Fertilization of perennial legumes

Prepared for Park County, January 29, 2014

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Goals

1. Cover soil fertility basics
2. Show nutrient deficiency symptoms of P K S and micros on forages
3. Review use of Fertilizer Guidelines to determine P and K rates on forages
4. Present timing, source and placement considerations of P fertilization
5. Illustrate yield and quality responses of hay to P, K, and S
6. 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)?
There are 14 mineral nutrients that have been found to be essential for growth of most plants:

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

The macronutrients are simply needed in larger amounts by the plant than the micronutrients. I’ll focus on P, K, and S.
Why often deficient in Montana soils?

Binds with calcium to form poorly soluble calcium phosphate minerals
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
Potassium (K)

Needed in Montana?

Useful on many soils, even some having high K values (especially in spring due to cool temperatures)
K deficiency symptoms

1. Alfalfa – white spots on leaf edges
2. Corn and grasses – 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.
S deficiency symptoms

1. Upper leaves light green to yellow. WHY?
   S is immobile in plant

2. Small, thin stems

3. Low protein

4. Delayed maturity

5. No characteristic spots or stripes
Visual tissue assessment

MOBILE NUTRIENTS

Older or lower leaves affected
YES
Effects mostly generalized; plants dark or light green

NO
Effects mostly localized; chlorosis with or without spotting

YES
Plants dark green, often developing purple or red color

NO

PHOSPHORUS (P)

Plants light green with leaves light green or yellow; no necrotic spotting

YES

NO

NITROGEN (N)

Plants light green; necrotic spotting on leaves; pale leaves sometimes scorched, cupped or rolled

YES

NO

MAGNESIUM (Mg)

No interveinal chlorosis; chlorotic areas with a burning of leaf margins; spotting sometimes along leaf margins

YES

NO

POTASSIUM (K)

No interveinal chlorosis; distinct chlorotic and necrotic lesions (spotting) with abrupt boundary between dead and live tissue

YES

NO

* MOLYBDENUM (Mo)

* CHLORIDE (Cl)

* COPPER (Cu)

* ZINC (Zn)

* CALCIUM (Ca)

* MANGANESE (Mn)

IMMOBILE NUTRIENTS

Newer or younger leaves affected; symptoms localized

YES
Growing point (terminal bud) dies

NO
Growing point typically remains alive

YES

NO

BORON (B)

Young leaves of terminal bud become light green at bases; leaves become twisted and brittle and die back at growing point; chlorosis of young leaves

NO

Chlorosis without interveinal chlorosis

YES

NO

SULFUR (S)

Chlorosis without interveinal chlorosis

NO

NO

IRON (Fe)

Young leaves light green; typically no chlorotic spotting or striping

NO

NO

Sharp distinction between veins and chlorotic areas; spotty appearance

YES

NO

MANGANESE (Mn)

Chlorosis of young leaves; tips appear withered and will eventually die

NO

NO

Middle leaves with interveinal chlorosis; stunted growth

YES

NOTE: Since nickel (Ni) was only recently added as an essential nutrient, specific Ni deficiency symptoms are not well defined. Common symptoms include chlorosis and interveinal chlorosis in younger leaves.

In Nutrient Management Module 9
http://landresources.montana.edu/nm
Questions?
Focus of N or P and K depends on % legume in stand

- < 25 % legume treat as grass stand
- > 75 % legume treat as legume stand
- Yield increases and net returns greatest if < 36% alfalfa in stand and soil N < 5 lb N/acre (Malhi et al. 2004)
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
    - MAP is safer than DAP
- Too much K can lead to luxury consumption by crop and risk of milk fever
### 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 P₂O₅/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
Alfalfa response to P

- Alfalfa more likely to respond if soil levels low.
  - Irrigated alfalfa in Utah (Koenig et al 2009):
    Olsen P = 7.8 ppm (top 12”), minimal P response
    Olsen P = 4.0 ppm (top 12”), large P response

- 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).
Response to broadcast MAP depends on soil P level

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

Koenig et al. 2009 - Iron County, UT
2 site-years
P rate = lb P\(_2\)O\(_5\)/acre

Medium Olsen P
7.8 ppm (0-12 in.)

Low Olsen P
4.0 ppm (0-12 in.)
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

Medium Olsen P
7.8 ppm (0-12 in.)

Low Olsen P
4.0 ppm (0-12 in.)
P rate and source on yield

<table>
<thead>
<tr>
<th>Medium soil P</th>
<th>Low soil P</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

- P > no P
- MAP > APP
- full P > \( \frac{1}{2}P \)
Single P application increases alfalfa yield for 4 years (N, K, and S had minimal effect)

Wichman unpubl. data

Economics?

Location (Olsen P)

Geyser (6.2 ppm)

Moore (5.2 ppm)
What would you do?

Single large or smaller annual applications over 5 years?

@ $400/ton MAP and $100/ton hay
@ $1050/ton MAP and $100/ton hay
P fertilization for timothy hay

- On irrigated timothy hay in Alberta (Pfiffner et al. 2007)
- If P deficient then yield response equal with 5 annual broadcast applications of 26 lb P$_2$O$_5$/ac or single pre-seeding application of 174 lb P$_2$O$_5$/ac
QUESTIONS?
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 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 K₂O/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 (50/50)</td>
<td>192</td>
<td>165</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 ½ the rate after first cutting and rest after last cutting for following year.
Relative alfalfa yield vs soil test K

\[ y = -0.00157x^2 + 0.55x + 40 \]

\[ r^2 = 0.82 \]

Koenig 2001 WNMC
Relative alfalfa yield vs tissue K

soil tests appear better indicator of availability than tissue tests

Koenig 2001 WNMC

$y = -6.6x^2 + 27x + 50$

$r^2 = 0.14$
QUESTIONS?
Sulfur (S)

- Useful on sandy, acidic or low organic matter soils, especially after high rainfall (sulfate leaches)

- Tissue sampling is more reliable than soil testing. If < 0.22% S in top 6 inches of alfalfa during early bud stage then should get a yield increase with S.

- S > 0.30% can cause livestock health problem
Sulfur

- Visual symptoms and field history, or tissue concentrations determine S deficiency – soil tests are not reliable
- 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), or with N:S = 17:1.
- S > 0.30% can cause livestock health problem
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
- 45 lb S/acre annually sustains high alfalfa yield and protein (Manitoba, Malhi et al. 2004)
S influence on annual forage quality

N conversion to protein requires S

25 lb S/ac on dryland alfalfa and alfalfa/grass mix increased forage protein 0.8 points
Provide S before mid-vegetative stage in alfalfa

Union, Oregon
Pumphrey and Moore 1965
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 advice on 1 yr studies!)
- Soil testing is essential for determining fertilizer needs.
Keep eyes out for soon to be printed Extension Bulletins