KSU RESEARCH FOR CORN PRODUCTION USING SDI

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ABSTRACT

Studies were initiated in 1989 at Kansas State University (KSU) to develop the methodology for successful application of subsurface drip irrigation (SDI) for corn production on the deep silt loam soils of western Kansas. Research efforts included evaluations of: the water requirement of subsurface drip-irrigated corn; the effect of SDI application frequency; irrigation uniformity for various length driplines; optimum dripline spacing and nitrogen management for subsurface drip-irrigated corn. SDI for row crops in the Central Great Plains is an emerging, but sound technology. Changing economic and environmental factors and/or resource constraints could result in increased adoption of this technology.

INTRODUCTION

The Ogallala or High Plains Aquifer is one of the largest freshwater sources of groundwater in the world. There is a large amount of irrigated crop production in the High Plains and as a result the aquifer is experiencing overdraft. Additional efforts are needed to develop improved water management techniques to conserve nonrenewable resources such as the Ogallala Aquifer. SDI is one technology that can make significant improvements in water management. However, it has traditionally been ignored as an irrigation method for crops such as corn because of high initial investment costs. Times change as well as the constraints under which irrigators operate. Economics, environmental issues and water resource constraints may dictate the adoption schedule of this irrigation method, but the methodology needs to be developed before the practice is adopted.

KSU has taken the initiative to determine the methodology for successful application of SDI for corn on the deep silt loam soils of western Kansas. This paper will summarize the engineering research efforts at KSU evaluating SDI for corn. The overall objectives of the research were to conserve water, to protect groundwater quality, and to develop sound methodologies for subsurface drip-irrigated corn. Research efforts have been broad, including evaluations of the water requirements of subsurface drip-irrigated corn, effects of SDI application frequency, irrigation uniformity for various length driplines, optimum dripline spacing and nitrogen management for subsurface drip-irrigated corn.

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This material is based upon work supported by the U.S. Department of Agriculture Cooperative State Research Service under Agreement Nos. 89-COOP-1-4927 and 93-34296-8454. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the U.S. Department of Agriculture.

PROCEDURES

This report summarizes several studies conducted at the KSU Northwest and Southwest Research-Extension Centers at Colby and Garden City, Kansas, respectively. A complete discussion of all the employed procedures lies beyond the scope of this paper. For further information about the procedures for a particular study the reader is referred to the accompanying reference papers when so listed. The following general procedures apply to all studies unless otherwise stated.

The two study sites were located on deep, well-drained, loessial silt loam soils. These medium-textured soils, typical of many western Kansas soils, hold approximately 18.9 inches of plant available soil water in the 8 ft profile at field capacity. Study areas were nearly level with land slope less than 0.5% at Colby and 0.15% at Garden City. The climate is semi-arid, with an average annual precipitation of 18 inches. Daily climatic data used in the studies were obtained from weather stations operated at each of the Centers.

The studies utilized SDI systems installed in 1989-90 (Lamm et al., 1990). The systems have dual-chamber drip tape 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 each dripline lateral is centered between two corn rows (Figure 1).

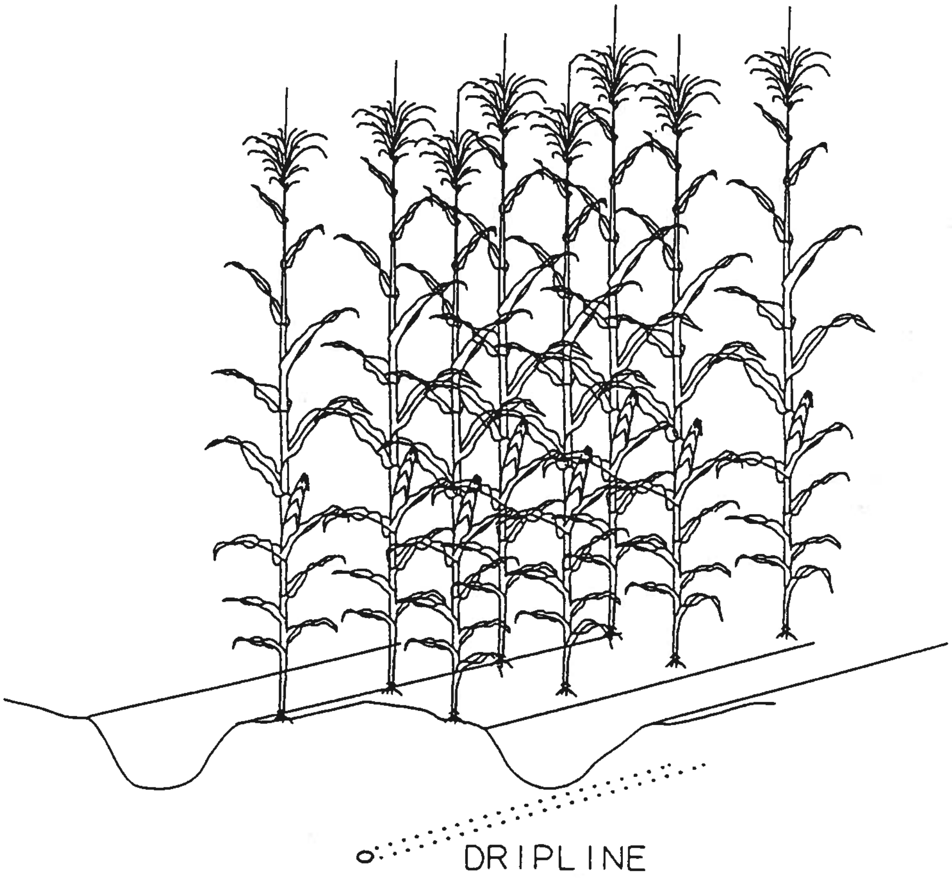

Figure 1. Arrangement of corn rows on permanent bed system in relation to the dripline.

A ridge-till system was used in corn production with two corn rows, 30 inches apart, grown on a 5 ft wide bed. Flat planting was used for the dripline spacing studies conducted at both locations. In these studies, it was not practical to match bed spacing to dripline spacing with the available tillage and harvesting equipment. Additionally at Garden City, corn rows were planted perpendicular to the driplines in the dripline spacing study. All corn was grown with conventional production practices for each location. Wheel traffic was confined to the furrows.

Reference evapotranspiration and actual evapotranspiration (AET) was calculated using a modified Penman combination equation similar to the procedures outlined by Kincaid and Heerman (1974). The specifics of the calculations are fully described by Lamm et al. (1995).

Irrigation was scheduled using a water budget to calculate the root zone depletion with precipitation and irrigation water amounts as deposits and calculated daily corn water use (AET) as a withdrawal. Modification of the individual treatment irrigation schedules to simulate the various regimes was accomplished by multiplying the calculated AET value by the respective regime fraction, such as, 0.75 for a treatment designed to replace 75% of AET. If the root-zone depletion became negative, it was reset to zero. Treatments were irrigated to replace 100% of their calculated root-zone depletion, when the depletion was within the range of 0.75 to 1.25 inches. Root zone depletion was assumed to be zero at crop emergence. Irrigation was metered separately onto each plot. Soil water amounts were monitored weekly in each plot with a neutron probe in 12 inch increments to a depth of 8 ft.

RESULTS AND DISCUSSION

Spacing and Length of the Driplines

Increasing the spacing and/or length of dripline laterals would be some of the most important factors in reducing the high investment costs of SDI. Soil type, dripline installation depth, crop type and the reliability and amount of in-season precipitation are major factors which determine the maximum spacing. Dripline size, emitter flowrate and spacing, and land slope are major hydraulic factors which determine acceptable length of run.

Two studies have been conducted in western Kansas to determine the optimum dripline spacing (installed at a depth of 16-18 inches) for corn production on deep, silt-loam soils. The Garden City study evaluated 4 spacings (2.5, 5, 7.5, and 10 ft) with corn planted in 30 inches rows perpendicular to the dripline lateral. At Colby, 3 spacings (5, 7.5, and 10 ft) were examined with corn planted in 30 inch rows parallel to the driplines. Average yields were similar between sites even though row orientation was different (Table 1).

Table 1. Corn yields obtained with various dripline spacing treatments under full and reduced irrigation at Garden City and Colby, Kansas, 1989-91.

Spacing Trt.	Irrigation Trt.	Dripline Ratio in relation to 1.52 m	Corn Yield (bu/a) Garden City 1989-91	Corn Yield (bu/a) Colby 1990-91
2.5 ft	Full Irrigation	2.00	230	----
5.0 ft	Full Irrigation	1.00	218	216
7.5 ft	Full Irrigation	0.67	208	204
7.5 ft	Reduced Irrigation (67%)	0.67	----	173
10.0 ft	Full Irrigation	0.50	194	194
10.0 ft	Reduced Irrigation (50%)	0.50	----	149

The highest average yield was obtained by the 2.5 ft dripline spacing at Garden City. However, the requirement of twice as much dripline (dripline ratio, 2.00) would be uneconomical for corn production as compared to the standard 5 ft dripline spacing. The results, when incorporated into an economic model, showed an advantage for the wider dripline spacings (7.5 and 10 ft) in some higher rainfall years. However, the standard 5 ft dripline spacing was best when averaged over all years for both sites.

Wider dripline spacings will not consistently (year-to-year) or uniformly (row-to-row) supply crop water needs. In 1990 at Colby, yields for the 5 and 7.5 ft dripline spacings were equal when full irrigation was applied, partially because soil water reserves were high at planting. In 1991, following a dry winter, yields for the wider 7.5 ft dripline spacing were reduced by 25 bu/a (Lamm et al., 1992). Similar results were reported by Spurgeon et al. (1991) at Garden City. The studies at Colby also sought to resolve whether equivalent amounts of water should be applied to the wider dripline spacings or whether irrigation should be reduced in relation to the dripline ratio. Yields were always lower for the corn rows furthest from the dripline in the wider dripline spacings regardless of which irrigation scheme was used (Figure 2). However in 1991, there was complete crop failure in the corn rows furthest from the dripline when irrigation was reduced in relation to the dripline ratio. Full irrigation on the wider dripline spacings at Colby resulted in excessive deep percolation (Darusman, 1994) and reduced overall water use efficiency (Lamm et al., 1992). Soils having a restrictive clay layer below the dripline installation depth might allow a wider spacing without affecting crop yield. Wider spacings may also be allowable in areas of increased precipitation as the dependency of the crop on irrigation is decreased (Powell and Wright, 1993). One of the inherent advantages of a SDI system is the ability to irrigate only a fraction of the crop root zone. Careful attention to proper dripline spacing is, therefore, a key factor in conserving water and protecting water quality.

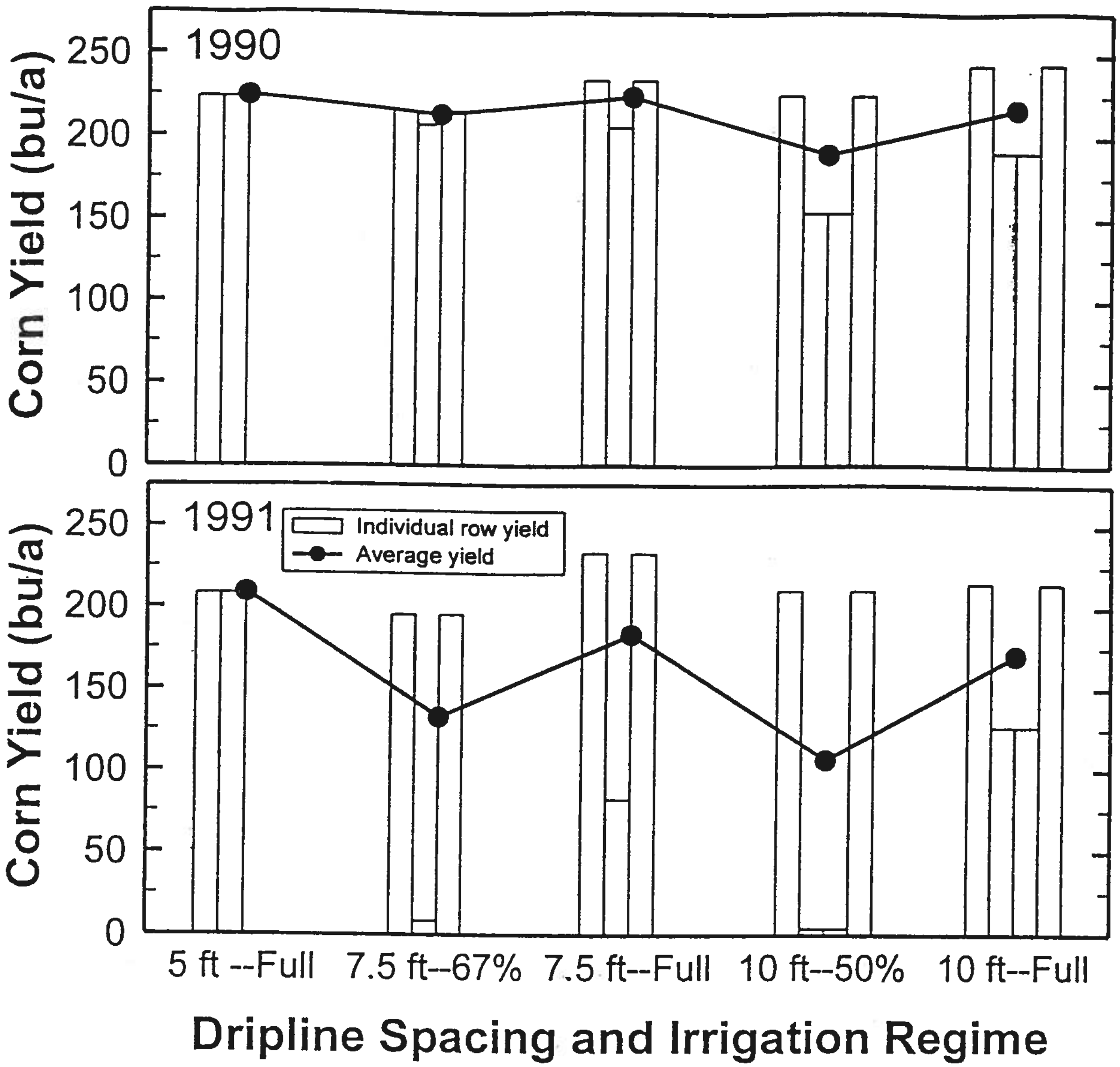

Figure 2. Corn yield as affected by dripline spacing and irrigation regime, Colby KS, 1990-91. Note: Bars represent the individual corn row yields between two adjacent driplines.

Studies conducted at Colby and Garden City, Kansas have indicated that lateral lengths as long as 660 ft are acceptable on slopes up to 0.5% for driplines with 0.625 inch inside diameter applying 0.25 gpm/100 ft for corn production on the deep silt loam soils (Makens et al., 1992). Calculations of the dripline hydraulics has indicated that a flow variation of approximately 17% exists between the water inlet and the terminal end of the dripline laterals for the 660 ft driplines when flowing upslope. However, corn yields were not significantly different at various distances along the lateral, even in 1991 when the study was deficit irrigated to replace only 75% of water use needs as estimated by a climatic- based ET model that has been used successfully for furrow and sprinkler irrigation. Overall yields were high, averaging 210 bu/a for the two locations during the two years of study. There also were no appreciable differences in water use or water use efficiency in either year. Corn is a relatively deep rooted crop and on these deep soils, can apparently buffer moderate water stress that might be caused by the flow variation.

Frequency of Subsurface Drip Irrigation

Typically, a smaller volume of soil is wetted with SDI as compared to other types of irrigation systems and as a result, crop rooting may be limited. Crops may benefit from frequent irrigation under this condition. However, in a study conducted at Garden City, Kansas, corn yields were excellent (190 to 200 bu/a) regardless of whether a frequency of 1, 3, 5, or 7 days was used for the SDI events (Caldwell et al., 1994). Higher irrigation water use efficiencies were obtained with the longer 7-day frequency because of improved storage of in-season precipitation and because of reduced drainage below the rootzone. The results indicate there is little need to perform frequent SDI events for fully-irrigated corn on the deep silt loam soils of western Kansas. There could be an advantage for more frequent irrigation events if the corn was deficit-irrigated or fertigated.

Water Requirement of Subsurface Drip-Irrigated Corn

Studies were conducted at Colby and Garden City, Kansas from 1989-1991 to determine the water requirement of subsurface drip-irrigated corn. Careful management of SDI systems reduced net irrigation needs by nearly 25%, while still maintaining top yields of 200 bu/a. The 25% reduction in irrigation needs translates into 35-55% savings when compared to sprinkler and furrow irrigation systems which typically are operating at 85 and 65% application efficiency. SDI technology can make significant improvements in water use efficiency through better management of the water balance components.

Corn yields at Colby were linearly related to calculated crop water use (Figure 3), producing 19.6 bu/a of grain for each mm of water used above a threshold of 12.9 inches (Lamm et al., 1995). The relationship between corn yields and irrigation is nonlinear (Figure 3) primarily because of greater drainage for the heavier irrigation amounts (Figure 4). The 25% reduction in net irrigation needs is primarily associated with the reduction in drainage, a non-beneficial component of the water balance (Figure 3 and 4).

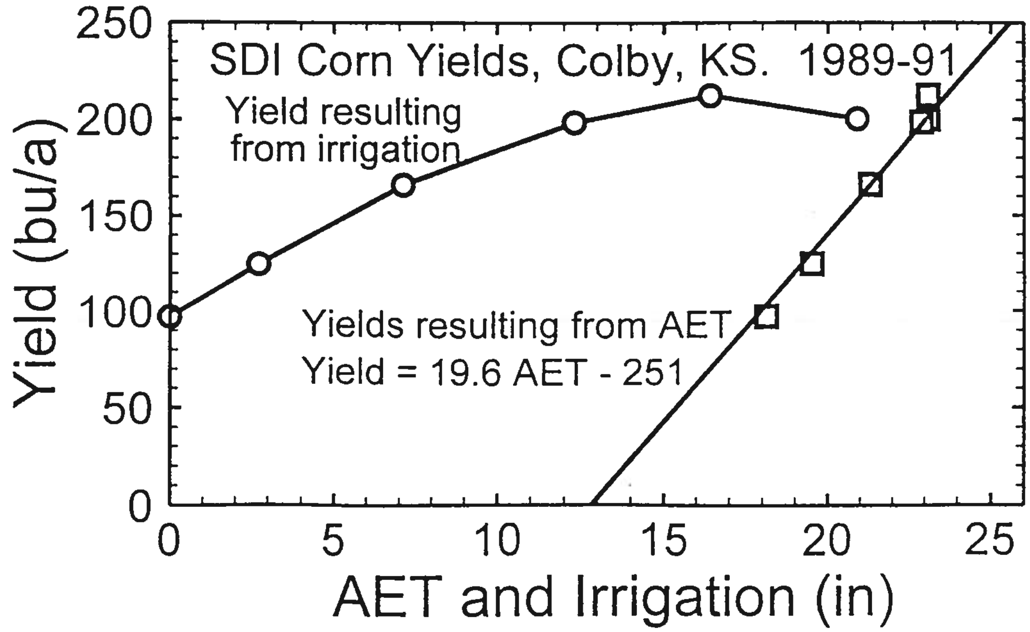

Figure 3. Corn yield as related to irrigation and calculated evapotranspiration (AET) in a SDI study, Colby, KS., 1989-1991.

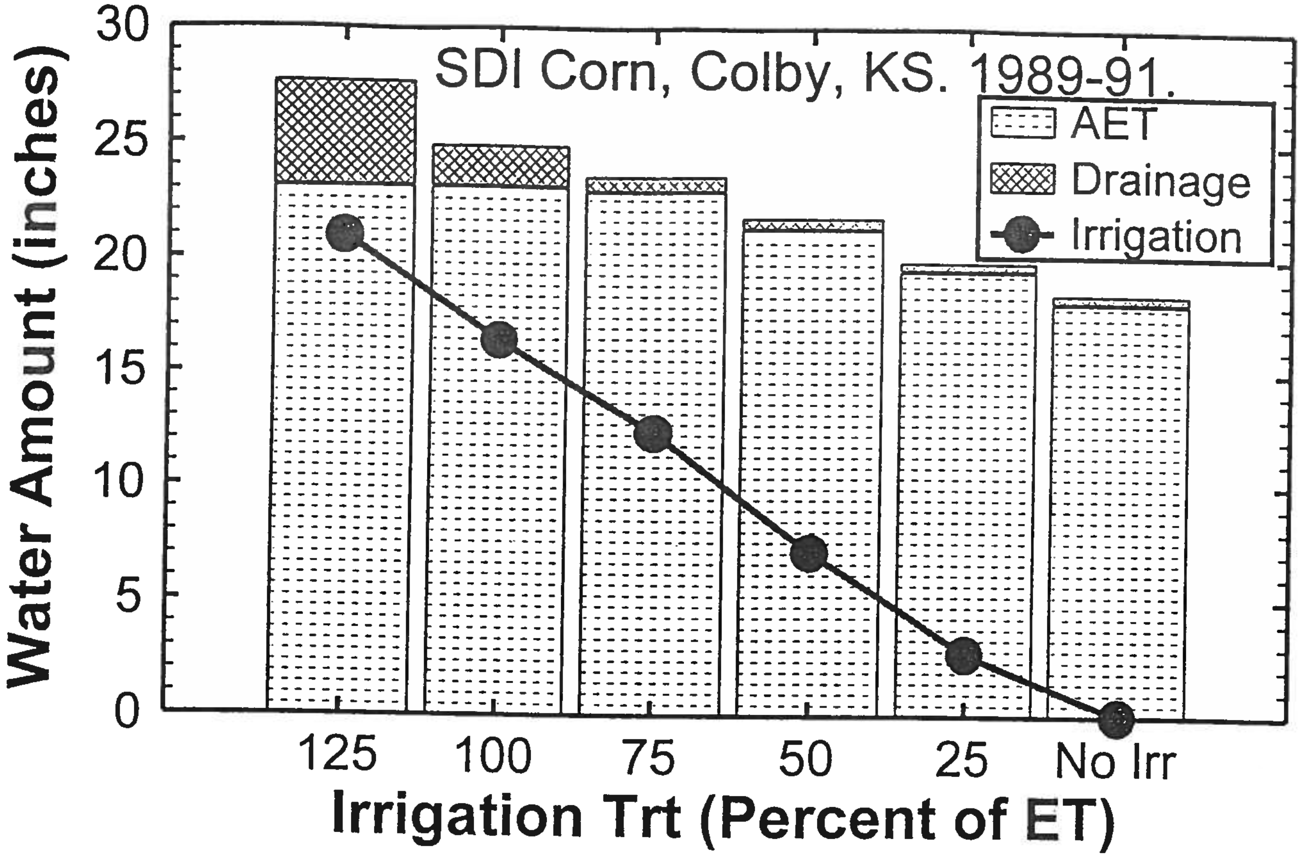

Figure 4. Calculated evapotranspiration (AET) and seasonal drainage as related to irrigation treatment in a SDI study, Colby, KS., 1989-1991.

Nitrogen Fertigation

Since properly designed SDI systems have a high degree of uniformity and can apply small frequent irrigation amounts, excellent opportunities exist to better manage nitrogen fertilization with these systems. Injecting small amounts of nitrogen solution into the irrigation water can spoonfeed the crop, while minimizing the pool of nitrogen in the soil that could be available for percolation into the groundwater.

In a study conducted at Colby, Kansas from 1990-91, there was no difference in corn yields between preplant surface-applied nitrogen and nitrogen injected into the driplines throughout the season. Corn yields averaged 225 to 250 bu/a for the fully irrigated and fertilized treatments. In both years, nearly all of the residual nitrate nitrogen measured after corn harvest was located in the upper 12 inches of the soil profile for the preplant surface-applied nitrogen treatments, regardless of irrigation level. In contrast, nitrate concentrations increased with increasing levels of nitrogen injected with SDI and migrated deeper in the soil profile with increased irrigation (Lamm and Manges, 1991). Nitrogen applied with SDI at a depth of 16-18 inches redistributed differently in the soil profile than surface-applied preplant nitrogen banded in the furrow (Figure 5). Since residual soil-nitrogen levels were higher where nitrogen was injected using SDI, it may be possible to obtain similar high corn yields using lower amounts of injected nitrogen.

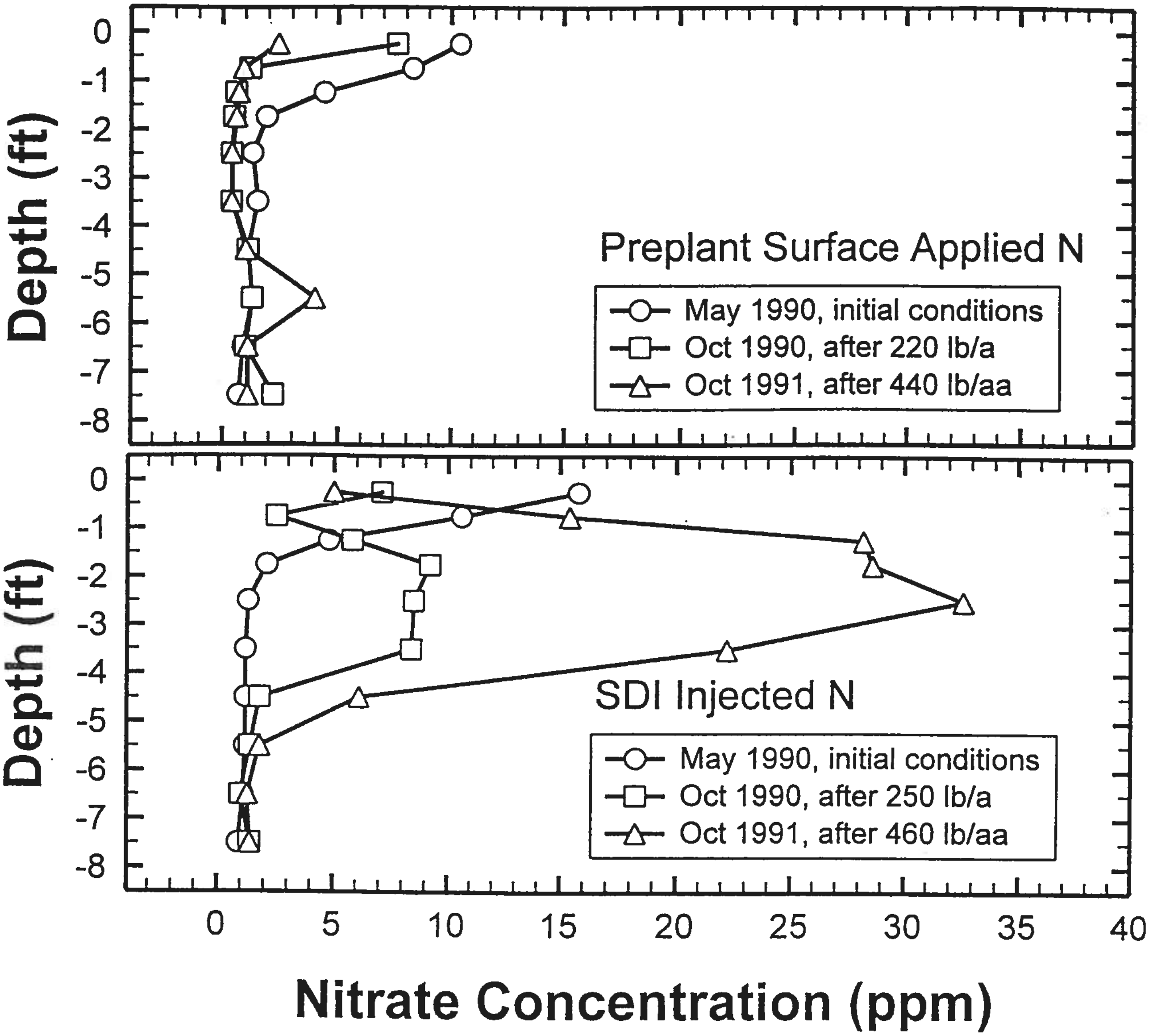

Figure 5. Nitrate concentrations in the soil profile for preplant surface-applied and SDI injected nitrogen treatments, Colby, Kansas, 1990-91. Data is for selected nitrogen fertilizer rate treatments with full irrigation (100% of AET).

CONCLUSIONS

SDI technology can be successfully applied for corn production on the deep silt loam soils of western Kansas. Soil, climate and topography factors indicate that successful designs can utilize 5 ft dripline spacings for lateral lengths of 660 ft. SDI application frequencies of 1-7 days did not affect yields of fully irrigated corn. The technology can reduce net irrigation needs by 25% while maintaining high corn yields. Potential exists for reduced application of nitrogen for corn production when injected with SDI. Nitrogen redistribution is different between surface applied nitrogen and nitrogen applied using SDI.

REFERENCES

Caldwell, D. S., W. E. Spurgeon and H. L. Manges. 1994. Frequency of irrigation for subsurface drip-irrigated corn. Trans. ASAE 37(4):1099-1103.

Darusman. 1994. Drainage evaluation under drip-irrigated corn. Ph.D. dissertation, Kansas State University, Manhattan, KS.

Kincaid, D. E. and D. F. Heerman. 1974. Scheduling irrigation using a programmable Calculator. USDA Publication ARS-NC-12, February, 1974. 55 pp.

Lamm, F. R., H. L. Manges, D. H. Rogers, W. E. Spurgeon, and M. H. Farmer. 1990. Design and installation of a drip irrigation system for research purposes. Presented at the international winter meeting of the American Society of Agricultural Engineers, Chicago, IL, Dec. 18-21, 1990. ASAE Paper No. 902530, ASAE, St. Joseph, MI. 21 pp.

Lamm, F. R. and H. L. Manges. 1991. Nitrogen fertilization for drip-irrigated corn in northwest Kansas. Presented at the international winter meeting of the American Society of Agricultural Engineers, Chicago, IL, Dec. 17-20, 1991. ASAE Paper No. 912596, ASAE, St. Joseph, MI. 17 pp.

Lamm, F. R., L. R. Stone, and H. L. Manges. 1992. Optimum lateral spacing for drip-irrigated corn. Presented at the international winter meeting of the American Society of Agricultural Engineers. ASAE Paper No. 922575, ASAE, St. Joseph, MI. 15 pp.

Lamm, F. R., H. L. Manges, L. R. Stone, A. H. Khan, and D. H. Rogers. 1995. Water requirement of subsurface drip-irrigated corn in northwest Kansas. Trans. ASAE. 38(2) 441-448.

Makens, T. P., W. E. Spurgeon, F. R. Lamm, and H. L. Manges. 1992. Subsurface dripline length for corn production. Presented at the mid-central regional meeting of the American Society of Agricultural Engineers. ASAE Paper No. MC92-100, ASAE, St. Joseph, MI. 12 pp.

Powell, N. L. and F. S. Wright. 1993. Grain yield of subsurface microirrigated corn as affected by irrigation line spacing. Agron. J. 85:1164-1170.

Spurgeon, W. E., H. L. Manges, and T. P. Makens. 1991. Drip line spacing and plant population for corn. Presented at the international winter meeting of the American Society of Agricultural Engineers. ASAE Paper No. 912592, ASAE, St. Joseph, MI. 12 pp.

This paper represents a non-SI (metric) unit version of a paper first presented at the Fifth International Microirrigation Congress, April 2-6, 1995, Orlando Florida. The original paper is entitled Corn Production Using Subsurface Drip Irrigation and is found on pages 388-394 of the proceedings of that conference. The proceedings is available from ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659. Phone: 616-429-0300. Fax: 616-429-3852 Email: hq@asae.org

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FILTRATION AND MAINTENANCE CONSIDERATIONS FOR SDI SYSTEMS

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Introduction

All irrigation systems require proper maintenance and subsurface drip irrigation (SDI) systems are no exception. The major cause of failures in SDI and other microirrigation systems worldwide is clogging. The emitters in SDI systems are small, leaving a small margin for error, so it is important to understand the filtration and maintenance requirements of SDI systems and take a proactive approach to the prevention of clogging.

Fortunately, most SDI users in the Great Plains are pumping from high-quality groundwater, such as the Ogallala aquifer, reducing the potential for clogging. Even so, proper steps must be taken to prevent clogging and maintain effective SDI system operation. With proper precautions and maintenance, SDI also can be used with surface water and other, lower quality, waters.

Prevention of clogging and proper maintenance of the SDI system start before it is installed. Chemical and biological analysis of the irrigation water will indicate which preventative filtration measures may be required to prevent clogging. Dripline requirements may also play a role in the selection of filtration measures to employ. Proper placement and use of flow meters and pressure gauges are required to provide feedback to the system operator. Monitoring the flow meters and pressure gauges over time can reveal system performance anomalies that may require attention. Check valves, air vents, and vacuum relief valves may be required at various places in the system to prevent entry of chemically treated water into the water source and soil particles into the driplines. Also, flushlines are required to occasionally remove the material accumulated in the driplines.

Clogging hazards for SDI systems, regardless of the water source, fall into three general categories: physical, chemical, and biological. This paper will discuss prevention of clogging problems in these three categories with special emphasis on how they apply to SDI systems in the Great Plains.

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This material was first presented at the Central Plains Irrigation Association Short Course and Equipment Exposition, North Platte, NE, February 17-18, 1998.