Texas Corn Producers Board
Final 2017 Progress Report

Title: Corn hybrid and population effects on grain yield losses during the early reproductive growth stage

Principal Investigator: Jourdan Bell, Assistant Professor, Agronomist, Texas A&M AgriLife, Amarillo
Co-Principal Investigators(s): Robert Schwartz, Research Soil Scientist, USDA-ARS, Bushland, TX

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Research Rationale and Value

In the Texas Panhandle, peak irrigation requirements for corn typically coincides with the critical reproductive phases from fertilization through early kernel development. For "average" weather conditions in Bushland, TX, irrigation required by corn during this period (in addition to that supplied by rainfall and available stored water) is 0.22 inches/day (4.1 gpm/acre) although peak irrigation requirements can be as high as 0.40 inches/day (7.9 gpm/acre). Failure to meet the water requirements of corn during fertilization and early kernel development is likely the predominant abiotic factor responsible for sub-optimal grain yield and water use efficiencies of corn in the region. Assessing the magnitude of these yield reductions is the first step in evaluating corn production risks and making informed production decisions on planted acreage. Water stress during the V12 through R2 stages can reduce yield potential primarily through asynchrony in fertilization (esp. reduced silk elongation rate) and abortion of the fertilized ovule both of which reduce kernel set. Recently developed cultivars exhibit some drought tolerance through a shortened anthesis to silking interval and rooting morphologies that can extract a greater proportion of soil water. Quantification of how hybrids with these traits respond to water stress and influence crop water use, water use efficiency, kernel set and other yield components are important considerations for irrigation management that have not been fully evaluated under Texas Panhandle growing conditions. The 2017 report includes final combine yield and crop water use data. The report supplements the 2016 final report. Multi-year datasets will be compiled for delivery at Extension programs and publication.

Methods

Field plots were established under a lateral-move irrigation sprinkler at the USDA-ARS Conservation and Production Research Laboratory in Bushland, TX (35°11'N, 102°5'W; 3861 feet elevation). Experimental plots were established on Pullman clay loam (Fine, mixed, superactive, thermic Torrertic Paleustoll) with < 1% slope in a split plot design with irrigation level on main plots and cultivar × population on subplots within a randomized complete block design. Plots were planted on May 7, 2016 under conventional tillage with Bicep II as a pre-plant herbicide (Atrazine + Metolachlor). Three corn hybrids (DKC 62-27 DGVT2PRO, DKC62-98 VT2PRO and P1151HR) were planted at 26,000 and 36,000 plants/acre. Plot dimensions were 6-30 inch rows by 100 feet with three replications. Experimental plots were sampled and analyzed for fertility requirements in April for a yield goal of 250 bu/ac yield goal; 10-25-0-3 was applied at planting at a rate of 30 lbs P2O5/ac and 24 lbs N/ac., and 26 lbs of N was supplemented with 32-0-0. Subsequent nitrogen applications were planned through the sprinkler in increments of 50 lbs N/ac at V3, V6, V9, V12 and R1. However during the 2017 season, only 100 lbs N/ac were applied (at V3 and V5) in addition to the preplant N because of considerable rainfall received later in the season that precluded irrigation.

Following the initial June progress report, corn conditions quickly deteriorated due to herbicide drift (Figs. 1 and 2). Herbicide symptoms included thickened roots, clubbing brace roots, poor secondary root with bottle brushed roots and purpling tissue. It was determined that herbicide damage resulted from drift with a metsulfuron herbicide applied for fallow weed control in a neighboring field. Because of significant plant damage and plot variability, all plots were terminated on June 16. Plots were replanted on June 19, 2017. To establish plots, coulters were used to move top-soil away from the furrow and seeds were planted at 2" deep so that seeding would be below the herbicide layer. Due to elevated temperatures, all plots/treatments were irrigated after planting to ensure uniform emergence (Figs. 3 and 4). Germination was uniform and irrigation treatments were imposed. On July 2, corn plants were severely shredded by hail when corn was V2-V3. Because damage was uniform, and the corn was in an early stage of vegetational development, plots were maintained. Although plants recovered, and the growing point was not affected, there were noticeable differences in stands following the hail storm. As a result of replanting, the critical stages from V12 to R2 were shifted later in the 2017 growing season.

Figures 1 and 2. Herbicide damage in May 7 planted corn.

Imposed irrigation treatments were 1 inch/3 day (fully irrigated; FI) equivalent to 3.14 gal/min per acre, and 1 inch/6 day (deficit irrigated; DI) equivalent to 6.28 gal/min per acre. Irrigation was applied with a three-span, lateral-move sprinkler system (Model 6000, Valmont Irrigation, Valley, NE). Drop hoses, spaced 4.95-ft. apart, were equipped with No. 14 low drift nozzles (0.28 L s^{-1}) (Senninger Irrigation, Inc., Clermont, FL) at 1.5-ft. above the soil surface, convex-medium grooved spray pads, and 68.9 kPa (10 psi) pressure regulators. Irrigation was scheduled based on prescribed irrigation capacities of 1 inch every third or sixth day. If stored soil water with the rooting zone (0 to 4.6 ft.) exceeded 85% of plant available water capacity, irrigation was withheld until soil water dropped to below this threshold. Daily plant available water was evaluated based on measured precipitation and irrigation, weekly measurements of soil water content, and daily evaluations of reference ET Soil water contents were determined using a neutron moisture gage (model 503DR, InstroTek, Inc., Raleigh, NC) from 0.33- to 7.6-ft. depth in 0.66-ft. increments at weekly intervals throughout the growing season.

Micrometerological variables were monitored using a datalogger (model CR3000, Campbell Scientific, Inc., Logan, UT) and environmental instrumentation located in a small grain (oats) field downwind (south-east) of the experimental field. Measurements were recorded at 0.25-h intervals and included ambient air temperature and relative humidity (model HC2S3 Temperature and Humidity Probe, Rotronic Instrument Corp., Hauppauge, NY), wind velocity (model 014A wind sensor, MET-ONE Instruments, Inc, Grants Pass, OR), and shortwave global irradiance (CM-14 albedometer (two CM-11 pyranometers to measure incoming and outgoing shortwave radiaton), Kipp and Zonen, Delft, The Netherlands) all at 6.6-ft. above the surface. Precipitation was measured using a tipping bucket rain gage (TE525M, Texas Electronics, Dallas, TX). Reference evapotranspiration (ET_o) was calculated from monitored variables using the ASCE standardized reference evapotranspiration equation at hourly intervals (Allen et al., 2005).

Hand-samples were harvested on October 31 through November 3, 2017 and combine samples were harvested on 17-18 November:
1. Four hand sampled subplots per replication with an area of 3.3 ft. by x 2-30 in. rows. Both aboveground biomass and grain were sampled from these plots.
2. Two combine samples per plot were acquired from an area of 20 ft. by 2-30 in. rows. Only grain was sampled from these plots.
Yield components including kernels per ear, kernel mass, above ground biomass and harvest index will be determined upon completion of processing hand samples.

Figure 3. VE-V1 corn on June 28; two days after emergence (planted on June 19).

Figure 4 (right). Replanted corn on July 10, 2017.

Results and Discussion

In-season precipitation was 19.17 inches (486.9 mm), which was 9.72 inches (246.8 mm) greater than the long-term average in-season precipitation for Bushland (Fig. 5). Due to above average in-season precipitation, irrigation treatments were only periodically required when the soil moisture fell below the threshold of 85% of plant available water. The goal is to keep as much water in the profile as the irrigation capacity allows so that there is sufficient storage to meet the crop water demand if ETo is high and there is insufficient precipitation. Above average precipitation coupled with below average late-season temperatures resulted in the cumulative ETo for the fully irrigated crop being 6.9 inches below the long-term average (Fig. 6). The cumulative ETo for the FI corn was 19.3 inches compared with the long-term average of 26.2 inches, and the cumulative ETo for the DI corn was 17.7 inches (Figs. 6 and 7).

In-season irrigation was 8.75 inches for FI treatment and 4.9 inches for the DI treatment. Total in-season water use including the change in stored soil water, precipitation and irrigation was 22.56 and 20.51 inches for the FI and DI treatments, respectively (Table 1). Using calculated ETo for 2017 and 2016 crop water use data, the fraction of plant available water was also estimated to model predicted soil water deficits. The measured fraction of plant available water based on neutron moisture gage measurements is compared with the predicted values in (Figs. 8 and 9). Accurate estimation of the fraction of plant available water throughout the growing season is key towards improving estimates of yield reductions associated with inadequate irrigation and water stress.

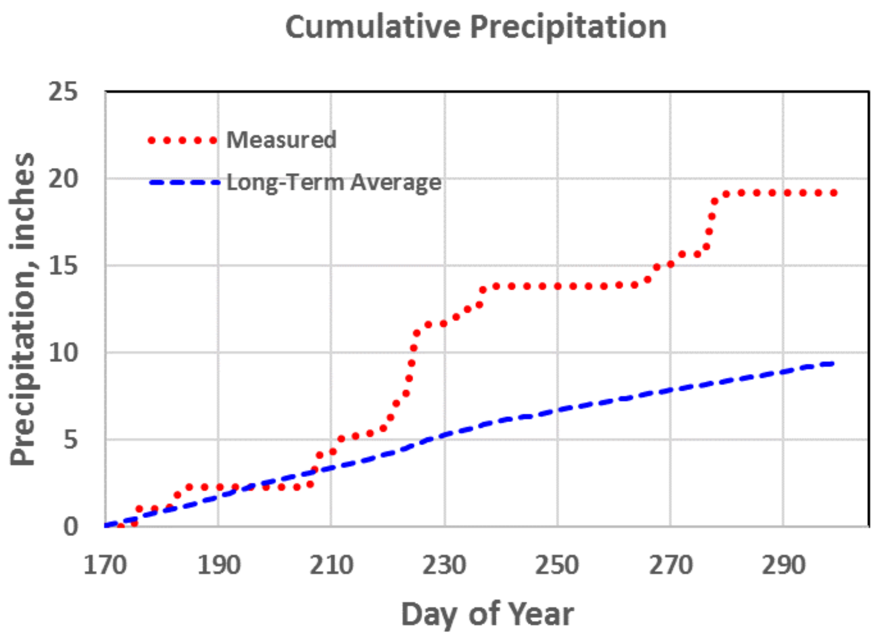

Figure 5. Cumulative 2017 precipitation compared with the long-term average precipitation at Bushland for the corn growing season.

Table 1. 2017 water balance including total water use (soil water + precipitation + irrigation).

Irrigation Rate	Precip.	Irrigation	Change in Soil Water Storage	Runoff & Drainage	Total Water Use
	---------------------------	---------------------------	inches	---------------------------	---------------------------
1"/ 3 days	19.17	8.75	-1.77	-7.13	22.56
1"/ 6 days	19.17	4.90	-1.60	-5.16	20.51

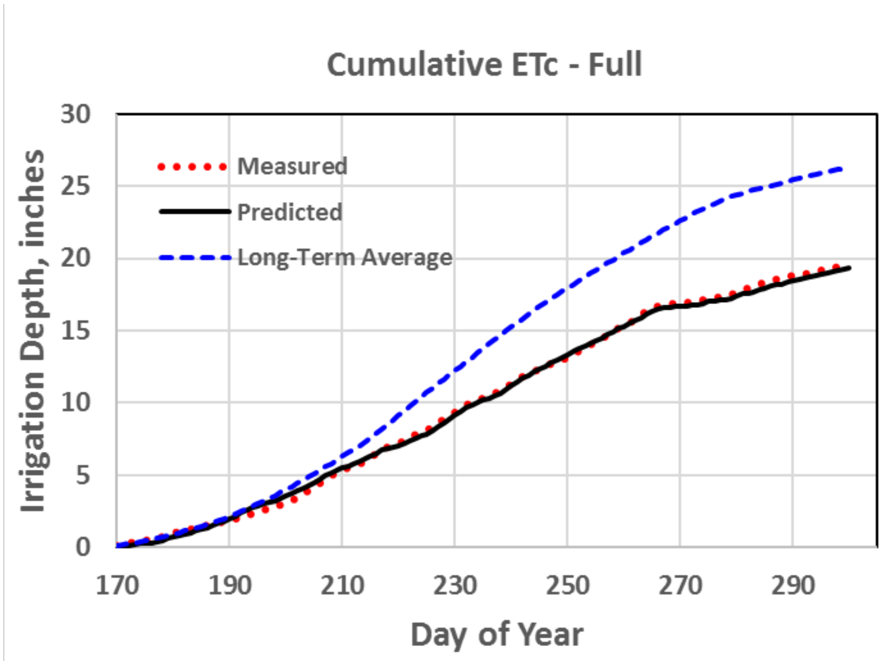

Figure 6. Cumulative crop water use (ETc) for the fully irrigated 2017 corn compared to the long-term average ETc for a fully irrigated corn crop at Bushland.

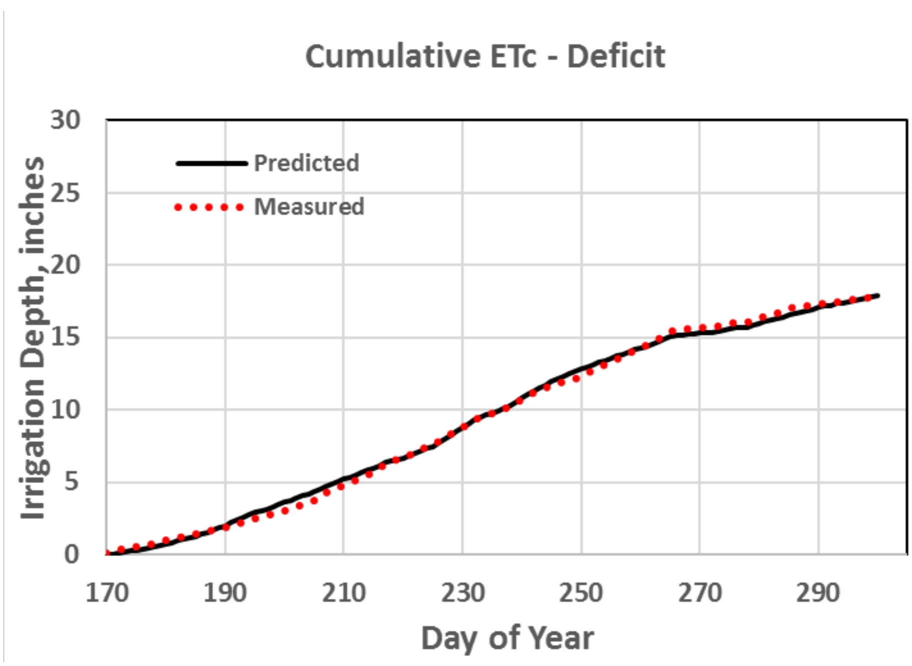

Figure 7. Cumulative crop water use (ETc) for the deficit irrigated 2017 corn.

Due to early season environmental stress (high temperatures and low precipitation between days 170 and 176), both the measured and predicted soil plant available water triggered irrigation (Figs. 8 and 9) for both FI and DI treatments. Throughout the remainder of the season, the plant available water remained at levels above the threshold below which yield reductions occur because of water stress. For deficit irrigation, mild water stress was observed during the milk stage (between days 250 and 270). Water stress at this time likely resulted in yield reductions compared with full irrigation. Confirmation of this theory will be confirmed upon completion of hand samples to obtain yield components. Unlike in 2016, frequent heavy rains, runoff and drainage below the root zone, resulted in poor estimation of the crop coefficient (Fig. 10). Soil water and ETo data obtained during this period will help calibrate the corn yield response to water deficits during the late reproductive phase. Yields for all hybrids and populations were greater for the full irrigation treatment (p=0.02); however, there were no significant differences among hybrids or plant populations for each irrigation treatment (Table 2). Visual evaluation of ear size reflects that a combination of fewer ears, kernels per ear and kernel mass all contributed to the reduction in yields under DI treatments (Figs. 11 and 12).

Table 2. 2017 grain yield and water use efficiencies.

Irrigation Rate	Hybrid	Grain Yield	WUE
	-----bu/ac -----		bu/in
1"/3 days	P1151	195.78	8.52
1"/3 days	DKC6227	188.85	8.55
1"/3 days	DKC6298	196.65	8.70
1"/6 days	P1151	167.25	8.13
1"/6 days	DKC6227	168.70	8.33
1"/6 days	DKC6298	176.20	8.51

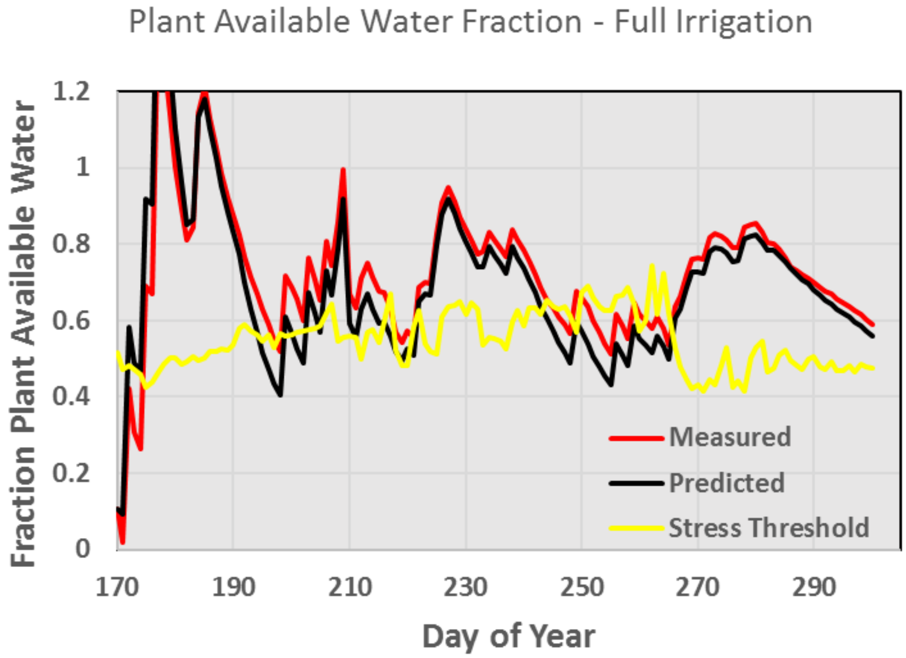

Figure 8. Measured and predicted fraction of plant available water in comparison to the stress threshold for the fully irrigated treatment.

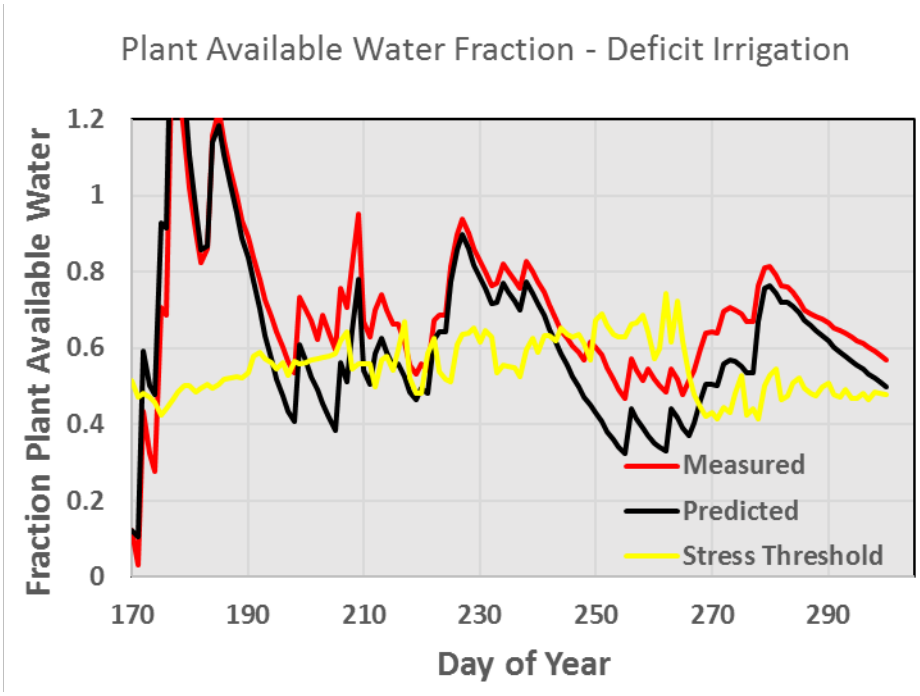

Figure 9. Measured and predicted fraction of plant available water in comparison to the stress threshold for the deficit irrigated treatment.

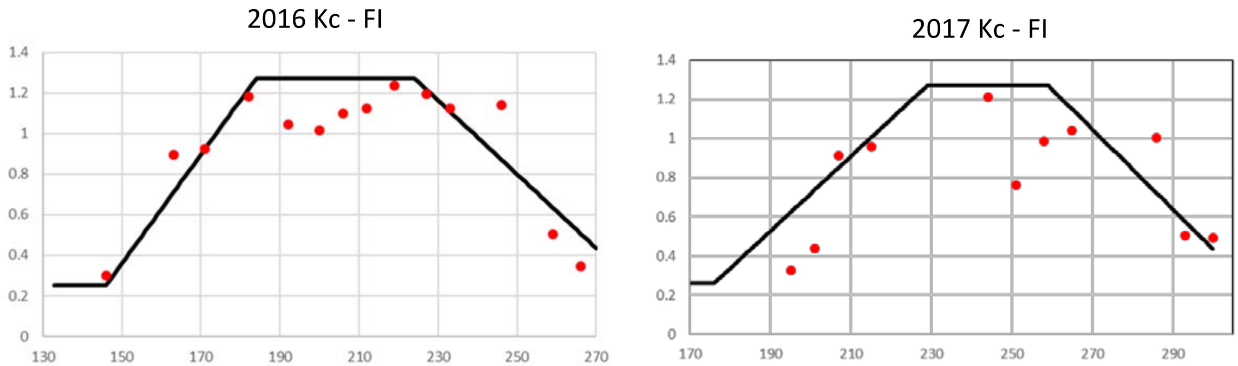

Figure 10. 2016 and 2017 estimation of the crop coefficient for the full irrigation (FI) treatment.

Figure 11. All ears harvested from one representative plot for each respective treatment under full irrigation.

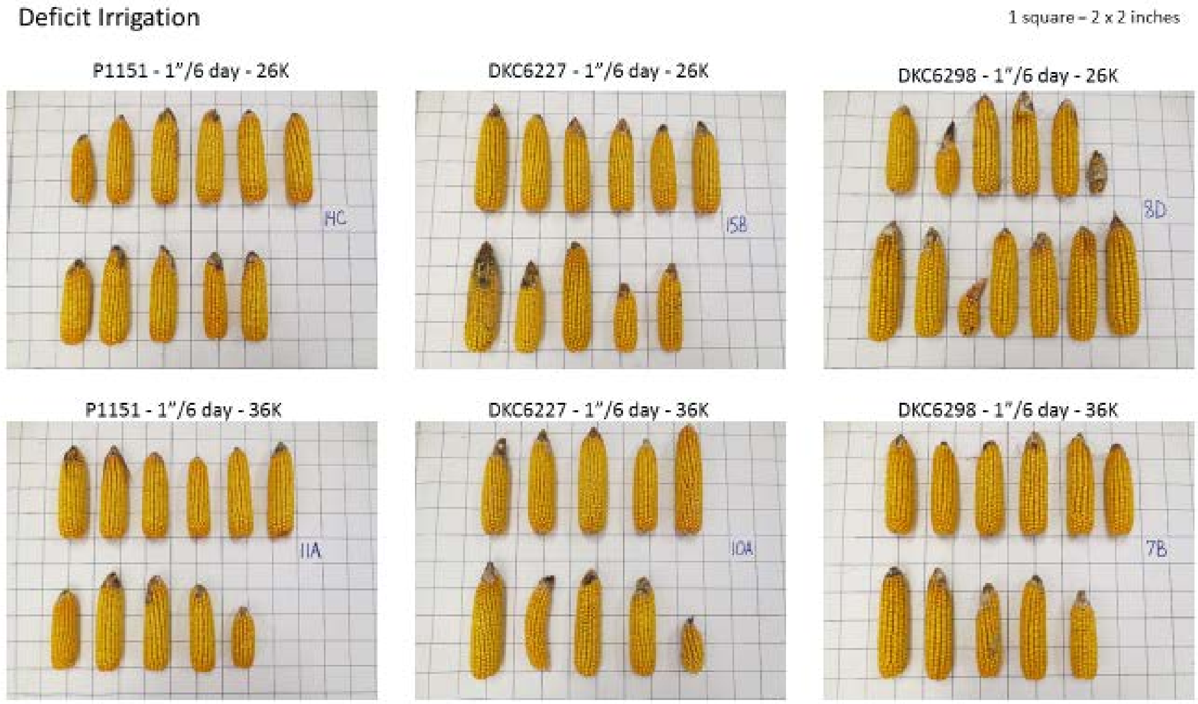

Figure 12. All ears harvested from one representative plot for each respective treatment under deficit irrigation.

Impacts

The steep grain yield response of 2016 corn to water use implied that that the DI rate of 3.14 gal/min per acre would be insufficient to meet the crop water. The 2016 results demonstrated that 22% greater total harvested yield could be obtained by planting and irrigating only half the acreage at 6.28 gal/min per acre. The 2017 yield loss under DI resulted from water stress during the late reproductive (milk) phase. This data confirms that even in years with above average precipitation, a capacity of 3.14 gal/min per acre is insufficient to meet the crop water demand without sustaining a yield loss, albeit small. The long-term objective of this research collaboration between Texas A&M AgriLife, USDA-ARSS and Kansas State University field research stations in the southern US Great Plains is to determine optimal planted acreage and associated production risks for a given irrigation capacity to achieve the maximum harvested yield and/or profitability as well as the most beneficial use of groundwater. As groundwater becomes increasingly limited, data from this project will be provided to producers to assist in determining planted acreage to maximize production with a known well capacity. Data from this trial will be used to prepare Extension materials and refereed publications.