Nutrient Management for Northern Forages

Tom Bruulsema, Phosphorus Program Director
The **International Plant Nutrition Institute** is supported by leading fertilizer manufacturers.

Its mission is to promote scientific information on responsible management of plant nutrition.
Typical Pennsylvania dairy farm

Marvin Hall, Pennsylvania State University
Perennial legume species
- lucerne and red clover (white clover and trefoil).

Often grown with one or two grasses
- timothy, bromegrass, cocksfoot, tall fescue.

2-4 cuts per year
- Bud to early flower stage of lucerne

Susceptible to winter conditions
- winter tolerance is an important factor.
Forage Production in Eastern Canada

• Typical forage mixtures (2 - 3 species)
  – Lucerne (9 kg/ha) + timothy (7 kg/ha)
  – Lucerne (9 kg/ha) + tall fescue (10 kg/ha)
  – Red clover (7 kg/ha) + timothy (7 kg/ha)

• Fertilization
  – P and K based on soil test
  – N: 30-160 kg/ha
    • Presence of legumes
    • Yield target

Gilles Bélanger & Gaëtan Tremblay, 2013
Agriculture & Agri-Food Canada
Timothy forage regrows better in Finland than in Canada

Gilles Bélanger & Gaëtan Tremblay, 2013
Agriculture & Agri-Food Canada
Interseeded clover cover crop in corn silage at time of harvest.

Photo: Paul Salon, NY NRCS
Preparing the Soil Before Planting Is Key

Prior to planting:

- Incorporate P for establishment of strong root systems, promoting rapid recovery, and maintaining healthy stands.
- Provide balanced nutrition: Adequate K, Ca, Mg, S, B, etc.
- Eliminate soil pH problems - alfalfa does not thrive in acid soils.
Alfalfa Root Development

• Most lateral roots are near the soil surface for the first year, but more deep lateral roots develop as the plant ages
• Alfalfa has lower root density than many grasses and a deeper rooting zone
• Nutrient applications increase root growth, enabling roots to obtain moisture and nutrients from greater volume of soil
Keys to producing good forage crops

- Fertilization with N, P, K
- Cutting regime

- Yield
- Persistence
- Quality
  - Crude Protein
  - Neutral Detergent Fiber (NDF)
  - NDF Digestibility
  - Soluble sugars
  - Ensiling quality (fermentability)
  - Nitrates

Gilles Bélanger & Gaëtan Tremblay, 2013
Agriculture & Agri-Food Canada
Hand held NIR instrument measuring quality of slice of hay bale. No grinding and instant results.

Marvin Hall, Pennsylvania State University
Nitrogen increases yield & protein but not NDF

Pour les stades début et fin épiaison

Digestibilité de la fibre NDF

Protéines brutes

Gilles Bélanger & Gaëtan Tremblay, 2013
Agriculture & Agri-Food Canada
N fertilization can reduce fermentation for silage

Pour les stades début et fin épiaison

Rendement (tonnes MS / ha)

Sucres solubles (% MS)

Pouvoir tampon (g acide lactique/ kg MS)

Fertilisation azotée (kg N / ha)

Gilles Bélanger & Gaëtan Tremblay, 2013
Agriculture & Agri-Food Canada
High N rates can increase nitrate accumulation in timothy forage

**Graphical Data**

- **Y-axis**: Concentration en nitrates de la fléole (% N-NO$_3$ base MS)
- **X-axis**: Fertilisation azotée (kg N / ha)

- **Labels**:
  - Aliment potentiellement problématique
  - Aliment sécuritaire

- **Data Points**:
  - Normandin, 1999
  - Lévis, 1999
  - Lévis, 2000

- **Legend**:
  - Aliment potentiellement problématique
  - Aliment sécuritaire
Grass forage may still show N deficiency in mixtures with legumes

Marvin Hall, Pennsylvania State University
## Rates of N recommended for hay meadows in Quebec

<table>
<thead>
<tr>
<th>Hay value ($/tonne)/Fertilizer Cost ($/kg N)</th>
<th>Dry Matter Yield Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 t/ha</td>
</tr>
<tr>
<td>200</td>
<td>160</td>
</tr>
<tr>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>100</td>
<td>45</td>
</tr>
<tr>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>

Guide de référence en fertilisation, 2ᵉ édition, CRAAQ
Forages Often Need Additional P

- Soil testing and tissue analysis can reveal need for fertilization.
- P fertilizer does not move far in soil:
  - Soil incorporation prior to planting is best
  - Top-dressed and irrigated P is suitable for subsequent fertilization
- P moves during freeze/thaw cycles, washes into soil cracks, and is taken up by shallow surface roots and crowns — and becomes available for plant uptake.
Yield response to added P most evident at first cutting.

Soil P fertility was maintained by small annual applications or a large one-time application.
P Source? Not a Significant Factor for Alfalfa Yields

• Four P sources compared (2 liquid, 2 solid):
  – Yield response to P fertilization (11 to 27% increase) under irrigation

No differences in P fertilizer sources

• Placement compared:
  – Surface banding or broadcast on established alfalfa stands

No yield differences due to fertilizer placement
Fléole des prés - Normandin

**Analyse (kg P$_{M-3}$/ha) = 51**

Recommandations: 17 – 26 kg P/ha

*Gilles Bélanger & Gaëtan Tremblay, 2013*  
*Agriculture & Agri-Food Canada*
Fléole des prés - Québec

Analyse (kg P M-3/ha) = 38
Recommandations: 17 – 26 kg P/ha
Flêole des prés - Finlande

Analyse (kg P M⁻³/ha) = 150
Recommandations: 0 – 11 kg P/ha

Dose de P (kg/ha)
0 10 20 30 40 50 60
Rendement en matière sèche (t/ha)1 2 3 4 5 6 7
2010
2011
2012
Maaninka (FI)
NS
NS
NS

Gilles Bélanger & Gaëtan Tremblay, 2013
Agriculture & Agri-Food Canada
How Potassium Moves in Soil

Forms of soil K:
- Unavailable
- Slowly available
- Readily available

SFM 5-9
In K-deficient alfalfa, small white or yellowish spots first appear around the outer edges of older leaves.
K Deficiency in Alfalfa

Moderate K Deficiency

Severe K Deficiency
Typical K Concentrations
(at optimum fertility)

- Stems near top of plant contain the most K
- Leaf K concentration is similar among upper and lower leaves
- Roots contain less K
- Forage containing 2.5% K removes 60 lb of K$_2$O per ton of dry matter harvested

<table>
<thead>
<tr>
<th>Plant part and growth stage</th>
<th>K, % on dry matter basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stems: near ground level</td>
<td>2%</td>
</tr>
<tr>
<td>Stems: near top</td>
<td>up to 6%</td>
</tr>
<tr>
<td>Leaves:</td>
<td>1.8 - 2.2%</td>
</tr>
<tr>
<td>Roots:</td>
<td>1.1%</td>
</tr>
<tr>
<td>Forage harvested at early bloom:</td>
<td>1.8% to 2.5%</td>
</tr>
<tr>
<td>Top 6 in. at bud to early bloom:</td>
<td>2.0% to 3.5%</td>
</tr>
</tbody>
</table>

Lanyon and Smith, 1985
K Concentration Declines with Maturity

Barton and Reid, 1977 (WV)
Soil Testing and Plant Analysis

• Soil Testing
  – Verify that K levels are being maintained
  – Soil pH 6.5 or higher for efficient N fixation

• Plant Analysis
  – Usually sample the top 15 cm at harvest
  – Indication of adequate K fertility:
    • <2% indicates insufficient K for winter hardiness
    • Optimum yields usually contain around 2.5% K
    • Record yield of 20+ t/ha had K content of 3%
K Improves More Than Yield

Adequate K Improves:
- Plant persistence
- Number of shoots per plant
- Shoot yield

Deficient K:
- Reduces root starch storage
- Reduces protein concentration in root
- Results in poor survival and slow shoot growth

Li et al., 1997 (IN)
K Helps Reduce Winterkill in Alfalfa

Plant counts taken in May as % of those previous September

<table>
<thead>
<tr>
<th>Year</th>
<th>No K</th>
<th>100 kgK/ha/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1972</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>1973</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>1974</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>1975</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>1976</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>1977</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Bailey, 1983 (MB)
Alfalfa Responses to K in Mixed Stands

- Largest where soil K fertility levels are low
- Increases over the life of the stand
- Includes quality as well as yield
  - Increased proportion of legume to grass $\rightarrow$ more protein
- Increases in irrigated production
The yield increase in response to K application gets larger as the alfalfa stand ages.
Proper Attention to All Nutrients Is Required for Healthy Plants and High Yield Levels

Berg et al., 2005; IN
Balanced P and K Nutrition Is Essential for Optimal Yields and Stand Maintenance
A stand of timothy that lasted 25 years !!!

- Trial started in 1960 in New Brunswick on sandy soil;
- Annual fertilization with 64 treatments: 4 levels each of N x P x K;
- 2 cuts per year;
- No herbicide or lime;
- Results from 1985-86:

Gilles Bélanger & Gaëtan Tremblay, 2013
A stand of timothy that lasted 25 years !!!

- Hay yields of 6-7 t / ha after 25 years without reseeding;
- 90% timothy

- Required balanced application of N + P + K:
  - N = 160 kg/ha
  - P = 44 kg/ha
  - K = 110 kg/ha
  - Ratio:  4 - 1 - 3

=  
  - N = 160 kg/ha
  - P₂O₅ = 100 kg/ha
  - K₂O = 130 kg/ha
  - Ratio: 2 - 1,2 - 1,6

Bélanger et al. 1989

Gilles Bélanger & Gaétan Tremblay, 2013
Placement and Application Options

• Establishment
  – Broadcast to build up soil test K before seeding
  – Banded starters should contain mostly P

• Maintenance
  – Apply following harvest to replace removal
  – High rates: split over several cuts to avoid salt injury
  – To boost winter hardiness, apply before critical fall growth period (before last 6 weeks of growth)
  – When soil K levels are high, spring applications can lead to higher K levels than desired, and may be unnecessary
Swine manure is like mineral fertilizer

<table>
<thead>
<tr>
<th></th>
<th>Grass dry matter yield, t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loam</td>
</tr>
<tr>
<td>Without fertilizer</td>
<td>5.04</td>
</tr>
<tr>
<td>+ Mineral fertilizer</td>
<td>6.42</td>
</tr>
<tr>
<td>+ Raw manure</td>
<td>6.14</td>
</tr>
</tbody>
</table>

Average of three years in Quebec; 80 kg N/ha in spring, 60 after first cut (Chantigny et al. 2007)
Right rate, right time, right place applies to all sources.
Forages for dry cows

- Hypocalcaemia
  - 5% of the cows, clinical level (milk fever)
  - 66% of the cows, sub-clinical
- Anionic salts vs. forages with low dietary cation-anion difference

Forages for dry cows

• How to produce forage for dry cows
  – Field with low soil available K
  – Timothy or reed canarygrass
  – Chloride fertilisation
  – Harvest at heading stage

• Forage for dry cows
  – Improves the capability of the cow to regulate its blood Ca level at calving
  – Without affecting DM intake
Luxury Uptake of K for Dairy Feed

• K in alfalfa varies from <1.5% to >3%
  – Luxury uptake when soil K is very high
  – K levels above 3% unnecessary
  – Liquid manure systems efficiently recycle K

• High K forage: A concern for dry dairy cows
  – Leads to milk fever, retained placentas after calving
  – For the transition period (2 to 4 weeks before calving) forage with <2% K desired; dietary K should be <1.2%
  – Corn silage, grains, distillers grains are low K feeds
  – Anionic salts (chlorides or sulfates of NH$_4^+$, Mg, or Ca) can help correct the problem
Imbalance between K and Mg in grass tissue can lead to grass tetany in cattle.
Enriching forages with Selenium

- Quebec soils can be low in Se
- Se may be added to feeds
- Can forage be enriched in Se?
- How is such forage utilized by the dairy cow?
Enriching forages with Selenium

✔ Applying 1 kg of Selcote Ultra®/ha (10 g Se/ha) allows production of timothy hay with more than 0.1 mg of Se/kg of dry matter.
Enriching forages with Selenium

Se is better absorbed and the levels of Se in serum and milk are higher when the dairy cow receives forage enriched in Se than when organic Se supplements are added to feed.

# Appendix 1. Best Management for Fertilizers on Northeastern Dairy Farms.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Best</th>
<th>Making Progress</th>
<th>Improvements Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RIGHT SOURCE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Credit nutrients from manure and composts</td>
<td>Analyze for total and available nutrients</td>
<td>Occasional or partial analysis</td>
<td>No nutrient credits considered</td>
</tr>
<tr>
<td>2. Credit N from previous crops</td>
<td>Adjust N rates based on research data for credits from previous crops, particularly legume hay or sod</td>
<td>Reduce corn N rates when following alfalfa</td>
<td>No consideration of N credits from previous crops</td>
</tr>
<tr>
<td>3. Choose a fertilizer nutrient source to suit the crop, soil, and placement</td>
<td>Source chosen to suit application method, blend compatibility, crop needs and sensitivities, and price</td>
<td>Compare anhydrous ammonia, urea, urea-ammonium nitrate, ammonium sulfate, and ammonium nitrate for price</td>
<td>No consideration of sources</td>
</tr>
<tr>
<td>4. Assess use of enhanced-efficiency N sources</td>
<td>Use controlled-release N or inhibitors to match N release to crop N needs where split application is impractical</td>
<td>Partial use of controlled-release sources or inhibitors</td>
<td>Not considered</td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Frequency</td>
<td>Testing Frequency</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>-----------</td>
<td>-------------------</td>
</tr>
<tr>
<td>5.</td>
<td>Measure soil nutrient supply</td>
<td>Soil analysis for pH, P, K, and other nutrients every 2 to 3 years</td>
<td>Most soils analyzed within past 5 years</td>
</tr>
<tr>
<td>6.</td>
<td>Maintain soil pH</td>
<td>Lime applied in fall whenever required</td>
<td>Lime applied occasionally</td>
</tr>
<tr>
<td>7.</td>
<td>Calculate nutrient removal and balance</td>
<td>Calculated from measured yield and nutrient content</td>
<td>Based on estimated yields and nutrient content</td>
</tr>
<tr>
<td>8.</td>
<td>Determine crop yield potential and nutrient demand</td>
<td>Measured yields from at least 5 past years</td>
<td>Measured yields from at least 3 past years</td>
</tr>
<tr>
<td>9.</td>
<td>Estimate most economic rates at current prices</td>
<td>Use a calculator based on regional crop response data</td>
<td>Use a generalized calculator based on price ratios</td>
</tr>
<tr>
<td>10.</td>
<td>End-of-season evaluation for appropriate N rates</td>
<td>Use late season cornstalk nitrate test or soil nitrate test</td>
<td>Monitored occasionally</td>
</tr>
</tbody>
</table>
### RIGHT TIME

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Frequency</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Assess split application to match crop nutrient uptake</td>
<td>Split applications used whenever practical</td>
<td>Partial use of split applications</td>
<td>Not considered</td>
</tr>
<tr>
<td>12. Crop scouting and plant analysis</td>
<td>Done regularly and systematically for each field</td>
<td>Occasionally done to diagnose problem areas</td>
<td>Rarely or never</td>
</tr>
<tr>
<td>13. Manage cover crop for optimum nutrient-release timing</td>
<td>Cover crop killed at optimum time for yield of following crop</td>
<td>Cover crop killed in fall</td>
<td>No cover crop</td>
</tr>
<tr>
<td>14. Assess optimum timing to suit tillage system</td>
<td>Fertilizer applications with conservation tillage or planting</td>
<td>Fertilizers applied before conservation tillage or planting</td>
<td>Not considered</td>
</tr>
</tbody>
</table>

### RIGHT PLACE

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Frequency</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Calibrate equipment for accurate metering and placement</td>
<td>Maintain and test application equipment annually</td>
<td>Equipment well maintained</td>
<td>Equipment functioning poorly; rate adjustment “seized”</td>
</tr>
<tr>
<td>16. Assess possibilities for with-seed and band placement</td>
<td>Banded or with-seed starter use based on soil test</td>
<td>Banding or with-seed starter for some crops</td>
<td>No equipment for directed placement</td>
</tr>
<tr>
<td>17. Management zones for variable rate application</td>
<td>Management zones based on multiple-year yield data</td>
<td>Zones delineated by expected productivity</td>
<td>Not considered</td>
</tr>
<tr>
<td>18. Apply soil survey information</td>
<td>Detailed soil survey maps available and in use for each field</td>
<td>Soil survey maps used for some fields</td>
<td>Soil survey information not used for any fields</td>
</tr>
<tr>
<td>19. Use risk indices to protect water quality</td>
<td>Use Nitrate Leaching Index and Phosphorus Index</td>
<td>Maintain unfertilized buffer of set width from watercourses</td>
<td>Full field practice to stream bank</td>
</tr>
<tr>
<td>20. Incorporate or inject volatile sources</td>
<td>Manure injected; urea banded or soil-incorporated</td>
<td>Manure incorporated within one day after application</td>
<td>Manure or urea surface-applied</td>
</tr>
</tbody>
</table>
4R: “right” = sustainable

Right source
Right rate
Right time
Right place

“Building public trust”
Cool Forages – key points

1. Many economic analyses show production of alfalfa to be at least as profitable as corn. Return on fertilizer investments that correct nutrient deficiencies can be expected to be high.

2. Perennial forages provide predictable nitrogen credits for following crops.

3. An on-line soil-crop-nitrogen modeling tool at www.NLOS.ca can improve understanding of nitrogen cycling and adapt its management to local weather conditions.

4. Perennial forages lose less nutrients in drainage water than annual crops, but a greater fraction of the phosphorus loss may be in the dissolved form.
Cool Forages – key points

5. Understanding the methods of testing for soil phosphorus can help predict crop response to applications of phosphorus, and the potential for its loss in drainage water.

6. The mysteries of variable response to applied sulfur are important for both the yield and the quality of forages.

7. Whole-farm nitrogen budgets can help identify changes in diets, species selection and grass harvest frequency that improve nutrient use efficiency on dairy farms.

8. Manure application timing and placement require innovative tools to optimize nutrient use.
Cool Forages – key points

9. Stand termination method and timing needs careful management to minimize potentially substantial losses of nitrate and nitrous oxide.

10. Carefully managed manure applications can effectively supply nutrients for alfalfa production.

11. Mineral balances to produce a quality of timothy grass hay appropriate for the calcium nutrition of the dry cow in transition can be achieved by cutting at the right growth stage, managing soil potassium levels, and applying chloride fertilizers.
Nutrient management of forages in cool climates requires attention to soil testing, plant analysis, nutrient balance, forage quality, and environmental impact. These contribute to defining the right source of nutrients to apply, and the right rate, right time and right place of nutrient application.