Effects of Cropping Systems on Nitrogen and Phosphorus Availability

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Agronomy Workshop 2009, Baker
Questions for you

- What crops do you grow?
- What crops have you considered growing?
- How many of you primarily recrop?
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

- Timing of N release
  - Spring vs winter crop
  - Legumes decompose quickly
  - Small grain and oilseed stubble slowly
Effect of Previous Crop on N Needed to Optimize Wheat Yield

Wheat needs 0 to 45 lb/ac less fertilizer N when grown on fallow or 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

Note: There was good moisture in 2006

Data from C. Chen
Effect of Previous Crop on Residual Nitrate-N

Why different?
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.
- Benefit TO 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 Green Manure on Spring Soil Nitrate-N Levels

Swift Current, SK
Zentner et al. 2004

Sowing Nitrate-N (lb/acre)

Fallow
Lentil
Green
Manure
Fallow

1988-1993
1994-1999
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 possibly be increased by:
    Legumes, buckwheat, and some mustards through root zone acidification
P can accumulate near surface in both no-till and tilled systems.

Shallow rooted crops can scavenge P from near surface, increasing efficiency of P fertilizer.
## Maximum Rooting Depths
(Mandan, North Dakota)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Maximum rooting depth (ft.)</th>
</tr>
</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>

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.
Crop Species that Acidify Rootzone

Buckwheat  Legumes  Some Mustards
Rootzone pH of four crops
Mechanism for Acidification of the Rhizosphere

Plant Uptake

Ca$^{2+}$

H$_2$PO$_4^-$

Apatite

2H$^+$

Dissolves

Rock Phosphate

Rhizosphere
Effect of previous crop and rock phosphate on P uptake

- Big Sandy, Montana
- Organic farm
Effect of previous crop on winter wheat phosphorus uptake

<table>
<thead>
<tr>
<th>Previous Crop</th>
<th>Control</th>
<th>7 lb P$_2$O$_5$/ac</th>
<th>17 lb P$_2$O$_5$/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buckwheat</td>
<td>a</td>
<td>a</td>
<td>ab</td>
</tr>
<tr>
<td>Mustard</td>
<td>a</td>
<td>a</td>
<td>ab</td>
</tr>
<tr>
<td>Spring Pea</td>
<td>ab</td>
<td>ab</td>
<td>a</td>
</tr>
<tr>
<td>Tilled Fallow</td>
<td>ab</td>
<td>ab</td>
<td>a</td>
</tr>
</tbody>
</table>
Long-term Effect of Cropping System on Soil Fertility

• 1983 to 2004 near Culbertson, MT
• Comparing tillage and crop
• Small-plot field trial
• Soil samples:
  – Collected in October 2004, 4-6 weeks after fall tillage
  – Taken to 8 inch depth
Tillage and Crop Combinations

- **NT-CW**: No Till-Continuous Spring Wheat
- **SpT-CW**: Spring Till-Continuous Sp. Wheat
- **FSpT-CW**: Fall & Spring Till – Continuous Sp. Wheat
- **FSpT-WB/P**: Fall & Spring Till – Wheat/Barley (17 years), Wheat/Pea (4 years)
- **SpT-WF**: Spring Till – Sp. Wheat/Fallow

All residue was left on the field
Soil Total N

Culbertson, MT 2004
20 year study
Sainju et al. 2009
Soil tested in 2004
Why does fallow have less soil total N than recrop?

• Little to no plant N uptake in fallow year
• More rapid decomposition of residue
• Leading to greater potential for N loss to leaching
Potential N from Organic Matter

Culbertson, MT 2004
20 year study
Sainju et al. 2009
Potential N from organic matter (PMN) and microbial biomass N (MBN) are highest in SpT-CW. Why?

• In NT the residue may sit on the soil surface with minimal decomposition potential.

• In twice tilled systems, adding fall-tillage to spring tillage increases the decomposition of residue to plant available N sources – PMN and MBN are reduced more quickly.
Ammonium N

Culbertson, MT 2004
20 year study
Sainju et al. 2009
Nitrate N

Culbertson, MT 2004
20 year study
Sainju et al. 2009
Why does FSpT-WB/P have higher ammonium N than all the other treatments?

• Pea residue decomposes more rapidly than wheat and has higher N than wheat
• Incorporation by fall tillage enhances residue decomposition
Estimated N loss
Spring 1983 to Fall 2004

Culbertson, MT 2004, 20 year study
Sainju et al. 2009
N loss = Initial soil N + fertilizer N + surface residue N
- grain N - final soil N

N loss (lb/acre)

NT-CW  SpT-CW  FSpT-CW  FSpT-WB/P  SpT-WF

Not Avail
Why does fallow lose much more soil N than the other systems?

- No N uptake in fallow year
- Residue decomposition is more rapid because of higher soil moisture and perhaps soil temperatures
- N is not retained on site in plant residue
Soil Organic Carbon

Culbertson, MT 2004
20 year study
Sainju et al. 2009
Effect of Straw Removal

• If you bale and remove 3/4 ton residue per acre as straw

• Per acre this removes:
  
  750 lb C (value?)
  11 lb N = $11
  3 lb P₂O₅ = $3
  19 lb K₂O = $13

  Total = $27/ac

Using 2008 fertilizer prices

Oct. 2009 straw sold for $45/ton or ~$34 for ¾ t
Conclusions

• Adding legumes to rotation increases plant available soil N and may reduce fertilizer needs.
• Continuous cropping and reduced tillage increase stored soil N.
• Minimum till may increase plant available N, compared to NT.
• Fallow has high potential soil N loss to leaching, volatilization and N$_2$O emission. NT-CW stored 40 lb N/acre/year more than ST-WF by reducing N losses.
• Fallow reduces organic matter; organic matter increases with residue.
Other Resources

• Soil Fertility information: http://landresources.montana.edu/soilfertility
  Ex: Nitrogen Rate Economic Calculator

• MSU-Bozeman Cropping Systems: http://scarab.msu.montana.edu/CropSystems/
Questions?