Consequences of Shallow NH₃ Placement and Timing on N Use Efficiencies in Corn Production

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Introduction
Anhydrous ammonia (NH₃) 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 NH₃ 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 NH₃ placement and timing on corn response. This study focused on corn N use efficiencies following alternative NH₃ application timings at multiple N rates.

Materials and Methods
Field experiments were conducted on a Chalmers silty clay loam (Fine-silty, mixed, mesic Typic Hapludalfs) in 2010 and on Drummer silty clay loam (Fine-silty, mixed, mesic Typic Hapludalfs) 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 (15 cm 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 NH₃ 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 5 cm by 5 cm 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

<table>
<thead>
<tr>
<th>Field activity</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-plant NH₃ application</td>
<td>April 13</td>
<td>May 12</td>
</tr>
<tr>
<td>Planting</td>
<td>April 15</td>
<td>May 13</td>
</tr>
<tr>
<td>Side-dress NH₃ application</td>
<td>May 20</td>
<td>June 18</td>
</tr>
<tr>
<td>Silking time</td>
<td>July 1-9</td>
<td>July 16-23</td>
</tr>
<tr>
<td>Machine harvest</td>
<td>September 18</td>
<td>October 5</td>
</tr>
</tbody>
</table>

Figure 1. (A) Pre-plant NH₃ application 15-cm offset from future corn row; (B) side-dress NH₃ 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 °C 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:

\[
NRE = \frac{Grain\ yield\ at\ N\ rate - Grain\ yield\ at\ 0\ N}{Grain\ yield\ at\ 0\ N} = \frac{N_{\text{grain}}}{N_{\text{applied}}} - 1
\]

\[
NIE = \frac{Grain\ yield\ at\ N\ rate}{Grain\ yield\ at\ 0\ N} = \frac{N_{\text{grain}}}{N_{\text{applied}}}
\]

\[
NUE = \frac{Grain\ yield\ at\ N\ rate - Grain\ yield\ at\ 0\ N}{Grain\ yield\ at\ 0\ N}
\]

Results
Grain yield (Figure 2) increased with increasing NH₃ 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).

Grain yield was strongly correlated to the ear-leaf N concentration at silking (r²=84% in 2010 and 81% in 2011) as Figure 3 displays.

Shallow pre-plant NH₃ 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 NH₃ application and corn planting is still recommended.

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

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.

<table>
<thead>
<tr>
<th>Application timing and N rate (kg ha⁻¹)</th>
<th>HI (%)</th>
<th>Grain N Concentration (%)</th>
<th>Grain N Uptake (kg ha⁻¹)</th>
<th>Total Plant N Uptake (kg ha⁻¹)</th>
<th>NHI (%)</th>
<th>NRE (%)</th>
<th>NIE (%)</th>
<th>NUE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-plant 0</td>
<td>53.1</td>
<td>58.2 b</td>
<td>227.5 b</td>
<td>165.9 b</td>
<td>50.6</td>
<td>0.617</td>
<td>0.54</td>
<td>0.32</td>
</tr>
<tr>
<td>Pre-plant 20</td>
<td>56.0</td>
<td>62.9 c</td>
<td>260.7 c</td>
<td>205.2 c</td>
<td>56.5</td>
<td>0.617</td>
<td>0.54</td>
<td>0.36</td>
</tr>
<tr>
<td>Pre-plant 145</td>
<td>59.4</td>
<td>65.9 b</td>
<td>280.1 b</td>
<td>224.1 b</td>
<td>57.0</td>
<td>0.617</td>
<td>0.55</td>
<td>0.36</td>
</tr>
<tr>
<td>Pre-plant 200</td>
<td>61.8</td>
<td>69.8 c</td>
<td>294.6 c</td>
<td>248.8 c</td>
<td>59.7</td>
<td>0.617</td>
<td>0.56</td>
<td>0.35</td>
</tr>
<tr>
<td>Side-dress 0</td>
<td>58.0</td>
<td>58.2 b</td>
<td>228.6 b</td>
<td>166.1 b</td>
<td>49.1</td>
<td>0.597</td>
<td>0.54</td>
<td>0.32</td>
</tr>
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<td>258.9 c</td>
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</table>

1 Treatments with different letters 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

The authors would like to thank Deere and Co. for grant funding and providing implements for the research. The Agronomy Farm crew of Purdue University, Terry West and the Cropping System Research group’s graduate and undergraduate students for their extensive help. Seeds were donated by Pioneer Hi-Bred.

Acknowledgements

References