Nitrogen Mineralization and Uptake, and Effects of Cropping Systems on Nitrogen and Phosphorus Availability

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Questions for you

• What crops do you grow?
• What crops have you considered growing?
• Are your nitrate-N levels on fallow any different this year than last few?
Factors increasing ‘Nitrogen mineralization’ (Conversion of organic N to plant available N)

- Warm Temperature
- High Moisture
- Legumes as previous crop (vs small grain stubble)
- High Organic Matter
- Tillage - Why?

How did last late spring/summer compare to ‘normal’?

Take home message: soil N will vary year to year making soil testing essential for determining N needs
Timing of N Uptake

- Relevance: Affects Yield and Protein
What makes yield?

Heads/area $\times$ Kernels/heads $\times$ Weight/kernel
When are yield components “set”? 

- **Head/acre set**
- **Kernels/head set**
- **Weight/kernel set**
Impacts of nitrogen

**Nitrogen early**
- Number of tillers and kernels/head

**Grain protein from remobilized N**

**Nitrogen late**
- Weight/kernel
- Higher grain protein

**Growth Stages in Cereals**
- Stage 1: one shoot
- Stage 2: tillering begins
- Stage 3: tillers formed
- Stage 4: leaf sheaths lengthen
- Stage 5: leaf sheaths strongly erected
- Stage 6: first node of stem visible
- Stage 7: second node visible
- Stage 8: last leaf just visible
- Stage 9: ligule of last leaf just visible
- Stage 10: in "boot" (wheat)
- Stage 10.1: flowering (wheat)
- Stage 10.5: ripening
- Stage 11: ripening (wheat)
Spring Wheat N Uptake

Jacobsen et al. 1992
Effect of Slow Release N Fertilizer

• CAN increase establishment if N seed-placed (due to less seed germination problems, esp. in dry sandier soils)
• CAN increase protein
• CAN decrease yield (if soil N is low)
• CAN decrease N losses (volatilization, leaching), possibly increasing yield
Effect of N Rate and Source on Spring Wheat Protein

G. Jackson, 1993, WTARC Annual Report

N fertilizer topdressed after flowering

No significant N source effects at these 2 sites nor at Inverness or Loma
QUESTIONS?
As diversity of cropping system increases:

Efficiency of fertilizer use increases. Why?

Different rooting depths scavenge nitrogen and phosphorus at different depths.

Deep rooted crops can bring nutrients from subsurface to surface for use by shallow rooted crops (winter wheat → pea)
Some basics on effects of cropping systems on soil nitrogen (N)

Previous crop affects:

- Amount of N
  
  Small grain and oilseed stubble ties up N 
  Legumes release N

- Vertical distribution of N
  
  Depends on rooting depth and fallow frequency

- Timing of N release
  
  Spring vs winter crop 
  Legumes decompose quickly. Affected by harvest timing 
  Small grain and oilseed stubble slowly
Wheat needs less N when grown on fallow or winter pea than on barley.
Moccasin Cropping System/Tillage Study

Previous crop: Winter Pea (forage)  Spring Wheat  Spring Pea (grain)

Winter Wheat

Photo by C. Chen
Effect of Previous Crop and N on 2006 Winter Wheat Grain Yield (NT)

Moccasin, MT

Data from C. Chen

Nitrogen Units (lb N/acre)

WW Grain Yield (bu/acre)

Fallow

Spring Wheat

0 20 40 60 80 100 120

0 10 20 30 40 50 60
Effect of Previous Crop and N on 2006 Winter Wheat Grain Yield (NT)

Moccasin, MT

Data from C. Chen

Note: There was good moisture in 2006
Effect of Previous Crop on Residual Nitrate-N

Why different?

Spring Soil Nitrate-N (lb/ac)

Previous Crop

Fallow
Winter Pea
Spring Pea
Spring Wheat

C. Chen
Nitrogen Benefits from Legumes

• Peas and lentils CAN ‘fix’ about 2-4 lb N/bu. Ex: 50-100 lb N/acre for 25 bu crop.
• Over 1/2 of this is removed at harvest.
• N credit for NEXT CROP is between 0 and 20 lb N/acre. Where did rest go?
• If replacing a small grain or oilseed with a legume, bigger N savings will be in legume year.
• If replacing fallow with legume, bigger N savings will be in long-term.
Effect of Lentil on Spring Soil Nitrate-N Levels

Swift Current, SK
Zentner et al. 2004

<table>
<thead>
<tr>
<th>Year Range</th>
<th>Fallow</th>
<th>Lentil Green Manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988-1993</td>
<td>140</td>
<td>100</td>
</tr>
<tr>
<td>1994-1999</td>
<td>80</td>
<td>60</td>
</tr>
</tbody>
</table>
QUESTIONS?
Some basics on effects of cropping systems on soil phosphorus (P)

• Previous crop affects:
  - Soil moisture. Dry soil decreases available P.
    
    Sunflowers, safflower, corn, wheat, barley can use substantial amounts of water
    
    Legumes use similar amounts of water at shallow depth, but very little at deeper depth
  
  - Available P can be increased by:
    
    Legumes, buckwheat, and some mustards through root zone acidification
# Maximum Rooting Depths
(Mandan, North Dakota)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Maximum rooting depth (ft.)</th>
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</thead>
<tbody>
<tr>
<td>Dry Pea</td>
<td>3.0</td>
</tr>
<tr>
<td>Canola</td>
<td>3.5</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>4.0</td>
</tr>
<tr>
<td>Sunflower</td>
<td>4.5*</td>
</tr>
</tbody>
</table>

* 6 ft. in Montana (Miller, pers. comm.)

Merrill et al. 2002
What is More Important than Max. Root Length for Nutrient Uptake?

Dry pea will use more nutrients from surface; canola will use more from depth.

Merrill et al. 2002
P can accumulate near surface in both no-till and tilled systems.

Chen and Jones: Shallow rooted crops can scavenge P from near surface, increasing efficiency of P fertilizer.
Crop Species that Acidify Rootzone

Buckwheat  Legumes  Some Mustards
Root zone pH of four crops

- Barley
- Rape
- Buckwheat
- Lupin

Soil pH vs. Distance from root surface (mm)
QUESTIONS?
Effects of Diversified No-till Cropping Systems on Soil Nutrient Status

by Clain Jones and Perry Miller
Question

Are yield differences partly due to the effects of rotation on nutrient levels?
## Rotations

**Crop Diversification Rotation Study (Miller) 2000-2003**

<table>
<thead>
<tr>
<th>System</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
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</thead>
<tbody>
<tr>
<td>Organic</td>
<td>AWP fallow</td>
<td>WWheat</td>
<td>Lentil</td>
<td>Barley</td>
</tr>
<tr>
<td>NT Winter</td>
<td>Winter Pea</td>
<td>WWheat</td>
<td>RR Canola</td>
<td>WWheat</td>
</tr>
<tr>
<td>NT Spring</td>
<td>Pea</td>
<td>SWheat</td>
<td>RR Canola</td>
<td>SWheat</td>
</tr>
<tr>
<td>NT Diverse</td>
<td>Pea</td>
<td>WWheat</td>
<td>Hybrid Corn</td>
<td>Sunflower</td>
</tr>
<tr>
<td>NT CW</td>
<td>SWheat</td>
<td>WWheat</td>
<td>SWheat</td>
<td>WWheat</td>
</tr>
</tbody>
</table>
Dormant canola

Yellow pea
RESULTS
Critical Level

Olsen P

Critical Level

Olsen P (mg/kg)

0 5 10 15 20 25

Organic  NT WW-based  NT SW-based  NT Diverse  NT CW

a b a b ab
Effect of Available N on WW Yield

- Winter wheat grain yield (bu/ac)
- Fertilizer N + March nitrate-N (lb/ac)

- NTD2-H
- NTD2-L
- NTW2-H
- NTW2-L
- PFP2
- Org2
Effects of other Nutrients on Yield

Other nutrients also had no effect on winter wheat yield.

So what was causing large yield differences?
Effect of Plant-Available Water on WW Yield

Best fit line for NT rotations
P < 0.01
Study Summary

1) Some small but measurable differences were observed in soil nutrient concentrations between no-till rotations after 4 yr.

2) Spring based rotations may require somewhat higher fertilizer levels.

3) Nutrient concentrations did not appear to substantially affect winter wheat grain yield in 2004.

4) Grain yield was highly influenced by water, and hence water use of previous crop.
Conclusions

• Legumes can increase soil N, though mainly a long-term effect.

• Legumes, oilseeds, and buckwheat can acidify root zone, increasing P availability

• Crop rotations have relatively small effects on nutrient availability in a 4 year period, but effects likely increase with time.

• Diverse cropping systems can help use fertilizer more efficiently, especially when crops with different rooting depths are grown.
For additional information:

• Soil Fertility Website:
  http://landresources.montana.edu/soilfertility

• Cropping Systems Website:
  http://scarab.msu.montana.edu/CropSystems/
QUESTIONS?