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Optimal Corn Management with Diminished Well Capacities

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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. Considerable research was conducted on preseason irrigation in the US Great Plains region during the 1980s and 1990s. In general, the conclusions were that in-season irrigation was more beneficial than preseason irrigation and that often preseason irrigation was not warranted. The objective of this study was to determine whether preseason irrigation would be profitable with today's lower capacity wells. A field study was conducted at the KSU-SWREC near Tribune, KS, from 2006 to 2009. The study was a factorial design of preplant irrigation (0 and 75 mm), well capacities (2.5, 3.8, and 5 mm day^{-1} capacity), and plant population (55,000, 68,000, and 80,000 plants ha^{-1}). Preseason irrigation increased grain yields an average of 1.0 Mg ha^{-1}. Grain yields were 29% greater when well capacity was increased from 2.5 to 5.0 mm day^{-1}. Water use efficiency was not significantly affected by well capacity or preseason irrigation. Preseason irrigation was profitable at all well capacities. At well capacities of 2.5 and 3.8 mm day^{-1}, a seeding rate of 68,000 seeds ha^{-1} was generally more profitable than lower or higher seeding rates. A higher seeding rate (80,000 seeds ha^{-1}) increased profitability when well capacity was increased to 5 mm day^{-1}.*

Keywords. Preseason irrigation, well capacity, corn, irrigation management

Introduction

Irrigated crop production is a mainstay of agriculture in western Kansas. However, with declining water levels in the Ogallala aquifer and increasing energy costs, 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 (97% of the groundwater pumped in western Kansas in 1995 [Kansas Department of Agriculture, 1997]). In 1995, of 3 billion m^3 of water pumped for irrigation in western Kansas, 1.41 million acre-ft (57%) were applied to corn (Kansas Water Office, 1997). This amount of water withdrawal from the aquifer has reduced saturated thickness (up to 45 m in some areas) and well capacities.

Considerable research was conducted on preseason irrigation in the US Great Plains region during the 1980s and 1990s (Stone et al., 1983, 1987, and 1994; Lamm and Rogers, 1985; Musick and Lamm, 1990; Rogers and Lamm, 1994). In general, the conclusions were that in-season irrigation was more beneficial than preseason irrigation and that often preseason irrigation was not warranted because overwinter precipitation could replenish a significant portion of the soil water profile. Much of this research was conducted during a generally wetter climatic period in the Great Plains and also under circumstances of ample in-season irrigation capacity. The Great Plains drought that occurred during the early part of the last decade (2000-2009) renewed producer interest and has brought new questions about preseason irrigation. In a more recent study Stone et al. (2008) used simulation modeling to examine the effectiveness of preseason irrigation. They found the differences in storage efficiency between spring and fall irrigation peaked at approximately 37 percentage points (storage efficiency of approximately 70% for spring and 33% for fall irrigation) when the maximum soil water during the preseason period was at approximately 77% of available soil water.

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. Therefore, this study was conducted to evaluate whether preseason irrigation would be profitable when well capacity is limited and insufficient to fully meet crop requirements.

Materials and Methods

A field study was conducted at the KSU-SWREC near Tribune, KS from 2006 to 2009. Growing season precipitation (April through September) was 188, 328, 266, and 461 mm in 2006, 2007, 2008, and 2009, respectively. Normal precipitation for the growing season is 319 mm and normal annual precipitation is 443 mm. The study was a factorial design of preseason irrigation (0 and 75 mm), well capacities (2.5, 3.8, and 5 mm day^{-1} capacity), and plant population (55,000, 68,000, and 80,000 plants ha^{-1}). The irrigation treatments were whole plots and the plant populations were subplots. Each treatment combination was replicated four times and applied to the same plot each year. The irrigation treatments were applied with a lateral-move sprinkler with amounts limited to the assumed well capacities. The preseason irrigations were applied in early April and in-season irrigations were applied from about mid-June to early September. The in-season irrigations were generally applied weekly except when precipitation was sufficient to meet crop needs. Corn was planted in late April or early May each year. The center two rows of each plot were machine harvested with grain yields adjusted to 0.155 g g^{-1} moisture (wet basis). Plant and ear populations were determined by counting plants and ears in the center two rows prior to harvest. Seed weights (oven-dried) were determined on 100-count samples from each plot. Kernels per ear were calculated from seed weight, ear population, and grain yield. Soil water measurements (2.4 m depth in 30 cm increments) were taken throughout the growing season using neutron attenuation. All water inputs, precipitation and irrigation, were measured.

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 were 243, 320, and 483 mm in 2006; 183, 257, and 397 mm in 2007; 209, 278, and 375 mm in 2008; and 225, 299, and 453 mm in 2009 for the 2.5, 3.8, and 5.0 mm day^{-1} well capacity treatments, respectively. In-season precipitation was 176 mm in 2006, 205 mm in 2007, 238 mm in 2008; and 364 mm in 2009. Non-growing season soil water accumulation was the increase in soil water from harvest to the amount at planting the following year. Non-growing season precipitation was 381 mm in 2007, 107 mm in 2008, and 217 mm in 2009 with an average of 235 mm. Precipitation storage efficiency (without preseason irrigation) was calculated as non-growing season soil water accumulation divided by non-growing season precipitation. Water use efficiency was calculated by dividing grain yield (kg ha^{-1}) by crop water use (mm). Local corn prices ($3.39, 4.80, 3.96, and 3.46 in 2006, 2007, 2008, and 2009, respectively), crop input costs, and custom rates were used to perform an economic analysis to determine net return to land, management, and irrigation equipment for each treatment.

Results and Discussion

Preseason irrigation increased grain yields an average of 1.0 Mg ha^{-1} (Table 1). Although not significant, the effect was greater at lower well capacities. For example, with 68,000 plants ha^{-1}, preseason irrigation (75 mm) increased grain yield by 1.3 Mg ha^{-1} with a well capacity of 2.5 mm day^{-1} while only 0.4 Mg ha^{-1} with a well capacity of 5 mm day^{-1}. As expected, grain yields increased with increased well capacity. Grain yields (averaged across preseason irrigation and plant population) were 29% greater when well capacity was increased from 2.5 to 5.0 mm day^{-1}. Preseason irrigation and increased well capacity increased the number of seeds ear^{-1} but had little impact on seed weight.

The optimum plant population varied with irrigation level. With the two lowest well capacities and without preseason irrigation, a plant population of 55,000 plants ha^{-1} was generally adequate. However, if preseason irrigation was applied, then a higher plant population (68,000 plants ha^{-1}) increased yields. With a well capacity of 5 mm day^{-1}, a plant population of 80,000 plants ha^{-1} provided greater yields with or without preseason irrigation.

Water use efficiency was not significantly affected by well capacity or preseason irrigation (Table 1), although the trend was for greater WUE with increased water supply. Similar to grain yields, the effect of plant population varied with irrigation level. With lower irrigation levels, a plant population of 68,000 plants ha^{-1} tended to optimize water use efficiency. It was only at the highest well capacity that higher plant populations improved water use efficiency.

Crop water use increased with well capacity and preseason irrigation (Table 2). Soil water at harvest increased with increased well capacity, but this caused less soil water to accumulate during the winter. Non-growing season soil water accumulation averaged 69 mm (without preseason irrigation). Average non-growing season precipitation was 235 mm giving an average non-growing season precipitation storage efficiency of 29%. Preseason irrigation (about 75 mm) increased available soil water at planting by 58 mm. Seeding rate had minimal effect on soil water at planting or crop water use but increased seeding rate tended to decrease soil water at harvest and increase over-winter water accumulation.

Preseason irrigation was found to be profitable at all irrigation capacities (Table 3). At the two lower well capacities, a seeding rate of 68, 000 seeds ha^{-1} was generally the most profitable. However, the highest irrigation capacity benefited from a seeding rate of 80,000 seeds ha^{-1}.

Conclusions

Corn grain yields responded positively to preseason irrigation and increases in well capacity. This yield increase generally resulted from increases in kernels ear^{-1}. Preseason irrigation was profitable at all well capacities. Seeding rate should be adjusted for the amount of irrigation water available from both well capacity and preseason irrigation. At well capacities of 2.5 and 3.8 mm day^{-1}, a seeding rate of 68,000 seeds ha^{-1} was generally more profitable than lower or higher seeding rates. A higher seeding rate (80,000 seeds ha^{-1}) increased profitability when well capacity was increased to 5 mm day^{-1}.

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Table 1. Crop parameters as affected by well capacity, preseason irrigation (0 or 75 mm), and seeding rate. Tribune, KS 2006-2009.

Well capacity	Pre-season irrig.	Seed rate	Grain yield	Water use eff.	Plant pop.	Ear pop.	1000 seed	Kernel
mm day^{-1}		10^3 ha^{-1}	Mg ha^{-1}	kg ha^{-1}mm^{-1}	- - 10^3	ha^{-1} - -	g	# / ear
2.5	No	56	9.6	17.0	55.3	53.0	317	476
		68	9.9	17.5	66.1	61.0	306	442
		80	9.7	17.2	77.1	71.2	299	379
	Yes	56	10.7	17.8	54.1	53.0	322	531
		68	11.2	18.3	66.0	62.6	316	478
		80	11.5	18.5	77.9	73.1	307	427
3.8	No	56	10.8	17.2	54.9	52.5	318	543
		68	10.9	17.4	66.6	64.0	310	465
		80	10.7	16.9	76.8	72.2	308	406
	Yes	56	11.6	17.8	55.4	54.2	321	563
		68	12.3	19.0	66.7	64.6	314	512
		80	12.6	19.1	77.6	74.7	307	466
5.0	No	56	12.6	17.8	55.0	54.3	319	615
		68	13.3	18.3	66.7	66.1	312	544
		80	14.0	19.4	78.5	77.2	306	503
	Yes	56	12.8	17.5	54.7	54.1	326	617
		68	13.7	18.3	66.6	66.2	319	551
		80	14.4	19.2	78.7	77.1	306	517
			ANOVA (Probability>F)					
Well capacity (WC)			0.001	0.411	0.086	0.001	0.687	0.001
Preseason			0.002	0.099	0.659	0.107	0.160	0.001
WC*Preseason			0.222	0.297	0.452	0.401	0.752	0.138
Seed rate			0.001	0.001	0.001	0.001	0.001	0.001
Seed rate*WC			0.001	0.018	0.012	0.001	0.212	0.176
Seed rate*Preseason			0.018	0.126	0.089	0.345	0.186	0.263
Seed rate *WC*Preseason			0.402	0.626	0.427	0.373	0.518	0.295
MEANS	Well cap.	2.5	10.4	17.7	66.1	62.3	311	456
		3.8	11.5	17.9	66.3	63.7	313	493
		5.0	13.4	18.4	66.7	65.8	315	558
		$LSD_{0.05}$	0.7	1.1	0.5	1.3	8	21
	Preseason	No	11.3	17.6	66.3	63.5	311	486
		Yes	12.3	18.4	66.4	64.4	315	518
		$LSD_{0.05}$	0.6	0.9	0.4	1.1	7	17
	Seed rate	56	11.3	17.5	54.9	53.5	321	558
		68	11.9	18.1	66.5	64.1	313	499
		80	12.2	18.4	77.8	74.2	306	450
		$LSD_{0.05}$	0.2	0.4	0.4	0.6	2	10

Table 2. Available soil water in a 2.4 m profile, crop water use, and non-growing season water accumulation for corn as affected by well capacity, preseason irrigation, and seeding rate, Tribune, 2006-2009.

Well capacity	Preseason irrigation	Seed rate	Available soil water: Planting	Available soil water: Harvest	Water use	Non-growing season accumulation
$mm\ day^{-1}$		$10^3\ ha^{-1}$	mm in 2.4 m profile		- - - - - - mm	- - - - -
2.5	no	56	212	132	541	71
		68	209	123	547	69
		80	204	118	547	71
	yes	56	271	138	593	128
		68	267	124	604	135
		80	275	126	610	135
3.8	no	56	223	139	618	69
		68	233	154	613	65
		80	230	144	620	76
	yes	56	267	157	644	103
		68	266	156	644	121
		80	272	152	654	128
5.0	no	56	267	230	710	54
		68	253	200	726	77
		80	268	217	725	72
	yes	56	341	275	739	80
		68	336	257	751	93
		80	328	250	751	90
		ANOVA (Probability>F)				
Well capacity (WC)			0.010	0.001	0.001	0.001
Preseason irrigation			0.001	0.266	0.001	0.001
WC*Preseason irrigation			0.647	0.587	0.010	0.001
Seed Rate			0.779	0.076	0.001	0.002
Seed Rate*WC			0.692	0.173	0.059	0.156
Seed Rate*Preseason irrigation			0.985	0.820	0.546	0.424
Seed Rate *WC*Preseason irr.			0.389	0.625	0.749	0.303
MEANS	Well capacity	2.5	240	127	574	101
		3.8	248	150	632	94
		5.0	299	238	734	78
		$LSD_{0.05}$	38	45	10	10
	Preseason irr.	No	233	162	627	69
		Yes	291	182	666	113
		$LSD_{0.05}$	31	37	8	8
	Seed rate	56	264	179	641	84
		68	261	169	648	93
		80	263	168	651	95
		$LSD_{0.05}$	9	10	5	6

Note: Fallow accumulation includes only 2007, 2008, and 2009 data.

Table 3. Net return to land, irrigation equipment, and management from preseason irrigation (0 or 75 mm) at three irrigation capacities and three seeding rates at Tribune, KS 2006-2009.

Well capacity	Preseason Irrigation	Seeding rate (10^3 ha^{-1}) 56	68	80
mm day^{-1}		\$ ha^{-1} yr^{-1}		
2.5	No	566	585	524
	Yes	698	737	730
3.8	No	713	694	640
	Yes	788	865	878
5.0	No	1015	1099	1188
	Yes	1019	1120	1204