Alternative Approaches to Predicting Corn N Adequacy

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Problem Statement

• Nitrogen deficiency is difficult to diagnose because of the range in internal N use efficiency (IN) experienced during a given growing season.

\[ \text{IN} = \frac{\text{grain yield}}{\text{total N uptake}} \]

• Critical plant or leaf N concentration, \([N] = \text{g N/g tissue}\), is subject to variations in both N uptake and dilution caused by changes in tissue weight with age, hybrid or seasonal/site dependent internal N use efficiency.
Corn Yield and N Uptake

Maize (avg. 1.4% N in grain, 1.2% N in DM)

Maize

\[ Y = -3710 + 995 x^{0.5} \]

Boundary of maximum N dilution

NC region, n=470
ARE THERE RELIABLE NITROGEN DIAGNOSTIC CRITERIA?

• Maize leaf photosynthesis and radiation use efficiency is optimized at a canopy leaf N content of 1.5 g N m\(^{-2}\) leaf.

• Biomass yield vs. N content has been shown to be a tightly conserved relationship within C4 and C3 species.
  – \%N(C4)=4.1(DM)\(^{-0.5}\)  \%N(C3)=5.7(DM)\(^{-0.5}\)
“GREENWOOD” CURVE

Light energy

N associated with Chlorophyll

Specific leaf weight (g/m²)  A < B
N concentration (g N/g leaf)  A > B
Chl. concentration (umol/g leaf)  A > B
Specific leaf N (g N / m² leaf)  A = B
Specific Leaf Chl.(umol/m² leaf)  A = B
Radiation Use Efficiency (g / MJ)  A = B
Data from nine site-years and six hybrids
OBJECTIVES

- Compare differences among corn hybrids and population density in leaf development, leaf nitrogen and chlorophyll content in relation to N stress.
- Determine threshold diagnostic criteria for N sufficiency in maize.
- Test the ability to predict N sufficiency using “diagnostic leaf” measurements of specific leaf chlorophyll.
Materials and Methods

- **Experiment 1:**
  - 2 IRRIGATED SITES
    - Mead, NE – Typic Argiudoll sicl, pc=Soybean
    - Clay Center, NE – Typic Argialboll sil, pc=Maize
  - 4 HYBRIDS (113 d RM) @ 28,000 pl acre⁻¹
    - P-33A14-Bt  P-33R88-Bt  DK632  GH2581-Bt
  - 4 NITROGEN RATES 0, 80, 160, 240 kg N ha⁻¹

- **Experiment 2:**
  - 3 POPULATIONS – 30, 37 and 44 thousand pl acre⁻¹
  - 2 LEVELS OF FERTILITY MANAGEMENT
    - M1 - 138 kg N ha⁻¹ (2 splits)
    - M2 - 298 kg N ha⁻¹ (4 splits) + P and K
Measurements

- **Destructive plant sampling @ 5 stages**
  - V8, V15, R1, R4, R6
    - 45, 65, 78, 98, 135 dap (Mead, NE)
    - 51, 71, 85, 104, 142 dap (Clay Center, NE)

- **Parameters** (1 m row)* (12 m row)†
  - **LAI** – Leaf area index (m² m⁻²)
  - **SLW** – Specific leaf weight (g m⁻²)
  - **SLNₜₚ** - Whole plant specific leaf N (g N m⁻²)
  - **SLCHwp** - Whole plant spec. leaf chlorophyll (umol chl m⁻² leaf)
  - **LNla** – Leaf N / land area (g N m⁻² land area)
  - **TN**† – Total N uptake (g N m⁻²)
  - **GY**† – Grain Yield (12 m row)
  - **SY**† – Stover Yield (12 m row)
"Diagnostic" leaf measurement

**UEL** - Uppermost expanded leaf
- V8, V12, R1, R4

**Ear Leaf**
- R1, R4

- $SLW_{dl} \text{ g/m}^2 \text{ leaf}$
- $SLN_{dl} \text{ gN/m}^2 \text{ leaf}$
- $SLCH_{dl} \text{ umol chl/m}^2 \text{ leaf}$

SPAD-502 Chlorophyll meter

# SPECIFIC LEAF WEIGHT

<table>
<thead>
<tr>
<th>N RATE kg N/ha</th>
<th>V8</th>
<th>V15</th>
<th>R1-UEL</th>
<th>R1-Ear</th>
<th>R4-UEL</th>
<th>R4-Ear</th>
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<tbody>
<tr>
<td>0</td>
<td>48.00</td>
<td>50.34</td>
<td>54.07</td>
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<td>160</td>
<td>50.10</td>
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<td><strong>58.07</strong></td>
<td><strong>67.08</strong></td>
<td><strong>58.04</strong></td>
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</tbody>
</table>
Hybrid Effects

Experiment 1

- **Grain Yield, bu/acre**
  - Mead, NE
  - Clay Center, NE
- **Leaf Area Index, m²/m²**
  - Mead, NE
  - Clay Center, NE

- **Nitrogen Rate, kg/ha**
  - Site x Hybrid
  - Tassel stage
  - Hybrid

- **Hybrid Varieties**
  - P-33A14
  - P-33R88
  - DK - 632
  - GH-2581
CHANGE IN LEAF NITROGEN

Mead, NE

SLNwp (gN m$^{-2}$ leaf)

0 N Rate
80 N Rate
160 N Rate
240 N Rate

Clay Center, NE

0 N Rate
80 N Rate
160 N Rate
240 N Rate

Mead, NE

LNla (gN m$^{-2}$ land)

Clay Center, NE

Day of Year
Regression (Linear Plateau) estimates of “threshold” values of whole plant SLN. Colored symbols are observations on or above the “Greenwood” curve.

V8

\[ y = -0.648 + 0.939x \]
\[ r^2 = 0.04 \text{ (SLN}_{\text{crit}} = 1.62) \]

V15

\[ y = -0.366 + 0.864x \]
\[ r^2 = 0.61 \text{ (SLN}_{\text{crit}} = 1.52) \]

R1

\[ y = -0.167 + 0.740x \]
\[ r^2 = 0.63 \text{ (SLN}_{\text{crit}} = 1.52) \]

R4

\[ y = -0.431 + 0.941x \]
\[ r^2 = 0.65 \text{ (SLN}_{\text{crit}} = 1.46) \]
Regression (Linear Plateau) estimates of “threshold” values of leaf N / land area. Colored symbols are observations on or above the Greenwood” curve.
Predicted $\ln_{10} a = a + b(SLCH_{dl}) + c(LA1)$. Line is 1:1.
## POPULATION EFFECTS

<table>
<thead>
<tr>
<th>Stage</th>
<th>Popul. 1000pl acre (^1)</th>
<th>Leaf Area Index m(^2) leaf m(^2) land</th>
<th>Specific Leaf N g N m(^2) leaf</th>
<th>Leaf N/land area g N m(^2) land area</th>
<th>N management level (^1)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>M1</td>
<td>M2</td>
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<td>V6</td>
<td></td>
<td></td>
<td>M1</td>
<td>M2</td>
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<td>30</td>
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<td>Pop**</td>
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<td>M1</td>
<td>M2</td>
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<td>Man**</td>
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<td>Pop x Man</td>
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</table>

\(^1\) M1 = 138 kg N ha\(^{-1}\) (split pre-plant and V6 stage)
M2 = 298 kg N ha\(^{-1}\) (split pre-plant, V6, V10 and V14 stage)
CONCLUSIONS

- Although differences in yield and leaf development were observed among hybrids, there was no direct effect of hybrid on leaf N and chlorophyll status.
- Both $\text{SLN}_{wp}$ (g N m$^{-2}$ leaf) and $\text{LN}_{la}$ (g N m$^{-2}$ land) are good diagnostic measures of maize N status.
- Grain yield was optimized at a whole plant specific leaf N $\geq 1.5$ g N m$^{-2}$ from mid to late vegetative stage and into reproductive stages. (Muchow and Sinclair)
CONCLUSIONS

- \( \text{LN}_{\text{la}} \) seems superior to \( \text{SLN}_{\text{wp}} \) as a predictor of N status at early vegetative growth stages. This suggests that \( \text{LN}_{\text{la}} \), a population dependent diagnostic, more accurately reflects ecosystem N supply than individual whole plant SLN.

- Maize N status in our study also fit the “Greenwood” curve implying a consistent and conserved relationship between biomass yield and N content of C4 plants.
• Prediction of maize N status with nondestructive measurement of a diagnostic leaf (i.e. SPAD) will depend on specific calibrations for leaf stage, age and canopy density.

• The ability to nondestructively predict maize N status from diagnostic leaf measurement was improved when variation in LAI was removed.
CONCLUSIONS

• Remote sensing of canopy N status will most likely be improved when sensing devices that adequately measure canopy biomass and LAI are coupled to algorithms that relate canopy reflectance to SLN.