COMPARISON OF SDI AND SIMULATED LEPA SPRINKLER IRRIGATION FOR CORN

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ABSTRACT

A seven-year field study (1998-2004) was conducted to compare simulated low energy precision application (LEPA) with sprinkler irrigation to subsurface drip irrigation (SDI) for field corn production on the deep silt loam soils of western Kansas. Averaged over the seven-year period there was very little difference in corn grain yields between system type (235 and 233 bushels/acre for LEPA and SDI, respectively) across all comparable irrigation capacities. However, LEPA had higher grain yields for 4 extreme drought years (approximately 15 bushels/acre) and SDI had higher yields in 3 normal to wetter years (approximately 15 bushels/acre). Higher LEPA yields were associated with higher kernels/ear as compared to SDI (534 vs. 493 kernels/ear in dry years). Higher SDI yields were associated with higher kernel weight at harvest as compared to LEPA (34.7 vs. 33.2 grams/100 kernels in normal to wetter years). Seasonal water use was approximately 4% higher with LEPA than SDI and was associated with the period from anthesis to physiological maturity.

INTRODUCTION

LEPA and other in-canopy center pivot sprinkler irrigation systems have been in use in Kansas since the 1980s. Adoption and successfulness of these systems is somewhat dependant on soils, topography and management. The potential for the widespread usage of SDI for corn production in Kansas remains a debatable topic. Yet, there is a large amount of interest in its potential in western Kansas, where water resources are declining. It is estimated there is 12000 to 15000 SDI acres in western Kansas. No statistically valid, scientific data exists that directly compares corn production under LEPA center pivot sprinkler and SDI systems. The scale and operating logistics of these systems make replicated studies difficult and/or expensive to conduct. This paper describes research where the LEPA application is closely simulated on an SDI study site to help provide statistically valid data.

PROCEDURES

This experiment was conducted at the Kansas State University Northwest Research-Extension Center at Colby, Kansas, USA during the period 1998-2004.

The deep Keith silt loam soil can supply about 17.5 inches of available soil water for an 8 foot soil profile. The climate can be described as semi-arid with a summer precipitation pattern with an annual rainfall of approximately 19 inches. Average precipitation is approximately 12 inches during the 120-day corn growing season.

The seven treatments were simulated LEPA sprinkler irrigation with capacities of 1 inch every 4, 6 or 8 days and subsurface drip irrigation (SDI) with capacities 0.25, 0.17, 0.13 or 0.10 inch/day. Each treatment was replicated three times in a complete randomized block design in the North to South direction. Total plot length was 289 ft with the LEPA sprinkler irrigation being simulated in the first 81 ft of the plot length. All plot cultural practices, sampling, and data collection for both the LEPA and SDI plots were conducted in this 81 ft segment with the remaining length serving as a buffer from south winds. Plot width was eight corn rows spaced 2.5 ft apart (20 ft).

The study utilized an SDI system installed in 1989. The dual-chamber thin-walled collapsible dripline was installed at a depth of approximately 16-18 inches with a 5-ft. spacing between dripline laterals. Emitter spacing was 12 inches and the dripline flowrate was 0.25 gpm/100 ft. The corn was planted so that each dripline lateral was centered between two corn rows (Figure 1). Each plot was instrumented with a municipal-type flowmeter to record total accumulated flow. Mainline pressure entering the driplines was first standardized to 20 psi with a pressure regulator and then further reduced with a throttling valve to the nominal flowrate of 2.89 gpm/plot, coinciding with an operating pressure of approximately 10 psi.

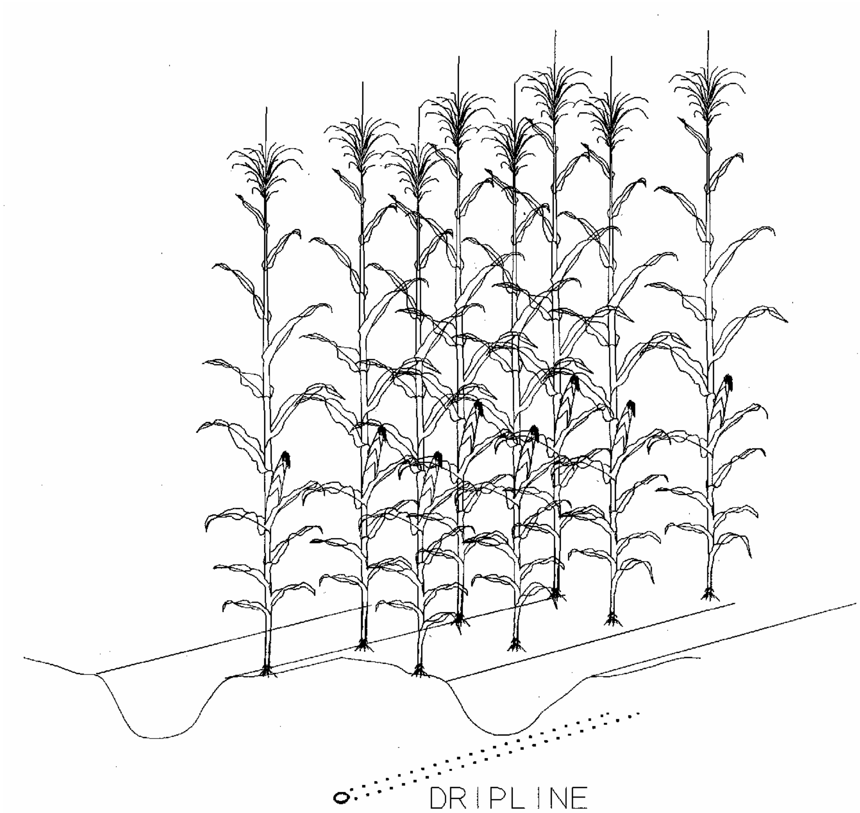

Figure 1. Physical arrangement of the subsurface dripline in relation to the corn rows.

The SDI system was disconnected for the plots associated LEPA treatments during the season to prevent any water application by SDI. The simulated LEPA treatments were accomplished by setting up a surface PVC pipe down the 81 ft length with pressure regulated flow dividers for each 30 ft increment. Each flow divider (Figure 2) had 9 equal length supply tubes (0.25 inches ID) delivering water to 9 individual furrow basins. Furrow basins were approximately 9 ft in length and were constructed in the furrows. The amount of water necessary to apply the one-inch application to the LEPA plots was calculated from the number of flow dividers and supply tubes in relation to the land area covered (3 flow dividers with 9 tubes each covering 81 ft of plots and 15 ft of width [3 furrow basins]). The application rate of the simulated LEPA irrigation treatments was approximately 1.5 in/hour which would nearly match the application rate of typical LEPA irrigation in the region. Furrow basins were used to retain applied water until it could infiltrate into the soil. Furrow basins are an integral part of the LEPA system and practices.

Figure 2. Flow divider used to supply water to 9 individual furrow basins for the purpose of simulating LEPA sprinkler irrigation.

Irrigation was scheduled for the studies using a water budget to calculate the root zone depletion with precipitation and irrigation water amounts as deposits and calculated daily water use by corn as a withdrawal. Irrigation was scheduled when the calculated root-zone depletion was in the range of 1 to 1.5 inches. However, irrigation was limited to the capacities imposed by the irrigation treatments. Irrigation amounts were fixed for the LEPA treatments at 1 inch and thus frequency of irrigation treatments varied with the irrigation capacity. Irrigation frequency for the SDI treatments was fixed at a daily interval and thus the irrigation capacity fixed the amount of irrigation. Soil water amounts were monitored with a neutron probe in 12 inch increments to a depth of 8 ft approximately once a week during each crop season, but were not used to update the irrigation schedule.

A ridge-till system was used in corn production with two corn rows, 30 inches apart on a 5 ft. bed. The corn was grown with the conventional production practices for each location. Tractor traffic was confined to the furrows. Pioneer hybrid 3162 seed corn was used in 1998 -2003 and Pioneer hybrid 32B33 in 2004. These hybrids are full season hybrid for the region with an approximately 118 day comparative relative maturity requirement. Pest (weeds and insects) control was accomplished with standard practices for the region. In the years 1999-2001 nitrogen fertilizer was applied to the study area with approximately 180-200 lbs N/acre in an early preplant application. In 2002, the nitrogen fertilization scheme was changed to apply 75 lbs N/acre early preplant and an additional 100 lbs N/acre through fertigation in late June or early July each year. A starter fertilizer application at planting banded an additional 30 lbs N/acre and 45 lbs $P_2 0_5$/acre. These fertilizer rates can be described as non-limiting for high corn yields. Agronomic practices are summarized in Table 1.

Table 1. Agronomic information from a LEPA-SDI study for corn. KSU Northwest Research-Extension Center, Colby, Kansas, 1998-2004.

	Year						
Agronomic parameter	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Corn hybrid (Pioneer brand no.)	3162	3162	3162	3162	3162	3162	32B33
Seeding plant population (p/a)	32000	32000	28000	34000	34000	34000	36000
Planting date	30-Apr	9-May	27-Apr	30-Apr	30-Apr	30-Apr	28-Apr
Emergence date	15-May	21-May	8-May	13-May	13-May	13-May	10-May
N-Source was UAN 32-0-0 and AP 10-34-0							
P-Source was AP 10-34-0							
Preplant N fertilizer (lb/a)	200	200	180	200	75	75	75
Banded N at planting (lb/a)	30	30	30	30	30	30	30
Banded P at planting (lb/a)	45	45	45	45	45	45	45
Inseason N fertigation (lb/a)	-	-	-	-	100	100	100
Fertigation date	-	-	-	-	27-Jun & 10-Jul	23-Jun	28-Jun
Initial soil water measurement date	22-May	13-May	8-May	14-May	13-May	13-May	11-May
Final soil water measurement date	29-Sep	30-Sep	18-Sep	27-Sep	30-Sep	17-Sep	24-Sep
Hand-harvest date at physiological maturity	29-Sep	11-Oct	18-Sep	27-Sep	30-Sep	18-Sep	24-Sep

Corn production data collected during the growing season included irrigation and precipitation amounts, weather data, yield components (yield, harvest plant population, ears/plant, kernels/ear, mass/100 kernels), and periodic soil water content. Weather data were collected with an automated weather station approximately 0.5 mile from the research site. Values calculated after final data collection included seasonal water use and water use efficiency. Water use was calculated as the change in soil water between the initial and final dates, plus any irrigation and rainfall. Calculation of water use in this way can include deep percolation if it exists and also runoff and runon. In this region, deep percolation losses usually occur only in the early part of the season when cumulative precipitation exceeds evapotranspiration. Furrow basins and the low land slope (<0.5%) reduced the chances for runoff and runon.

RESULTS AND DISCUSSION

Weather Conditions

Briefly, the weather conditions can be specified as normal to wetter than normal in 1998, 1999, and 2004 and excessively dry in 2000-2003. Precipitation during the cropping season was 12.71, 17.60, 6.18, 9.26, 9.61, 9.12 and 12.65 inches for the respective years, 1998-2004. Calculated evapotranspiration for a standard 120-day period May 15-September 11) was slightly below normal in 1998 and 1999 (21.26 and 21.64 inches), above normal at 27.48, 26.28, 27.68 and 25.96 inches for the years 2000-2003, respectively, and about normal in 2004 (23.08 inches). The years 2000-2003 can be considered extreme drought years and summer dryland crops in the region generally failed.

Corn Grain Yield

Corn yields were generally high in all seven years ranging from 196 to 278 bushels for the highest irrigation capacities (1 inch/4 days or 0.25 inches/day) (Table 2.) There were significant yield differences due to irrigation capacity in each of the drought years (2000-2004) and there were smaller numerical differences in yields in the wetter years (1998, 1999, and 2003) with higher capacities resulting in higher grain yields. Averaged over the seven year period there were no statistically significant differences in yields between LEPA and SDI for equivalent irrigation capacities. However there were statistical differences and/or numerical trends that varied by system type across years. In general, the SDI treatments had higher numerical yields in the normal and wetter years and the LEPA had higher statistical yields in the extreme drought years. A statistical analysis of the 3 normal and wet years separately showed an approximately 14 bushels/acre advantage for SDI over LEPA irrigation. The same analysis procedure for the 4 extreme drought years gave LEPA a 15 bushel/acre advantage. The difference in system types between years was unanticipated and remains unexplained. In the course of conducting this experiment it became apparent that system type was affecting grain yields particularly in the extreme drought years. It was hypothesized that the surface-applied nitrogen fertilizer was becoming positionally unavailable for the SDI treatments. Indeed there were some informal visual observations of N-stress in some of the SDI plots in 2000 and 2001. In 2002, the fertilization scheme was adjusted to apply both a preplant surface amount and an inseason fertigation amount (Table 1). This adjustment did not remove the yield differences between irrigation system types in the continuing drought years of 2002 and 2003.

Table 2. Summary of corn yield components and water use data from LEPA-SDI study.
KSU Northwest Research-Extension Center, Colby, Kansas, 1998-2004.

System type and Irrigation capacity	***Corn plant population at harvest, 1000 plants/acre*** 1998	1999	2000	2001	2002	2003	2004	**All years**	**Wet years[1]**	**Dry years[2]**
LEPA, 1in/4 days	31.7	30.2	27.0	34.4	33.4	34.0	36.3	32.4	32.7	32.2
LEPA, 1in/6 days	32.2	30.5	27.7	35.1	33.8	33.4	36.0	32.7	32.9	32.5
LEPA, 1in/8 days	31.1	31.1	26.7	33.8	32.2	34.0	36.0	32.1	32.7	31.7
SDI, 0.25 in/day	32.2	31.1	27.0	34.0	33.5	34.6	35.7	32.6	33.0	32.3
SDI, 0.17 in/day	31.9	30.8	27.3	33.4	33.5	34.0	36.9	32.5	33.2	32.1
SDI, 0.13 in/day	32.5	32.5	27.3	33.7	33.5	34.0	35.7	32.8	33.6	32.1
SDI, 0.10 in/day	31.9	32.2	27.6	33.1	32.5	33.4	36.3	32.4	33.5	31.7
Mean	31.9	31.2	27.2	33.9	33.2	33.9	36.1	32.5	33.1	32.1
LSD $_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

System type and Irrigation capacity	***Corn ears/plant*** 1998	1999	2000	2001	2002	2003	2004	**All years**	**Wet years**	**Dry years**
LEPA, 1in/4 days	0.99	1.00	1.01	0.98	0.98	1.00	0.98	0.99 a	0.99	0.99
LEPA, 1in/6 days	1.00	0.98	0.99	0.99	0.96	1.00	0.98	0.99 a	0.99	0.99
LEPA, 1in/8 days	0.99	0.99	1.00	0.97	0.96	0.98	0.98	0.98 ab	0.99	0.98
SDI, 0.25 in/day	0.98	1.00	1.00	0.99	0.98	0.99	0.99	0.99 a	0.99	0.99
SDI, 0.17 in/day	0.98	1.01	1.00	0.99	0.97	1.00	0.97	0.99 a	0.99	0.99
SDI, 0.13 in/day	0.98	0.99	1.01	0.97	0.95	0.95	0.97	0.97 b	0.98	0.97
SDI, 0.10 in/day	0.99	0.98	0.99	0.97	0.93	0.94	0.99	0.97 b	0.99	0.96
Mean	0.99	0.99	1.00	0.98	0.96	0.98	0.98	0.98 ab	0.99	0.98
LSD $_{0.05}$	NS	NS	NS	NS	NS	NS	NS	0.01	NS	NS

System type and Irrigation capacity	***Corn kernels/ear*** 1998	1999	2000	2001	2002	2003	2004	**All years**	**Wet years**	**Dry years**
LEPA, 1in/4 days	568	630 a	539 a	594 a	493 a	629 a	569	575 a	589	564 a
LEPA, 1in/6 days	566	612 a	541 a	540 b	475 a	558 b	565	551 b	581	529 b
LEPA, 1in/8 days	621	612 a	536 a	528 b	445 ab	521 b	576	548 b	603	508 bc
SDI, 0.25 in/day	590	601 ab	542 a	541 b	453 ab	579 a	579	555 ab	590	529 b
SDI, 0.17 in/day	580	632 a	486 b	526 b	415 ab	545 b	584	538 b	599	493 c
SDI, 0.13 in/day	606	559 bc	470 b	474 c	385 b	501 b	585	511 c	583	458 d
SDI, 0.10 in/day	612	544 c	469 bc	449 c	336 b	394 c	542	478 d	566	412 e
Mean	592	599	512	521	429	532	571	537	587	499
LSD $_{0.05}$	NS	43	42	45	86	84	NS	22	NS	35

System type and Irrigation capacity	***100 Corn kernel weight, grams*** 1998	1999	2000	2001	2002	2003	2004	**All years**	**Wet years**	**Dry years**
LEPA, 1in/4 days	35.1 bc	34.8	41.5 a	34.9	36.9	26.2 bc	30.7	34.3 b	33.5 bc	34.9
LEPA, 1in/6 days	34.8 bc	35.1	39.1 ab	33.7	36.2	29.3 a	30.5	34.1 bc	33.5 bc	34.6
LEPA, 1in/8 days	33.5 c	34.3	36.7 b	34.6	36.1	26.6 bc	30.3	33.2 bc	32.7 c	33.5
SDI, 0.25 in/day	37.8 a	35.8	42.1 a	34.7	38.1	25.1 c	33.9	35.4 a	35.9 a	35.0
SDI, 0.17 in/day	36.4 b	34.0	42.1 a	34.3	37.5	26.5 bc	32.2	34.7 a	34.2 b	35.1
SDI, 0.13 in/day	35.3 b	36.1	40.5 a	33.9	36.3	26.5 bc	30.1	34.1 bc	33.9 b	34.3
SDI, 0.10 in/day	35.6 b	34.1	36.3 b	33.3	35.5	27.0 bc	30.0	33.1 c	33.2 bc	33.0
Mean	35.5 b	34.9	39.7	34.2	36.6	26.7	31.1	34.1	33.8	34.3
LSD $_{0.05}$	1.8	NS	3.7	NS	NS	2.0	NS	1.1	1.2	NS

System type and Irrigation capacity	***Corn grain yield, bushels/acre*** 1998	1999	2000	2001	2002	2003	2004	All years	Wet years	Dry years
LEPA, 1in/4 days	246	260	239 a	275 a	234 a	221 a	246	246 a	251 bc	242 a
LEPA, 1in/6 days	250	252	230 ab	249 b	219 a	215 a	239	236 b	247 bc	228 b
LEPA, 1in/8 days	252	254	206 c	235 b	194 b	182 ab	242	224 c	249 bc	204 c
SDI, 0.25 in/day	278	263	242 a	248 b	222 a	196 ab	274	246 a	272 a	227 b
SDI, 0.17 in/day	261	263	219 bc	235 b	198 b	194 ab	265	234 b	263 a	212 c
SDI, 0.13 in/day	268	256	206 c	207 c	176 b	172 b	240	218 c	255 bc	190 d
SDI, 0.10 in/day	271	231	184 d	190 c	140 c	132 c	229	197 d	244 c	161 e
Mean	261	254	218	234	197	187	248	229	254	209
LSD $_{0.05}$	NS	NS	17	22	25	41	NS	8	12	12

System type and Irrigation capacity	***Total seasonal irrigation amount, inches*** 1998	1999	2000	2001	2002	2003	2004	All years	Wet years	Dry years
LEPA, 1in/4 days	11.0	12.0	18.0	19.0	18.0	17.0	12.0	15.3	11.7	18.0
LEPA, 1in/6 days	10.0	9.0	15.0	14.0	14.0	13.0	10.0	12.1	9.7	14.0
LEPA, 1in/8 days	9.0	8.0	12.0	11.0	11.0	10.0	8.0	9.9	8.3	11.0
SDI, 0.25 in/day	11.0	10.3	18.0	18.5	18.0	17.0	12.0	15.0	11.1	17.9
SDI, 0.17 in/day	8.8	8.3	15.5	13.9	13.8	12.9	10.0	11.9	9.1	14.0
SDI, 0.13 in/day	7.2	6.5	11.8	10.9	10.5	9.9	8.1	9.3	7.2	10.8
SDI, 0.10 in/day	5.6	5.1	9.1	8.4	8.1	7.6	6.2	7.2	5.6	8.3
Mean	8.9	8.5	14.2	13.7	13.3	12.5	9.5	11.5	9.0	13.4

System type and Irrigation capacity	***Total seasonal water use, inches*** 1998	1999	2000	2001	2002	2003	2004	All years	Wet years	Dry years
LEPA, 1in/4 days	28.5 a	32.4 a	28.2 a	32.6 a	31.6 a	29.3 a	28.3 a	30.1 a	29.7 a	30.4 a
LEPA, 1in/6 days	26.8 bc	29.9 bc	26.2 b	29.4 c	29.0 b	28.3 ab	27.1 a	28.1 bc	27.9 b	28.2 b
LEPA, 1in/8 days	26.4 bc	30.0 bc	24.0 cd	28.5 c	26.4 d	25.4 c	25.6 bc	26.6 d	27.3 bc	26.1 d
SDI, 0.25 in/day	27.0 b	31.0 b	25.7 bc	30.9 b	29.9 b	28.6 ab	27.0 ab	28.6 b	28.3 b	28.7 b
SDI, 0.17 in/day	25.6 cd	29.4 cd	25.2 b	28.8 c	27.9 c	27.6 b	26.2 bc	27.3 c	27.1 c	27.4 c
SDI, 0.13 in/day	24.8 d	28.4 d	23.6 d	27.1 d	25.6 d	25.4 c	24.9 c	25.7 e	26.0 d	25.4 e
SDI, 0.10 in/day	23.3 e	29.0 cd	20.3 e	24.3 e	23.8 e	23.9 c	23.1 d	24.0 f	25.1 e	23.1 f
Mean	26.1	30.0	24.7	28.8	27.7	26.9	26.0	27.2	27.4	27.1
LSD $_{0.05}$	1.3	1.1	1.6	1.2	1.1	1.7	1.7	0.6	0.8	0.6

System type and Irrigation capacity	***Seasonal water use until anthesis, inches*** 1998	1999	2000	2001	2002	2003	2004	All years	Wet years	Dry years
LEPA, 1in/4 days	13.0 a	14.5 a	10.1 a	14.9 a	15.0 a	15.9	11.4	13.5 a	13.0 a	14.0 a
LEPA, 1in/6 days	12.1 bc	13.1 b	8.9 b	14.3 ab	14.2 a	16.0	11.1	12.8 b	12.1 b	13.4 b
LEPA, 1in/8 days	12.2 abc	13.5 ab	9.1 ab	14.6 a	13.0 c	15.3	10.5	12.6 b	12.0 b	13.0 b
SDI, 0.25 in/day	12.9 a	14.6 a	10.0 a	14.1 ab	14.0 b	16.1	11.3	13.3 a	12.9 a	13.5 ab
SDI, 0.17 in/day	12.4 ab	13.7 a	9.0 ab	13.4 bc	14.1 a	16.2	10.7	12.8 b	12.3 b	13.2 b
SDI, 0.13 in/day	11.5 c	12.8 b	8.5 bc	13.4 bc	12.3 c	15.1	10.5	12.0 c	11.6 c	12.3 c
SDI, 0.10 in/day	11.3 c	13.8 a	7.6 c	12.9 c	12.6 c	15.0	10.2	11.9 c	11.7 bc	12.0 c
Mean	12.2	13.7	9.0	14.0	13.6	15.6	10.8	12.7	12.2	13.1
LSD $_{0.05}$	0.9	1.1	1.2	1.2	1.0	NS	NS	0.5	0.7	0.6

System type and Irrigation capacity	Seasonal water use after anthesis, inches 1998	1999	2000	2001	2002	2003	2004	All years	Wet years	Dry years
LEPA, 1in/4 days	15.5 a	17.9 a	18.1 a	17.8 a	16.6 a	13.4 a	16.8 a	16.6 a	16.8 a	16.5 a
LEPA, 1in/6 days	14.7 b	16.7 b	17.4 a	15.1 c	14.8 b	12.3 ab	16.0 a	15.3 b	15.8 b	14.9 bc
LEPA, 1in/8 days	14.3 b	16.6 b	14.9 c	13.9 d	13.4 bc	10.1 cd	15.1 b	14.0 cd	15.3 c	13.1 d
SDI, 0.25 in/day	14.1 b	16.4 b	15.7 bc	16.7 b	15.8 a	12.5 ab	15.7 ab	15.3 b	15.4 bc	15.2 b
SDI, 0.17 in/day	13.3 c	15.7 c	16.3 b	15.4 c	13.8 bc	11.4 bc	15.5 ab	14.5 c	14.8 d	14.2 c
SDI, 0.13 in/day	13.4 c	15.6 c	15.1 c	13.6 d	13.2 c	10.3 cd	14.5 b	13.7 d	14.5 d	13.1 d
SDI, 0.10 in/day	12.0 d	15.3 c	12.7 d	11.4 e	11.2 d	8.8 d	12.9 c	12.0 e	13.4 e	11.0 e
Mean	13.9	16.3	15.7	14.8	14.1	11.3	15.2	14.5	15.1	14.0
LSD $_{0.05}$	0.7	0.7	1.1	0.8	1.6	1.7	1.5	0.6	0.5	0.8

System type and Irrigation capacity	Seasonal water use efficiency, lbs./acre-inch 1998	1999	2000	2001	2002	2003	2004	All years	Wet years	Dry years
LEPA, 1in/4 days	484 d	451	474	472	414 a	422	488	458	474 c	446 a
LEPA, 1in/6 days	523 cd	475	490	475	423 a	425	494	472	497 bc	453 a
LEPA, 1in/8 days	534 cd	474	484	462	413 a	403	530	471	513 b	441 ab
SDI, 0.25 in/day	577 bc	476	527	450	416 a	384	569	486	541 ab	444 a
SDI, 0.17 in/day	570 bc	502	488	456	398 a	393	566	482	546 a	434 ab
SDI, 0.13 in/day	606 ab	507	488	427	385 a	373	539	475	551 a	418 b
SDI, 0.10 in/day	651 a	446	506	437	330 b	309	558	462	552 a	396 b
Mean	564	476	494	454	397	387	535	472	525	433
LSD $_{0.05}$	59	NS	NS	NS	51	NS	NS	NS	33	25

System type and Irrigation capacity	Available soil water at anthesis, inches/8 ft profile 1998	1999	2000	2001	2002	2003	2004	All years	Wet years	Dry years
LEPA, 1in/4 days	12.9	12.1 a	10.7 a	9.1 ab	8.7 ab	9.4	10.5	10.5 a	11.8 a	9.5 a
LEPA, 1in/6 days	12.6	12.9 a	9.9 a	8.2 bc	6.3 cd	8.2	10.3	9.8 a	11.9 a	8.2 b
LEPA, 1in/8 days	11.6	12.3 a	8.1 bc	6.6 d	6.6 cd	7.1	10.9	9.0 c	11.6 a	7.1 cd
SDI, 0.25 in/day	11.8	11.7 a	10.3 ab	9.7 a	9.2 a	9.2	11.0	10.4 a	11.5 a	9.6 a
SDI, 0.17 in/day	11.8	12.2 a	10.3 ab	8.1 bc	7.4 bc	7.5	9.9	9.6 bc	11.3 a	8.3 b
SDI, 0.13 in/day	11.8	12.0 a	9.0 b	7.8 cd	7.2 c	7.7	10.1	9.4 bc	11.3 a	7.9 bc
SDI, 0.10 in/day	11.1	9.6 b	7.2 c	6.6 d	5.2 d	6.6	9.6	8.0 d	10.1 b	6.4 d
Mean	11.9	11.8	9.3	8.0	7.2	8.0	10.3	9.5	11.4	8.1
LSD $_{0.05}$	NS	1.4	1.5	1.3	1.5	NS	NS	0.8	1.0	1.0

System type and Irrigation capacity	Available soil water at maturity, inches/8 ft profile 1998	1999	2000	2001	2002	2003	2004	All years	Wet years	Dry years
LEPA, 1in/4 days	8.6	9.4 a	6.4 bc	9.6 b	6.7 b	10.0 a	7.8 a	8.3 b	8.6 a	8.2 b
LEPA, 1in/6 days	10.1	9.4 a	5.4 c	8.3 bc	5.1 cd	6.9 b	7.4 a	7.5 cd	9.0 a	6.4 c
LEPA, 1in/8 days	8.7	7.9 b	4.0 cd	5.9 d	4.8 cd	6.0 b	6.9 b	6.3 e	7.8 bc	5.2 d
SDI, 0.25 in/day	9.7	9.5 a	8.9 a	11.1 a	7.9 a	10.7 a	9.4 a	9.6 a	9.5 a	9.7 a
SDI, 0.17 in/day	9.5	9.9 a	7.4 b	8.4 bc	6.8 b	7.6 b	7.5 a	8.2 bc	9.0 a	7.6 b
SDI, 0.13 in/day	8.7	8.7 ab	5.0 cd	7.9 c	5.4 c	6.9 b	7.2 b	7.1 d	8.2 b	6.3 c
SDI, 0.10 in/day	8.4	5.6 c	3.9 d	7.4 c	4.1 d	5.8 b	6.8 b	6.0 e	6.9 c	5.3 d
Mean	9.1	8.6	5.9	8.4	5.8	7.7	7.6	7.6	8.4	6.9
LSD $_{0.05}$	NS	1.3	1.5	1.5	1.1	2.0	2.2	0.8	1.2	0.8

[1] *Normal to wetter years were 1998, 1999 and 2004.*

[2] *Dry years were extreme drought years from 2000 to 2003.*

These yield differences in performance of system type across years and weather conditions (Figure 3) are important to note because it may be possible to adjust irrigation management to remove the differences. Subsequent discussion that follows below will indicate some of the possible reasons for the yield differences.

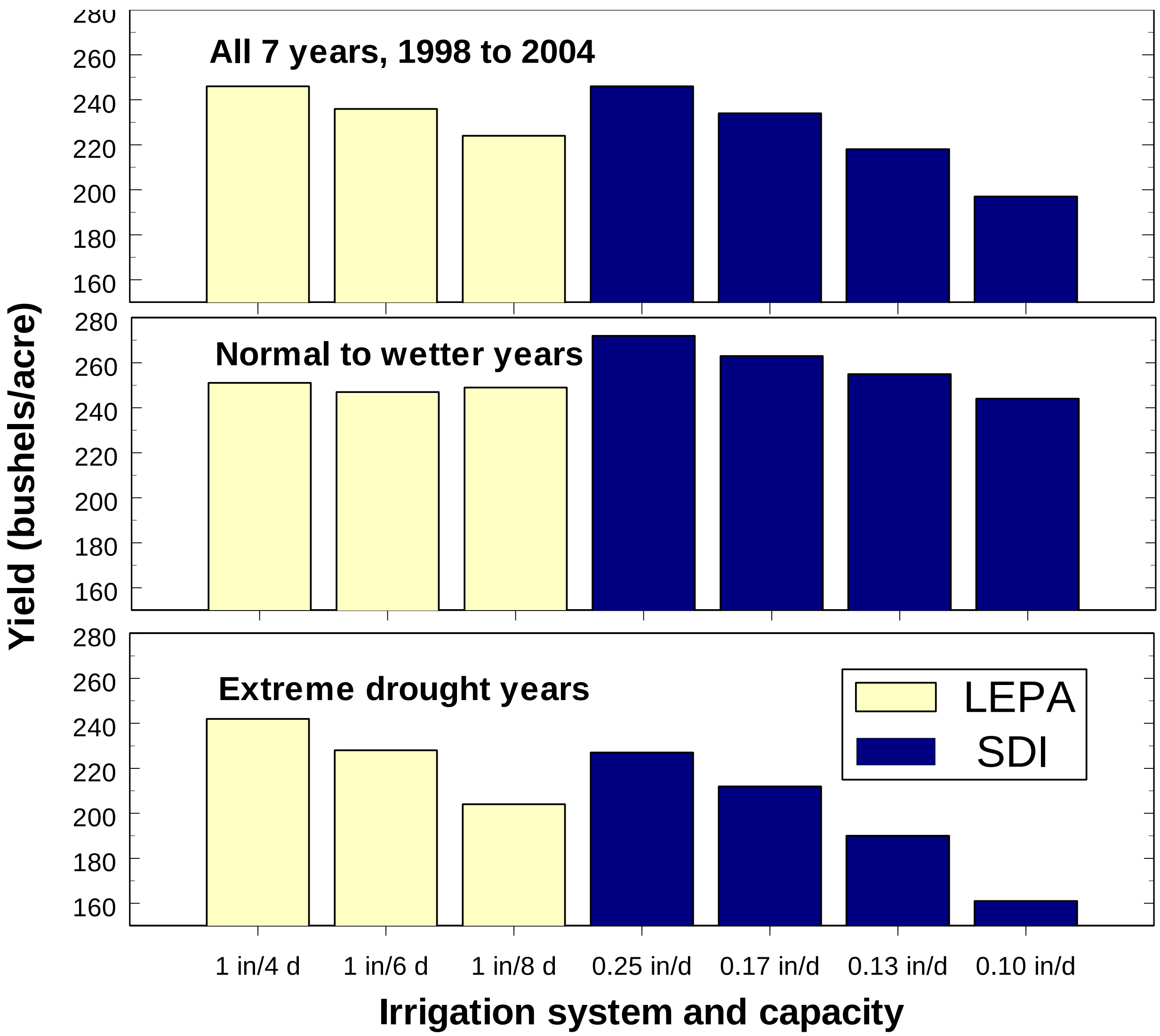

Figure 3. Variation in corn yields across years and weather conditions as affected by irrigation system type and capacity, KSU Northwest Research-Extension Center, Colby Kansas.

Corn Yield Components

Although plant population varied between years from approximately 27000 to 36000 plants/acre (Table 1 and 2) there were no significant differences in harvest plant population within a given year related to treatment. This would be as anticipated. Similarly there was very little difference in the number of ears/plant across years averaging approximately 0.98 ears/plant (Table 2). When averaged across all 7 years, there was a slight decrease from 0.99 to 0.97 ears/plant as irrigation capacity decreased.

There were generally statistical differences or numerical trends in the number of kernels/ear related to irrigation system type and capacity (Table 2). In the normal and wetter years there was generally no statistical difference in the kernels/ear with decreases occurring only with decreases in irrigation capacity in 1999. However, in the extreme drought years, for a given irrigation capacity, LEPA had an approximately 41 kernels/ear advantage. Although the potential number of kernels/ear is determined by hybrid genetics and early growth before anthesis, the actual number of kernels is usually set in a 2-3 week period centering around anthesis. Water and nitrogen availability and hormonal signals are key factors in determining the actual number of kernels/ear. The adjustment of splitting the fertilizer applications to both preplant and inseason in 2002 did not remove the differences in kernels/ear between irrigation system types. Soil water and water use differences will be discussed in a latter section. Hormonal signals sent by the roots may have been different for the SDI treatments in the drought years because SDI may have had a more limited root system.

Kernel weight was statistically higher for higher irrigation capacity in 3 of the 7 years and was numerically higher in additional years. Averaged over the 7 years, for a given irrigation capacity, SDI generally had higher kernel weight and in the normal and wetter years this higher kernel weight was approximately 1.5 grams/100 kernels which resulted in the approximately 14 bushels/acre yield advantage. The number of kernels/ear was not statistically different during these normal and wetter years, so this higher kernel weight for SDI must be reflecting better grain filling conditions for this system type. Grain filling is regulated by general water availability and weather conditions favoring good photosynthesis, so it is somewhat surprising that irrigation system type had an effect in the normal and wetter years but not much effect in the dry years.

Water Use and Water Use Efficiency

Irrigation amount varied with irrigation capacity (Table 2), so it is not surprising to see that total seasonal water use was statistically different with irrigation capacity in all 7 years. There were also statistical differences in total seasonal water use between LEPA and SDI in most years with LEPA using higher amounts. It was initially thought that these differences might be related to higher irrigation efficiencies with SDI compared to LEPA, since total seasonal irrigation amounts were relatively similar. However, when examined in light of the grain yield differences, it appears the differences might be more related to an unexplained reduced transpiration from the SDI plots. This might be further supported by the similarity in water use efficiencies (WUE) for the higher two irrigation capacities in the drought years. Although grain yields were higher for LEPA in these years, the similarity in WUE suggests that SDI obtained the same yield for a given amount of water use. Water use efficiency was seldom affected by irrigation system type in the 7 years but was affected by irrigation capacity in two years. In 1998, a wetter year, WUE was lowered by irrigation capacity and in 2002, an extreme drought year, higher irrigation capacity increased WUE. A partitioning of the corn water use into the periods of emergence to anthesis and anthesis to physiological maturity sheds more light on the irrigation system differences. Prior to anthesis, the results indicate the differences in water use are related only to irrigation capacity (Table 2), but after anthesis, the SDI treatments are utilizing less water. After anthesis, full crop canopies drastically limit the amount of soil evaporation, high crop water use limits the amount of deep percolation for well managed irrigation treatments and runoff from rainfall can be considered negligible with the furrow basins. Differences in water use by irrigation system type after anthesis were unanticipated and unexplained. The list of possible reasons would include smaller crop canopies with SDI which were not visually observed, smaller root systems with SDI that reduced transpiration, and possibly some hormonal adjustments that affected the stomatal control of transpiration.

Soil Water at Anthesis and Physiological Maturity

Water availability at anthesis can affect the actual number of kernels/ear. However, there were no statistical differences in soil water in the 8 foot profile at anthesis as related to irrigation system type (Table 2). An analysis of soil water data in the upper 3 foot of the profile did not indicate any system type differences either (data not shown). However, it should be noted that soil water measurements with the neutron attenuation method do not have a great amount of resolution of minute differences in the near surface layers. Additionally there could have been horizontal soil water distribution differences not revealed by the neutron attenuation method.

Soil water at maturity was statistically higher with SDI than LEPA (Table 2), once again reflecting the differences in water use that occurred during the period from anthesis to physiological maturity. It is possible that this higher level of soil water may have allowed better grain fill in the normal and wetter years, but a counter argument might be that grain fill was not affected by system type in the drier years though soil water still differed at maturity.

CONCLUSIONS

Corn yields were generally high under both simulated LEPA sprinkler irrigation and SDI. Both systems can be managed to give a high level of production and efficient water use.

There were consistent differences in corn production under the two system types as related to the climatic conditions. LEPA performed better in 4 extreme drought years primarily due to higher numbers of corn kernels/ear and SDI performed better in normal to wetter years primarily due to higher kernel weight at harvest. The reasons for these differences were unanticipated and remain unexplained. Further study is required that can hopefully explain the differences. It is possible, once the reasons for the differences are understood that appropriate managements strategies can be developed to optimize production under both system types. The severity of the drought might lead some to assume that SDI might have higher yields than LEPA under average conditions and the data could be used to suggest that. However, it would seem more important to gain an understanding of the reasons between the shifting of the yield components (kernels/ear and kernel weight) between systems as climatic conditions vary.

Water use was higher with LEPA systems in all years as calculated from changes in seasonal soil water amounts plus irrigation and rainfall. These differences were primarily during the period from anthesis to physiological maturity. This period under these study conditions (good irrigation management, good soils and low land slope) would not be typically associated with losses from non-benificial sources, such as deep percolation, soil evaporation and runoff and runon. This suggests that transpiration was less for the SDI during this period for some unknown reason.

[1] *Mention of tradenames is for informational purposes and does not constitute endorsement of the product by the authors or Kansas State University.*

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