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IRRIGATION OF CORN WITH REDUCED WELL CAPACITY

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ABSTRACT

Many of the irrigation systems today in the Central Great Plains no longer have the capacity to apply peak irrigation needs during the summer and must rely on soil water reserves to buffer the crop from water stress. The objective of this study was to determine grain and biomass yield response of corn hybrids to different irrigation capacities. Field studies were conducted at the KSU-NWREC near Colby, KS and KSU-SWREC near Garden City, KS from 2014 to 2017. An additional site at KSU-SWREC near Tribune, KS was conducted from 2015 to 2017. The studies were a factorial design of irrigation capacities (ranging from 0.08 to 0.25 inch/day) and corn hybrids (drought tolerant and conventional). Additional seeding rates and hybrids were included at the Tribune site. Average grain yields increased 7 to 15% when increasing irrigation capacity from about 0.08 to 0.25 inch/day. Yield increases were due to an increase in the number of kernels/ear, greater seed mass or both components. Grain yields were not increased by use of a drought tolerant hybrid. At one site with a seeding rate variable, increasing seeding rate from 24,000 to 40,000 kernels/acre increased grain yields an average of 14% with some increase observed at all irrigation capacities.

INTRODUCTION

Irrigated crop production is a mainstay of agriculture in western Kansas. However, with declining water levels in the Ogallala aquifer, optimal utilization of limited irrigation water is required. The most common crop grown under irrigation in western Kansas is corn (about 50% of the irrigated acres). Almost all of the groundwater pumped from the High Plains (Ogallala) Aquifer is used for irrigation. Irrigators are faced with the problem of declining well capacities due to water withdrawals from the Ogallala aquifer for irrigation exceeding mean annual recharge. In addition to limited well capacities, public policy may also impose limits on total amounts of water that can be pumped. For example the 20% reduction in pumped water that is being implemented as part of a Local Enhanced Management Area (LEMA) policy in parts of Groundwater Management District (GMD) 4 and several Water Conservation Areas (WCAs) that have been implemented in GMD 1 and GMD 3. One of the major challenges facing irrigated corn producers in Kansas is how to maintain or increase yields under declining well capacities or limited water supplies.

The major corn seed companies have extensive hybrid development work underway in the western Corn Belt to develop hybrids that are drought tolerant. The overall goal is to develop hybrids that will not incur a yield reduction under ideal conditions, yet stabilize yield under water-stressed conditions. A major secondary trait associated with drought tolerance in corn is the shortening of the anthesis to silk interval (ASI) which has a strong influence on biomass partitioning (Bolaños and Edmeades, 1996). The flowering period of corn often coincides with the period of greatest irrigation demand and consequently a limited irrigation capacity during this critical stage can markedly affect the ASI, biomass partitioning, and grain yield.

Although corn yields have increased greatly during the last 30 years, much of the increase can be attributed to achieving greater final kernel set at higher plant densities (i.e., greater number of kernels/unit area). However, Lobel et al. (2014) suggested that greater plant densities result in greater sensitivity to drought.

Most of the irrigation systems today in the Central Great Plains no longer have the capacity to apply peak irrigation needs during the summer and must rely on soil water reserves to buffer the crop from water stress. Therefore, this study was conducted to evaluate whether management factors such as hybrid selection and seeding rate can be used to increase productivity when well capacity is limited and insufficient to fully meet crop requirements.

MATERIALS AND METHODS

Field studies were conducted at three sites in Kansas (in cooperation with another site near Bushland, TX). All sites evaluated multiple irrigation capacities and corn hybrids but some treatments differed among sites. At the NWREC near Colby and SWREC near Garden City, whole-plot treatments were sprinkler irrigation capacities of 1 inch every 4, 6, 8, 10, or 12 d (0.25, 0.17, 0.13, 0.10, and 0.08 inch/day, respectively) in randomized complete block designs. Garden City also had a dryland treatment. Two DeKalb corn hybrids DKC 62-27 DGVT2PRO (DroughtGard) and DKC 62-98 VT2PRO planted at 32,000 seeds/acre were superimposed as split plot treatments. At the SWREC site near Tribune, the whole plot treatments were sprinkler irrigation capacities of 1.5 inch every 1, 2, or 3 weeks (approximates about 1 inch every 4, 8, or 12 days) in a randomized complete block design. Subplots were three corn hybrids (the two Dekalb hybrids along with Pioneer P1151AMX [AquaMax]) at three seeding rates (24,000, 32,000, and 40,000 seeds/acre).

Corn was planted in late April to early May under lateral move sprinkler systems at all locations. Irrigations were scheduled as needed according to weather- or soil- based water budgets, but limited to the irrigation capacity treatments as indicated in the specific site procedures. Soil water was measured in the complete root zone (0 to 240 cm) periodically throughout the season to help quantify periods of water stress and to determine crop water use. Weather data was measured using automated weather stations that exist on all sites and phenological and growth stages data were recorded throughout the growing season. Corn grain yield was determined by harvesting a representative sample at physiological maturity. Determinations were made of all corn yield components; (grain yield, plant density, ears/plant, kernels/ear, and kernel mass) as well as the important intermediate yield component, kernels/area. Total dry aboveground biomass was also determined through destructive sampling of 5 adjacent plants and drying the samples and weighing the resultant sample.

Crop water use was calculated by summing soil water depletion (soil water at planting less soil water at harvest) plus in-season irrigation and precipitation. In-season irrigations and precipitation amounts at each site-year are shown in Table 1. Crop water productivity (CWP) was calculated by dividing grain yield (lb a^{-1}) by crop water use (in).

RESULTS AND DISCUSSION

Growing conditions were generally favorable during the years of this study. At Colby, growing season precipitation (May through August) was above normal 3 years of the 4 years (Table 1). At Garden City, growing season precipitation was above normal in 3 of the 4 years and, at Tribune, precipitation was above normal every year. However, at Tribune in 2017, hail damage caused some reduction in grain yield.

Colby

Averaged across 4 years, grain yields were increased about 7% (16 bu/a) by increasing irrigation capacity from 1 inch every 12 days to 1 inch every 4 days (Table 2). This was due mainly to an increase in number of kernels/ear. Biomass was also increased by increasing irrigation capacity. Crop water productivity decreased with increased irrigation capacity. There was little difference (5 bu/a or less) in grain yield between the conventional and drought tolerant hybrids at any irrigation level with an average of 3 bu/a greater yield with the drought tolerant hybrid. The drought tolerant hybrid had greater number of kernels/ear but less seed mass. Biomass production was least with the lowest irrigation capacity with little difference between hybrids.

Garden City

Irrigation at the lowest capacity (1 inch every 12 days) increased yields 66% (79 bu/a) compared to non-irrigated (Table 3). This was due to increased seed mass and greater number of kernels/ear. Increasing capacity to 1 inch every 4 days increased yields and additional 15% (30 bu/a) due primarily to greater seed mass. Biomass was about 6500 lb/a greater with the lowest irrigation capacity compared to dryland and increased an additional 3000 lb/a with the highest irrigation capacity. Crop water productivity was greater for all irrigation capacities than for dryland. However, CWP was similar for all levels of irrigation capacity. Hybrid selection had little effect on grain yield when averaged across all irrigation capacities (including dryland) with 4 bu/a less yield with the drought tolerant

Tribune

Increasing irrigation capacity from 0.08 inch/day to 0.25 inch/day increased average corn grain yields by 11% due primarily to greater kernel mass and a tendency towards greater number of kernels/ear as there were no differences in plant or ear population (Table 2). Increasing seeding rate from 24,000 to 40,000 seeds/acre increased average yields by about 14%. The increase in seeding rate and corresponding increase in ear population more than made up for the decreases in kernel mass and kernels/ear. The total number of kernels/ft^2 was increased with increased seeding rate. The drought tolerant hybrid did not produce greater yield than the conventional hybrid. The conventional hybrid had greater plant and ear populations, and kernel mass than the drought tolerant hybrids but fewer number of kernels/ear. Total biomass production was also greater for the conventional hybrid. Increasing seeding rate and irrigation capacity also increased biomass production. Crop water productivity was increased by increased seeding rate but decreased by increased irrigation capacity. Crop water productivity was greater with the conventional hybrid than the drought tolerant hybrids.

CONCLUSIONS

Increasing irrigation capacity from about 0.08 to 0.25 inch/day increased average grain yields at all sites with the magnitude of the increase ranging from 7 to 15%. The yield increase was due to an increase in the number of kernels/ear and/or greater seed mass. Grain yields were generally similar for the conventional and drought tolerant hybrids. At the site with a population variable, increasing seeding rate from 24,000 to 40,000 kernels/acre increased grain yields an average of 14% with some increase observed at all irrigation capacities. Crop water productivity decreased with increased irrigation capacity at two sites and was similar for all irrigation capacities at the other site.

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Table 1. Growing season precipitation (May to August) and in-season irrigation amounts at Colby, Garden City, and Tribune from 2014 to 2017.

Year	Colby	Garden City	Tribune
Precipitation		inches	
2014	13.28	16.93	--
2015	15.94	16.37	13.78
2016	7.61	12.35	14.19
2017	16.05	7.20	15.63
Normal	12.25	11.41	10.50
Irrigation			
2014	7.5 – 13.4	5.0 – 12.0	--
2015	6.7 – 15.4	4.0 – 8.0	6.1 – 15.3
2016	7.7 – 14.4	3.0 – 9.0	6.2 – 12.1
2017	7.7 – 14.4	5.0 – 12.0	6.0 – 14.1

Table 2. Average crop parameters as affected by irrigation capacity and corn hybrids, Colby, KS, 2014 - 2017.

Irrigation	Hybrid	yield	CWP†	Plant pop.	Ear pop.	1000 seed	Kernels		Biomass
1" per		bu/a	lb/in	- - 10^3/acre - -		oz	no/ear	no/foot^2	lb/a
4 days	DKC 62-98	248	472	33.5	33.6	12.51	537	414	21737
	DKC 62-27 DG	251	479	33.1	33.2	10.96	623	475	23311
6 days	DKC 62-98	245	502	33.2	33.2	12.51	535	408	22748
	DKC 62-27 DG	248	507	33.3	32.7	10.83	643	482	22671
8 days	DKC 62-98	242	519	33.5	33.3	12.51	528	403	22071
	DKC 62-27 DG	243	519	33.4	33.1	11.01	603	459	22642
10 days	DKC 62-98	243	568	33.4	33.2	12.48	535	408	22028
	DKC 62-27 DG	245	546	33.1	33.0	10.79	631	478	22070
12 days	DKC 62-98	232	521	33.4	33.4	12.56	504	386	20513
	DKC 62-27 DG	237	537	33.1	33.0	10.73	604	458	21779
MEANS									
4 days		250	475	33.3	33.4	11.74	580	445	22529
6 days		246	504	33.3	32.9	11.67	589	446	22709
8 days		242	519	33.4	33.2	11.76	565	431	22357
10 days		244	557	33.3	33.1	11.64	583	443	22050
12 days		234	529	33.3	33.2	11.65	554	422	21149
	DKC 62-98	242	516	33.4	33.3	12.52	528	404	21821
	DKC 62-27 DG	245	517	33.2	33.0	10.87	621	470	22494
2014		238	499	32.9	33.0	11.81	551	418	22155
2015		249	473	32.9	32.9	11.21	616	465	22061
2016		238	585	32.9	32.5	11.33	601	448	21516
2017		249	511	34.4	34.3	12.41	529	416	- - -

† CWP = crop water productivity.

Table 3. Average crop parameters as affected by irrigation capacity and corn hybrids, Garden City, KS, 2014 - 2017.

Irrigation	Hybrid	yield	CWP†	Plant pop.	Ear pop.	1000 seed	Kernels		Biomass
1" per		bu/a	lb/in	- - 10^3/acre - -		oz	no/ear	no/foot^2	lb/a
4 days	DKC 62-98	230	601	29.8	29.8	16.98	406	290	20888
	DKC 62-27 DG	226	549	27.8	27.8	14.47	474	308	20802
6 days	DKC 62-98	218	591	29.0	28.8	17.01	404	275	19707
	DKC 62-27 DG	214	568	27.8	27.7	14.70	461	299	19882
8 days	DKC 62-98	219	622	29.9	29.9	17.13	379	263	19642
	DKC 62-27 DG	219	606	28.0	27.6	14.01	495	320	19707
10 days	DKC 62-98	207	624	29.9	29.7	15.65	396	272	17852
	DKC 62-27 DG	195	608	27.0	26.6	13.37	493	309	17242
12 days	DKC 62-98	202	613	30.6	30.2	15.27	367	250	17798
	DKC 62-27 DG	195	555	28.0	27.9	12.23	478	316	17767
Dryland	DKC 62-98	119	427	28.8	27.6	11.26	332	192	11452
	DKC 62-27 DG	119	446	28.0	27.8	8.99	405	258	10987
MEANS									
4 days		228a	575a	28.8	28.8	15.72a	440a	299a	20845a
6 days		216ab	580a	28.4	28.3	15.86a	432a	287a	19794a
8 days		219ab	614a	28.9	28.7	15.57a	437a	291a	19674a
10 days		201b	616a	28.5	28.2	14.51b	445a	290a	17547b
12 days		198b	584a	29.3	29.0	13.75b	422a	283a	17783b
Dryland		119c	437b	28.4	27.7	10.13c	369b	225b	11219c
$LSD_{0.05}$		25	85	1.6	1.7	0.80	43	31	1783
	DKC 62-98	199	580	29.7a	29.3a	15.55a	381b	257b	17890
	DKC 62-27 DG	195	555	27.8b	27.6b	12.96b	468a	302a	17731
	$LSD_{0.05}$	8	30	0.8	0.9	0.58	20	15	807
2014		175b	635a	29.9a	29.3a	13.16b	392b	265b	15711c
2015		184b	538b	27.2c	27.1b	- - -	- - -	- - -	17910b
2016		217a	529b	28.6b	28.2ab	15.53a	456a	294a	19809a
2017		211a	- - -	29.2ab	29.1a	- - -	- - -	- - -	- - -
$LSD_{0.05}$		11	37	1.2	1.2	0.58	20	15	988
<u>ANOVA (P>F)</u>									
Irrigation		0.001	0.004	0.803	0.528	0.001	0.016	0.001	0.001
Hybrid		0.284	0.116	0.001	0.001	0.001	0.001	0.001	0.697
Hybrid*Irrigation		0.947	0.739	0.678	0.330	0.908	0.412	0.259	0.993
Year		0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001

† CWP = crop water productivity

Table 4. Average crop parameters as affected by irrigation capacity, corn hybrids, and seeding rate, Tribune, KS, 2015 - 2017.

Irrigation	Hybrid	Seed Rate	yield	CWP†	Plant pop.	Ear pop.	1000 seed	Kernels		Biomass
1” per		10^3/acre	bu/a	lb/in	- - 10^3/acre - -		oz	no/ear	no/foot^2	lb/a
4 days	DKC 62-98	24	211	414	24.3	24.0	14.01	566	312	17302
		32	233	454	32.5	32.0	13.68	478	351	19096
		40	235	449	39.7	39.0	13.22	411	368	23180
	DKC 62-27 DG	24	199	398	23.3	23.2	11.96	649	344	16994
		32	222	426	30.8	30.0	11.42	587	402	19272
		40	229	452	36.8	35.3	11.19	528	425	20805
	P1151 AMX	24	191	375	21.8	22.7	13.31	572	297	15088
		32	201	386	27.7	27.3	12.44	537	338	16363
		40	235	456	36.4	35.7	12.12	493	404	19351
8 days	DKC 62-98	24	199	460	23.4	23.2	13.82	560	298	16029
		32	220	498	32.9	32.1	13.00	470	347	19397
		40	223	511	39.3	38.2	12.90	407	356	20203
	DKC 62-27 DG	24	185	410	23.0	22.5	11.66	634	326	15184
		32	205	449	30.5	30.2	11.07	553	381	16615
		40	206	465	35.8	35.1	10.77	500	397	18419
	P1151 AMX	24	180	407	21.5	21.6	12.90	586	290	14354
		32	200	464	28.6	28.0	12.42	522	334	16910
		40	203	458	34.3	33.5	12.07	483	353	17213
12 days	DKC 62-98	24	183	449	23.6	23.5	13.44	517	279	15684
		32	190	460	31.6	31.5	12.54	426	309	17611
		40	214	518	38.7	38.1	12.54	399	350	19109
	DKC 62-27 DG	24	181	438	22.9	23.3	11.21	623	332	14568
		32	206	481	30.4	30.3	10.72	567	395	16723
		40	195	465	38.3	37.8	10.33	449	390	18484
	P1151 AMX	24	180	433	22.2	23.1	12.67	558	293	14965
		32	201	484	29.1	28.9	11.94	525	348	15512
		40	203	477	35.1	34.7	11.82	452	359	16513

† CWP = crop water productivity. ** Hail event on 8/18/17 **

Table 4 (cont.). Average crop parameters as affected by irrigation capacity, corn hybrids, and seeding rate, Tribune, 2015 - 2017.

Irrigation	Hybrid	Seed rate	yield	CWP[1]	Plant pop.	Ear pop.	1000 seed	Kernels		Biomass
1” per		10^3/a	bu/a	lb/in	- - 10^3/acre - -		oz	no/ear	no/foot[2]	lb/a
MEANS										
4 days			217a	423b	30.4	29.9	12.59a	536	360	18606a
8 days			202b	458a	29.9	29.4	12.29ab	524	343	17147b
12 days			195b	467a	30.2	30.1	11.91b	502	339	16575b
LSD $_{0.05}$			13	30	1.7	1.7	0.46	31	24	1419
	DKC 62-98		212a	468a	31.8a	31.3a	13.24a	470c	330b	18624a
	DKC 62-27 DG		203b	443b	30.2b	29.7b	11.15c	565a	377a	17452b
	P1151 AMX		199b	438b	28.5c	28.4c	12.41b	525b	335b	16252c
	LSD $_{0.05}$		7	15	0.9	0.9	0.19	15	12	734
		24	190c	420c	22.9c	23.0c	12.78a	585a	308c	15574c
		32	208b	456b	30.5b	30.0b	12.14b	518b	356b	17500b
		40	216a	472a	37.2a	36.4a	11.88c	458c	378a	19253a
		LSD $_{0.05}$	7	15	0.9	0.9	0.19	15	12	734
		2015	182c	438b	27.3b	26.8c	12.66b	502c	297c	14918c
		2016	223a	444b	31.7a	30.7b	12.97a	519b	355b	19636a
		2017	209b	467a	31.5a	31.9a	11.17c	541a	389a	17774b
		LSD $_{0.05}$	7	15	0.9	0.9	0.19	15	12	734
ANOVA (P>F)										
Irrigation			0.015	0.028	0.826	0.573	0.030	0.089	0.152	0.031
Seed rate			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Seed rate*Irrigation			0.605	0.755	0.719	0.750	0.972	0.697	0.563	0.182
Hybrid			0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Hybrid*Irrigation			0.232	0.169	0.770	0.562	0.701	0.641	0.325	0.413
Hybrid*Seed rate			0.600	0.925	0.312	0.099	0.958	0.024	0.452	0.542
Irrigation*Seed rate*Hybrid			0.521	0.206	0.819	0.894	0.890	0.397	0.553	0.766
Year			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

† CWP = crop water productivity * Hail event on 8/18/17