EFFECT OF IRRIGATION FREQUENCY FOR LIMITED SUBSURFACE DRIP IRRIGATION OF CORN

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ABSTRACT

A three-year field study (2002-2004) was conducted to examine the effect of irrigation frequency on limited subsurface drip-irrigated field corn on the deep silt loam soils of western Kansas. Results indicate that SDI frequency on this soil type is not a major issue in corn production. Grain yield was only affected in 2002, an extreme drought year, with less frequent, larger irrigation events being advantageous. The grain filling stage was also unaffected by irrigation frequency as was seasonal water use and water use efficiency. Higher plant population (34000 plants/acre) was advantageous in the good production year, 2004, and had no negative effect in the extreme drought years 2002 and 2003.

INTRODUCTION

Subsurface drip irrigation (SDI) is a relatively new technology in the U. S. central Great Plains but producers are beginning to adopt and adapt the technology to their farms. Many of the SDI systems are manually operated and SDI event duration is often 12 to 24 hours to match available labor schedules. This will result in approximate irrigation frequencies of two to six days for irrigated corn depending on SDI system capacity. There are a few fully automated SDI systems which can shift irrigation between the various zones on a more frequent basis. Although it is often assumed that high irrigation frequency is a "given" with microirrigation systems, a literature review of SDI (Camp, 1998) indicates that SDI frequency is often only critical for shallow rooted crops on shallow or sandy soils. At least two studies conducted in the U. S. Great Plains indicate that irrigation frequencies from 1 to 7 days had no effect on corn yields provided soil water was managed within acceptable stress ranges (Caldwell et al., 1994; Howell et al., 1997). However, the question arises about what effect irrigation frequency may have when SDI is limited by institutional or hydrologic constraints on pumping.

Limited or deficit irrigation of corn is difficult to implement successfully without reducing grain yields (Lamm et al., 1993; Eck, 1986; Musick and Dusek, 1980; Stewart et al., 1975). However, some strategies are more successful than others at maintaining corn yields under limited irrigation. Conceptually, one limited irrigation method that might work successfully (both economically and water efficient) is to provide small frequent supplemental, but deficit, amounts of irrigation using subsurface drip irrigation (SDI). These frequent "doses" might attenuate crop water stress allowing crop processes to continue and also allowing the crop to "scavenge" the soil profile for its remaining daily crop water needs. In 2002, Kansas State University initiated a field study to evaluate the effect of frequency for limited SDI for field corn production.

PROCEDURES

This experiment was conducted at the Kansas State University Northwest Research-Extension Center at Colby, Kansas, USA during the period 2002-2004. The deep 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 treatments were four irrigation frequencies at a limited irrigation capacity plus the addition of a fully irrigated and non-irrigated treatment each with three plant populations. The four irrigation frequencies were 0.15 inches/day, 0.45 inches/3 days, 0.75 inches/5 days and 1.05 inches/7days which are equivalent but limited capacities. As a point of reference a 0.25 inch/day irrigation capacity will match full irrigation needs for corn for center pivot sprinkler irrigation in most years. The fully irrigated treatment was limited to 0.30 inches/day. The non-irrigated treatment only received 0.10 inches in a single irrigation to facilitate nitrogen fertigation for those plots. However, the non-irrigated treatment was irrigated each year in the dormant season to replenish the soil water in the profile. Irrigation was scheduled using a climatic water budget, but was limited to the specific irrigation frequency treatment. Irrigations were scheduled when the calculated soil water depletion exceeded 1 inch for a given treatment.

The driplines with a 12-inch emitter spacing were spaced 60 inches apart with an installation depth of 17 inches. Each dripline was centered between two corn rows spaced 30 inches apart on the 60 inch crop bed. The nominal flow rate was 0.25 gal/min for each 100 ft of dripline. There were four driplines in each plot and each whole plot was 330 ft long. 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 3.3 gpm/plot that resulted in an operating pressure of approximately 10 psi.

The three target plant populations were approximately 34000, 30000, and 26500 plants/acre. The experiment was conducted in a randomized complete block, split-plot design with four replications. Plant population was the split plot variable and irrigation level was the whole plot variable. Pioneer[1] hybrid 32R42 was used in 2002 and its corn borer resistant related hybrid 32R43 was used in 2003 and 2004. This hybrid is a full season hybrid for the region with an approximately 118 day comparative relative maturity requirement. The corn was planted on May 1, 2002, April 30, 2003 and May 3, 2004. Pest (weeds and insects) control was accomplished with standard practices for the region. A starter fertilizer application was banded at planting at the rate of 30 lbs N/acre and 45 lbs P_20_5/acre. Nitrogen fertilizer was applied to the study area through the SDI system in multiple events during mid to late June each year for an additional total amount of 200 lbs N/acre. These fertilizer rates can be described as non-limiting for high corn yields. The corn rows were planted parallel with the dripline with each corn row approximately 15 inches from the nearest dripline. A raised bed was used in corn production. This allows for centering the corn rows on the dripline and limits wheel traffic to the furrow (Figure 1). This controlled traffic can allow for some shallow cultivation procedures.

Soil water content was measured on a periodic basis (weekly or biweekly) with a neutron attenuation moisture meter in 1-ft increments to a depth of 8 ft at the corn row (approximately 15 inches horizontally from the dripline. Corn production data collected during the growing season included irrigation and precipitation amounts, weather data, and yield components (yield, harvest plant population, ears/plant, kernels/ear, mass/100 kernels). Yield samples (20 row ft from the center of the plot) from selected treatments were hand harvested on an approximately biweekly schedule during the month preceding corn physiological maturity to ascertain the effect of frequency on grain filling. Weather data were collected with an automated weather station approximately 0.35 mile from the research site to schedule irrigation. Factors calculated after the season included seasonal water use and water use efficiency.

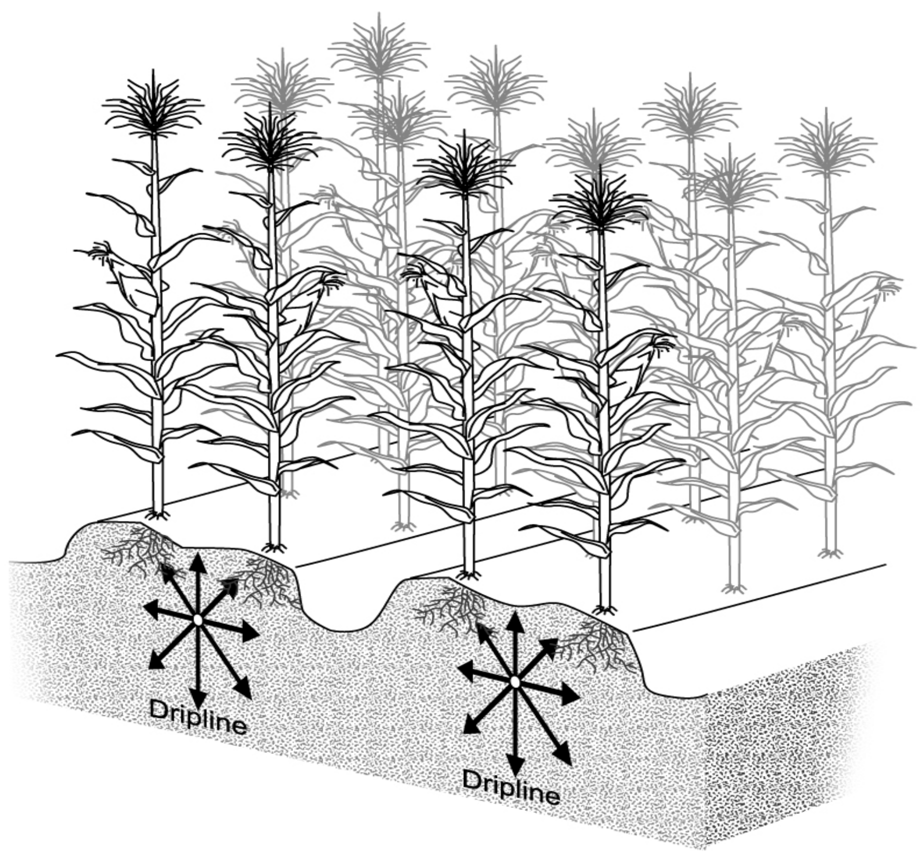

Figure 1.   Physical arrangement of the subsurface dripline in relation to the corn rows.

RESULTS AND DISCUSSION

Weather Conditions

Briefly, the weather conditions can be specified as a severe drought (both hot and dry) during 2002 and 2003 and near normal conditions in 2004. Precipitation during the cropping season was 10.58, 9.12, and 12.24 inches for the respective years, 2002 to 2004 as compared to a normal amount of approximately 12 inches. Calculated evapotranspiration for the 120-day period May 15 through September 11 was much above normal in 2002 and 2003 (27.68 and 25.96 inches, respectively) and near long-term normal (23 inches) at 22.56 inches in 2004. Hot and dry conditions during 2003 led to an increased problem with spider mites which could not be controlled with two insecticide applications.

Corn Yield and Yield Components

Corn yields were high in all three years for all irrigated treatments ranging from 192 to 282 bushels/acre (Table 1, 2, and 3 and Figure 2.) Only in 2002 did irrigation frequency significantly affect yields and the effect was the opposite of the hypothesis. In the extreme drought year of 2002, the less frequent irrigation events with their larger irrigation amounts (0.75 inches/5 days and 1.05 inches/7 days) resulted in yields approximately 10 to 20 bushels/acre higher. The yield component most greatly affected in 2002 was the kernels/ear and was 30-40 kernels/ear higher for the less frequent events. It is suspected that the larger irrigation amounts for these less frequent events sent an early-season signal to the corn plant to set more potential kernels. Much of the potential kernel set occurs before the ninth leaf stage (corn approximately 24-36 inches high), but there can be some kernel abortion as late as two weeks after pollination. It is believed that for this study, the early period (ninth leaf stage) is when the effect occurred. Kernels/ear was numerically higher for the fully irrigated treatment in both 2002 and 2003 which may be further indication of the severity of early season drought conditions in those years. There was no consistent effect of irrigation frequency on corn yields in 2003 and 2004. It is thought the grain filling was truncated in 2003 due to heavy spider mite pressure and this is also the implication of the lower 100 kernel weight that was obtained in 2003. The crop year 2004 was excellent during the grain filling period with very mild conditions. However, even in 2004 there was no consistent effect of irrigation frequency on any of the yield components. The results suggest that irrigation frequencies from daily to weekly should not have much effect on corn yields in most years.

The average daily yield gain for the periods August 30 to October 8, 2002 (39 days), August 25 to September 19, 2003 (25 days) and September 7 to October 5, 2004 (28 days) were calculated for the various treatments. There was no consistent advantage for any of the frequency treatments over another and they often had daily yield gains similar to the fully irrigated treatment (Figure 3).

Averaged over the three years of the study, the deficit irrigated frequency treatments produced 97% of the fully-irrigated treatment yield on 70% of the full irrigation amount. The deficit irrigated treatments required approximately 12.4 inches of irrigation, but outyielded the non-irrigated treatment by 126 bu/acre.

Table 1. Summary of corn yield and water use data from 2002 SDI frequency study, Colby Kansas.

Irrigation Treatment	Plant Pop. Trt.	Yield bu/a	Plants/ acre	Ears/ Plant	Kernels/ Ear	100 Kernel Weight, g	Irrigation inches	Water use inches	WUE lb/a-inch
0.15 in/d	34.0 K	222.2	31145	0.99	523	35.49	13.05	25.46	489
	30.0 K	212.7	28096	0.98	550	35.83		26.58	448
	26.5 K	195.0	25047	0.97	572	35.02		25.19	435
0.45 in/3 d	34.0 K	199.2	32234	0.96	477	34.28	13.50	26.32	424
	30.0 K	223.7	29185	0.98	553	36.01		25.89	485
	26.5 K	199.7	25264	0.91	611	36.04		25.57	438
0.75 in/5 d	34.0 K	213.2	32016	0.97	507	34.43	13.50	26.56	449
	30.0 K	232.0	28750	0.96	588	36.56		26.58	490
	26.5 K	218.0	26790	0.87	642	37.50		26.46	462
1.05 in/7 d	34.0 K	240.6	32452	0.94	543	36.94	13.65	26.42	510
	30.0 K	225.4	28967	0.94	559	37.70		26.60	474
	26.5 K	231.1	26571	0.90	664	36.92		26.85	484
0.30 in/d (Full)	34.0 K	264.1	32017	0.97	612	35.61	20.40	29.32	505
	30.0 K	236.0	28750	0.99	595	35.68		29.41	450
	26.5 K	231.3	26354	1.00	597	36.92		29.00	447
No irrigation	34.0 K	67.9	31363	0.78	218	32.34	0.10	15.47	243
	30.0 K	85.6	28314	0.82	290	32.25		15.92	302
	26.5 K	64.2	24394	0.85	240	32.97		16.28	220
Mean of Irrigation Trt									
0.15 in/d		210.0	28096	0.98	548	35.75	-	25.74	457
0.45 in/3 d		207.5	28895	0.95	547	35.44	-	25.93	449
0.75 in/5 d		221.0	29185	0.93	579	36.16	-	26.53	467
1.05 in/7 d		232.4	29330	0.93	588	37.19	-	26.62	489
0.30 in/d (Full)		243.8	29040	0.98	601	36.22	-	29.24	467
No irrigation		72.6	28024	0.81	249	32.52	-	15.89	255
LSD (p<0.05)									
Any 2 irrigation means within same P Pop		6.3	NS	0.03	19	0.50	-	0.33	15
Mean of P Pop Trt									
34.0 K		201.2	31871	0.93	480	34.85	-	24.92	436
30.0 K		202.6	28677	0.94	522	35.67	-	25.16	441
26.5 K		189.9	25737	0.92	554	36.12	-	24.89	414
LSD (p<0.05)									
Any 2 P Pop means within same Irr Trt Pop		19.2	592	NS	67	1.80	-	NS	50

Table 2. Summary of corn yield and water use data from 2003 SDI frequency study, Colby Kansas.

Irrigation Treatment	Plant Pop. Trt.	Yield bu/a	Plants/ Acre	Ears/ Plant	Kernels/ Ear	100 Kernel Weight, g	Irrigation inches	Water use inches	WUE lb/a-inch
0.15 in/d	34.0 K	209.8	34413	0.98	491	32.39	12.60	26.20	449
	30.0 K	206.4	30057	1.03	507	33.51		26.74	433
	26.5 K	204.1	27225	1.03	532	34.71		26.10	439
0.45 in/3 d	34.0 K	211.7	33759	0.98	496	32.86	12.60	25.94	457
	30.0 K	192.2	30274	0.96	510	33.04		25.85	417
	26.5 K	210.1	27007	1.05	535	35.25		25.88	456
0.75 in/5 d	34.0 K	220.4	33977	0.99	494	33.88	12.75	26.97	458
	30.0 K	228.8	31581	1.02	535	33.78		27.09	473
	26.5 K	193.8	27443	1.00	521	34.47		26.76	406
1.05 in/7 d	34.0 K	203.1	35284	0.95	476	32.76	12.60	26.79	425
	30.0 K	206.9	31799	0.99	492	34.16		26.62	436
	26.5 K	200.0	26354	1.08	532	33.82		26.37	425
0.30 in/d (Full)	34.0 K	235.8	31799	1.01	562	33.20	18.30	28.54	463
	30.0 K	217.5	29839	1.02	522	34.77		28.58	427
	26.5 K	217.4	27225	0.97	557	37.42		28.58	426
No irrigation	34.0 K	33.1	32670	0.40	238	28.46	0.10	15.95	115
	30.0 K	44.7	30928	0.54	229	29.48		16.17	155
	26.5 K	58.5	27007	0.69	265	30.79		15.96	206
Mean of Irrigation Trt									
0.15 in/d		206.7	30565	1.01	510	33.54	-	26.35	440
0.45 in/3 d		204.6	30347	1.00	514	33.72	-	25.89	443
0.75 in/5 d		214.3	31000	1.00	517	34.04	-	26.94	446
1.05 in/7 d		203.3	31145	1.00	500	33.58	-	26.59	428
0.30 in/d (Full)		223.6	29620	1.00	547	35.13	-	28.56	439
No irrigation		45.5	30202	0.54	244	29.58	-	16.02	158
LSD (p<0.05) Any 2 irrigation means within same P Pop		5.8	NS	0.03	15	0.70	-	0.31	15
Mean of P Pop Trt									
34.0 K		185.6	33650	0.88	460	32.26	-	25.06	394
30.0 K		182.7	30746	0.93	466	33.12	-	25.17	390
26.5 K		180.7	27044	0.97	490	34.41	-	24.94	393
LSD (p<0.05) Any 2 P Pop means within same Irr Trt Pop		NS	539	0.10	52	2.47	-	NS	NS

Table 3. Summary of corn yield and water use data from 2004 SDI frequency study, Colby Kansas.

Irrigation Treatment	Plant Pop. Trt.	Yield bu/a	Plants/ Acre	Ears/ Plant	Kernels/ Ear	100 Kernel Weight, g	Irrigation inches	Water use inches	WUE lb/a-inch
0.15 in/d	34.0 K	282.0	35284	0.98	519	40.17	10.65	25.45	621
	30.0 K	268.1	30928	0.96	536	42.63		25.32	594
	26.5 K	251.2	27878	0.98	531	44.20		25.24	559
0.45 in/3 d	34.0 K	267.1	34195	0.94	526	40.13	10.80	25.14	595
	30.0 K	268.1	31363	0.94	544	42.60		25.75	583
	26.5 K	243.5	27661	0.96	541	43.43		24.98	546
0.75 in/5 d	34.0 K	270.3	33106	0.97	529	40.57	11.25	25.54	594
	30.0 K	264.8	31146	0.98	525	42.01		25.31	586
	26.5 K	253.0	28314	0.97	538	43.61		25.12	564
1.05 in/7 d	34.0 K	274.2	35066	0.97	509	40.19	11.55	26.33	584
	30.0 K	266.8	31146	0.97	532	42.16		26.02	574
	26.5 K	243.0	23789	0.96	562	43.23		25.77	528
0.30 in/d (Full)	34.0 K	273.5	33324	0.95	541	40.81	14.70	26.21	585
	30.0 K	256.4	30710	0.94	534	42.29		26.49	542
	26.5 K	240.7	26572	0.95	553	44.14		26.20	514
No irrigation	34.0 K	180.9	34195	0.97	480	28.94	0.10	17.99	563
	30.0 K	180.2	29839	0.94	546	30.15		18.24	553
	26.5 K	170.1	26354	0.98	507	33.27		18.04	529
Mean of Irrigation Trt									
0.15 in/d		267.1	31363	0.97	528	42.33	-	25.33	591
0.45 in/3 d		259.5	31073	0.94	537	42.05	-	25.29	575
0.75 in/5 d		262.7	30855	0.97	531	42.06	-	25.32	581
1.05 in/7 d		261.3	31000	0.97	534	41.86	-	26.04	562
0.30 in/d (Full)		256.9	30202	0.95	542	42.41	-	26.30	547
No irrigation		177.0	30129	0.96	511	30.79	-	18.09	548
LSD (p<0.05) Any 2 irrigation means within same P Pop		5.2	NS	NS	NS	0.57	-	0.28	12
Mean of P Pop Trt									
34.0 K		258.0	34195	0.96	517	38.47	-	24.44	590
30.0 K		250.7	30855	0.96	536	40.31	-	24.52	572
26.5 K		233.6	27261	0.96	538	41.98	-	24.22	540
LSD (p<0.05) Any 2 P Pop means within same Irr Trt Pop		19.0	1928	NS	46	2.00	-	NS	43

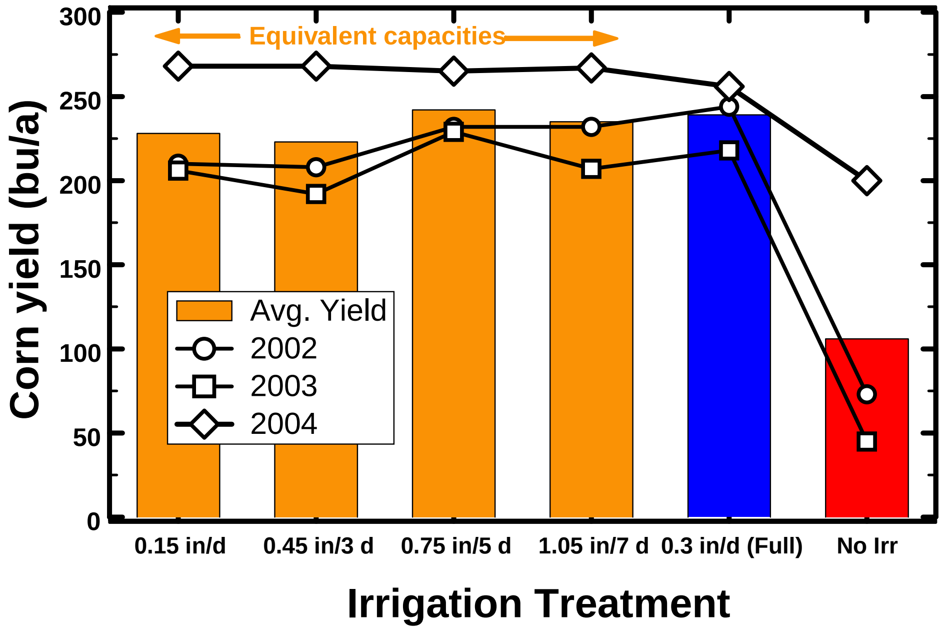

Figure 2. Corn grain yields as affected by irrigation treatment, Colby, Kansas, 2002 to 2004.

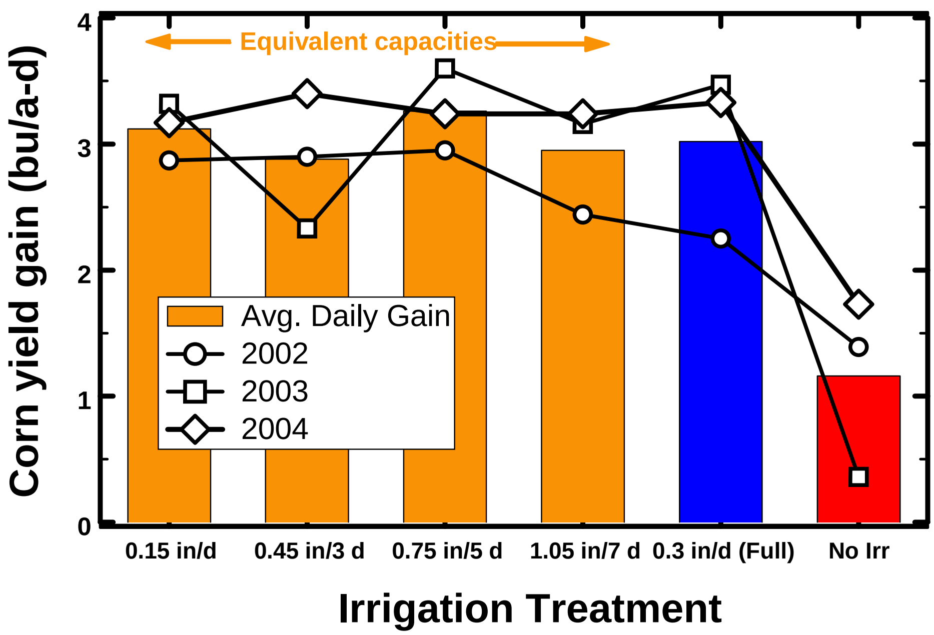

Figure3. Average daily yield gain for corn as affected by irrigation treatment, Colby, Kansas, 2002 to 2004.

Plant population had little effect on corn yields in 2002 and 2003 (Tables 1 and 2) but higher plant population had a large effect in 2004 (Table 3) increasing yields by approximately 15-20 bu/acre. This is consistent with an earlier study (Lamm and Trooien 2001) that indicated that higher plant population was seldom a drag on yield but allowed for higher yields in good years.

Water use and Water Use Efficiency

Water use for the 8-ft soil profile tended to be slightly higher for the less frequent irrigation treatments (0.75 inches/5 days and 1.05 inches/7 days) and was significantly higher in 2002 which may explain the higher yields for those treatments in that year (Tables 1, 2 and 3). Water use for the deficit irrigated frequency treatments averaged only 7% less than the fully irrigated treatment although irrigation was 30% less. This indicates the deficit irrigated treatments were effective at “mining” soil water and also perhaps had less deep percolation losses. Water use efficiency (yield divided by total water use) was significantly higher for the less frequent treatments in 2002, but tended higher for the more frequent treatments in 2003 and 2004.

Plant population did not affect total water use in any year. This would be anticipated since there is little difference in water use after sufficient leaf area index is obtained. These populations were sufficiently high to obtain good ground cover early in the season. Water use efficiency was higher for the higher plant population in 2004, reflecting the increased yield with plant population.

SUMMARY AND CONCLUSIONS

Corn production was not strongly affected by SDI frequency in two of three years and less frequent larger irrigation events were beneficial in the extreme drought year of 2002. Further research is being conducted to determine why early season corn kernel set can be affected in extreme drought years. Average daily yield gain during the grain filling stage was not affected by SDI frequency. Water use and water use efficiency for the 8-ft soil profile also were not strongly affected.

Combining these results with earlier studies from the U.S. Great Plains and elsewhere (Camp, 1998; Howell et al., 1997; Caldwell et al., 1994) continues to suggest that SDI frequency is not a significant issue for corn production on these deeper silt loam soils. Irrigators may want to continue to use less expensive manually operated systems unless they are engaged in automated nutrient management programs.

Higher plant population is generally beneficial in corn production with SDI systems even under deficit irrigation.

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[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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