Proceedings of the 24th Annual Central Plains Irrigation Conference, Colby, Kansas, February 21-22, 2012
Available from CPIA, 760 N.Thompson, Colby, Kansas

IRRIGATION CAPACITY IMPACT ON LIMITED IRRIGATION MANAGEMENT AND CROPPING SYSTEMS

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INTRODUCTION

Irrigation capacity is an important issue for irrigation management. Having enough capacity to supplement precipitation and stored soil moisture to meet crop water needs during the growing season to maximize grain yield is important. However, declines in the Ogallala Aquifer have resulted in decreases in well outputs to the point where systems on the fringe of the aquifer can no longer meet crop water needs during average growing seasons and especially during drought years. Changing cropping practices can impact the irrigation management by irrigating crops that have different water timing needs so that fewer acres are irrigated at any one point during the growing season and concentrating the irrigation capacity on fewer acres while still irrigating the majority or all acres during the year.

Many producers have not changed cropping practices with marginal capacity systems due to management increases and the potential for an above-average year. However, the risk of producing lower yields increases. Crop insurance has been used to offset those lower yields. However, the frequency of insurance claims has increased to the point where practices need to be changed on these systems.

Akron

The system capacity research was conducted at the Central Great Plains Research Station near Akron, CO. Three irrigation capacity strategies and timings were used to determine the response of corn to early season and late season water stress. The experimental field was divided into three sections and irrigated with a solid set irrigation system with an application rate of 0.42 inches per hour. The three capacities and timings were: 5 gallons per minute per acre (gpm/a) with season long irrigation (Full), 2.5 gpm/a with season long irrigation (Inadequate) and 6.7 gpm/a with irrigation delayed until 2 weeks prior to tassel emergence (Growth Stage Limited, GSL). These 3 capacities represent full irrigation capacity, inadequate capacity and growth stage timing with reduced acres for an inadequate capacity well. Three varieties were tested with varying relative maturity (99, 101 and 103 days to maturity).

Corn was planted in mid to late May at populations of 28,000 plants acre^{-1} in 2009 and 33,000 plants acre^{-1} in 2010 and 2011. Fertility management was according to soil tests. Total nitrogen applied was 175 lbs acre^{-1} and phosphorus at 40 lbs acre^{-1}.

Irrigation was applied for the full and inadequate capacity treatments if there was allowable storage for the application. During the early growth stages, irrigation applications were 0.5 inch per irrigation event while later applications were 0.75 inch per irrigation. Irrigation for the GSL treatment was withheld until 2 weeks prior to tassel emergence. Irrigation applications for this treatment were 1.0 inch per application.

Neutron probe access tubes were installed in the center of each plot (in the row) at the beginning of the experiment. Soil water was measured periodically throughout the growing season with a neutron probe (Model 503 Hydroprobe, Campbell Pacific Nuclear) at depths of 6, 18, 30, 42, 54, and 66 inches. Irrigation water was applied through a solid set irrigation system equipped with impact sprinkler heads producing an application rate of 0.42 inches hr^{-1}. Irrigation amounts were estimated from irrigation run times and sprinkler nozzle flow rates. Precipitation was measured with a standard rain guage (NWS-type with 8" receiving orifice) in the plot area. Water use (evapotranspiration) was calculated by the water balance method from the changes in soil water, applied irrigation, and precipitation. Deep percolation and runoff were assumed to be negligible.

Measurements of infrared leaf temperatures were made on one fully sunlit leaf oriented towards the sun in the upper canopy of the corn crop in the center of each of the 36 plots (three hybrids, three irrigation treatments, four replications) in 2009 and 2010 and in each of the 48 plot (four hybrids, three irrigation treatments, four replications) in 2011. Measurements were made using an Optris LS LaserSight infrared thermometer (IRT) beginning at 1300 MDT (approximately yield (lb a^{-1}) by crop water use (in). Local corn prices ($3.39, 4.80, 3.96, and 3.46 bu^{-1} 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

Akron

Irrigation capacity significantly decreased grain yields compared to full irrigation (Table 1). Inadequate capacities resulted in yield reductions of 26% on average compared to full irrigation. Yield reductions were as much as 46% in 2011. When water was limited during the vegetative growth stage, yield reductions were not significant compared with full irrigation.

The different irrigation treatments resulted in differential water stress development (Table 1). Water stress was generally less in 2009 compared with 2010 due to increased rainfall in 2009 (seasonal CWSI for the full irrigation treatment was 0.12 in 2009 and 0.24 in 2010). In all three years CWSI values were highest during the vegetative growth stages under the GSL treatment when irrigation was withheld during the vegetative period (CWSI = 0.59 in 2009, 0.47 in 2010 and 0.70 in 2011, averaged over hybrids). The water stress was relieved after tasseling for the GSL treatment when irrigation was applied on the same schedule as applied for the full treatment (CWSI = 0.11 in 2009, 0.24 in 2010 and 0.09 in 2011, averaged over hybrids during the reproductive stages). Because of the greater rain in 2009 the inadequate capacity treatment did not develop the high levels of water stress seen in 2010 or 2011 (CWSI = 0.09 during vegetative stages and 0.19 during reproductive stages in 2009 compared with CWSI = 0.32 during vegetative stages and 0.67 during reproductive stages in 2010 and 2011). There were no differences in CWSI due to hybrid. Yield was highly correlated with CWSI averaged over the reproductive period (Figure 1).

The ET values generally followed the same pattern as CWSI, with greater water use corresponding to lower CWSI. There were no differences in ET due to hybrid. Water use was about three inches less in 2010 than in 2009 for the full irrigation treatment, resulting in about 34 bu/a lower yield in 2010 compared with 2009 for the full irrigation treatment. Under the more favorable growing conditions of 2009, ND4903 produced higher yield than the other two hybrids under full irrigation (252 vs. 214 bu/a) and under the growth stage limited irrigation. But all three hybrids produced the same yield under the inadequate capacity irrigation treatment (220 bu/a). In 2010 NE5321 had much lower yield (164 bu/a) than the other two hybrids (207 bu/a) under full irrigation; ND4903 had lower yield (188 bu/a) than the other two hybrids (204 bu/a) with the growth stage limited treatment. Yields were lowest in 2011 with the inadequate capacity treatment, with ND4903 yielding highest (127 bu/a) and NE5321 yielding lowest (105 bu/a).

tended to optimize crop productivity. It was only at the highest well capacity that a higher seeding rate improved crop productivity.

Crop water use increased with well capacity (not shown). 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 2.7 in. Average non-growing season precipitation was 9.3 in giving an average non-growing season precipitation storage efficiency of 29%. 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.

<u>Overall</u>

Yield compared to ET at Akron, CO and Tribune, KS was a linear response (Figure 2). The yield response at Akron was slightly greater than the yield response observed at Tribune. A linear response at both locations shows that as irrigation system capacity is diminished, yield reductions will occur.

Economics of irrigation with limited well capacities is important in determining the acreage of corn to be grown with a specific well capacity. At Akron and Tribune, a limited well capacity resulted in net returns to risk and management of 58% of adequate capacities (Table 3). When well capacities are such that only 50% of the irrigated acreage can be fully irrigated, total returns are only reduced by less than $6,000 when irrigating only 50% of the acres. However, during years of drought such as 2008 at Tribune and 2010 and 2011 at Akron, yield reductions by irrigating all the acres resulted in losses.

CONCLUSIONS

Timing and capacity had an impact on grain yield when precipitation was below average. With an inadequate capacity well a 25% reduction in grain yields as compared with a full irrigation capacity well was observed. Timing irrigation towards reproductive growth with a higher capacity well resulted in similar grain yields to full season irrigation with a high capacity well. Reducing irrigation during the vegetative growth stage resulted in higher crop water stress indexes. However, an irrigation capacity which can meet crop water needs reduced the crop water stress index to values similar to full irrigation capacities and resulted in little or no yield loss during reproductive development.

When capacities are limited on the entire system, management strategies and cropping practices that result in fewer acres of an irrigated crop can alleviate the potential for severely reduced yields as compared with irrigating the entire system with inadequate capacities. Variety selection is important as the yield potential can vary by water management.

Table 1. Evapotranspiration, yield, and crop water stress index for irrigation capacities and strategies for 2009, 2010, and 2011.

Year	Irrigation	Hybrid	ET (in)	Yield (bu/a)	Average CWSI†	Vegetative CWSI‡	Reproductive CWSI ζ
2009	Full	ND4903	26.01	251.6	0.10	0.06	0.07
		EXP151	23.62	213.7	0.11	0.14	0.07
		NC5607	26.61	215.3	0.16	0.08	0.14
	Growth Stage	ND4903	22.37	239.5	0.29	0.58	0.11
		EXP151	22.19	202.4	0.40	0.76	0.16
		NC5607	22.40	216.6	0.23	0.43	0.08
	Inadequate Capacity	ND4903	24.25	218.7	0.27	0.09	0.32
		EXP151	24.73	218.0	0.13	0.05	0.14
		NC5607	25.42	222.9	0.14	0.12	0.12
	Avg. by Irrigation	Full	25.41	226.9	0.12	0.09	0.09
		GSL	22.32	219.5	0.31	0.59	0.11
		Inad Cap	24.80	219.8	0.18	0.09	0.19
2010	Full	ND4903	22.83	203.8	0.26	0.24	0.30
		TXP151	22.39	209.5	0.24	0.20	0.30
		NE5321	21.98	164.1	0.23	0.22	0.24
	Growth Stage	ND4903	22.6	187.8	0.38	0.48	0.25
		TXP151	22.34	204.9	0.34	0.45	0.22
		NE5321	22.77	203.6	0.39	0.50	0.26
	Inadequate Capacity	ND4903	18.86	140.6	0.51	0.34	0.69
		TXP151	19.02	133.5	0.48	0.33	0.65
		NE5321	19.13	121.9	0.45	0.29	0.65
	Avg. by Irrigation	Full	22.40	192.5	0.24	0.22	0.28
		GSL	22.57	198.8	0.37	0.47	0.24
		Inad Cap	19.00	132.0	0.48	0.32	0.67
2011	Full	ND4903	21.05	223.1	0.02	0.03	0.01
		TXP151	22.13	221.4	0.03	0.03	0.03
		NE5321	21.63	202.4	0.04	0.08	-0.01
		NC5209	20.69	210.7	0.01	0.04	-0.03
	Growth Stage	ND4903	21.47	205.9	0.47	0.77	0.13
		TXP151	21.77	217.8	0.41	0.69	0.07
		NE5321	21.81	203.6	0.30	0.53	0.03
		NC5209	19.65	197.2	0.48	0.79	0.12
	Inadequate Capacity	ND4903	19.10	127.2	0.37	0.14	0.62
		TXP151	18.55	119.2	0.38	0.14	0.66
		NE5321	18.93	105.2	0.42	0.18	0.70
		NC5209	18.91	115.3	0.44	0.19	0.73
	Avg. by Irrigation	Full	21.37	214.4	0.02	0.04	0.00
		GSL	21.17	206.1	0.41	0.70	0.09
		Inad CP	18.87	116.7	0.40	0.16	0.68

†Averaged over all measurements taken: 7/1 to 9/8/2009, 6/29 to 8/31/2010, and 7/18 to 9/1/2011

‡Averaged over vegetative development

ζ Averaged over reproductive development

Table 3. Net return to risk and management from three irrigation well capacities and three seeding rates at Tribune, KS and irrigation well capacity and management at Akron, CO.

Tribune			
Well capacity	Seeding rate (10^3 a^{-1})		
	22.5	27.5	32.5
in day^{-1}	Net return, \$ a^{-1} yr^{-1}		
0.1	\$346	\$359	\$334
0.15	\$419	\$414	\$389
0.2	\$533	\$575	\$620

Akron	
	Net return, \$ a^{-1} yr^{-1}
Inadequate	\$356
Growth Stage Limited (GSL)	\$599
Full	\$620

Figure 2. Yield vs Evapotranspiration for Akron, CO and Tribune, KS.