Nitrogen and Soybeans

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2009 Area Soil, Water, and Nutrient Management Meetings
Outline

• Nitrogen budget of soybean field
• Review of nitrogen and soybean research
  – List of review papers on last slide
• Updates to the “soybean N credit”
Nitrogen Budget

INPUT

OUTPUT

UPTAKE
Nitrogen budget of soybean field

- **Output** = N content of grain
- **Review of 57 studies** (Salvagotti et al., 2008):
  - Average yield = 40 bu/ac
  - N concentration of grain = 6.34%
  - 3.8 lb of N is removed with 1 bu of yield
Nitrogen budget of soybean field

- **Input** = Biological N fixation
- Symbiotic relationship between bacteria (*Bradyrhizobium*) and plant

Nodules house the bacteria
Nodulation process

- Bacteria infect root hairs
- First nodules form 1 week after planting
- Active $N_2$ fixation begins @V2-V3
- Highest $N_2$ fixation occurs R5/R6
- Soybeans can regulate this process – lack of available nitrogen triggers the nodulation process
N2 fixation is not a free lunch!

- Requires energy
- \( \text{N}_2 + 3\text{H}_2 + \text{energy} = 2\text{NH}_3 \)
- Microbes obtain this energy from carbohydrates
- Photosynthetically-derived carbohydrates from plant
- Thus, it is more energy efficient to take up available soil nitrogen from organic matter, manure, or fertilizer application
Nitrogen budget of soybean field

- Uptake = Plant available nitrogen in the soil + biological N fixation
- 58% of total N uptake comes from N2 fixation (36 to 74%; Salvagotti et al., 2008)
- 5 lb of uptake per 1 bu yield
N Budget in Soybean Field

[Graph showing nitrogen budget in soybean field with outputs and inputs indicated.]
Nitrogen budget of soybean field

• Soybean phase of rotation is N neutral (inputs=outputs)

• Are there any benefits to N fertilizer application?
Fertilizer N vs. N fixation

Adapted from Marshner 1995
Fertilizing soybean with N

Overall consensus:

- Applying N can delay nodulation, reduce the amount of N$_2$ fixation, or both
- Has been shown to be beneficial in very specific circumstances
Fertilizing soybean with N

Potential options:

- Preplant
- Early season “yellowing”
- During high N demand stage
- Manure applications
Preplant N application

• This is an attempt to boost early season soybean growth before nodulation develops
Preplant N application

- **No clear benefit on most soils**
- Research conducted in MN, IA, and WI does not suggest this is a beneficial strategy

- Potential benefit: when soil has low ability to provide N in early season (low residual N, low soil organic matter)
- No such scenarios have been identified in WI
Early season yellowing


N application would only further delay nodulation –

Some level of N stress is required for symbiotic relationship to fully develop
In-season application

• Results in MN, SD, IA, and IL do not suggest that this is a recommended practice for this region
• Small percentage of studies show yield increase
• This yield increase is rarely economic
In season application

- Potential benefit seen in irrigated soybeans (Kansas, Nebraska)
- High yield potential (> 65 bu/ac)
- Extra N supplements during high N demand periods

<table>
<thead>
<tr>
<th>Yield (bu/ac)</th>
<th>Total N uptake (lb/ac)</th>
<th>N₂ fixation (lb/ac)</th>
<th>N from soil (lb/ac)</th>
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</thead>
<tbody>
<tr>
<td>70</td>
<td>460</td>
<td>267</td>
<td>193</td>
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Manure application

• Studies in IA – yield increase of 0 to 7 bu/acre
• Studies in MN – yield decrease of -3 to increase of 9 bu/acre
Manure application

- Unclear what causes yield increase
  - Slow-release of ammonium from manure from mineralization
  - Lower negative impact on N\textsubscript{2} fixation reduction
- N application as manure does not appear to decrease yields
- Yield decrease attributed to incidence of white mold
- Other precautions:
  - salt injury to seed if manure applied near seed
  - enhancement of soybean disease – should be avoided in fields with history of white mold or damping off diseases
Constraints for soybean production

Black dot = no constraints for normal growth

All other responsive sites had limitations of: environmental stress (low temp, drought) or mismanagement (no inoculation, low pH)

Adapted from Salvagotti et al., 2008
N fertilization

• Response to N fertilization is often a result of something else suppressing yields
  – Stress conditions
    • Which you can’t control or predict
  – Inoculation and pH

• Proper inoculation and soil testing/lime application are better soybean management practices than N application
The bottom line...

- Is it possible to increase yields with fertilizer N additions in WI – yes
- Is it possible to increase net profits with fertilizer N additions in WI – not really
- No nitrogen source, rate, timing, or application method consistently improves productivity in soybeans
Soybean N “credit”

If the soybean crop is N neutral (inputs=outputs), how can there be a credit?
No longer a credit

Corn following soybeans has its own N recommendation, established independently of corn following corn N recommendations. It is a rotation effect.
Soybean rotation effect

- Research from Bundy and Schoessow determined that the rotation effect is not based on above ground biomass
- Soybean stubble was removed and had no impact on optimal N fertilizer rate for subsequent corn crop
- Forage legume credits are still based on above ground biomass
Soybean rotation effect

Possible causes:

- Change in N mineralization rate (below ground biomass?)
- Reduction in pest pressure through interruption of pest cycles.
- Enhanced corn root functioning in the year after soybean
- Changes in physical soil properties and moisture availability
Conclusions

• N application to soybean not recommended
• Manure application to soybean does not negatively impact yield
• New N recommendations for corn were designed specifically for corn-soybean rotations
Questions?

www.soils.wisc.edu/extension

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References