Soil Acidification: What have we learned

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MFAC supported

Photo courtesy – Joe Jensen, Dave Wichman, Shabig Briar – June 2015
Factors Affecting Soil Acidity

Increasing soil acidity in crop production systems is caused by (1) use of commercial fertilizers, especially \( \text{NH}_4^+ \) sources that produce \( \text{H}^+ \) during nitrification; (2) crop removal of cations in exchange for \( \text{H}^+ \); (3) leaching of cations being replaced first by \( \text{H}^+ \) and subsequently by \( \text{Al}^{3+} \); and (4) decomposition of organic residues.
Causes - Montana fertilizer N use - history

- Consumption of fertilizer N is up 3x since 1985
Project Components

- Surveys of farms in Chouteau County
- On-farm sugar beet lime trials (large field-scale)
- P fertilizer trials with & without Aglime (-,+) (small-plot)
- Questions & comments

Education and outreach
Project Components

Surveys of farms in Chouteau County

On-farm sugar beet lime trials (large field-scale)

Education and outreach

P fertilizer trials with & without Aglime (-,+), (small-plot)

Questions & comments
Chouteau County acidity survey

Summary

- spatial variance in soil pH can be very large within fields & over short distances
- typically lowest pH found in low lying areas, and/or foot slope position
Spatial gradients in pH – typical example

toe slope, bottom positions – low pH

summit positions – higher pH
Chouteau County acidity survey

Summary

- spatial variance in soil pH can be very large within fields & over short distances
- typically lowest pH found in low lying areas, and/or foot slope position
Crop production issues – Al toxicity

soil pH < 4.5 (0-3″)
Aluminum toxicity affected safflower - 2018
west Big Sandy
necrotic tissue and J-shaped effect
N-fertilizer legacy effect NW Big Sandy - Telstad loam

farmer acquired property with prior low N input
Daniels County tour – fall 2019

High fertilizer N inputs
pH 4.4 - 4.8

Low fertilizer N inputs
pH 6.2 - 6.8

Turner sandy loam
Project Components

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On-farm sugar beet lime trials (large field-scale)

P fertilizer trials with & without Aglime (-,+)(small-plot)

Questions & comments
What is sugar beet lime (spent lime)?

- Byproduct of raw juice purification process.
- Generated by heating quarried calcium carbonate limestone in a kiln to temperatures that >2,000 degrees Fahrenheit.
- Extreme heat results in production of CaO and CO$_2$, which is injected into raw juice. CaO binds to about everything in the raw juice (impurities) except sucrose. CaO then reacts with the CO$_2$ to form a calcium carbonate precipitate.

- Chemical characteristics
  - contains a lot of water (e.g. 30%)
  - organic matter (beet impurities)
  - CaCO$_3$ (75-80% of dry wgt)

- free – 0 $
Sugar beet lime – Western Sugar Co.

35$ per ton to ship to Chouteau County field sites

October 2017
Sugar beet lime – Western Sugar Co.

Stolzfus wet lime applicator
Sugar beet lime – Western Sugar Co.

October 2017

Stolzfus wet lime applicator
On-farm sugar beet lime strip trials

Lime app rates (each strip is 60’ wide)

Summary

• trials at three farms (Big Sandy, Fort Benton, N. Geraldine)

• grower cooperation with application of beet lime

• incorporation with tillage at two farms, one farm without
SB lime strip trials at Fort Benton - lentils

May 29, 2018 photo – lime applied Oct 31, 2017 + incorp with tillage
June 15, 2018

- Biomass = 384 lb ac⁻¹ (unlimed)
- Biomass = 570 lb ac⁻¹ (+ lime (4 ton/ac))

SB lime strip trials at Fort Benton - lentils
SB lime strip trials at Fort Benton - lentils

June 15, 2018

seed at harv =

unlimed

+ lime (4 ton/ac)

1371 lb ac\(^{-1}\)

1383 lb ac\(^{-1}\)
SB lime trial - N Geraldine - yellow peas
June 19, 2019

+ lime

- lime
SB lime trial - N Geraldine - yellow peas

Yield results - 2019

- lime = 23.3 bu/ac

+ lime = 30.0 bu/ac *
On-farm sugarbeet lime strip trials - soil pH results

Soil sampling approach

- GPS referenced points*
- collected before (fall 2017 & after lime application (fall 2018 & 2019)
- composite soil cores (0-2", 2-4", 4-6" and 6-8")

Lime app rates (each strip is 60’ wide)
Soil pH (0-4") as affected by sb lime vs. time

Summary points

- initial pH 4.55 - 4.90
- sugar beet lime is very reactive (effective) and soil pH changes (pH > 5) are observed soon after application
- 6 months > yr 1 > yr 2
- incorporation with tillage is important!
Sugar beet lime effect on $\Delta$ soil pH (1 yr, 2 yr)

Summary points:

- two locations
  \( \text{pH}_{\text{initial}} = \text{FB 4.6, NG 4.9} \)
- pH remediation year 1 > year 2
- 2.5 ton/ac required to change pH 1.3 units (pH target 6)
- seed-placed lime will likely not correct acidity problem
## Pelletized lime in furrow (PL) - Oklahoma

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Oct 2010</th>
<th>June 2011</th>
<th>June 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.9</td>
<td>4.8</td>
<td>4.7</td>
</tr>
<tr>
<td>200 lb/ac/yr PL</td>
<td>5.0</td>
<td>4.9</td>
<td>4.8</td>
</tr>
<tr>
<td>400 lb/ac/yr PL</td>
<td>5.1</td>
<td>4.9</td>
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</tr>
<tr>
<td>1 ton/ac Aglime + incorp.</td>
<td>5.9</td>
<td>5.5</td>
<td>5.3</td>
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### Soil pH (0-6”)

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**Source:** Lollato et al., 2013

### Summary

- Pelletized lime only ameliorated pH around band less effective than Aglime with incorporation
Soil pH profile 2 yr after liming with & w/o tillage

- lime does not wash/leach into soil profile – w/o tillage pH remediation will be confined to surface
Big Sandy trial
safflower showed no benefit from lime without tillage
Does a single tillage event affect SOC?

Summary

- A single tillage event (beavertail spike + harrow) did not destroy SOC.
- Consistent with long-term studies in Wyoming and Saskatchewan.

<table>
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<th>Depth</th>
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<tr>
<td>0-2&quot;</td>
<td>2.26</td>
</tr>
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<td>2-4&quot;</td>
<td>1.41</td>
</tr>
<tr>
<td>4-6&quot;</td>
<td>1.15</td>
</tr>
<tr>
<td>6-8&quot;</td>
<td>1.14</td>
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Fort Benton SOC post vs pre-tillage (2018 vs. 2017)
Sugar beet lime remediation – partial cost analysis

Cash outlay

• 2.5 tons of lime ac\(^{-1}\) required to achieve target pH 6
• 2.5 tons x $35 T\(^{-1}\) transport = $87.50 ac\(^{-1}\) cash outlay
• application cost = $12 ac\(^{-1}\) = $100 ac\(^{-1}\)

Soil chemistry – agronomic considerations

• 2.5 tons sugar beet lime = 2860 lb CaCO\(_3\) (55% CaCO\(_3\) equiv. @ 30% H2O)
• 2750 lb CaCO\(_3\) can neutralize the acidity produced from ~ 3300 lb urea
Sugar beet lime remediation - partial cost analysis

How long does the lime application last & amortized cost (3 examples)?

1. high input N crop system (e.g. continuous grain)
   - 200 lbs urea or 92 lb N/ac per year
   - 16.5 years = $100/ac/16.5 yr = $6.05/ac/yr

2. diverse crop system (grain-oil-pulse)
   - 61 lb N/ac per year – 25 years = $4.00/ac/yr

3. low input N system (e.g. wheat-fallow, wheat-pulse)
   - 50 lb N/ac per year – 33 years = $3.02/ac/yr
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Summary

- Large yield and growth benefits from seed-placed P at field sites with acidic pH and responsive to lime
Summary

- large yield and growth benefits from seed-placed P at field sites with acidic pH and responsive to lime
Aglime applic had a big effect on durum growth

Highwood Bench study, 2018

+ Aglime soil pH 6.1

- Aglime soil pH 4.4
Seeded-placed P can mitigate Al toxicity

Durum trials (cv. Alzada) – Highwood Bench

0 P (tissue P = 0.17%)

90 P₂O₅ (tissue P = 0.37%)

Soil P test was very high (Olsen P - 50 ppm)!
Seeded placed P can mitigate Al toxicity

Durum trials (cv. Alzada) – Highwood Bench

Soil P test was very high (Olsen P - 50 ppm)!
Seeded-placed P can mitigate Al toxicity

Summary

- soil acidity effect = 50% yield loss relative to + Aglime (5 ton ac\(^{-1}\))
- + P fertilizer = + Aglime yield & 22 bu ac\(^{-1}\) response!
- + P fertilizer is short-term solution & not remediation
- perhaps appropriate for leased land

**Durum trials (cv. Alzada) - 2018**

\[
y = 23.23 + 23.23 \times (1 - e^{-0.043x})
\]

- lime (pH 6.1)
- - lime (pH 4.4)

Yield, bu/ac

Phosphorus fertilizer (0-45-0), lb P\(_2\)O\(_5\)/ac
Seeded-placed P can mitigate Al toxicity

Summary

- similar effect to 2018, but trial impacted by two hailstorms (50% yield loss)

Durum trials (cv. Alzada) - 2019

Yield, bu/ac

Phosphorus fertilizer (0-45-0), P₂O₅ lb/ac
Summary – take home messages

- Montana cropland surface soils are becoming more acidic
- N fertilizer inputs are a big reason
  - no-till may have contributed to pH stratification (0-2” layer)?
  - problem is not unique to Montana

- Chouteau Co surveys revealed large gradients in pH with terrain and topography changes – soil sampling needs to be localize

- Al toxicity if soil pH < 5, maybe even lower pH < 4.5

- N fixation – pulses can be affected at soil pH < 6, a lot unknowns

- Management options exist to cope/adapt to this problem (seed-placed P, Al tolerant genotypes) but liming is only way to remediate acidity
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Questions & comments
Thank you