies for the 21 years from 1997 to 2017. The nine management strategies comprised all combinations of three planting dates and three planting densities, as presented in Table 1. A late maturing sorghum hybrid (>70 days to mid-bloom) was selected for the strategies comprising the two earlier planting dates to ensure adequate time for grain maturity. In contrast, an early maturing hybrid (<60 days to mid-bloom) was used for strategies with the latest planting date. The model estimated the irrigation requirements by assuming enough water was applied in each irrigation to replace crop water consumption and to avoid any water stress (full irrigation).

Table 1. Simulated management strategies for grain sorghum

Strategy	Planting Date	Planting Density (seeds/acre)
1	May 25	55,000
2	June 10	
3	June 25	
4	May 25	65,000
5	June 10	
6	June 25	
7	May 25	75,000
8	June 10	
9	June 25	

Results

The AquaCrop model accurately simulated soil moisture in the root zone, crop water use (evapotranspiration), and grain yield compared to field measured values. As an example, Figure 2 shows the time series of the measured and simulated soil moisture under full and limited irrigation for the study site in TX. The simulated soil moisture generally followed the trend of the measured values throughout the growing season, with minimum and acceptable deviations. The average deviations between the measured and simulated values were zero and -0.08 in/ft for the full and limited irrigation treatments, respectively. The horizontal dashed lines represent the two moisture limits of field capacity (FC) and wilting point (WP), critical thresholds for optimizing irrigation management. For more information on these limits, please see the fact sheet by Datta et al. (2017).

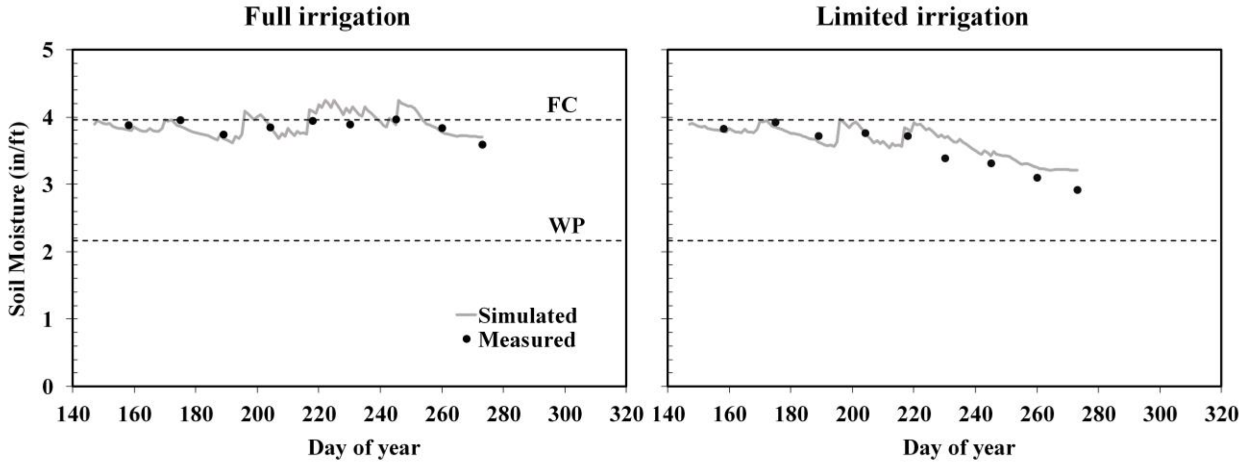

Figure 2. Time series of simulated and measured soil moisture in units of an inch of water per foot of soil.

Grain yield predictions by the AquaCrop model were close to the measured values, as shown in Figure 3. The yield estimates were fairly close to measured values over a wide range, spanning from about 80 to 160 bushels per acre (bu/acre). These findings indicated the model's adequacy for simulating sorghum's response to variable irrigation levels. Additionally, these results showed the model's potential to be used as a tool to study the impact of management practices on sorghum for making timely recommendations to producers.

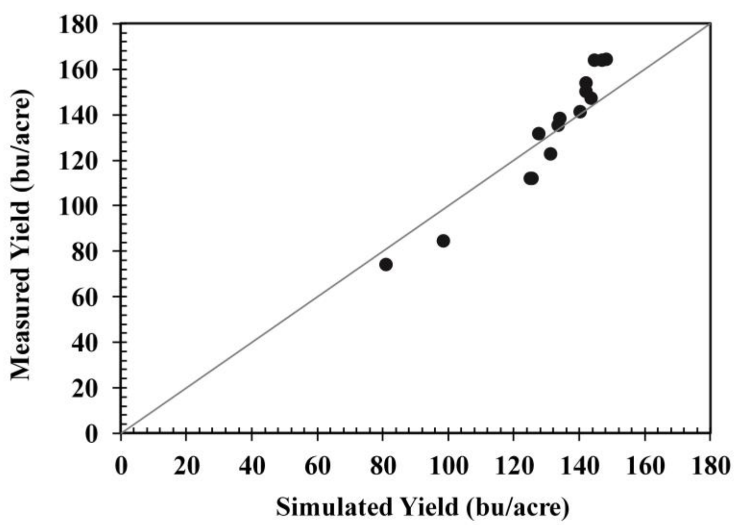

Figure 3. Measured vs. simulated grain yield of sorghum.

The results from running the calibrated model over 21 years (1997-2017) showed the year-to-year variability of grain yields for each strategy. The yield variability was mainly caused by differences in growing season weather conditions, particularly temperature and rainfall. Temperature affects the accumulated heat units, which ultimately determines the crop development and grain production processes, including the timing and length of each growth stage for grain sorghum. Cooler temperatures early in the growing season may delay germination, especially for earlier planting dates. Cooler temperatures late in the growing season may limit the required accumulated heat units for the later planting dates and could also suppress grain yield. This information highlights the importance of selecting appropriate maturity groups of sorghum hybrids to optimize yield based on the planting date and the potential growing season conditions.

Figure 4 shows simulated grain yield for the lowest (left plot) and highest (right plot) planting densities. Under each planting density, the yields are graphed for the earliest (black line) and latest (gray line) planting dates. The May 25 planting date always yielded higher than the June 25, although the magnitude of differences changed from year to year. Also, the analysis showed no benefit from the higher seeding rate.

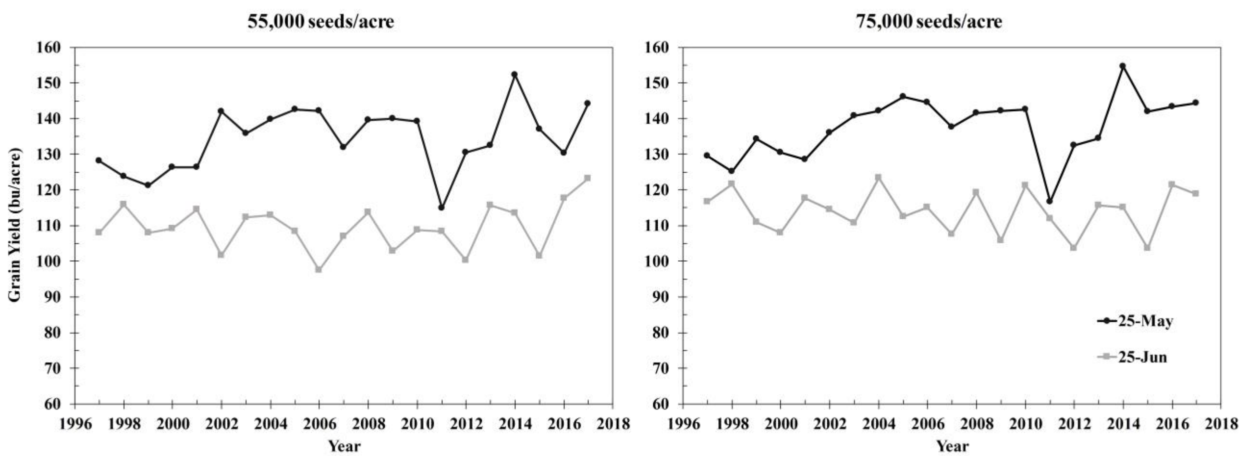

Figure 4. Time series of grain yield throughout the 21-year study period.

The simulated irrigation requirements were mainly influenced by the planting date, timing, and amount of rainfall received during the growing season. The earliest planting date always had a larger irrigation requirement (Figure 5). In addition, larger irrigation amounts were needed for growing seasons that received smaller amounts of rainfall. Under the highest planting density (75,000 seeds/acre), for example, the seasonal irrigation demands were 23.6 and 13.1 inches in 2012 and 2015, respectively. This 10-inch difference indicates the great opportunity for conserving irrigation water in seasons with adequate and timely rainfall if precision irrigation approaches are implemented. These findings also demonstrate the need to incorporate weather forecasts in irrigation management of grain sorghum in the Oklahoma Panhandle due to the high variability of growing season rainfall.

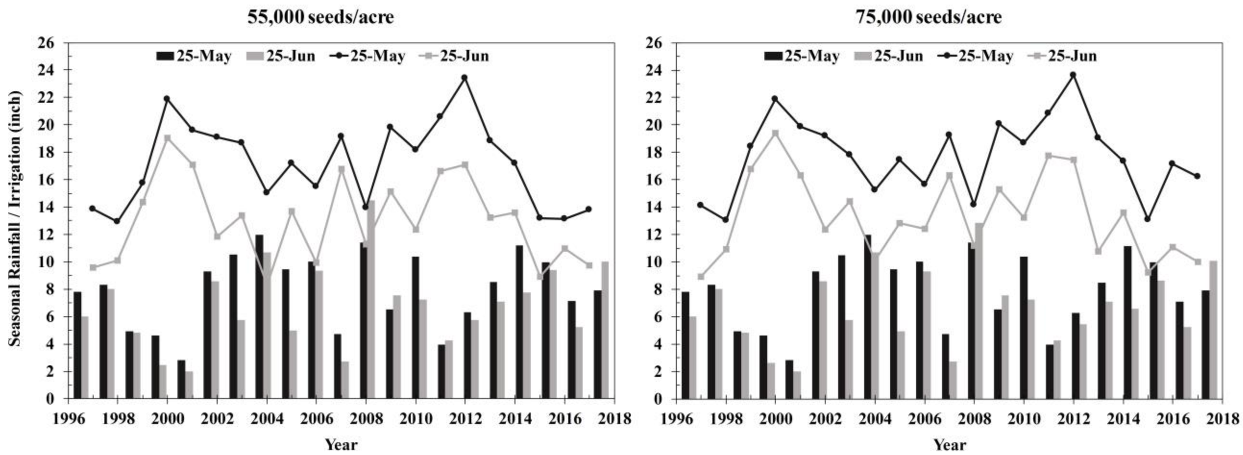

Figure 5. Seasonal irrigation requirement (lines) and rainfall (bars) throughout the 21 years.

When model estimates were averaged over the entire 21-year period, yields were 136, 123, and 112 bu/acre for the May 25, June 10, and June 25 planting dates, respectively. Average seasonal irrigation requirements for the May 25, June 10, and June 25 planting dates were 18, 16, and 13 inches, respectively. As explained before, the model made irrigation decisions to replace the full crop water use and avoid water stress. The decrease in seasonal irrigation requirement with later planting pointed to the shortened growing season due to the cooler weather conditions that usually occur late in the season in the Oklahoma Panhandle. On the other hand, the planting density in the range of 55,000 to 75,000 seeds/acre caused no significant impact on the overall grain yield and seasonal irrigation requirement estimated. These findings suggested that no significant grain yield and water savings could be achieved by considering planting densities between 55,000 and 75,000 seeds/acre. However, producers may cut the seed cost by adopting the 55,000 seeds/acre planting density.

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