Exercises 4, 5, 7, and 9

Prepared for Comprehensive Nutrient Management Planning Workshop
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Questions

• How many of you are certified crop advisers?
• How many of you have made manure management recommendations?
Goals Today

• Focus on nitrogen and phosphorus cycling and differences in their plant-availability

• Introduce fertilization concepts of sufficiency vs. build/maintenance

• Show how to use Fertilizer Guidelines and soil lab results to estimate fertilizer and/or manure needs for a variety of crops.

• Have you determine fertilizer rates given soil test data

• Leave time for questions (I’ll be asking some too)
Nutrient Reactions and Cycling

• Will focus on N and P because
  1) These have best chance of limiting yield and quality
  2) Rates of both are stipulated in Nutrient Management Plans, whereas most other nutrients are not. Why?
Exercise 4: Nitrogen (N) Cycling
<table>
<thead>
<tr>
<th>Nitrogen form</th>
<th>Molecular formula</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen gas</td>
<td>N(_2) (g)</td>
<td>Represents about 80% of the air we breathe but not available to plants</td>
</tr>
<tr>
<td>Ammonia gas</td>
<td>NH(_3) (g)</td>
<td>Volatilizes from animal manures; toxic at high concentrations</td>
</tr>
<tr>
<td>Ammonium</td>
<td>NH(_4^+)</td>
<td>Plant available, attracted to exchange sites on clay particles</td>
</tr>
<tr>
<td>Nitrate</td>
<td>NO(_3^-)</td>
<td>Plant available, very mobile, requires more energy by plant than NH(_4^+)</td>
</tr>
<tr>
<td>Nitrite</td>
<td>NO(_2^-)</td>
<td>Mobile, generally low concentrations, toxic to young mammals</td>
</tr>
<tr>
<td>Organic N</td>
<td>-</td>
<td>Generally highest pool of N in manure-slowly produces available N</td>
</tr>
</tbody>
</table>
Mineralization

Release of mineral N as organic matter (O.M.) is oxidized, releasing available N

Organic-N → Plant-Available N

Increased by:
• Higher moisture, temperature, and O.M.

MSU Fertilizer Guidelines assume 2% O.M.

<table>
<thead>
<tr>
<th>Soil O.M.</th>
<th>N fertilizer rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 3%</td>
<td>- 20 lb N/ac</td>
</tr>
<tr>
<td>&lt; 1%</td>
<td>+ 20 lb N/ac</td>
</tr>
</tbody>
</table>
Immobilization

Incorporation of available N into microbial cells or plant tissue

Plant-Available N → Organic-N

Occurs more with high C:N stubbles (ex: small grains) and less with low C:N stubbles (ex: legumes)

If leave more than ½ ton grain stubble, increase N by 10 lb/ac per ½ ton stubble.

How many work with producers applying manure to small grains?
N Fixation

- Nitrogen gas → Plant-available N
- Performed by *Rhizobia* on legumes, such as alfalfa
- Increased with
  - Good inoculation
  - Moderate moisture
  - Low soil N
  - High soil P and K

### N credits from legumes

<table>
<thead>
<tr>
<th>Previous crop</th>
<th>N credit (lb N/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa, sweet clover</td>
<td>40</td>
</tr>
<tr>
<td>Chickpeas, lentils, peas</td>
<td>0-20</td>
</tr>
</tbody>
</table>
Ammonia Volatilization

• $\text{NH}_4^+ \rightarrow \text{NH}_3\text{(gas)}$

• Volatilization of ammonia from manure depends on:
  - Type of animal
  - Storage (stacked, lagoon, time, etc.)
  - Environmental Conditions (next slide)

Rick will cover how to account for this loss in manure calculations.

IF want more information on ammonia volatilization from UREA, see Management of Urea Fertilizer to Minimize Volatilization (http://landresources.montana.edu/soilfertility) under Ammonia Volatilization
Factors Affecting Volatilization

1. Soil pH and Temperature
2. Wind
3. Cation Exchange Capacity (CEC). WHY?
4. Buffering capacity (resistance to pH change)
5. Soil moisture/humidity
6. Broadcast vs Incorporated
7. Ground cover/vegetation/residue. WHY?
8. Soluble and Exchangeable Calcium

Bottom line: Large number of factors make volatilization amounts VARIABLE and difficult to predict.
Soil pH and Temperature Effects on Relative Amount of Ammonia in Soil Solution

Ammonia (% of ammonia+ammonium) vs. pH

- ▲ 77 deg. F
- ■ 35 deg. F
Nitrification

- \( \text{NH}_4^+ \rightarrow \text{NO}_3^- \)
- Relatively fast (generally less than 2 weeks if greater than 50 deg. F)
- Only occurs under aerobic conditions
- Why important?
Denitrification

• $\text{NO}_3^- \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2(\text{gas})$

Occurs only under anaerobic conditions, though can occur in unsaturated surface soils, especially when manure is present. Why?
Phew! Enough chemistry!

QUESTIONS?
If you want more information on N cycling, go to MSU Extension’s publication on the topic at:

http://landresources.montana.edu/nm
Exercise 5: Nitrogen Rates and Recommendations
Need to know:

- Yield potential (Rick has covered)
- Soil nitrate-N in top 2 feet
- Previous crop, esp. if a legume

Soil N (lb/ac) = 2 x NO₃-N (ppm) x # of 6 in. depth increments

<table>
<thead>
<tr>
<th>Depth (in.)</th>
<th>NO₃-N (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>10</td>
</tr>
<tr>
<td>6-24</td>
<td>4</td>
</tr>
</tbody>
</table>

Soil N (lb/ac) = 2 x 10 x 1 + 
2 x 4 x 3
= 20 + 24
= 44 lb N/ac
Manure or Fertilizer available N = 
Needed available N – Soil N – N credit +/- N to 
account for O.M. if different than 2%

• Needed available N levels from MSU Guidelines 
(EB 161) for commercial fertilizers can be 
adjusted based on region, and knowledge of 
specific field.

• Can N rates for manure be adjusted if part of a 
CAFO’s CNMP?
How much N should be applied to grass?

Fertilizer Guidelines for Montana Crops (EB 161):

<table>
<thead>
<tr>
<th>Yield Potential (t/a) *</th>
<th>Available N (lbs/a) **</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
</tr>
</tbody>
</table>

Need to divide total N need by fraction of available N in manure and/or fertilizer to find total fertilizer need

http://www.montana.edu/wwwpb/pubs/eb161.html
• Rick will show how to determine how much manure N is plant-available.
Your turn to calculate N need

Crop: Orchard Grass, Irrigated
Yield potential = 3 t/ac
O.M. = 3.1%

Soil N data:

<table>
<thead>
<tr>
<th>Depth (in.)</th>
<th>NO$_3$-N (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>6</td>
</tr>
<tr>
<td>6-24</td>
<td>2</td>
</tr>
</tbody>
</table>

Soil N (lb/ac) =

N need (lb/ac) =
QUESTIONS?
What are available N needs for alfalfa-grass stands?

Fertilizer Guidelines for Montana Crops (EB 161)

<table>
<thead>
<tr>
<th>Yield Potential (t/a)*</th>
<th>80/20</th>
<th>60/40</th>
<th>40/60</th>
<th>20/80</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>30</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>60</td>
<td>90</td>
<td>120</td>
</tr>
</tbody>
</table>

Dilemma or problem with using alfalfa for manure application?
What if want to apply more manure, to the point of essentially stopping N fixation?

• Use N uptake figures in Table 21:

• Ex: 100% alfalfa, 4 ton/ac:
  
  • N uptake = (48 lb N/ton) (4 ton/ac)
  
  = 192 lb N/ac
If manure application is ‘Phosphorus-based’, what else might you need to add to maximize crop growth?
Your turn again

- Crop: Feed barley
- Yield potential: 80 bu/ac
- Previous crop: alfalfa (depleted stand)
- O.M. = 1%
- Soil N = 24 lb N/ac
- N needed from manure?
Exercise 7: Phosphorus Cycling
Movement of P is largely through erosion/runoff, NOT leaching. Why?

Why simpler than N cycle?
Precipitation/Dissolution

• Precipitation: The binding of two dissolved ions (ex: $\text{HPO}_4^{2-}$ and $\text{Ca}^{2+}$) to form a solid mineral (ex: monocalcium phosphate)

• Dissolution: The opposite of precipitation

What factors affect the amount of P precipitation?
Sorption/Desorption

- Sorption: The binding of an ion \((\text{HPO}_4^{2-})\) to a soil surface.
- Desorption: The reverse of sorption

What factors increase the amount of P sorption?
Soluble P concentrations in soil are generally very low (0.01 – 1 mg/L) due to:

1. Precipitation and low solubility of calcium phosphate minerals. This is very relevant in our region due to high pH, calcareous soils.

2. Strong sorption to aluminum, and iron oxides and hydroxides (example: rust). This process increases at low pH so is less of an issue here.

At what pH levels would you likely need to fertilize with more P?

pH 6.5 for optimum availability

Insoluble Fe/Al phosphates. Adsorption to oxides and clay

Insoluble Ca phosphates. Adsorption to CaCO$_3$

EXTENT OF RETENTION

Very High

High

Medium

Low

pH
Banding Phosphorus

Banding P is much more effective than banding N, because P is much more immobile in the soil.

Relevance to manure application?

Figure 7. The advantages of P banding are greatest when STP levels are very low (VL) to low (L). From Randall and Hoeft (1988).
If you want more information on P cycling, go to Nutrient Management Module 4 at:

http://landresources.montana.edu/nm
Questions so far?
Exercise 9: P recommendations
Why is the necessary sampling depth for N higher than for P in the MSU Fertilizer Guidelines?

• N fertilizer can easily move to 2 feet (and beyond) and the lower depths often have the majority of N.

• P fertilizer generally stays in upper ½ foot and P levels are often very low below there.
‘Sufficiency’ approach (MSU): Minimum needed, on average, to maximize yield in that year.
Why does yield potential affect N fertilizer guidelines, but not P guidelines?

• N is very soluble, so the amount of soil nitrate-N + available N added will have a direct effect on yield.

• P is very insoluble- It’s been found if the P soil test is greater than the ‘critical level’ (16 ppm), yield is not greatly increased by fertilizing more, regardless of yield potential.

If Olsen P = 16 ppm, and your client wants to really push yield goals, would you recommend more P than guidelines? Could you recommend more manure P based on DEQ requirements?
What table should I use?

**SUFFICIENCY APPROACH (MSU)**
- If Olsen P ≤ 16 ppm, use Table 18.
- If Olsen P > 16 ppm, use Table 21-crop removal amounts.

**BUILD/MAINTENANCE APPROACH**
- Add Table 18 values to Table 21 removals.
- Question: Is this approach allowed by DEQ for manure?
## Phosphorus

**Table 18. Phosphorus fertilizer guidelines based on soil analysis.**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Olsen P Soil Test Level (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>P Fertilizer Rate (lbs P₂O₅/a)</td>
<td></td>
</tr>
<tr>
<td>Alfalfa</td>
<td>140</td>
</tr>
<tr>
<td>Alfalfa-Grass</td>
<td>55</td>
</tr>
<tr>
<td>Barley-Feed/Malt</td>
<td>50</td>
</tr>
<tr>
<td>Bean</td>
<td>30</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>45</td>
</tr>
<tr>
<td>Canola</td>
<td>45</td>
</tr>
<tr>
<td>Corn-Grain</td>
<td>100</td>
</tr>
<tr>
<td>Corn-Silage</td>
<td>80</td>
</tr>
<tr>
<td>Flax</td>
<td>35</td>
</tr>
<tr>
<td>Grass</td>
<td>45</td>
</tr>
<tr>
<td>Lentil, Chickpea and Pea</td>
<td>35</td>
</tr>
<tr>
<td>Millet</td>
<td>40</td>
</tr>
<tr>
<td>Oat</td>
<td>45</td>
</tr>
<tr>
<td>Potato</td>
<td>170</td>
</tr>
<tr>
<td>Safflower</td>
<td>50</td>
</tr>
<tr>
<td>Soybean</td>
<td>60</td>
</tr>
<tr>
<td>Sugarbeet</td>
<td>85</td>
</tr>
<tr>
<td>Sunflower</td>
<td>35</td>
</tr>
<tr>
<td>Wheat-Spring</td>
<td>50</td>
</tr>
<tr>
<td>Wheat-Winter</td>
<td>55</td>
</tr>
</tbody>
</table>
# Phosphorus

<table>
<thead>
<tr>
<th>Crop</th>
<th>Olsen P Soil Test Level (ppm)</th>
<th>P Fertilizer Rate (lbs P\textsubscript{2}O\textsubscript{5} /a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Wheat-Spring</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>Wheat-Winter</td>
<td>55</td>
<td>50</td>
</tr>
</tbody>
</table>

**Example**

Winter wheat

Olsen P = 10 ppm

P\textsubscript{2}O\textsubscript{5} needed = 42.5 lb/ac
Your turn

• Soil test P = 65 ppm
• P index indicates P applied should not exceed crop removal
• Crop: Alfalfa/Grass (50/50), 4 t/ac yield
• Available P$_2$O$_5$ to add=?

Use Table 21:
P removed =
If you would rather use a web based calculator, Montana fertilizer guidelines are at:

http://www.sarc.montana.edu/calculators
Conclusions

• Nitrogen is much more soluble and mobile than phosphorus.
• Nitrogen levels are largely dependent on breakdown of organic matter.
• Phosphorus levels are low in Montana due to insoluble calcium-P minerals.
• Nutrient needs can be determined if know soil test levels of N and P, yield potential, and previous crop.
• Nutrient management with manure is not as straightforward as with commercial fertilizers.
Want more information on soil fertility?

Go to:

http://landresources.montana.edu/soilfertility