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Grain Sorghum Response to Water Supply and Environment

Abstract

Three grain sorghum hybrids were selected to compare under different water supply scenarios across Kansas. The environments ranged from dryland in western Kansas to dryland and irrigated in central and eastern Kansas. The three hybrids that were selected represent different sorghum genotypes used commercially. Looking at two situations from higher and lower yielding environments, hybrids 1 and 3 had different strategies to attain final yields. In the higher yielding environment, both grain harvest index (HI, expressed as the dry weight ratio of grain yield to plant biomass at maturity) and biomass were maximized for hybrid 1 and hybrid 2. In the lower yielding environment, their yields were similar, but hybrid 1 produced less biomass and had a greater HI. Hybrid 3 exhibited the opposite scenario in that environment: greater biomass production and smaller HI. Following these outcomes, grain sorghum hybrids use multiple strategies to produce grain yield in each environment. In high yielding environments though, plants need to maximize both biomass and efficiency in partitioning to grain.

Keywords

grain sorghum, yield, genotypes, environments

Authors

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Summary
Three grain sorghum hybrids were selected to compare under different water supply scenarios across Kansas. The environments ranged from dryland in western Kansas to dryland and irrigated in central and eastern Kansas. The three hybrids that were selected represent different sorghum genotypes used commercially. Looking at two situations from higher and lower yielding environments, hybrids 1 and 3 had different strategies to attain final yields. In the higher yielding environment, both grain harvest index (HI, expressed as the dry weight ratio of grain yield to plant biomass at maturity) and biomass were maximized for hybrid 1 and hybrid 2. In the lower yielding environment, their yields were similar, but hybrid 1 produced less biomass and had a greater HI. Hybrid 3 exhibited the opposite scenario in that environment: greater biomass production and smaller HI. Following these outcomes, grain sorghum hybrids use multiple strategies to produce grain yield in each environment. In high yielding environments though, plants need to maximize both biomass and efficiency in partitioning to grain.

Introduction
Due to decreases in available irrigation water and an increase in water restrictions, the question arises whether there is a more economical way to use available irrigation water. Corn has a better yield potential in higher yielding environments, but sorghum genetic yield increase has been slower. In low-yielding environments, <100 bu/a, grain sorghum presents a yield advantage over corn due to having a greater tolerance to drought (Staggenborg et al., 2008). Economics behind deciding to plant corn or sorghum will vary from year to year based on commodity prices and input costs, but sorghum can present economic advantages since it typically has lower input costs. Kansas is the largest producer of sorghum in the United States. According to the 2015 U.S. Department of Agriculture report ("Crop Production 2015 Summary," 2016), 3.2 million acres of sorghum were harvested for grain in Kansas with an average of 88 bushels per acre. United States had a total of 7.85 million acres, which means that Kansas planted roughly 40% of the total U.S. acres.

Information on how sorghum responds to different environments and water inputs (both rainfall and irrigation) is needed. Further research should be conducted to see how genetic variability (represented by commercial hybrids) can react to the water input and to explore the main physiological mechanisms underpinning yield formation for this crop.

Procedures

Sorghum was planted under nine different environments across the state of Kansas by location and irrigation level (Tribune, Garden City, Scandia, Hutchinson, and Topeka). Tribune and Garden City sites were grown without irrigation ("dryland" sites), while Scandia and Topeka included one experiment under dryland and a replicated experiment under full-irrigation conditions. At the Hutchinson site, three research trials were tested under diverse irrigation strategies: fully irrigated, 50% irrigated, and dryland. Full irrigation was based on KanSched to replenish the evapotranspiration by the crop at all sites. The water scenarios tested in different locations were not replicated; thus each water scenario is treated as a separate study and comparisons between them within each site cannot be performed.

At all sites, three different hybrids were planted in a completely randomized block design (RCB), with 4 to 6 replications per sorghum hybrid evaluated (depending on the site). The three hybrids were chosen for each site based on previous knowledge of their likelihood of reacting differently to the environment. Pioneer 85Y40 was selected for Hybrid 1 and was substituted with Pioneer 87P06 in the Tribune and Garden City sites. Pioneer 84G62 was selected as Hybrid 2, and DeKalb 53-67 was selected for Hybrid 3.

Nutrients were applied at each site to be non-limiting. Seeding rates were set for each scenario to try to optimize the yield for the environment and were based on a feasible yield goal for the environment. Sorghum was planted in 30 inch row spacing with four rows in each plot to make each plot 10 feet wide by anywhere from 30 to 45 feet long (depending on the site).

Between growth stages 1 and 2 (3rd and 5th leaf collar visible, respectively), stand counts were performed at each site. At the end of the growing season when plants had reached physiological maturity, 10 plants were taken from each plot to determine the grain HI and to estimate total above ground biomass (root excluded). Grain HI was calculated as dry weight ratio of grain yield to total above ground biomass (both adjusted to 0% moisture). Total biomass was presented in dry basis (adjusted to 0% moisture). The middle two rows of each plot were harvested to estimate grain yield. Harvested area was 150 to 225 square feet (depending on the site). All grain yields were adjusted to 13% moisture.

Results

Due to the rainfall throughout the growing season (Figure 1), individual hybrid yields for grain sorghum ranged from the low of 124 bushels per acre to the high of 169 bushels per acre. The lowest average yield for all hybrids for a site was documented in the dryland treatment at the Hutchinson site with 126 bushels per acre, and the highest average yield for all hybrids was observed under dryland at Topeka with 163 bushels per acre. The Topeka site had considerable bird damage, but no significant difference was noticed between hybrids for yield reduction. The yields in all environments were higher than the suggested threshold mentioned earlier due to timely rains and/or higher seasonal precipitation than average. Cumulative seasonal precipitation during the growing season from planting until physiological maturity is presented in Figure 1. Hutchinson had a period of dryer weather immediately before flowering at the end of July. This would be the most likely reason why average yields in dryland were the lowest out of all sites.

The highest-yielding hybrids attained this yield level via improvement of both total biomass (Figure 4) and efficiency in partitioning to the grain (high grain HI) (Figure 3). In one of the lower yielding environments where the yields of all hybrids were similar, hybrid 1 had a lower total biomass with higher grain HI. Hybrid 3 had a greater total biomass but with a lower grain HI.

Summarizing all data collected from two years of field research, individual hybrid yield by treatment were regressed against the mean for each environment (site-water supply) in order to identify how hybrids respond under contrasting yielding environments (Figure 5). Hybrids 1 and 2 tended to yield better in high-yielding environments (>140 bu/acre) relative to hybrid 2 (Figure 5). The opposite is true at low yielding environments (<120 bu/acre), with hybrid 3 out yielding hybrids 1 and 2.

Looking at the high- and low-yielding environment extremes, the hybrids had different strategies to attain final yield. In the higher yielding environment, both grain HI and biomass were maximized for hybrid 1 and 2. In the lower yielding environment, their yields were similar, but hybrid 1 produced less biomass and had a greater harvest index. The opposite scenario resulted for hybrid 3: greater biomass production with lower HI. Following these outcomes, it seems that there are multiple strategies for grain sorghum hybrids to achieve the target yield in each environment. In high yielding environments, though, plants need to maximize both biomass and harvest index. This study also shows the need for more research in sorghum to increase yields and to better understand how to create more efficient hybrids in both stressed environments and non-stressed environments.

References

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Table 1. Phenological data from the different sites and seeding rate

Phenological data	KRV Topeka	NCK Scandia	SCK Hutchinson	SWK Tribune	SWK Garden City
Planting date	5/19/2015	5/19/2015	6/8/2015	6/2/2015	6/19/2015
Emergence	6/3/2015	6/5/2015	6/16/2015	N/A [£]	N/A [£]
Seeding rate	60,000 Dry[#] 90,000 Irr[&]	50,000 Dry 90,000 Irr	45,000 Dry 67,500 50% 90,000 Irr	40,000 Dry	40,000 Dry
Anthesis	7/27/2015	8/3/2015	8/6/2015	Na	Na
Physiological maturity	9/30/2015	10/26/2015	10/12/2015	Na	Na
Harvest date	9/30/2015	11/24/2015	10/21/2015	10/17/2015	11/4/2015

[#] Dryland.
[&] Irrigated.
[£] Not available.

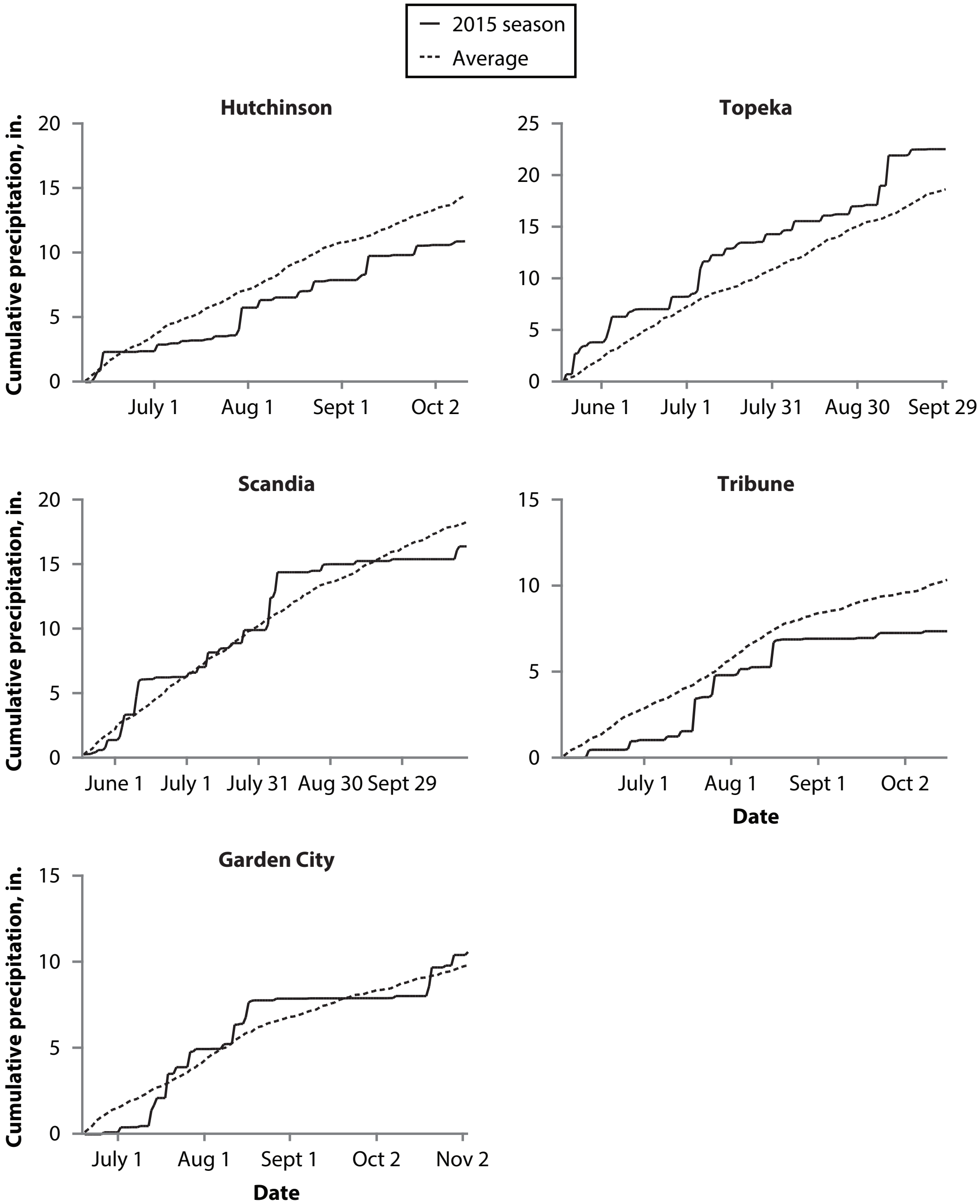

Figure 1. A comparison of cumulative precipitation during the 2015 season and the long-term 30-year average precipitation.

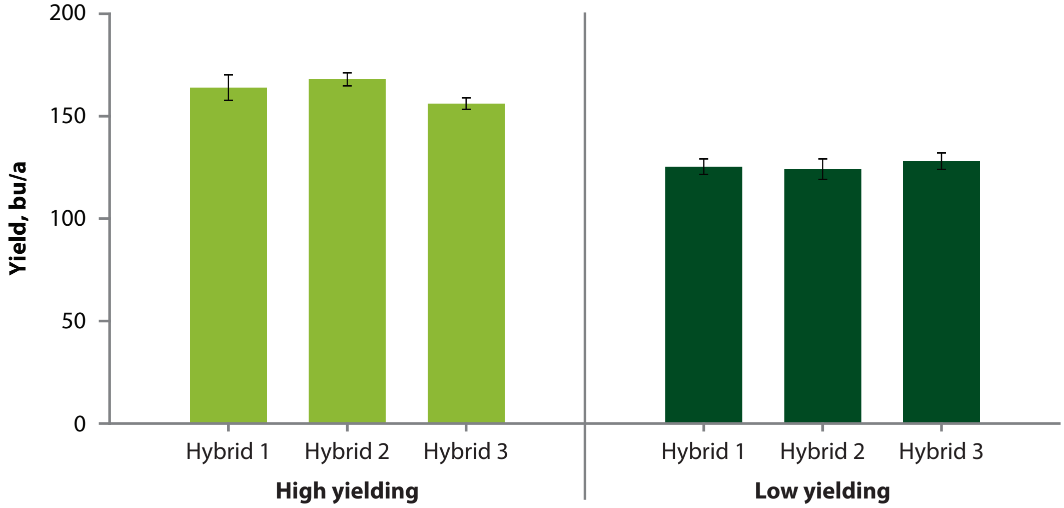

Figure 2. Yields for the high (Topeka) and low (Hutchinson) yielding environments (adjusted to 13% moisture) in 2015.

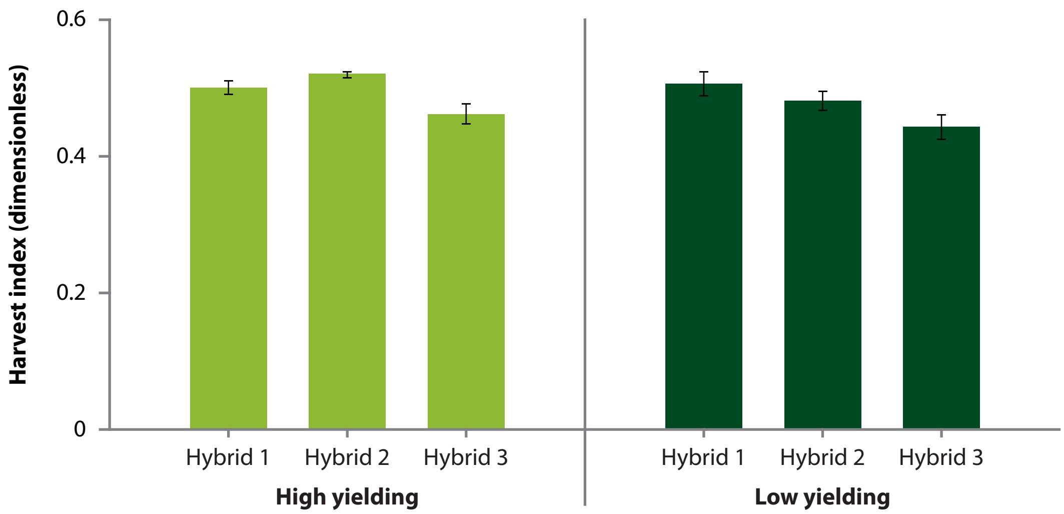

Figure 3. Grain harvest index (dry weight ratio of the grain yield to the total biomass) in 2015.

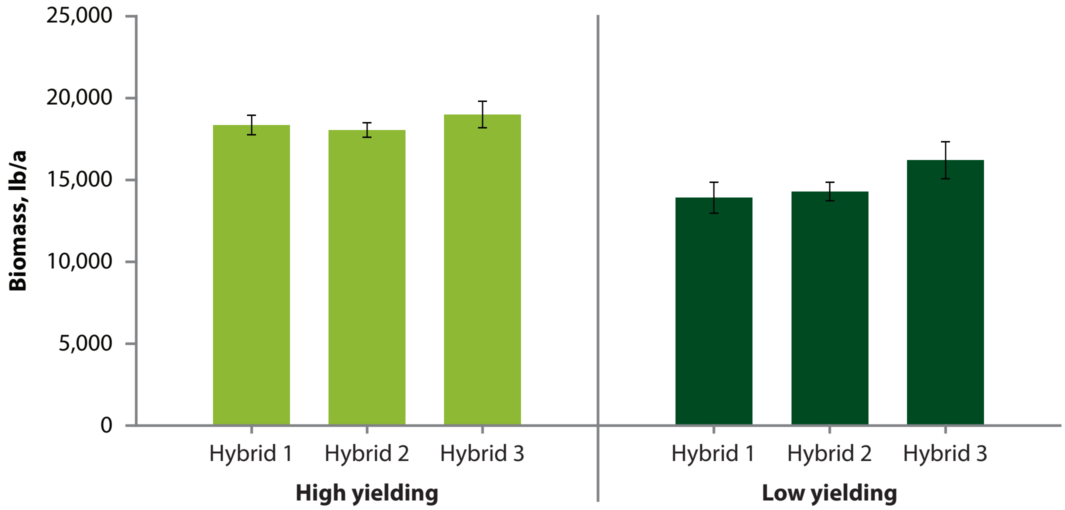

Figure 4. Total aboveground dry weight biomass in 2015.

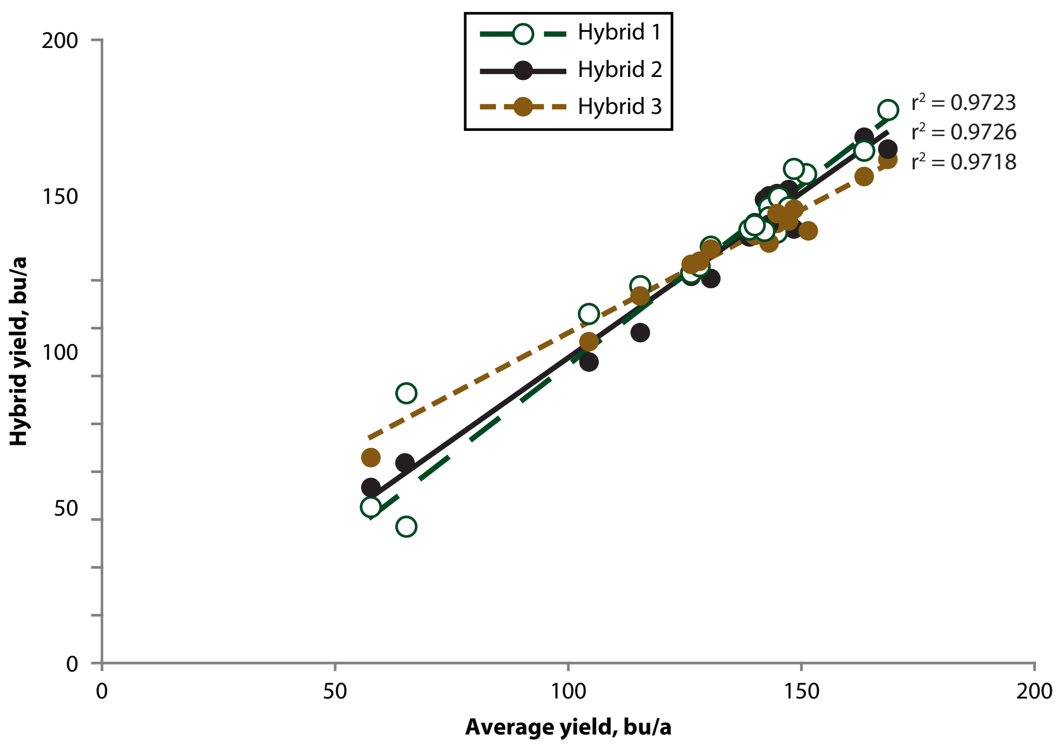

Figure 5. Hybrid yield in each environment compared to the average yield (of all three hybrids) in each environment.