Development of Intensive N Management Strategies to Enhance Yield and Nitrogen Use Efficiency in High Yielding Dryland and Irrigated Corn

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Abstract

Nitrogen (N) management is becoming one of the more complex aspects of modern corn production. Changes in plant genetics, earlier planting dates, larger farm size, equipment innovations, increasing fuel and N costs, as well as concerns with potential environmental contamination all contribute to this increased complexity. Balancing time and financial resources in an effort to maximize yield and profitability, while still being a good environmental steward has become difficult for Producers. The purpose of this study was to evaluate the effects of different N management systems on yield and Nitrogen Use Efficiency (NUE). Results indicate increased N efficiency and grain yield can be achieved by changing the time, rate, and number of N applications to coincide with corn N demand and the potential for N loss in the current growing environment. Further research is needed to evaluate the effects of the N application timing and N management strategies under different weather conditions and soil types to determine their applicability in corn production.

Introduction

Nitrogen management is becoming one of the more complex aspects of modern corn production. Changes in plant genetics, earlier planting dates, larger farm size which compresses time available for field work per acre, equipment innovations, increasing fuel and N costs, as well as concerns with potential environmental contamination all contribute to this increased complexity. Balancing time and financial resources in an effort to maximize yield and profitability, while being a good environmental steward, has become difficult for producers.

In the Midwestern portion of the U.S., many states use a system which focuses on the average economic response to N across a defined geographic area adjusting a general response function for changes in N and corn price (Sawyer et al, 2006). The developers of the system recognize that differences in soil organic matter (SOM), as a source of mineralizable N, soil texture and drainage and their impact on N loss, in season temperature and precipitation, and how and when fertilizer is applied to the crop, all change the shape of the response function. These factors are addressed by using response functions specific to states or soil regions within states (Camberato, Nielsen, Miller and Joern, 2012). While these approaches are a definite improvement over traditional “rules of thumb” of 1.1 or 1.2 pounds of N per bushel of yield, for growers managing the crop on a rate per field basis, they don’t provide guidance on how to adjust rates for differences in drainage, texture or SOM found in different management zones within a field.

Other states, such as Kansas, take a more mechanistic approach to making N recommendations and try to adjust “rule of thumb” recommendations for residual soil N in the profile, SOM content and resulting mineralized N, and previous crop (Leikam, Lamond and Mengel, 2003). These approaches are more easily applied to a management zone or “on the go” application system, but still have limits, as most do not reflect changes in NUE due to drainage or soil physical properties, or changes in N utilization efficiency (Moll et al, 1980) and resulting changes in N need per bushel of response as yields increase.

A considerable body of information exists in the literature on the impact of soil properties, such as SOM and crop residue levels, soil drainage and texture, fertilizer source, urease and nitrification inhibitors, as well as method and time of N application on nitrogen fertilizer recovery, required N rate and corn yield (Trembley et al, 2012; Stamper, 2010; Weber, 2010).

The concept of the 4-R’s, applying the right source, at the right rate, at the right time and in the right place sounds simple enough, but the devil is in the details, as all the factors interact making that right rate a moving target (IPNI, 2010). Rate is a function of each of the other three variables and the efficiency associated with that choice/decision, as impacted by yield level, soil properties, soil N supply and climate. The key is to understand how all of these factors interact and to design a management system, which can respond to changes in these factors throughout a given field to enhance yield, NUE and farmer profits without adding additional risk or complexity to the management system.

The objectives of this study were as follows:

1. Measure the impact of N rate and time of application (N management system) on yield, profitability and nitrogen use efficiency in high yielding corn production.
2. Determine if the use of split application systems utilizing crop sensors or professional Agronomists judgment of N need late in the growing season, can improve NUE compared to a fixed rate system using current N rate recommendations applied early in the growing season.

Materials and Methods

Experiments were established at four locations in Kansas during 2013 in cooperation with Kansas Producers and KSU Agronomy Experiment Fields. The Scandia, Partridge, and Rossville locations are all department experiment Fields and were irrigated while the Sterling location was a cooperating farmer’s field and was rain fed. Crop rotations, tillage, cultural practices, and corn hybrids utilized were representative of each area (Table1.). Each field study utilized small research plots 10 feet in width by 40 feet in length. Treatments consisted of five N rates that were applied in single or split applications at different times during the growing season with UAN as the N source. Treatments were placed in a randomized complete block design with four replications.

Soil samples to a depth of 24 inches were taken by block, prior to planting and fertilization. 0-6 inch samples were analyzed for soil organic matter, Mehlich-3 phosphorus, potassium, pH, and zinc. The 0-24 inch samples were analyzed for nitrate-N, chloride, and sulfate. Fertilizer needs other than N were applied near planting.

Canopy reflectance of the corn was measured multiple times throughout the growing season with V-4, V-6, V-10, and R-1 being key growth stages for measurement. Optical sensors used were the Greenseeker (Trimble Navigation, Ag Division, Westminster, CO), the CropCircle ACS-470 (Holland Scientific, Lincoln NE), and Rapid Scan (Holland Scientific, Lincoln NE). Wavelengths in nanometers (nm) utilized were as follows: 660, 670, 700, 710, 735, 760, 770, and 780. Canopy reflectance was used to calculate the Normalized Difference Vegetation Index (NDVI = NIR-visible/NIR+visible) and was averaged for each plot.

Ear Leaf tissue samples were taken at R-1 and whole plant samples at half milk line and analyzed for N content. Grain yield was measured by harvesting an area of 5 feet by 40 feet within each plot at the Partridge, Scandia, Rossville locations. Harvest area for the Sterling location consisted of 5 feet by 17.5 feet. Yields were adjusted to 15 percent moisture, and grain was analyzed for N content and protein. Statistical analysis was conducting using SAS software PROC GLM with 0.10 alpha.

Table 1. Location information, 2013

Location	Sterling	Partridge	Scandia	Rossville
Soil Type	Saltcreek and Naron Fine Sandy loams	Nalim loam	Crete silt loam	Eudora sandy loam
Previous Crop	Soybeans	Soybeans	Soybeans	Soybeans
Tillage Practice	No-till	Conventional	Ridge Till	Conventional
Corn Hybrid	35F-50 Refuge	DK 64-69		H9138 3000GT
Plant Population (plants/ac)	19000	25700	29500	30,400
Irrigation	No	Yes	Yes	Yes
Residual NO_3 lb. N ac^{-1}	26	46	48	24
Planting Date	4/30/13	4/30/13	5/16/13	4/29/13
First Treatment at Planting	4/30/13	4/30/13	5/16/13	4/29/13
Second Treatment V-4	6/7/13	6/7/13	6/11/13	6/6/13
Third Treatment V-10	6/24/13	7/1/13	7/5/13	6/24/13
Last Treatment R1	7/10/13	7/10/13	7/18/13	7/12/13
Harvest Date	9/21/13	10/10/13	10/25/13	9/23/13

Results and Discussion

Results from this experiment are summarized in tables 2 through 5.

The Sterling location consisted of fine sands, low organic matter with low water holding capacity and high potential for nitrate leaching. High rainfall events were observed throughout the season, however only three rainfall events exceeded 0.5 inch during the vegetative growth stages (Figure 4.). Differences in observed yield and N uptake are likely due to water availability caused by soil variation across the study area. Despite distribution in rainfall not being ideal, high yields for this dryland site were obtained across all treatments with a yield range of 110-133 bu. ac^{-1} (Table 5., Figure 4.). No statistical response to applied N was observed, however there was a strong trend for yield increase by later applications of N.

Moderately high yields and good response to applied N were observed at Partridge (Table 2.). The greatest yields were observed from V-4 and R-1 N applications, while V-10 and at-planting N applications resulted in lower yield. The at-planting treatments resulted in lower yields and decreased efficiency due to the time of N application not matching crop demand and resulting in increased N loss. A rainfall event of almost 3 inches occurred May 30 prior to V-4 which could lead to nitrate leaching and account for the decreased efficiency of the “at-planting” treatments (Figure1.). The V-4 180 lb. ac^{-1} treatment 7 was able to carry enough N in the soil profile to obtain the third highest yield, thus showing a marked improvement in yield by shifting the N application time to more coincide with N demand. The R-1 120 lb. ac^{-1} treatment 14 obtained the highest yield, but was not statistically different from treatment 7. Sensor treatments at the V-10 and R-1 time underestimated N need considerably, thus resulting in severe reductions in yield. The Agronomist estimation made an accurate assessment of N need and achieved high yield for the site.

Excellent yields and a moderate response to applied N was observed at Rossville (Table 3.). There were no statistical differences in yield between at-planting, V-4, and R-1 N applications times with N rates greater than 120 lb. ac^{-1}. However, yield had an increasing trend with the earlier at-planting and V-4 N applications of 120 lb. ac^{-1} or greater N rates. This was due to the prevention of N stress during earsize determination starting at V-6. Indicating that the lack of Starter N and the 60 lb. ac^{-1} N rate applied at V-4 for the split application treatments was not enough to provide adequate levels of N in the soil profile to prevent N stress at V-6 and carry the corn to the next N application time at R-1. The R-1 sensor treatments resulted in yields equal to the Agronomist assessment with less applied N. The sandy loam soil at the Rossville location creates an environment that is prone to nitrate leaching losses, thus resulting in an overall reduction in potential NUE for the site. However, rainfall distribution was excellent during 2013 and only one rainfall event exceed 2 inches (Figure 2.). Therefore weather conditions were not conducive for nitrate leaching, which explains the respectable performance of the at-planting treatments compared to treatments with delayed N applications.

Although moderate yield and N response was observed at the Scandia location (Table 4.), severe early weed pressure resulted in increased variance and decreased yields. Statistical response to applied N was only observed over treatments 2, 1, and 11. Weather conditions were not conducive for nitrate leaching or denitrification in the silt loam soils of the study area (Figure 3.). The greatest efficiencies coupled with high yields were observed from the Agronomist assessment. Sensor treatments underestimated N need and therefore resulted in reduced yield.

The N loss potential of the discussed sites was significantly different from each other, and this can be a similar issue that Kansas Producers will observe across their farm. Sidedress applications at V-4 can offer a significant NUE advantage at locations with higher loss potential. Intensive N management systems could improve NUE without sacrificing yield by implementing split N applications that utilize R-1. However, it is important that adequate levels of N are applied in the early season to ensure the corn crop doesn't come under N stress during earsize determination and carries the corn crop to R-1. This is difficult to achieve under a fixed rate system, thus emphasizing the value of a trained Agronomist to help assess N need throughout the growing season and determine right time and rate of N application. Sensor technology offers the potential to assist Agronomist and Producers with assessing N needs, but continued research and development is needed to improve KSU algorithms before they are field ready for corn production. Increased N efficiency and grain yield can be achieved by changing the time, rate, and number of N applications to coincide with corn N demand and the potential for N loss in current growing environment.

Further research is needed to evaluate the effects of the N application timing and N management strategies under different weather conditions and soil types to determine their applicability in corn production.

Table 2. Effects of Nitrogen application timing on corn grain yield and Total Uptake, Partridge, 2013

Treatment	Starter N	Planting N	V-4 N	V-10 N	R1 N	Total N	Grain Yield	Total N Uptake
		lb. N ac^{-1}					bu. ac^{-1}	lb. N ac^{-1}
14	22	0	60	0	120	202	192 A	194 AB
12	22	0	60	0	180	262	191 A	211 A
7	22	0	180	0	0	202	190 AB	196 AB
Agronomist	22	0	60	0	130	212	190 AB	190 BC
9	22	0	0	120	0	142	181 BC	184 BC
4	22	180	0	0	0	202	180 CD	197 AB
10	22	0	0	180	0	202	180 CD	189 BC
13	22	0	60	0	60	142	179 CD	176 CD
6	22	0	120	0	0	142	176 CD	186 BC
5	22	0	60	0	0	82	173 CD	158 DEF
3	22	120	0	0	0	142	173 D	194 AB
2	22	60	0	0	0	82	162 E	162 DEF
Sensor	22	0	60	0	0	82	161 E	157 EF
8	22	0	0	60	0	82	159 E	174 CDE
Sensor	22	0	0	92	0	114	156 E	148 F
1	22	0	0	0	0	22	154 E	147 F

Results with the same letter are not statistically different at 0.1 alpha

Table 3. Effects of Nitrogen application timing on corn grain yield Total N Uptake, Rossville, 2013

Treatment	Starter N	Planting N	V-4 N	V-10 N	R1 N	Total N	Grain Yield	Total N Uptake
		lb. N ac^{-1}					bu. ac^{-1}	lb. N ac^{-1}
6	0	0	120	0	0	120	239 A	222 AB
7	0	0	180	0	0	180	238 A	219 AB
3	0	120	0	0	0	120	235 AB	218 AB
4	0	180	0	0	0	180	234 AB	233 A
13	0	0	60	0	60	120	231 ABC	213 BC
Sensor	0	0	60	0	0	60	230 ABC	206 BCD
12	0	0	60	0	180	240	230 ABC	213 BC
14	0	0	60	0	120	180	224 BCD	210 BCD
Agronomist	0	0	60	0	60	120	222 BCD	211 BCD
8	0	0	0	60	0	60	221 BCDE	193 DEF
5	0	0	60	0	0	60	219 CDE	193 DEF
2	0	60	0	0	0	60	217 CDE	187 EF
9	0	0	0	120	0	120	215 DE	204 BCDE
Sensor	0	0	0	198	0	198	212 DE	206 BCD
10	0	0	0	180	0	180	207 EF	197 CDE
1	0	0	0	0	0	0	194 F	177 F

Results with the same letter are not statistically different at 0.1 alpha

Table 4. Effects of Nitrogen application timing on corn grain yield and Total N Uptake, Scandia, 2013

Treatment	Starter N	Planting N	V-4 N	V-10 N	R1 N	Total N	Grain Yield	Total N Uptake
		lb. N ac^{-1}					bu. ac^{-1}	lb. N ac^{-1}
7	20	0	180	0	0	200	189 A	161 ABCD
13	20	0	60	0	60	140	184 AB	163 AB
Agronomist	20	0	60	0	7.5	87.5	183 AB	159 ABCD
10	20	0	0	180	0	200	182 AB	165 A
4	20	180	0	0	0	200	181 AB	163 ABC
3	20	120	0	0	0	140	179 ABC	167 A
8	20	0	0	60	0	80	179 ABC	149 CD
Sensor	20	0	60	0	0	80	179 ABC	158 ABCD
5	20	0	60	0	0	80	178 ABC	146 DE
6	20	0	120	0	0	140	178 ABC	156 ABCD
9	20	0	0	120	0	140	177 ABC	150 BCD
14	20	0	60	0	120	200	176 ABC	154 ABCD
12	20	0	60	0	180	260	175 BC	164 A
2	20	60	0	0	0	80	166 CD	150 BCD
1	20	0	0	0	0	20	161 D	131 E
Sensor	20	0	0	45.5	0	65.5	158 D	133 E

Results with the same letter are not statistically different at 0.1 alpha

Table 5. Effects of Nitrogen application timing on corn grain yield and Total N Uptake, Sterling, 2013

Treatment	Starter N	Planting N	V-4 N	V-10 N	R1 N	Total N	Grain Yield	Total N Uptake
		lb. N ac^{-1}					bu. ac^{-1}	lb. N ac^{-1}
4	7	180	0	0	0	187	118 A	147 A
Sensor	7	0	0	110	0	117	133 A	145 AB
12	7	0	60	0	180	247	129 A	144 ABC
3	7	120	0	0	0	127	115 A	136 ABCD
6	7	0	120	0	0	127	125 A	136 ABCD
2	7	60	0	0	0	67	117 A	135 ABCD
14	7	0	60	0	120	187	120 A	135 ABCD
Sensor	7	0	60	0	0	67	123 A	134 ABCD
10	7	0	0	180	0	187	118 A	132 CD
7	7	0	180	0	0	187	116 A	132 BCD
9	7	0	0	120	0	127	120 A	130 CD
13	7	0	60	0	60	127	115 A	126 DE
1	7	0	0	0	0	7	110 A	115 EF
Sensor	7	0	60	0	0	67	119 A	114 EF
5	7	0	60	0	0	67	117 A	113 EF
8	7	0	0	60	0	67	118 A	109 F

Results with the same letter are not statistically different at 0.1 alpha

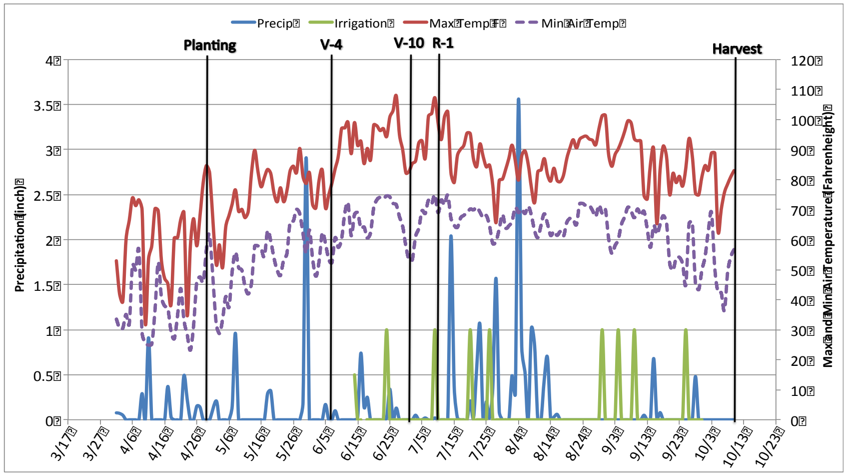

Figure 1. Partridge Corn treatment dates and weather data

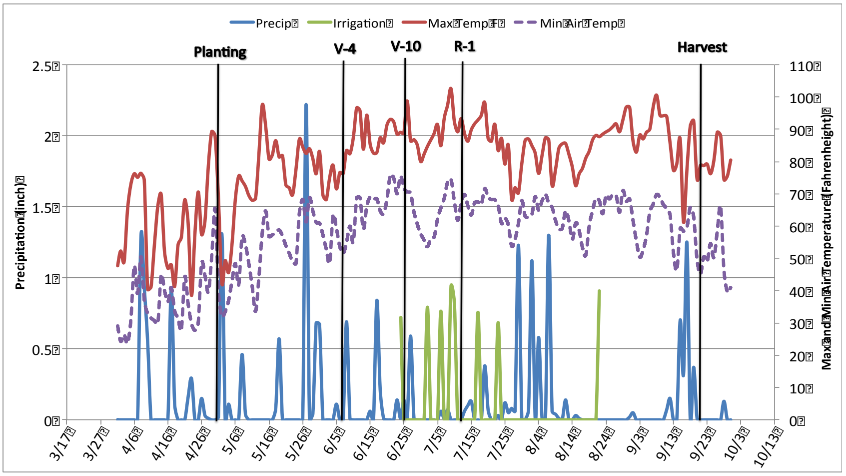

Figure 2. Rossville Corn treatment dates and weather data

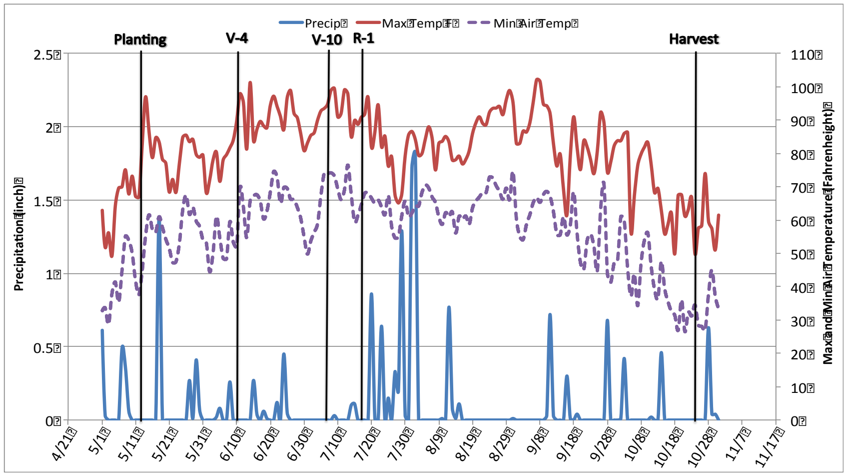

Figure 3. Scandia Corn treatment dates and weather data

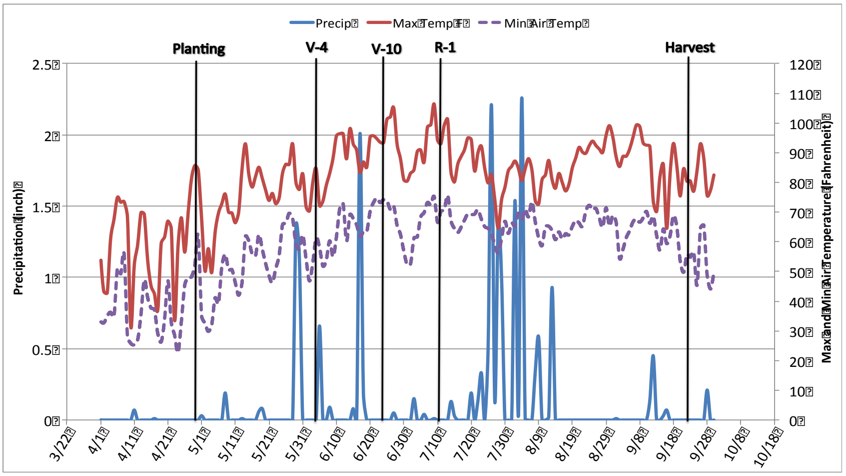

Figure 4. Sterling Corn treatment dates and weather data