Soybean Nutrient Uptake, Partitioning, and Removal

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Adam P Gaspar
CA.M. Laboski, S.L. Naeve, S.P. Conley

Background and Justification

- Soybean nutrient uptake and partitioning models are primarily built from work conducted in the 1960’s......

Objectives and Primary Questions

- Our objective is to determine soybean nutrient requirements with modern genetics and production practices across a range of yield potential environments.

- Total plant nutrient uptake
- Nutrient partitioning through the growing season
  - How this varies as yield changes?
- Peak nutrient uptake periods and rates
- Nutrient remobilization during grain fill

NP Study Description

- Environments: 2 years at 3 locations with non-limiting fertility levels
  - Arlington, WI
  - Hancock, WI *irrigated
  - St. Paul, MN

- RCBD in a split-plot arrangement with 4 reps
  - Whole Plot: Early and late May Planting Dates
  - Split Plot: 8 Pioneer Varieties (RM 1.0-2.5)
    - P10T02R
    - P10T03R
    - P10T09R
    - P10T91R
    - P19T01R
    - P19T09R
    - P19T69R
    - P19T51R

Yield Range Attained

- Min = 42 (3,608)  Avg. = 66 (4,421)  Max = 110 bu a⁻¹ (5,483) (kg ha⁻¹)
Total Biomass Collection

 Partitioned plant parts for each sampling stage.

<table>
<thead>
<tr>
<th></th>
<th>Stems</th>
<th>Petioles</th>
<th>Leaves</th>
<th>Pods</th>
<th>Seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>VE</td>
<td>×</td>
<td>×</td>
<td></td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td></td>
<td>×</td>
<td>×</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>×</td>
<td>×</td>
<td></td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>R5.5</td>
<td></td>
<td>×</td>
<td>×</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>R6.5</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>R8</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
</tbody>
</table>
| *Fallen Petioles and Leaves collected every 3 days from R1-R8.

- **Nutrients Quantified:** N, P, K, S, Ca, Mg, Zn, Mn, B, Cu, Fe, Al, and Na
- **240 plots comprised of 6700 tissue samples analyzed**

**Results**

- Analyzed across the whole yield range and a high and low yield level.
- **High** = >5,034 kg ha\(^{-1}\) (5,483 kg ha\(^{-1}\) avg.)
- **Average** = 4,421 kg ha\(^{-1}\) (whole data set)
- **Low** = 2,689 – 4,027 kg ha\(^{-1}\) (3,608 kg ha\(^{-1}\) avg.)
- *We will focus on N and K*

**Nitrogen Uptake**

Table 8. Total N uptake regression over seed yield equations and N uptake, within each environment, at the mean seed yield.

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Linear Regression (\text{N} = A + B(Y))</th>
<th>Standard error</th>
<th>(\text{N}) uptake (\text{kg ha}^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>ARL</td>
<td>25.3 (0.054) (0.87) (8.0) (265.7\ d)</td>
<td>7.9 (277.4\ c)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HAN</td>
<td>36.9 (0.054) (0.82) (8.0) (277.4\ c)</td>
<td>7.9 (277.4\ c)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STP</td>
<td>16.6 (0.054) (0.89) (7.7) (257.1\ e)</td>
<td>9.0 (299.0\ a)</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>ARL</td>
<td>68.6 (0.054) (0.74) (9.0) (309.0\ a)</td>
<td>8.7 (270.8\ d)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HAN</td>
<td>30.3 (0.054) (0.75) (8.3) (257.1\ e)</td>
<td>9.0 (299.0\ a)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STP</td>
<td>46.8 (0.054) (0.78) (8.3) (287.3\ b)</td>
<td>8.7 (270.8\ d)</td>
<td></td>
</tr>
</tbody>
</table>

- Similar slope between all environments, but individual environments will still vary at any specific yield level.
- **4,421 bu/a yield level**
  - Salvagiotti showed uptake of 0.079 \(\text{kg N kg}^{-1}\) grain = 350 lbs N
  - However they used older genetics, their lower bound matched ours exactly

**Nitrogen Partitioning: Low**

Uptake after R5.5 = 29.7%

69% of veg. N is remobilized after R5.5

**Nitrogen Partitioning: High**

Uptake after R5.5 = 40.1%

67% of veg. N is remobilized after R5.5
Changes in Veg. Remobilization and Uptake

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|| Shift in N supply | Current | 1960's |
|---|---|---|
| Vegetative N Remobilization to Grain | 68% | 55% |
| % of Total N Uptake after R5.5 | 35% | 25% |

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Compared to Hanway and Weber (1971) this suggests a fundamental difference in seed N supply dynamics where old varieties and production practices not only resulted in a greater percentage of N taken up before R5.5, but also less efficient remobilization of this vegetative N to the seed.

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N Uptake Rate

- Less time in lag phase for greater early season uptake, higher peak rate and longer duration and higher late season rates.

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Nitrogen Harvest Index

Table 10: Nitrogen harvest index (NHI) regression over seed yield equations and NHI, within each environment, at three different seed yield levels.

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Linear Regression†</th>
<th>Standard Error</th>
<th>Yield level (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NHI = A + B(Y)</td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>ARL</td>
<td>77.6</td>
<td>0.0021 b²</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>HAN</td>
<td>74.3</td>
<td>0.0023 b</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>STP</td>
<td>72.8</td>
<td>0.0030 ab</td>
<td>3.3</td>
</tr>
<tr>
<td>2015</td>
<td>ARL</td>
<td>63.7</td>
<td>0.0032 ab</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>HAN</td>
<td>73.4</td>
<td>0.0024 b</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>STP</td>
<td>63.6</td>
<td>0.0041 a</td>
<td>4.6</td>
</tr>
</tbody>
</table>

- Slopes are not similar, but show increasing NHI as yield increases at all environments.
- Is there a possible max NHI near 90%?

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Nitrogen Removal

- Average seed N content of 6.02%, DM basis.

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Nitrogen Summary

- Total N uptake varied by environment and was substantially less than previous reports at a specific yield level. (0.054 kg N kg⁻¹ grain)
  - This was due to variation in the NHI and greater NHI compared to previous reports (~90%). Also NHI increased with seed yield.
  - Also due to fundamental shift in seed N supply dynamics where current varieties and production practices are much more efficient users of N
- Improved yields are associated with a shorter duration in the lag phase of early season N uptake, a higher peak N uptake rate, extended peak uptake period, and greater late season uptake amounts and rates.
- While N remobilization capacity has increased, higher yields place a greater reliance on more N uptake past R5.5 rather than remobilization.

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The Soy Report

www.coolbean.info
@badgerbean
thesoyreport.blogspot.com