Nitrogen, Irrigation Timing Key To Higher Corn Yields

Performance of remote sensors is essential in achieving high yields.

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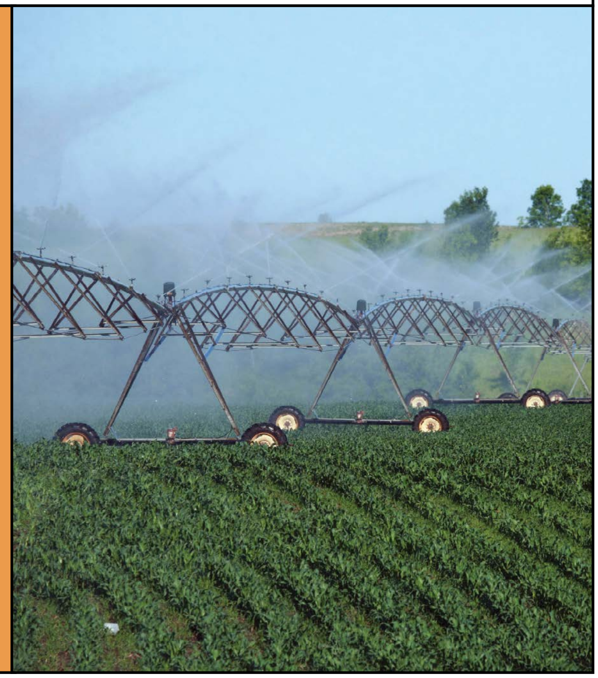
Summary: *Nitrogen use efficiency (NUE) in high-yield irrigated corn production systems has many economic and environmental implications. Many producers in the region rely on single pre-plant applications of granular urea or anhydrous ammonia as the primary N source in irrigated production systems. This practice increases the likelihood of N loss, environmental impact, and reductions in profit per acre. The increasing conversion of irrigated land in Kansas to center pivot irrigation systems presents the opportunity to develop automated systems for advanced N management through fertigation that can potentially increase NUE, reduce environmental impact and increase profit per acre. The purpose of this study was to measure the impact of the relationship between irrigation timing, N rate, and timing of N application on corn grain yield and determine the potential for developing algorithms for fertigation systems. Results indicate that overall performance of the sensors and algorithms used was effective at achieving high yields but has the tendency to overestimate N requirements. In order to optimize sensor based N recommendations for fertigation systems, algorithms must be specifically designed for these systems in order to take advantage of their full capabilities, thus allowing advanced N management systems to be implemented.*



Nitrogen use efficiency (NUE) in high-yield irrigated corn production systems has many economic and environmental implications. In the sub-humid region of North Central and North East Kansas, risk of in-season N loss is higher than in drier irrigated corn production regions of the Central Plains. Many producers in the region rely on single pre-plant applications of granular urea or anhydrous ammonia fertilizer as the primary N source in irrigated corn production systems. These practices increase the likelihood of N loss, environmental impact, and reductions in profit per acre. The continued conversion of flood irrigated land in Kansas to center pivot irrigation systems presents the opportunity to develop automated systems for advanced N management use of multiple N applications through fertigation, which can potentially reduce environmental impact and increase profit per acre.

The recent developments in remote sensing technology have made it possible to improve N recommendations using hand-held or machine-mounted active sensors. Sripada, et. al. (2005) demonstrated that remotely sensed NIR radiance could be used to estimate economic optimum N rates through corn growth stage VT. Improvements in center pivot application technology raise the possibility of using pivot-mounted sensors to control site-specific variable rate N rates across a given field. Hence, it is necessary to understand how to best use this technology to optimize N application practices through fertigation in anticipation of widespread adoption of variable-rate center pivot equipment.

Objective

The objectives of this study were to:

- Measure the impact of the relationship between irrigation timing, N rate, and timing of N application on corn grain yield
- Evaluate the potential for developing algorithms designed for fertigation systems.

Methodology

The study was initiated in 2012 and conducted through the 2014 crop year in cooperation with Kansas producers and Kansas State University Agronomy Experiment Fields. The Scandia and Rossville Experiment Fields were irrigated with a lateral sprinkler irrigation system while the cooperative farmer's field, located outside Scandia (Scandia Site 2), was flood irrigated. Crop rotations, tillage, cultural practices, and corn hybrids used were representative of each area.

Plots. Each field study used small research plots, 10 feet in width by 40 feet in length.

Irrigation events were scheduled using the KanSched2 evapotranspiration-based irrigation scheduling tool (http://mobileirrigationlab.com/kansched2).

Applications. Sidedress N applications were made prior to scheduled irrigation events to stimulate an N fertigation system. Application timing methods implemented at each site consisted of single pre-plant application, split application between pre-plant and corn growth stage V-4, and split application between pre-plant and variable treatments based on plant reflectance. Fertilizer needs other than N were applied near planting.

Design. Treatments were placed in a randomized complete block design with four replications.

Canopy reflectance of corn was measured prior to each irrigation event with focus being on V-10 and R-1 growth stages, respectively. Canopy

Table 1. 2012 Scandia Farmer Cooperative Field Results

Year	Treatment	Timing Method	Starter N lb/A	Preplant N lb/A	In-Season N lb/A	Total N applied (lb/A)	Yield (bu/A)	LSD Grouping
2012	4	Pre-plant/V4	20	20	20	60	209	A
2012	9	Pre-plant/Sensor	20	125	30	175	209	ABC
2012	1	Pre-plant	20	60	0	80	203	ABC
2012	2	Pre-plant	20	140	0	160	201	ABC
2012	3	Pre-plant	20	230	0	250	199	ABC
2012	7	Pre-plant/Sensor	20	40	94	154	199	ABC
2012	8	Pre-plant/Sensor	20	80	86	186	198	ABC
2012	5	Pre-plant/V4	20	80	80	180	197	BC
2012	6	Pre-plant/V4	20	105	105	230	193	C
2012	10	Check	20	0	0	20	193	C

Treatments with same letter are not statistically different at an 0.05 alpha

Table 2. 2012 Scandia Station Field Results

Year	Treatment	Timing Method	Starter N lb/A	Preplant N lb/A	In-Season N lb/A	Total N applied (lb/A)	Yield buA	LSD Grouping
2012	6	Preplant/V4	20	105	105	230	188	A
2012	5	Preplant/V4	20	80	80	180	187	A
2012	3	Preplant	20	230	0	250	185	A
2012	9	Preplant/Sensor	20	125	86	231	185	A
2012	8	Preplant/Sensor	20	80	44	144	173	B
2012	2	Preplant	20	140	0	160	166	BC
2012	7	Preplant/Sensor	20	40	91	151	166	BC
2012	1	Preplant	20	60	0	80	156	C
2012	4	Preplant/V4	20	20	20	60	138	D
2012	10	Check	20	0	0	20	119	E

Treatments with same letter are not statistically different at an 0.05 alpha

reflectance was used to calculate the Normalized Difference Vegetation Index (NDVI = NIR-visible/NIR+visible) and was averaged for each plot. The algorithm used to provide sensor-based N recommendations was developed by Tucker and Mengel (2010).

Sensor. The optical sensor used for canopy reflectance was the Greenseeker (Trimble Navigation, Ag Division, Westminster, CO).

Sampling. Soil samples, to a depth of 24 inches, were taken by block, prior to planting and fertilization. Samples (0 to 6 inches) were analyzed for soil organic matter (Mehlich-3 phosphorus, potassium, pH, and zinc). The 0 to 24-inch samples were analyzed for nitrate-N, chloride, and sulfate. Irrigation was sampled at each location for NO_3-N and NH_4-N. Rossville and Scandia experiment stations tested with less than 1 ppm for NO_3-N and NH_4-N, respectively and, therefore, would not have a large impact on the results of this study. The farmer's cooperative field near Scandia tested greater than 11 ppm NO_3-N, and therefore this site was used only in 2012.

Yields. Grain yield was measured by harvesting an area of 5 feet by 40 feet within each plot at the Scandia and Rossville experimental stations. The farmer cooperative site at Scandia site 2 was hand harvested from as area 5 feet by 17.5 feet. All yields were adjusted to 15 percent moisture, and grain was analyzed for N content. Statistical analysis was conducted using SAS software PROC MIXED with 0.05 alpha. Blocks, locations, and years were treated as random effects during single site and pooled analysis.

Results

2012. Data analysis from Scandia Site 2, a farmer cooperative field (Table 1), show response to applied N was low. This is likely due to the abnormally high nitrate levels in the irrigation water used at this site. Because the growing season was uncharacteristically dry, irrigation water use was above normal, giving the crop a significant N supply through the irrigation water. Approximately 60 pounds of N per acre were added in 2012 through irrigation water.

There were significant N treatment effects on corn yield observed at the Scandia Station in 2012 (Table 2). In general, the treatments that split N applications between pre-plant and in-season application resulted in the highest yields. The exception was treatment 3 (230 lbs/A pre-plant). This treatment was statistically equal to the highest yield split application treatments 5 and 6. This may be explained by the abnormally dry weather resulting in very little N loss from the pre-plant applications. Two of the three sensor-based N treatments (treatments 7 and 8) yielded significantly lower than the pre-plant/V4 split applications (Treatments 5 and 6). The yield differences are likely attributed to the lower total N rates recommended by the sensors.

2013. The 2013 Rossville experiment site showed a significant response to applied N also (Table 3). All sensor treatments generated the highest yield and were statistically higher than the two lowest rate pre-plant-only treatments. This can be explained by frequent leaching losses in the early season. The soil at this location was a deep sandy loam that is prone to leaching losses if

"Algorithms must be specifically designed"

rainfall events are high and/or frequent. Figure 1 shows two treatments were applied but prior to the V-4 treatment applications. Overall, the yields were lower than expected at this site due to the frequent leaching events, which occurred throughout the season. This

Table 3. 2013 Rossville Station Field Results

Year	Treatment	Timing Method	Starter N lb/A	Preplant N lb/A	In-Season N lb/A	Total N applied (lb/A)	Yield bu/A	LSD Grouping
2013	8	Pre-plant/Sensor	0	80	144	224	148	A
2013	7	Pre-plant/Sensor	0	40	212	252	148	A
2013	9	Pre-plant/Sensor	0	120	149	269	144	AB
2013	6	Preplant/V4	0	90	90	180	139	AB
2013	5	Preplant/V4	0	60	60	120	135	ABC
2013	2	Pre-plant	0	120	0	120	127	ABC
2013	3	Pre-plant	0	180	0	180	123	BC
2013	4	Preplant/V4	0	30	30	60	116	CD
2013	1	Pre-plant	0	60	0	60	96	D
2013	10	Check	0	0	0	0	70	E

Treatments with same letter are not statistically different at an 0.05 alpha

Table 4. 2013 Scandia Station Field Results

Year	Treatment	Timing Method	Starter N lb/A	Preplant N lb/A	In-Season N lb/A	Total Napplied (lb/A)	Yield bu/A	LSD Grouping
2013	5	Preplant/V4	20	60	60	140	179	A
2013	8	Pre-plant/Sensor	20	80	87	187	177	AB
2013	4	Preplant/V4	20	30	30	80	176	AB
2013	3	Pre-plant	20	180	0	200	173	AB
2013	6	Preplant/V4	20	90	90	200	172	AB
2013	7	Pre-plant/Sensor	20	40	123	183	172	AB
2013	2	Pre-plant	20	120	0	140	170	AB
2013	9	Pre-plant/Sensor	20	120	133	273	169	AB
2013	1	Pre-plant	20	60	0	80	167	B
2013	10	Check	20	0	0	20	149	C

Treatments with same letter are not statistically different at an 0.05 alpha

indicates that fertigation systems may need to make frequent low rate N applications with limited amounts of water to satisfy N demand for high-yielding corn in high N loss environments even if plant water requirements have been met or exceeded.

In 2013, the Scandia Station experiment location showed a small response to applied N (Table 4). Primary response was to N rate and was only significant over the check treatment. The soil at this location is a very forgiving and productive silt loam that is not prone to N loss through leaching, but can suffer from denitrification loss at times. It also is capable of releasing significant amounts of mineralized N. Wet soil conditions before and after planting could have created some denitrification loss potential in late April-early May, and again in late May. Soil moisture remained high throughout June and July, near optimal for mineralizing N (Figure 2). Overall, yield levels were lower than expected at this location with the highest yield being 179 bu/A. Expected yields were 250 bu/A, and this overall yield reduction could be attributed, in part, to the late planting date. Highest yielding treatment was #5, a planned application of 140 pounds of N split with starter, pre-plant and in-season. All sensor treatments overestimated N requirements

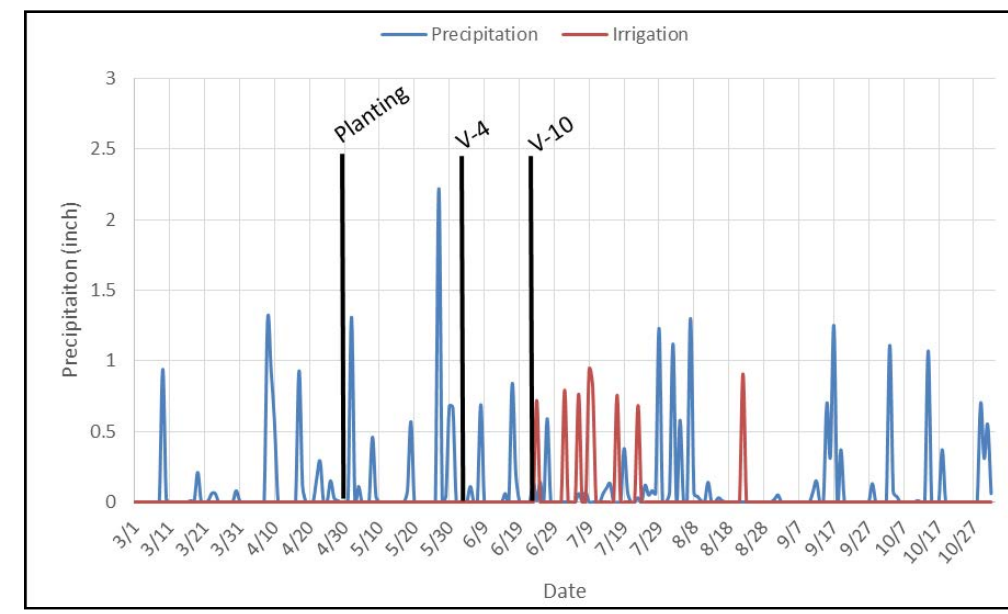


Figure 1. *2013 Rossville Rainfall and Irrigation.*

compared to treatment 5, and resulted in an unnecessary over application of N.

2014. The Rossville experiment site produced excellent yields and a significant response to applied N (Table 5). Figure 4 shows rainfall events in late May and June that would lead to significant N leaching losses in the sandy loam soil at Rossville. However, in the study area, a clay lens was located 34 to 36 inches deep. So, despite the leaching events, N and water would be held up in the rooting area, resulting in much higher yields than the 2013 Rossville site, which lacked the clay lens. Largest yield response was to total N rate. Sensor treatments were effective at fertilizing for the 90 percent economic optimum, achieving 237 bu/A from 55 lbs of applied N per acre.

Scandia station achieved excellent yields and also showed a significant response to applied N (Table 6). Rainfall and N loss was low and frequent small rain events created conditions that were good for mineralizing N (Figure 3), which resulted in the check treatments achieving 163 bu/A. This is a strong indication that overall site productivity was high. Sensor treatments were effective at determining the optimum N rate for high yield and profitability.

Summing up

Pooled analysis of all locations (Table 7) shows that overall performance of the sensors and algorithm used was effective at achieving high yields, but has the tendency to overestimate N requirements. However, this result is not surprising as the algorithm was designed for single N applications of N at V-10 and achieving the highest yield possible rather than the agronomic optimum yield.

Fertigation systems present the possibility of monitoring the corn crop throughout the growing season and making multiple applications, thus allowing the opportunity to determine the optimum N rate for a given field any particular year. However, in order to optimize sensor-based N recommendations for fertigation systems, algorithms must be specifically designed for these systems in order to take advantage of their full capabilities, thus allowing advanced N management systems to be implemented.

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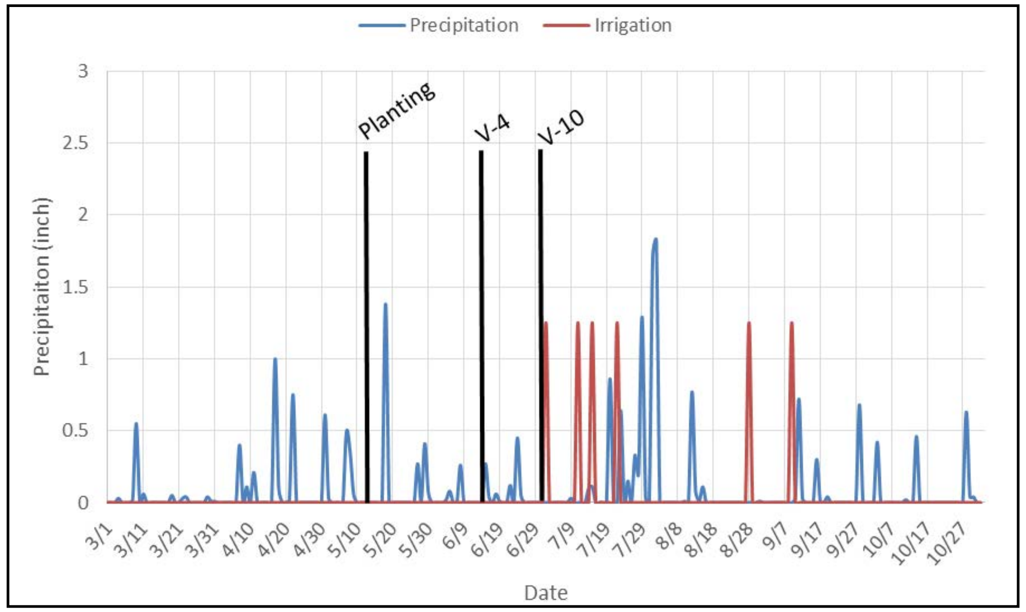

Figure 2. *2013 Scandia Station Rainfall and Irrigation.*

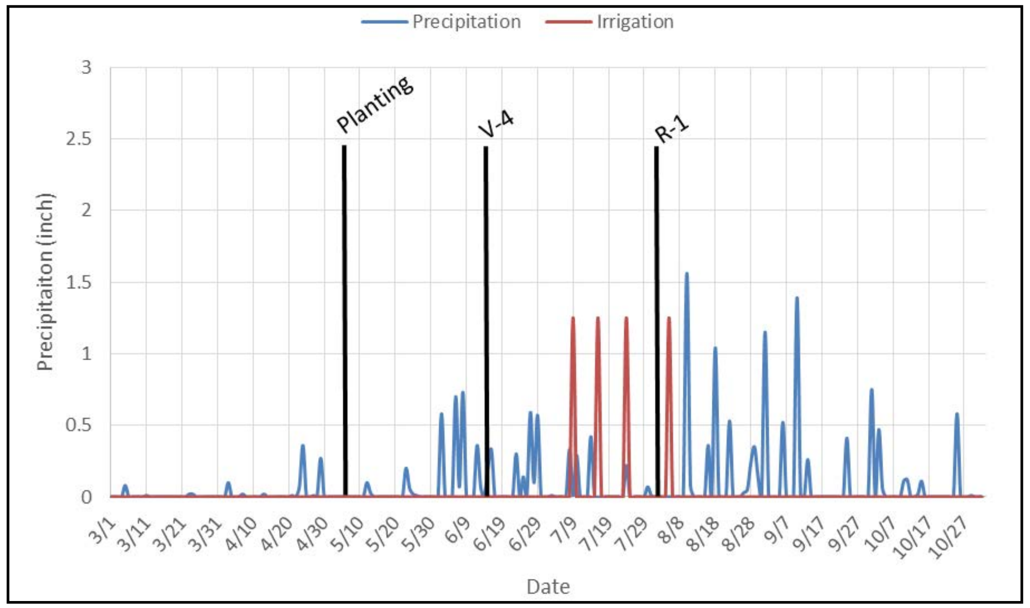

Figure 3. *2014 Scandia Station Rainfall and Irrigation.*

Table 5. 2014 Rossville Station Field Results

Year	Treatment	Timing Method	Starter N lb/A	Preplant N lb/A	In-Season N lb/A	Total N applied (lb/A)	Yield bu/A	LSD Grouping
2014	2	Pre-plant	0	120	0	120	257	A
2014	6	Preplant/V4	0	90	90	180	254	AB
2014	5	Preplant/V4	0	60	60	120	248	ABC
2014	3	Pre-plant	0	180	0	180	248	ABC
2014	1	Pre-plant	0	60	0	60	239	ABC
2014	7	Pre-plant/Sensor	0	40	15	55	237	ABC
2014	9	Pre-plant/Sensor	0	120	0	120	228	BC
2014	4	Preplant/V4	0	30	30	60	225	C
2014	8	Pre-plant/Sensor	0	80	0	80	223	C
2014	10	Check	0	0	0	0	186	D

Treatments with same letter are not statistically different at an 0.05 alpha

Table 6. 2014 Scandia Station Field Results

Year	Treatment	Timing Method	Starter N lb/A	Preplant N lb/A	In-Season N lb/A	Total N applied (lbA)	Yield bu/A	LSD Grouping
2014	6	Preplant/V4	0	90	90	180	239	A
2014	3	Pre-plant	0	180	0	180	232	AB
2014	9	Pre-plant/Sensor	0	120	30	150	231	AB
2014	7	Pre-plant/Sensor	0	40	120	160	229	AB
2014	2	Pre-plant	0	120	0	120	223	B
2014	8	Pre-plant/Sensor	0	80	60	140	223	B
2014	5	Preplant/V4	0	60	60	120	218	BC
2014	1	Pre-plant	0	60	0	60	204	C
2014	4	Preplant/V4	0	30	30	60	189	D
2014	10	Check	0	0	0	0	163	E

Treatments with same letter are not statistically different at an 0.05 alpha

Table 7. All Site Pooled Analysis

Year	Treatment	Timing Method	Starter N lb/A	Preplant N lb/A	In-Season N lb/A	Total N applied (lb/A)	Yield bu/A	LSD Grouping
Pooled	6	Preplant/V4	0	95	95	190	198	A
Pooled	9	Pre-plant/Sensor	0	122	71	193	194	A
Pooled	5	Preplant/V4	0	67	67	133	194	A
Pooled	3	Pre-plant	0	197	0	197	193	A
Pooled	7	Pre-plant/Sensor	0	40	109	149	192	A
Pooled	2	Pre-plant	0	127	0	127	191	A
Pooled	8	Pre-plant/Sensor	0	80	70	150	190	A
Pooled	1	Pre-plant	0	60	0	60	177	B
Pooled	4	Preplant/V4	0	27	27	53	175	B
Pooled	10	Check	0	0	0	0	147	C

Treatments with same letter are not statistically different at an 0.05 alpha