CONSEQUENCES OF SHALLOW NH_3 PLACEMENT AND TIMING ON N USE EFFICIENCIES IN CORN PRODUCTION

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Abstract

A field study in west-central Indiana was conducted to investigate the effects of shallow anhydrous ammonia (NH_3) placement and timing on N use efficiencies in a conventionally tilled corn production system following soybean crop. The spring NH_3 was applied either pre-plant (6-inches offset from future corn row) or side-dress (at mid-row position) at different rates (0, 80, 130 or 180 lbs N acre^{-1}). Aboveground biomass harvest and combine harvested yield were used to determine N recovery, N internal and N use efficiencies. Slightly higher aboveground biomass production and grain yield resulted following side-dress application, while grain and total N uptake and N recovery were slightly better after pre-plant application timing. Ear-leaf N concentration at silking and final grain yield was strongly correlated. Close (6-inches offset) NH_3 placement to the future corn row did not appear to be detrimental to corn response; however, enough temporal separation between shallow pre-plant NH_3 application and planting is strongly recommended.

Introduction

Efficient corn (Zea mays L.) production in modern intensified agriculture relies heavily on extensive use of fertilizers especially N. Anhydrous ammonia (NH_3) is one of the most widely used (Stamper, 2009 and USGS, 2011) N fertilizers in the United States due primarily to its lower cost (per unit of N) relative to other N sources. Farmers and researchers are always interested in how, when and where to apply the NH_3 to derive maximum benefit from the fertilizer source.

John Deere recently introduced a new line of NH_3 applicators (2510H Nutrient Applicator) to the market (John Deere, 2008) which is fundamentally different from the traditional knife type NH_3 applicators in design and also in operation. This is a single-disk opener system mounted on a high clearance frame where the applicator provides shallower nutrient placement than the traditional shank type injectors; the constant depth is controlled by a 3-inch wide gauge wheel and maintained with active hydraulic down pressure (John Deere, 2012). The reported advantages of the new 2510H applicators are:

- shallower nutrient placement and the disk opener enable higher-speed NH_3 application with less horsepower requirement than traditional knife type of applicators,
- reduced soil disturbance provides farmers the opportunity to apply NH_3 in no-till and minimum tillage systems,
- higher clearance opens a longer timeframe for optimal side-dress application.

Sawyer et al. (2009) reported slow corn seedling emergence, severely reduced growth rates, and greater visual damage at higher fertilizer rates (160 and 200 lbs N acre^{-1}) in Iowa, when NH_3 was pre-plant applied in the spring with a high-speed, low-disturbance applicator under the future corn row. Spatial placement of the fertilizer is very important when the NH_3 is applied at shallow depth. Today's technology allows farmer to use global positioning systems (GPS) and real time kinetic (RTK) systems, such as the StarFire system (John Deere, 2011) in their field to precisely and repeatable find the same position within the field. This provides opportunity to place pre-plant fertilizer parallel but a safe off-set position from the future corn row.

The yield advantages of the RTK system in precise parallel placement of corn rows 5-inches away from pre-plant, coulter-injected UAN applications at total N rates up to 200 lbs N acre^{-1} were previously demonstrated in Indiana (Vyn and West, 2009). The NH_3 application toxicity not only depends on the proximity of the fertilizer band to the corn row but also the time interval between the application and planting (Colliver et al., 1970). When using shallow NH_3 applicators, both spatial and temporal distance is very important to avoid corn seedling growth delays or plant death.

Timing of any N fertilizer application is a key management factor for a number of reasons. On one hand, farmers want maximum yield response for their costly fertilizer investment and, on the other hand, environmental concerns make it increasingly essential for farmers to minimize N fertilizer losses. Most uncertainty about N availability to corn plants occurs with fall-applied N versus either pre-plant or side-dress N. Vetsch and Randall (2004) observed weather dependent results; in wetter and warmer than normal springs, fall N application resulted in significant reductions in both N recovery and grain yield, while differences between fall and spring applied N were not observed in normal moisture and cooler springs in Minnesota. Sainz Rosas et al. (2004) reported benefits in grain yield and N uptake when N application was adjusted for plant uptake requirements (i.e. applying at V6 stage rather than at planting). Sawyer et al. (2009) reported highest grain yield with side-dress applications for both types of NH_3 applicators (the coulter and knife type) even when applying N only in every other mid-row position.

Limited studies have been conducted to date on agronomic consequences of shallow NH_3 placement and timing on corn response. This study focused on corn N use efficiencies following alternative NH_3 application timings at multiple N rates.

Materials and Methods

The study was conducted between 2010 and 2012 at Purdue University's Agronomy Center for Research and Education near West Lafayette, IN (40.4855246, -87.0006963). The research site was located on a Chalmers silty clay loam soil (Fine silty, mixed, mesic Typic Hapluaquolls) in 2010 and 2012 and on a Drummer silty clay loam (Fine silty, mixed, mesic Typic Hapluaquolls) soil in 2011 in soybean-corn rotation system. Two experimental factors were under investigation:

NH_3 application timing and placement:

- Pre-plant (6-inches offset from future corn row)
- Side-dress (at V6-7 growth stage in mid-row position)

Applied N rate:

- 0 lb N A^{-1}
- 80 lbs N A^{-1} (90 kg ha^{-1})
- 130 lbs N A^{-1} (145 kg ha^{-1})
- 180 lbs N A^{-1} (200 kg ha^{-1})

The two examined factors were assigned in a randomized complete block design in 6 replications. The field were chisel plowed in the prior fall and a secondary spring tillage were applied prior to NH_3 application. Individual plot dimensions were 105' in length and 15' in width (6 rows). Pioneer 1395XR (2010) and the Pioneer 1567 XR (2011, 2012) seeds were planted using a JD1780 6 row unit at 34,500 seeds $acre^{-1}$ rate with 15 gallon $acre^{-1}$ additional 10-34-0 starter fertilizer. Table 1 displays the key agronomic field activities for both growing seasons.

Table 1 Date of key field activities during 2010 and 2011 growing season

Field activity	2010	2011
Pre-plant NH_3 application	April 13	May 12
Planting	April 15	May 13
Side-dress NH_3 application	May 20	June 18
Silking time	July 1-9	July 16-23
Machine harvest	September 18	October 5

Ear-leaf samples were taken from 10 consecutive plants at silking from 3 replications. Samples were dried, ground and analyzed for N concentration by a commercial laboratory (A & L Great Lakes Inc. Fort Wayne, IN).

Aboveground biomass was harvested from 3 replications at physiological maturity, dried at 140ºF until constant weight, ground and analyzed for determination of whole-plant N uptake, harvest index (HI) and N harvest index (NHI).

The center 2 rows were harvested by Kincaid 8XP plot combine and yield was corrected to 15.5% moisture content.

Ear-leaf N concentrations at silking were regressed against final machine harvested grain yield.

N recovery efficiency (NRE), N internal efficiency (NIE) and N use efficiency (NUE) were calculated and derived from biomass samples and machine harvested yield via these equations:

$$NRE = \frac{N_{uptake\ at\ N\ rate} - N_{uptake\ at\ 0\ N}}{N_{applied} - N_0}$$

$$NIE = \frac{Grain\ yield_{at\ N\ rate}}{N_{uptake\ at\ N\ rate}}$$

$$NUE = \frac{Grain\ yield_{\ at\ N\ rate} - Grain\ yield_{\ at\ 0\ N}}{N_{applied} - N_0}$$

Results

Machine harvested yields are displayed in Figure 1. Grain yield increased with increasing applied NH_3 ($p<0.0001$) and timing of application also affected grain yield ($p=0.0026$). Bulk grain yield were consistently higher following side-dress application but a statistical difference due to timing was only observed at the highest N rate. Yield following pre-plant application seems to have plateaued by the highest N rate while yield was still increasing at side-dress application. Grain moisture content at harvest was also higher as the N rate increased.

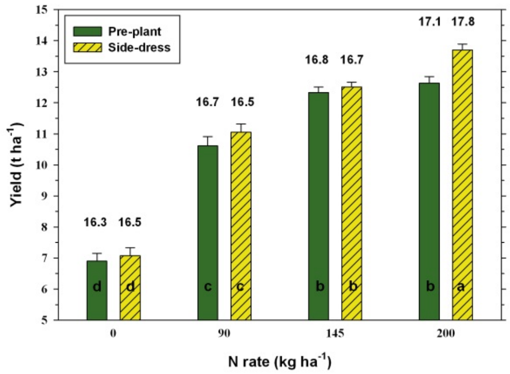

Figure 1 Moisture corrected machine harvested yield in 2010 and 2011. Treatments with different letters are statistically significantly different at p=0.05 level. Values above bar presents the grain moisture content at harvest

Differences between ear-leaf N concentrations at silking were due to fertilizer rate ($p<0.0001$) only (Table 2). Applied N rate increased the ear-leaf N concentration. Total aboveground biomass increased with increasing N rates, but only absence of fertilizer resulted statistical differences between treatments. Harvest index were higher following side-dress application except at 80 lbs rate but application timing did not result in statistical differences. Grain N concentration increased with increasing applied fertilizer. Pre-plant treatments had higher grain N concentration ($p=0.0154$) when averaged across N rates, but no N rate by application timing interaction was detected. Both grain and total N uptake were higher at higher fertilizer level; pre-plant application resulted in slightly higher overall N uptake.

Table 2 Anhydrous ammonia application timing and rate effects on ear-leaf N concentration, aboveground biomass at physiological maturity, harvest index (HI), grain N concentration, grain and total plant N uptake in 2010 and 2011 near West Lafayette, IN.

Application timing and N rate (lbs A^{-1}) combination	Ear-leaf N conc. (%)	Aboveground biomass ($g\ m^{-2}$)	HI (%)	Grain N conc. (%)	Grain N uptake ($kg\ ha^{-1}$)	Total N uptake ($kg\ ha^{-1}$)
Pre-plant 0	1.62 d[1]	1456 b	47.8 c	1.09 d	75.8 c	123.9 c
Pre-plant 80	2.62 bc	1984 a	53.8 b	1.17 cd	124.6 b	192.6 b
Pre-plant 130	2.82 abc	2096 a	54.3 ab	1.33 ab	150.8 a	228.9 a
Pre-plant 180	2.94 ab	2144 a	54.8 ab	1.38 a	161.7 a	246.5 a
Side-dress 0	1.86 d	1559 b	48.8 c	1.04 d	78.8 c	127.3 c
Side-dress 80	2.57 c	1983 a	53.7 b	1.09 d	117.1 b	179.9 b
Side-dress 130	2.97 a	2165 a	56.4 a	1.24 bc	151.1 a	221.4 a
Side-dress 180	2.98 a	2168 a	55.1 ab	1.28 abc	152.6 a	239.8 a

[1]Treatments with different letter are statistically significantly different at p=0.05

Strong relationships were detected between ear-leaf N concentration (samples taken at silking) and final bulk grain yield (Figure 2) (r^2=84% and 81% in 2010 and 2011 respectively) suggesting a possible in-season indicator for grain yield.

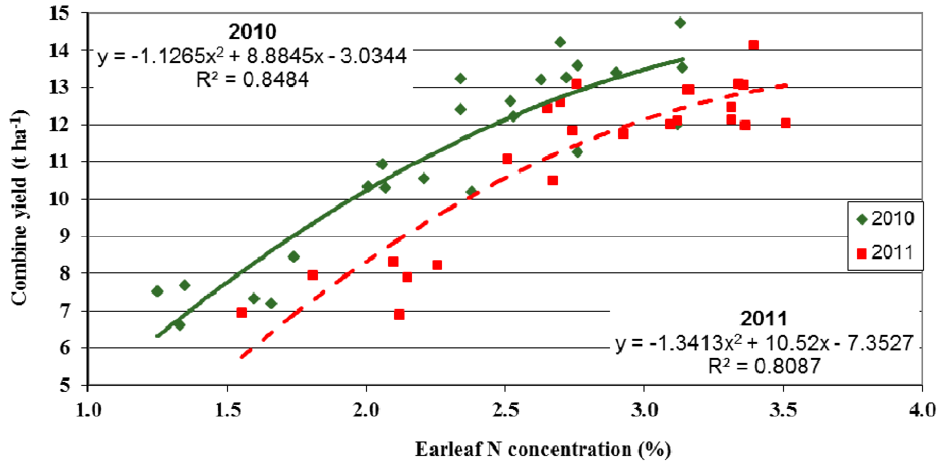

Figure 2 Relationship between machine harvested yield and ear-leaf N concentration at silking time in 2010 and 2011

Pre-plant application resulted better N recovery and overall NUE than side-dress application (Table 3). Similar high recovery efficiencies with pre-plant NH_3 application was also reported earlier (Vetsch and Randall, 2004). The internal efficiency of N tended to be better following side-dress application, but NIE response was more N rate dependent. As expected, all N efficiency values decreased as the applied fertilizer rate increased.

Table 3 Anhydrous ammonia application timing and rate effects on N harvest index (NHI), N recovery efficiency (NRE), N internal efficiency (NIE) and on N use efficiency (NUE) in 2010 and 2011 near West Lafayette, IN.

Application timing and N rate (lbs A^{-1}) combination	NHI (%)	NRE (kg N kg^{-1} N applied)	NIE (kg grain kg^{-1} N uptake)	NUE (kg grain kg^{-1} N applied)
Pre-plant 0	60.7 c[1]	-	-	-
Pre-plant 80	64.5 abc	0.776 a	58 ab	40.3 a
Pre-plant 130	65.9 ab	0.730 ab	56.3 b	35.6 abc
Pre-plant 180	65.6 ab	0.617 ab	52.3 b	27.1 d
Side-dress 0	61.9 bc	-	-	-
Side-dress 80	64.6 abc	0.597 ab	62.9 a	38.7 ab
Side-dress 130	68.1 a	0.656 ab	56.5 ab	32.8 bcd
Side-dress 180	63.6 bc	0.568 b	57.4 ab	29.9 cd

[1]Treatments with different letter are statistically significantly different at p=0.05

Summary

Shallow NH_3 application that maintained a safe spatial distance between the application and planting proved to be non-detrimental to corn plants even at full N rate. Just 6-inches of NH_3 displacement from corn rows did not appear to be detrimental to corn response at rates up to 180 lbs N acre^{-1}. With this close NH_3 placement to the corn row timely separation of application and planting is still recommended. Side-dress NH_3 delivery resulted in slightly higher aboveground biomass, grain yield and internal N efficiency, but slightly lower grain and total N uptake, ear-leaf N concentration and NRE than for pre-plant NH_3 applied at similar N rates. Data from the 2 years are suggesting that ear-leaf N concentration at silking can be a good mid-season predictor for final grain yield with either application timing.

Acknowledgements

Authors would like to thank and acknowledge Deere and Co. for the grant funding and for providing implements to do the research. Assistance from Deere employees to help solve technical issues during the study was also appreciated. The Agronomy Farm crew of Purdue University helped with this research. Terry D. West and the Cropping System Research group's graduate and undergraduate students provided extensive help throughout the growing seasons.

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PROCEEDINGS OF THE

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NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 28

November 14-15, 2012
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