IN-SEASON NITROGEN MANAGEMENT FOR SUB-SURFACE DRIP IRRIGATED CORN

Richard Ferguson and Suat Irmak
University of Nebraska, Lincoln, Nebraska

Abstract

Irrigation water and nitrogen (N) management for subsurface drip irrigated (SDI) corn was evaluated from 2004 through 2006 at the South Central Agricultural Laboratory of the University of Nebraska. SDI irrigation and N management strategies to increase both water and N use efficiency were compared to preplant N application for furrow irrigation, commonly used in the area. Irrigation water levels of 100, 75 and 50% of measured evapotranspiration (ET) were applied with SDI, and N was applied in treatments of either preplant (75% preplant/25% fertigation), fertigation (25% preplant/75% fertigation) or reactive (25% preplant/chlorophyll meter scheduled). In 2004 and 2005, there were no interactions of irrigation water level and N management strategy on grain yield or fall residual nitrate-N. Grain yield was reduced in both years with 50% ET irrigation, and slightly in 2005 with 75% ET irrigation. There were no significant effects of N strategy on grain yield in 2004 or 2005. Fall residual nitrate-N tended to be reduced with the reactive N management strategy. SDI treatments near the optimum yield level (75 and 100% ET) tended to reduce residual nitrate-N in the root zone compared to the furrow treatment. Irrigation at approximately 75% of measured ET with SDI for corn appears to be a good combination of efficient irrigation water use and near maximum yield.

Introduction

Water use efficiency of corn is increasingly of concern in parts of Nebraska, Kansas, Colorado and other states with significant irrigated corn production. Recent successive years of drought conditions have depleted water storage in reservoirs as well as groundwater resources, and also increased the demand for irrigation water. The result in parts of Nebraska has been the imposition of regulatory limits on irrigation water use from both surface and groundwater resources, often below the amount of water necessary to maximize yield potential. Irrigators are interested in ways to increase the efficiency with which they use irrigation water. Over the past ten years or so, there has been a steady shift from furrow irrigation to center pivot sprinkler systems in Nebraska, such that today approximately 75% of the states 8.2 million irrigated acres is sprinkler irrigated, compared to about 50% a decade ago. This change in irrigation method has been due to a combination of decreased labor and increased efficiency associated with center pivot systems. However, there are many furrow-irrigated fields which are irregularly shaped or too small for center pivot systems to be used effectively. Sub-surface drip irrigation (SDI) is an alternative irrigation method which has the potential for increasing irrigation water use efficiency beyond that of either furrow or sprinkler systems, and can be adapted to fields of irregular shape. The central component of SDI systems is a plastic tube – typically referred to as drip tape – with regularly spaced emitters buried below the soil surface. The drip tape is placed below the depth of routine tillage, usually parallel to the row orientation and at intervals equal to every other row spacing.

The primary advantage to SDI compared to sprinkler systems is that evaporation of irrigation water from the soil surface and crop canopy is greatly reduced or eliminated. Irrigation water is released directly into the root zone. Evapotranspiration (ET) from SDI systems is significantly less than from sprinkler or furrow-irrigated fields, primarily due to reduced evaporation. Research in Kansas has found that irrigation through SDI systems can reduce water use of corn by 35-55% compared to other forms of irrigation used in the region (Lamm and Trooien, 2003; Lamm et al., 1995) The main disadvantage to SDI is the cost of installation, which historically has substantially exceeded that of center pivot systems. However, the cost of SDI systems continue to decrease to the point they are becoming competitive with center pivot systems. It is common to apply fertilizer with irrigation water supplied through SDI systems. To some degree fertigation through the system is necessary, as fertilizer applied to the soil surface, or even injected slightly below, may remain positionally unavailable to the crop due to dry soil conditions near the surface. Also, root development near the soil surface may be less due to dry soil. Fertilizer injected into the root zone with irrigation water allows immediate access by plant roots, and minimizes potential for nutrient loss or reduced plant availability due to immobilization, volatilization, runoff, etc. Lamm et al. (2001) found fertigation via SDI for corn resulted in redistribution of residual N in the soil profile compared to preplant N banded in the furrow, with SDI fertigation resulting in residual N concentration higher at greater depths.

Materials and Methods

A subsurface drip irrigation system was installed in June 2004 to a 33 acre field at the South Central Agricultural Laboratory (SCAL) of the University of Nebraska, near Clay Center. Drip tape was placed at a depth of approximately 15 inches below the soil surface, in the center of the furrow midway between rows, parallel to the row at 60 inch intervals (every other row). Pressure-compensating emitters were located 18 inches apart, each with a flow rate of 0.26 gal/hr. The initial study on the field was designed to provide information on combined water and nitrogen (N) management for SDI systems compared to conventional furrow irrigation. A randomized, complete block design with four replications was used with 10 treatments. Irrigation water was applied to SDI treatment strips at levels to match 100, 75 and 50% of measured ET. Within each of these water levels, three N management strategies were imposed: 75% preplant/25% fertigated; 25% preplant/75% fertigated; and reactive, in which approximately 25% of the N requirement was applied preplant, and the balance fertigated as necessary based on chlorophyll meter readings. The first two strategies were chosen to reflect common practices in the area used with center pivot irrigation, where application timing ranged from a majority of N applied prior to planting to situations where the majority of N is applied in-season. The reactive treatment was based on weekly chlorophyll meter measurements collected from V8 to R1. Three reference strips were located within the field, which received 100% ET SDI water application. 100 lb N/acre preplant and 150 lb N/acre through the irrigation system, scheduled between V8 and R1. Nitrogen application was triggered for the reactive N treatment when the treatment chlorophyll readings reached a value of 0.95 or less relative to the reference strips. SDI treatments were compared to a furrow-irrigated treatment to which all N was applied prior to planting. Treatments were applied to field-length strips 40 ft wide (16 rows) and 845 ft long. The study has been conducted over three years – 2004 – 2006.

Fertilizer application rates were established each year based on soil sample information and the University of Nebraska (UNL) N algorithm for corn. Soil samples were collected to a depth of 8 inches for organic matter, pH, P, K, nitrate-N, and to a depth of 6 ft for nitrate-N. Residual nitrate-N concentrations to a depth of 3 ft were used in calculating the recommended N rate for the successive crop. Samples were collected in the spring of 2004 to establish treatment rates, and in the fall thereafter to assess treatment effects on residual nitrate-N and establish fertilizer rates for the following year. Starter fertilizer was used each year (10-34-0), supplying approximately 5 lb N and 19 lb P_2O_5/acre. In 2006, phosphorus injection through the system was planned, but due to equipment problems ammonium polyphosphate (10-34-0) was instead injected between rows after planting, in addition to starter fertilizer at planting. In 2006, a total of 58 lb P_2O_5 was applied between starter and sidedress applications.

Planting dates and hybrids were May 4, 2004 with Pioneer 33M54; April 22, 2005 with Pioneer 33B51, and May 12, 2006 with Pioneer 33B54. The seeding rate each year was 28,500 seeds/acre. The entire area of each strip was harvested with a calibrated yield monitoring combine, with grain from each strip weighed with a weigh wagon. Reported grain yields were adjusted to 15.5% moisture.

Results and Discussion

To simplify reporting and discussion, the SDI-irrigated treatments receiving 25% of total N through fertigation, and 75% of total N preplant, will be termed the preplant strategy. SDI-irrigated treatments receiving 75% of total N through fertigation, and 25% of total N preplant, will be termed the fertigation strategy. Treatments with the majority of N applied based on chlorophyll meter readings will be termed the reactive strategy.

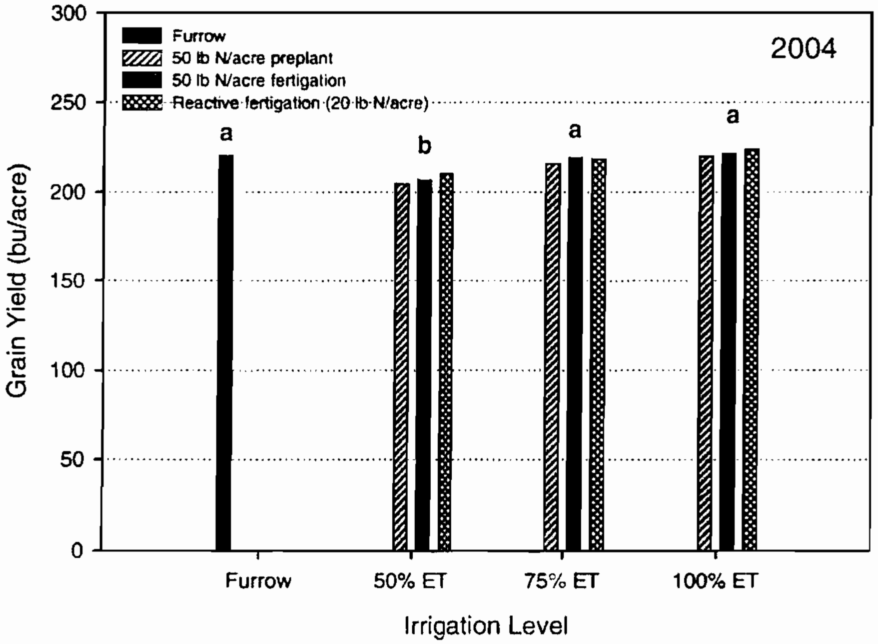

Figure 1. Treatment effects on grain yield, 2004. Irrigation levels with different letters are significantly different at P=0.05.

The study field had substantial residual nitrate-N in the spring of 2004 due to crop and weather conditions the preceding year, when the field was not irrigated. Grain sorghum was raised with a target yield of 100 bu/acre, but drought limited yield to approximately 30 bu/acre. Consequently, the average residual nitrate-N concentration in the root zone to a depth of 4 ft was 24.4 ppm – approximately 350 lb available N. With an average soil organic matter level for the field of 3.5% (although a maximum of 3% used in the UNL recommendation algorithm) and an expected yield of 220 bu/acre, the UNL recommended N rate was zero. In order to impose some N treatment for 2004, the planned treatments were changed to strategies of 50 lb N/acre preplant, 50 lb N/acre fertigation, and reactive N management with no preplant N (other than starter). Two of three reactive N treatments received 20 lb N/acre at the R2 growth stage, based on the ratio of the treatment chlorophyll readings to reference readings. However, there was no effect of any of the N treatments on yield, nor interactions between SDI water level and N strategy. There were trends for increasing yield with increasing water application rates (Figure 1), but only the SDI 50% ET treatment yields were significantly lower than the other water treatments.

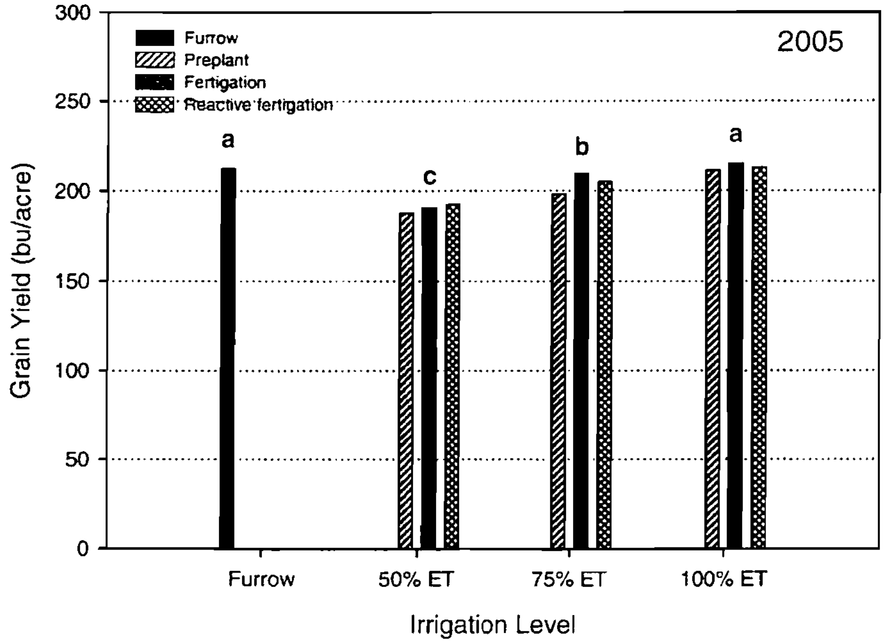

Figure 2. Treatment effects on grain yield, 2005. Irrigation levels with different letters are significantly different at P=0.05.

The treatment strategy used in 2004 tended to substantially reduce residual nitrate-N in the root zone in the spring of 2005. Though there were not statistically significant differences in residual nitrate-N in the top 3 ft among treatments, fertilizer N rates for 2005 were adjusted according to treatment average residual nitrate-N in the top 3 ft, to insure that total N availability would be as uniform as possible among treatments. Consequently, there was considerable variability in preplant and fertigation N rates among treatments. Preplant N rates ranged from 25 to 150 lb N/acre, fertigation N rates ranged from 0 (for furrow treatments) to 118 lb N/acre, and total fertilizer N applied ranged from 113 to 161 lb N/acre (aside from the reference strips, which received a total of 250 lb N/acre). Summing total fertilizer N applied with residual nitrate-N in the top 3 ft, there generally were no differences in total N supply among treatments in 2005, with an average of 254 lb N/acre. The reactive treatments were the only exception, with significantly less total N supply – 220 lb N/acre, than other N management strategies. As in 2004, there were no significant effects of N strategy, nor interactions between SDI water level and N strategy, on grain yield. There were significant differences between water management strategies, with furrow and SDI 100% ET strategies with highest yield, and SDI 50% ET the lowest yield (Figure 2).

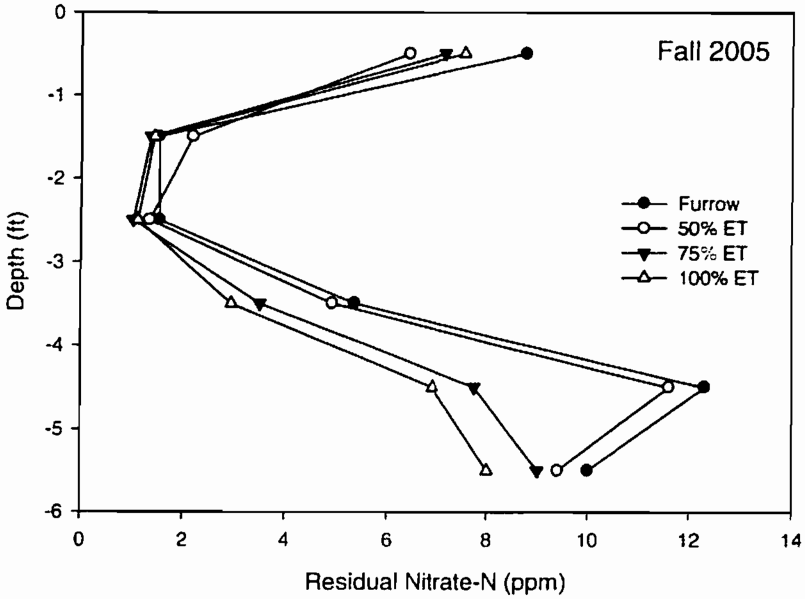

Figure 3. Irrigation level effects on root zone residual nitrate-N, fall 2005.

Residual nitrate-N in the fall of 2005 was further reduced from levels in the fall of 2004. There were no significant effects of irrigation level, N strategy, or interactions of irrigation level and N strategy on total residual nitrate-N to a depth of 6 ft. There generally were no treatment effects on nitrate-N distribution through the root zone, with the exception of the 4-5 ft layer, where the furrow and SDI 50% ET treatments had significantly higher nitrate-N concentrations than the SDI 75% and 100% ET treatments (Figure 3). There was a trend for higher concentrations of nitrate-N remaining from 2004 to move deeper in the root zone.

With residual nitrate-N in the top 4 ft unaffected by treatment from 2005, a constant recommended N rate of 160 lb/acre was used for all but the reactive treatments and reference strips for 2006. This rate was based on an expected yield of 240 bu/acre, 3% soil organic matter, and average residual nitrate-N to 4 ft of 3.6 ppm. Actual N rates applied to treatments in 2006 were: furrow – 177 lb N/acre; preplant strategy – 158 lb N/acre; fertigation strategy – 160 lb N/acre; reactive strategy 172 lb N/acre (Table 1). To date yield and residual nitrate-N information for 2006 is unavailable.

Chlorophyll Assessment – Reactive Strategy

Figures 4 and 5 illustrate trends in relative chlorophyll for the reactive and furrow treatments in 2005 and 2006. Chlorophyll readings were collected weekly between V8 and R4 each year. Due to equipment malfunctions, irrigation and fertilizer application were not started in 2005 until about 10 days after relative chlorophyll levels reached the critical value of 0.95. Consequently, relative chlorophyll levels for two of three reactive treatments remained below the critical value for 3-4 weeks. This N stress did not seem to reduce grain yield relative to other treatments, although moisture deficit during this period may have reduced overall yield. In 2006, fertigation began earlier, and relative chlorophyll levels were maintained closer to the 0.95 critical level. In both years, there have been trends for the SDI 50% ET water treatment to have lower relative chlorophyll readings than the 75% or 100% ET treatments.

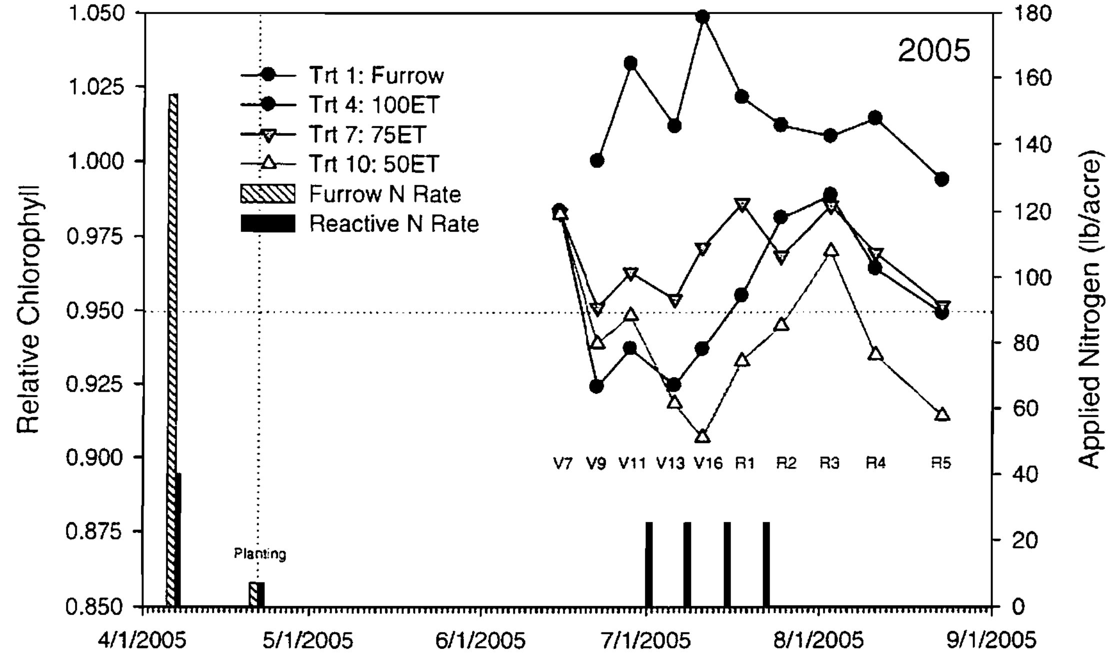

Figure 4. Nitrogen applications and relative chlorophyll for reactive treatments, 2005.

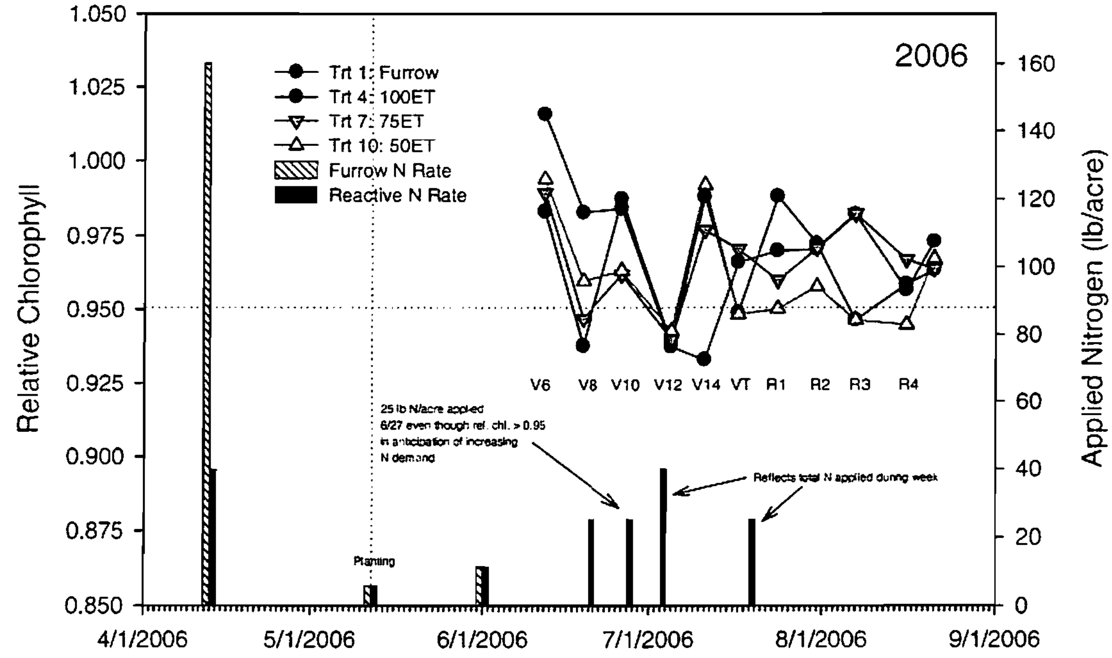

Figure 5. Nitrogen applications and relative chlorophyll for reactive treatments, 2006.

Irrigation Water Use

Figures 6 and 7 illustrate cumulative irrigation water applied to treatments in 2004 and 2005. Growing season precipitation was 18.8 inches in 2004, and 11.4 inches in 2005. Thus, the cumulative available water, other than stored soil moisture, ranged from 29.2 inches for the furrow to 23.8 inches for SDI 50% ET treatments in 2004, and 20.6 inches for furrow to 15.8 inches for SDI 50% ET treatments in 2005. Grain yield was significantly reduced with the SDI 50% ET treatment in both years, and slightly reduced with the SDI 75% ET treatment in 2005.

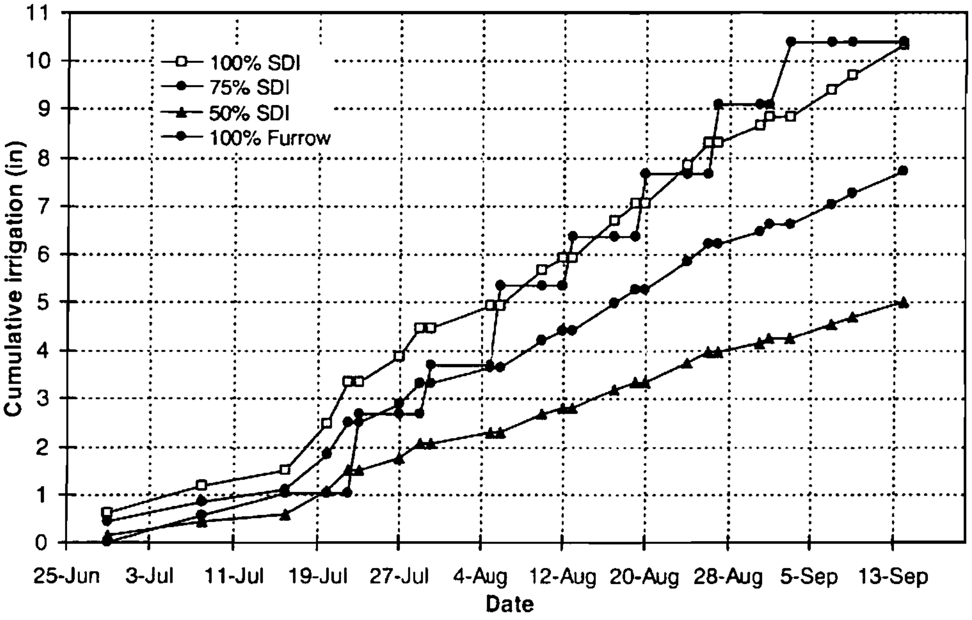

Figure 6. Cumulative irrigation for furrow and SDI treatments, 2004.

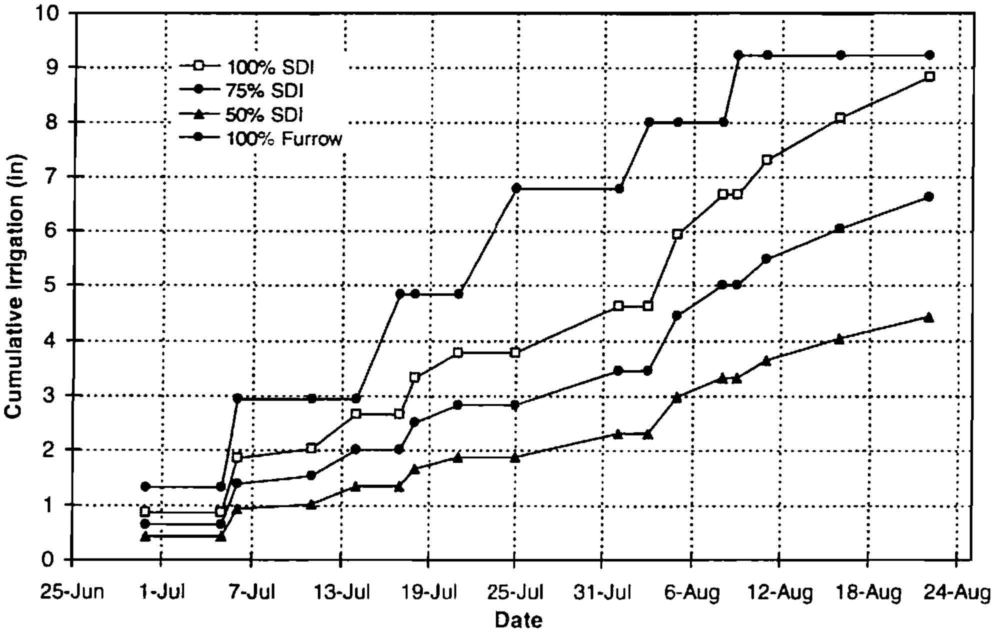

Figure 7. Cumulative irrigation for furrow and SDI treatments, 2005.

Summary

The process of accurately accounting for N stored in the root zone, along with timing fertilizer application close to crop N demand, allowed for efficient N use in 2004 and 2005 (Table 1). In 2004, total fertilizer N rates of 20 lb N/acre for the reactive treatments, and 50 lb N/acre for preplant and fertigation treatments, produced yields averaging 215 bu/acre. Through 2005, there have not been significant differences in yield or fall residual nitrate-N among N management strategies, nor interactions between N management strategies and irrigation water level. There appears to be at least some trend for reduced residual nitrate-N with the reactive N strategy. Both 2004 and 2005 were below average in growing season precipitation. The SDI 75% ET treatments received a total of 7.7 inches of irrigation in 2004, and 6.6 inches in 2005. The strategy to apply approximately 75% of measured ET with SDI appears to be a good compromise between maximizing yield and optimizing irrigation water use efficiency.

Table 1. Means within irrigation level or N management strategy with the same letter are not significantly different at P=0.05.

	Treatment	Grain Yield (bu/acre)	Fertilizer N (lb/acre)	Fertilizer N Use Efficiency (bu grain/lb N)	Fall Residual N (lb/acre/4 ft)
2004	Reference	226	250	0.9	200
	Furrow 100% ET	220 a	50	4.4	153 a
	SDI 100% ET	221 a	40	5.5	115 a
	SDI 75% ET	217 a	40	5.4	121 a
	SDI 50% ET	207 b	40	5.2	156 a
	Preplant (75/25)	215 a	50	4.3	125 a
	Fertigation (25/75)	215 a	50	4.3	158 a
	Reactive (25/R)	217 a	20	10.8	118 a
2005	Reference	212	250	0.84	172
	Furrow 100% ET	212 a	155	1.37	62 a
	SDI 100% ET	213 a	147	1.45	47 a
	SDI 75% ET	204 b	144	1.42	47 a
	SDI 50% ET	190 c	138	1.38	53 a
	Preplant (75/25)	202 a	158	1.28	52 a
	Fertigation (25/75)	205 a	139	1.47	52 a
	Reactive (25/R)	203 a	132	1.54	46 a
2006	Reference		250		
	Furrow 100% ET		177		
	SDI 100% ET		163		
	SDI 75% ET		163		
	SDI 50% ET		163		
	Preplant (75/25)		158		
	Fertigation (25/75)		160		
	Reactive (25/R)		172		

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Program Chair:
Dale Leikam
Kansas State University
Manhattan, KS
(785) 532-6183
dleikam@ksu.edu

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Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
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