EFFECT OF DRIPLINE DEPTH ON FIELD CORN PRODUCTION IN KANSAS

Freddie R. Lamm
Kansas State University
Northwest Research-Extension Center
Colby, Kansas
flamm@ksu.edu

Todd P. Trooien
South Dakota State University
Agricultural and Biosystems Engineering
Brookings, South Dakota
todd_trooien@sdstate.edu

ABSTRACT

A four-year yield study (1999-2002) was conducted to examine the effect of dripline depth on subsurface drip-irrigated field corn on the deep silt loam soils of western Kansas. An additional year (2003) was included in the analysis of long term dripline flowrates and temperatures at the soil/water interface along the dripline. Germination of the field corn with the subsurface drip irrigation system was not examined in this field study. Results indicate that dripline depths ranging from 8-24 inches are acceptable for field corn production on silt loam soils in the region. There was a tendency for slightly decreased corn yields for the deepest dripline depth (24 inches). The results suggest other factors external to the study might have a larger influence on selection of dripline installation depth. These other factors might include producer preferences, tillage schemes, rodent management, perceived need for surface wetting for germination, and installation draft requirements and costs.

INTRODUCTION

Subsurface drip irrigation (SDI) is a relatively new technology in the central Great Plains but producers are beginning to adopt and adapt the technology to their farms. Most of the SDI research for field corn conducted at Kansas State University has been with driplines at a 16-18 inch depth in deep silt loam soils. Generally, at this depth the soil surface stays dry and this helps to eliminate evaporative losses. However, low flow driplines at this depth for the typical 5-foot dripline spacing centered between 30-inch corn rows will not adequately wet the corn seed zone for germination. In many years, irrigation is not required to establish a summer crop in the central Great Plains as May-June have the highest precipitation amounts during the year in this semi-arid, summer precipitation pattern climate. Some producers in the region wish to have the capability to use SDI for germination in those isolated dry years and feel shallower dripline depths may enhance those prospects. However, the question arises about what effect dripline depth has on corn production, water use and also on system management and maintenance for the long term. SDI system life is an extremely important factor in the economics of SDI for the lower value commodity crops such as field corn. In 1999, Kansas State University initiated a field study to evaluate the effect of dripline depth 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 1999-2003. Cropping system and soil water results will be reported for the years 1999-2002. Long-term flow measurements will be reported for the 5 seasons (1999-2003) and soil temperature measurements will be reported for 2003.

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 five microirrigation dripline depths of 8, 12, 16, 20 or 24 inches replicated four times in a complete randomized block design. Plot length was 139 ft and plot width was eight corn rows spaced 2.5 ft apart (20 ft).

The subsurface drip irrigation (SDI) system was installed in the spring of 1999 prior to corn planting in May. Low flow (0.22 gpm/100 ft) Toro Ag[1] dripline with a 12 inch emitter spacing and 7/8 inch inside diameter (Aquatraxx EA7XX1222) was installed with a 5 ft dripline spacing with a shank type injector at the specified treatment depths. The emitter exponent for the dripline is 0.54 and the manufacturer's coefficient of variation is approximately 3%. There were four driplines in each plot. 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 1.39 gpm/plot, coinciding with an operating pressure of approximately 10 psi. Irrigation water was supplied from an unlined surface reservoir to which groundwater was pumped for temporary storage. The surface reservoir adds two major issues to the study, the introduction of biological activity and varying water temperatures.

Pioneer hybrid 3162 seed corn was used in 1999 -2002. This hybrid is a full season hybrid for the region with an approximately 118 day comparative relative maturity requirement. In 2003, the corn planting was purposely delayed until mid-May to attempt an examination of germination potential of the different depths. Heavy rains following planting negated this study and the results are excluded from discussion. This late-planting date resulted in a much later first irrigation for this study than normal. Pest (weeds and insects) control was accomplished with standard practices for the region. Nitrogen fertilizer was applied to the study area with approximately 125 lbs N/acre early preplant and 75 lbs N/acre through the SDI system in late June each year. A starter fertilizer application at planting banded an additional 30 lbs N/acre and 45 lbs P_20_5/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.

Irrigation was scheduled using a climatic water budget each year and all dripline treatments received the same amount of water within a given year. Daily or bi-daily irrigations were scheduled when the calculated soil water depletion exceeded approximately 1 inch. Irrigation amounts ranged from 0.25 to 0.5 inches for each event depending on availability of pumping capacity for the given event. 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.

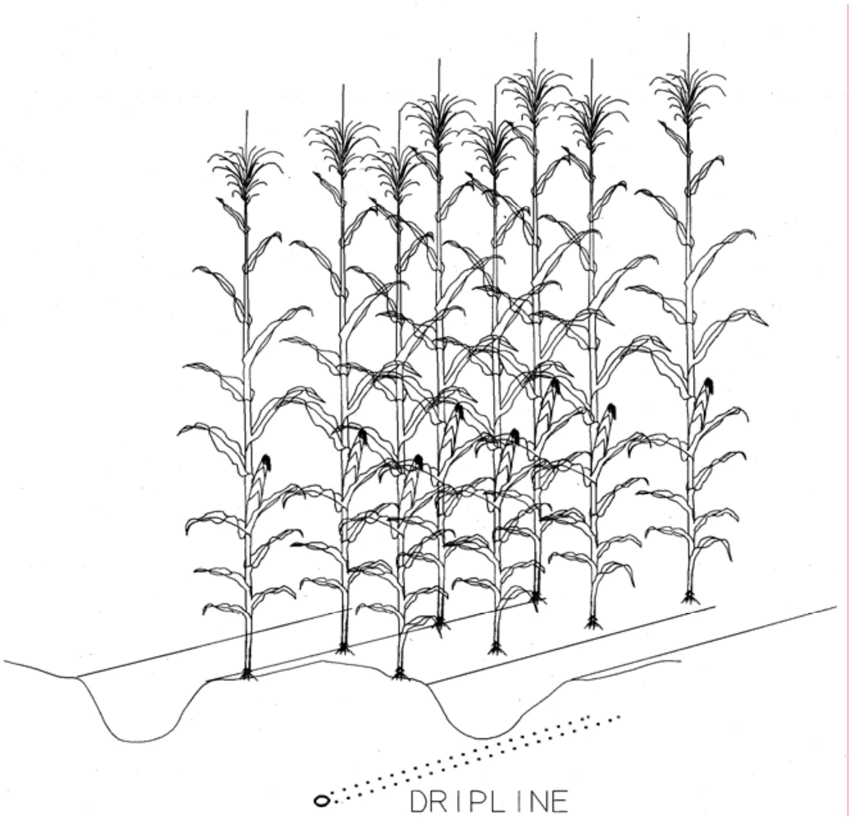

Figure 1. Physical arrangement of the subsurface dripline in relation to the corn rows.

Pressure and flow measurements were made at the beginning of the study and also at the end of each irrigation season using the municipal grade flowmeters for an approximately 20 minute period and recording the pressure at the inlet and tail end of the plots. High quality 0-30 psi (4-inch face) pressure gauges with approximate accuracy of +/- 1% of full scale were used in 1999-2002 and 0-30 psi pressure transducers with +/- 0.5% of full scale were used in 2003. Flowrates were normalized to 10 psi through use of the emitter exponent to allow comparisons between years and small pressure variations between events.

In 2003, thermocouples were installed in each plot right next to the dripline (closer than 0.25 inch) at a distance of 100 ft from the water inlet for the plot. Additionally, three thermocouples were installed in three plots in the soil surface layer (0-3/4 inch). The water inlet temperature was measured for two plots by installing a thermocouple directly in the inlet pipe immediately prior to entering the plot. During these 2003 temperature tests, large irrigation amounts were used (2-4 inches for each event) to examine the duration of temperature effects.

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 0.25 mile from the research site. Values calculated after final data collection included seasonal water use and water use efficiency.

RESULTS AND DISCUSSION

Weather Conditions

Briefly, the weather conditions can be specified as wetter than normal in 1999 and excessively dry in 2000-2002. Precipitation during the cropping season was 16.98, 6.21, 9.26 and 9.90 inches for the respective years, 1999-2002. Calculated evapotranspiration was slightly below normal in 1999 (21.64 inches) and above normal at 27.48, 26.28, and 27.68 inches for the years 2000-2002, respectively. This resulted in irrigation requirements of 10.50, 18.00, 19.00, and 19.65 inches for the four respective years, 1999-2002. The SDI system was not used to enhance germination in any year although some additional residual soil water in the surface layers for the shallower dripline depths may have existed in the spring of 1999 shortly following the late spring installation. The crop year 2002 was very dry at planting and it is possible the shallower depths could have benefited in crop germination if they had been irrigated. However, this was not part of the experimental protocol, so no irrigation was performed at this time.

Tillage and Rodent Management Aspects

Although tillage and rodent management was not specifically examined in the study, it should be noted that there were no instances of dripline damage due to tillage or rodents at any point in time. Shallow cultivation for weeds during the corn season was accomplished even for the 8-inch depth. This may have been enhanced by the controlled-traffic bed management scheme used in this study area (Figure 1.). Deep tillage schemes would definitely be affected by dripline depths less than 12 inches. There are thoughts by some researchers that deeper dripline depths (greater than 1 ft) may reduce rodent activity.

Corn Yield and Yield Components

Corn yields were very high in all four years ranging from 249 to 291 bushels/acre (Table 1 and Figure 2.) In any given year there were no significant differences in yield attributable to differences in dripline depth. However, when averaged over the 4 years there was a significant difference with the 24-inch depth resulting in slightly lower yields (Table 1 and Figure 2.) In general, there were no significant effects on the yield components with the exception of a higher number of kernels/ear for the 8 inch depth in 1999 (Table 1.) and a slightly higher ears/plant for the 16-inch depth for the 4-year average. The higher kernels/ear for the 8-inch depth in 1999 may possibly reflect more favorable soil water conditions early in the season that were caused by higher residual soil water conditions in the surface layers following SDI system installation. Corn grain yield levels were very high in all cases and very similar, so there is very little reason to select one dripline depth over another on the basis of grain yield.

Table 1. Yield component and water use data from a dripline depth study for corn, 1999-2002.

Dripline depth inches	Yield bu/acre	Plants/acre	Ears/Plant	Kernels/ear	100 Kernel wt. g	Water use inches	WUE lb/acre-in
Year 1999							
8	290.9	30710	1.00	691	34.79	33.93	480
12	270.6	29621	1.02	647	35.17	33.79	449
16	278.3	30710	1.00	628	36.76	33.41	467
20	275.3	31363	1.00	624	35.81	33.71	458
24	272.8	30274	1.01	642	35.39	33.03	462
Mean	277.6	30536	1.01	646	35.58	33.57	463
LSD 0.05	NS	NS	NS	44	NS	NS	NS
Year 2000							
8	252.6	26354	1.00	642	37.92	29.55	479
12	256.1	27225	1.00	629	38.02	28.56	503
16	265.5	26354	1.05	635	38.45	28.56	521
20	248.7	26789	1.01	622	37.61	27.71	503
24	253.7	27443	1.00	619	38.02	28.00	508
Mean	255.3	26833	1.01	629	38.00	28.48	503
LSD 0.05	NS	NS	NS	NS	NS	NS	NS
Year 2001							
8	268.8	35284	0.96	585	34.58	32.52	464
12	270.0	33977	1.01	594	33.76	32.47	466
16	274.6	35719	1.00	572	34.40	31.98	481
20	277.9	34412	1.00	570	36.05	31.56	493
24	269.0	34848	0.98	582	34.61	31.62	477
Mean	272.0	34848	0.99	580	34.68	32.03	476
LSD 0.05	NS	NS	NS	NS	NS	NS	NS
Year 2002							
8	277.2	34413	0.99	519	39.96	31.91	487
12	264.1	33106	0.99	529	39.11	31.49	470
16	286.0	34194	0.99	547	39.21	32.04	500
20	263.0	34195	0.99	485	41.22	30.61	482
24	254.3	33324	0.98	507	39.39	30.79	463
Mean	268.9	33846	0.99	518	39.78	31.37	480
LSD 0.05	NS	NS	NS	NS	NS	NS	NS
All Years							
8	272.4	31690	0.99	609	36.81	31.98	478
12	265.2	30982	1.00	600	36.51	31.58	471
16	276.1	31744	1.01	595	37.21	31.50	492
20	266.2	31690	1.00	575	37.67	30.90	484
24	262.4	31472	0.99	587	36.85	30.86	478
Mean	268.5	31516	1.00	593	37.01	31.36	481
LSD 0.05	9.0	NS	0.02	NS	NS	0.66	NS

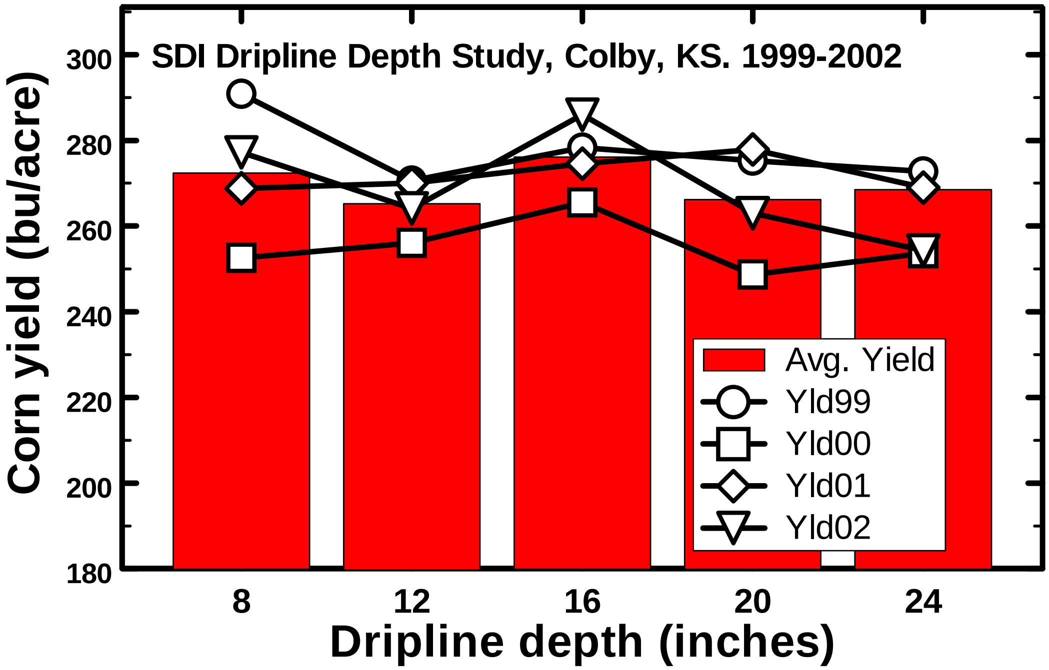

Figure 2. Field corn grain yields as affected by dripline depth, Colby, Kansas, 1999-2002.

Water use and Water Use Efficiency

Water use for the 8-ft soil profile was not affected in any given year but when averaged over the four years was slightly less for the 20 and 24-inch dripline depths (Table 1). There were no significant differences in water use efficiency (grain yield divided by water use) in any year. The fact that no appreciable differences exist suggests that all treatments received adequate water and that dripline depth in the range of 8-24 inches is not a major design issue in terms of water use and water use efficiency.

Soil Water in the Top Three Feet

Visual observations of the various treatments throughout the irrigation seasons indicated that the 8 and 12 inch dripline depths had more wetting at or near the soil surface. This might be an advantage in germinating crops, but has little or no advantage once the crop is germinated. Damp soil surfaces can result in higher evaporative losses and perhaps more weed growth. Visual observations indicated that there were slightly higher flushes of late-season grasses for the 8-inch dripline depth, but the small weed pressure increase was not considered to affect the corn crop. Soil water measurements in the top 3 ft are shown for 2002 in Figure 3. The graph shows a few instances where soil water is noticeably higher for the shallower dripline depths in the top foot of the soil profile but the deeper dripline depths show slightly higher soil water in the second and third foot of the soil profile. Under the full irrigation scheme used in this study, none of the soil water differences would be considered of critical importance, with the exception of the possible germination enhancement by shallower dripline depths that was previously discussed.

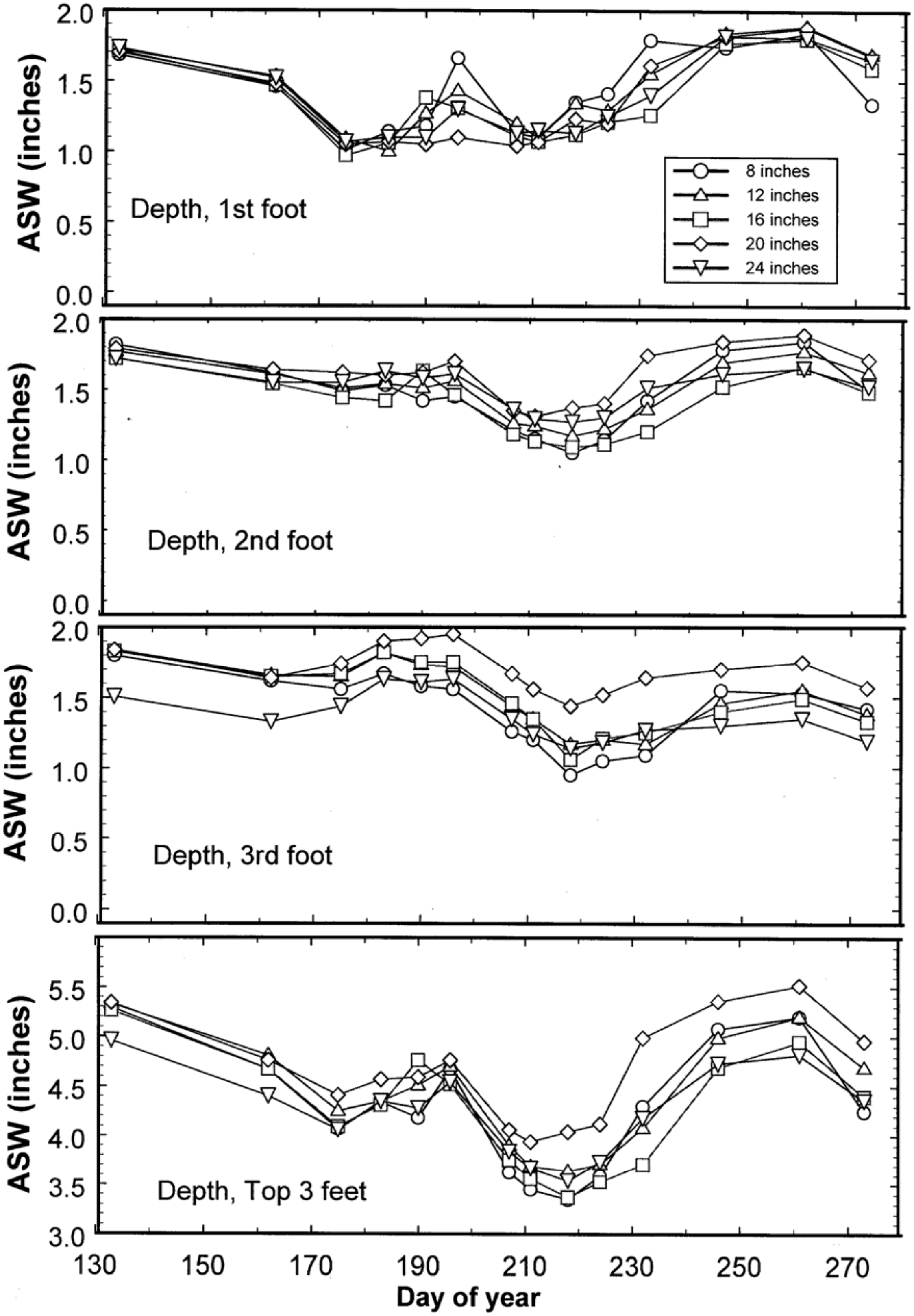

Figure 3. Soil water conditions in the top 3 feet as affected by dripline depth in the dry year of 2002.

Long-Term Flow Measurements and Soil/Water Interface Temperatures.
As previously discussed the water source for this SDI system is an unlined surface reservoir. It was hypothesized that there might be an interaction between dripline depth and emitter clogging because there might be differences in water temperature at the dripline depth. Both biological and chemical clogging hazards are temperature dependent and can be higher with warmer temperatures.

Flowrates did vary appreciably over the course of the five seasons reflecting decreases caused by the silt and biological loads experienced by the driplines (Figure 4). During the course of each season, dripline flowrates would decrease. Acid and chlorine were injected periodically every 2-3 weeks for a period of 1 hour (approximately 50 ppm chlorine and acid to adjust to pH of 4), but dripline flushing during 1999-2001 was restricted to the spring and fall. During 2002, it became more apparent that clogging was becoming more difficult to manage with just acid and chlorine, so one additional flushing was added mid-season. By the end of 2002, dripline flowrates were 10-25% lower than the initial flowrate. There was no clear pattern in terms of flowrate decreases as affected by dripline depth (Figure 4.). Some of the differences that did exist were more related to the random nature of a particular plot being affected by clogging rather than a specific dripline depth treatment. In 2003, additional flushing events were added (approximately monthly) along with more aggressive acid and chlorine treatments (about 2 hours for each event followed by leaving the system off overnight and then flushing again). This stricter maintenance regimen helped recover much of the flow that had been lost during the previous seasons and the treatment average (4 plots) flowrates were within approximately 8% of the initial flowrates at the close of the season.

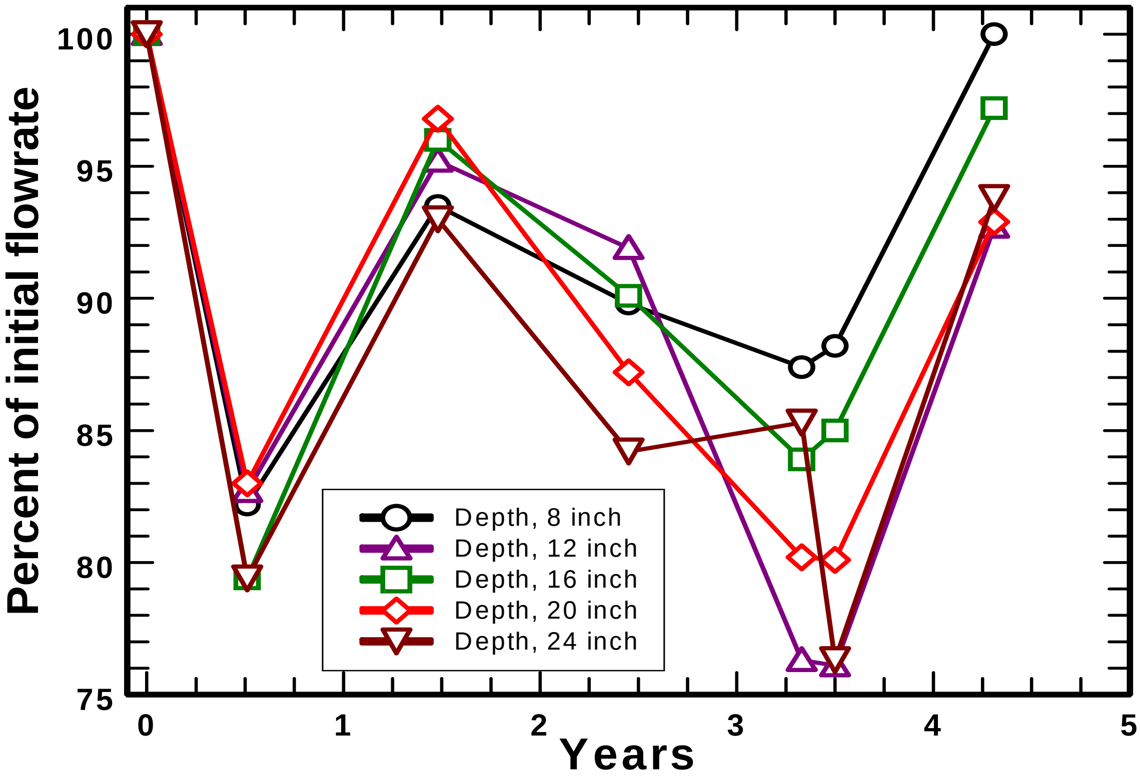

Figure 4. Dripline flowrate as percentage of initial flowrate for the 5 different depths, 1999-2003.

In 2003, temperatures were measured at the soil/water interface at the dripline at a point 100 feet from the water inlet. The first measurements were made in early July just prior to the first irrigation of the corn. The corn was approximately 18 inches tall at this point and did not fully shade the soil surface. Soil temperatures near the surface and also at the different dripline depths were higher at this point in time than they were at any time during the rest of the season. This is because the solar radiation load to the soil surface was still high due to less shading and because no large increment of water at the dripline had been added at this point. Temperatures prior to the first irrigation were varying diurnally for the 8-inch depth from about 75-80 °F and less variable at the deeper depths in the range of 75 °F (Figure 5.). This compared with soil surface temperatures varying diurnally from 75 to 105 °F. During the first irrigation event, the temperatures varied with the water inlet temperature falling about 5 degrees during the initial portion of the event while the water temperature fell approximately 10 °F and then slowly rising back to about 74°F as the water temperature at the inlet increased to about 73 °F. Much of the diurnal variance for the 8-inch dripline depth disappeared following this irrigation event suggesting the large temperature buffering capacity of the wetted soil.

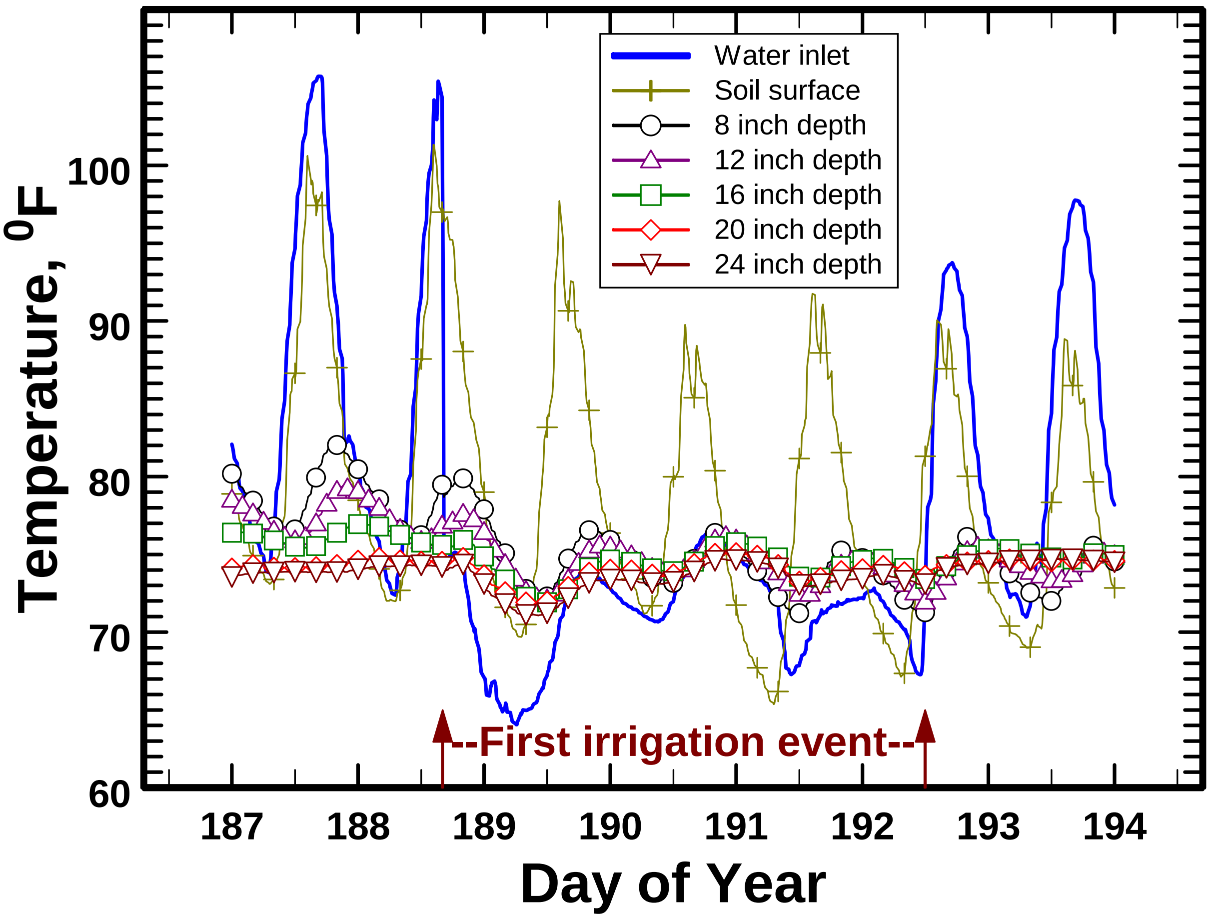

Figure 5. Temperatures at the water inlet, near the soil surface and near the dripline for the 5 dripline depths prior to corn canopy closure and the first irrigation in 2003.

Later in the season (August), temperatures at all of the various dripline depths ranged from approximately 72-73 °F with even cold irrigation water (approximately 62 °F) only decreasing the dripline temperature 1-2 degrees (Figure 6). No appreciable temperature differences were attributable to dripline depth. This suggests that dripline depths of 8-24 inches would greatly moderate temperature variations that would occur for driplines placed on the soil surface. These relatively stable temperatures may be helpful in reducing biological and particularly chemical clogging hazards.

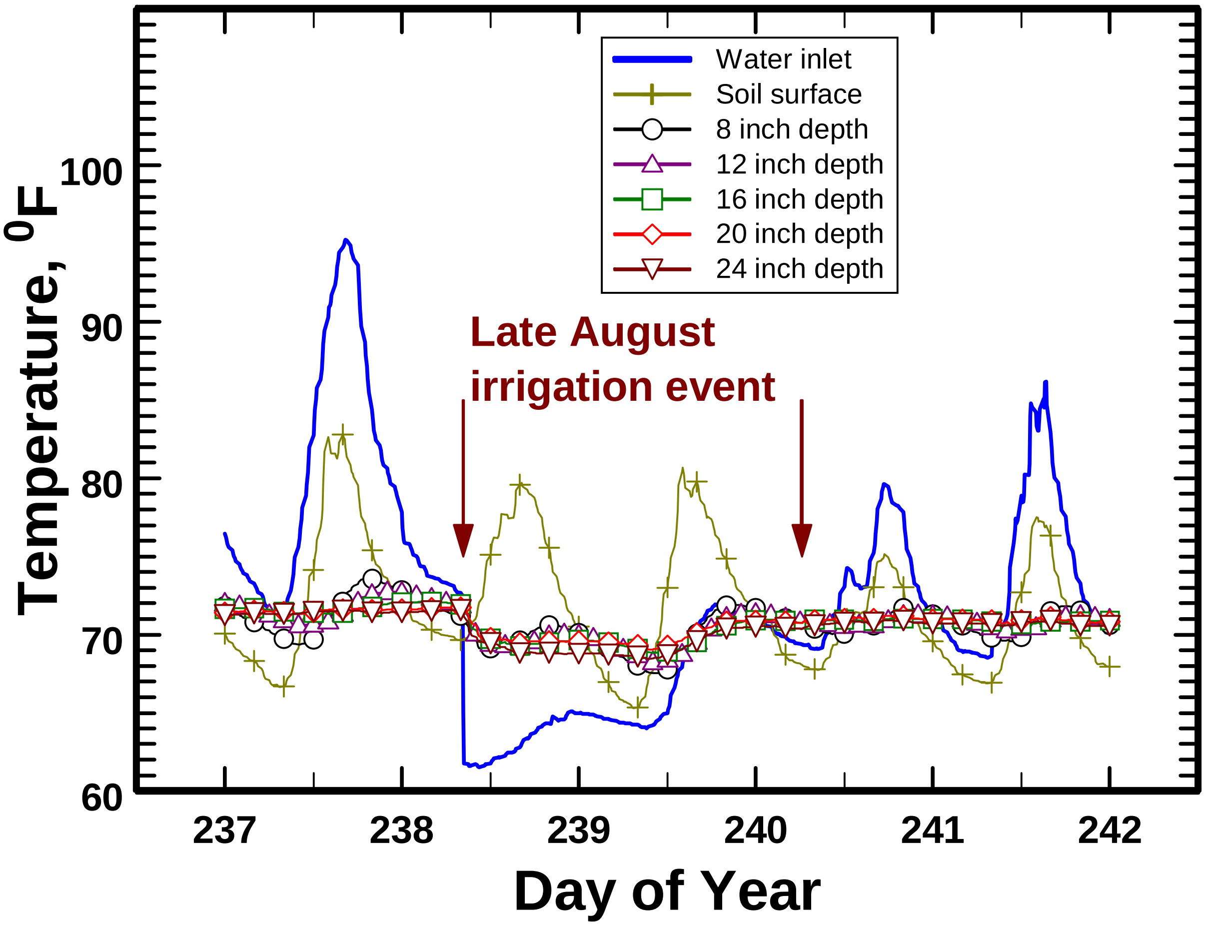

Figure 6. Temperatures at the water inlet, near the soil surface and near the dripline for the 5 dripilne depths near the end of the corn irrigation season in 2003.

SUMMARY AND CONCLUSIONS

Corn production was not strongly affected by dripline depths ranging from 8-24 inches in this study where crop germination was not a factor. A slight tendency existed for corn yields to be reduced for the deepest dripline depth (24 inches) which might be related to early season growth or water and nutrient availability. The deep, well drained silt loam soil with good water holding capacity is conducive to deep rooting of field corn and this may be part of the reason there was no strong effect of dripline depth on corn production. Water use and water use efficiency for the 8-ft soil profile also were not strongly affected.

The shallower 8 and 12-inch dripline depths resulted in slightly higher amounts of soil water at the row location in the top foot of the soil profile. This may be advantageous in years where irrigation is needed for germination, but may also cause larger soil evaporation losses during the cropping season.

Flowrates varied throughout the 5 seasons indicating some clogging problems that were occurring due to the pumping of water from a reservoir. More aggressive maintenance during the 2003 season remediated much of the clogging problems. There was no apparent effect of dripline depth on clogging in this study.

Dripline depths of 8-24 inches resulted in temperatures at the soil/dripline interface in the 72-77 °F range for the whole irrigation season. The greatest amount of temperature variation occurred for the 8-inch depth, but it was only 4-6 degrees during the period preceding canopy closure and the first irrigation. After canopy closure and the start of the irrigation season, temperatures at the dripline were generally about 72-73 °F. These temperatures may have helped reduce biological and chemical plugging hazards.

The results indicate that there is little effect of dripline depths ranging from 8-24 inches for corn production on the deep silt loams of western Kansas provided there is adequate water for establishment of the crop. Other factors not specifically examined in the study such as producer preferences, tillage schemes, rodent management, need for surface wetting for germination, and installation draft requirements and cost might be better criteria for the dripline depth decision.

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

This paper was first presented at the 24th Annual International Irrigation Association Exposition and Technical Conference, San Diego, California, November 18-20, 2003. Paper No. IA03-0495. Proceedings available on CD-Rom from Irrigation Association, Falls Church, Virginia

This file was slightly revised on October 14, 2004 to reflect a correction to Figure 2.