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I. Kisekka
Kansas State University, ikisekka@ksu.edu

F. Lamm
Kansas State University, flamm@ksu.edu

J. D. Holman
Kansas State University, jholman@ksu.edu

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Response of Drought Tolerant and Conventional Corn to Limited Irrigation

Abstract

With declining water levels in the Ogallala aquifer, many wells cannot supply peak irrigation water needs for corn. Emerging drought-tolerant (DT) corn hybrids could help farmers maintain yield with limited capacity wells. A knowledge gap exists comparing transgenic DT and conventional corn hybrids in yield response to water level. The purpose of this study was to compare yield, yield components, water productivity, and irrigation water use efficiency response of DT corn with cspB (DKC 6267 DGVT- 2PRO) transgene trait and conventional corn hybrid (DKC 62-98 VT2PRO) with similar maturity to full and limited irrigation. Preliminary results from the 2014 growing season indicate the effect of irrigation level on corn yield was significant (P-value <0.001). The effect of the cspB transgene trait in the DT hybrid did not affect yield (P-value=0.32), and there was no effect of the interaction between irrigation level and corn hybrid on yield (P-value=0.82). The effect of irrigation and hybrid on 100 kernel weight was significant, with P-value<0.001 and P-value<0.001 respectively. The 100 kernel weight is a measure of kernel size, and was higher for the conventional hybrid compared to the DT hybrid.

Keywords

irrigation, corn, crop water, irrigation, water supply, drought tolerant corn, DT hybrid, Ogallala Aquifer, yield response, water use efficiency

Cover Page Footnote

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Response of Drought Tolerant and Conventional Corn to Limited Irrigation

I. Kisekka, F. Lamm, and J. Holman

Summary

With declining water levels in the Ogallala aquifer, many wells cannot supply peak irrigation water needs for corn. Emerging drought-tolerant (DT) corn hybrids could help farmers maintain yield with limited capacity wells. A knowledge gap exists comparing transgenic DT and conventional corn hybrids in yield response to water level. The purpose of this study was to compare yield, yield components, water productivity, and irrigation water use efficiency response of DT corn with cspB (DKC 6267 DGVT-2PRO) transgene trait and conventional corn hybrid (DKC 62-98 VT2PRO) with similar maturity to full and limited irrigation. Preliminary results from the 2014 growing season indicate the effect of irrigation level on corn yield was significant (*P-value <0.001)*. The effect of the cspB transgene trait in the DT hybrid did not affect yield (*P-value=0.32)*, and there was no effect of the interaction between irrigation level and corn hybrid on yield (*P-value=0.82)*. The effect of irrigation and hybrid on 100 kernel weight was significant, with *P-value<0.001* and *P-value<0.001* respectively. The 100 kernel weight is a measure of kernel size, and was higher for the conventional hybrid compared to the DT hybrid.

As would be expected, irrigation level significantly affected crop water use (*P-value <0.001*). Corn hybrid also had a significant effect on crop water use (*P-value=0.0005*). Crop water use ranged between 24.5 to 15.4 and 25.5 to 15.1 inches for the conventional and DT corn hybrids, respectively. Irrigation level had a significant effect on water productivity (*P-value<0.001*), but the effect of hybrid on water productivity was not significant (*P-value=0.1252*). The effect of the interaction between irrigation level and hybrid on water productivity was also not significant (*P-value=0.5804*). Seasonal water productivity ranged between 10.03 to 4.00 and 9.18 to 3.95 bu ac-in^{-1} for conventional and DT corn hybrids, respectively. DT and conventional corn hybrids had curvilinear yield response to irrigation and linear response to seasonal crop water evapotranspiration (ETc). The DT hybrid had a slightly lower ET threshold compared to the conventional hybrid: 9.9 inches compared to 11.6 inches, respectively. Marginal water productivity occurring above the yield threshold was 19.84 and 14.93 bu ac-in^{-1} for conventional and DT hybrids, respectively. Irrigation water use efficiency decreased with increased irrigation. These preliminary results indicate no significant differences in yields between DT and conventional hybrids under full and limited irrigation. More research is needed to confirm these findings.

Introduction

Corn is the primary irrigated crop in western Kansas, and reducing the amount of irrigation water required for profitable corn production is important to extend the usable life of the Ogallala Aquifer. Declining water levels in the aquifer have resulted in an increased number of low-capacity wells, causing producers to switch from irrigated to dryland production. Many low-capacity wells cannot supply peak irrigation water needs for corn during the summer, causing producers to rely on soil water reserves from preseason irrigation or overwinter precipitation capture and storage. Emerging drought-tolerant (DT) corn hybrids (both transgenic and those selected through advanced screening techniques) are being marketed as having the potential to minimize yield loss during minor to moderate drought. Limited irrigation management strategies — such as reducing irrigated area and allocating water to different crops, reduced tillage and residue management, preseason irrigation, nutrient management, and crop rotations — are used by producers to cope with low-capacity systems. Combining limited irrigation management strategies and DT corn technologies could help producers stabilize yields and incomes with limited water.

DT corn response to the amount of irrigation water applied is an emerging area of research: Publicly available literature on yield response and water savings from growing DT corn hybrids is limited. Castiglioni et al. (2008) conducted a study at various locations in the Midwest, including Kansas, and reported that corn hybrids expressing the cspB (cold shock protein B) transgenic trait had higher chlorophyll content and photosynthesis rates relative to the nontransgenic controls. They concluded that the observed growth rate improvements under limited water indicated that the cspB transgene had a positive impact on plant productivity. They also reported that yield improvements in water-limited environments were not associated with yield penalties under well-watered environments and that the predominant impact of the transgene was on kernel numbers and not kernel weight. Another study by Chang et al. (2014) reported that no evidence suggested the cspB transgene in the corn hybrid evaluated impacted shoot or root architecture or yield when grown in moderate- to high-yield environments. Nemali et al. (2014) reported the DT corn expressing the cspB transgene trait averaged 6% higher yields compared to the control under water-limited conditions, but there were no consistent results under well-watered conditions.

A knowledge gap exists related to how transgenic DT and conventional corn hybrids compare in yield response to different levels of water under the semi-arid climate of western Kansas. The purpose of this study was to compare yield, yield components, water productivity, and irrigation water use efficiency response of DT corn hybrid with cspB (DKC 6267 DGVT2PRO) transgene trait and conventional corn hybrid (DKC 62-98 VT2PRO) to full and limited irrigation.

Procedures

Experimental Design

The study was conducted at the Kansas State University Southwest Research-Extension Center's Finnup Farm (38°01'20.87''N, 100°49'26.95"W, elevation of 2,910 feet above mean sea level) near Garden City, Kansas. The soil at the study site is a deep, well-drained Ulysses silt loam with water holding capacity of 2 in./ft. The experimental design was split-plot with whole plots (irrigation capacity/frequency with 6 levels) arranged in a randomized complete block and subplot factor being corn hybrid with two levels (DT and convention corn hybrids) arranged as split-plots within the whole plots. The experiment was replicated four times. Rainfall recorded from May 1, 2014, to October 31, 2014, was 18.4 in. The 54-year average (1959–2013) for this period was 13.8 in. More than half of this rainfall was received in June, as shown in Figure 1.

Irrigation Management

Irrigation was applied using a linear move sprinkler system (Model: Valley 8000 series, Valmont Industries, Inc., Valley, Nebraska) with four spans and each span serving as a replicate. Irrigation treatments were designed to mimic the following irrigation capacities:

1. T1: Irrigate every 4 days unless available soil water (ASW) is above 50% in the top 4 feet
2. T2: Irrigate every 6 days unless ASW is above 50%
3. T3: Irrigate every 8 days unless ASW is above 50%
4. T4: Irrigate every 10 days unless ASW is above 50%
5. T5: Irrigate every 12 days unless ASW is above 50%
6. T6: Dryland treatment

Soil water measurements were taken weekly using a neutron probe (CPN 503DR, CPN International, Concord, California) at 12-in. increments up to 8 ft deep in both the DT and conventional corn subplots. Each irrigation event applied 1 in. for all treatments irrigated on a given day, and irrigation treatments were based on frequency and soil water monitoring.

Water productivity (WP) was estimated using equation (1) and irrigation water use efficiency (IWUE) was estimated using equation (2):

$$WP = \frac{Y}{ET_c} \quad (1)$$

$$IWUE = \frac{(Y_i - Y_d)}{I_i} \quad (2)$$

WP is water productivity (bu ac-in^{-1}); *Y* is economic yield (bu ac^{-1}); ET_c is seasonal crop water use (in.). *IWUE* is irrigation water use efficiency (bu ac-in^{-1}); Y_i is economic yield of irrigation level *i* (bu ac^{-1}); Y_d is economic yield from an equivalent dryland crop (bu ac^{-1}); and *I* is depth of irrigation water applied for irrigation level *i* (in.).

Agronomic Management

The experiment was set up in a field that had been in no-till for more than 10 years. The previous crop was corn. Two Monsanto corn cultivars: 1) DT corn containing the cspB transgenic trait [Genuity® DroughtGard, 62-27 DGVT2PRO], and 2) non-isoline locally adapted conventional corn hybrid [DeKalb DKC 62-98 VT2PRO] were planted. Both hybrids had a relative maturity of 112 days. Planting occurred May 7, 2014. The planting was done using a no-till planter. Planting depth was 2 in. and seeding rate was 30,000 seeds a^{-1} applied uniformly across all treatments. The no-till planter was equipped with a single coulter preceding a double-disc furrow opener, and two rubber-tire closing wheels. The crop row direction was north-south. Fertilizer application and weed control were done according to Kansas State University recommendations for high-yielding corn production.

Statistical Analysis

Statistical analysis was implemented using the PROC GLIMMIX procedure in SAS studio (*http://www.sas.com/en_us/software/foundation/studio.html*). Statistical tests were conducted at a 5% level of significance.

Preliminary Results and Discussion

Corn Yield and Yield Components

Corn yields adjusted to 15.5% moisture (bu ac^{-1}), and 100 kernel weight (g) are summarized in Table 1. The effect of irrigation level on yield of the DT and conventional hybrid corn was significant at 5% level with *P-value<0.0001*. The effect of the cspB transgene trait did not affect yield (*P-value=0.32*), and the interaction between irrigation level and corn hybrid on yield was not significant *(P-value=0.82*). Yields ranged between 242 and 60 bu ac^{-1} for conventional hybrid and 214 to 60 bu ac^{-1} for the DT hybrid, as shown in Table 1. Averaged across all irrigation levels the conventional hybrid had a yield of 171 bu ac^{-1} while the DT hybrid had a yield of 179 bu ac^{-1}. The effect of irrigation and hybrid on 100 kernel weight was significant, with *P-value<0.001* and *P-value<0.001*, respectively. The 100 kernel weight, which is a measurement of kernel size, was higher for the conventional hybrid compared to the DT hybrid. According to the U.S. Grain Council, average nationwide 100 kernel weight in 2014 was 34 g. Treatments T1 to T3 for the conventional hybrid and T1 to T2 for the DT hybrid produced above-average 100 kernel weights, but the100 kernel weight was significantly reduced by reduction in irrigation amounts.

Crop Water Use

As would be expected, irrigation level had a significant effect on crop water use (*P-value <0.001*). Corn hybrid also had a significant effect on crop water use (*P-value=0.0005*). Crop water use ranged between 24.5 to 15.4 and 25.5 to 15.1 in. for the conventional and DT corn hybrids respectively, as shown in Table 2. Irrigation level had a significant effect on water productivity (*P-value<0.001*). The effect of hybrid on water productivity was not significant (*P-value=0.1252*). The effect of the interaction between irrigation level and hybrid on water productivity also was not significant (*P-value=0.5804*). Seasonal water productivity ranged between 10.03 to 4.00 and 9.18 to 3.95 bu ac-in^{-1} for conventional and DT corn hybrids respectively, as shown in Table 2.

The seasonal crop water use for the fully irrigated treatment are within range of corn seasonal crop water use estimates determined from other studies in western Kansas (Lamm and Aiken, 2007; Klocke et al., 2015). Results in Fig. 2 indicate both DT and conventional corn had curvilinear yield response to irrigation. As mentioned earlier, yield response to irrigation between DT and conventional corn was not significantly different at 5% level. As shown in Fig. 3 (grain yield versus season crop evapotranspiration), the DT hybrid had a slightly lower ET threshold compared to the conventional hybrid: 9.9 inches compared to 11.6 inches, respectively. These preliminary data imply that, under water stress conditions, the DT hybrid starts forming grain earlier than the conventional hybrid. However, the conventional hybrid had higher marginal water productivity occurring above the yield threshold of 19.84 bu ac-in^{-1} versus 14.93 bu ac-$^{in-1}$ for the DT hybrid. Irrigation water use efficiency (IWUE), decreased with the amount of irrigation, as shown in Fig. 4. This means that not all the applied irrigation water was used in producing grain.

Conclusion

With declining water levels in the Ogallala Aquifer, many wells cannot supply adequate peak irrigation water for corn. Emerging drought-tolerant (DT) corn hybrids are being marketed as having the potential to minimize yield loss during minor to moderate drought. A knowledge gap exists on how transgenic DT and conventional corn hybrids compare in yield response to water level under semi-arid climatic conditions of western Kansas. The purpose of this study was to compare yield, yield components, water productivity, and irrigation water use efficiency of DT corn hybrid with cspB transgene trait (DKC 6267 DGVT2PRO) to a locally adapted conventional corn hybrid (DKC 62-98 VT2PRO) with same maturity period under full and limited irrigation.

Preliminary results from the 2014 growing season indicate that the effect of irrigation level on yield was significant (*P-value*$<$*0.0001)*. The effect of the cspB transgene trait in the hybrid did not have a significant effect on yield (*P-value=0.32)*, and the interaction between irrigation level and corn hybrid on yield was insignificant (*P-value=0.82)*. Yields ranged between 242 and 60 bu ac^{-1} for conventional hybrid and 214 to 60 bu ac^{-1} for the DT hybrid from full to limited irrigation. Irrigation and hybrid affected 100 kernel weight with *P-value*$<$*0.001* and *P-value*$<$*0.001,* respectively. The 100 kernel weight that is a measure of kernel size was higher for the conventional hybrid compared to the DT hybrid.

The two hybrids used similar amounts of water, 24.5 and 25.5 in., for the conventional and DT corn hybrids, respectively. DT and conventional corn hybrids had curvilinear yield response to irrigation. The two hybrids had linear response of yield to ETc. The DT hybrid had ETc threshold of 9.9 in., while the conventional hybrid had an ETc threshold of 11.6 in. Water productivity was 19.84 and 14.93 bu ac-in^{-1} for conventional and DT hybrids, respectively. These preliminary results indicate no significant yield differences between DT and conventional hybrids. More research is needed to confirm these findings.

Acknowledgements

The authors would like to thank Ogallala Aquifer Program and K-State Research and Extension for providing funding and material support. We would like to thank Mr. Dennis Tomsicek and Mr. Jaylen Koehn for implementing the research protocols and for collecting and processing field data.

References

Castiglioni, P., D.Warner, R. J. Bensen, D. C. Anstrom, J. Harrison, M. Stoecker, M. Abad, G. Kumar, S. Salvador, R. D'Ordine, S. Navarro, S. Back, M. Fernandes, J. Targolli, S. Dasgupta, C. Bonin, M. H. Luethy, and J. E. Heard. 2008. Bacterial RNA chaperones confer abiotic stress tolerance in plants and improved grain yield in maize under water-limited conditions. *Plant Physiology*, 147:446–455.

Chang, J., D. E. Clay, S. A. Hansen, S. A. Clay, and T. Schumacher. 2014. Water stress impacts on transgenic corn in the northern Great Plains. *Agronomy Journal*. 106, 125-130.

Klocke N., R. Currie, I. Kisekka, L. Stone. 2015. Corn and grain sorghum response to limited irrigation, drought, and hail. *Applied Engineering in Agriculture*. 30(6): 915-924.

Lamm, F.R. and R.M. Aiken. 2007. Conventional, strip and no tillage corn production under different irrigation capacities. *CPIA 2007*. Available from CPIA, 760 N.Thompson, Colby, Kansas.

Nemali, K.S., C. Bonin, F. G. Dohleman, M. Stephens, W. R. Reeves, D. E. Nelson, P. Castiglioni, J. E. Whitsel, B. Sammons, R. A. Silady, D. Anstrom, R. E Sharp, O. R. Patharkar, D. Clay, M. Coffin, M. A. Nemeth, M. E. Leibman, M. Luethy, M. Lawson. 2014. Physiological responses related to increased grain yield under drought in the first biotechnology-derived drought-tolerant maize. *Plant Cell Environ*. doi: 10.1111/pce.12446.

Table 1. Conventional and drought tolerant corn yield, and 100 kernel weight for the 2014 growing season at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, Kansas.

Irrigation Frequency (days)	Yield (bu ac^{-1})		100 Kernel Weight (g)	
	Con.[1] Corn	DT[2] Corn	Con. Corn	DT Corn
4	242 ± 12 a[3]	214 ± 4 a	40 ± 0.6 a	35 ± 0.6 a
6	219 ± 8 a	218 ± 13 a	41 ± 0.6 a	35 ± 0.6 a
8	211 ± 19 ab	194 ± 4 ab	39 ± 1.7 a	33 ± 1.7 ab
10	176 ± 15 bc	183 ± 18 ab	33 ± 1.7 b	30 ± 1.7 b
12	162 ± 25 c	157 ± 17 b	32 ± 2.0 b	26 ± 2.0 c
Dryland	62 ± 6 d	60 ± 12 c	20 ± 0.9 c	15 ± 0.9 d
	NS[4]		**[5]	

[1] Conventional corn hybrid (DKC 62-98 VT2PRO)
[2] Drought tolerant corn hybrid (DKC 6267 DGVT2PRO)
[3] Numbers with the same letter in a column are not significantly different at 5% level
[4] NS the means in the two columns are not statistically significant at 5% level
[5] Means in the two columns are statistically significant P<0.001

Table 2. Conventional and drought tolerant corn seasonal crop water use and water productivity for the 2014 growing season at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, Kansas.

Irrigation Frequency (days)	Crop Water Use (in.)		Water Productivity(bu ac-in^{-1})	
	Con.[1] Corn	DT[2] Corn	Con. Corn	DT Corn
4	24.5 ± 2 a[3]	25.5 ± 2 a	10.03 ± 0.99 a	9.18 ± 0.98 a
6	22.7 ± 5 b	24.5 ± 5 b	9.88 ± 0.64 a	8.98 ± 2.35 a
8	21.0 ± 2 c	22.5 ± 3 c	9.68 ± 1.48 a	8.68 ± 1.80 a
10	20.8 ± 2 c	20.6 ± 2 d	8.45 ± 1.31 a	8.43 ± 1.29 a
12	19.2 ± 4 d	19.9 ± 5 d	8.4 ± 2.58 a	7.6 ± 2.62 a
Dryland	15.4 ± 3 e	15.1 ± 3 e	4.00 ± 0.61 b	3.95 ± 3.55 b
	**[4]		**	

[1] Conventional corn hybrid (DKC 62-98 VT2PRO)
[2] Drought tolerant corn hybrid (DKC 6267 DGVT2PRO)
[3] Numbers with the same letter in a column are not significantly different at 5% level
[4] Means in the two columns are statistically significant P<0.001

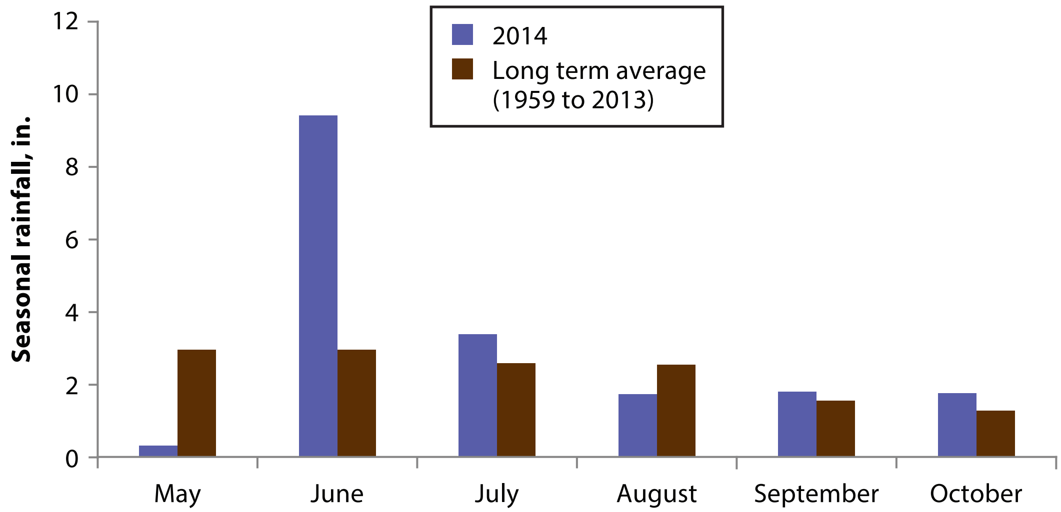

Figure 1. Long-term average (1959 to 2013) and May through October 2014 rainfall at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, Kansas.

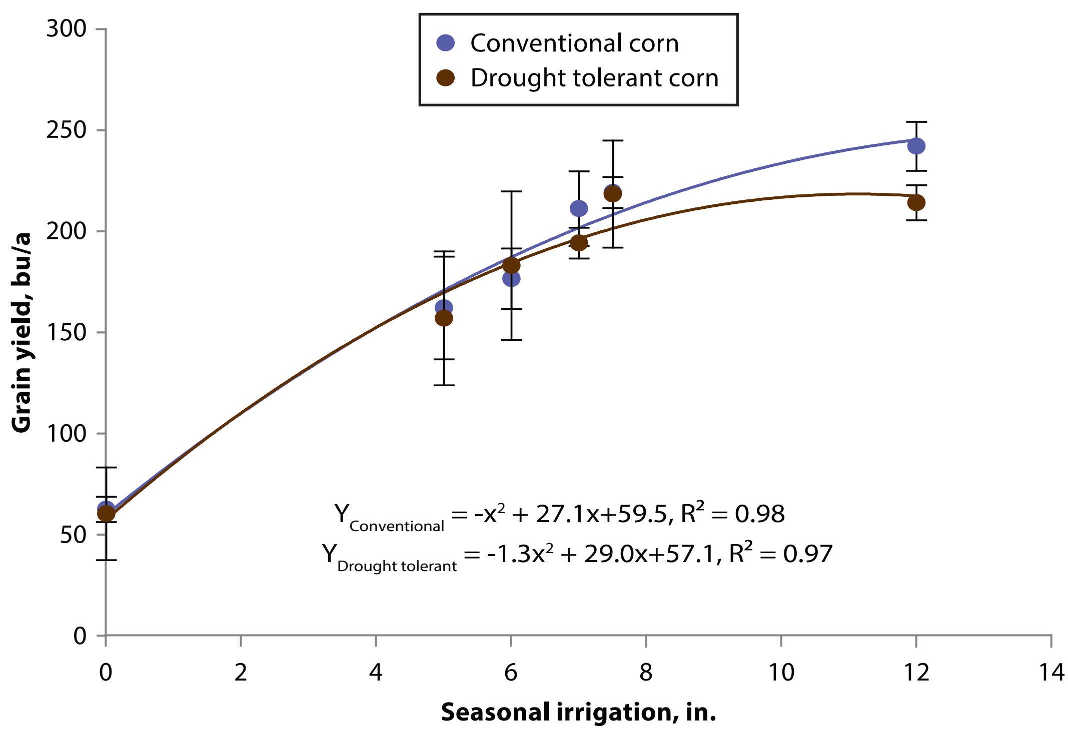

Figure 2. Response of conventional and drought tolerant corn to limited irrigation during the 2014 summer growing season at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, Kansas.

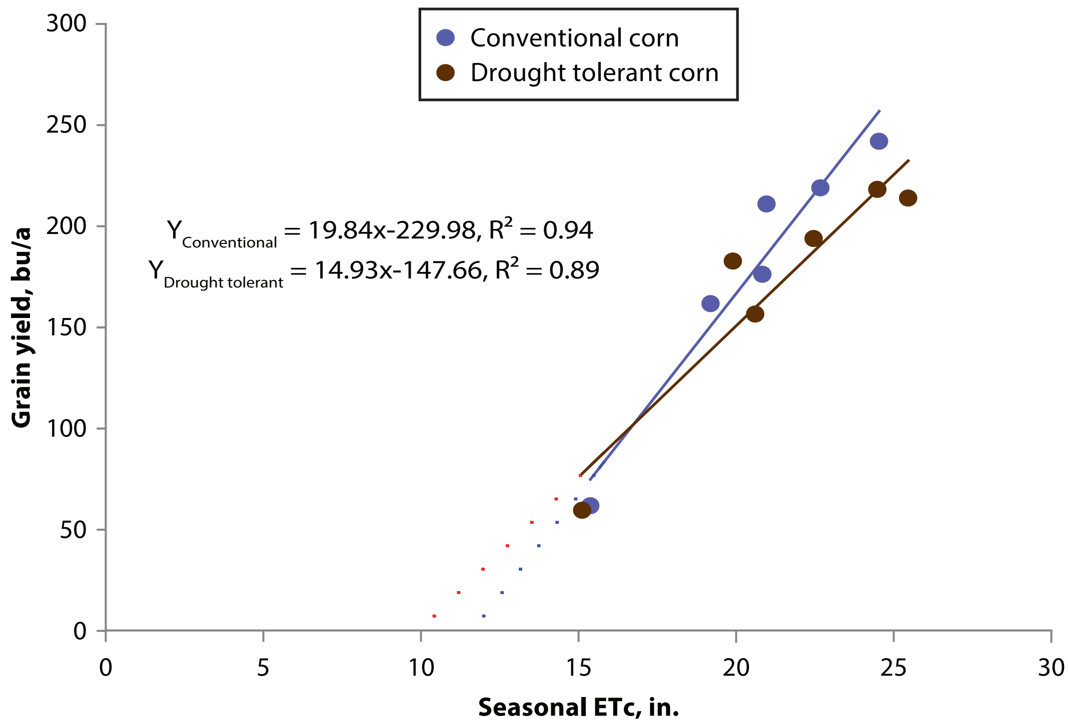

Figure 3. Yield versus seasonal evapotranspiration for conventional and drought tolerant corn during the 2014 summer growing season at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, Kansas.

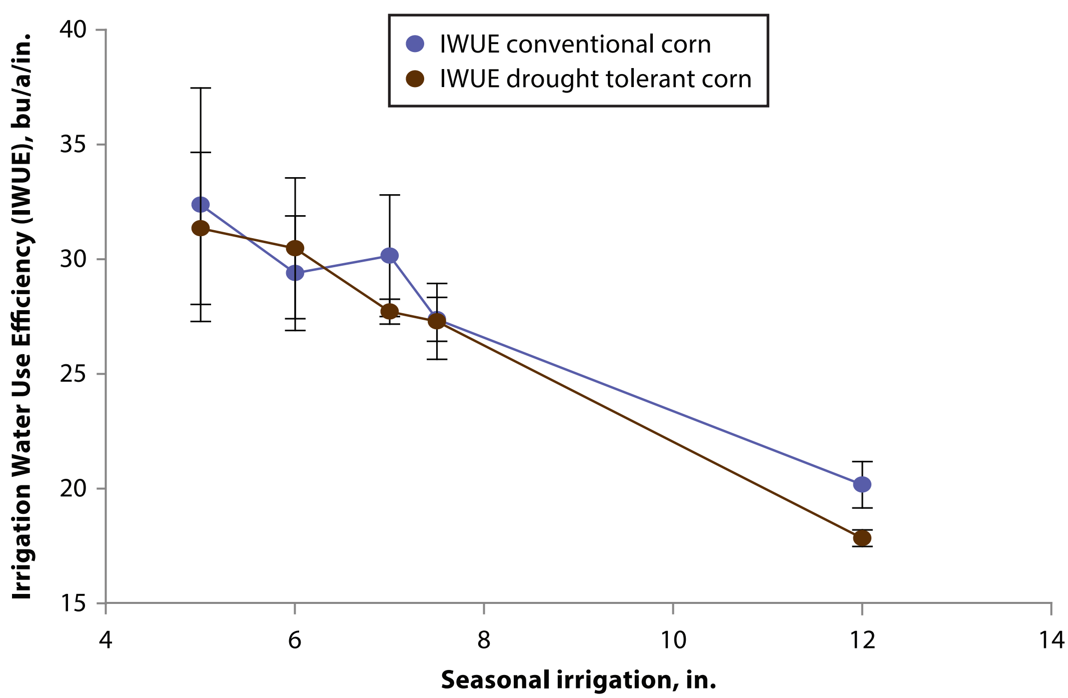

Figure 4. Irrigation water use efficiency (IWUE) yield versus irrigation for conventional and drought-tolerant corn during the 2014 summer growing season at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, Kansas.