N Fertilizer Rates and Soil Acidification

Winter Series
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Image courtesy Rick Engel

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MSU Soil Fertility Extension
Objectives

1. Explain how to determine N fertilizer rates
2. Demonstrate the MSU N rate calculator, and adjustments to calculated N rates
3. Show impact of N fertilization and other factors on soil pH
4. Present ways to identify low soil pH
5. Discuss steps to prevent or reverse acidification

The Montana Fertilizer Check-Off and the Western Sustainable Agriculture Research and Education Program help fund our studies.
How much N fertilizer do I need to apply? Soil test

Soil nitrate-N: can vary greatly by year due to e.g. plant residue decomposition, leaching loss.

Fertilizer rate based on soil test results:

• Soil test ideally 2-3 ft.

• Best done in early spring, but not when soil is wet, therefore in our climate perhaps best done in late fall

• See MT200702AG and MT200803AG for details on ‘how-to’
Calculating N rates

Rates are based on soil test results and reasonable yield goal

- Provided by lab (check if they use MT rate guidelines)
- Guidelines & calculations in MSU MontGuides and crop specific bulletins

http://landresources.montana.edu/soilfertility/publications.html

- MSU soil test calculator
  http://www.sarc.montana.edu/php/soiltest/
More ≠ better: Law of diminishing returns

Yield increases with increasing N

Additional N does not produce any additional YIELD

Optimal N for 45 bu/ac yield

Applied N (lb/ac)

Soil N = 10 lb/acre, SOM = 2%

http://econtools.msuextension.org/nitrogen/
Because it’s not that simple:
MSU N Rate Econ Calculator

• Inputs
  • N fertilizer cost, grain price, protein discount/premiums
  • Yield goal
  • These help calculate **TOTAL** available N for max net return
  • Residual soil N
  • SOM

Calculators online for barley, SW, and WW after fallow
(and hopefully for recrop soon)

http://www.msueextension.org/econtools/nitrogen/
Soil N = 10 lb/acre, SOM = 2%, 45 bu/ac
Economically optimal N when discounts are high: protein discounts (15¢/0.25%) & premiums (10¢/0.25%)

Soil N = 10 lb/acre, SOM = 2%, 45 bu/ac

Economic optimal N for max yield

At MSU guideline of 3.3 lb N/bu, applied N would be ~140 lb N/ac

Net Revenue, $/acre

Economic optimal N at high prices ($6/bu) and N cost (50¢/lb)

Economic optimal N at low prices ($3.50/bu) and N cost (30¢/lb)

N for max yield

Net Revenue

Soil N = 10 lb/acre, SOM = 2%, 45 bu/ac
N rate adjustment: Fall soil tests can lead to over or under-fertilized fields

High N on shallow or coarse soil

High N crop residue and/or high O.M.

Mineralization

Over winter

High Precip

N leaching (or $\text{N}_2$ gas losses?)

Under fertilized

Over fertilized

Compare fall with spring a few times to see patterns of loss or gain for given pastures/rotation
N rate adjustments: prior crop

- Stubble: small grains stubble high carbon to N (C:N). Adjust fertilizer N up or down?
  - 10 lb N/1000 lb stubble up to 40 lb N
- Fallow: assume ½ of stubble has decomposed over previous year when adjusting
- After legume rotation: Adjust fert up or down?
  - Legumes credit (add) N

<table>
<thead>
<tr>
<th>Crop</th>
<th>N credit (lb N/acre)</th>
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<tbody>
<tr>
<td>Alfalfa</td>
<td>40</td>
</tr>
<tr>
<td>Annual legume 1 x</td>
<td>~10</td>
</tr>
<tr>
<td>Annual legume &gt;3 x</td>
<td>~20</td>
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Variable rate N application: Zone or site specific farming

- At this time economic advantage is inconsistent (and hard to study)
- At simplest, divide field into zones of low, med, high productivity
- NDSU has bulletin series on Zone farming SF1176 series at www.ag.ndsu.edu/publications

53B silt loam 0-4% slope
155F cobbly loam 15-60% slope
451C silt loam 4-8% slope

https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
Questions?

What are consequences of over fertilization?
Low soil pH: MT counties with at least one field with pH < 5.5

40% of 20 random locations in Chouteau County have pH < 5.5 in top 2"

Dec. 2018
Symbol is not on location of field(s)
Agronomic reasons for low soil pH

- Ammonium-based N fertilizer above plant needs due to nitrification:

\[ \text{ammonium or urea fertilizer} + \text{air} + \text{H}_2\text{O} \rightarrow \text{nitrate (NO}_3^-) + \text{acid (H}^+\text{)} \]

- Leaching loss of nitrate: less nitrate to take up = less root release of basic anions (OH\(^-\) and HCO\(_3^-\))

- Crop residue removal: removes Ca, Mg, K (‘base’ cations).

- Lack of deep tillage concentrates acidity where N fertilizer applied

- Legumes acidify their rooting zone through N-fixation. Perennial legumes (e.g., alfalfa) more so than annuals (e.g., pea). Yet apparently much less than fertilization of wheat.
14-yr of N fertilization reduce top 4” pH on dryland cropping west of Bozeman up to 1 pH

What rotations lower pH the least? The most?

Silt loam, 2% OM

Engel, Ewing, Miller, unpub data
6-yr N fertilization reduce soil pH (0-3”) west of Big Sandy

sandy clay loam, 1.1% OM

Alternate year was always winter wheat; Jones and Miller unpub data

why faster rate?
Low pH increases soil aluminum (Al) to toxic levels. pH where yield declines can occur. Engel unpub. data, 2016, 5 farms near Highwood, MT.
At pH < 4.8 → Al toxicity

- Unexplained poor health in low or mid-slope areas
- **Al** toxicity
  - stubby club roots, no fine branching (similar to nematode damage)

photo sources: Engel

Above ground symptoms of Al toxicity

- small leaves, short thick internodes
- yellow along margin near tip on older leaves
- purple or brown lesions in chlorotic regions, indentations
- leaf withering and collapse in center
Acid soils have additional negative impacts

- N fixation hurt below ~ pH 6
- Increase in some fungal diseases (e.g., Cephalosporium stripe) and root rot
- Change efficacy and persistence of chems

May be first indicators of pH change
Diagnose: scout, soil test

Look at pH on prior soil tests from composited samples

- pH < 6 likely have spots with pH ≤ 5
- 6 < pH < 7.5 don’t assume no areas have low pH
- pH > 7.5, likely don’t have problem (yet).

Symptoms are not uniform across field landscapes
Soil test

1. Scout or use aerial maps to locate healthy and unhealthy areas
2. Field pH test, use soil/water slurry of top 3”. Why not the standard 6”? 
3. Avoid compositing samples from different slope areas. 
4. Send 0-3” depth sample to lab for pH (<5?). Test 3-6” if might till. 
5. pH varies seasonally and annually, test from same area and time of year by same lab using same procedure to see trend
6. Veris can also sample for pH
Questions?

*On to prevention*
Management to prevent acidification:
Increase N fertilizer use efficiency

- Soil test close to application time. Make sure enough PKS
- Use conservative pre-plant rate, top-dress if adequate moisture
- Apply N close to peak crop uptake
- Use variable, site specific rates: Less N in low production areas limited by factors other than N (e.g., low pH, shallow soils)
- Reduce N rates especially when protein discounts low
- Takes steps to reduce N leaching (see our N Leaching Extension bulletin and MTGuide)
Management to prevent acidification:
Change N source?

- Use calcium ammonium nitrate (27-0-0; $$) instead of urea or UAN (CAN shouldn’t volatilize so can likely also lower rate)
- Include legume rotations, manure if available

Most acidifying
MAP = AS ≈ 2x urea
DAP (18-46-0)
Urea (46-0-0), UAN (28-0-0)
CAN ≈ 1/3x urea
Potassium nitrate (13-0-46)

Least acidifying
More preventive options

• Leave crop residue in field – retains base cations and SOM buffers pH changes and Al toxicity. 6x base cations removed by oat straw harvest than just oat grain harvest (Pierre and Banwart 1973)

• Legumes in rotation – no N fertilizer and residue increases soil surface pH more than non-legumes (Paul et al., 2003)

Which of these (or previous) might you try?
Perennial forage can maintain or increase soil pH

pH differs between crops with * > 90%, ** > 95%, *** > 99% confidence, Mandan, ND, Liebig et al., 2018
What else are people trying?

Questions?

On to adaptation and restoration options
Seed-placed $\text{P}_2\text{O}_5$: increased durum grain yield in one farm, no response another farm

Olsen P = 48 ppm

Olsen P = 53 ppm

Economics? Engel unpub data using Ag lime
Seed-placed $\text{P}_2\text{O}_5$ may or may not pay off

What to do?

Field strip trials

TSP $\$0.50$/lb $\text{P}_2\text{O}_5$

Grain yield, bu/acre

Net revenue, $$/acre

$pH$ 4.4

$pH$ 4.8

What to do?

Field strip trials

TSP $\$0.50$/lb $\text{P}_2\text{O}_5$
Adaptation: Select tolerant crop species. Legumes are least tolerant.

“Wheat high” are Al and acid tolerant varieties

MT variety trial results are available at [http://landresources.montana.edu/soilfertility/acidif/index.html](http://landresources.montana.edu/soilfertility/acidif/index.html)

Mahler and McDole 1987
Long pers comm
Restoration: liming

**pH Goal**
- > 5 to reduce Al toxicity
- > 5.5 to have some buffer, rhizobia health for N fixation
- > 6 to be good for 10+ years

The lower the soil pH, the more lime it takes to get to pH 6
- 10 acidic MT cropland soils tested, 6 shown here
- Incubated in lab with fine grade lime for 90 days
- pH 4 soil = 3-4 ton CaCO$_3$ → pH 6
- pH 4.7-5.4 soil = 1.75 ton CaCO$_3$ → pH 6

Engel unpub data
Restoration needs a lot of lime

- Rate:
  - Find from online tables (or your lab) with buffer pH and target pH
  - Or use MSU preliminary results
- Only lime field areas with low soil pH

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<tr>
<th>Initial pH</th>
<th>Ton SBeet lime</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>To pH 6.0</td>
<td>To pH 6.5</td>
</tr>
<tr>
<td>4.0</td>
<td>4.7</td>
<td>7.2</td>
</tr>
<tr>
<td>4.5</td>
<td>3.8</td>
<td>6.3</td>
</tr>
<tr>
<td>5.0</td>
<td>2.8</td>
<td>5.2</td>
</tr>
<tr>
<td>5.5</td>
<td>1.6</td>
<td>4.0</td>
</tr>
</tbody>
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Liming is a capital investment

Mahler and McDole 1987 yield decline curves
50 bu/ac yield potential, $6/bu grain, $35/ton lime + $10/ac to spread
low-pH tolerant wheat/low-pH sensitive durum rotation; 100 lb N/ac/yr
Lime sources

- Sugarbeet lime
  - Good – it doesn’t cost anything
  - Bad – shipping costs (up to $35/ton); challenging material to work with (moisture and clumping), need a wet lime spreader, contains chunks and some trash, and incorporation w/ tillage needed for best results
  - Rates of 3-6 tons/acre may be necessary to bring pH to acceptable level (pH > 6)

- Aglime – more expensive and further away

- Pelletized lime? Expensive and need about 400 lb/acre per year just to offset typical N rate.
Tillage?

• Inversion till to mix acid zone with higher pH zone below – one-time summer tillage doesn’t negate long term benefits of no-till (Norton et al., 2014)

• Problem: eventually make low pH zone deeper, when need to lime, requires more lime and deeper tillage. Will negate some no till benefits.
Summary

• Soil tests, the online economic N calculator and assorted publications are available to help determine N rates
• Cropland soils are becoming more acidic, largely due to N fertilization
• This reduces yields for several reasons
• Identify whether fields have a problem now to slow or prevent acidification with sound management
• Selecting crop rotations with lower N needs is likely best way to prevent further acidification
• Crop and variety selection or seed placed P fertilizer can help adapt to acid soils
• Liming or planting perennials can reverse acidification
Questions?

For more info. on soil acidification see MSU’s cropland soil acidification website
http://landresources.montana.edu/soilfertility/acidif/index.html

This presentation and more info. on soil fertility topics is available at
http://landresources.montana.edu/soilfertility