Optimizing rate of nitrogen for corn - how good can it be?

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Objective of better N management

• Choose a combination of source, placement, timing, and rate of N application that minimizes the amount of unused N and its susceptibility to loss while optimizing profit
Indiana corn production

• 6 million acres
• 90% grown in rotation with soybean
• 50% anhydrous ammonia, 40% urea-ammonium nitrate solution, 10% granular urea
• Less than 25% of the N is applied in the fall (AA) mostly in the northern half of the state
Indiana precipitation equal or lesser to Iowa during the growing season

Indiana has greater prec. than Iowa in the off-season – 18-24” vs 11-14”
Indiana soils vary a lot

~230-260 lb N/ac

~210 lb N/ac
Thanks John Sawyer!
Experimentally-derived N rate recommendations replaced yield-based N recommendations
Indiana - no/weak relationship between N fertilizer needed and yield achieved

250 site-years
Yield-based N rec. for corn was suggested first in 1966 (G. Stanford, USDA-Beltsville, Md.)

Fertilizer N recommendation =
(Yield x N factor at harvest - soil N contributed) / efficiency of fertilizer use
Comparison of MRTN to a mechanistic model N recommendation across 22 Indiana C/S locations
Predictions needed for an accurate yield-based N recommendation

• Accurate prediction of:
  • Crop yield
  • Plant N content associated with crop yield
  • Soil N mineralized
  • Fertilizer lost (efficiency of fertilizer use)
Variation in yield

Maximum yield, bu/acre

Optimum N rate, lb/acre

113 bu/acre
136 lb N/acre

P34A20, 33K
2006-2008
20 site-years
Yield range per field over 5 corn years in C/S rotation

<table>
<thead>
<tr>
<th></th>
<th>Grain yield, bu/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>29</strong>*</td>
<td>235</td>
</tr>
<tr>
<td>45</td>
<td>230</td>
</tr>
<tr>
<td>28</td>
<td>240</td>
</tr>
<tr>
<td>54</td>
<td>225</td>
</tr>
</tbody>
</table>

| ACRE-93  | 210                  |
| ACRE-92  | 215                  |
| PPAC-A4  | 220                  |
| PPAC-C4  | 225                  |

* indicates a significant difference.
An example of modeled yield vs achieved yield at ACRE and PPAC

Across 33 site-years of data at ACRE and PPAC maximum yield was predicted at 201 bu/acre vs actual yield of 204 bu/acre
Crop N requirement

• Based on expected yield x the concentration of N in the above-ground plant at physiological maturity (expressed on a bushel of grain basis)
Stanford, N factor

• Yield target (bu/ac) x plant N concentration (1.2 lb N/bu)

• Based on experiments conducted from 1946 through 1960 in GA, MS – 3 years each; NE – 4 and 2 years at 2 locations
Regional N management project

Nitrogen rates

0 to 280 lb N ac\(^{-1}\) in 40 lb N ac\(^{-1}\) increments, all at planting or 40 lb N ac\(^{-1}\) at-planting and the remainder at V9.

Hybrids

Several used based on location

16 locations across 8 states 2014-2016
Corn is less efficient at higher N rates in producing grain per unit of N content.
Determine EONR for each location

**Tracy loamy sand**

- **EONR**

Grain yield, bu/a

- $y = -0.0018x^2 + 0.8496x + 131.86$ ($R^2 = 0.9946$)
- $y = -0.0016x^2 + 0.6954x + 151.23$ ($R^2 = 0.9417$)

Total nitrogen, lb/a

- All at-planting
- 40 lb N/a at planting
- 80 lb N/a at planting

Shafer, 2016
Efficiency at the optimum is key
Variation in IE@EONR across 30 sites resulted in ~90 lb N/a range in plant N

<table>
<thead>
<tr>
<th></th>
<th>Bushel per lbs. N</th>
<th>lbs. N per bushel</th>
<th>Yield Goal</th>
<th>Plant N at harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least effic.</td>
<td>0.83</td>
<td>1.20</td>
<td>200</td>
<td>240</td>
</tr>
<tr>
<td>Most effic.</td>
<td>1.30</td>
<td>0.77</td>
<td>200</td>
<td>154</td>
</tr>
<tr>
<td>Avg.</td>
<td>1.07</td>
<td>0.93</td>
<td>200</td>
<td>187</td>
</tr>
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</table>

Shafer, 2016
IE@EONR was related to plant N content at VT when no fertilizer was applied – soil N supplying capacity

\[ Y = -0.002x + 1.230, \ R^2 = 0.41, \ P \leq 0.05 \]

Shafer, 2016
Variation in crop N requirement

• Assuming yield is predictable, IE can vary enough to cause meaningful difference in crop N requirement

• Variation in IE was related to soil N supplying capacity, but not EONR, Yield@EONR, soil OM, or most indices of adequate and well-distributed rainfall
Mineralization of soil N

• Soil N – microbial release of N from soil organic matter, microbial biomass, and crop residues. Perhaps release of ammonium ($\text{NH}_4^+$) form the interlayer of 2:1 clay minerals

• Soil N can contribute a significant portion of the N accumulated by the crop in some soils

• Substantial differences can arise from year to year in soil N contribution
Grain yield without fertilizer N

101 Indiana trials, corn after soybean
Nitrogen mineralization

• **Field** - N uptake by corn fertilized with ~25 lb N/acre as 2x2 starter was used to assess soil N mineralization in 2015 season

• **Laboratory** - N mineralization potential was determined under temp. and moisture conditions for expt. areas at 6 locations after 10 years of corn/soybean rotation
Field evaluation
Crop N content at maturity with starter-only

Moser, 2016

<table>
<thead>
<tr>
<th>Location</th>
<th>Total plant N at R6 (lb acre⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Lafayette</td>
<td>O.M. 4.0%</td>
</tr>
<tr>
<td>Farmland</td>
<td></td>
</tr>
<tr>
<td>Columbia City</td>
<td>b</td>
</tr>
<tr>
<td>Wanatah</td>
<td>a</td>
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<tr>
<td>Butlerville</td>
<td>a</td>
</tr>
<tr>
<td>Lafayette</td>
<td></td>
</tr>
</tbody>
</table>

O.M. 4.0%  3.6%  2.9%  4.1%  2.8%  2.7%
Laboratory incubation
N release after 50 days under ideal temp. and moisture

Total inorganic N (mg kg\(^{-1}\))

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<tr>
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<tr>
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<td>Wanatah</td>
<td>100</td>
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<td>Butlerville</td>
<td>220</td>
</tr>
<tr>
<td>Lafayette</td>
<td>50</td>
</tr>
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O.M. 4.0% 3.6% 2.9% 4.1% 2.8% 2.7%
Moser, 2016
Nitrogen mineralization decreases above and below field capacity
Yields with starter-only were greater in soils with better internal drainage.

\[ y = 365.54x + 2733.6 \]

\[ R^2 = 0.58 \]
Yield and Excess Water

Moser, 2016

Ksat (μm/s)
- DPAC: 3.1
- ACRE: 8.6
- TPAC: 9.6

R² = 0.431
R² = 0.83
R² = 0.70
Yield and Excess Water

- **Ksat (μm/s)**
  - SEPAC: 8.0
  - PPAC: 14.1
  - NEPAC: 8.6

- **Starter-only grain yield, bu/acre** (Moser, 2016)
Summary

• Yield-goal based and model-driven N recommendation systems attempt to estimate N requirement by predicting
  • \((\text{yield per acre} \times \text{total plant N content per bushel of grain anticipated minus soil N}) / \text{an efficiency factor}\)
Yield

• The range in yield from an available N recommendation model varied 50 bu/acre, sometimes high sometimes low

• All other things being equal the N requirement based on yield can vary by approximately 50 lb N/acre
Nitrogen content per bushel

• Assuming yield is predicted accurately and all other things are equal

• Variation in plant N content per bushel at the optimum N rate can vary as much as ~0.45 lb N per bushel which would result in a 90 lb N per acre variation in plant N content at a yield of 200 bu per acre
Soil N mineralization

• Soil N mineralization can provide little to all of the N accumulated by the crop at physiological maturity.

• In a particular field year-to-year variability ranged from 40 to 100 lb N acre$^{-1}$.
Conclusion

• Variation in currently difficult to predict factors suggest that static yield-goal based N recommendations systems can at best estimate fertilizer N requirement no better than 40-50 lb N/acre in Indiana systems which is no better than experimentally-derived N recommendations.

• Models should be thoroughly tested with existing data to evaluate whether or not they can do better.
Questions?