Consequences of Shallow NH_3 Placement and Timing on N Use Efficiencies in Corn Production

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Introduction

Anhydrous ammonia (NH_3) is one of the most commonly used fertilizers in maize (Zea mays L.) production in the Midwest US. John Deere recently introduced a new shallow NH_3 applicator (Model 2510H) which claims the advantages of higher application speed, less horsepower requirement during application, less soil disturbance and a longer side-dress application window. (John Deere, 2012). 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

Field experiments were conducted on a Chalmers silty clay loam (Fine-silty, mixed, mesic Typic Hapluaquolls) in 2010 and on Drummer silty clay loam (Fine-silty, mixed, mesic Typic Hapluaquolls) soil in 2011 at Purdue University's Agronomy Center for Research and Education near West Lafayette, IN (40.4855246, -87.0006963).

Experiment parameters:

Application timing:
Pre-plant (15cm offset from future corn row, Figure 1A)
Side-dress (mid-row position at V6-V7 growth stage, Figure 1B)

N rates: 0, 90, 145, and 200 kg N ha^{-1}

Experimental design: Randomized Complete Block Design with 6 replications

Crop rotation: Soybean – Corn rotation

Tillage: Fall chisel plow + secondary tillage before pre-plant NH_3 application

Corn hybrids: Pioneer 1395 XR (2010)
Pioneer 1567 XR (2011)

Seeding rate: 85200 seeds ha^{-1}

Planter: JD1780 6 row unit delivering 140 l ha^{-1} 10-34-0 starter fertilizer in a typical 5cm by 5cm placement (20 kg N ha^{-1})

Plot dimension: 32 m length and 4.58 m (6-row) width

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

Figure 1. (A) Pre-plant NH_3 application 15-cm offset from future corn row; (B) side-dress NH_3 application in mid-row position; (C) biomass harvest at physiological maturity; (D) machine harvest in the center 2 rows

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 (Figure 1C), dried at 60 ºC 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 155 g kg^{-1} moisture content (Figure 1D). Ear-leaf N concentrations at silking were plotted against grain yield.

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

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

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

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

Results

Grain yield (Figure 2) increased with increasing NH_3 rates ($p<0.0001$), and timing of application also affected final grain yield ($p=0.0026$).

Yields were consistently higher following side-dress application but a statistical difference due to timing was observed only at the highest N rate. Grain moisture contents at harvest were also higher with higher N rates (Figure 2).

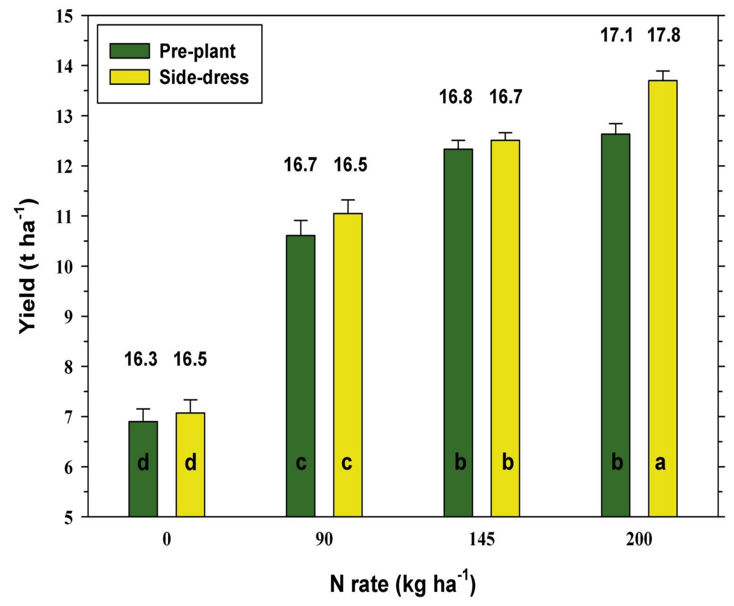

Figure 2. Anhydrous ammonia rate and timing impacts on corn yields (average of 2010 and 2011). Treatments with different letters are statistically significantly different (at p=0.05). Values above bars represent the grain moisture content at harvest.

Grain yield was strongly correlated to the ear-leaf N concentration at silking (r^2=84% in 2010 and 81% in 2011) as Figure 3 displays.

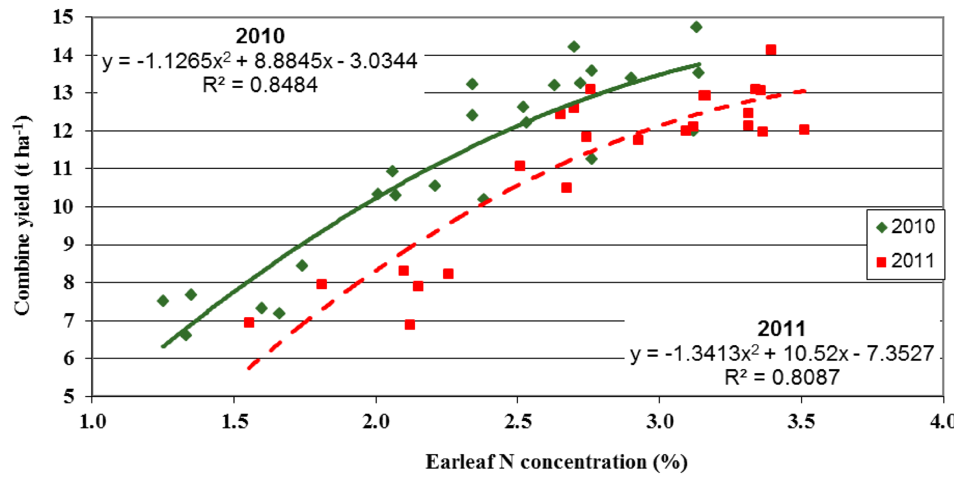

Figure 3. Relationship between machine harvested yield and ear-leaf N concentration at silking time in 2010 and 2011.

Table 2. Anhydrous ammonia application timing and rate effects on harvest index (HI), grain N concentration, grain and total plant N uptake, N harvest index (NHI), N recovery efficiency (NRE), N internal efficiency (NIE) and N use efficiency (NUE) averaged for 2010 and 2011 near West Lafayette, IN.

Application timing and N rate (kg ha^{-1}) combination	HI (%)	Grain N Concentration (%)	Grain N Uptake (kg ha^{-1})	Total Plant N Uptake (kg ha^{-1})	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	47.8 c[1]	1.09 d	75.8 c	123.9 c	60.7 c	-	-	-
Pre-plant 90	53.8 b	1.17 cd	124.6 b	192.6 b	64.5 abc	0.776 a	58.0 ab	40.3 a
Pre-plant 145	54.3 ab	1.33 ab	150.8 a	228.9 a	65.9 ab	0.730 ab	56.3 b	35.6 abc
Pre-plant 200	54.8 ab	1.38 a	161.7 a	246.5 a	65.6 ab	0.617 ab	52.3 b	27.1 d
Side-dress 0	48.8 c	1.04 d	78.8 c	127.3 c	61.9 bc	-	-	-
Side-dress 90	53.7 b	1.09 d	117.1 b	179.9 b	64.6 abc	0.597 ab	62.9 a	38.7 ab
Side-dress 145	56.4 a	1.24 bc	151.1 a	221.4 a	68.1 a	0.656 ab	56.5 ab	32.8 bcd
Side-dress 200	55.1 ab	1.28 abc	152.6 a	239.8 a	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.

Both HI and NHI were generally higher following side-dress application than pre-plant application (Table 2), but not for NHI at 200 kg N rate. Grain N concentration and N uptake (both grain and total) increased with increasing fertilizer rate and were slightly higher following pre-plant application.

Pre-plant application resulted in better N recovery and overall N use efficiency than side-dress application.

The NIE tended to be higher following side-dress application, but the NIE response to application timing was N rate dependent.

As expected, all N efficiency values decreased as the N fertilizer rate increased.

Conclusions

Shallow pre-plant NH_3 application with just a 15-cm displacement from the corn rows did not appear to be detrimental to corn response at rates up to 200 kg N ha^{-1}. However, temporal separation between spring NH_3 application and corn planting is still recommended.

Side-dress NH_3 application timing resulted in slightly higher grain yield, but slightly lower grain N concentration and NRE than for pre-plant NH_3 applied at similar N rates.

Relatively high N efficiencies in modern corn production were achieved in both pre-plant and side-dress N systems at intermediate N rates.

Mid-season ear-leaf N concentrations (samples taken at silking) can be a good indicator for final grain yield with either application timing.

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References

John Deere 2012. http://www.deere.com/wps/dcom/en_US/products/equipment/nutrient_application/nutrient_applicators/2510h/2510h.page accessed on October 3, 2012