To Add or Not to Add? AGVISE Demonstration Project Update

2022 Soil Fertility Seminars

Jodi Boe
Agronomist, AGVISE Laboratories

Project background

- AGVISE in a unique position to initiate and complete long-term soil fertility projects
- Four projects have been initiated in 2020 or 2021

In agriculture, adding something seems like the right thing to do.

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In agriculture, adding something seems like the right thing to do.

https://www.thewinecompany.net/lutefisk/

https://www.landolakes.com/recipe/17394/clarified-butter/

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In agriculture, adding something seems like the right thing to do.

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% Base Saturation (Typical Range)				
% Ca	% Mg	% K	% Na	% H
(65-75) 71.3	(15-20) 26.2	(1-7) 0.9	(0-5) 1.6	(0-5) 0.0

"Low" %K

Low pH

Soil pH	Buffer pH
0-6" 5.2 6-24" 7.9	6.4

Carbonate(CCE)	5.6 %	*****************
0-6" Sol. Salts	2.82 mmho/cm	**********************

Soil pH
0-6" 7.9

High pH and High Calcium Carbonate

Olsen Phosphorus	3 ppm	******
Carbonate(CCE)	2.1 %	**********
0-6" Sol. Salts	2.86 mmho/cm	***********************

Low soil test P

Soil pH
0-6" 7.8

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We can't always fix a problem with the addition of something.

https://www.thewinecompany.net/lutefisk/

https://www.landolakes.com/recipe/17394/clarified-butter/

We can't always fix a problem with the addition of something.

AGVISE Projects:

1. Long-term elemental sulfur project (high soil pH)
2. Long-term potassium project (%K?????)

Sometimes we can fix a problem with the addition of something.

3. Long-term phosphorus project (low soil-test P)
4. Long-term liming project (low soil pH)

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Is there an easy way to lower high pH?

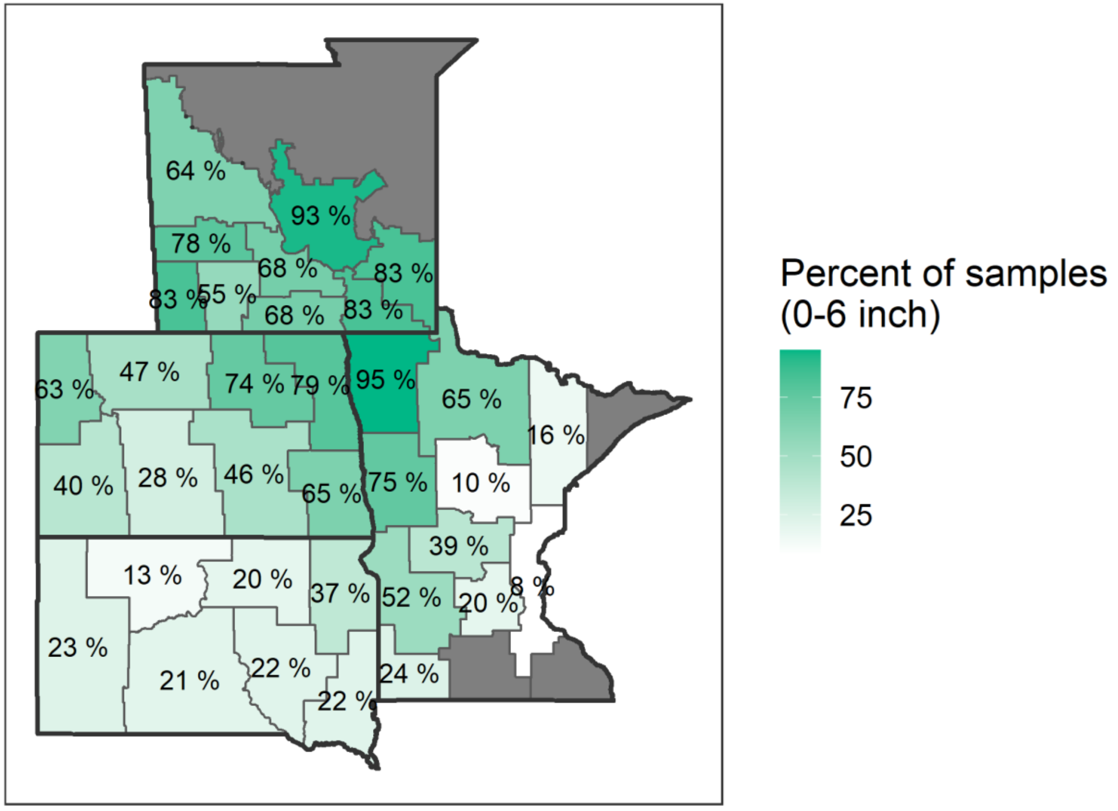
Carbonate(CCE)	5.6 %	*****************
Sol. Salts 0-6"	2.82 mmho/cm	************************

Soil pH
0-6" 7.9

High pH and High Calcium Carbonate

Is there an easy way to lower high pH?

Soil samples with soil pH above 7.3 in 2021



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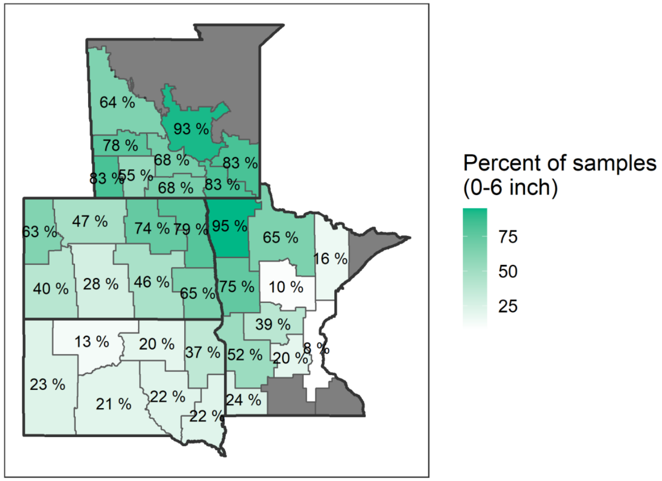
Is there an easy way to lower high pH?

- Soils in the Northern Plains and Canadian Prairies often have soils with high pH (>7.3)
  - Soils with free calcium carbonate ($CaCO_3$) will have a pH buffered around 8

Soil samples with soil pH above 7.3 in 2021



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- Elemental sulfur often marketed as an “easy solution” to reduce pH

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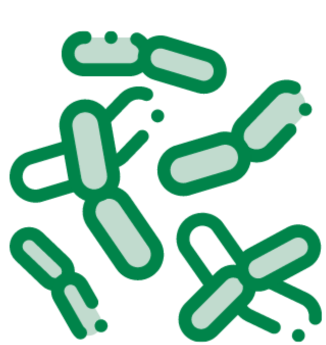
Picture from: https://www.amazon.com/Walts-Elemental-Sulfur-Pellets-10/dp/B016YYNMB4

The science behind lowering pH with elemental sulfur

- High pH soils have “free lime” ($CaCO_3$)
- Free lime must be neutralized before pH can be reduced
- When S^0 is applied to soil, it is oxidized by soil bacteria, forming sulfuric acid

+



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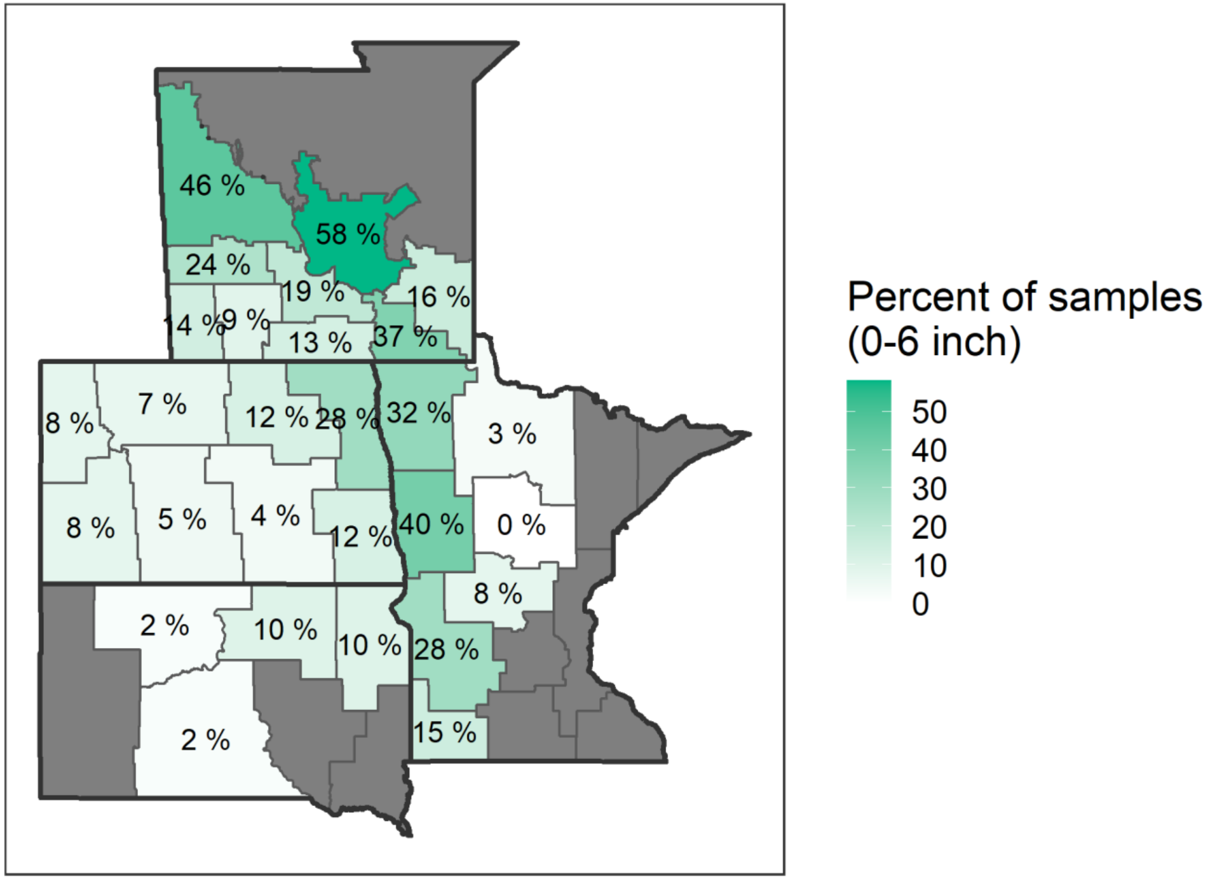
- Sulfuric acid produces H^+ ions, which can neutralize free lime in the soil
- Any other form of fertilizer sulfur (e.g. gypsum, AMS) is the sulfate form of sulfur and CAN NOT neutralize free lime

Soil samples with calcium carbonate above 5.0 % CCE in 2021



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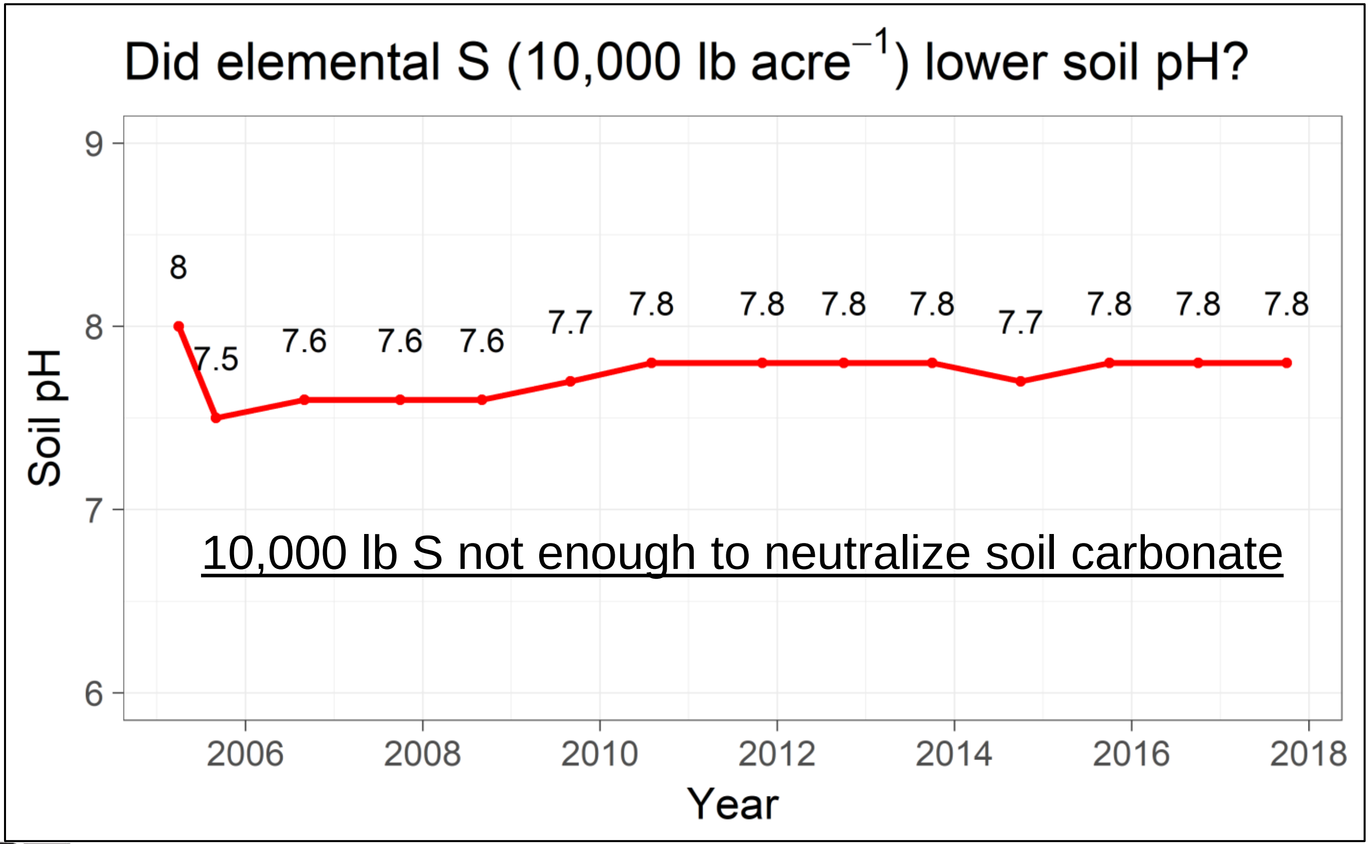
I only need about 100 lb/A elemental sulfur, right?

AGVISE Demonstration 2005-2017

Soil had 2.5% CCE, starting pH was 8

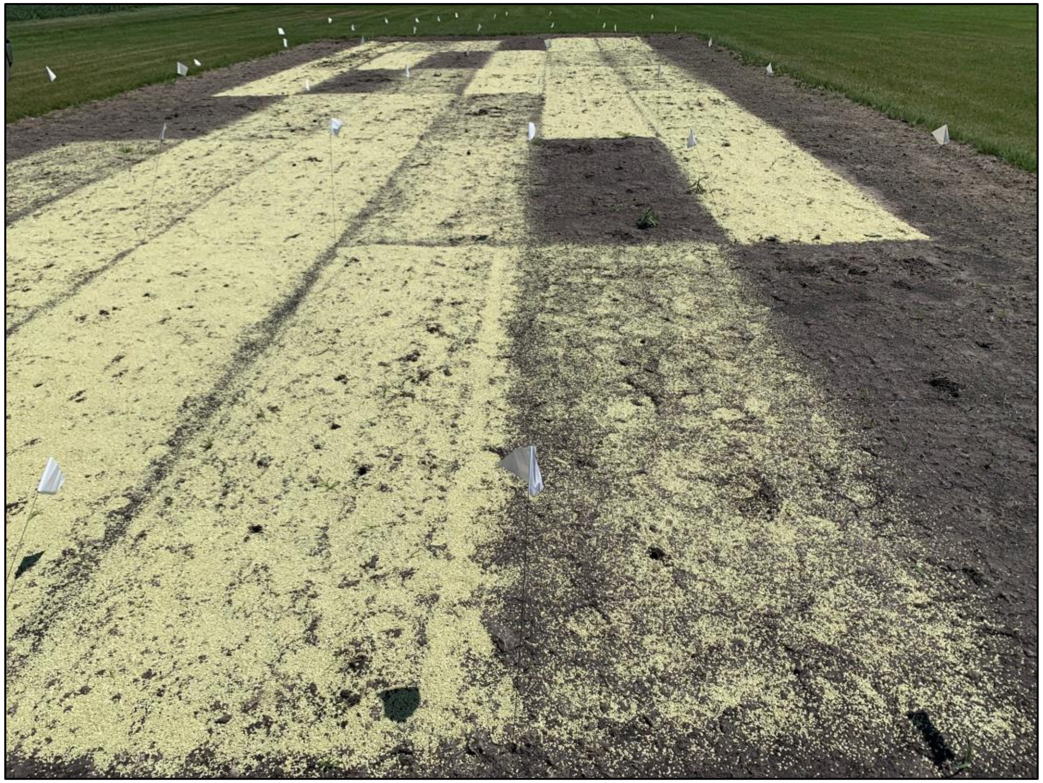


Again starting in 2020, with higher rates!

Objective: evaluate long-term effectiveness of elemental S as a soil amendment to reduce soil pH on a calcareous Northern Plains soil

Site: Northwood, ND
Bearden silty clay loam
average soil pH: 8.0,
average **CCE: 4.5%**

Treatments: 0 to 40,000 lbs/A elemental sulfur, tilled to 6” after application



It takes about 3.2 tons elemental sulfur/acre to neutralize 1% CCE in soil

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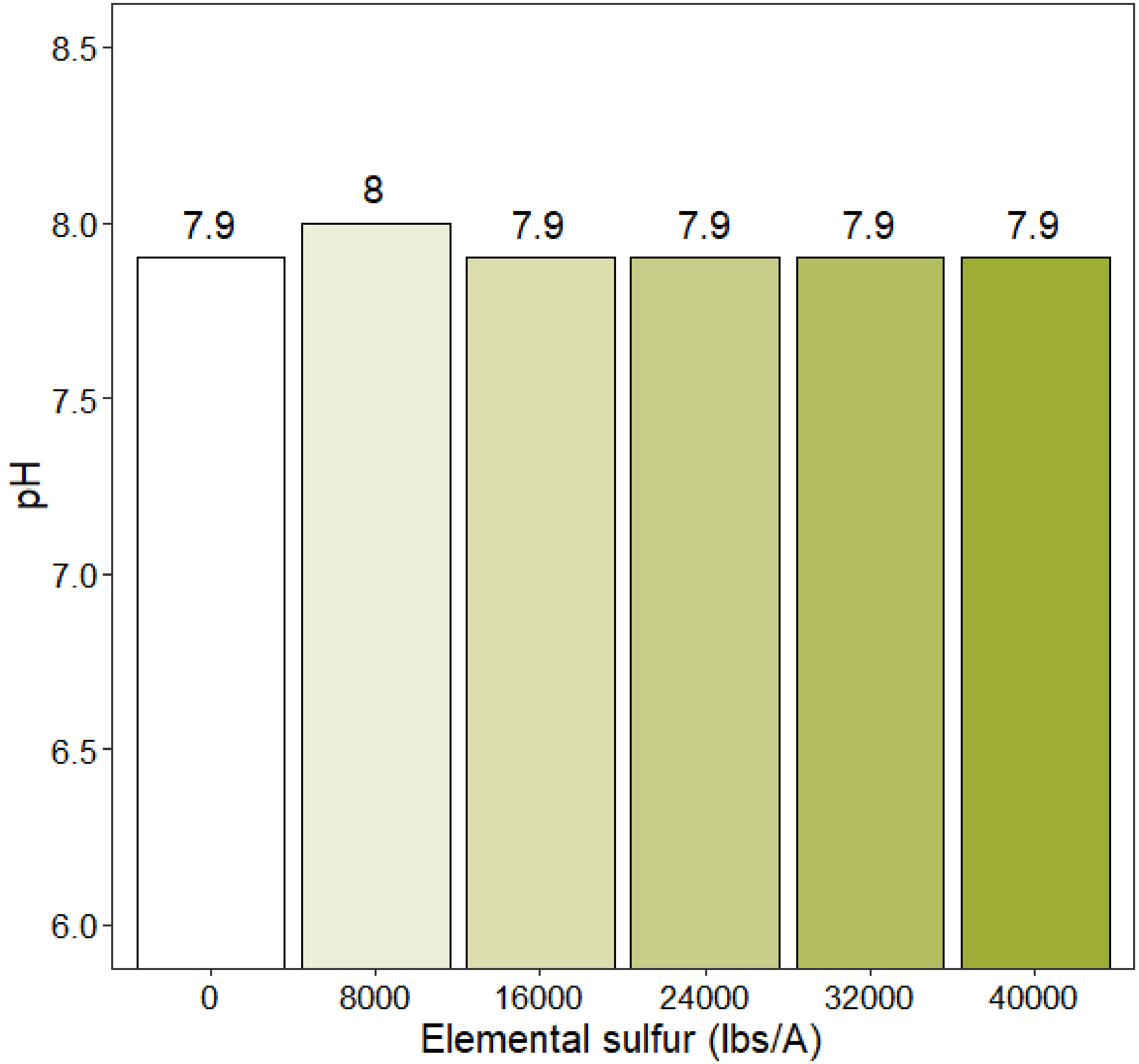
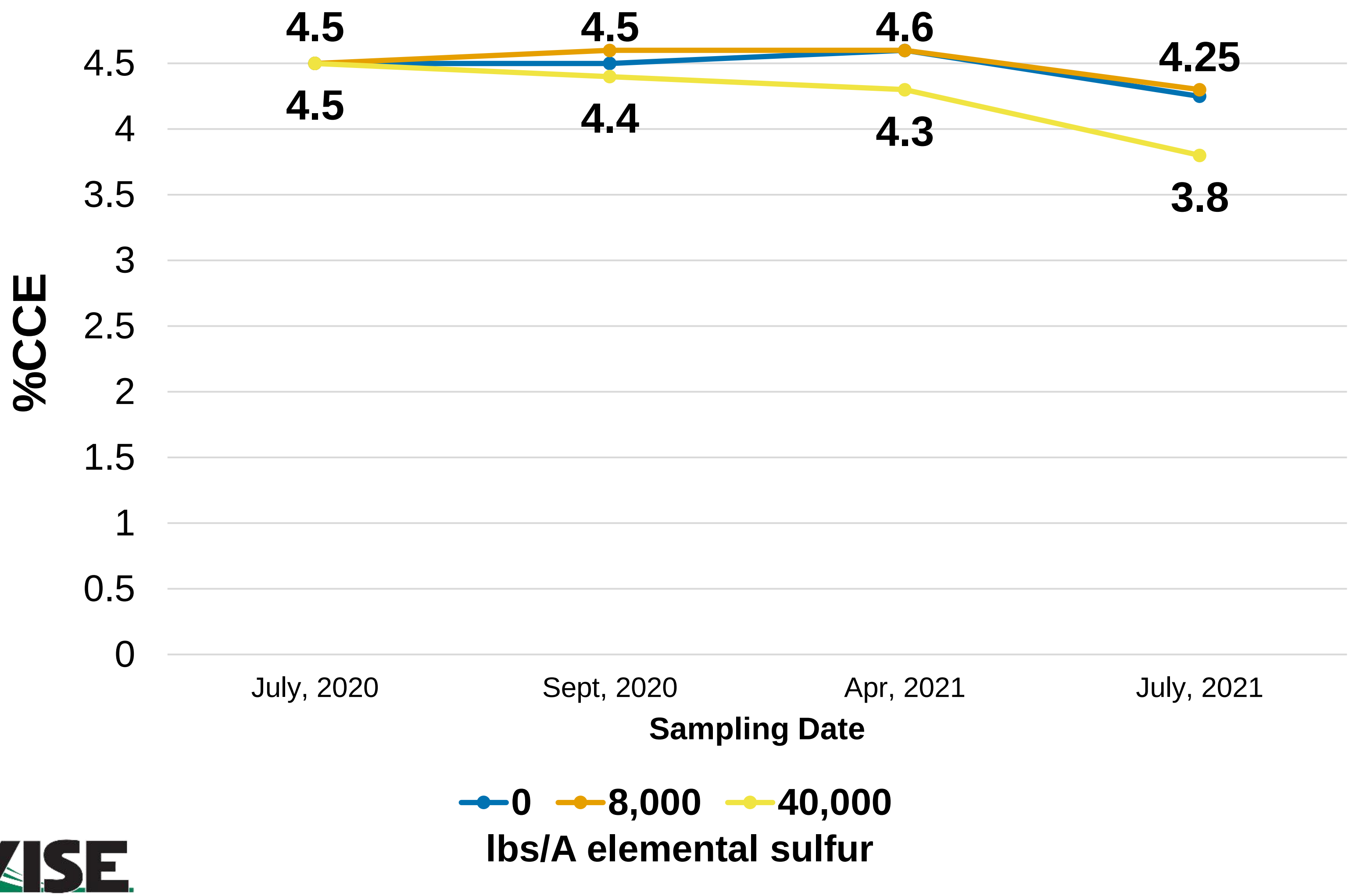
Effect of elemental sulfur rate on soil pH one year after application



Effect of elemental sulfur on %CCE over one year



Is there an easy way to lower high pH?

Carbonate(CCE)	5.6 %	******************
Sol. Salts 0-6"	2.82 mmho/cm	***************************

Soil pH
0-6" 7.9

High pH and High Calcium Carbonate

There is no quick, easy solution to reducing soil pH in the northern Great Plains

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Practical alternatives to manage soils with high pH

- For IDC (high pH soils with carbonates, salinity) use IDC tolerant soybean varieties, plant in wide rows, use Fe-EDDHA
- Apply more P fertilizer in bands
- Apply higher rates of P fertilizer
- Building P soil test levels not easy in high pH soils, but it is much less expensive than trying to reduce the soil pH

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Is it possible to build soil test P levels in high pH soils?

Phosphorus Olsen	3 ppm	******
Carbonate(CCE)	2.1 %	**********
Sol. Salts 0-6"	2.86 mmho/cm	*************************

Low soil test P

Soil pH	
0-6"	7.8

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Is it possible to build soil test P levels in high pH soils?

- Soils in the Northern Plains and Canadian Prairies often have soils with high pH (>7.3)

- Soil pH controls availability of plant nutrients (especially phosphorus)

- Building soil-test P in high pH soils requires more P than building in neutral pH soils

- P is fixed by calcium in the soil; Ca is abundant in most of the soils in our region

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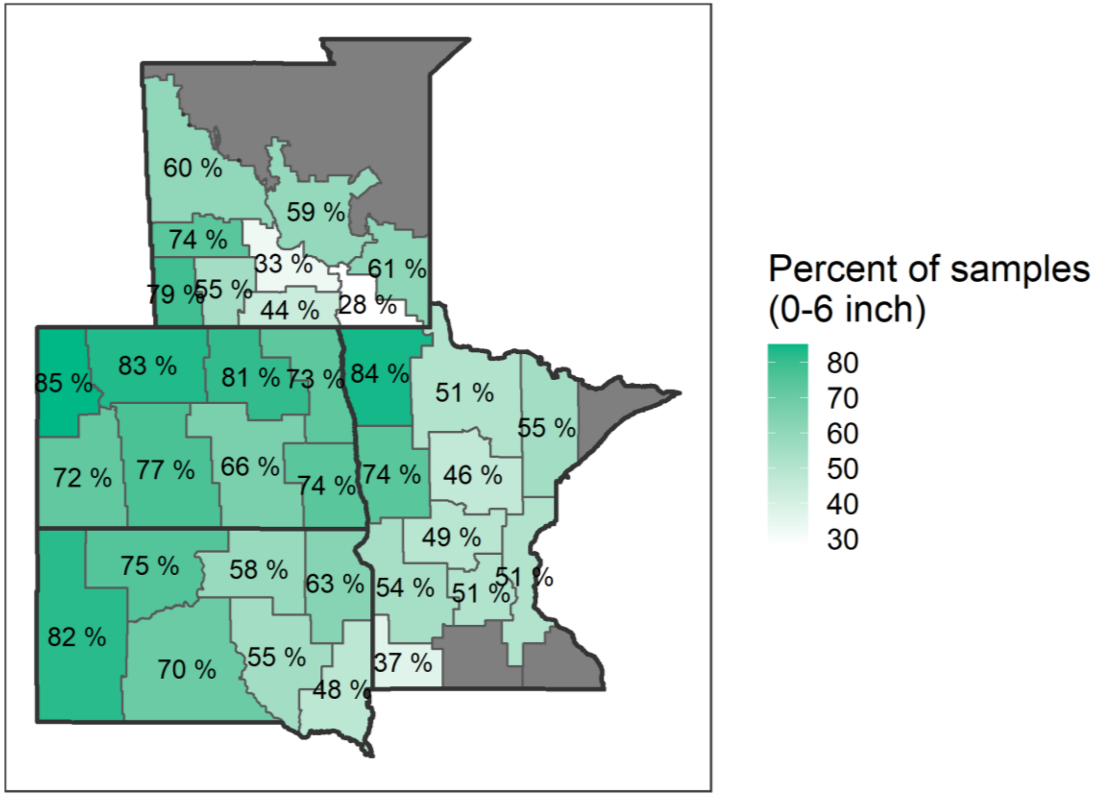
Is it possible to build soil test P levels in high pH soils?

Soil samples with soil test phosphorus below 15 ppm (Olsen P) in 2021



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AGVISE long-term phosphorus project

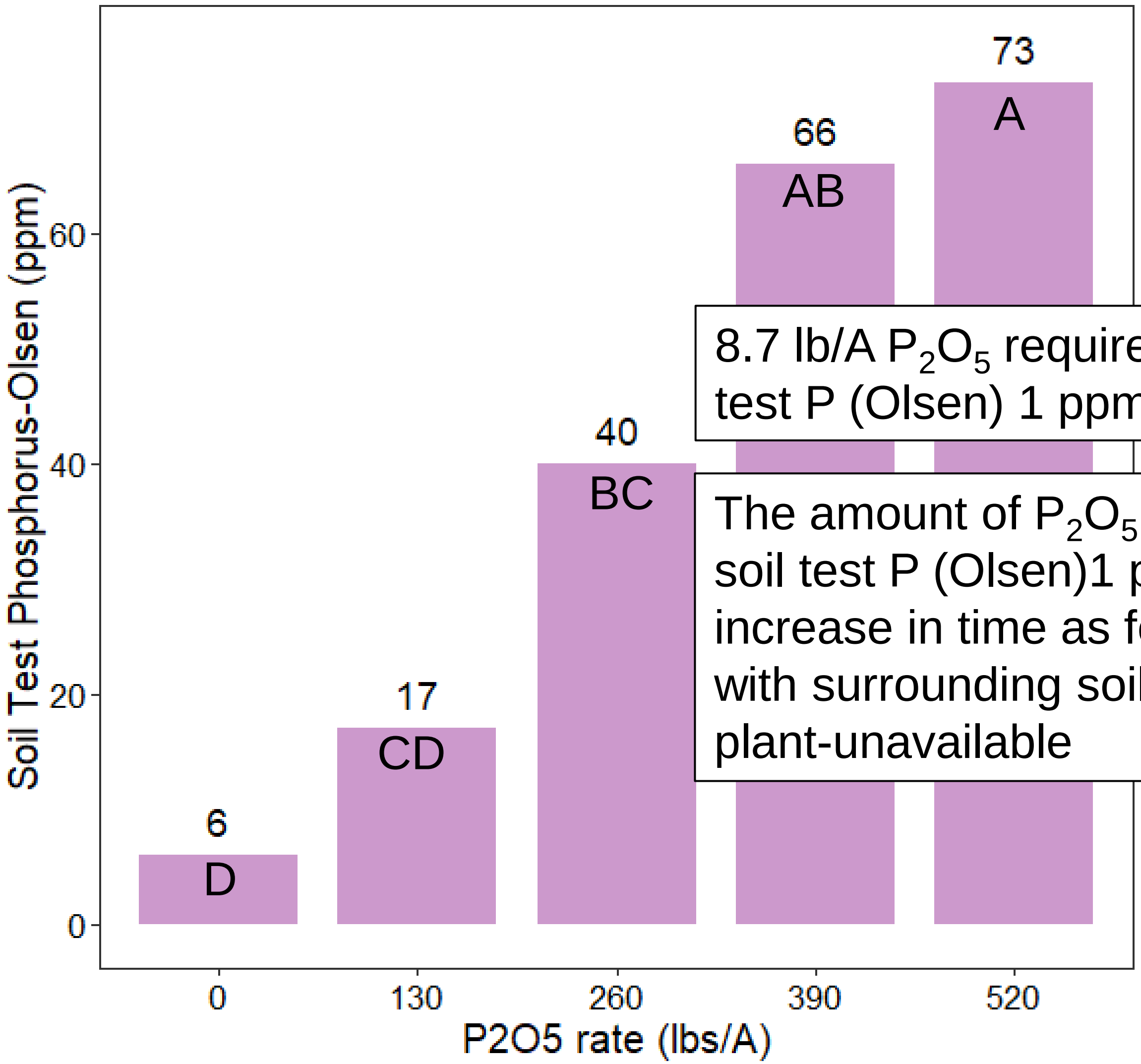
Objective: Determine rate of P needed to build soil test P levels; monitor over time

Site: Northwood, ND
Bearden silty clay loam
soil pH: 7.9
average CCE: 4.5%
average initial soil test P: 4 ppm

Treatments: 0 to 520 lbs/A P_2O_5 (in MAP form), tilled to 6" after application

Trial Initiated: September 1, 2021
Soil Sampled: October 29, 2021

Effect of MAP fertilizer on soil-test P (ppm) two months after application



8.7 lb/A P_2O_5 required to raise soil test P (Olsen) 1 ppm **after 2 months**

The amount of P_2O_5 required to raise soil test P (Olsen)1 ppm will likely increase in time as fertilizer reacts with surrounding soil and becomes plant-unavailable

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Is it possible to build soil test P levels in high pH soils?

Olsen Phosphorus	3 ppm	******	
Carbonate(CCE)	2.1 %	**********	
0-6" Sol. Salts	2.86 mmho/cm	************************	

Low soil test P

Soil pH	
0-6"	7.8

It is possible to build soil test P levels in high pH soils, but requires a lot of P fertilizer

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Can I increase soil %K?

% Base Saturation (Typical Range)				
% Ca	% Mg	% K	% Na	% H
(65-75) 71.3	(15-20) 26.2	(1-7) 0.9	(0-5) 1.6	(0-5) 0.0

“Low” %K

~~Can I increase soil %K?~~
Should I worry about increasing %K?

% Base Saturation (Typical Range)				
% Ca	% Mg	% K	% Na	% H
(65-75) 71.3	(15-20) 26.2	(1-7) 0.9	(0-5) 1.6	(0-5) 0.0

"Low" %K

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~~Can I increase soil %K?~~

~~*Should I worry* about increasing %K?~~

Should I *acknowledge* %K?

% Base Saturation (Typical Range)				
% Ca	% Mg	% K	% Na	% H
(65-75) **71.3**	(15-20) **26.2**	(1-7) **0.9**	(0-5) **1.6**	(0-5) **0.0**

"Low" %K

What is %K? Sufficiency? Base Cation Saturation Ratio (BCSR)?

% Base Saturation (Typical Range)				
% Ca	% Mg	% K	% Na	% H
(65-75) **71.3**	(15-20) **26.2**	(1-7) **0.9**	(0-5) **1.6**	(0-5) **0.0**

Concentrations of soil Ca, Mg, and K are interpreted two different ways:

- the scientifically-backed way, using sufficiency level (e.g. soil-test K ppm shows soil is above or below a critical level)
- the scientifically-debunked way, using “ideal” base cation saturation ratios (BCSR) (e.g. fertilizing to push base cation % into arbitrary “ideal” ranges that were conceived in the 1940s)

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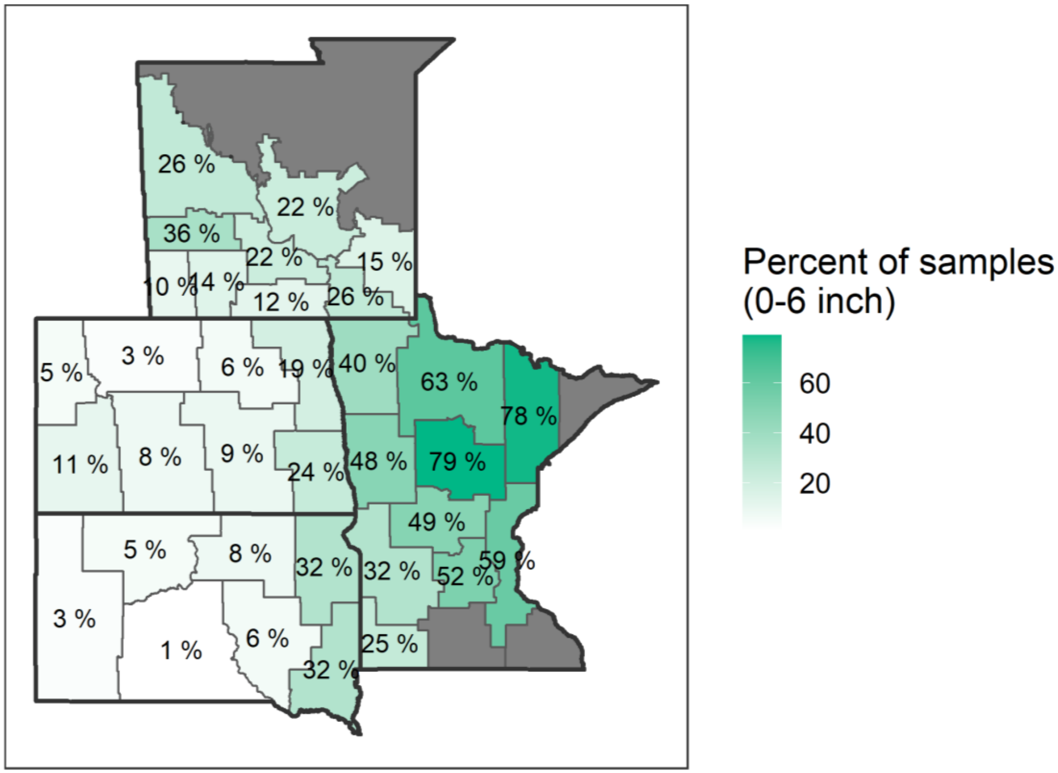
Should I acknowledge %K?

- Many soils in the northern Great Plains have high levels of background soil-test K ppm levels.

Should I acknowledge %K?

Soil samples with soil test potassium below 150 ppm in 2021



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Should I acknowledge %K?

- Many soils in the northern Great Plains have high levels of background soil-test K ppm levels.
- Concept of "ideal" BCSRs *still* floating around, despite no replicated research to support it
- Soils with varying %K values (outside of "ideal" range) grow crops without K deficiency
- Soil test sufficiency level is important to focus on, <u>not % of specific cations</u>

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How is %K calculated, anyway?

Potassium		211 ppm
Chloride	0-6"	52 lb/acre
Sulfur	0-6"	120 +lb/acre
Boron		
Zinc		
Iron		
Manganese		
Copper		
Magnesium		1544 ppm
Calcium		6602 ppm
Sodium		193 ppm
Org.Matter		5.8 %
Carbonate(CCE)		2.1 %

$$\frac{211\ ppm\ K^{+}}{390\,\frac{meq}{100g\ soil}} = 0.54\,\frac{meq}{100g\ soil}$$

$$\frac{0.54}{47.3} = 0.011\ (1.1\ \%K)$$

Hypothetically,
%K = percentage of CEC occupied by potassium cations

In reality, %K reported in the Northern Great Plains is lower than "real" %K

Soil pH	Buffer pH	Cation Exchange Capacity	% Base Saturation (Typical Range)				
			% Ca	% Mg	% K	% Na	% H
0-6" 7.8		47.3 meq	(65-75) 69.9	(15-20) 27.2	(1-7) 1.1	(0-5) 1.8	(0-5) 0.0

General Comments: Soil texture is not estimated on high pH soils.

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AGVISE long-term potassium project

Objective: determine the amount of potash fertilizer required to raise imaginary %K in soil from 1.0% to 8.0%

Site: Northwood, ND
Bearden silty clay loam
soil pH 7.9
average initial STK: 226 ppm
average initial %K: 1.1%
average initial %Ca: 70%
average initial CCE: 4.5%

Treatments: 0 to 5,100 lbs/A K2O (as potash), tilled to 6" after application

Trial Initiated: September 1, 2021
Soil Sampled: October 29, 2021

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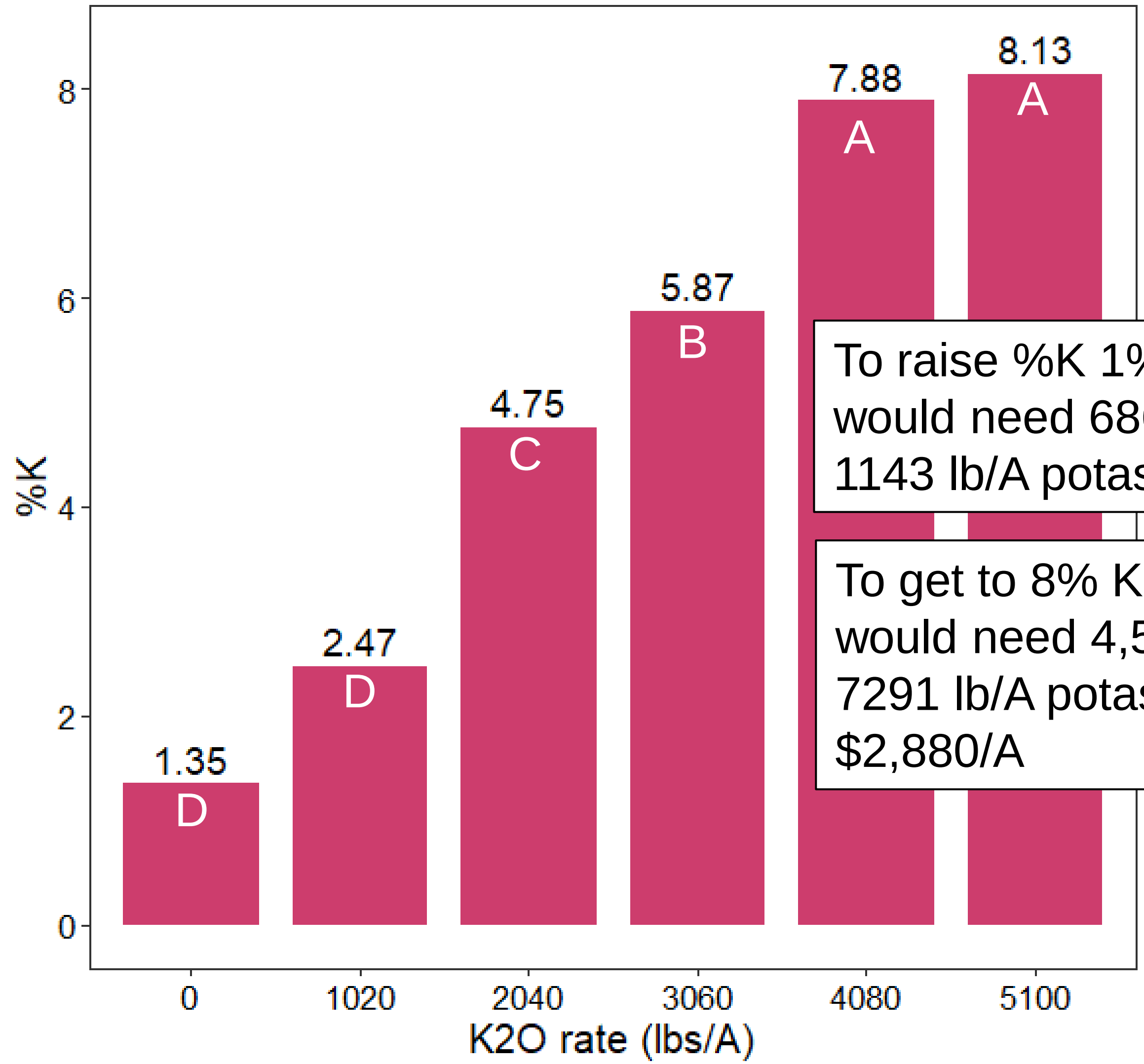
Effect of potash rate on soil %K



To raise %K 1% in this soil, we would need 686 lb/A K_2O, or 1143 lb/A potash (0.5 TONS!)

To get to 8% K in this soil, we would need 4,521 lb/A K_2O, or 7291 lb/A potash (3.6 TONS!) $2,880/A

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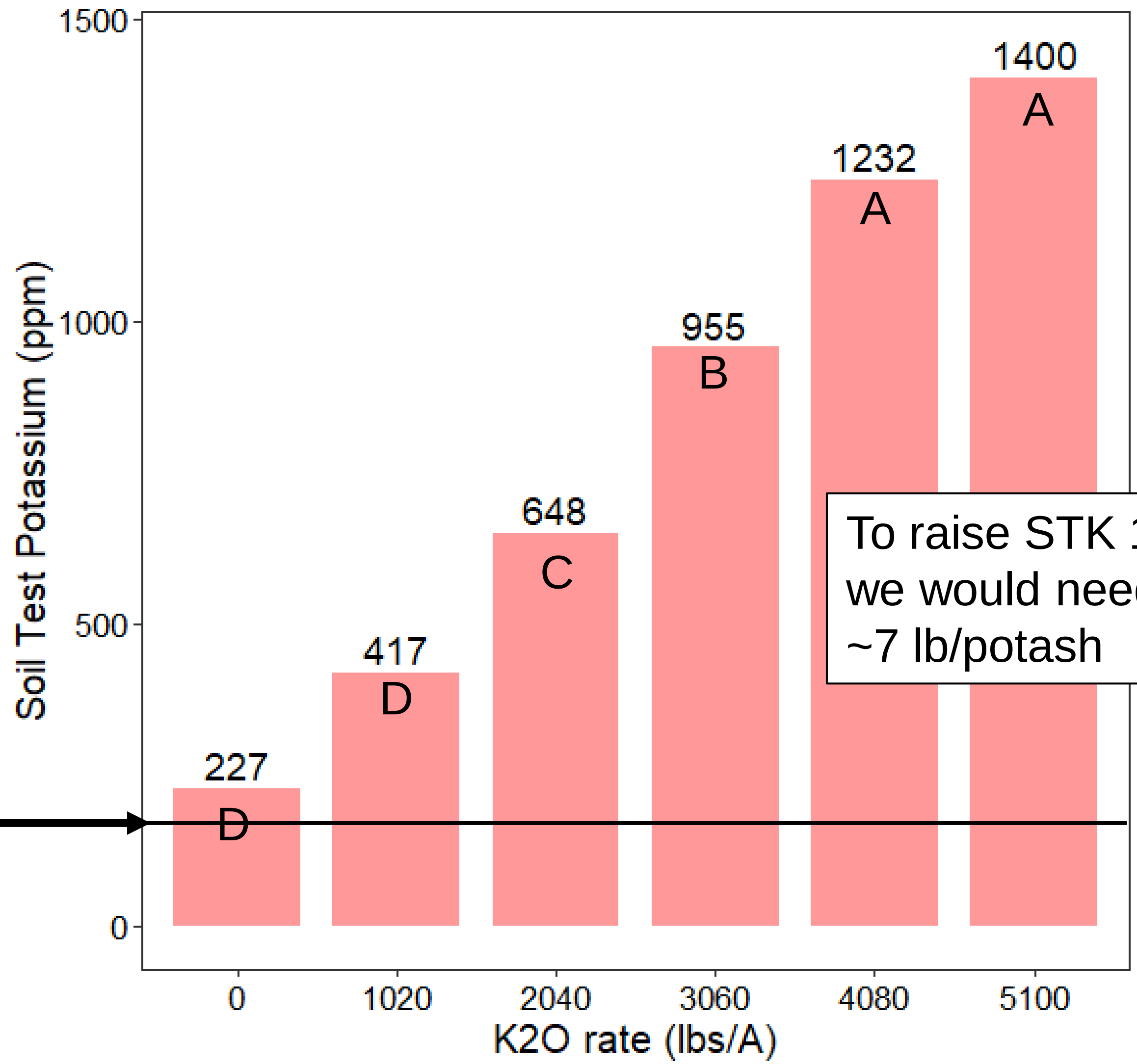
Effect of potash rate on soil-test K (ppm)

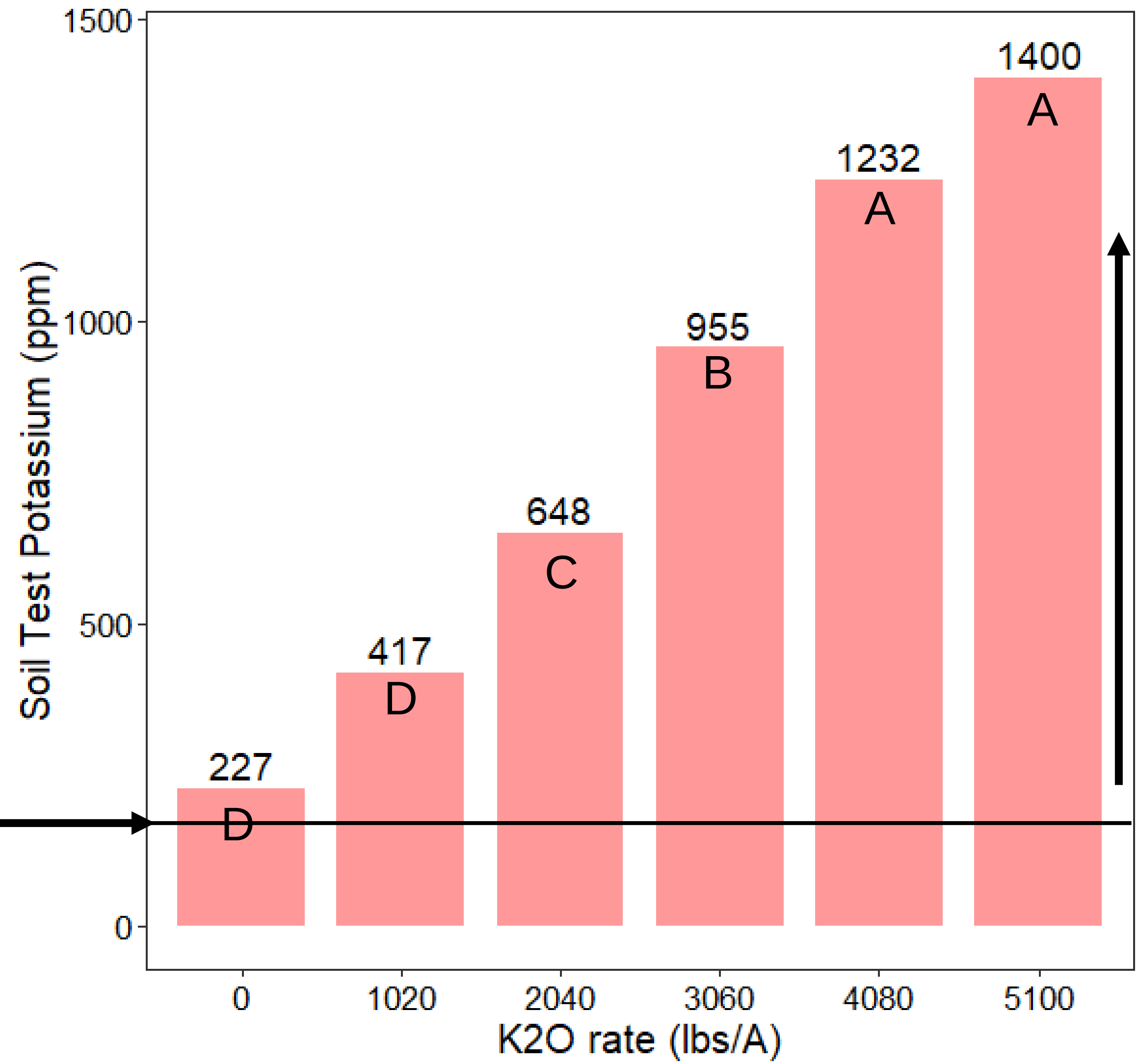


200 ppm STK

To raise STK 1 ppm in this soil, we would need 4 lbs/A K_2O, or ~7 lb/potash

Effect of potash rate on soil-test K (ppm)

200 ppm STK



What about yield?

- Remember, potash is potassium chloride, or KCl, 0-0-60-50Cl
- Univ. of MN researchers have found that high rates of KCl fertilizer can decrease soybean yields and occasionally corn yields when over 200 lb/acre KCl (0-0-60) is applied
  - Excessive chloride has been implicated as the cause of soybean yield reduction
  - Strategically apply potassium chloride in a corn-soybean rotation. Apply the full two-year rate prior to corn or split for both years
  - Do not apply more than 200 lb/acre KCl before corn or 100 lb/acre KCl before soybean

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What about yield?

- The following slides are corn yield data from the 2021 growing season from Dr. Jason Clark at SDSU
- The goal was to measure yield response to differing rates of KCl fertilizer with differing soil-test K level
  - Rates: 0, 90, 120, 150 lbs K_2O plus two site-specific rates to reach %Ksat of 4% and 7%
  - Sites had initial soil-test K levels ranging from 120 to 306 ppm

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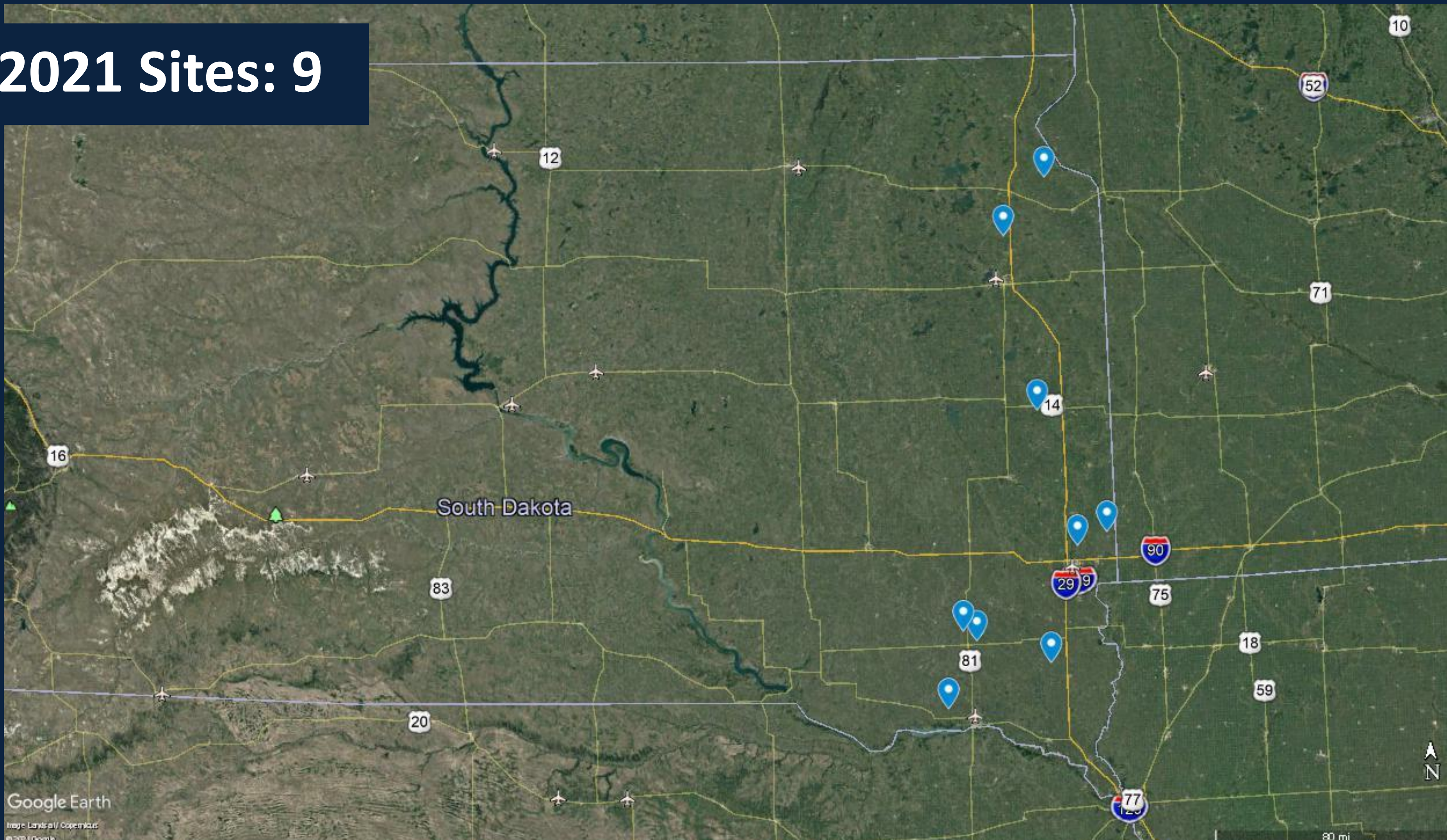
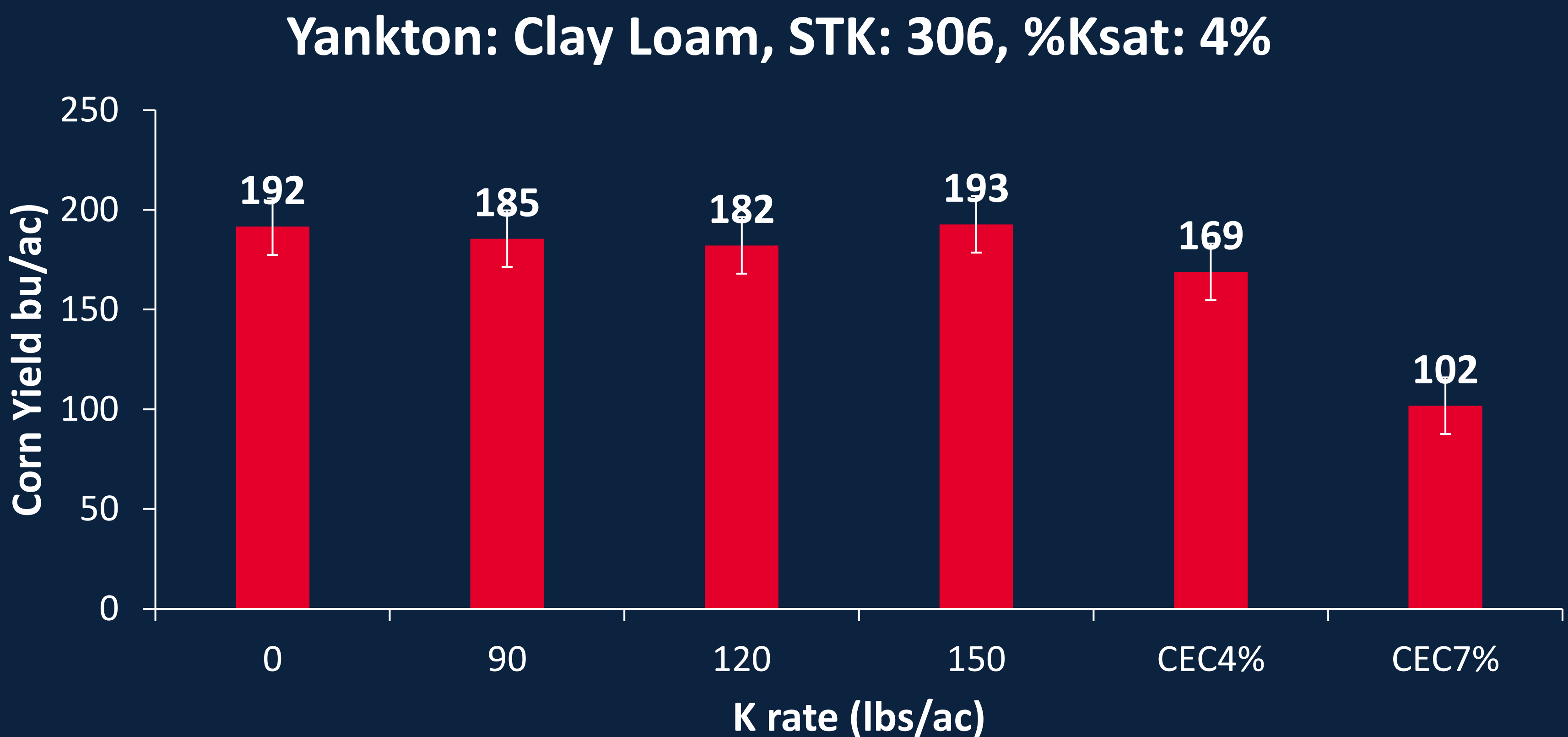
2021 Sites: 9



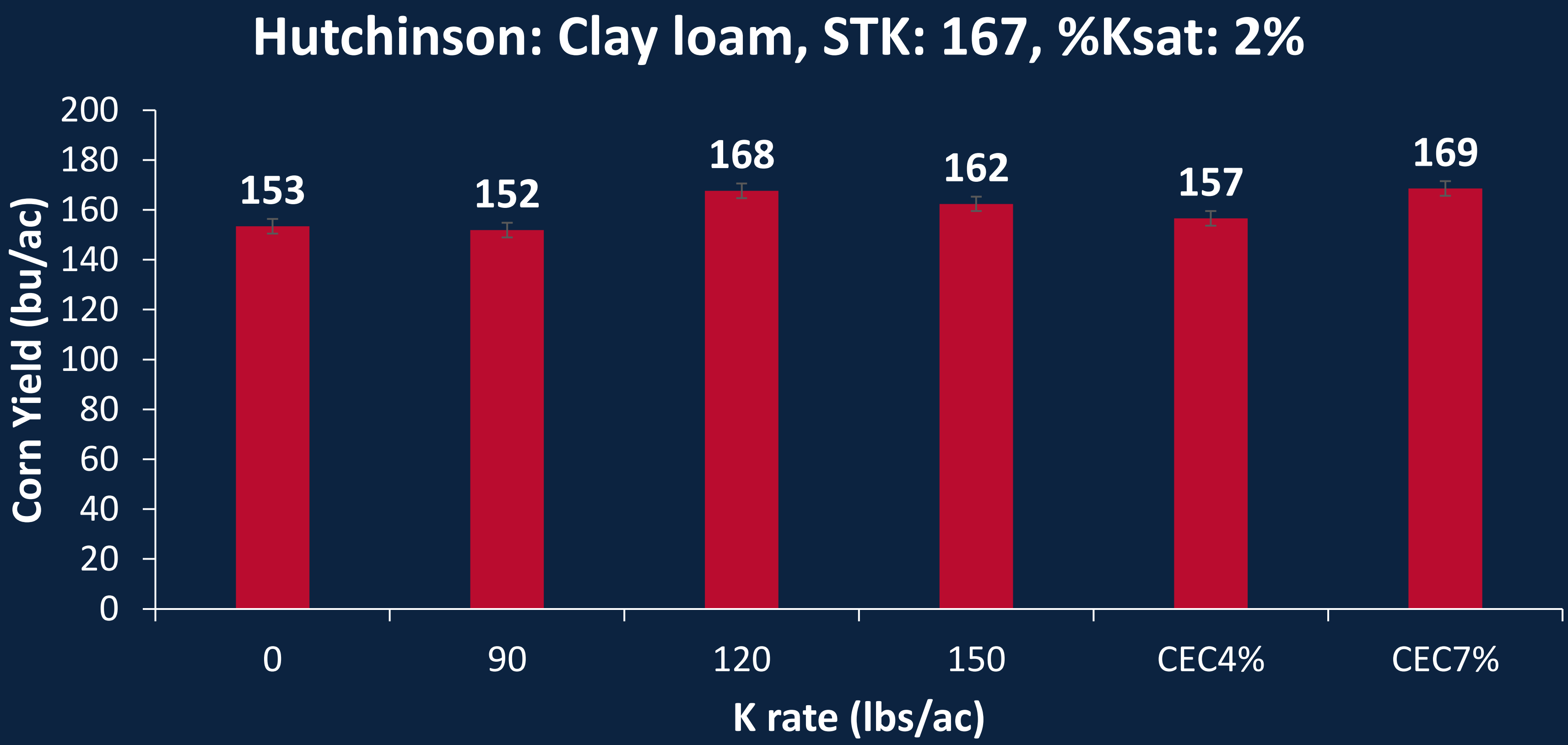
Slide courtesy of Dr. Jason Clark, SDSU

2021 Corn Yield Data



Slide courtesy of Dr. Jason Clark, SDSU

2021 Corn Yield Data



Slide courtesy of Dr. Jason Clark, SDSU

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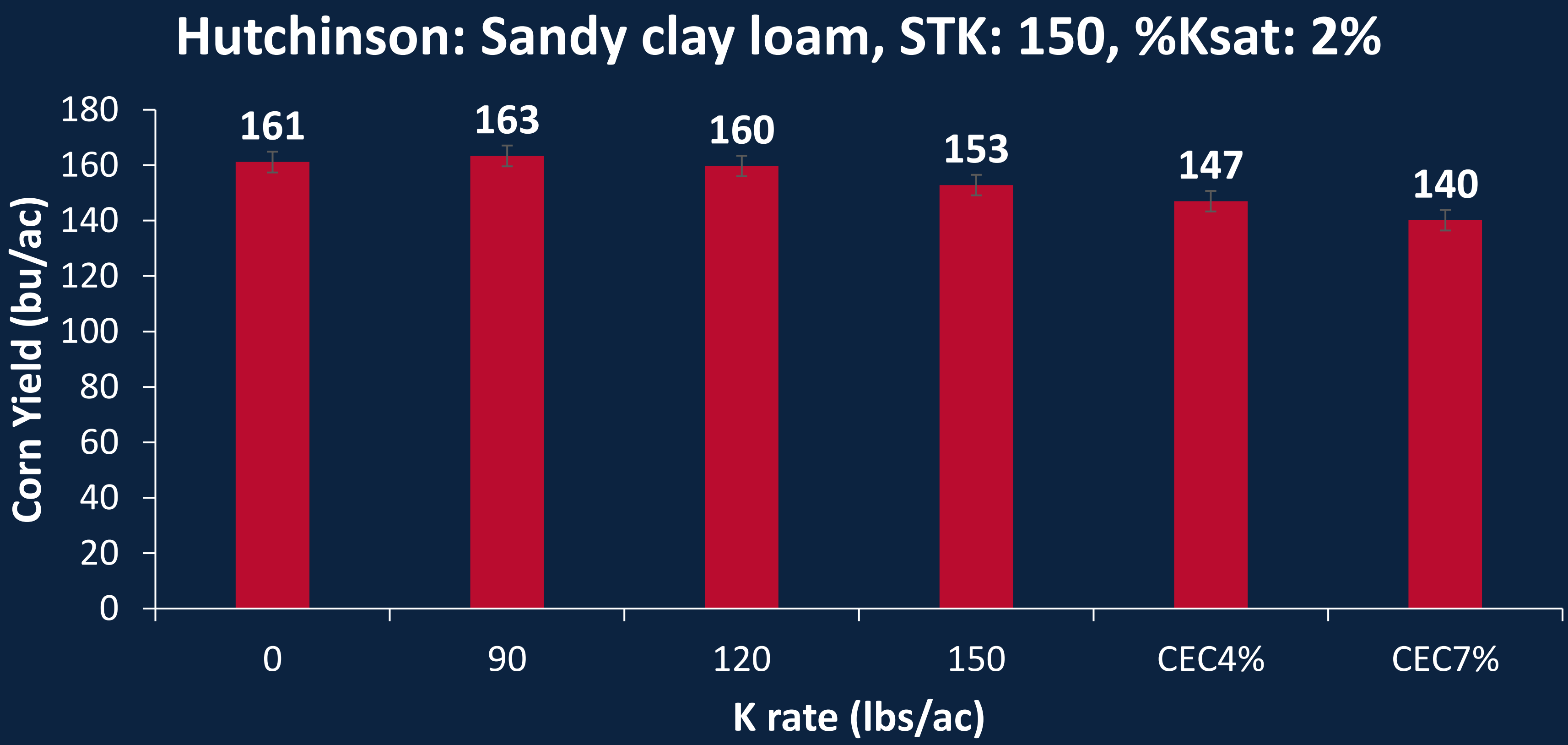

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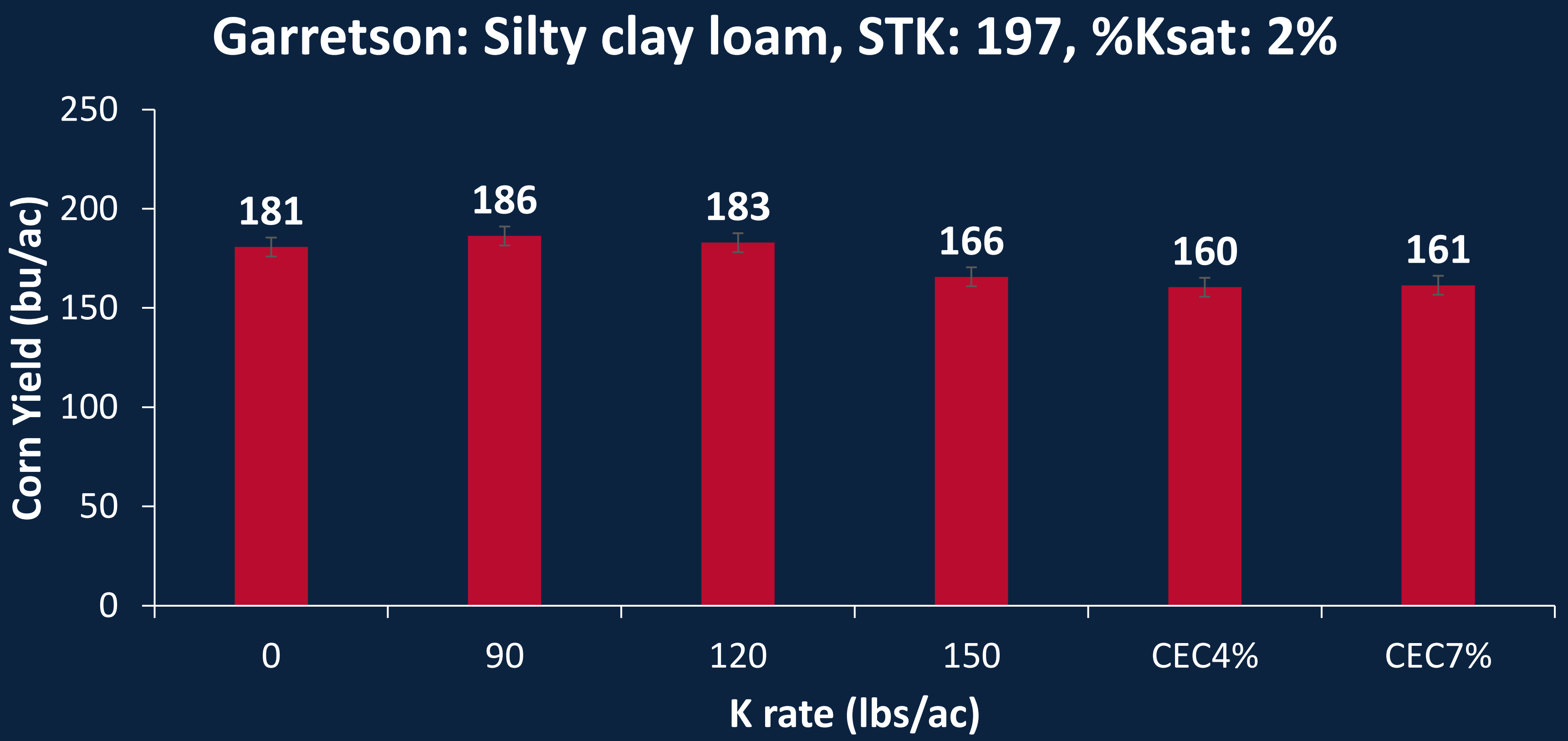
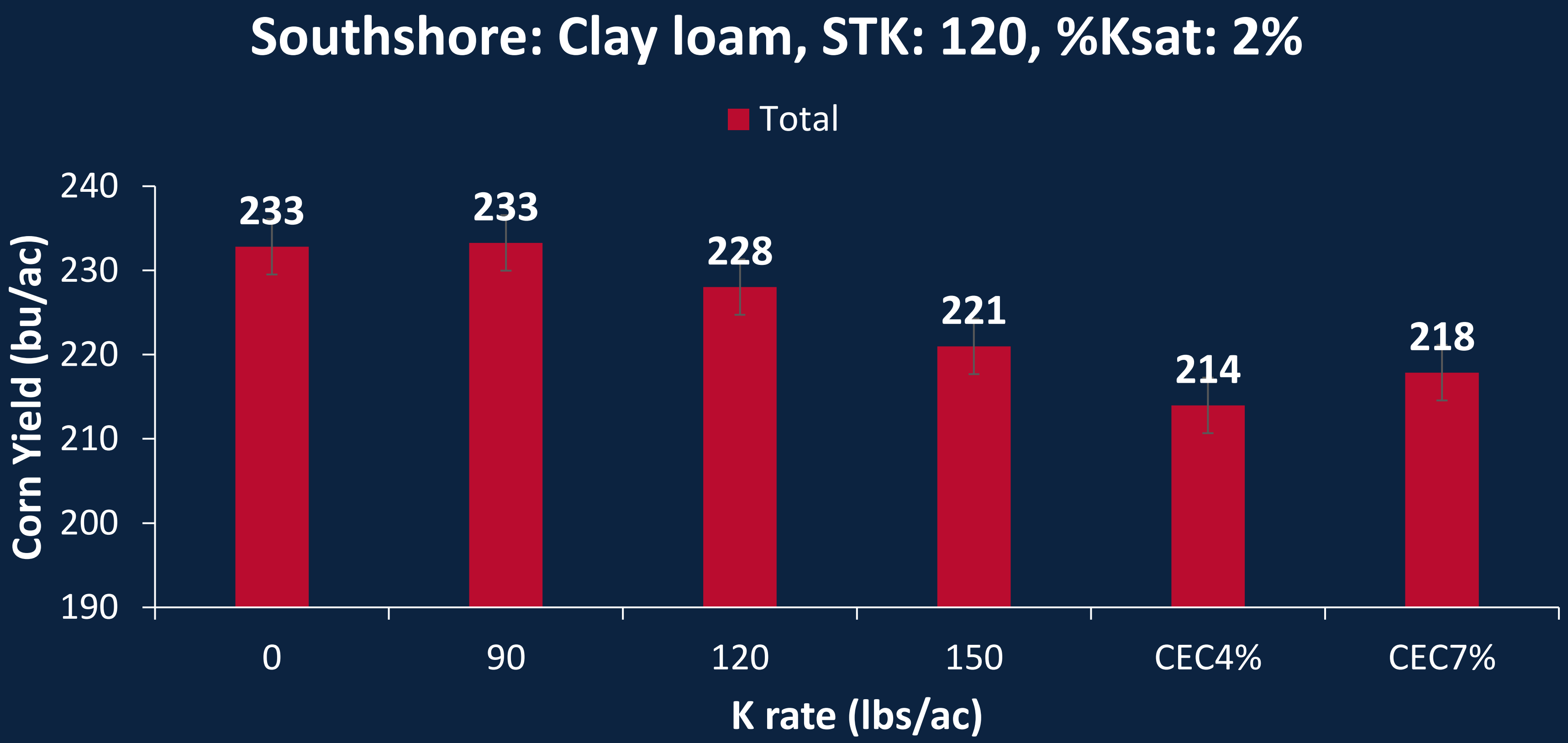


Slide courtesy of Dr. Jason Clark, SDSU

2021 Corn Yield Data



Slide courtesy of Dr. Jason Clark, SDSU

Summary: 2021

- No site above 120 ppm K responded to K fertilization
- Fertilizing to base saturation of 4 or 7%
  - Reduced yield or at best maintained yield

Slide courtesy of Dr. Jason Clark, SDSU

~~Can I increase soil %K?~~

~~*Should I worry* about increasing %K?~~

Should I *acknowledge* %K?

% Base Saturation (Typical Range)				
% Ca	% Mg	% K	% Na	% H
(65-75) 71.3	(15-20) 26.2	(1-7) 0.9	(0-5) 1.6	(0-5) 0.0

"Low" %K

Using base cation saturation ratios to make soil fertility plans is not a good idea.

Good way to spend a lot of money with no yield increase

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Potassium fertility basics

Soil test category	Ammonium acetate K (ppm)
Very low (probability of getting a yield response to applied potassium >80%)	<40
Low	41-80
Medium	81-120
High	121-160
Very high (VH - Probability of getting a yield response to applied nutrient <10%)	>160 (critical level)

- Most soils with a loam soil texture or heavier have high soil test K. Sandy soils usually test low in K and are prone to leaching (difficult to build soil test K on sandy soil).
- Potassium deficiency can develop on high testing soils if soil is compacted or if soil contains high proportion of smectitic clays
- Potassium deficiency is one of the first nutrient problems to show up when water is limiting. Tissue analysis is helpful.

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When should I fertilize with potash?

- Soil test K below 150 ppm (zone or grid sample)
- Soil test K below 200 ppm (composite sample/variable)
- Tissue K historically below sufficiency range
- Compaction restricting root growth (confirmed with tissue analysis)
- Replicated strip trials showing significant yield increase
- Low soil chloride (small grains may require Cl from KCl)

Is it possible to increase soil pH on the Northern Plains?

Low pH

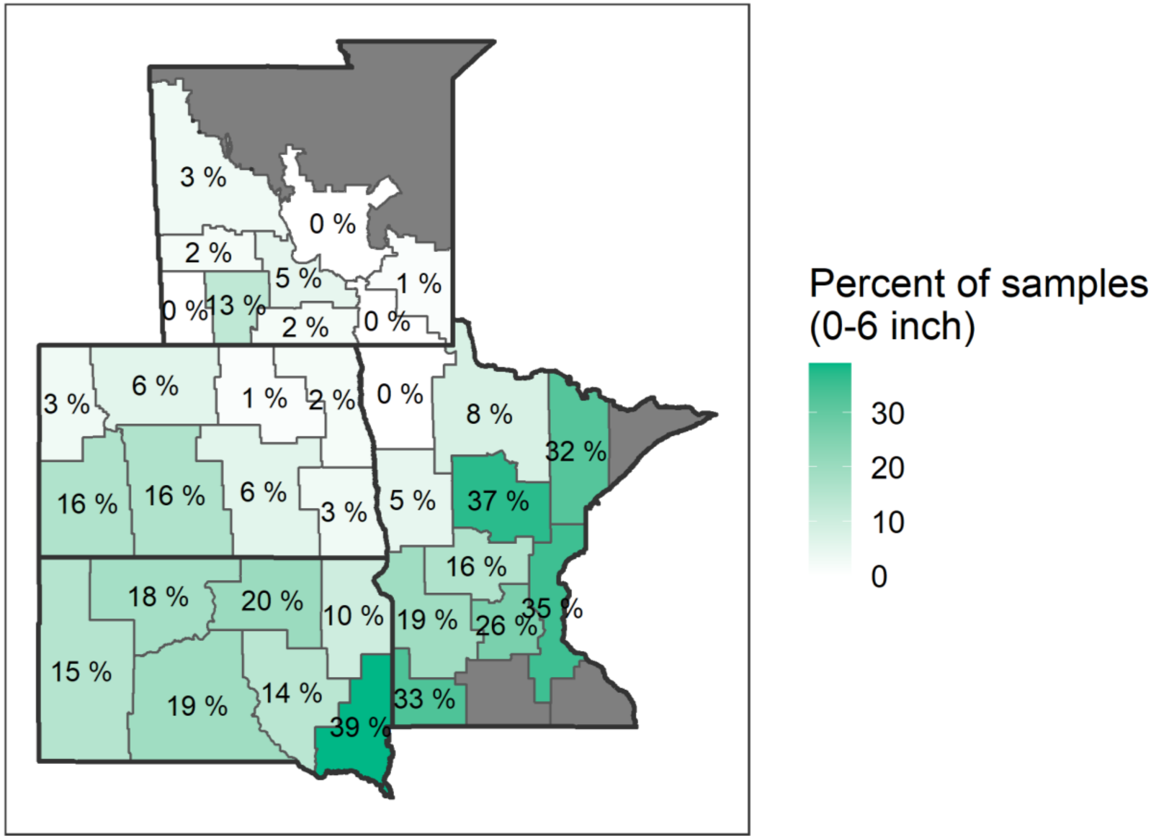
Soil pH	Buffer pH
0-6" 5.2 6-24" 7.9	6.4

Soil acidity (pH <6.0) an emerging soil fertility issue on the Northern Plains

- Soil pH on N. Plains is generally high, thanks to soil parent material and climate
- Long-term use of nitrogen, adoption of long-term no-till, and zone/grid soil sampling have contributed to increased frequency of acid soils
- Soil pH controls availability of plant nutrients
  - Low pH decreases phosphorus availability and increases availability of plant toxic aluminum
  - Soil pH 5.0-5.5, aluminum toxicity
  - Soil pH 6.0-6.6, reduced legume N fixation

Soil acidity (pH <6.0) an emerging soil fertility issue on the Northern Plains

Soil samples with soil pH below 6.0 in 2021



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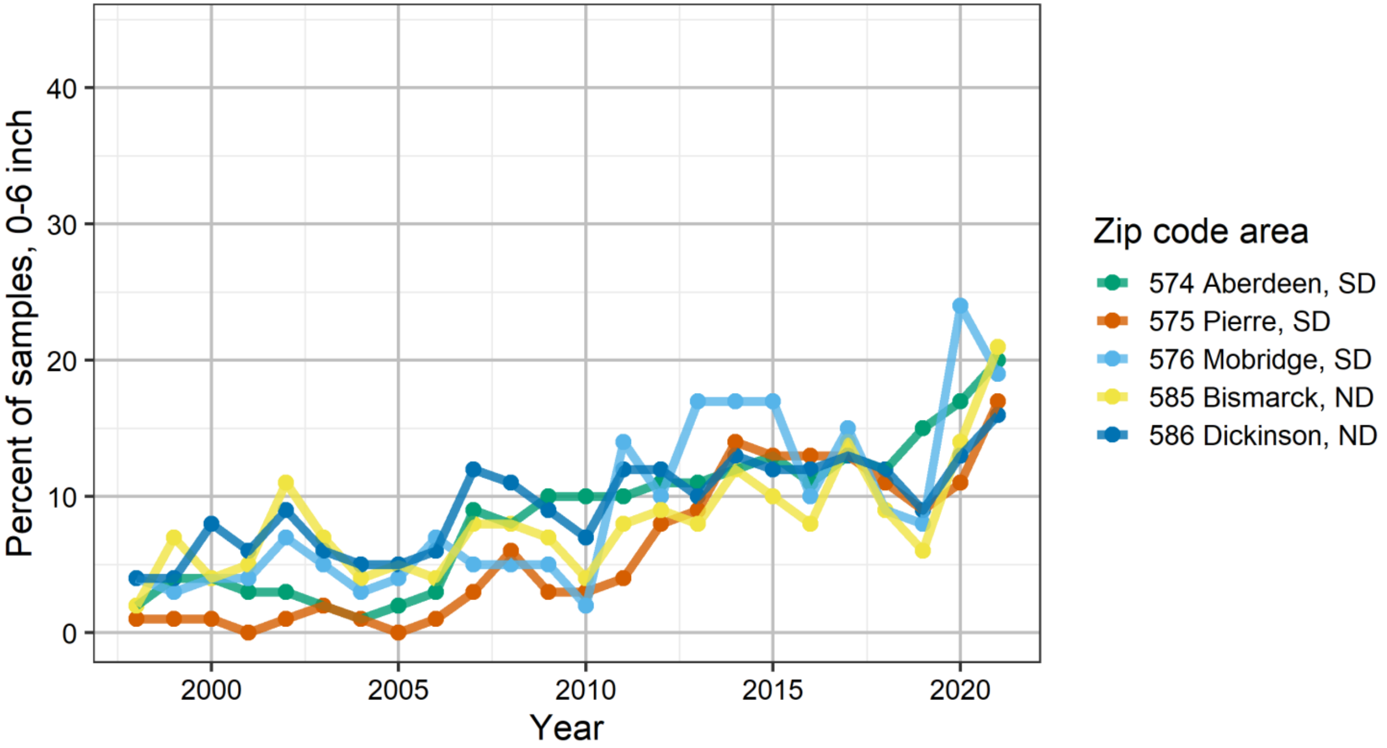
Managing soil acidity is an emerging soil fertility issue in North Dakota

Soil pH trend (pH < 6 1:1) across the northern Great Plains



Data not shown where n< 100
AGVISE Laboratories, Northwood, ND

Long-term solution to acid soils: liming

$$\mathrm{CaCO_3} + 2\mathrm{H^+} \rightarrow \mathrm{Ca^{2+}} + \mathrm{H_2O} + \mathrm{CO_2}(g) \uparrow$$

lime *hydrogen* *calcium* *water* *carbon dioxide*

- Lime ($MgCO_3$ or $CaCO_3$) reacts with hydrogen in the soil solution, reducing H concentration, increasing soil pH
- Carbonate (CO_3) is important, as this is the part of the material that neutralizes acidity
- In eastern Corn Belt, lime is applied every 3 to 6 years
- Very limited sources of lime in Northern Great Plains
- Unknown how frequent liming will need to be in our climate regime or cropping systems

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AGVISE Western ND Lime Project

Objective: determine the amount of surface-applied lime required to raise pH to 6.5 and determine how long the effect lasts

Site: Golden Valley, ND
Grail silty clay loam
average initial soil pH:
- 0-3”: 5.2
- 3-6”: 5.4

average initial buffer pH:
- 0-3”: 6.3
- 3-6”: 6.4

Treatments: 0 to 2.5 tons/A ENP, surface-applied (lime product had 1,782 lbs ENP/ton)

Trial Initiated: May 5, 2021
Soil Sampled: August 24, 2021

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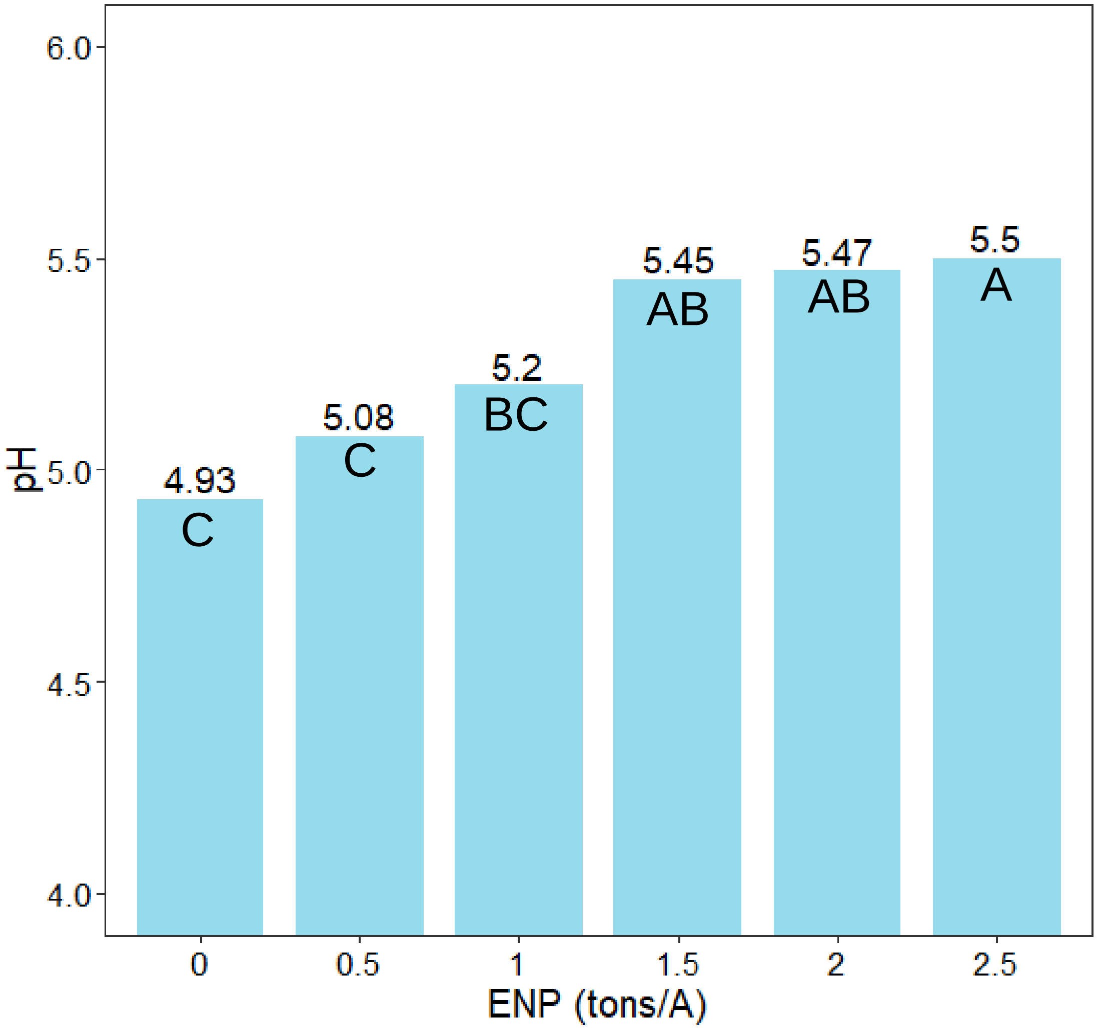
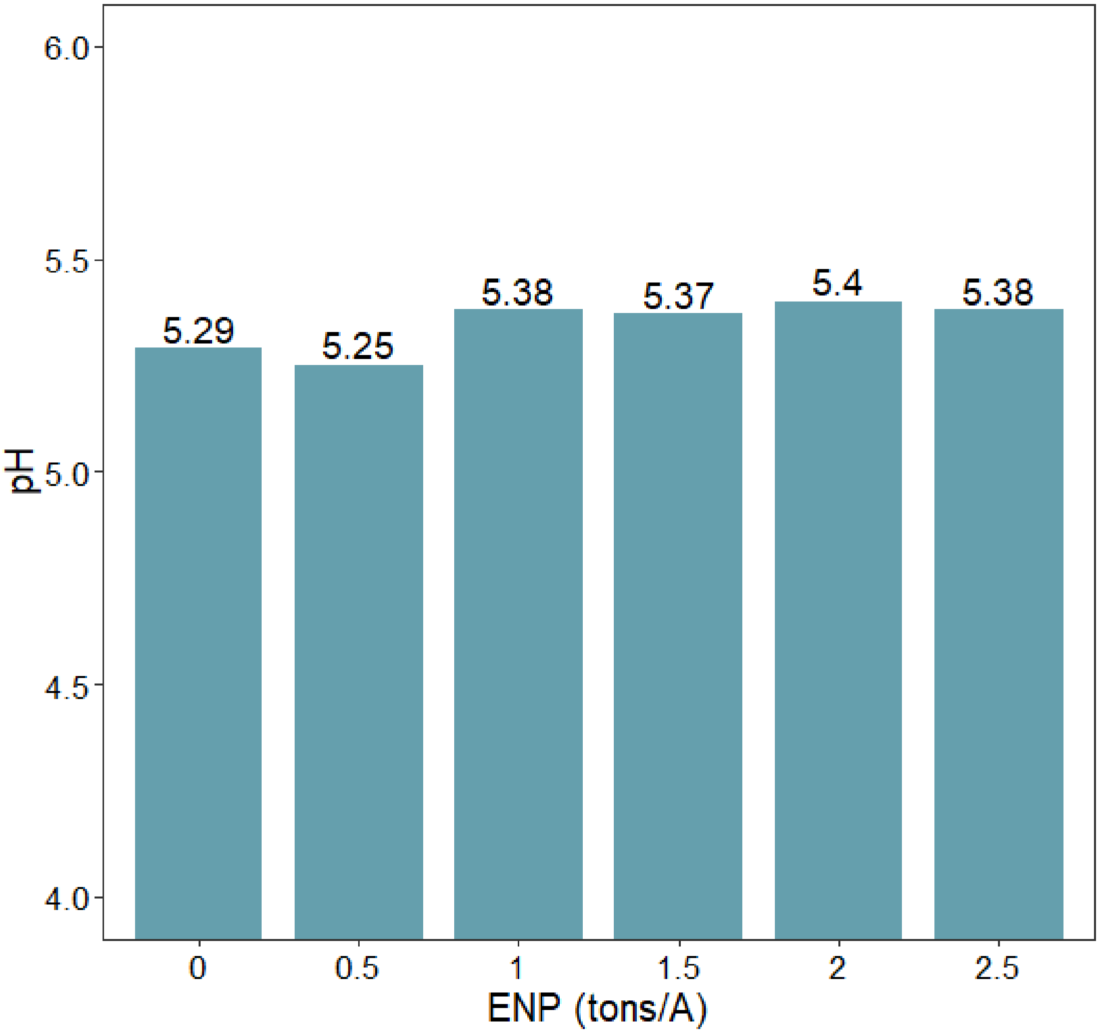
Effect of lime on soil pH, 3.5 months after application, 0-3” depth



Effect of lime on soil pH, 3.5 months after application, 3-6" depth



Alternatives to lime application

- Higher seed-placed P rate (40 lb P_2O_5/acre)
  - Phosphate binds with soluble aluminum (P fixation)
  - Seedlings establish, roots reach higher subsoil pH
  - Less effective if subsoil pH also low

- Utilize aluminum-tolerant crops and varieties
  - Few aluminum-tolerant varieties developed for northern Great Plains
  - Legumes, especially alfalfa, are most sensitive to low soil pH

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Is it possible to increase soil pH on the Northern Plains?

Low pH

Soil pH	Buffer pH
0-6" 5.2 6-24" 7.9	6.4

Adding lime (CO_3) to soils with low pH is the only way to increase pH and stop aluminum toxicity. Still much work to be done on frequency of applications, best sources, economics, etc.

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We can't always fix a problem with the addition of something.

AGVISE Projects:

1. Long-term elemental sulfur project (high soil pH)
2. Long-term potassium project (%K?????)

Sometimes we can fix a problem with the addition of something.

3. Long-term phosphorus project (low soil-test P)
4. Long-term liming project (low soil pH)

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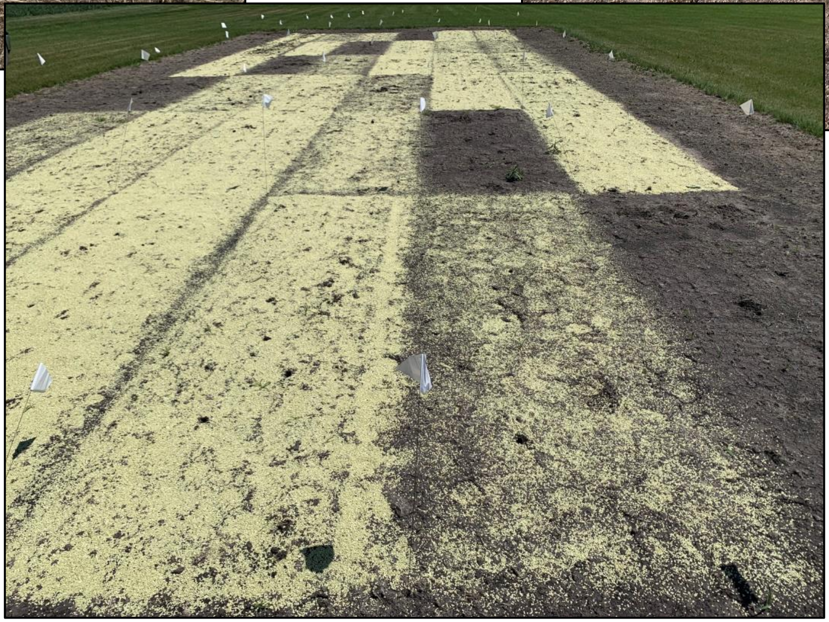
We look forward to continuing these projects in 2022!



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Thank you!

Are there any questions?