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Subsurface Drip Nitrogen Fertigation of Corn

Abstract

The efficient management of nitrogen (N) fertilizer and irrigation is of utmost importance because they are two of the greatest expenses for corn production. This project was conducted to determine if yield and efficiency of fertilizer N in corn could be improved by applying N at later developmental stages through a subsurface drip irrigation (SDI) system. Experiments in 2014 and 2015 compared a Preplant Surface application that injected fertilizer in bands below the residue at planting, to four versions of SDI fertigation that differed in timing and total amount of N applied. The SDI Sidedress treatment concluded at corn tassel stage (VT). The SDI Maximum treatment supplied an additional 40 lb N/a through corn blister stage (R2). The SDI Sensor treatment received N fertigations after corn V10 stage only if the ratio of the SPAD readings from SDI Sensor plots to Reference plots was less than 95%. The Reference treatment received both the surface band injections and all SDI fertigations for total seasonal N application that far exceeded crop N requirements. The Reference treatment produced up to 32 bu/a more grain than the Preplant Surface treatment, but produced an average of 0.7 bushels of grain per pound of N fertilizer. The SDI Maximum treatment averaged only slightly less grain yield than the reference treatment but produced 1.15 bushels of grain per pound of N fertilizer on average. The SDI Sidedress and SDI Sensor treatments resulted in similar yields that averaged 16 bu/a more than the Preplant Surface treatment. The SDI Sidedress treatment used fertilizer N the most efficiently, producing 1.3 bushels of grain per pound of N fertilizer. Applying N into the reproductive stages of corn increased yield, but N fertilizer was used most efficiently when N applications were completed by VT. Although using the sensor to determine later N applications reduced fertilizer input slightly compared to a maximum fertilizer approach, yields were reduced enough to result in similar efficiency of fertilizer use.

Keywords

corn, fertigation, nitrogen fertility, subsurface drip irrigation

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Subsurface Drip Nitrogen Fertigation of Corn

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Summary
The efficient management of nitrogen (N) fertilizer and irrigation is of utmost importance because they are two of the greatest expenses for corn production. This project was conducted to determine if yield and efficiency of fertilizer N in corn could be improved by applying N at later developmental stages through a subsurface drip irrigation (SDI) system. Experiments in 2014 and 2015 compared a Preplant Surface application that injected fertilizer in bands below the residue at planting, to four versions of SDI fertigation that differed in timing and total amount of N applied. The SDI Sidedress treatment concluded at corn tassel stage (VT). The SDI Maximum treatment supplied an additional 40 lb N/a through corn blister stage (R2). The SDI Sensor treatment received N fertigations after corn V10 stage only if the ratio of the SPAD readings from SDI Sensor plots to Reference plots was less than 95%. The Reference treatment received both the surface band injections and all SDI fertigations for total seasonal N application that far exceeded crop N requirements. The Reference treatment produced up to 32 bu/a more grain than the Preplant Surface treatment, but produced an average of 0.7 bushels of grain per pound of N fertilizer. The SDI Maximum treatment averaged only slightly less grain yield than the reference treatment but produced 1.15 bushels of grain per pound of N fertilizer on average. The SDI Sidedress and SDI Sensor treatments resulted in similar yields that averaged 16 bu/a more than the Preplant Surface treatment. The SDI Sidedress treatment used fertilizer N the most efficiently, producing 1.3 bushels of grain per pound of N fertilizer. Applying N into the reproductive stages of corn increased yield, but N fertilizer was used most efficiently when N applications were completed by VT. Although using the sensor to determine later N applications reduced fertilizer input slightly compared to a maximum fertilizer approach, yields were reduced enough to result in similar efficiency of fertilizer use.

Introduction
Efficient management of input and fixed expenses is crucial for producers in a competitive market for agricultural commodities. Some of the largest expenses for an irrigated corn crop are water and fertilizer (Ibendahl et al., 2015).

Water and application methods used are essential to achieving high yields efficiently. Lamm and Trooien (2003) examined 10 years of research from western Kansas and concluded that subsurface drip irrigation (SDI) systems, when managed properly, can decrease net irrigation needs of the crop by 25%. That reduction transforms into 35-55% savings when compared to traditional sprinkler and furrow irrigation systems.

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SDI systems are not widely used because of high start-up costs, but they can have 95 to 99% application efficiency, compared to sprinkler irrigation systems at 85%, and furrow irrigation at 65% (Lamm and Trooien, 2003). Typically, crops show a stronger response to the use of SDI systems with more frequent, and lower volume irrigation applications. This allows for the opportunity to dose fertilizer over an extended period of time and through later developmental stages of the crop (Lamm and Trooien, 2003). Some advantages associated with using subsurface drip systems to supply fertilizers were identified by Bar-Yosef (1999): nutrient is supplied to root system center, weed germination is reduced by keeping fertilizer and water beneath the soil surface, and the crop root system is cushioned from water and nutrient stresses because the roots grow deeper. Though SDI systems have a high initial cost, these studies indicate that they are the most efficient means of transporting water and liquid nutrients to a crop.

Fertility is a major factor managed by growers to produce greater yields and improve production efficiency. In corn, two-thirds of total nitrogen (N) uptake occurs by VT or R1, one-third will still be accumulated in the reproductive stages (Bender et al., 2013). Ruiz Diaz et al. (2008) indicated that split N fertilizer applications, N applications in the mid to late vegetative stages, and sidedress applications are more effective in most cases than a preplant application. Generally, N fertilizer is most needed at stages V8 to V10 because maximum N uptake occurs around the time of silking (Binder et al., 2000). Chlorophyll meters or SPAD meters (Soil Plant Analysis Development, Minolta Co., Ltd. USA, Oklahoma City Oklahoma), can be used to determine when N is needed by the crop. The concentration of N that is present in the plant is correlated with the amount of chlorophyll in the leaves, which in turn is correlated with leaf greenness. Chlorophyll meter readings can be compared to readings from N-rich reference areas to determine if additional N fertilizer is required (Schlemmer et al., 2005). Waiting to let the plant indicate if it needs additional fertilizer effectively saves the input of N fertilizer for when it is needed by the crop, rather than applying it all at the beginning of the season when it is susceptible to several kinds of loss mechanisms (Samborski et al., 2009).

The purpose of this study was to increase yield and efficiency of irrigated corn production by managing N fertilizer through SDI fertigation systems that allow application at later developmental stages. One objective was to determine if N use efficiency could be improved by using SPAD meter readings to determine N application needs of the crop. The second was to determine if yield and/or N use efficiency could be improved by applying N fertilizer at later developmental stages.

Procedures

This study was conducted at the Ashland Bottoms Research Farm near Manhattan, Kansas (39.1387, -96.6362), for two consecutive years, 2014 and 2015. The soil series were Belvue silt loam and Eudora silt loam. Soil samples collected each year indicated that the Mehlich P and K levels were well above the critical levels for these nutrients.

The experimental site had been managed in a no-till corn-corn-soybean cropping system for six years before the start of this research project with soybeans planted in 2013. The no-till system continued throughout the two years of this project. A 114-day relative maturity hybrid with proven irrigated yield potential for this area, DKC64-69RIB, was planted on May 7, 2014 at 30,000 seeds per acre and on April 17, 2015 at 36,000 seeds per acre. Plots were harvested on September 19, 2014, and September 29, 2015.

Weed Control

A preplant application of glyphosate and 2,4-D was applied each year of the study to burn down early-emerging weeds. Degree Xtra was applied immediately before planting in 2014 and immediately after planting in 2015. Bicep II was sprayed as a pre-emergent nine days after planting in 2014. Glyphosate was applied approximately one month after planting in 2014 and thirty-five days after planting in 2015, and again two weeks later in a mix with 2,4-D to control late emerging broadleaf weeds. All herbicide applications were made at rates consistent with the crop and soil texture limits indicated on product labels.

Subsurface Drip Irrigation

The subsurface drip irrigation (SDI) system installed at the site was manufactured by Netafim USA, Fresno California. The irrigation tape is located fifteen inches beneath the soil surface on thirty–inch spacing. Twenty independent zones, each 20 ft by 220 ft in size, facilitated independent dispersal of liquid (N) fertilizer for each treatment via a dosing pump immediately downstream from the flow meter and immediately upstream from the system filter. Irrigation was applied daily to match crop water demands as determined by KanSched (2015). In 2014, 19 inches of irrigation was applied, and 20 inches of water was applied in 2015 to maintain available soil water at less than 50% depletion in both years.

Experimental Design and Treatment Structure

The experimental design used a randomized complete block design with four replications, each consisting of five N application systems: Preplant Surface, SDI Sidedress, SDI Maximum, SDI Sensor, and Reference. These treatments differed in method, quantity, and timing of N fertilizer application (Table 1). The N fertilizer product used in this study was UAN 28%.

All plots received a 20-20-0 (pounds of N, P_2O_5, and K_2O per acre) starter fertilizer application placed two inches from the seed furrow and two inches deep using coulter injectors mounted on the planter. Immediately after planting, the balance of seasonal N fertilizer was applied to the Preplant Surface plots using a tractor mounted coulter injector. The SDI Sidedress plots had the same amount of seasonal N applied as in the Preplant Surface treatment. The N was applied via the SDI system in five doses of 18 lb N/a during the V5 to V10 growth stages of the corn plus three doses of 18 lb N/a and one dose of 16 lb N/a in 2014, and three doses of 23.3 lb N/a in 2015 during the V11 to VT corn growth stages (Table 1). The zones allocated to the SDI Maximum system received the same applications as the SDI Sidedress system plus an additional three doses of 13.3 lb of N/a, each applied during corn growth stages VT to R2, making a total application of 220 lb of N/a (Table 1). The plots allocated to the SDI Sensor system were treated the same as the SDI Sidedress plots until corn growth stage V10. During corn growth stages V11 to R2, SPAD meter readings were used to determine if N should be applied at each application date. In 2014, the SDI Sensor plots received all N applications scheduled between V11 and VT but one less application during the VT to R2 corn growth stages, reducing the total N applied by 13.3 lb/a compared to the SDI Maximum system. During the 2015 season, the SDI Sensor plots received only two of the three scheduled doses during the V11 to VT stages and all doses during the VT to R2 stages, reducing N applied to those plots by 23.3 lb N/a compared to the SDI Maximum system (Table 1). The plots allocated to the Reference system were intended to create a system where N was not limited and received all surface and SDI N applications.

SPAD meter readings were taken from stages V11 through R2 to determine if the SDI Sensor system required the next scheduled N fertigation. For each plot, SPAD readings were taken from 20 plants, with three readings taken on one leaf of each plant (the topmost expanded leaf in vegetative stages, ear leaf after VT) for a total of 60 readings taken in each plot. Readings were averaged for each plot, and those averages were used for calculations. The SDI Sensor plots received the next scheduled SDI fertigation if the SPAD meter readings for those plots were less than 95% of the SPAD values from the Reference plots. In 2014, the SDI Sensor plots were not fertigated on July 7, during the VT-R1 stages, or on July 6, 2015, when the corn was at stage VT.

Precipitation events for both years were recorded by a Kansas Mesonet weather station located 0.8 miles from the experimental site (Figure 1). Two events of more than two inches and four events of more than one inch occurred in 2014. During the 2015 growing season, there were three events of more than two and a half inches in May, July and September. There were also three events of more than one inch, all of which occurred from the end of May to mid-June.

Results

In both years of this project, the different N application treatments did not affect days to silk, grain moisture, or seed weight (Table 2). The only instance where N application treatment affected test weight was in 2015 when the Reference treatment resulted in greater test weight than the other treatments. Yield, grain protein, and grain nitrogen use efficiency (NUE, defined as bushels of grain per pound of fertilizer N) were all influenced by N application treatment in both years. In 2014, the Reference and SDI Maximum treatments had greater grain protein concentration than the other treatments, but the Reference treatment was the only treatment to increase grain protein concentration in 2015. The yield responses to N application treatments were similar in both years as well (Table 2). The Preplant Surface treatment produced the least grain in both years. The SDI Sidedress and SDI Sensor treatments had similar yields in each year that were 14 to 19 bushels greater than the yield from the Preplant Surface treatment. The SDI Maximum and Reference treatments produced 24 to 32 additional bushels per acre compared to the Preplant Surface treatment. Grain NUE also had a consistent response to N application treatment in both years (Table 2). The Reference treatment produced the least amount of grain per pound of fertilizer N applied. The Preplant Surface, SDI Sensor, and SDI Maximum treatments produced from 0.4 to 0.6 more bushels per unit of N fertilizer compared to the Reference treatment. In 2014, the Preplant Surface treatment was slightly more efficient than the SDI Sensor and SDI Maximum treatments. The SDI Sidedress treatment had the greatest NUE in both years.

The timing, amount, and method of N application all influenced NUE. The Reference treatment was intended to create a situation where N was not limiting, resulting in poor

NUE. The SDI Sidedress treatment included N applications through the V10 stage, but the SDI Sensor, SDI Maximum, and Reference treatments included applications until R2, with different total amounts of N applied. The greater NUE associated with the SDI Sidedress treatment implies that N applications are used more efficiently when applied during the V8 to V10 stages, in agreement with Binder (2000). Though the Reference treatment plots produced the greatest yields, they had the lowest NUE. The SDI Maximum treatment produced yields similar to those produced by the Reference treatment but without the surface N application at planting, resulting in much better NUE.

Method, timing, and amount of N applied all influenced yield and NUE. The Reference and SDI Maximum treatments had the greatest yields, but the SDI Sidedress treatment utilized N the most efficiently. Economics of irrigation, fixed and variable costs, and N fertilizer costs relative to grain prices will drive decision making relative to the most profitable N application strategy. However, the results of these experiments indicate that N fertigation via SDI systems produces greater yields and uses N more efficiently than surface N applications. Use of the SPAD meter to determine need for mid-season N applications did not improve yield or NUE compared to the SDI Maximum treatment in this experiment.

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Table 1. Nitrogen application systems imposed in 2014 and 2015

Treatment	Starter	At planting	V5-V10	V11-VT	VT-R2	Total
	N-P-K	---------------------------------- lb N/a ----------------------------------				
2014						
Preplant Surface	20-20-0	160	0	0	0	180
SDI Sidedress	20-20-0	0	90	70	0	180
SDI Maximum	20-20-0	0	90	70	40	220
SDI Sensor	20-20-0	0	90	70	27	207
Reference	20-20-0	160	90	70	40	380
2015						
Preplant Surface	20-20-0	160	0	0	0	180
SDI Sidedress	20-20-0	0	90	70	0	180
SDI Maximum	20-20-0	0	90	70	40	220
SDI Sensor	20-20-0	0	90	47	40	197
Reference	20-20-0	160	90	70	40	380

Table 2. Corn response to N application treatments in 2014 and 2015 near Manhattan, KS

Treatment	Days to silk	Yield	Grain moisture	Test weight	Seed weight	Grain protein	Grain NUE
	days	bu/a	%	lb/bu	grams/ 300 seeds	%	bu grain/ lb N fert
2014							
Preplant Surface	62	256 b†	17.0	57.5	134	7.3 b	1.4 b
SDI Sidedress	61	275 ab	17.8	57.7	125	7.2 b	1.5 a
SDI Sensor	62	271 ab	18.4	57.4	124	7.2 b	1.3 c
SDI Maximum	60	288 a	18.6	56.2	122	8.2 a	1.3 c
Reference	63	288 a	17.5	57.1	127	8.1 a	0.8 d
2015							
Preplant Surface	84	182 c	16.8	56.8 b	87.8	7.1 b	1.0 b
SDI Sidedress	88	198 b	16.9	56.5 b	84.5	7.0 b	1.1 a
SDI Sensor	87	196 bc	17.1	56.9 b	82.6	7.1 b	1.0 b
SDI Maximum	87	206 ab	17.1	56.4 b	83.5	7.3 b	1.0 b
Reference	85	215 a	17.3	58.0 a	84.7	8.0 a	0.6 c

† Values within each year within a column followed by the same letter are not different $\alpha = 0.10$.
No letter after values within a year within a column indicates that treatment values are not different.

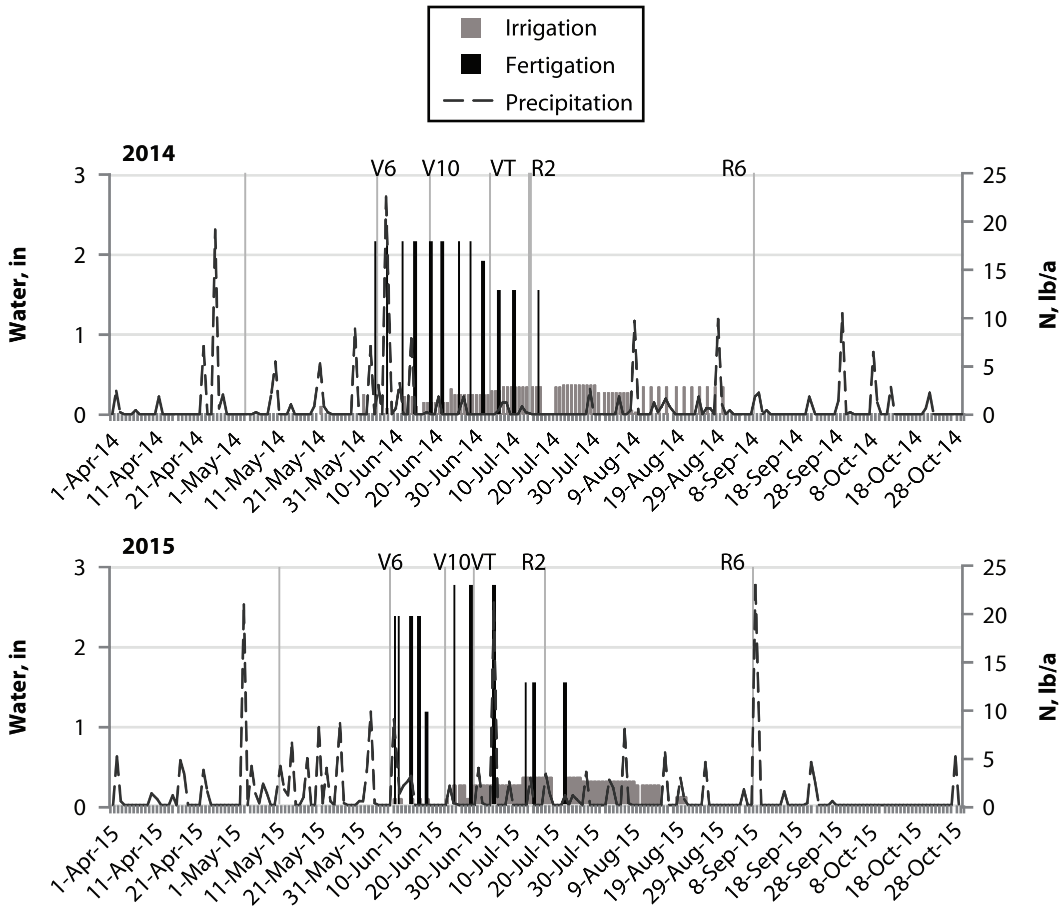

Figure 1. Key corn growth stages and precipitation, irrigation, and fertigation amounts and timing in 2014 and 2015.