# *A BRIEF RESEARCH UPDATE ON SUBSURFACE DRIP IRRIGATION*

***Suat Irmak***
***Department of Biological Systems Engineering***
***University of Nebraska-Lincoln***
***241 L.W. Chase Hall***
***Lincoln, NE 68583***
***sirmak2@unl.edu, (402) 472-4865***

## What is Subsurface Drip Irrigation?

Subsurface drip irrigation (SDI) supplies water directly to the crop root-zone via buried polyethylene drip lines and emitters. The irrigation laterals are buried below the soil surface (typically between 13 to 20 inches, depending on the soil and crop type, climate, and management practices, etc.). Burying driplines underground minimizes surface soil evaporation due to irrigation and there is no runoff due to irrigation with the SDI system. Placing the irrigation system underground coupled with an effective irrigation management program provide the opportunity to supply proper amount of crop water and nutrients needs directly to the crop root-zone. Crops can be "spoon-fed" water and nutrients. The "spoon-fed" characteristic of the SDI system has a great potential to minimize or eliminate the movement of water and nutrients below the crop root-zone when properly managed. With SDI, the irrigation water is filtered at the filter and control station before application to the field through the drip laterals. When properly managed, irrigation application losses (wind drift, soil evaporation, deep percolation, and runoff) with the SDI are significantly lower compared to other irrigation systems (read more about SDI: **UNL-Extension Circular EC776-2005**).

Subsurface drip irrigation applies water and nutrients directly to the crop root zone using buried polyethylene tubing, also known as a dripline, dripperline, or drip tape. Driplines have varying diameters and thicknesses in order to maintain acceptable irrigation uniformity for different field lengths. Smaller diameter driplines are used when short lateral lengths are required. As lateral length increases, a larger diameter dripline must be selected to maintain adequate irrigation uniformity. The thickness of the dripline wall is directly related to its durability. Driplines with small thicknesses are mainly used for temporary installations, which will be discarded after a short time, such as when being used to irrigate high value crops. Thicker driplines are used for permanent installations. The thicker driplines can also withstand higher operating pressures. The cost of the dripline is directly related to both diameter and thickness. Small holes called *emitters* are usually spaced every 8 to 24 inches along the length of the dripline. During irrigation, pressure forces the water out of the emitters drop by drop. Once the water is in the soil, its movement and wetting pattern will depend on the initial soil water status, flow rate, and physical characteristics of the soil. In a fine-textured soil, for instance, water will tend to move laterally and upward, compared with a sandy soil where water tends to move mainly downward. The amount of water that can be delivered through a drip system depends on dripline diameter and spacing, emitter spacing, operating pressure, emitter size, and emitter design. A variety of driplines are now available from different manufacturers to fit the specific design requirements for different soils, crops and weather conditions.

**Advantages**

One of the main advantages of SDI over other irrigation methods is that it has the *potential* to be the most efficient irrigation method available today. The word *potential* is stressed because irrigation efficiency not only depends on the irrigation system itself, but also on its proper design, installation and management. Only if designed, installed and managed properly can SDI be more efficient than any other irrigation system. Since the driplines are usually installed in the soil between every other crop row, in the middle of the furrow, the system only wets a fraction of the soil volume, compared with other systems. This leaves space in the soil to store water from rainfall and may reduce the net irrigation requirements. Also, since driplines are buried, about 13-18 inches below the soil surface for corn, the soil surface stays dry. A dry soil surface means that practically no irrigation water is lost due to evaporation and runoff. In addition, if the system is managed correctly, deep percolation losses due to irrigation can be eliminated. The only small inevitable water losses are those needed for flushing the driplines and filtering system. Therefore, an SDI system can deliver water with an efficiency of 95 percent or higher. This means that for every inch of water that is pumped, 0.95 inch or more stays in the crop root zone, where it is needed. Because of the potential high irrigation efficiency that can be obtained with SDI, it may be a good alternative for areas where irrigation water is limited. It should be noted, however, that although water savings is an important consideration, it should not be the only factor to consider when selecting an irrigation system.

**Disadvantages**

For detailed information on disadvantages of the system in terms of initial investment cost, potential emitter clogging issues, and rodent issues the readers are refereed to
**UNL-Extension Circular EC776-2005**.

**Potential SDI applications in the High Plains:**

- Fields with relatively large slopes
- Small and/or odd shaped fields where installation of center pivot may not be feasible
- Conversion from surface and other irrigation methods
- Areas with low capacity wells (≈<400 gal/min)

## RESEARCH UPDATE WITH SUBSURFACE DRIP IRRIGATION AT THE UNL-IANR-SOUTH CENTRAL AGRICULTURAL LABORATORY: SDI FIELD 1

A 33-acre (1,720 ft wide and 845 ft long) SDI system was installed at the UNL South Central Agricultural Laboratory near Clay Center, NE, in 2004 to study following **objectives**:

1. Use the system as a demonstration site for clientele for them to get first-hand experience with system installation, operation, and maintenance, and monitor irrigation and nutrient management practices throughout the season.
2. Learn more about system hydraulics and behavior
3. Develop corn and soybean specific SDI best management practices that utilize the automation and fertigation advantages of SDI system to improve profitability while reducing water, energy, fertilizer, and labor.

4. Investigate whether SDI and reactively scheduled nitrogen fertigation can minimize nitrate leaching and substantially decrease precipitation-driven nitrate leaching.
5. Measure crop evapotranspiration and crop coefficients for SDI-irrigated corn and soybean
6. Provide clientele information and practical suggestions on system management

There are 11 treatments (including furrow irrigation treatments, F) and each treatment is replicated four times with the exception of reference treatment (R) which is replicated three times (Figure 1). The SDI laterals were installed at 15 in. deep with every other row in the center of the row. The drip emitters are pressure compensating with 0.26 gal/hr discharge rate.

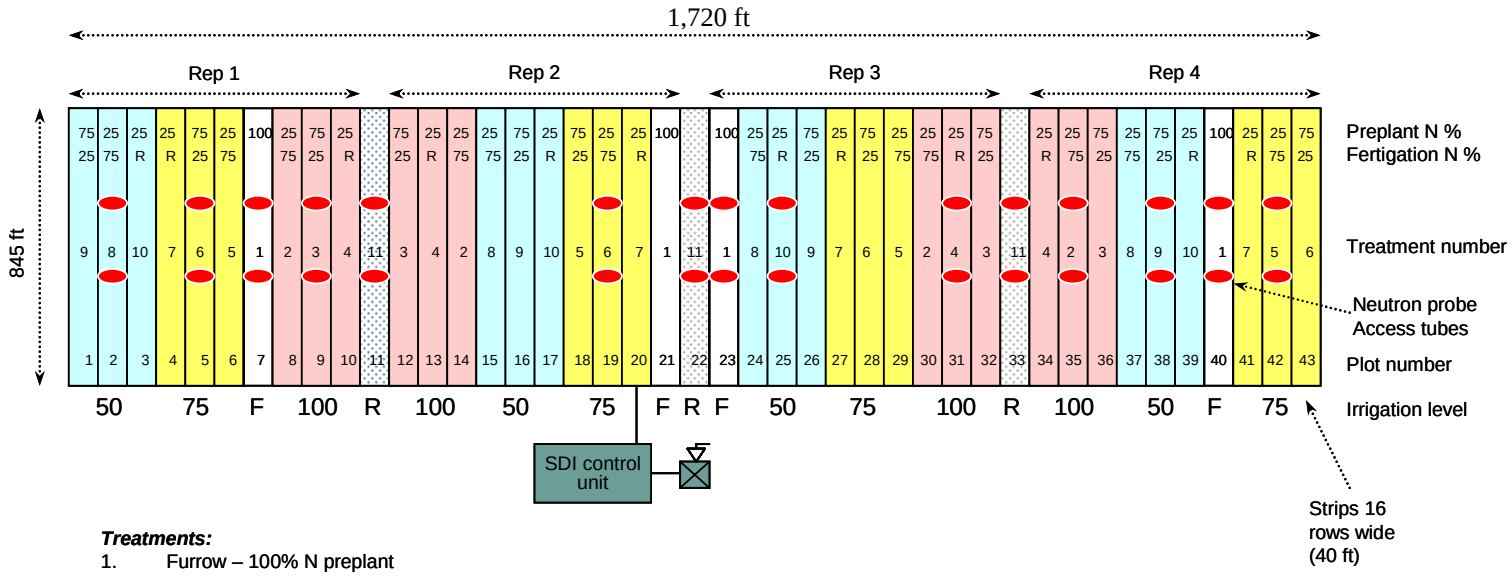
**Procedures:**

• Three irrigation levels that are evaluated: (100% $ET_c$, 75% $ET_c$, and 50% ET where $ET_c$ is crop evapotranspiration determined on a daily basis. Irrigations are applied two or three times a week to replenish soil profile. Soil water content is measured at 18 different locations in different treatments every foot up to 6 ft using profile probe and/or neutron probe soil moisture probe. In addition, soil matric potential is being measured every foot up to 6 ft using Watermark granular matrix sensors and Watermark Monitor dataloggers.

• Three N management strategies are evaluated within each irrigation level. These are predominately preplant N (75% preplant/25% fertigation), predominately fertigated (25% preplant/75% fertigation), and a reactive strategy (25% preplant, balance reactive). Nitrogen application rates for these treatments will be derived according to current UNL recommendations. Reactive N applications are based on chlorophyll meter readings taken weekly in target plots from V8 to R2 growth stages, and compared to reference strips to which N is applied at a non-limiting rate. If during this period the ratio of chlorophyll meter readings in target plots relative to reference plot falls below 0.95, N is applied twice a week until the ratio increases above 0.95. This strategy has the potential to more effectively account for soil N mineralized during the growing season than N management strategies which result in a fixed application rate.

• SDI and nitrogen management strategy treatments are compared to a furrow-irrigated, preplant N treatment, which represents a common system with anticipated lower efficiency of water and N.

The experimental design is a split-split plot with main plots arranged in a randomized complete block replicated four times (Figure 1). The main effect plots are irrigation level, and the secondary effect is the fertilizer strategy. Nitrogen amount in different treatments is applied in two different ways: some amount injected through the system and some amount is applied pre-plant depending on the treatment. The soil at the experimental site is Hastings silt loam which was well-drained soil on uplands, fine, *montmorillonitic*, *mesic Udic Argiustoll*, with field capacity of 0.34 $m^3$ $m^{-3}$ and permanent wilting point of 0.14 $m^3$ $m^{-3}$, and with 15% sand, 62.5% silt, 20% clay, and 2.5% organic matter content




***Treatments:***

1. Furrow – 100% N preplant
2. 100% ET – 25% N preplant, 75% fertigation
3. 100% ET – 75% N preplant, 25% fertigation
4. 100% ET – 25% N preplant, balance reactive
5. 75% ET – 25% N preplant, 75% fertigation
6. 75% ET – 75% N preplant, 25% fertigation
7. 75% ET – 25% N preplant, balance reactive
8. 50% ET – 25% N preplant, 75% fertigation
9. 50% ET – 75% N preplant, 25% fertigation
10. 50% ET – 25% N preplant, balance reactive
11. Reference – 100% ET, 100 lb N/acre preplant, 150 lb N/acre fertigation

All treatments receive 5 gal/acre 10-34-0 as in-furrow starter at planting, providing 5.7 lb/acre N, 19.4 lb/acre $P_2O_5$

Figure 1. South Central Agricultural Laboratory Subsurface Drip Irrigation Field-1 treatment layout.

**Crop and soil management:**

**Soil:** Hastings Silt-Loam (*Udic Argiustoll*) moderately well drained, fine, *montmorillonitic* and *mesic*.

| | **2004** | **2005** |
|---|---|---|
| Planting date: | May 4, 2004 | April 22, 2005 |
| Emergence date: | May 16, 2004 | May 8, 2005 |
| Planting depth: | 2 in. | 2 in. |
| Row spacing: | 30 in. | 30 in. |
| Planting Rate: | 28,500/ac | 28,500/ac |
| Hybrid: | Pioneer 33M54 | Pioneer 33B51 |
| Harvest date: | October 29, 2004 | October 17, 2005 |

**Weed control:**

**Type:** Callisto **Date:** 6/23/2004 **Rate (amount):** 3 oz/ac
**Type:** Buctril **Date:** 6/23/2004 **Rate (amount):** 1 cup/ac

**Weed control:**

**Type:** Lexar **Date:** **4/25/05** **Rate (amount):** 3 qt/acre

**Soil Practices: Cultivation, till, etc. (2004):**

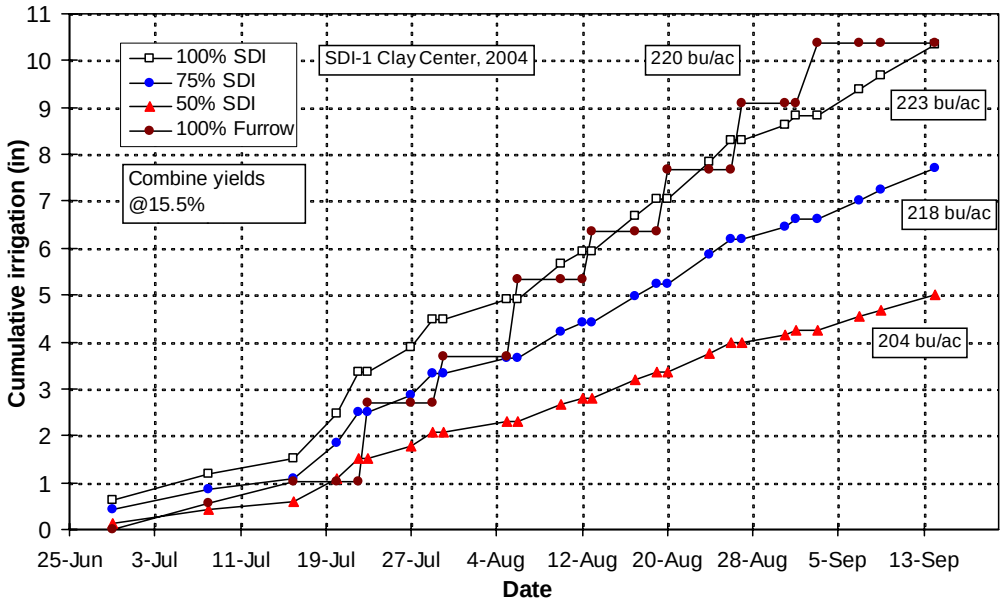
Field was ridge planted on top of existing ridges from year before and only furrow treatments were ridged to allow furrow irrigation.

**Soil Practices: Cultivation, till, etc. (2005):**

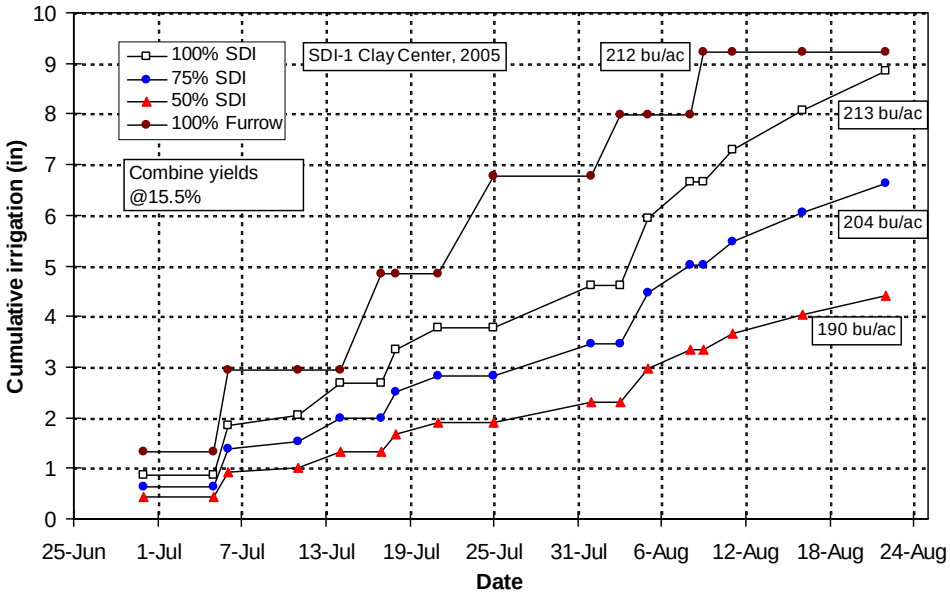
Field was slot planted with minimal soil movement due to wet conditions and was cultivated on June 17, 2005. A 4.4 lbs/acre of Force 3G granular insecticide was applied at planting.

The first two years of results showed that the SDI can be a viable irrigation system for irrigating corn in Nebraska soil, crop, and climate conditions. First two years, the full irrigation (100% ET) treatments resulted in 235 bu/ac corn yield with 10 in. net irrigation. Promisingly, 50% ET treatments resulted in 204 and 190 bu/ac corn yield in 2004 and 2005 with about 5 in. irrigation water.

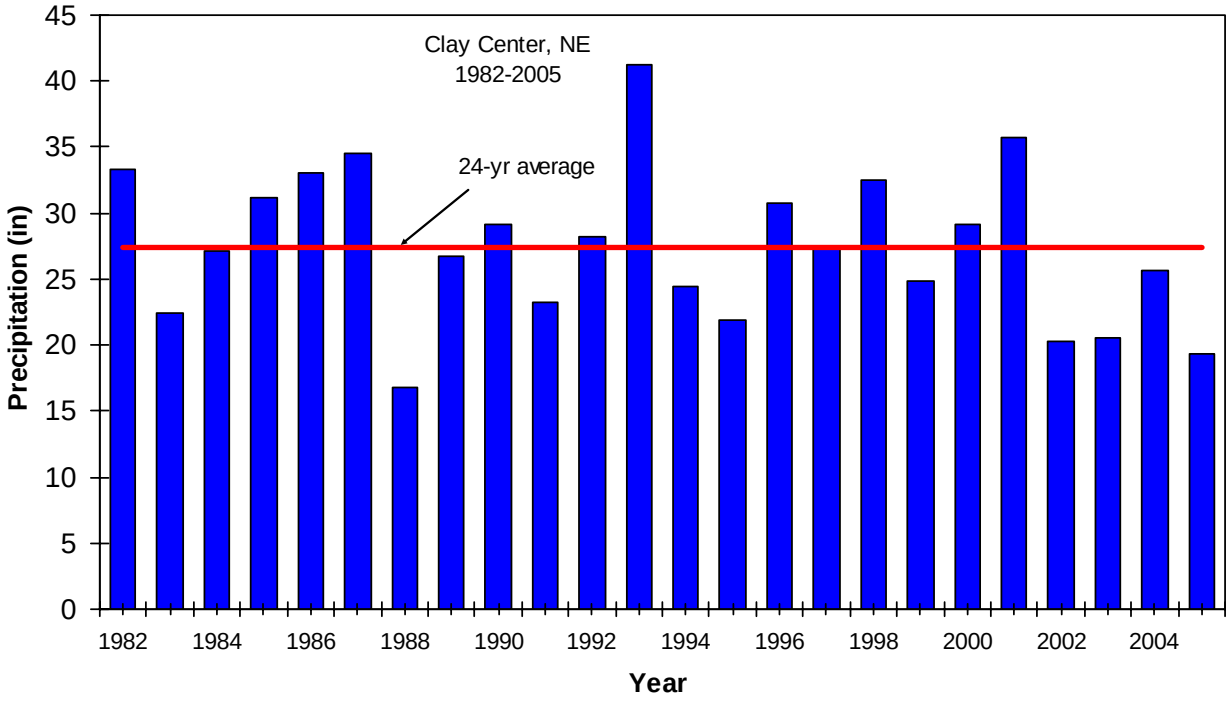
**Irrigation and Yield - 2004**



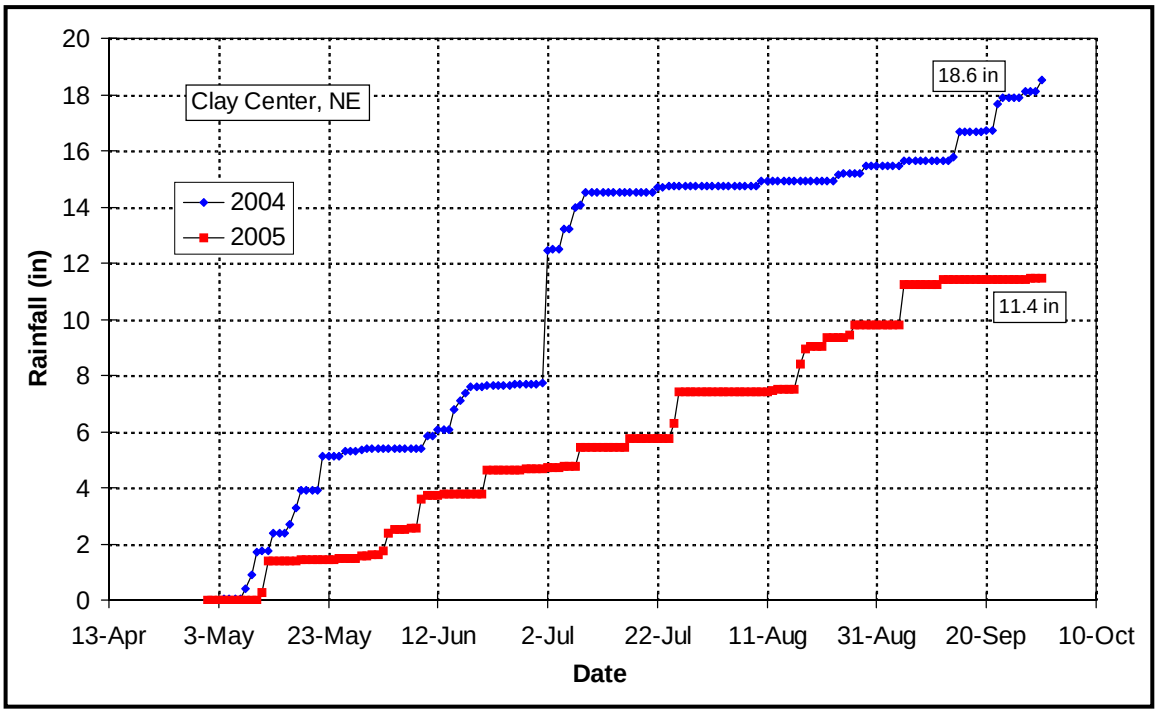

**Irrigation and Yield - 2005**



**Long-term rainfall**




**Rainfall in 2004 and 2005**




Trenching for the mainlines at the top end of the field.


Three-row planter used to install the driplines at 15 in. deep every other row in the center of the row.

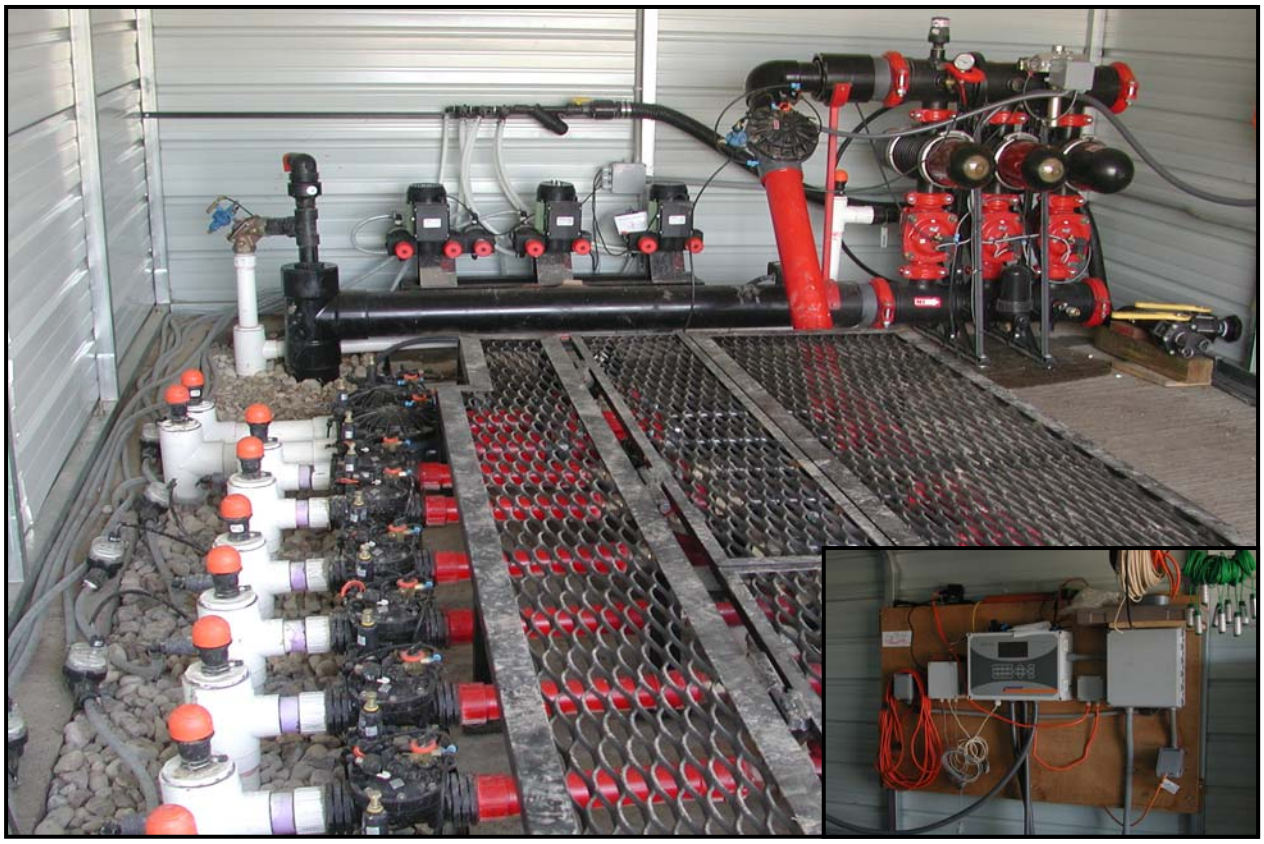
Packing the topsoil after installing the driplines to minimize surface soil evaporation.

Gluing over 5 miles of PVC pipe for the mainlines at the top end of the field.

Connecting individual driplines to the mainlines using a polyethylene tube.

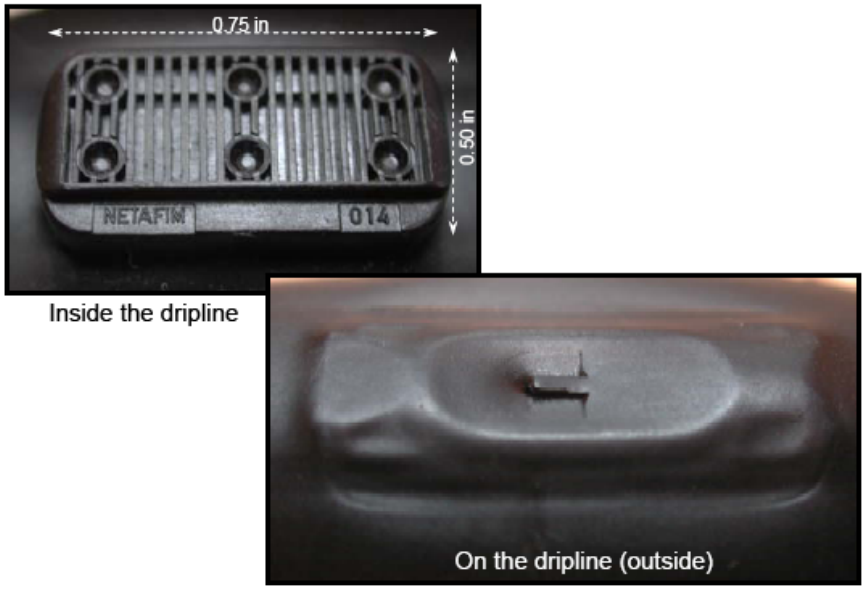
Making the connections between the mainlines and the riser tubes (air release valves).

Flushing valves at the bottom end of the field.



System control unit, including solenoid valves, fertilizer and water flowmeters, checmical injection pumps, air/vacuum release valves, filter, and irrigation controller.

A 400 gal/min capacity automatic disk filter. When the incoming (from the pump) and outgoing water (to the manifold) pressure differential exceeds 5 psi, the filter back-flushes automatically. The flushing velocity is 175 gal/min and the filter back-flushes each disk for about 10 seconds.




Pressure compensating (PC) drip emitters with 0.26 gal/h flow rate. Emitter spacing on the tape is 18 in. The PC emitters compensate for pressure variation and try to provide near-constant flow rate under variable pressure. They can be useful especially for increasing system uniformity in fields with relatively large slopes.

# Acknowledgement


- University of Nebraska-Lincoln Agricultural Research Division
- UNL Burlington Northern Endowment
- Diversity D Inc., Brownfield, TX (Special thanks to *Ross Roberts*)
- Netafim-USA
- Special thanks go to *Bill Rathje*, Research Technician in the Department of Biological Systems Engineering


***Disclaimer:*** The mention of trade names or commercial products is solely for the information of the user and does not constitute an endorsement or recommendation for use by the University of Nebraska-Lincoln or the author(s).

## RESEARCH UPDATE WITH SUBSURFACE DRIP IRRIGATION AT THE UNL-IANR SOUTH CENTRAL AGRICULTURAL LABORATORY (SCAL): SDI FIELD 2

This project addresses several key issues related to irrigation management and water conservation in Nebraska. Our overall objective is to study soil-water-plant-atmosphere dynamics of the SDI system and to determine whether the SDI system coupled with reduced tillage practices can help to counter water-limiting conditions in Nebraska. Our specific objectives are to:

1. Measure crop water use efficiency (CWUE), water savings, and crop growth and yield for SDI-irrigated corn coupled with three tillage practices: ridge-till, disk-till, and no-till. Crop yield obtained from non-irrigated treatments will be taken into account when quantifying the CWUE.

2. Determine optimum irrigation scheduling parameters for SDI-irrigated corn that will result in the minimum or no deep percolation or runoff.

3. Measure and/or model surface soil evaporation in irrigation amount and tillage treatments. This will help quantify water savings due to reduced evaporation with the SDI coupled with reduced tillage management practices.

4. Develop and deliver educational workshops on improved water management practices with SDI and on operation and maintenance to attain high efficiencies and maximize system life.

### Research with Subsurface Drip Irrigation: Field 2

An 11 acre SDI system was installed at the UNL South Central Agricultural Laboratory near Clay Center, NE, in 2005. There are 20 treatments and each treatment is replicated three times. The research project is designed as randomized complete block. The SDI laterals were installed at 15 in. deep with every other row in the center of the row. The drip emitters are pressure compensating with 0.26 gal/hr discharge rate. Each replication (plot) is 400 ft long and 8 rows wide on 30 in. row spacing.

**Procedures:**

- Five irrigation levels evaluated are: (125% $ET_c$, 100% $ET_c$, 75% ET, 50% $ET_c$, and non-irrigated treatment where $ET_c$ is crop evapotranspiration determined on a daily basis using the American Society of Civil Engineers Penman-Monteith (ASCE-PM) standardized combination equation and corn crop coefficients.

- All aforementioned treatments are being studied with three irrigation frequency levels: high, medium, and low. High frequency treatments are being irrigated every day with the exception of weekends and when rainfall exceeds daily crop water requirement. The medium frequency treatments are irrigated every other day, and the low frequency treatments are irrigated twice a week. The irrigation frequency effect on crop water use, crop growth, yield, and starch and protein content of the grain are being quantified.

- The soil water content is measured at more than 20 locations in different treatments every foot up to 6 ft using a neutron probe soil moisture probe. In addition, soil matric potential is being measured every foot up to 6 ft using Watermark granular matrix sensors and Watermark Monitor dataloggers in selected plots.

- The nitrogen management is based on the soil samples taken every spring and using the UNL nitrogen recommendation algorithm.

**Crop and soil management:**

**Soil:** Hastings Silt-Loam (*Udic Argiustoll*) moderately well drained, fine, *montmorillonitic* and *mesic*.

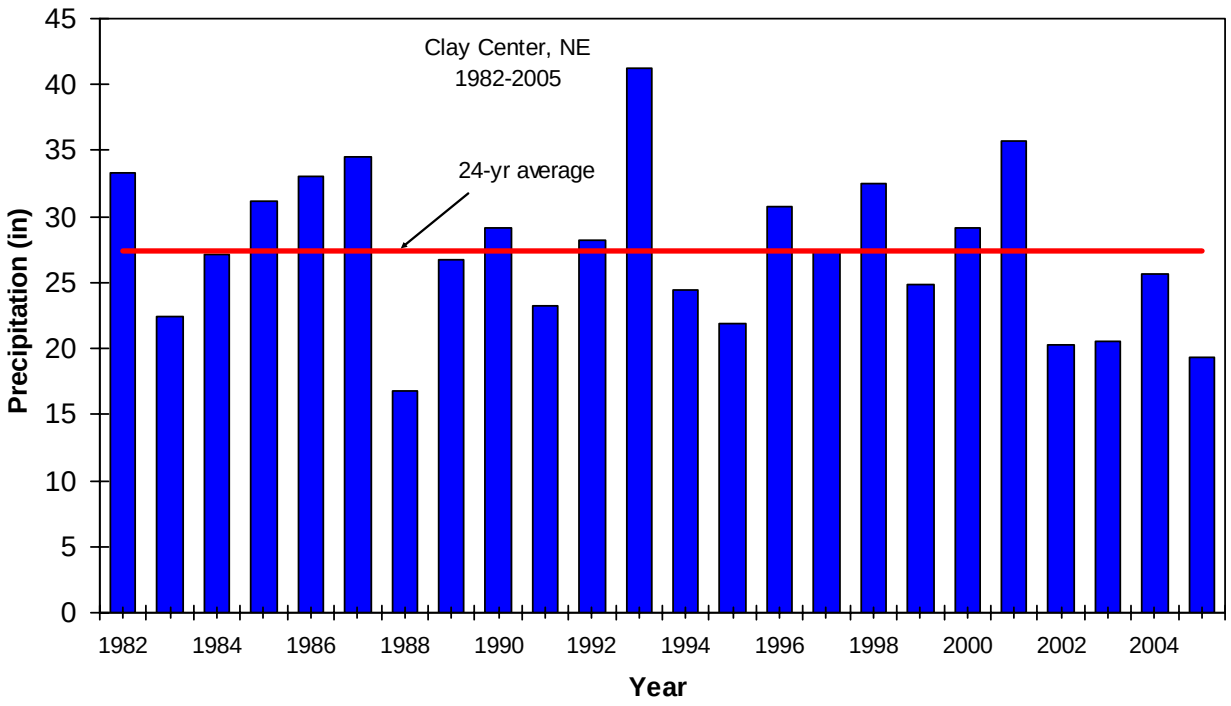
| Fertilizer Type | Amount Applied | Application Date |
|---|---|---|
| 11-52-0 dry phosphorus | 100 lbs/ac | October 18,2004 |
| 32-0-0 (32%N) | 125 lbs/ac | March 11, 2005 |
| 10-34-0 (starter) | 5 gal/ac | May 2, 2005 |
| 10-32-0 | 20 lbs/ac | July 12, 2005 |

**Planting Date:** May 2, 2005 **Planting Rate:** 29,500/ac
**Emergence Date:** May 13, 2005 **Hybrid:** Mycogen 2T780
**Planting Depth:** 2 in. **Harvest Date:** October 13, 2005
**Planting Spacing:** 30 in.

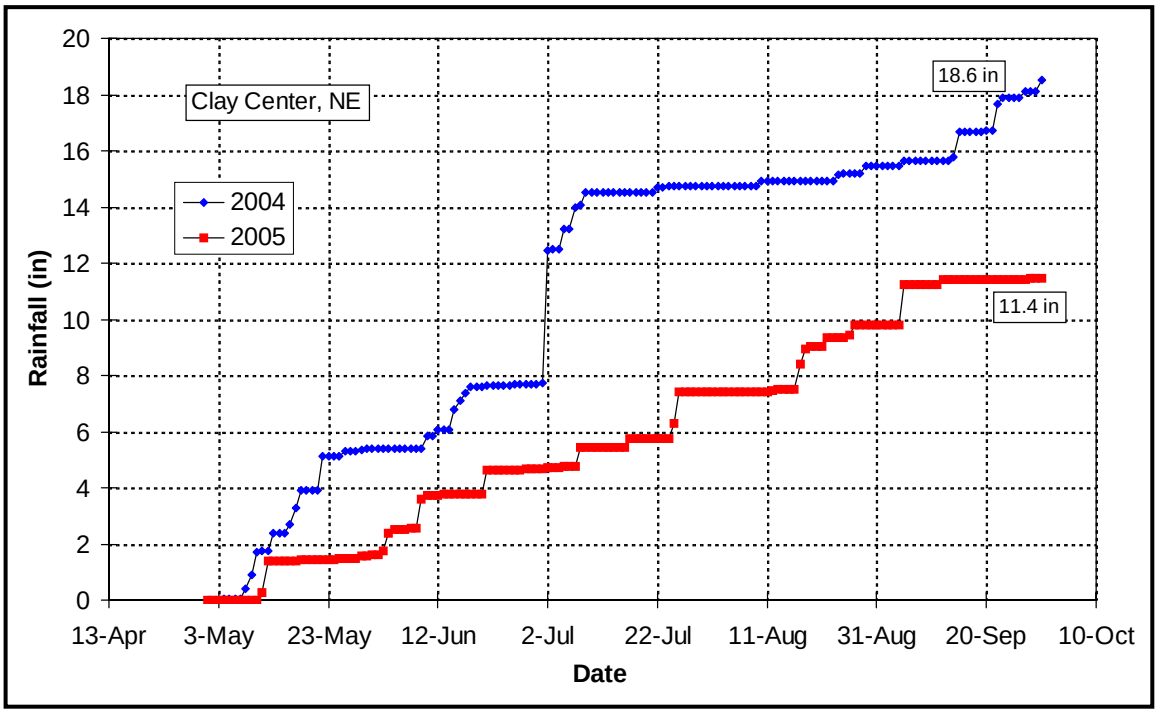
**Weed control:**
**Type:** Lexar **Date:** May 5, 2005 **Rate (amount):** 3 quarts/ac
**Type:** Callisto with Steadfast **Date:** June 7, 2005 **Rate (amount):** 3 oz/ac of Callisto and 0.75 on of Steadfast

**Soil Practices: Cultivation, till, etc.:**
The field was dryland corn until 2004. After harvest in 2004, stalks were shredded and field was cross ripped twice to a depth of 18 in. Field was then disked. After these ridges were put in using Hawkins hiller bottoms so corn could be planted on top of a ridge this year. Disk till plots were tilled on February 28, 2006. They will be tilled the second time just before planting in May 2006.

**Long-term rainfall**




**Rainfall in 2004 and 2005**



Infrared thermometers to monitor crop canopy temperature continuously (30 min interval) to quantify crop water stress index (CWSI) for corn.

Infrared thermometers to monitor crop canopy temperature continuously (30 min interval) to quantify crop water stress index (CWSI) for soybeans.

Infrared thermometer to measure surface soil temperature to account for soil temperature in crop water stress index (CWSI) calculations. Early in the growing season, soil temperature has an impact on the CWSI before 100% canopy cover is completed.


Plow (shank) used to install the driplines.

Placing mainlines.

Mainlines and individual driplines are connected for each treatment and group of replication.

Backfill process of the main trench.

Connecting the manifold and mainlines for individual treatment at the control unit or filter station.

Flushing valves at the bottom end of the field. The system is designed so that each dripline can be flushed.

Control unit of the subsurface drip irrigation system comprised of disk filter, solenoid valves, chemical injection pups, water flowmeters, fertilizer flowmeters, variable speed motor controller for the pump, irrigation system controller, manifold, air relief valves, etc.

# Acknowledgement


- University of Nebraska-Lincoln Agricultural Research Division
- UNL Burlington Northern Endowment
- Diversity D Inc., Brownfield, TX (Special thanks to *Ross Roberts*)
- Netafim-USA
- Special thanks go to *Bill Rathje*, Research Technician in the Department of Biological Systems Engineering


***Disclaimer:*** The mention of trade names or commercial products is solely for the information of the user and does not constitute an endorsement or recommendation for use by the University of Nebraska-Lincoln or the author(s).