K-STATE
Kansas State University

IRRIGATION
MANAGEMENT
SERIES

Management Considerations for Operating a Subsurface Drip Irrigation (SDI) System

Freddie R. Lamm
Research Agricultural Engineer

Danny H. Rogers
Extension Agricultural Engineer

Mahbub Alam
Extension Irrigation Specialist

Gary A. Clark
Research Agricultural Engineer

Kansas State University
Agricultural Experiment Station
and Cooperative Extension Service
Manhattan, Kansas

Subsurface drip irrigation (SDI) systems deliver water to the root zone of crops using polyethylene drip tubing that is permanently buried below the soil surface. In properly designed and operated systems, little or no wetting of the soil surface occurs, nor is there visual evidence of the system performance.

Because SDI systems apply water differently than center pivot sprinklers and surface flood systems, an SDI operator may need to change current irrigation management protocol or learn new procedures to ensure proper SDI performance. Pressure gauge and water meter readings become extremely important indicators of the health of an SDI system. Other management issues also may require some modification to use SDI system strengths, including tillage, fertilizer, and herbicide programs. SDI systems also may change the answer to the fundamental irrigation-scheduling question of how much and how frequently irrigation water should be applied.

This publication focuses on using SDI with lower-value field crops, such as corn, on the deeper silt loam soils of Kansas. Although many of the considerations apply to SDI systems for other crops and regions, it is always wise to consider how these guidelines apply to your own specific field and crop characteristics.

Maintenance Considerations

System Evaluation

The SDI system should be thoroughly evaluated immediately after installation. A similar evaluation should be completed before seasonal irrigation start-up or during the initial irrigation to check for minor leaks. Initial and annual evaluation records need to be maintained to develop a performance history, which can help detect developing problems. Off-season inspection should be performed on all components of the SDI system, including the well and pumping plant.

Well and Pumping Plant Inspection

Inspection for damage, wear, and necessary maintenance on the pumping plant should be done to ensure reliable performance. Records on static and pumping water levels, discharge rate and wellhead pressure should be maintained and are important to determine long-term water supply trends. These records also can be useful to evaluate pumping plant efficiency when combined with fuel use records. (See K-State Research and Extension publication L-885 *Evaluating Pumping Plant Efficiency Using On-Farm Bills* or use *Fuel Cost*, a software tool available at *www.oznet.ksu.edu/mil*.)

Regular well treatment using shock chlorination also may be an important preventative maintenance procedure that reduces potential bacterial clogging overload of the filtration system and driplines. Wells that have high iron or manganese concentrations and have known iron bacteria infestations should be treated at least annually. Wells that have severe iron bacteria infestations may need to be treated more often to reduce the bacterial population to an acceptable level. Never pump the treated water from a shock chlorinated well into an SDI filtration system or the driplines. (See K-State Research and Extension publication MF-2589, *Shock Chlorination Treatment for Irrigation Wells* for more information.)

SDI System Components

All valves, pressure regulators, pressure gauges, filters, fittings, and other system components need to be annually inspected and repaired or replaced if defective. Some inspection will be required during the system operation.

Whilethe SDI system is operating, the field can be observed for any dripline leaks. Dripline leaks may not be detectable during a short duration test, therefore observations should continue throughout the season, especially during irrigation or fertigation events that take place before full crop cover. In general, surface wetting does not occur with SDI systems. A wet surface indicates a leak. Tearing during the initial installation or rodent damage following installation may cause leaks.

Start-Up Procedure

After static inspection of the components, start the pumping plant and bring the irrigation system to normal operating conditions. It may be beneficial to do a shock chlorination treatment of the driplines at this time, followed by a complete system flush. This preventative maintenance procedure will help remove any biological growth or chemical reaction precipitants that might have occurred during the off-season. During this treatment process, pressure gauge tests and leak inspections can be conducted.

More rigorous treatment, such as using acid to lower the pH of the water, may be required for low flow rates caused by the partial clogging of emitters. This treatment may be better suited at the end of the season. The initial water quality test taken during the design phase of the SDI system will provide some indication of maintenance requirements. More frequent and rigorous treatment may be required if degraded water sources are used in the system.

The duration of a chlorine or acid treatment should be long enough to ensure complete disinfection of the system. The time for distribution of chemicals is also important for fertigation treatments. The time is unique to each system and should be determined and recorded as part of the design specifications.

Acid and chlorine treated water may be left in the driplines for extended periods to increase treatment effectiveness. However, after the treatment, the system needs to be thoroughly and completely flushed to remove any residue, sludge, or particles. After a long period of non-use, the driplines should be flushed. Flushing should continue until the flush water is clear.

Flushing the System

The recommended design criterion is that each irrigation zone of the system will have all driplines of that zone connected to a single flushing manifold. It is very important for successful flushing that sufficient flow velocity be available to carry material out of the ends of all driplines. Some pumping plants and wells may have sufficient capacity to accomplish this. However, the original design may include additional valves that allow each irrigation zone to be split into two parts. High flushing velocity will then be possible in the smaller flush zone. A minimum flow velocity of 1 foot per second is recommended, although some designers and equipment manufacturers may recommend higher velocity.

High flushing velocity requires that the inlet pressure be increased to account for the additional friction loss of the higher flow and the increased emitter discharge. The dripline must be able to accommodate the additional pressure required for flushing. The pumping plant and well may have to supply 8 to 10 psi additional pressure and 30 percent additional flow to ensure adequate flushing. If the pumping plant or well cannot supply this additional pressure and flow, then the irrigation zone should be divided into two or more flushing zones.

The overall system flushing procedure should begin with the pipes of the largest size, which would be the mains, followed by the submains, and then the driplines.

Collection of flush water samples can help determine the health of an SDI system. If significant amounts of material are in the flush water, it would be wise to determine if these materials are biological (bacterial slime) and/or physical (chemical precipitant). If sand particles are evident, then the filtration system may have failed or is not properly designed. Refer to K-State Research and Extension publication MF-2575 *Water Quality Assessment for SDI Systems* for identifying the material or send it to a lab for analysis.

Irrigation Considerations

Irrigation Scheduling

Unlike every-row furrow irrigation and most sprinkler systems, SDI systems neither wet nor fill the entire soil profile. While irrigation water is uniformly applied along the dripline, most SDI systems have one dripline positioned between two crop rows. In these systems, individual plants would have equal access to the water, but wetted and non-wetted strips would exist throughout the field. This watering arrangement challenges scheduling methodology that is based on soil water monitoring techniques, whether by hand probing or installed sensor. However, SDI systems lend themselves to evapotranspiration (ET) based irrigation scheduling techniques.

ET (for more information on ET, refer to K-State Research and Extension publication MF-2389 *What is ET?*) or crop water use can have daily peak use rates more

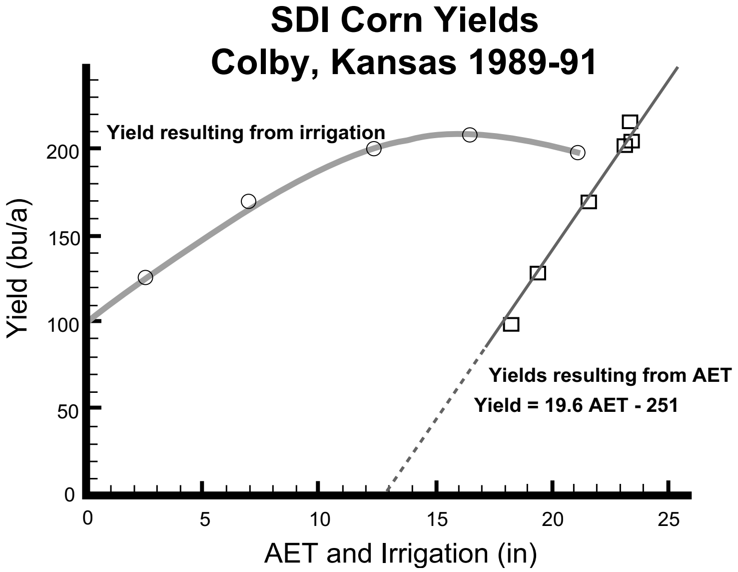

***Figure 1**. Corn yield as related to irrigation and calculated evapotranspiration (AET) in an SDI water requirement study, KSU Northwest Research-Extension Center, Colby, Kansas 1989 to 1991.*

than 0.35 inches per day. This can be determined using climatic information and the growth characteristics of a particular crop. Soil water holding capacity and the root zone determine the amount of soil water that can be stored for use by the crop. (For more information on soils, refer to K-State Research and Extension publication L-904 *Soil Water Plant Relationships*.) The higher the holding capacity and the deeper the rooting, the more water is available to meet crop water needs and act as a buffer during periods of peak use. KanSched (software available at *www.oznet.ksu.edu/mil* or see your local county agent) is an ET-based irrigation scheduling program that is useful in determining irrigation schedules for SDI systems.

Irrigation Capacity

The irrigation capacity, usually reported as inches per day, of SDI systems is calculated in the same way as surface and sprinkler irrigation systems. It is a measure of the ability of the system to meet the water needs of a growing crop (See K-State Research and Extension publication MF-2578 *Design Considerations for Subsurface Drip Irrigation (SDI) Systems* for more details). The water-holding capacity and the crop root zone also play a role in the reliability of an irrigation system to meet the crop's water needs.

The irrigation capacity for typical irrigation systems in Kansas varies widely. Irrigation systems watering deep-rooted crops, such as corn, grown on high water-holding soils are generally considered highly reliable for preventing crop water stress if the irrigation capacity is 0.25 inches per day or greater. An irrigation capacity of 0.32 inches per day or more is needed for sandy or low water-holding capacity soils, or soils with restrictive layers that limit crop root development. It may be possible to maintain full yield potential for crops with less capacity when using SDI systems.

Research studies were conducted at Colby, Kansas from 1989 to 1991 to determine the water requirement of subsurface drip-irrigated corn. Careful management of SDI systems reduced net irrigation needs by nearly 25 percent, while maintaining top yields of 200 bushels per acre (Lamm et al., 1995). The 25 percent reduction in irrigation needs potentially translates into 35 to 55 percent water and energy savings when compared to sprinkler and furrow irrigation systems, which typically operate at 85 and 65 percent application efficiency. Corn yields at Colby were linearly related to calculated crop water use (AET) (Figure 1), producing 19.6 bushel per acre of grain for each inch of water used above a threshold of 12.9 inches.

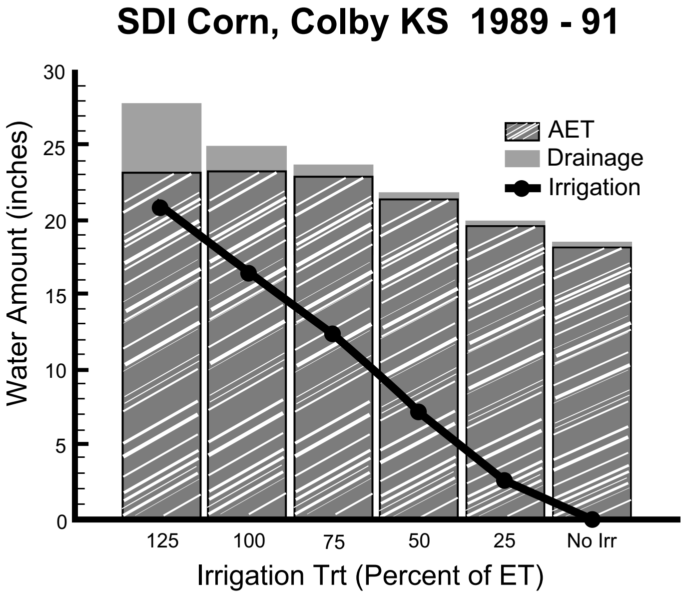

***Figure 2.** Calculated evapotranspiration (AET) and seasonal drainage as related to irrigation treatment in an SDI water requirement study, KSU Northwest Research-Extension Center, Colby, Kansas 1989 to 1991.*

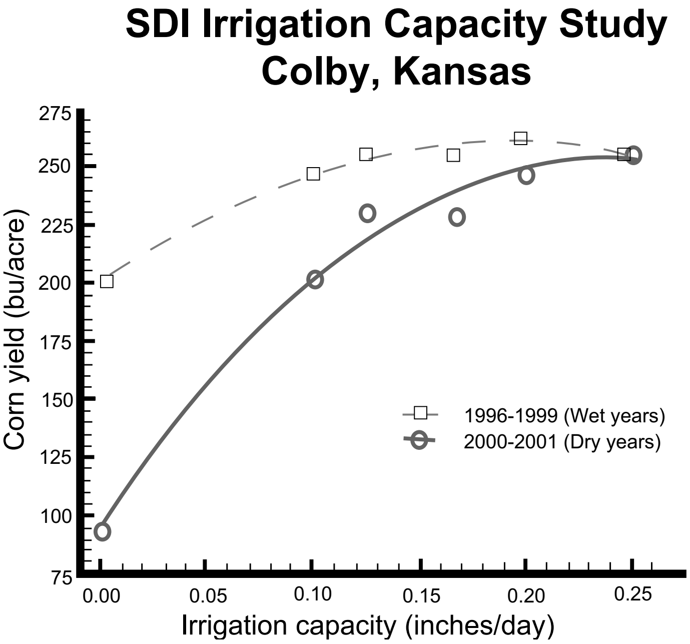

Figure 3. *SDI corn grain yields as affected by irrigation capacity for wet (1996 to 1999) and dry years (2000 to 2001), KSU Northwest Research-Extension Center, Colby, Kansas.*

The relationship between corn yields and irrigation is nonlinear, (Figure 1) primarily because of greater drainage associated with the heavier irrigation amounts (Figure 2).

SDI technology can make significant improvements in water use efficiency (WUE) through better management of the water balance components. The 25 percent reduction in net irrigation needs is associated with the reduction of in-season drainage, elimination of irrigation runoff, and reduction in soil evaporation — all non-beneficial components of the water balance. Drier surface soils allow for increased infiltration and storage of occasional precipitation.

In a later study (1996 to 2001), corn was grown with SDI under six different irrigation capacities (0, 0.10, 0.13, 0.17, 0.20 and 0.25 inches per day) and four different plant populations (33,100, 29,900, 26,800, and 23,700 plants per acre). All treatments were irrigated during the off-season to recharge the soil water profile to remove any differences in the soil water content of the soil due to the previous year's treatment. The purpose of the study was to determine appropriate in-season SDI capacities as related to different corn plant populations. Daily SDI application of even small amounts of water (0.10 inches) doubled corn grain yields from 93 to 202 bushels per acre in the extremely dry years 2000 and 2001 (Figure 3). These results suggest that an irrigation capacity of 0.17 inches per day might be an adequate SDI system capacity when planning new systems in this region on deep silt loam soils (Lamm and Trooien, 2001). Analysis of the yield component data indicates that the number of kernels per acre is greatly increased with low (0.10 inches per day) SDI capacity over the nonirrigated control. Daily applications of small amounts of water on deep silt loam soils will help establish the number of sinks (kernels) for grain accumulation. The final kernel weight is established by grain filling conditions between the reproductive period and physiological maturity, (usually the last 50 to 60 days of the crop season). The extent of mining of the soil water reserves during this period will have a large effect on final kernel weight and, ultimately, corn grain yield. Increasing plant population from approximately 22,500 to 34,500 plants per acre generally increased corn grain yields for SDI in this region, particularly in good corn production years. There was very little yield penalty for increased plant population even when irrigation was severely limited or eliminated.

SDI Frequency

Typically, a smaller amount of soil is wetted with SDI, as compared to other types of irrigation systems, therefore the extent of crop rooting may be limited. Crops may benefit from frequent irrigation under this condition. However, in a study conducted at the KSU Southwest Research-Extension Center in Garden City, Kansas, corn yields were excellent (190 to 200 bushels per acre) regardless of whether a frequency of 1, 3, 5, or 7 days was used for the SDI application 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 root zone. 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. These results agree with a literature review of SDI (Camp, 1998) that indicated that SDI frequency is often only critical for shallow rooted crops on shallow or sandy soils. An additional study conducted in southern Great Plains indicated that longer irrigation frequencies had no effect on corn yields, provided that soil water was managed within acceptable stress ranges (Howell et al., 1997). There is some evidence that daily irrigation events may be beneficial under deficit irrigation conditions

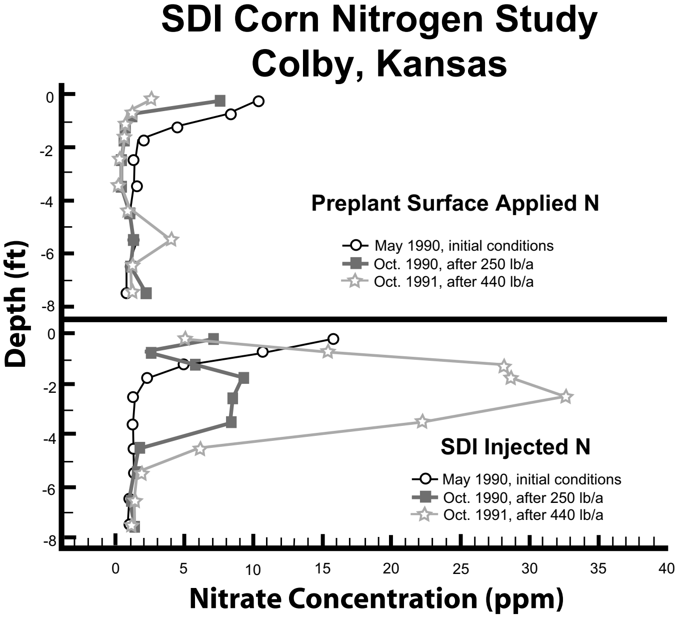

Figure 4. Nitrate concentrations in the soil profile for preplant surface-applied and SDI injected nitrogen treatments, KSU Northwest Research-Extension Center, Colby, Kansas, 1990 to 1991. Data is for selected nitrogen fertilizer rate treatments with full irrigation (100 percent of Crop ET).

or in cases where fertigation is practiced. Several of the more advanced research studies currently underway at Kansas State University routinely use daily irrigation events.

Nitrogen Fertilization with SDI

Because 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. Injecting small amounts of nitrogen solution into the irrigation water can "spoon-feed" 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 to 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 bushels per acre 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 et. al., 2001). Nitrogen applied through driplines installed at a depth of 16 to 18 inches redistributed differently in the soil profile than surface-applied preplant nitrogen banded in the furrow (Figure 4). Because 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.

A follow-up 4-year study was conducted at the KSU Northwest Research-Extension Center at Colby Kansas on a deep Keith silt loam soil to develop a Best Management Practice (BMP) for nitrogen fertigation for corn using SDI. Residual ammonium- and nitrate-nitrogen levels in the soil profile, corn yields, apparent nitrogen uptake (ANU) and water use efficiency (WUE) were used as criteria for evaluating six different nitrogen fertigation rates, 0, 80, 120, 160, 200, and 240 pounds per acre. The final BMP was a nitrogen fertigation level of 160 pounds

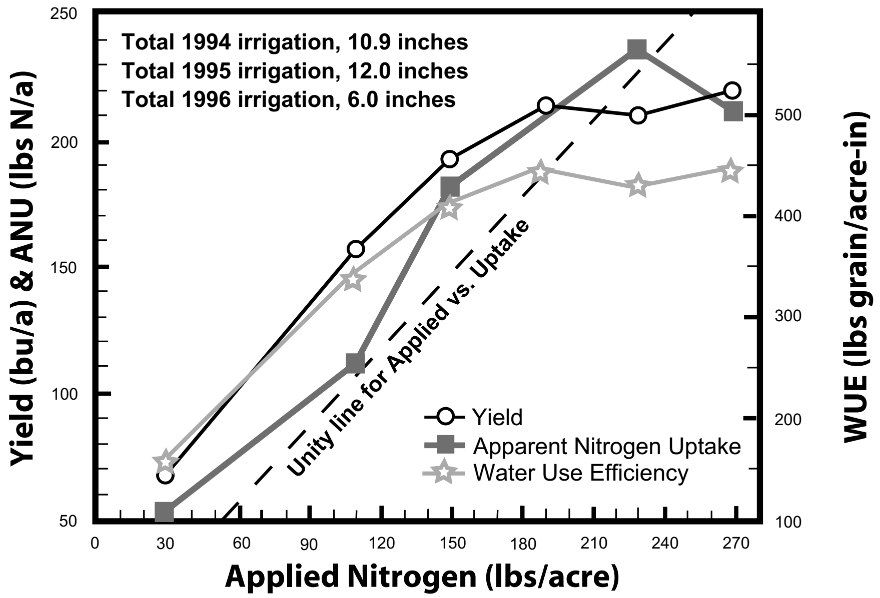

Figure 5. Average (1994 to 96) corn yield, apparent nitrogen uptake (ANU) in the above-ground biomass, and water use efficiency (WUE) as related to the total applied nitrogen (preseason amount, starter fertilizer, fertigation, and the naturally occurring N in the irrigation water). Total applied nitrogen exceeded fertigation-applied nitrogen by 30 pounds per acre.

per acre with other nonfertigation applications bringing the total applied nitrogen to approximately 190 pounds per acre (Lamm et. al., 1997). The BMP also states that irrigation is to be scheduled and limited to replace approximately 75 percent of ET. Corn yield, ANU, and WUE all plateau at the same level of total applied nitrogen, (Figure 5) which corresponded to the 160 pounds per acre nitrogen fertigation rate. Average yields for the 160-pounds per acre-nitrogen fertigation rate was 213 bushels per acre. Corn yield to ANU ratio for the 160 pounds per acre nitrogen fertigation rate was a high 53: 1 (pounds of grain per pounds of nitrogen). The results emphasize that high-yielding corn production also can be efficient in nutrient and water use.

Other Management Issues

Salinity

Kansas is fortunate that most of the major irrigated areas have irrigation waters of good quality. However, some areas of the state have water with either high or increasing salinity levels. Irrigation water can deposit the salts in the soil, which remain after the crop has removed the water. Salts can build up over time in the soil. This could be a problem in the deeply placed alternate row configuration for SDI systems, as the salt accumulation will usually build up on the outer edges of the wetted area. With the dripline placement between rows, a salinity barrier could prevent roots growing from the row toward the dripline, decreasing water accessibility. Fortunately, most areas of the state receive sufficient quantities of rainfall to prevent soil salinity buildup. Refer to K-State Research and Extension publication MF-2575, *Subsurface Drip Irrigation Systems (SDI) Water Quality Assessment Guidelines* for more information on irrigation water suitability.

Root Intrusion

The root hairs of the crop can enter drip emitters and cause emitter clogging. In general, well-watered, seasonal (summer grown) crops have not caused emitter clogging. However, root intrusion may be a problem for perennial crops, such as alfalfa. Root intrusion may be minimized by frequent and non-deficit irrigation. Use of acidic fertilizers also helps to prevent root intrusion. Preventive treatments of acid also can deter root intrusion by lowering the water pH. Some herbicides also may be used to discourage root intrusion. Dripline with herbicides impregnated in the line can be purchased, but are considerably more expensive than normal driplines.

Soil Ingestion

Soil particles can be pulled into the emitter orifice due to a vacuum effect during shut down. This problem should be addressed during the design and installation phase by installing vacuum relief valves at all high points of the submains for each irrigation zone. These valves allow air to enter the pipeline system, thus neutralizing the associated vacuum during shutdown and drainage.

Rodent Control

Rodent damage to the driplines can be a serious problem. The driplines are especially vulnerable immediately following installation and somewhat so during the off-season. SDI has the potential of being ideally suited to no-till systems, because fertilizers could be fed through the SDI system to the root zone. However, habitat control, though tillage, may be a tool to control rodent population, by reducing shelter and food sources in the field. Control of habitat in adjacent field edges also may help reduce rodent pressure. Baiting of edges next to fields adjacent to pastures or other lands with permanent cover may help prevent field infestations.

Monitoring SDI Systems

SDI systems offer very few visual clues as to their performance. Reliance on visual crop stress indicators would result in the loss of yield and probable damage or clogging of the system. Therefore, the system should have a flow meter and a number of pressure gauges to use as performance indicators. Each irrigation zone needs to have an established flow rate and pressure operation standard. A monitoring schedule will then determine if a variation in the performance occurs.

The flow meter needs to be installed to the manufacturer's recommended standards. It should be independently checked for accuracy by comparison to another meter. Many groundwater management districts have this service available for sites within their district. Well drillers and other water agencies also may be able to conduct this test. Most flow meters have totalizers and flow rate indicators. The totalizer is the more accurate measurement instrument of the meter, so zone monitoring flow tests should be conducted by timing how long it takes a certain volume of water to pass through the meter. Flow checks of each zone might be very frequent during the initial season and be reduced in subsequent years after the standard operation flow is established. However, frequent observations may be considered if marginal, variable, or problematic water sources are used. Experience may be the best guide.

Flow Rate Increasing

If the flow rate within a zone is increasing, check the system for breaks. Locating breaks after the crop canopy closes can be challenging. If no breaks are found and preset pressure regulators are used to control zone pressures, check these regulators to determine if they are operating properly. Higher dripline operating pressures generally result in higher emitter discharge rates. However, a lower than normal zone pressure could indicate a line break or system leak.

Flow Rate Decreasing

Higher than normal system pressures, with lower than normal flow rates, indicate that emitter clogging may be occurring. If the flow rate is decreasing and all monitoring equipment is working correctly, then the type of clogging needs to be determined and the driplines need to be treated immediately.

Record Keeping

Record keeping is extremely important in assessing the health of an SDI system. Flow rates and pressure readings establish the baseline operating conditions compared to the initial design specifications, and then later, determine any changes or trends in performance characteristics. Water quality tests also should be saved to watch for changes in conditions, especially for surface water sources and alluvial wells, which can have seasonal changes in water quality. Static and pumping water levels may be important records because declines in the water table effect the water yield of the well and require SDI system modifications. Injection records of dripline treatments and chemigations for crops should also be kept. Such records should include system flow rate, as well as the type, amount, injection rate, and injection period of the treatment or chemigation process.

Summary and Conclusions

SDI system life must be long (at least 10 to 15 years) for it to be economically comparable to traditional surface and center pivot systems. SDI systems must also be properly managed and operated to be able to take full advantage of the system's capability to deliver precise and uniform water application to the crop root zone as well as any other chemicals or fertilizers that may be injected into the system.

However, this publication, as well as the other publications in the SDI series, does not cover all material that is available. Additional research and management information is available at K-State's SDI Web site at *www.oznet.ksu.edu.sdi/*.

SDI acreage in Kansas is only a small percentage of total irrigated acreage, but it is growing slowly. Some Kansas producers have systems approaching 10 years of service without any indication of system degradations, similar to the experience for the 1989 installed SDI system at the Northwest Research Extension Center at Colby. However, some systems have failed due to either improper design or operation within the first season. Therefore, education and preventative maintenance are key elements in protecting an investment in an SDI system and ensuring a long and beneficial system life.

As with any new technology, there are risks and new learning requirements, but many potential benefits and rewards are possible.

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.

Camp, C. R. 1998. *Subsurface Drip Irrigation: A Review.* Trans ASAE 41(5): 1353-1367. Also available at http://www.florence.ars.usda.gov/publist/sw

Howell, T. A., A. D. Schneider, and S. R. Evett. 1997. *Subsurface and Surface Microirrigation of Corn-Southern High Plains*. Trans ASAE 40(3): 635-641.

Lamm, F. R., T. P. Trooien, H. L. Manges, and H. D. Sunderman. 2001. *Nitrogen Fertilization for Subsurface Drip-Irrigated Corn*. Trans ASAE 44(3): 533-542. Also available at http://www.oznet.ksu.edu/sdi/Reports/2001/dfert.pdf

Lamm, R. R. and T. P. Trooien. 2001. *Irrigation Capacity and Plant Population Effects on Corn Production Using SDI*. In Proc. Irrigation Assn. Int'l. Irrigation Technical Conf., Nov. 4-6, 2001, San Antonio, TX. Pages 73-80. Available from Irrigation Assn., Falls Church, VA. Also available at http://www.oznet.ksu.edu/sdi/Reports/2001/icpp.pdf

Lamm, R. 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. Also available at http://www.oznet.ksu.edu/sdi/Reports/1995/WaterReq.pdf

Lamm, R. R., A. J. Schlegel, and G. A. Clark. 1997. *Nitrogen Fertigation for Corn Using SDI: A BMP*. Presented at the Int'l Meeting of the ASAE, Minneapolis, MN, August 10-14, 1997. Paper No. 972174 from ASAE, St. Joseph, MI, USA. 17 pp. Also available at http://www.oznet.ksu.edu/sdi/Reports/1997/Nfertigation.pdf

Additional Resources:

MF-2361	*Filtration and Maintenance Considerations for Subsurface Drip Irrigation (SDI) Systems*
MF-2242	*Economic Comparison of SDI and Center Pivots for Various Field Sizes*
MF-836	*Irrigation Capital Requirements and Energy Cost*
MF-2578	*Design Considerations for Operating a Subsurface Drip Irrigation (SDI) System*
MF-2576	*Subsurface Drip Irrigation (SDI) Components: Minimum Requirements*
MF-2575	*Subsurface Drip Irrigation Systems (SDI) Water Quality Assessment Guidelines*

Related K-State Research and Extension SDI Irrigation Web Sites:

General Irrigation

www.oznet.ksu.edu/irrigate

Mobile Irrigation Lab

www.oznet.ksu.edu/mil

Subsurface Drip Irrigation

www.oznet.ksu.edu/sdi

Acknowledgment: This material is based upon work supported by the U.S. Department of agriculture Cooperative State Research Service under Agreement No. 00-34296-9154. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the authors and do no necessarily reflect the views of the U.S. Department of Agriculture.

Publications from Kansas State University are available on the World Wide Web at: http://www.oznet.ksu.edu

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-2590 November 2003