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IMPACT OF DROUGHT GENETICS ON IRRIGATED CORN PRODUCTION

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INTRODUCTION

Irrigated corn is the major crop of choice in the High Plains of Colorado, Nebraska and Kansas. Declining water levels in the High Plains Aquifer have caused drops in irrigation well capacity over time. With these declines, many wells are now considered water-limited as the capacity does not always provide a dependable water supply for fully irrigated production.

Crop breeding has improved the genetics and production of corn hybrids over time. The utilization of genetically modified crops (GMO) has improved yields while also providing protection against insects and pathogens. The recent development of both GMO corn as well as conventionally bred corn for drought resistant hybrids has garnered interest among irrigated producers with limited water supplies. Even under full irrigation practices, these genetics offer the potential of yield protection during time periods when irrigation systems break down or weather conditions are such that well capacities will not meet crop ET.

Little is known about the potential value of drought genetics in irrigated production. If these genetics do offer increased production either with limited capacity systems or during severe drought periods, producers may be willing to utilize these genetics.

Methods

A study was initiated in 2012 at two locations (USDA-ARS Central Great Plains Research Station in Akron, CO and K-State Northwest Research—Extension Center in Colby, KS) to study the impacts of drought genetics on water stress in irrigated corn during the reproductive growth stages. Soil type at Akron, CO was a Weld silt loam; soil type at Colby, KS was a Keith silt loam. This study was conducted in cooperation with Monsanto, Inc. In 2012, three hybrids with the DroughtGard® gene were compared to four commercial hybrids with similar relative maturity ratings; in 2013 seven hybrids with the DroughtGard® gene were evaluated. The irrigation trials were conducted on a solid set irrigation system with a capacity of 0.40 inches day^{-1} (Akron) and micro-furrow (2012) or surface drip (2013) irrigation system (Colby). Irrigation was withheld during a 10-day time period beginning with the late vegetative growth stage. Successive water withholding treatments were initiated every 10 days after that. Irrigation intervals were 7 days at Colby. The approximate growth stages for treatments were the Late Vegetative to VT, VT to R1, R1 to R2. These growth stages are typically the most sensitive to water stress and show the greatest impact on grain yields. Relative maturity ratings ranged from 93 to 108 days.

Plots were planted in early May in 2012 and 2013 in 4-row plots in a split plot design replicated four times. Water treatments were the main plots and corn hybrids were the split plots. Planting rate was 33,000 seeds acre^{-1}. The middle two rows were harvested for grain yield. Soil moisture was monitored by the neutron attenuation method for two of the replications. Irrigations were scheduled based upon stored soil moisture and crop evapotranspiration. Irrigation was managed to maintain soil moisture in the upper 3-foot soil profile at or above 50% plant available soil moisture during the growing season. By maintaining soil moisture at or near 50% plant available, stress would be incurred quickly once water was withheld during the reproductive growth stages.

Water stress level was quantified weekly with measurements of leaf temperatures made with an infrared thermometer. The Crop Water Stress Index (CWSI) was calculated from these leaf temperatures. The CWSI ranges from 0 (no water stress) to 1 (maximum water stress, complete cessation of transpiration).

Plots were fertilized according to residual soil nitrogen and a yield goal of 200 bushels acre^{-1}. Weeds were controlled with a combination of residual and contact herbicides applied at V6. Tillage was done prior to planting for initial weed control.

Results

Weather conditions in 2012 exhibited above average temperatures with below average precipitation resulting in higher than average crop water requirements. Crop water use (early June through maturity) at Colby was 28.1” in 2012 and 26.2” in 2013. Water stress conditions developed during the reproductive time periods in response to the irrigation withholding treatments (Figure 1). Weather conditions in early 2013 were warmer than average with below average precipitation. Weather conditions changed to cooler than average with near to above normal precipitation when the reproductive growth stages began. With these conditions, water stress during the reproductive growth stages was marginal (Figure 2).

Grain yields in 2012 were considerably less than average due to the drought conditions. The average yield for all treatments was 144 bu acre^{-1} (Akron, Table 1) and 143 bu acre^{-1} (Colby, Table 2) Grain yields were the least when stress occurred during the R1-R2 growth stages (Colby, 122 bu acre^{-1}) and R2-R3 growth stages (Akron, 117.4 bu acre^{-1}) as compared to the other time periods of water stress. The greatest grain yields occurred when water stress was during the LV to VT growth stages (Akron, 175.0 bu acre^{-1} and Colby, 169 bu acre^{-1}). These results were somewhat confounded by the fact that, in Akron, the LV-VT water treatment block had greater beginning soil moisture compared to the other treatment blocks and beginning soil moisture was less for the R2-R3 stages. However, differences in beginning soil moisture do not explain the total differences in grain yields between all stress time periods.

In 2012 the DroughtGard® genetics were statistically greater than the genetics without the DroughtGard®. The average difference between the DroughtGard® hybrids compared to non-

DroughtGard® hybrids was 9 bu acre^{-1}(Akron) and 11 bu acre^{-1} (Colby). . However, these statistics were greatly weighted by the differences within the 108-day variety where the average difference between the DroughtGard® and non-DroughtGard® genetics was 27 bu acre^{-1} (Akron) and 21 bu acre^{-1} (Colby) and were greater for all stress periods.

In Akron, average yields between the DroughtGard® and non-DroughtGard® treatments were not significant for the 99- and 102-day hybrids. However, there were yield differences during late reproductive stress during the R1-R2 and R2-R3 growth stages for the 102-day hybrids while the non-DroughtGard® yields during the LV-VT growth stages were greater than the DroughtGard® variety for the 102-day hybrids. Although differences were observed between the DroughtGard® and non-DroughtGard® hybrids, consistency of the yield differences between stress time periods would suggest that the yield differences may be more due to genetic variability rather than a drought tolerance with these hybrids.

In Colby, the 99-day and 107-day DroughtGard® hybrids had greater yields than conventional hybrids of similar maturity; the 99-day DroughtGard® hybrid yielded more than one of the conventional 99-day hybrids for stress during R1-R2 and R2-R3stages; the 101-day DroughtGard® hybrid had greater yield than the 102-day conventional hybrid when stress occurred during the R2-R3 stage.

In 2013, overall grain yields averaged 194 bu acre^{-1} (Akron, Table 3) and 182 bu acre^{-1} (Colby, Table 4) for all treatments. These yields were greater than observed in 2012 because of better growing conditions with cooler temperatures and greater than normal precipitation in August—when irrigation was with-held. The CWSI was less than 0.4 during 3 of the 4 water stress periods (Figure 2). In Colby, least yields (164 bu acre^{-1}) resulted from stress at LV-VT stage; DroughtGard® hybrid yields differed significantly (132 – 195 bu acre^{-1}) in response to stress at this stage. Averaged over stress periods, greatest yields resulted from 102-day and 107-day hybrids; significantly less yields were observed for 97-day, 101-day DroughtGard® hybrids and the108-day conventional hybrid, as in 2012 at both locations. In Akron, no significant differences in grain yields between water stress time periods were seen.although the VT-R1 time period had the lowest grain yields by approximately 2 to 7 bu acre^{-1}. Yield differences among DroughtGard® hybrids (observed in Colby), with similar maturities indicates that genetic background provides an important component of yield potential under these conditions.

Conclusions

Although the DroughtGard® genetics showed statistically greater yields when water stress occurred during the reproductive growth stages in 2012, the analysis was heavily influenced by one relative maturity comparison (108-day). It is unclear if the DroughtGard® genetics are consistently increasing grain yields as compared with non-DroughtGard® genetics.

Although yield loss will occur when water stress happens during any reproductive growth stage, when factoring in soil moisture conditions, the greatest potential for yield loss during the reproductive growth stages happened during the VT to R1 growth stages in 2012 and marginally lower in 2013. Making sure that adequate water can be delivered during the reproductive growth stages is important for maximizing grain yields with irrigation.

Table 1. Grain yields for DroughtGard® and Non-DroughtGard® hybrids during four water stress time periods for 2012 in Akron, Colorado.

		Grain Yield bu acre^{-1} Water Stress Period				
Relative Maturity	DroughtGard®	LV-VT	VT-R1	R1-R2	R2-R3	Average
99	No	177.1	130.2	144.8	106.8	139.7
99	No	171.4	133.0	161.0	119.5	146.2
99	Yes	170.9	134.1	157.6	120.5	145.8
102	No	198.5	146.9	144.8	119.4	152.4
101	Yes	179.0	141.9	162.7	126.6	152.6
108	No	147.1	110.2	124.0	104.0	121.3
107	Yes	180.9	135.4	152.0	125.0	148.3
Average		175.0	133.1	149.6	117.4	
	Yes	176.9	137.1	157.4	124.0	148.9
	No	173.5	130.1	143.7	112.4	139.9

Table 2. Grain yields for DroughtGard® and Non-DroughtGard® hybrids during four water stress time periods for 2012 in Colby, Kansas.

		Grain Yield bu acre^{-1} Water Stress Period				
Relative Maturity	DroughtGard®	LV-VT	VT-R1	R1-R2	R2-R3	Average
99	No	168.5	130.0	121.4	142.9	140.7
99	No	168.7	131.6	100.3	137.4	134.5
99	Yes	171.0	139.6	145.1	155.5	152.8
102	No	170.9	138.9	133.6	158.5	150.5
101	Yes	186.1	142.4	129.4	132.3	147.6
108	No	151.0	137.6	103.6	124.6	129.2
107	Yes	177.6	149.0	116.6	144.9	148.5
Average		169.0	137.8	121.6	143.8	
	Yes	178.2	143.7	130.4	144.2	149.6
	No	164.8	134.5	114.7	140.8	138.7

Table 3. Grain yields for DroughtGard® and Non-DroughtGard® hybrids during four water stress time periods for 2013 in Akron, Colorado.

		Grain Yield bu acre^{-1} Water Stress Period				
Relative Maturity	DroughtGard	LV-VT	VT-R1	R1-R2	R2-R3	Average
97	Yes	197.7	198.2	197.5	198.4	198.0
98	Yes	184.3	197.1	192.8	183.0	189.3
99	Yes	194.8	174.2	195.2	193.6	189.5
100	Yes	199.8	180.0	199.2	197.0	194.0
101	Yes	185.0	193.4	190.7	207.9	194.3
102	No	196.0	203.6	193.0	212.3	201.2
107	Yes	198.9	189.2	199.6	199.2	196.7
108	No	185.0	186.5	190.9	189.9	188.1
Average		192.7	190.3	194.9	197.7	

Table 4. Grain yields for DroughtGard® and Non-DroughtGard® hybrids during four water stress time periods for 2013 in Colby, Kansas.

		Grain Yield bu acre^{-1} Water Stress Period				
Relative Maturity	DroughtGard	LV-VT	VT-R1	R1-R2	R2-R3	Average
97	Yes	147.4	185.6	196.0	189.4	179.6
98	Yes	170.1	192.9	175.4	180.0	179.6
99	Yes	172.8	186.9	187.0	186.1	183.2
100	Yes	157.0	192.0	195.0	194.3	184.6
101	Yes	131.6	183.7	185.8	183.0	171.0
102	No	182.9	194.3	187.5	200.5	191.4
107	Yes	195.5	182.9	197.4	182.5	189.5
108	No	153.8	183.6	190.2	170.7	174.6
Average		163.9	187.7	189.3	185.8	

Figure 1. Crop Water Stress Index (CWSI) for 2012 by irrigation treatment.

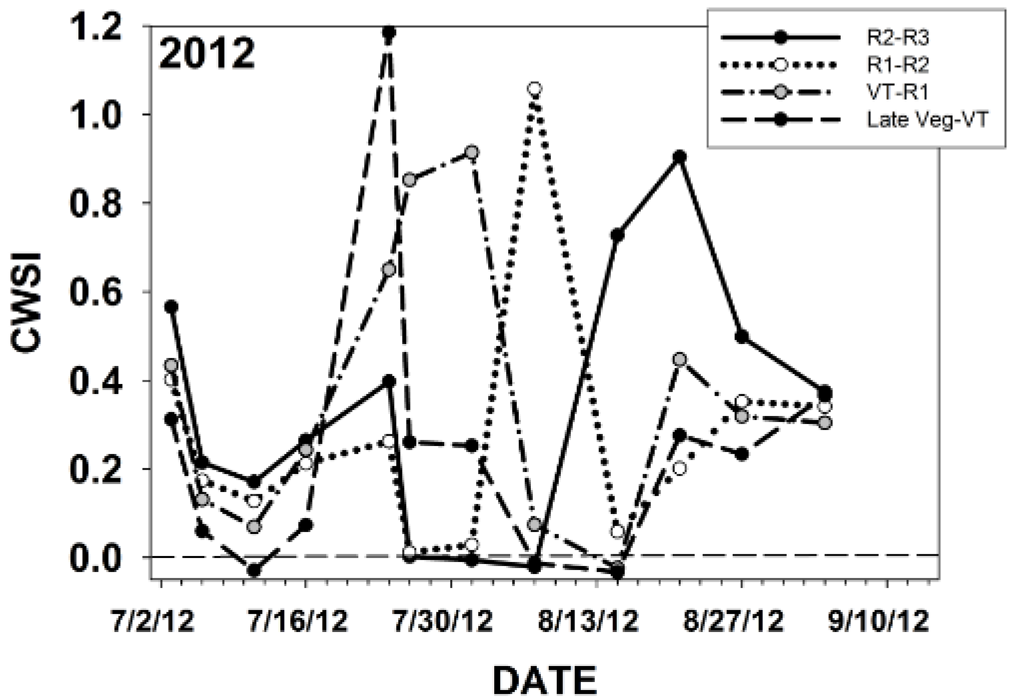

Figure 2. Crop Water Stress Index (CWSI) for 2013 by irrigation treatment.