Nutrient Management for Forage Production

Herdsmanship School, Hall
February 5, 2019

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MSU Soil Fertility Extension
Why learn about soils?

• For good forage yields, and cover for livestock and wildlife
• To protect the environment
• For efficient use of resources (water, fertilizer, $)
Goals

• Cover soil fertility basics
• Show nutrient deficiency symptoms of P K S and micros on forages
• Review use of Fertilizer Guidelines to determine P and K rates on forages
• Present timing, source and placement considerations of P fertilization
• Illustrate yield and quality responses of hay to P, K, and S
• Help your bottom line
Some questions for you

Who has raised alfalfa-hay or grass hay?
Who has worked with pastures?
Who has grown annual forages (ex: Haybet barley, Willow Creek winter wheat)?
14 mineral nutrients have been found essential for growth of most plants:

<table>
<thead>
<tr>
<th>Macronutrients</th>
<th>Micronutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nitrogen</strong> (N)</td>
<td><strong>Boron</strong> (B)</td>
</tr>
<tr>
<td><strong>Phosphorus</strong> (P)</td>
<td><strong>Chloride</strong> (Cl)</td>
</tr>
<tr>
<td><strong>Potassium</strong> (K)</td>
<td><strong>Copper</strong> (Cu)</td>
</tr>
<tr>
<td><strong>Sulfur</strong> (S)</td>
<td><strong>Iron</strong> (Fe)</td>
</tr>
<tr>
<td><strong>Calcium</strong> (Ca)</td>
<td><strong>Manganese</strong> (Mn)</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>Molybdenum (Mo)</td>
</tr>
<tr>
<td></td>
<td><strong>Nickel</strong> (Ni)</td>
</tr>
<tr>
<td></td>
<td><strong>Zinc</strong> (Zn)</td>
</tr>
</tbody>
</table>

The macronutrients are simply needed in larger amounts by the plant than the micronutrients.

Nutrient deficiencies of the **bolded red** nutrients have been observed in Montana.

Today’s focus on N, P, K and S.
Nutrient inputs need to eventually balance ‘losses’

- Leaching (N, S)
- As gas (ammonia, or N$_2$)
- Erosion (wind and water)
- Harvest

<table>
<thead>
<tr>
<th>Nutrient removed in harvested crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Alfalfa/ton</td>
</tr>
<tr>
<td>Grass/ton</td>
</tr>
</tbody>
</table>

- Nutrient changing to unavailable form (N into microbial biomass, P tied up with minerals)
Soil test

- To identify nutrient deficiency and calculate fertilizer rates
- Can increase yield and/or save on fertilizer costs, and decrease environmental risks
- Best done in early spring, but not when soil is wet, therefore in our climate perhaps best done in late fall
- See publications listed at end for details on ‘how-to’
Soil test report for 2 fields near Hot Springs, Sanders Co.

<table>
<thead>
<tr>
<th>YOUR SAMPLE NUMBER (LAB NUMBER)</th>
<th>INTENDED CROP</th>
<th>YIELD GOAL</th>
<th>PREVIOUS CROP</th>
</tr>
</thead>
<tbody>
<tr>
<td>DON (31396506)</td>
<td>ALF/GRASS - ton</td>
<td>5.0</td>
<td>WHEAT WINTER</td>
</tr>
<tr>
<td>SCH 2C (31396507)</td>
<td>ALF/GRASS - ton</td>
<td>5.0</td>
<td>GRASS HAY - ton</td>
</tr>
</tbody>
</table>

Important info:
- Intended crop
- Yield goal
- Prior crop

<table>
<thead>
<tr>
<th>LAB NUMBER</th>
<th>NITRATE-N (FIA)</th>
<th>SURFACE</th>
<th>depth (in)</th>
<th>SUBSOIL 1</th>
<th>depth (in)</th>
<th>SUBSOIL 2</th>
<th>depth (in)</th>
<th>Total lb/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>313</em></td>
<td>ppm</td>
<td>lb/ac</td>
<td>(in)</td>
<td>ppm</td>
<td>lb/ac</td>
<td>ppm</td>
<td>lb/ac</td>
<td></td>
</tr>
<tr>
<td>96506</td>
<td>8</td>
<td>19</td>
<td>0-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>96507</td>
<td>5</td>
<td>12</td>
<td>0-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

To determine N rate you need:
1. Yield goal
2. Soil sample depth to convert ppm to lb N/acre
   (ppm x 2 x actual depth in inches / 6)
Soil test report for 2 fields near Hot Springs, Sanders Co.

- **K** important for alfalfa
  - K should be ~ 250 ppm
- pH impacts P availability
  - P binds w/ Ca at pH > 7
  - P binds w/ Fe at pH < 6
  - pH < 6 poor legume nodulation

- **P**: MSU guidelines are based on Olsen P.
  - Bray works in pH < 7.3
  - Olsen works pH > 6
  - Olsen P should be ~ 16 ppm
Questions?

On to fertilizer rates
To get the most out of your fertilizer investment

The 4 Rs:

• Right rate
• Right source (including legumes)
• Right timing
• Right Placement
How much fertilizer do I need to apply?

- N based on yield goal and soil tests
- P and K based on soil tests
  - Rate recommendations are provided by testing lab
  - Or from tables given in Extension bulletins
  - Or SARC MSU Fertilizer Recommendation [http://www.sarc.montana.edu/php/soiltest/](http://www.sarc.montana.edu/php/soiltest/)
- S based on prior crop performance, tissue tests and deficiency symptoms – soil tests not reliable
- Published rates are developed for entire state and sometimes based on neighbor state’s trials. They are likely not accurate for a particular field. Adjust based on which soil properties??
Focus of N or P and K depends on % legume in stand

Yield increases and net returns with N greatest if < 36% alfalfa in stand and soil N < 5 lb N/acre (Malhi et al. 2004)
Diminishing return of increasing N

Applies to all crops, example on irrigated western wheatgrass, Blaine Co.
P Deficiency Symptoms

1. Dark green, often purple
2. Lower leaves sometimes yellow
3. Upward tilting of leaves may occur in alfalfa
4. Often seen on ridges of fields
P rates

P guidelines for alfalfa and grass in MT based on soil analysis (Table 18 in EB0161 w/ alfalfa/grass revised).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Olsen P Soil Test Level (ppm)</th>
<th>P Fertilizer Rate (lb P$_2$O$_5$/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>140</td>
<td>110</td>
</tr>
<tr>
<td>Alfalfa/grass (50/50)</td>
<td>93</td>
<td>73</td>
</tr>
<tr>
<td>Grass</td>
<td>45</td>
<td>35</td>
</tr>
</tbody>
</table>

If soil test is above 16 ppm then use removal rate
Potassium (K)

Needed in Montana?

- Useful on many soils, even some having high K values (especially in spring)
- Improved alfalfa stand persistence, shoots per plant and rhizobia activity
- Reduces leaf drop of alfalfa
- Improved resistance to plant diseases
How might lack of K affect an alfalfa-hay field?

K helps reduce winterkill

Soil K 116 ppm (0-6”)
Manitoba, IPNI
K deficiency symptoms

1. Alfalfa – white spots on leaf edges
2. Grasses and corn – chlorosis and necrosis on lower leaves first. WHY?
   - K is mobile in plant
3. Weakening of straw-lodging in small grains, breakage in corn.
4. Wilting, stunted, shortened internodes.
## K rates

K guidelines for alfalfa and grass in MT based on soil analysis (Table 19 in EB0161, alfalfa/grass rates revised).

<table>
<thead>
<tr>
<th>Crop</th>
<th>K Soil Test Level (ppm)</th>
<th>K Fertilizer Rate (lb K$_2$O/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>240</td>
<td>205</td>
</tr>
<tr>
<td>Alfalfa/grass</td>
<td>192</td>
<td>165</td>
</tr>
<tr>
<td>(50/50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td>80</td>
<td>70</td>
</tr>
</tbody>
</table>

If soil test is above 250 ppm then use removal rate.

To avoid toxic luxury consumption by first cutting, apply $\frac{1}{2}$ the rate after first cutting and rest after last cutting for following year.
Relative alfalfa yield vs soil test K

\[ y = -0.00157x^2 + 0.55x + 40 \]
\[ r^2 = 0.82 \]
Questions?
Alfalfa response to P

- P can be ‘banked’ for several years.
  - A single 100-400 lb P$_2$O$_5$/ac on alfalfa produced similar yield, protein and profit as same amount divided over 5 annual applications (Malhi et al. 2001).
- Alfalfa more likely to respond if soil levels low.
Response to broadcast MAP depends on soil P level

Irrigated alfalfa
Iron County, UT, Koenig et al. 2009
Marginal return on P by rate and source

Koenig et al. 2009 - Iron County, UT
P rate = lb P₂O₅/acre,
spring broadcast/sprayed
$400/ton MAP and APP, $100/ton hay

APP = fluid ammonium polyphosphate (10-34-0)
Single P application increases alfalfa yield for 4 years (N, K, and S had minimal effect).

Location (Olsen P)

- **Geyser (6.2 ppm)**
  - $0-0-0-0$
  - $50-0-50-25$
  - $50-100-50-25$

- **Moore (5.2 ppm)**
  - $50-100-50-25$

Total 4-yr Alfalfa Yield (ton/acre)

- $560/ton 11-52-0$
- $150/ton hay$
- $46/ac/yr profit$

One single application $\text{FF27 and Wichman unpubl. data}$
Phosphorus and potassium for new seedings

- Base rates on soil tests
- Build up soil P and K levels prior to seeding for several years worth
- Additional P and K seed placed can increase seedling establishment
  - < 10-15 lb (N + K₂O)/acre to reduce risk to seedlings
  - < 25 lb 11-52-0/acre with seed
- Too much K can lead to luxury consumption by crop and risk of milk fever
Questions?

On to sulfur
Sulfur

- Eroded or coarse-textured soils are more susceptible to sulfur deficiency, particularly after high rainfall.
- Alfalfa is S deficient at tissue concentrations <0.25% (leaves from top 1/3 of plant at budding). For other forages contact testing lab or see our Extension documents.
- S > 0.30% can cause livestock health problem.
Sulfur visual deficiency symptoms

- Yellow or light green upper leaves
- Small thin stems
- Delayed maturity
- No characteristic spots or stripes

Images from IPNI
S influence on forage quality

- N conversion to protein requires S
- Increased S can lead to increased protein (FertFact #27) and digestibility, and reduced nitrate concentration (Westcott unpub data)
Sulfur maintenance

- Grazing removes less S than hay harvest
- S can be maintained by elemental S every few years
- 20 lb S/acre sulfate-S for in-season S deficiency in legume/grass mix
Provide S before mid-vegetative stage in alfalfa

Union, Oregon
Pumphrey and Moore 1965
Visual tissue assessment flow chart

Once tissues show symptoms, yields may be already hurt

In Nutrient Management Module 9
http://landresources.montana.edu/nm

Just the flow chart online at
http://landresources.montana.edu/soilfertility/nutrientdeficiencies.html
Questions?

On to N placement, timing, N-credit
Challenges to high N use efficiency in perennial systems, and N options

- Urea needs 0.5” water or tillage to incorporate N
- Plant residue
  - intercepts fertilizer
  - increases volatilization
  - can tie up N
- Surface band liquid N
- Polymer coated N works for extended forage season or late cutting
Urea placement affects Hays annual forage yield

Angvick et al. unpub data
Optimal timing depends on source

Readily available N (urea, UAN): shortly after **GRASS** green-up

- Slowly available N (manure, slow-release N)
  - take time to become available
  - apply well before needed – e.g. fall

Willamette Valley, Oregon, Hart et al. 1989
N Application considerations

Conventional

- Do not apply on snow, before heavy rains or snowmelt
- Apply and incorporate (nitrogen) shortly before plants ‘take off’ in the spring
- Broadcast N fertilizer needs to be incorporated by tillage or ½” water ‘event’
- Provide additional N mid-season if needed

Manure

- Incorporate in the fall or spread composted in the spring, once ground thaws, but before growth starts
- Do not apply on snow or frozen ground
- Consider the salt, weed seed, pathogen and potential herbicide content - know your source!

Other options?
Adding N – having alfalfa in mix may be best source of N

Malhi et al. 2002, Eckville, Alberta

17.5” avg annual and 10.5” May-Aug precip
Benefits of alfalfa depend on age of stand and years after termination

- **N benefits**
  - greatest in first year after alfalfa termination, then declines over next 6 years for small grain yields
  - greater and longer with alfalfa stands at least 3-4 yrs old

- **Non-N benefits** of greater water extraction are improved for about 5 subsequent small grain yrs
  - more important in drier subsequent crop yrs
  - greater from at least 2 year old alfalfa stands

Forster 1998 Univ. Manitoba thesis
## Recommended N credits in Montana

Fertilizer N (lb/ac) to back off from a standard recommendation

<table>
<thead>
<tr>
<th>Crop</th>
<th>N Credit (lb N/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse grain crop grown 1-2x</td>
<td>~10</td>
</tr>
<tr>
<td>Pulse grain crop grown 3+ times</td>
<td>~20</td>
</tr>
<tr>
<td>Pulse cover crop grown 1-2x</td>
<td>20-30</td>
</tr>
<tr>
<td>Pulse cover crop grown 3+ times</td>
<td>30-50</td>
</tr>
</tbody>
</table>
What affects amount of residue N becomes available?

• Slower in no-till than till, e.g., pea residue decomposition was 43% (NT) vs. 55% (till) in 1 yr
• Faster with higher residue N and phosphorus (P) concentrations
• Pulse cover crop decomposes faster than pulse residue (Lupwayi et al. 2004, north-central Alberta)

BUT: rapid nutrient release is not necessarily desirable because potential loss from system before uptake by next crop
Alternating pea-hay with wheat can save on N fertilizer costs especially when protein discounts are low.

Net return on 2 cycles of pea-hay with wheat on dryland (4-yr total lb N applied/acre)

<table>
<thead>
<tr>
<th>N rate and protein premium/discounts</th>
<th>4-yr net return $/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full N, low</td>
<td>291 lb N/ac</td>
</tr>
<tr>
<td>Full N, high</td>
<td>67 lb N/ac</td>
</tr>
<tr>
<td>1/2 N, low</td>
<td></td>
</tr>
<tr>
<td>1/2 N, high</td>
<td></td>
</tr>
</tbody>
</table>

Miller et al. 2015, Bozeman
Interseeding pea and barley within row produces higher total forage than species in separate rows.

Fact 35, 3 years at each location, N broadcast at barley 2-3 leaf stage.
N fertilizing pea/barley increases yield and protein, above 60 lb N/ac beware of high forage nitrate.

Ffact 35, 3 years at each location, N broadcast at barley 2-3 leaf stage.
Decision to fertilize

- Immobile nutrients can be banked – know soil test levels and if low, build up P and K when prices low
- If goal is low input, long-term sustainable production rather than prime quality hay, adequate P and K are key and cheaper than re- or interseeding
- If a field containing legumes will be rotated into a different crop soon, consider N for immediate yield gain
- If you need to buy hay or rent pasture, you should consider fertilizing
Conclusions

- Nitrogen, phosphorus, potassium, and sulfur can all produce growth responses in forage.

- Economic benefits often aren’t realized in the first year (so don’t base decisions on 1 yr studies!)

- Soil testing is essential for determining fertilizer needs.
Questions?

Additional info at: http://landresources.montana.edu/soilfertility

Photo by Ann Ronning