

FREQUENTLY AND NOT-SO-FREQUENTLY ASKED QUESTIONS ABOUT SUBSURFACE DRIP IRRIGATION

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INTRODUCTION

K-State Research and Extension has been conducting research and extension efforts with subsurface drip irrigation since 1989 and over the years there have been many questions about this technology that we have attempted to answer. This paper will highlight some of the most pertinent questions and perhaps help practitioners have better conceptual understanding of the opportunities and challenges of this relatively new irrigation technology for the Great Plains.

QUESTIONS, QUESTIONS, QUESTIONS?

What is Subsurface Drip Irrigation?

Subsurface drip irrigation (SDI) is a type of microirrigation where water is applied to the crop root zone below the soil surface by small emission points (emitters) at fixed intervals that are in a series of plastic lines that are typically placed either under each row or between crop rows. Although the American Society of Agricultural and Biological Engineers includes in their definition of SDI (ASAE S526.2, 2001) that the discharge rate of the emitters is usually less than 2 gallons/hour, in practice in the Great Plains, most emitter discharge rates are in the range of 0.15 to 0.50 gallons/hour.

Subsurface drip irrigation is not the same and should not be confused with subirrigation. Subirrigation applies water below the ground surface by raising the water table to within or near the root zone. There is little or no subirrigation in the Central Great Plains. So to avoid confusion as one tries to obtain information about SDI, practitioners need to be precise and use either the term SDI or subsurface drip irrigation and avoid terms such as subirrigation, subsurface irrigation, sub-surface irrigation, subdrip, and other associated terms. It is advised to not use even the simpler terminology of drip irrigation, because in many aspects surface drip irrigation (DI) and subsurface drip irrigation (SDI) may perform very differently.

Some shallow subsurface systems (< 8 inch depth) are retrieved and/or replaced annually and are very similar to surface drip irrigation. Many research reports refer to these systems as surface drip irrigation, and reserve the term SDI for systems intended for multiple-year use that are installed below tillage depth (Camp and Lamm, 2003).

Key Ideas:

- Direct subsurface application of water through small plastic pipes to the crop root zone.
- Use precise and correct terminology of either subsurface drip irrigation or SDI.
- Surface drip irrigation (DI) and subsurface drip irrigation (SDI) can perform differently.

What Crops are Appropriate for SDI?

Most crops suitable for surface drip irrigation (DI) are also suitable for SDI (Lamm and Camp 2007). There are some exceptions when a particular inherent difference between SDI and DI expresses itself in a negative way. For example, some crops such as sweet potato, celery, asparagus and permanent crops that have a long period when irrigation is minimal or terminated, may exhibit high root intrusion into SDI emitters (Burt and Styles, 1999). Additionally, root crops such as potato and onion can result in crop harvest challenges when using SDI, although efforts have been made to overcome these obstacles (Abrol and Dixit, 1972; DeTar et al., 1996; Shock et al., 1998). Although peanuts are successfully grown with SDI in some regions (Sorenson et al., 2001), the plant process of pegging can be inhibited in arid regions and in cracking soils (Howell, 2001).

The major irrigated crops in the Great Plains region are corn, cotton, soybean, grain sorghum, sunflower, alfalfa, and wheat. Successful usage of SDI has been reported on all of these crops in this region (Lamm et al., 2010a) with the exception of wheat where there have been no reported studies. Lower-valued commodity crops, such as cotton and corn, may only be profitable with SDI instead of DI because of the ability to amortize SDI system and installation costs over the multiple years of operation (O'Brien et al., 1998; Lamm et al., 2014a). As early as 1982, SDI was suggested as a good, economical, irrigation system alternative for the small farmer in the United States (Mitchell and Tilmon, 1982). The components of SDI systems can be easily and economically designed to accommodate the field size (Bosch et al., 1992; O'Brien et al., 1998).

The largest usage of SDI in the Great Plains region is for cotton in Texas. In suitable climatic regions compatible with cotton production, cotton, with its lower water use, can be an excellent crop in water short areas when coupled with efficient SDI. There is also growing evidence (Colaizzi et al., 2010) that SDI, by not wetting up the soil surface, is providing a more favorable thermal environment (warmer) for irrigated cotton which is important, particularly as cotton production moves further northward in the Texas Panhandle, Oklahoma and southern Kansas. Alfalfa is also a good crop for SDI because it is deep rooted, and because irrigation can continue during the harvest period (Hutmacher et al., 1992; McGill, 1993, Lamm et. al, 2014a).

Key Ideas:

- The typical Great Plains grain, fiber, and oilseed crops can successfully use SDI.
- SDI is used instead of surface drip to allow for long term amortization of system costs.
- Crop results may vary, so consider crop suitability carefully.

What Soils are Appropriate for SDI?

Subsurface drip irrigation has been successfully used on a wide variety of soils around the world (Lamm and Camp, 2007). Areas with variable or shallow soil overlaying rock may not be suitable for SDI because of shallow or restricted depth. Coarse sands and non-bridging soils may also be unsuitable for SDI. When using thin-walled driplines, the weight of the overburden may collapse or deform the dripline, which will reduce or prevent normal flowrates. When SDI is installed on cracking and heavy clay soils, soil water distribution problems may occur either by not appropriately wetting the crop root zone (e.g., limited or excessive vertical or horizontal soil water redistribution) or may result in poorly-drained aeration problems. In arid and semiarid regions, the limitations on SDI use for crop establishment and salt leaching are added suitability considerations. Crop establishment with SDI can also be a problem on coarse-textured soils or when short drought periods occur at planting in the more humid regions. Fields that have excessive changes in soil texture or large variations in the depth of soil layers can be problematic. Soil layering or changes in

texture and density within the soil profile affect the choice of dripline depth. Driplines should be installed within a coarse-textured surface soil overlaying fine-textured subsoil so that there is greater lateral movement perpendicular to the driplines. Conversely, when a fine-textured soil overlays a coarse-textured subsoil, the dripline should be installed within the fine-textured soil to prevent excessive deep percolation losses. An excellent discussion of how soil texture and density affect soil water redistribution is provided by Gardner (1979). It is a good idea to discuss the SDI experiences of others with similar crops and soils in your region. These discussions should be specific as possible outlining the challenges of using SDI on these soils, so that the constraints can be properly assessed. A few local experiences should sometimes greatly outweigh much more extensive experiences from faraway regions. However, some soil constraints can be handled by careful design, installation, and system management.

It should be noted that there are somewhat more rare soil issues that can occur when the emitter discharge rate grossly exceeds the ability of the soil to appropriately redistribute the applied water. This issue is discussed later in “*What is the Best Emitter Discharge Rate?*”.

Key Ideas:

- SDI can be used successfully on many Great Plains soils, but excessively coarse (sand) or excessively heavy (clay) soils tend to present more concerns.
- Local experiences from others can be an excellent resource when considering SDI.

What is the Number One Cause of SDI System Failure in the World?

Similar to all other microirrigation systems, the number one cause of failure is clogging of the emitters. Emitter passageways are very small and a wide variety of physical (e. g. soil particles, crop residue, PVC pipe filings, debris, etc.), chemical (e. g., precipitates, compounds, and interactions with injected chemicals), and biological (e. g., algae, bacteria, slimes, hatchlings, etc.) hazards may clog the system. As these hazards may combine and conglomerate to form a much larger clogging hazard, the general rule is to provide filtration to 1/10 of the size of the smallest emitter passageway. This design criteria helps to provide an added margin of safety. The water quality of some water resources used for SDI may require constant or periodic water treatment. Don't cut corners on selection, management, and maintenance of the filtration and water treatment components of your SDI system. These components are the most important tools in achieving a long SDI system life which is important to economic viability . Filtration and water treatment for SDI systems are discussed in greater detail in Lamm et al. (2014b) and Rogers et al. (2003b).

Key Ideas:

- Clogging is the predominant cause of SDI system failure
- Filtration and chemical treatment systems are key factors in long SDI system life.

What are the Greatest Barriers to SDI Adoption in the Great Plains?

In the authors' opinion, the greatest obstacles to adoption of SDI in the Great Plains are:

- System cost.
- Germination and crop establishment.
- Prevention of animal and insect damage to driplines.

Industry, universities, and government agencies are evaluating options that may help reduce these barriers. (Lamm et al., 2012b).

Industry has begun to explore the possibility of more generic SDI designs and components to make SDI system costs more competitive with alternative irrigation systems. University faculty are examining system requirements and trying to streamline the design processes. Examples of such university efforts are provided by Bordovsky et al. (2008) and Rogers et al. (2003). Government cost sharing from federal and state resources is sometimes available to help defray system costs. SDI systems become more cost competitive with alternative irrigation systems when crop yields and crop prices are greater (Lamm et al., 2014a)

Germination and crop establishment can be a problem under drought conditions prevalent in the semi-arid Great Plains and also when short term drought occurs in the more humid region at the time of planting. Cropping and tillage management can help to reduce this problem. An excellent discussion of typical strategies to help avoid this SDI problem is given by Bordovsky et al. (2012). Although research is continuing to improve germination and crop establishment, a practical, economical and foolproof solution probably does not exist at the current time. Fortunately, the problem does not occur in every year.

In the authors' opinion insect and animal damage to driplines, primarily rodent damage is actually the largest barrier to greater adoption of SDI systems in the Great Plains. Of the three mentioned barriers, it is also the one with the least thorough solutions (Lamm et al., 2012b). It is not that rodent problems are widespread with the majority of systems being greatly affected. The issue is that when a widespread problem occurs on a particular system, it can be frustrating to the irrigator and the debilitating effects may lead to system abandonment. Bad news travels fast and this impedes further adoption in the Great Plains region. Some partial solutions to reduce or prevent rodent damage are discussed in Lamm et al. (2014b). Industry continues to look for more effective solutions to this problem with a focus on materials that might be impregnated in the plastic or injected into the dripline during the irrigation event to serve as a repellent.

Key Ideas:

- SDI systems are becoming more cost competitive with traditional alternatives in the Great Plains. Irrigators are advised to examine the current economics carefully.
- Cropping and tillage management can help reduce the potential for germination and crop establishment problems with SDI.
- Rodent damage is considered to be the greatest barrier to SDI adoption, although the damage is not experienced to a great extent by many producers. When the rodent damage is excessive, it may lead to system abandonment.

What is the Best Installation Depth for SDI?

The choice of the appropriate dripline depth is affected by crop, soil, and climate characteristics, anticipated cultural practices, grower experiences and preferences, the water source, and prevalence of pests, so there can be no single answer.

Deeper dripline placement minimizes soil water evaporation losses, but this must be balanced with the potential for increased percolation losses while considering the crop root-zone depth and rooting intensity. Shallower dripline depth tends to improve chances for germination and crop establishment. Soil layering or changes in texture and density within the soil profile affect the choice of dripline depth as discussed earlier in this paper (i.e., *What Soils are Appropriate for SDI?*).

SDI systems for lower-valued commodity crops (fiber, grains, and oilseeds) and perennial crops (trees and grapes) are usually set up exclusively for multiple-year use with driplines installed in the 12 to 18 inch depth range. Most of these crops have extensive root systems that function properly

at these greater depths. Corn, soybean, sunflower, and grain sorghum yields were not affected greatly by dripline depths ranging from 8 to 24 inches on a deep Keith silt loam soil at Colby, Kansas (Lamm and Trooien, 2005; Lamm et al., 2010b). Their results suggest that, in regions that typically receive precipitation during the growing season, dripline depth will not be the overriding factor in crop development and soil water redistribution. The dripline should be deep enough that the anticipated cultural practices can be accommodated without untimely delays, soil compaction, or damaging the SDI system. Pests such as rodents and insects are often more troublesome at the shallow dripline depths (Van der Gulick, 1999).

Key Ideas:

- Selection of system depth requires careful consideration of site characteristics, grower preferences and prevalence of pests.
- Twelve to eighteen dripline depths for SDI are typical for crops in the Great Plains.

What is the Best Dripline Spacing for SDI?

Crop row, or bed spacing, is usually set by cultural practices for a given crop in a given region and by planting and harvesting equipment specifications. As a general rule, SDI dripline spacing is a multiple of the crop row spacing, whereas emitter spacing is usually related to the plant spacing along the row. Providing the crop with equal or nearly equal opportunity to the applied water should be the goal of all SDI designs.

Dripline spacing in the Great Plains region is typically one dripline per row/bed or an alternate row/bed middle pattern (Fig. 1) with one dripline per bed or between two rows. The soil and crop rooting characteristics affect the required lateral spacing, but general agreement exists that the alternate row/bed dripline spacing (about 5 ft) is adequate for most of the deeper-rooted agronomic crops on medium- to heavy-textured soils. Closer dripline spacing may be used for high-valued crops on sandy soils, for small seeded crops where germination is problematic, and in arid areas to ensure adequate salinity management and consistent crop yield and quality.

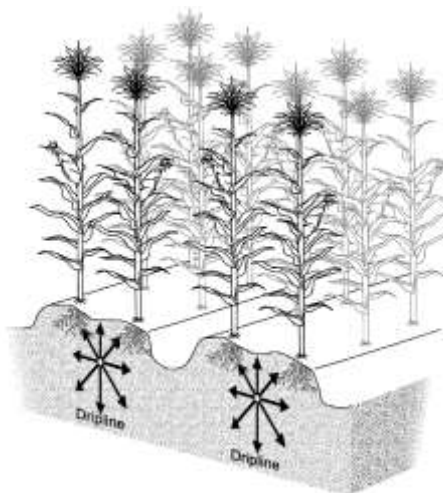


Figure 1. Alternate row/bed 5 ft SDI dripline spacing for corn rows spaced at 2.5 ft.

Key Ideas:

- Crop and crop row spacing typically influence dripline spacing.
- Alternate row/bed dripline spacing (about 5 ft.) is typical for many crops.

What is the Best Emitter Spacing for SDI?

Emitter spacings ranging from 4 to 30 inches are readily available from the manufacturers, and other spacings can be made to meet a specific application. Increasing the emitter spacing can be used as a techniques to allow larger emitter passageways that are less subject to clogging, to allow for economical use of emitters that are more expensive to manufacture, or to allow for longer length of run or increased zone size by decreasing the dripline nominal flowrate per unit length.

Generally, emitter spacing of 1 to 2 ft are used for SDI systems in the Great Plains. Emitter spacing ranging from 1 to 4 ft had little effect on corn production and soil water redistribution on a silt loam

soil in a three-year study at the KSU Northwest Research-Extension Center at Colby, Kansas (Arbat et al., 2010). It should be noted that using the widest possible emitter spacing consistent with good water redistribution can cause significant problems when emitters become clogged or under drought conditions. As a result, some plants will be inadequately watered.

Key Idea:

- Emitter spacings of 1 to 2 ft are common and sufficient for most Great Plains crops.

What is the Best Emitter Discharge Rate?

Wide ranges of emitter discharge rates are available from the various dripline manufacturers. The evapotranspiration (ETc) needs of the crop have little direct influence on the choice of emitter discharge rate because most emitter discharge rates at typical emitter and dripline spacings provide SDI system application rates greatly in excess of peak ETc.

Some designers prefer emitters with greater discharge rates because they are less subject to clogging and allow more flexibility in scheduling irrigation. However, when emitters with greater discharge are chosen, the length of run may need to be reduced to maintain good uniformity and to allow for adequate flushing within the maximum allowable operating pressure. In addition, the zone size may need to be reduced to keep the total SDI system flowrate within the constraints of the water supply system. In general, designers in the Great Plains region prefer emitter discharge rates in the range of 0.15 to 0.25 gal/hr, so that zone length and zone area can be maximized, thus lowering SDI system costs.

Physical limitations exist to further reducing emitter discharge rate because smaller passageways are more easily clogged. The nominal dripline flowrate can be reduced with smaller emitter discharge rates or by increasing the emitter spacing. Limitations also exist to increasing the emitter spacing that are related to adequately supplying the crop's water needs. Using a smaller emitter discharge rate in combination with a greater emitter spacing is often economically attractive (reduced design and installation costs) on deeper, medium-textured soils for crops with extensive root systems.

The choice of emitter discharge rate must also account for the soil hydraulic properties in order to avoid backpressure on the emitters and surfacing of water, although this problem is not common on SDI systems in the Great Plains. Surfacing is an SDI phenomenon in which excessive emitter flowrate, coupled with insufficient soil water redistribution, creates or uses an existing preferential flow path to allow free water to reach the soil surface. Surfacing can sometimes be avoided with deeply-placed driplines, but this is only an acceptable solution when the mismatch of emitter flowrate and soil properties is small and the added soil depth provides a larger soil volume for water redistribution. This

“surfacing” phenomenon also may be directly associated with a “chimney effect” in which small, fine soil particles are carried to the surface in the preferential flow path or macropore. The sorting



Figure 2. Caldera resulting from surfacing of water from an SDI emitter in California. Photo courtesy of F. R. Lamm, Kansas State University.

of soil particles and deposition into the walls of the chimney will further reinforce the preferential flow path and surfacing may become worse. The chimney can be disrupted by tillage, but will often reappear because the flow channel still exists in the region around the emitter which was undisturbed by tillage. The surfacing and chimney effects are somewhat analogous to volcanic activity (Zimmer et al., 1988), and the point where free water exits the soil has even been called a caldera (Fig. 2).

Key Ideas:

- Lower emitter discharge rates in the range of 0.15 to 0.25 gal/hr are common and preferable in the Great Plains when clogging hazards are reduced.
- Excessive emitter discharge rates can cause soil water redistribution problems that are difficult to avoid or remedy after SDI system installation. This problem is rare in the Great Plains because of typical selection of lower emitter discharge rates.

How Much Water do I Need for my SDI System?

This question must be approached from the perspective of the crop/soil characteristics and from the perspective of the SDI system characteristics.

The following equation is used to calculate Q_{soil}^{crop} , the required SDI system flowrate in gal/min considering the crop soil characteristic:

$$Q_{soil}^{crop} = Design ET_c \times Field Area \times 18.856 \tag{Eq 1}$$

where $Design ET_c$ is the design crop evapotranspiration that is considered necessary for the crop in inches/day, $Field Area$ is given in acres and 18.856 is a conversion factor. In some regions on soils with low available water holding capacity, $Design ET_c$ is considered to be the peak crop ET . Typically, in northwest Kansas with deep silt loam soils, a $Design ET_c$ of 0.25 inches/day is considered adequate for corn production using center pivot sprinklers. When using SDI, a design value of 0.17 inches/day was reported adequate for a deep silt loam soil in northwest Kansas (Lamm and Trooien, 2001). The required SDI system flowrate per unit area for various $Design ET_c$ is given in Table 1.

Table 1. Required SDI system flowrate, gpm/acre, to meet various design crop ET rates.	
$Design ET_c$ (inches/day)	Q_{soil}^{crop} (gpm/acre)
0.10	1.89
0.13	2.45
0.15	2.83
0.17	3.21
0.20	3.77
0.25	4.71
0.30	5.66
0.35	6.60
0.40	7.54

The maximum overall SDI system size could then be determined by dividing the total available system flowrate by a value from Table 1 or from Equation 1 using a *Field Area* of 1 acre.

The SDI system flowrate from the perspective of the SDI system characteristics must consider the nominal emitter discharge rate, q_e , at the design pressure, the emitter spacing, S_e and dripline spacing, S_d . The following equation is used to calculate Q_{system} , the required SDI system flowrate in gal/min considering only just the SDI system characteristics:

$$Q_{system} = q_e \times (Field\ Area \div (S_e \times S_d)) \times 726 \quad \text{Eq 2}$$

where q_e is given in gal/hr, *Field Area* is given in acres, S_e and S_d are given in feet and 726 is a conversion factor.

The required SDI system flowrate per unit area for various emitter discharge rates, emitter spacings and dripline spacings is given in Table 2.

Emitter discharge rate (gal/hour)	Emitter spacing (ft)	Dripline spacing (ft)	Q_{system} (gpm/acre)
0.15	1	5	21.78
0.20	1	5	29.04
0.25	1	5	36.30
0.15	2	5	10.89
0.20	2	5	14.52
0.25	2	5	18.15
0.15	1	2.5	43.56
0.20	1	2.5	58.08
0.25	1	2.5	72.60
0.15	2	2.5	21.78
0.20	2	2.5	29.04
0.25	2	2.5	36.30

So, it can be observed that the SDI system characteristics has a large effect on the required system flowrate per unit area. The overall available system flowrate could then be divided by the required system flowrate per unit area from Table 2 or Equation 2 with a *Field Area* of 1 acre to determine the size of each irrigation zone. The number of overall zones is then determined as the maximum overall system size discussed above by the zone size determined with rounding up to a whole integer. In some cases, if the overall available flowrate is small, the large number of irrigation zones might result in an uneconomical SDI system design when considering the lower value commodity crops.

Key Idea:

- The required SDI system flowrate must consider the crop, soil and system design characteristics.

How does Land Slope affect SDI?

Topography can complicate system design and may limit feasibility of SDI. Whenever possible, driplines should be installed downslope on slopes of less than 2%. For each 2.31 ft of elevation change along the dripline there will be a corresponding 1 psi pressure change. Since most SDI systems have low operating pressures, a small pressure change can have a considerable effect. Pressure changes along typical non-pressure compensating driplines (i. e., emitter exponent of 0.5) of approximately 20% will result in flow changes of approximately 10%. A 10% flow change is a general rule of thumb for an acceptable maximum flow variation along the lateral. On steeper terrain, the driplines should be installed along the field contour and/or techniques for pressure control should be employed.

The land slope can have either a positive or negative effect on the emitter discharge rate along the dripline lateral (Fig. 3). Driplines running uphill always result in increasing pressure losses along the dripline and thus lower system uniformity. When the downhill slope is too great, the emitter discharge rate at the end of the dripline becomes unacceptably high. In the example shown (Fig. 3), the optimum slope is 1% downslope, but this will vary with dripline and emitter characteristics. Designers may even use these hydraulic factors to their advantage to balance elevation head gains with increased friction losses from smaller diameter driplines.

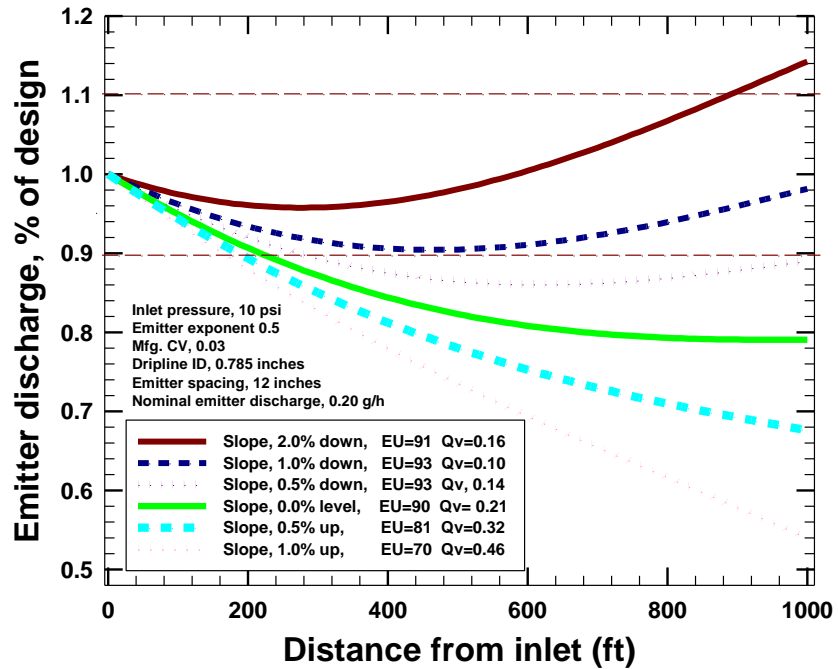


Figure 3. Calculated emitter discharge, emission uniformity (EU), and emitter discharge variation (qvar) as affected by topography. Results for hypothetical dripline calculated with software from Roberts Irrigation Products (2003).

Pressure compensating emitters can be utilized for pressure control, but are generally more expensive which may limit use of SDI for commodity type crops (e.g. corn, soybeans, wheat). Shorter lateral runs can also aid in pressure control but will decrease zone size and increase the overall number of zones. The presence of field slope may also cause inadvertent backsiphoning when the SDI system is shutdown. Checkvalves, air vents, and vacuum breakers may be required at various points in the SDI system to prevent back-siphoning of chemically treated water into the water supply and also to prevent ingestion of soil into the driplines at system shutdown. Undulating slopes can present problems in economical prevention of backsiphoning into the dripline laterals and may limit application of SDI if the backsiphoning hazard is great.

Key Ideas:

- Driplines should never be installed running uphill
- Large elevation changes within a field will complicate SDI design.
- A 20% pressure variation within a typical non-pressure compensating dripline will result in a flow variation of 10%.
- Presence of field slope may require additional components to prevent backsiphoning of contaminated water and ingestion of soil at SDI system shutdown.

SUMMARY

As with any new technology, there are issues and constraints that need to be understood before the technology can be fully utilized in a successful manner. This paper discussed many of the frequently and not-so-frequently asked questions about subsurface drip irrigation. Additional advantages and disadvantages of SDI are discussed by Lamm (2002). K-State Research and Extension has an extensive website devoted to SDI in the Great Plains.

<http://www.ksre.ksu.edu/sdi/>

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This paper is also part of an SDI technology transfer effort beginning in 2009 involving Kansas State University, Texas A&M University and the USDA-ARS and is funded by the Ogallala Aquifer Project. To follow other activities of this educational effort, point your web browser to <http://www.ksre.ksu.edu/sdi/>. Watch for this logo.



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