NITROGEN MANAGEMENT: UNRAVELING THE EFFECTS OF TIMING AND FORM

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Abstract

Improvement of nitrogen use efficiency by corn production would decrease the potential for nitrogen loss into the environment. A study has been conducted in Ames, Iowa on 16 different forms and rates of nitrogen in both a continuous corn and corn-soybean production systems. There were differences among treatments; however, the most consistent treatment was the SuperU applied as a 150 lb A^{-1} preplant or as 50 lb A^{-1} preplant and 100 lb A^{-1} sidedress and UAN with Agrotain added to both the 50 lb A^{-1} preplant and 100 lb A^{-1} sidedress nitrogen applications. In these treatments there was increased leaf chlorophyll content along with a greater duration of green leaf area during the grain-filling period compared to the responses in the other forms. The result of this change was a larger weight per 100 seed. The effect of stabilized forms of nitrogen has a positive physiological impact on corn and this increased the efficiency of grain development. Understanding the effects of forms of nitrogen will be enhanced by focusing on the physiological processes along with the yield components.

Introduction

Improvements in nitrogen use efficiency have been proposed to occur because of continual improvements in crop yield with no concurrent increase in nitrogen application rates. Hatfield et al. (2009) showed this to be true across the Raccoon River watershed in Iowa. They also showed that the continual increases in nitrate-N concentration in the Raccoon River could be related to the reduction in cropped area into crops which extracted soil water in the early spring leading to increased drainage of water through the soil profile. This prompted the question about the potential role of changing forms of nitrogen being applied to this watershed system to remove the available nitrate-N from the soil profile early in the spring season. To address this question, there is a need to compare the agronomic and environmental responses of different forms of nitrogen. The ideal experiment to address this comparison would include agronomic, water quality, and air quality (nitrous oxide) observations collected throughout a year to evaluate the fate of nitrogen forms and rates. In this experiment we addressed the air quality and agronomic responses to form and timing in a continuous corn and corn-soybean rotation. Our goal is to quantify the seasonal trajectories of the changes in the crop induced by nitrogen management.

Approach

Study Location: A field study was conducted at two sites on an Iowa State University research farm located in Boone Co., Iowa (42.04ºN, 93.71ºW).

Soil: There is a mixture of soils in this experimental area. The experimental site contains Okoboji silty clay loam, Nicollet loam, Harps loam, Clarion loam, and Canisteo silty clay loam. Detailed GIS maps for each experimental site have been developed so that the soils within each plot can be identified. Average soil properties of are: soil organic C of 2.5 % , soil organic N 0.02 %; pH of 6.7; and clay, silt, and sand content 20.5, 34.1, and 45.4%, respectively.

Crop Grown: Dekalb DKC 61-19 Vt3 was planted in the Corn on Corn experiment was planted at 35000 seeds A^{-1} in the 2008, 2009 and 2010 experiments. Dekalb DKC 61-22 was planted in the Corn on Soybean experiment at a seeding rate of 35,000 seeds A^{-1} in 2009.

Tillage and Production Systems Used: A corn on corn experimental system was used for the 2008, 2009, and 2010 experiments. In 2009 experiment a corn following soybean comparison was made for the nitrogen forms. In all experiments, planting was done onto a previously prepared strip that was done with a strip tillage unit during the previous fall. Seed were placed at a depth of 5 cm at planting. In the fall after harvest, the plots were prepared with a strip tillage unit with the incorporation of P_2O_5 and K_2O fertilizer applied as 18-80-120. Weed control was done with Roundup® at 0.017 lb A^{-1} and Lumax® at 3.67 pints A^{-1} applied after planting.

N Treatments: The N treatments were the same for each of the years and also the same for corn following soybean studies. The N treatments for these studies are shown in Table 1.

Table 1. Treatments utilized in the rate (lb A^{-1}) and form study for nitrogen management study in Ames from 2008 through 2011.

Treatment	Preplant (lb A^{-1})	Starter (lb A^{-1})	Sidedress (lb A^{-1})
0	0		
1	100 ESN		
2	150 ESN		
3		50 UAN	100 UAN
4	100 SuperU		
5		50 UAN + A	100 UAN + A
6	50 SuperU		100 SuperU
7	150 SuperU		
8	50 SuperU		90 SuperU
9		50 UAN + A	90 UAN
10		50 UAN + A	90 UAN + A
11	100 UAN		
12	150 UAN		
13	100 UAN + A		
14	150 UAN + A		
15	150 Anhydrous		

Experimental Design: The experimental design for the corn on corn experiment was a randomized complete block with five replications. The experimental design for the corn following soybean field was a randomized complete block with three replications.

Growing Season Precipitation: Total precipitation in 2008 was 50 in with 39 occurring during the April through September period. Total 2009 yearly precipitation totaled 37 in with an April through September corn growing season precipitation total of 21 in. In 2010, precipitation totaled

51 in for the year with an April through September total of 43 in. The precipitation during the 2010 growing season was one of the highest on record in Ames.

Observations: Data collected during the growing season on these experiments included leaf chlorophyll observations using a leaf chlorophyll meter (OptiSci) with 10 plants measured in each replicate. Observations were made on the uppermost fully expanded leaf until tasseling and then the ear leaf was measured. These observations were recorded on a weekly interval from the V6 stage through mid grain-filling. Leaf area observations were collected with a LAI-2000 unit for two locations in each replicate at a weekly interval from the V6 stage through maturity. At the beginning of the grain-filling period, destructive plant samples were collected on five plants from each replicate to record total plant biomass. Weekly observations were made with a 16 band CropScan radiometer over five locations within each replicate of the study. These observations were collected using the procedure described by Hatfield and Prueger (2010).

Observations of grain yield were collected at maturity with a combine equipped with a yield monitor, scales, and moisture meter. This unit was used to collect yield data from each plot and subsamples were extracted from the grain for quality measurements. These included weight per 100 kernals, protein, oil, and starch content.

Observations were also collected for nitrous oxide emissions using a closed chamber technique for each nitrogen form with six replicates measured using a gas chromatography method with samples extracted from each chamber once per hour throughout the day. These observations were collected throughout the growing season. These data are not reported in this paper but are part of the overall comparison in the study.

Statistical Analysis: All data were subjected to statistical analyses using the SAS program. Least Significance Difference tests were used as a means separation technique for these experimental results

Results and Discussion

This summary was designed to evaluate a combination of different nitrogen forms and rates and over the three years of the study the yields varied among the years caused by the variation in the weather among the years. Mean yields for the treatments are shown in Table 2. There was a large variation in yield among the years and among the nitrogen rates and forms. The consistent treatment was the No N applied treatment (Treatment 0). There was a decline in the yield across the years and the low yields in 2010 can be attributed to the excessive rainfall during the growing season coupled with above normal minimum temperatures during the grain-filling period which caused the grain-filling period to be shortened by eight days. Over all of the treatments,

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Treatment 6 (SuperU as 50 lb A^{-1} at preplant and 100 lb A^{-1} as sidedress) was the most consistent treatment over the different years and with the rotations followed by the single application of 150 lb A^{-1} of SuperU as a preplant application. The other treatment with the largest and most consistent yield over the years was treatment 5 (50 lb A^{-1} as a starter and 100 lb A^{-1} as sidedress of UAN + Agrotain). The largest yields were produced by the incorporation of some form of stabilization into the nitrogen form.

Table 2. Mean yields (bu A^{-1}) for the nitrogen treatments imposed on corn grown in Ames, Iowa from 2008 through 2010.

N Trt	2008 Cont Corn (bu A^{-1})	2009 Cont Corn (bu A^{-1})	2009 Corn-Soybean (bu A^{-1})	2010 Cont Corn (bu A^{-1})
0	91	68	114	53
1	94	133	191	130
2	117	153	209	144
3	181	124	198	149
4	168	127	199	112
5	182	144	200	156
6	163	161	223	149
7	190	172	215	118
8	199	142	205	134
9	187	132	190	155
10	187	126	204	142
11	128	109	189	105
12	163	157	204	122
13	116	128	183	120
14	140	143	206	129
15	92	160	209	123

We examined the yield component responsible for this response among the years and found there was an effect of the stabilized materials on the maintenance of the green leaf area in the highest yielding treatments. An example is shown in Figure 1 for the continuous corn field in 2009. In the SuperU form there was maintenance of the leaf chlorophyll levels during the grain-filling period until the end of the growing season (Fig.1).

A similar response was found for the corn-soybean rotation field with the leaf chlorophyll observations (Fig. 2). Noticeable for these two plots was that the leaves in the corn-soybean field showed higher leaf chlorophyll content compared to the continuous corn field with the values for all treatments at least 20 leaf chlorophyll units larger in the corn-soybean field. This would suggest that nitrogen was limiting the growth of the continuous corn field. This was also confirmed by the observations of leaf area in these plots in which the higher yielding treatments also had the larger green leaf area during the grain-filling period.

To evaluate the effect of the prolonged leaf greenness as measured by the leaf chlorophyll and green leaf area duration in the grain-filling period on yield components measurements were made of the weight per 100 seed in each of the treatments. The largest effect on the yield components was on the weight per 100 seed as shown in Table 3. The highest yielding treatment had the largest values of the weight per 100 seed. The larger kernel size can be related to the maintenance of the green leaf area longer during the grain-filling period and the resultant

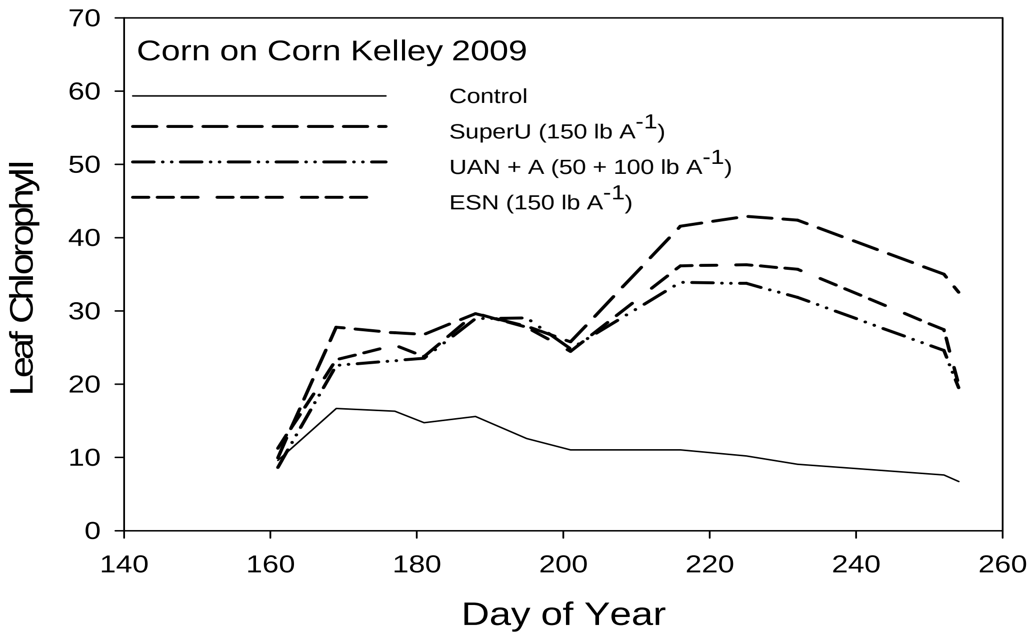

Figure 1. Seasonal trajectories of the leaf chlorophyll readings for selected nitrogen forms in the continuous corn field in 2009 from Ames, IA.

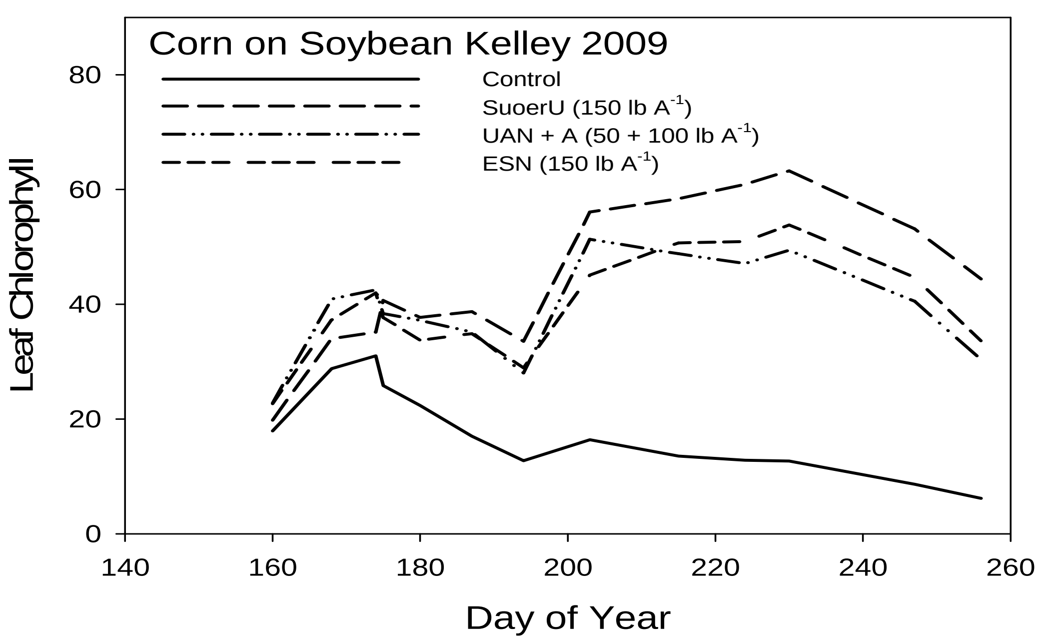

Figure 2. Seasonal trajectories of the leaf chlorophyll readings for selected nitrogen forms in the corn-soybean rotation field in 2009 from Ames, IA.

positive impact on the maintenance of the photosynthetic rates in these treatments. The N forms which maintain green leaf area are more photosynthetically active resulting in a larger kernel size. There was not consistent difference in the ear size among the treatments and the number of kernels per ear was not different. The positive impact of increasing individual kernel size due to a longer grain-filling period and more efficient photosynthesis from the stabilized nitrogen form is a major factor in the increased and more stable yield among years.

Table 3. Weight per 100 seed for the nitrogen treatments for the corn study in Ames, Iowa on various nitrogen forms.

N Trt	2009 Cont Corn (g/100 seed)	2009 Corn-Soybean (g/100 seed)	2010 Cont Corn (g/100 seed)
0	23.03	22.85	22.32
1	24.65	24.84	24.19
2	24.18	26.06	24.46
3	22.84	24.18	26.75
4	23.83	25.47	23.06
5	24.28	25.78	27.36
6	24.12	26.83	25.54
7	25.30	26.25	24.43
8	24.29	25.52	26.12
9	24.68	24.23	27.09
10	23.18	24.13	25.30
11	23.40	23.81	21.98
12	25.50	25.35	24.60
13	23.20	25.07	23.18
14	24.41	25.20	24.53
15	24.05	25.40	25.21

Summary

Yield responses in continuous corn and corn-soybean rotations showed consistency across the three years of this study in Ames, Iowa using combinations of nitrogen forms and timings. Typically, these studies have been conducted comparing crop yields at the end of the growing season. In this study, we evaluated the seasonal trajectories of green leaf area and leaf chlorophyll content for the various treatments. There were large differences among the growing seasons created by rainfall patterns; however, the treatments with the largest yields were consistent among years. These treatments were the SuperU applied as a 150 lb A^{-1} preplant or as 50 lb A^{-1} preplant and 100 lb A^{-1} sidedress with UAN with Agrotain added in both the 50 lb A^{-1} preplant and 100 lb A^{-1} sidedress nitrogen applications. In these treatments there was an increase in leaf chlorophyll content and increase in the duration of green leaf area during the grain-filling period. The effect on the corn plant was to increase the weight per 100 kernels as a yield component. If we are to understand the effect of changing the forms of nitrogen on corn yield and nitrogen use efficiency we need to utilize a detailed set of observations of the physiological response along with the yield components.

References

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NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 27

November 16-17, 2011
Holiday Inn Airport
Des Moines, IA

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Published by:

International Plant Nutrition Institute
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Brookings, SD 57006
(605) 692-6280
Web page: www.IPNI.net