MANAGING DIMINISHED IRRIGATION CAPACITY WITH PRESEASON IRRIGATION AND PLANT DENSITY FOR CORN PRODUCTION

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ABSTRACT. *Many of the irrigation systems today in the U.S. Central Great Plains no longer have the capacity to match 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 U.S. 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 preseason irrigation was often not warranted. The objective of this study was to determine whether preseason irrigation would be profitable with today's lower-capacity groundwater wells at different levels of corn plant density. A field study was conducted at the Kansas State University Southwest Research-Extension Center near Tribune, Kansas, from 2006 to 2009. The study was a factorial design of preseason irrigation (0 and 75 mm), irrigation capacities (2.5, 3.8, and 5.0 mm d^{-1}), and plant density (56,000, 68,000, and 80,000 plants ha^{-1}). Preseason irrigation increased grain yields an average of 1.0 Mg ha^{-1}. Grain yields were 28% greater when irrigation capacity was increased from 2.5 to 5.0 mm d^{-1}. Crop water productivity was not significantly affected by irrigation capacity or preseason irrigation. Preseason irrigation was profitable at all irrigation capacities, although only slightly profitable at the highest irrigation capacity. Therefore, it may not be prudent to preseason irrigate with irrigation capacities of 5.0 mm d^{-1} or greater so that the water can be conserved for later use. At irrigation capacities of 2.5 and 3.8 mm d^{-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 irrigation capacity was increased to 5.0 mm d^{-1}.*

Keywords. *Corn, Irrigation capacity, Irrigation management, Preseason irrigation.*

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; KSDA, 1997). In 1995, 3 billion m^3 of water were pumped for irrigation in western Kansas, and 1.71 billion m^3 (57%) were applied to corn (KWO, 1997). This amount of water withdrawal from the aquifer reduced the saturated thickness in some areas by more than 45 m by the year 2003 (McGuire, 2004) and has also reduced pumping flow rates. Similar problems exist in many parts of the High Plains aquifer, particularly in the Southern High Plains.

Considerable research was conducted on preseason irrigation (also referred to as preplant, off-season, or dormant season) in the U.S. Great Plains region during the 1980s and 1990s (Stone et al., 1983, 1987, 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 preseason irrigation was often not warranted because overwinter precipitation could replenish a significant portion of the soil water profile. In a survey from the late 1980s that assessed water management practices of irrigators, 65% of the 455 respondents from western Kansas, western Texas, and the Oklahoma Panhandle reported that they used off-season irrigation (Kromm and White, 1990). Preseason irrigation is an irrigation management technique that is relatively unique to the semi-arid Great Plains region; it is not usually needed in the humid and semi-humid regions and is not utilized in the arid region because irrigation systems are typically designed to apply peak irrigation requirements. The Great Plains also has nearly vertical precipitation isobars (i.e., lines of nearly equal annual precipitation amounts coinciding with longitudinal lines), thus

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Table 1. Irrigation and precipitation amounts in a sprinkler-irrigated corn study, KSU Southwest Research-Extension Center, Tribune, Kansas, 2006-2009.

		2006	2007	2008	2009
Preseason irrigation	Application date	April 4	April 24	April 12	April 17
In-season irrigation	Initial application date	May 27	June 22	June 13	June 19
	Final application date	Aug. 28	Aug. 31	Sept. 5	Sept. 2
	Total amount applied (mm)				
	2.5 mm d^{-1} treatment	243	183	209	225
	3.8 mm d^{-1} treatment	320	257	278	299
	5.0 mm d^{-1} treatment	483	397	375	453
Growing season precipitation	Amount (mm)	176	205	238	364
Non-growing season precipitation	Amount (mm)	--[a]	381	107	217

[a] Non-growing season precipitation was not measured prior to the 2006 crop.

making preseason irrigation research results more useful over the broad north-to-south expanse of the region.

Much of the previous research was conducted during a generally wetter climatic period in the Great Plains and 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 that 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 (ASW).

Corn yield is greatly impacted by irrigation capacity when in-season precipitation is limited. In northwest Kansas, corn yields were increased by approximately 10% when the irrigation capacity was increased from 25 mm every eight days to 25 mm every four days (Lamm et al., 2009). In the same study, increasing plant density from 66,300 to 82,300 plants ha^{-1} increased grain yield (and water productivity) by approximately 6%. In a study with subsurface drip irrigation at the same site, an irrigation capacity of 2.5 mm d^{-1} produced approximately 80% of maximum yield even in an extremely dry year, and an irrigation capacity of 4.3 mm d^{-1} produced near-maximum yields in most years (Lamm and Trooien, 2001). It was also found that increasing plant density from 55,600 to 85,200 plants ha^{-1} generally increased corn yields, particularly in good corn production years, without a yield penalty when irrigation was severely limited or eliminated.

Many of the irrigation systems today in the Central Great Plains are limited by available water resources. They can no longer 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 irrigation capacity is limited and insufficient to fully meet crop requirements.

Materials and Methods

A field study was conducted at the Kansas State University Southwest Research-Extension Center near Tribune, Kansas, from 2006 to 2009 on a deep silt loam soil (Ulysses silt loam; fine-silty, mixed, superactive, mesic Aridic Haplustolls). The region is semi-arid with a summer precipitation pattern and an average annual precipitation of 440 mm. The study was a factorial design of preseason irrigation (0 and 75 mm), irrigation capacity (2.5, 3.8, and 5.0 mm d^{-1}), and plant density (56,000, 68,000, and 80,000 plants ha^{-1}). The irrigation treatments were whole plots, and the plant densities were subplots. Each treatment combination was replicated four times and applied to the same plot each year. The whole plots (irrigation treatments) were approximately 36 m long and 18 m wide, and the plant population subplots were approximately 36 m long and 3 m wide (four 76 cm rows).

Corn was planted in late April or early May each year. The hybrids (Pioneer 33B53 in 2006, Pioneer 33B54 in 2007, Pioneer 34B99 in 2008, and Pioneer 34B94 in 2009) were all resistant to glufosinate and/or glyphosate herbicides. The study area was disked several times in the spring prior to planting to incorporate residue and form a seedbed. Pre-emergence herbicides were used for weed control along with post-emergence applications of glyphosate (2007 and 2009) or glufosinate (2006 and 2008). Nitrogen fertilizer (269 kg N ha^{-1}) as urea-ammonium nitrate was surface applied prior to planting, and P fertilizer (40 kg P_2O_5 ha^{-1}) was applied with the planter. A measured length (approx. 18 m) of the center two rows of all plots was machine harvested with grain yields adjusted to 0.155 g g^{-1} moisture (wet basis). Plant densities were determined along with the other yield components (kernels per ear and kernel mass).

The plots were irrigated with a linear-move sprinkler irrigation system that had been modified to allow water application from different span sections as needed to accomplish the randomization of plots. The preseason irrigation was applied in approximately 38 mm amounts in two passes several days apart to minimize runoff in April (table 1). The in-season irrigations were initiated in late May to mid-late June (table 1). All plots were irrigated in May after planting each year to aid emergence and incorporate herbicides. After in-season irrigations were initiated, the 5.0 mm d^{-1} treatment was applied as a weekly irrigation of about 35 mm, the 3.8 mm d^{-1} treatment was applied as a weekly irrigation of about 25 mm, and the 2.5 mm d^{-1} treatment was applied every two weeks as 35 mm (in conjunction with the 5.0 mm d^{-1} treatment). When abundant precipitation occurred near the time of planned irrigation events, the scheduled irrigations were not performed. This occurred once during the summers of 2006, 2007, and 2008. The final irrigation events were in late August to early September (table 1).

Corn in this region can extract water from a depth of approximately 2.4 m and will easily utilize water on these deep silt loam soils to a depth of 2 m (Lamm et al., 1994). Soil water within the profile was measured throughout the growing season using neutron attenuation (calibrated for this field), with probe activity centered at 0.3 m depth increments from 0.15 through 2.25 m soil depths. Care was taken to ensure that access tubes were installed with the appropriate height above ground so that all measurements were taken at consistent depths. Available soil water was calculated by subtracting unavailable water (measured previously to be 357 mm in the 240 cm profile) from measured soil water. All precipitation and irrigation inputs were measured (table 1). Seasonal crop water use was calculated by summing the soil water depletion (soil water near emergence less soil water at harvest) plus the in-season irrigation and precipitation. Non-growing season soil water accumulation was the increase in soil water from harvest to the amount at emergence the following year. Precipitation storage efficiency (without preseason irrigation) was calculated as non-growing season soil water accumulation divided by non-growing season precipitation. Storage efficiency from preseason irrigation was calculated as the difference between non-growing season accumulation with preseason irrigation compared with no preseason irrigation (averaged across plant densities) divided by the amount of preseason irrigation. Crop water productivity (WP) was calculated as the grain yield (kg ha^{-1}) divided by seasonal crop water use (mm). Statistical analyses were performed using the GLM procedure in SAS (version 9.1, SAS, 2009).

Local crop prices and input costs were used to perform an economic analysis to determine net return to land, management, and irrigation equipment for each treatment. Custom rates were used for all machine operations. Input costs, including the cost of seed ($2.49 per 1000 seeds), were kept uniform for all years. Although irrigation pumping depths (30 to 75 m) and energy sources (e.g., natural gas, electric, and diesel) vary greatly within the region, a representative irrigation cost of $0.157 mm^{-1} was used in all calculations. Harvest prices of corn were $0.133, $0.189, $0.156, and $0.136 kg^{-1} in 2006, 2007, 2008, and 2009, respectively.

Results and Discussion

Weather Conditions and Irrigation Requirements

Growing-season precipitation ranged from 176 mm in 2006 to 364 mm in 2009 (table 1). Normal growing season precipitation is 245 mm; therefore, 2006 and 2007 were drier than normal years, 2009 was a wet year, and 2008 was about average. Temperatures were below normal in 2006, near normal in 2007, near normal in 2008 except for a cool August, and slightly above normal in 2009. In-season irrigations ranged from 183 to 483 mm depending on irrigation capacity and year (table 1). Non-growing season precipitation ranged from 107 mm (2008) to 381 mm (2007), with an average of 235 mm.

Corn Grain Yield Response

Preseason irrigation significantly increased grain yields by an average of 1.0 Mg ha^{-1} (table 2 and fig. 1). Although the interaction with irrigation capacity was not significant, the effect tended to be greater at lower irrigation capacities. For example, with 68,000 plants ha^{-1}, preseason irrigation (75 mm) increased grain yield by 1.3 Mg ha^{-1} with an irrigation capacity of 2.5 mm d^{-1} but only by 0.4 Mg ha^{-1} with an irrigation capacity of 5.0 mm d^{-1}. As might be expected, grain yields increased significantly with increased irrigation capacity. Grain yields (averaged across preseason irrigation and plant density) were 28% greater when the irrigation capacity increased from 2.5 to 5.0 mm d^{-1}. This increase was greater than the 10% yield increase in northwest Kansas for a similar increase in irrigation capacity (Lamm et al., 2009). Preseason irrigation and increased irrigation capacity increased the number of kernels per ear but had little impact on kernel mass.

The optimum plant density varied with irrigation level (table 2 and fig. 1). With the two lowest irrigation capacities and without preseason irrigation, a plant density of 56,000 plants ha^{-1} was generally adequate. However, if preseason irrigation was applied, then a higher plant density (68,000 plants ha^{-1} or greater) increased yields. With an irrigation capacity of 5.0 mm d^{-1}, a plant density of 80,000 plants ha^{-1} provided greater yields with or without preseason irrigation.

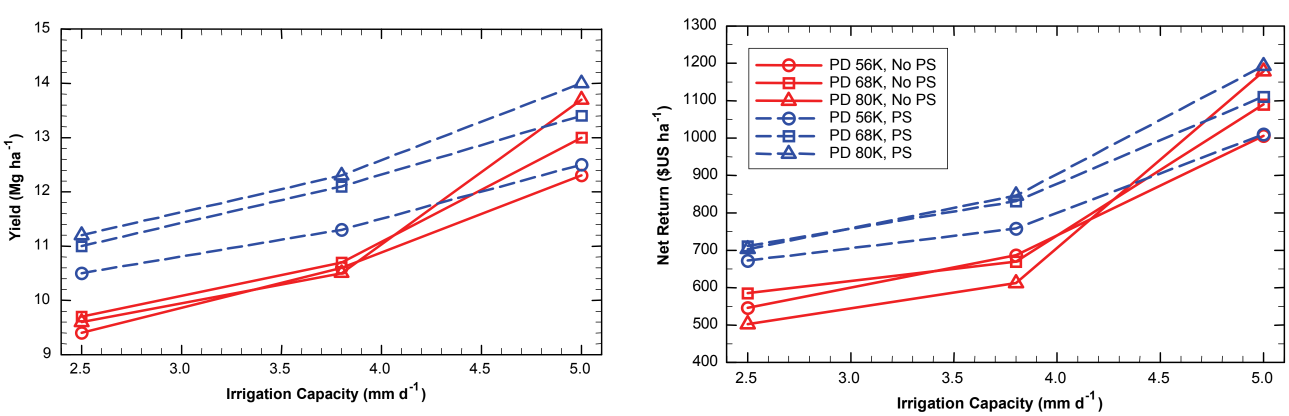

Figure 1. Average corn grain yields and net returns to land, irrigation equipment, and management as affected by irrigation capacity, plant density (PD; 56K, 68K, or 80K plants ha^{-1}) and preseason irrigation (PS; 0 or 75 mm) in a sprinkler-irrigated corn study, KSU Southwest Research-Extension Center, Tribune, Kansas, 2006-2009.

Table 2. Crop parameters as affected by irrigation capacity, preseason irrigation (0 or 75 mm), and seeding rate in a sprinkler-irrigated corn study, KSU Southwest Research-Extension Center, Tribune, Kansas, 2006-2009.

Irrigation Capacity (mm d^{-1})	Preseason Irrigation	Seed Rate (10^3 ha^{-1})	Grain Yield (Mg ha^{-1})	Water Productivity (kg ha^{-1} mm^{-1})	Plant Density (10^3 ha^{-1})	Ear Density (10^3 ha^{-1})	1000-Kernel Mass (g)	Kernels per Ear
2.5	No	56	9.4	16.7	55.3	53.0	317	467
		68	9.7	17.2	66.1	61.0	306	433
		80	9.6	16.8	77.1	71.2	299	371
	Yes	56	10.5	17.4	54.1	53.0	322	520
		68	11.0	18.0	66.0	62.6	316	468
		80	11.2	18.1	77.9	73.1	307	418
3.8	No	56	10.6	16.8	54.9	52.5	318	531
		68	10.7	17.1	66.6	64.0	310	456
		80	10.5	16.5	76.8	72.2	308	396
	Yes	56	11.3	17.4	55.4	54.2	321	551
		68	12.1	18.6	66.7	64.6	314	501
		80	12.3	18.7	77.6	74.7	307	456
5.0	No	56	12.3	17.4	55.0	54.3	319	601
		68	13.0	17.8	66.7	66.1	312	532
		80	13.7	18.9	78.5	77.2	306	491
	Yes	56	12.5	17.0	54.7	54.1	326	602
		68	13.4	17.9	66.6	66.2	319	538
		80	14.0	18.8	78.7	77.1	306	505
ANOVA ($p > F$)								
Irrigation capacity (ICap)			0.001	0.469	0.086	0.001	0.687	0.001
Preseason			0.002	0.103	0.659	0.107	0.160	0.001
ICap × Preseason			0.225	0.303	0.452	0.401	0.752	0.140
Seed rate			0.001	0.001	0.001	0.001	0.001	0.001
Seed rate × ICap			0.001	0.016	0.012	0.001	0.212	0.185
Seed rate × Preseason			0.016	0.114	0.089	0.345	0.186	0.242
Seed rate × ICap × Preseason			0.402	0.623	0.427	0.373	0.518	0.286
Means	Irrigation capacity	2.5	10.3	17.4	66.1	62.3	311	446
		3.8	11.2	17.5	66.3	63.7	313	482
		5.0	13.1	18.0	66.7	65.8	315	545
		$LSD_{0.05}$	0.7	1.1	0.5	1.3	8	21
	Preseason	No	11.0	17.3	66.3	63.5	311	475
		Yes	12.0	18.0	66.4	64.4	315	507
		$LSD_{0.05}$	0.6	0.9	0.4	1.1	7	17
	Seed rate	56	11.1	17.1	54.9	53.5	321	545
		68	11.6	17.7	66.5	64.1	313	488
		80	11.9	18.0	77.8	74.2	306	440
		$LSD_{0.05}$	0.2	0.4	0.4	0.6	2	10

WATER USE PARAMETERS

Water productivity (WP) was not significantly affected by irrigation capacity or preseason irrigation (table 2), although the trend was for greater WP with increased water supply. This contrasts with previous research (Stone et al., 1987; Musick and Lamm, 1990), in which WP was less with preseason irrigation. Similar to grain yields, the effect of plant density varied with irrigation level. With lower irrigation levels, a plant density of 68,000 plants ha^{-1} tended to optimize crop water productivity. It was only at the highest irrigation capacity that higher plant densities improved WP.

Crop water use increased with irrigation capacity and preseason irrigation (table 3). Soil water at harvest increased with increased irrigation capacity, but this resulted in less soil water accumulation during the winter. Non-growing season soil water accumulation averaged 69 mm (without preseason irrigation), storing approximately 29% of the average non-growing season precipitation (235 mm). When preseason irrigation (about 75 mm) was applied, the increase in accumulation of non-growing season water was 62, 47, and 20 mm for the 2.5, 3.8, and 5.0 mm d^{-1} irrigation capacities, respectively. Those values translate into storage efficiencies from preseason irrigation (net gain from gross irrigation amount) of 82%, 62%, and 27% for the 2.5, 3.8, and 5.0 mm d^{-1} irrigation capacities, respectively. The increasing irrigation capacities having increased amounts of available soil water (ASW) at harvest (table 3) are less efficient at storing the preseason irrigation. Similarly, on this Ulysses soil, Stone et al. (2008) found storage efficiency from fall preseason irrigation amounts decreased from 80% to 30% as ASW increased from 60% to 80% of the available water capacity. Available soil water at emergence was 58 mm greater with preseason irrigation from a combination of the storage from preseason irrigation and greater ASW at harvest. By mid-July (near time of silking), the effect of preseason irrigation on ASW had diminished, and although numerically greater (by 33 mm), was not significantly greater than without preseason irrigation. The effect of preseason irrigation was even further reduced at corn harvest, with only 20 mm greater ASW. Increasing irrigation capacity significantly increased ASW throughout

Table 3. Available soil water in a 2.4 m profile, crop water use, and non-growing season water accumulation for corn as affected by irrigation capacity, preseason irrigation, and seeding rate in a sprinkler-irrigated corn study, KSU Southwest Research-Extension Center, Tribune, Kansas, 2006-2009.

Irrigation Capacity (mm d^{-1})	Preseason Irrigation	Seed Rate (10^3 ha^{-1})	Available Soil Water (mm in 2.4 m profile) Emergence	Mid-July	Harvest	Water Use (mm)	Non-Growing Season Accumulation[a] (mm)
2.5	No	56	212	208	132	541	71
		68	209	191	123	547	69
		80	204	189	118	547	71
	Yes	56	271	237	138	593	128
		68	267	220	124	604	135
		80	275	220	126	610	135
3.8	No	56	223	210	139	618	69
		68	233	211	154	613	65
		80	230	213	144	620	76
	Yes	56	267	228	157	644	103
		68	266	231	156	644	121
		80	272	232	152	654	128
5.0	No	56	267	276	230	710	54
		68	253	255	200	726	77
		80	268	269	217	725	72
	Yes	56	341	326	275	739	80
		68	336	316	257	751	93
		80	328	310	250	751	90
ANOVA ($p > F$)							
Irrigation capacity (ICap)			0.010	0.002	0.001	0.001	0.001
Preseason irrigation			0.001	0.062	0.266	0.001	0.001
ICap × Preseason irrigation			0.647	0.726	0.587	0.010	0.001
Seed rate			0.779	0.087	0.076	0.001	0.002
Seed rate × ICap			0.692	0.368	0.173	0.059	0.156
Seed rate × Preseason irrigation			0.985	0.818	0.820	0.546	0.424
Seed rate × ICap × Preseason irrigation			0.389	0.908	0.625	0.749	0.303
Means	Irrigation capacity	2.5	240	211	127	574	101
		3.8	248	221	150	632	94
		5.0	299	292	238	734	78
		$LSD_{0.05}$	38	43	45	10	10
	Preseason irrigation	No	233	225	162	627	69
		Yes	291	258	182	666	113
		$LSD_{0.05}$	31	35	37	8	8
	Seed rate	56	264	247	179	641	84
		68	261	237	169	648	93
		80	263	239	168	651	95
		$LSD_{0.05}$	9	10	10	5	6

[a] Fallow accumulation includes only 2007, 2008, and 2009 data.

the growing season. Seeding rate had minimal effect on ASW at emergence, but increased seeding rate tended to increase crop water use, decrease soil water at harvest, and increase over-winter soil water accumulation.An increase in ASW in the soil profile at emergence from preseason irrigation occurred below 30 cm to a depth of at least 240 cm (extent of measurements) but not in the surface 30 cm (table 4). Lamm et al. (2009) reported no difference in ASW in a 2.4 m soil profile at emergence due to irrigation capacity. However, in the current study, an increase in irrigation capacity resulted in increased ASW at planting from 60 through 180 cm. This suggests that drainage losses will be increased when the amount of irrigation is increased either through preseason irrigation or higher irrigation capacity. The drainage rate for this Ulysses soil was shown to be 5, 1, and 0.1 mm d^{-1} at profile available water amounts of 100%, 85%, and 65% of maximum, respectively (Stone et al., 2008). Seeding rate had no effect on ASW at emergence at any depth in the profile, which agreed with earlier reports (Lamm et al., 2009).

Net Returns

Preseason irrigation was found to be profitable at all irrigation capacities (table 5 and fig. 1), although the difference was minimal at the 5.0 mm d^{-1} irrigation capacity. At the two lower irrigation 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}.

Table 4. Available soil water (mm) at emergence in a 240 cm profile as affected by irrigation capacity, preseason irrigation (0 or 75 mm), and seeding rate in a sprinkler-irrigated corn study, KSU Southwest Research-Extension Center, Tribune, Kansas, 2006-2009.

Irrigation Capacity (mm d^{-1})	Preseason Irrigation	Seed Rate (10^3 ha^{-1})	Soil Depth (cm)							
			0-30	30-60	60-90	90-120	120-150	150-180	180-210	210-240
2.5	No	56	47	29	25	23	23	23	22	21
		68	45	29	26	24	22	21	21	23
		80	46	26	24	22	21	20	21	24
	Yes	56	49	37	35	32	31	29	29	29
		68	48	38	36	32	29	28	28	28
		80	49	36	35	33	32	29	30	31
3.8	No	56	47	30	24	25	24	24	25	24
		68	48	30	27	26	25	26	26	25
		80	47	30	26	25	25	26	26	25
	Yes	56	49	38	34	33	31	29	27	26
		68	50	36	34	33	29	27	30	26
		80	50	39	34	33	31	28	28	29
5.0	No	56	50	36	33	32	30	29	29	29
		68	47	35	32	30	30	29	25	25
		80	49	36	34	32	30	31	29	28
	Yes	56	53	42	45	44	42	41	38	37
		68	52	42	46	43	41	39	38	36
		80	51	43	44	42	40	37	36	34
ANOVA ($p > F$)										
Irrigation capacity (ICap)			0.270	0.088	0.001	<0.001	0.002	0.009	0.052	0.138
Preseason			0.116	0.003	<0.001	<0.001	<0.001	0.012	0.008	0.027
ICap × Preseason			0.934	0.919	0.675	0.685	0.526	0.525	0.476	0.595
Seed rate			0.519	0.687	0.778	0.765	0.535	0.659	0.991	0.346
Seed rate × ICap			0.042	0.072	0.837	0.836	0.836	0.945	0.565	0.297
Seed rate × Preseason			0.387	0.244	0.767	0.932	0.547	0.670	0.664	0.994
Seed rate × ICap × Preseason			0.223	0.818	0.451	0.513	0.670	0.535	0.569	0.451
Means	Irrigation Capacity	2.5	47	33	30	28	26	25	25	26
		3.8	48	34	30	29	27	27	27	26
		5.0	50	39	39	37	35	34	32	31
		$LSD_{0.05}$	4	6	5	4	5	6	6	6
	Preseason	No	47	31	28	27	25	25	25	25
		Yes	50	39	38	36	34	32	32	31
		$LSD_{0.05}$	3	5	4	4	4	5	5	5
	Seed rate	56	49	35	33	32	30	29	28	28
		68	48	35	33	31	29	28	28	27
		80	49	35	33	31	30	29	28	28
		$LSD_{0.05}$	1	1	1	1	2	2	2	2

Table 5. Net return to land, irrigation equipment, and management ($ ha^{-1}) from preseason irrigation (0 or 75 mm) at three irrigation capacities and three seeding rates in a sprinkler-irrigated corn study, KSU Southwest Research-Extension Center, Tribune, Kansas, 2006-2009.

Irrigation Capacity (mm d^{-1})	Preseason Irrigation	Seeding Rate (10^3 ha^{-1})		
		56	68	80
2.5	No	546	561	502
	Yes	672	711	703
3.8	No	686	670	612
	Yes	758	831	846
5.0	No	1006	1090	1178
	Yes	1010	1111	1193

CONCLUSIONS

Corn grain yields responded positively to preseason irrigation and increases in irrigation capacity. This yield increase generally resulted from increases in kernels per ear, suggesting that the grain filling stage was less affected by these two factors. Grain yield increased 28% by increasing the irrigation capacity from 2.5 to 5.0 mm d^{-1}, which is considerably greater than reported in earlier work (Lamm et al., 2009), which showed an increase of 10% with a similar increase in irrigation capacity. Preseason irrigation increased grain yields by approximately 9% and was profitable at all irrigation capacities, although the differences were small at 5.0 mm d^{-1} irrigation capacity. Therefore, it may not be prudent to preseason irrigate with irrigation capacities of 5.0 mm d^{-1} or greater so that the water can be conserved for later use. Seeding rate should be adjusted for the amount of irrigation water available from both irrigation capacity and preseason irrigation. At irrigation capacities of 2.5 and 3.8 mm d^{-1}, a seeding rate of 68,000 seeds ha^{-1} was generally more profitable than lower or higher seeding rates. However, a higher seeding rate (80,000 seeds ha^{-1}) increased profitability when the irrigation capacity was increased to 5.0 mm d^{-1}. With the anticipated continuing decrease of irrigation capacities above the Ogallala Aquifer, producers will need to consider the benefits from adjustment of plant population and limited use of preseason irrigation for profitable corn production.

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