To Add or Not to Add? AGVISE Demonstration Project Update

2022 Soil Fertility Seminars

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

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

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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 %	**********	Soil pH
0-6" Sol. Salts	2.82 mmho/cm	**********	0-6" 7.9

High pH and High Calcium Carbonate

Olsen Phosphorus	3 ppm	******	Soil pH
Carbonate(CCE)	2.1 %	**********	0-6" 7.8
0-6" Sol. Salts	2.86 mmho/cm	**********	

Low soil test P

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

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

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

AGVISE Projects:

1. Long-term elemental sulphur 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)

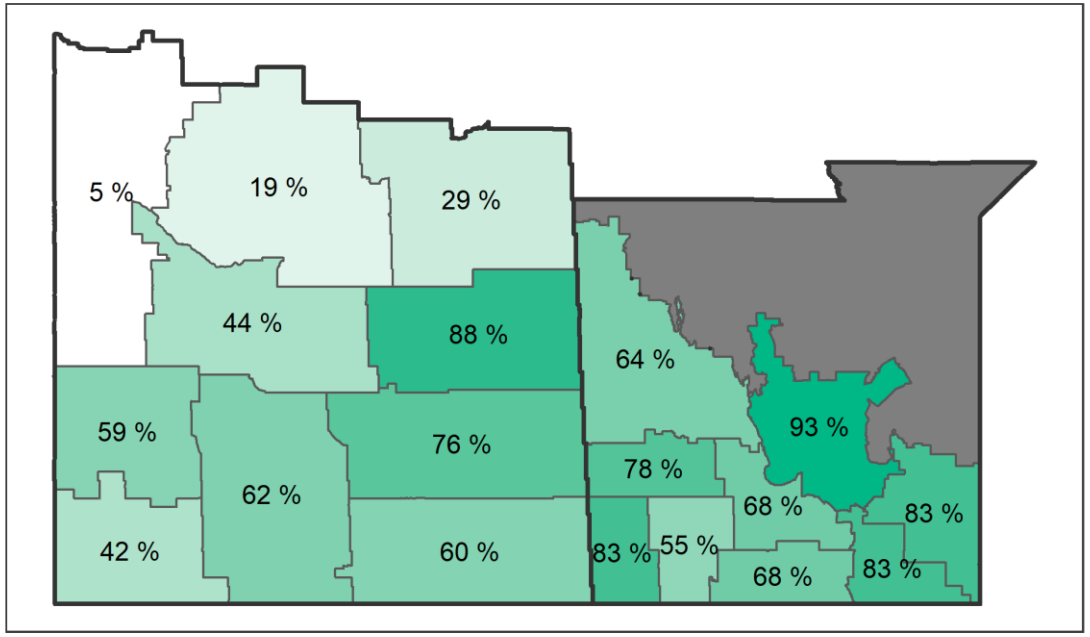
Is there an easy way to lower high pH?

Carbonate(CCE)	5.6 %	**********	Soil pH
0-6"	2.82 mmho/cm	**********	0-6" 7.9
Sol. Salts			

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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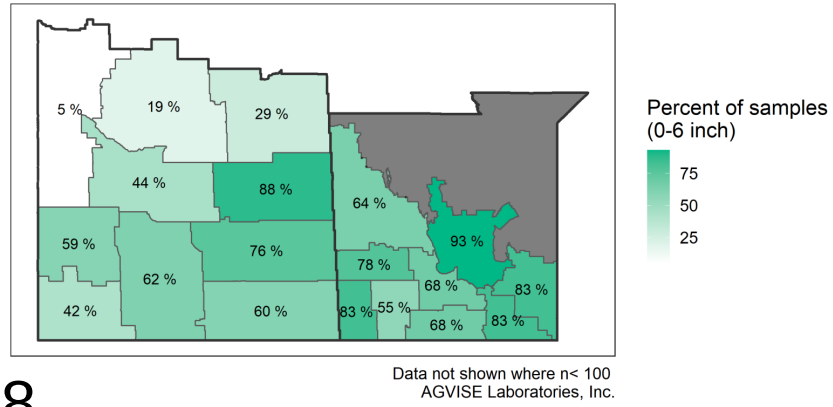
Is there an easy way to lower high pH?

- 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
  - High calcium carbonate levels increase soybean IDC incidence, reduce P availability
- Elemental sulphur often marketed as an “easy solution” to reduce pH

Soil samples with soil pH above 7.3 in 2021



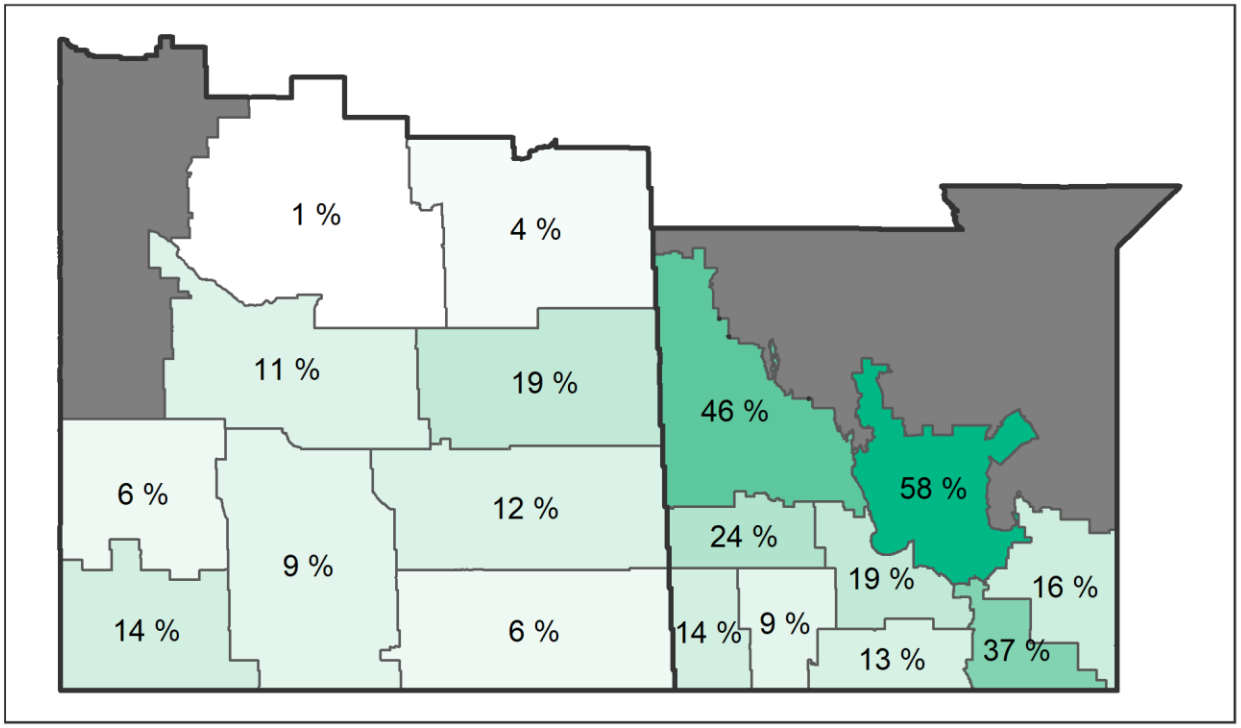
Picture from: https://www.amazon.com/Walts-Elemental-Sulfur-Pellets-10/dp/B016YYNMB4

The science behind lowering pH with elemental sulphur

- 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 sulphuric acid

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

Soil samples with calcium carbonate above 5.0 % CCE in 2021



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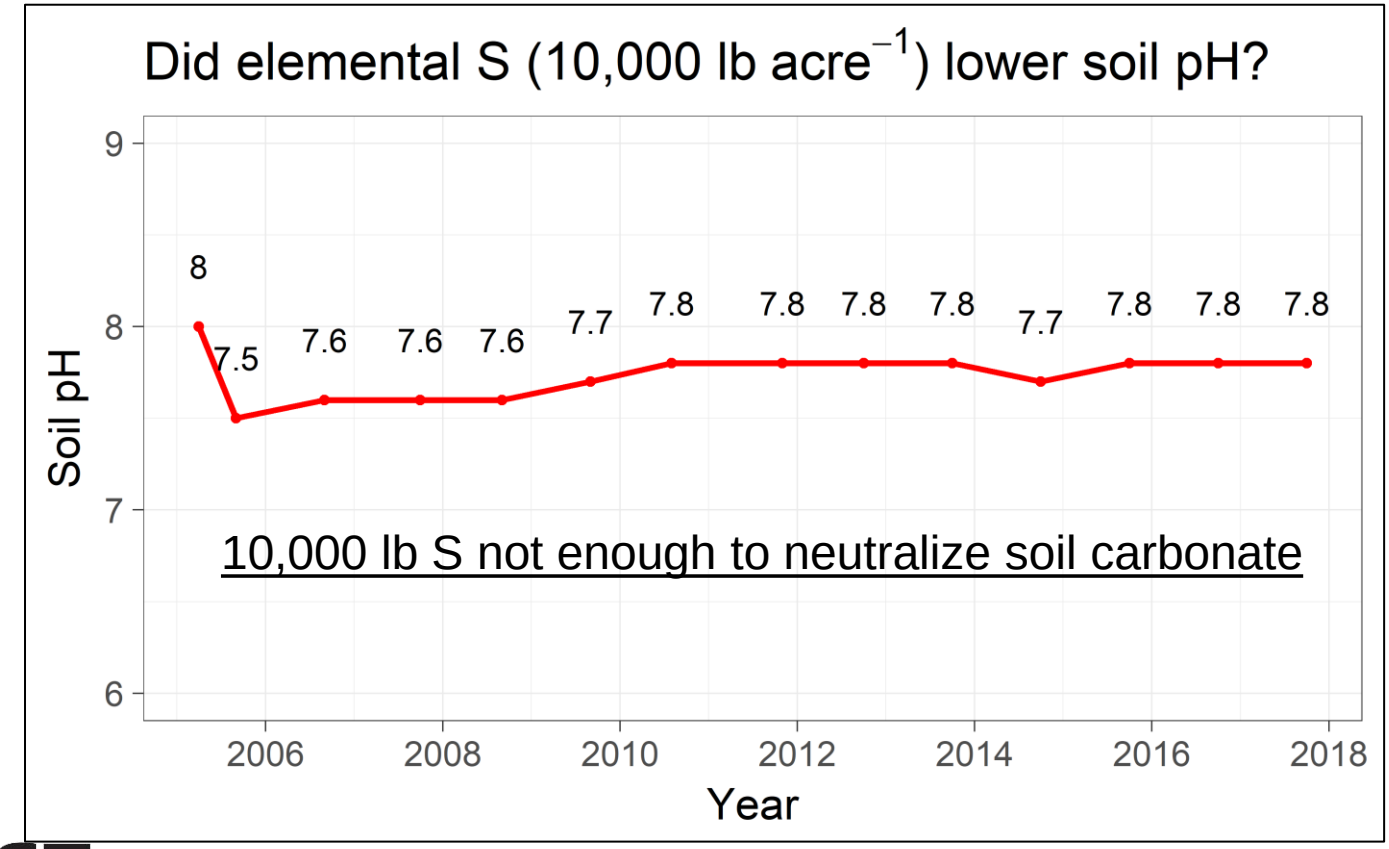
I only need about 100 lb/A elemental sulphur, right?

AGVISE Demonstration 2005-2017

Soil had 2.5% CCE, starting pH was 8

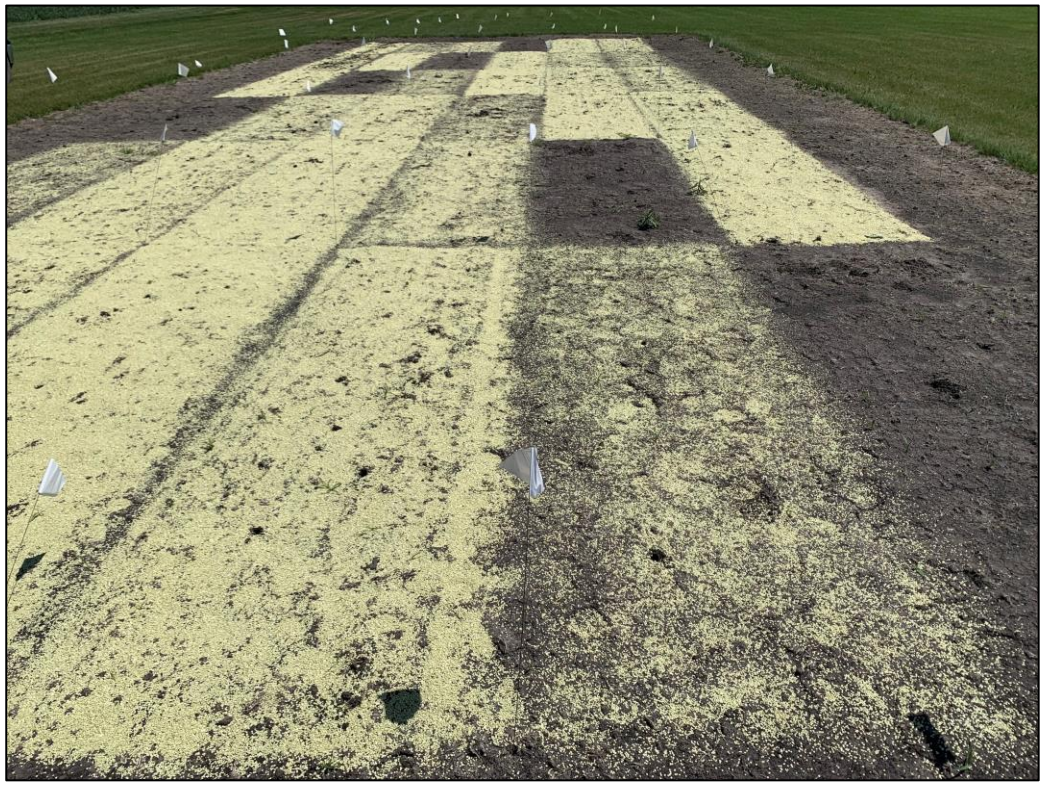


Again starting in 2020, with higher rates!

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 sulphur, tilled to 15 cm after application



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

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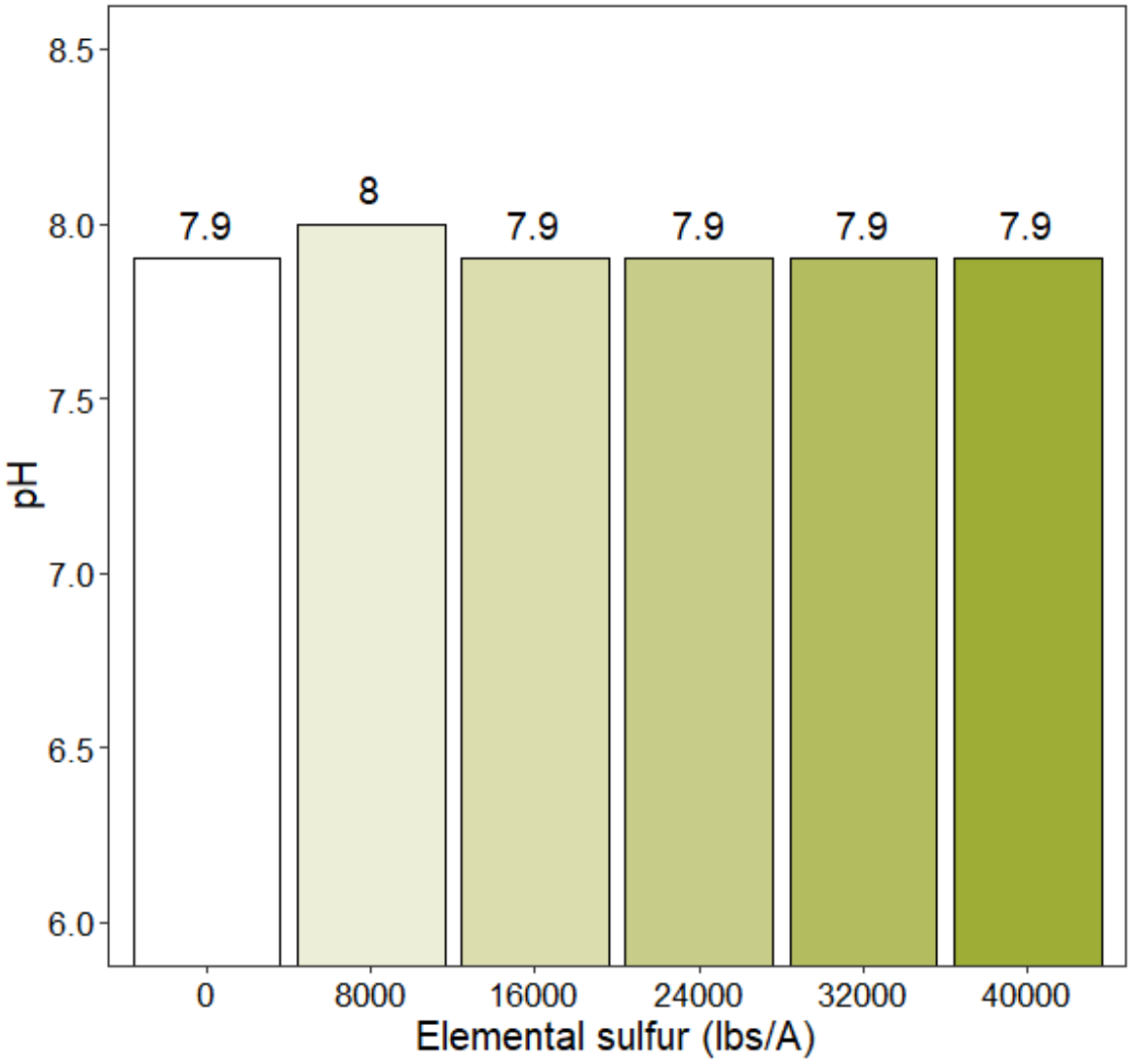
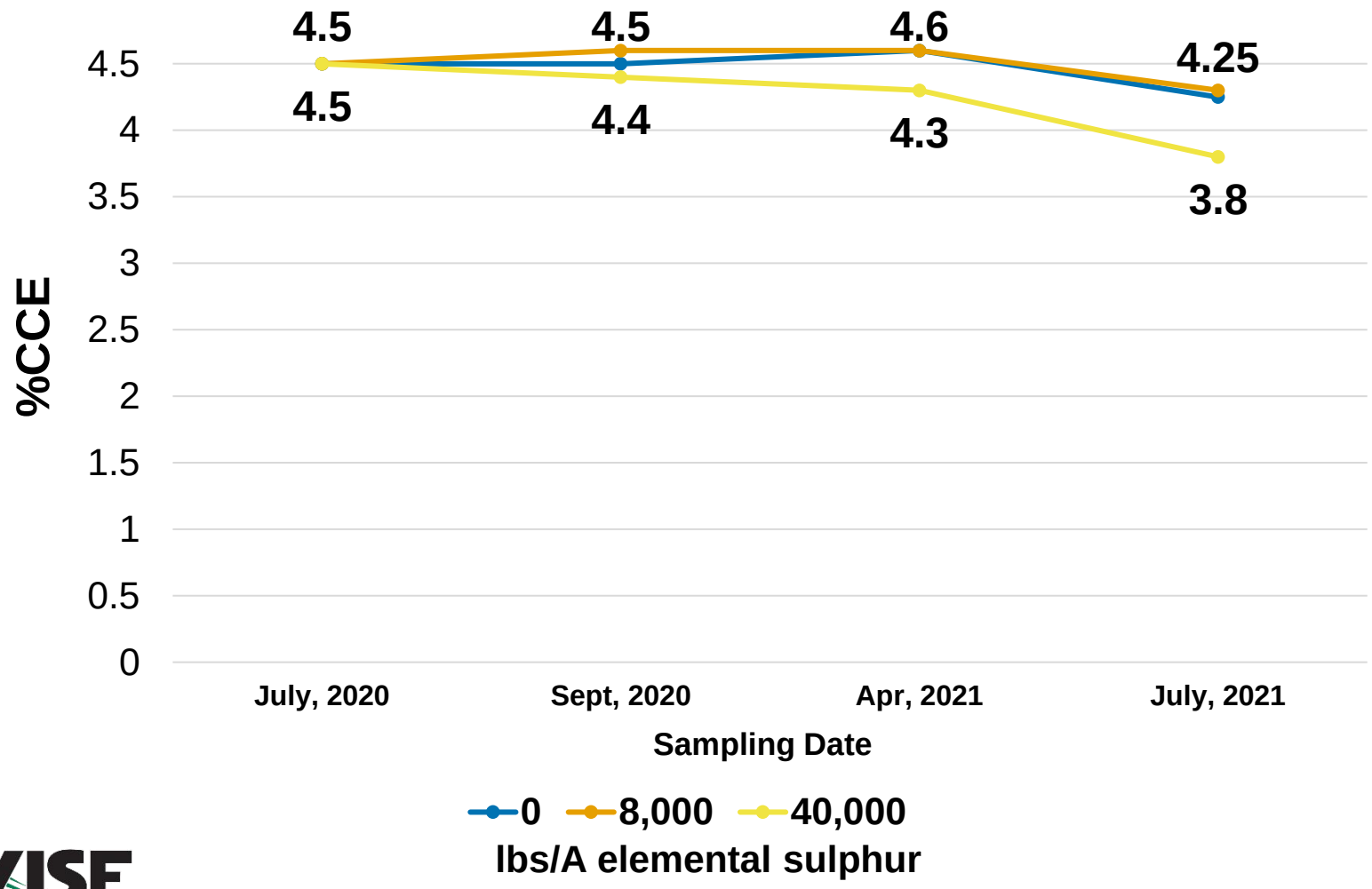
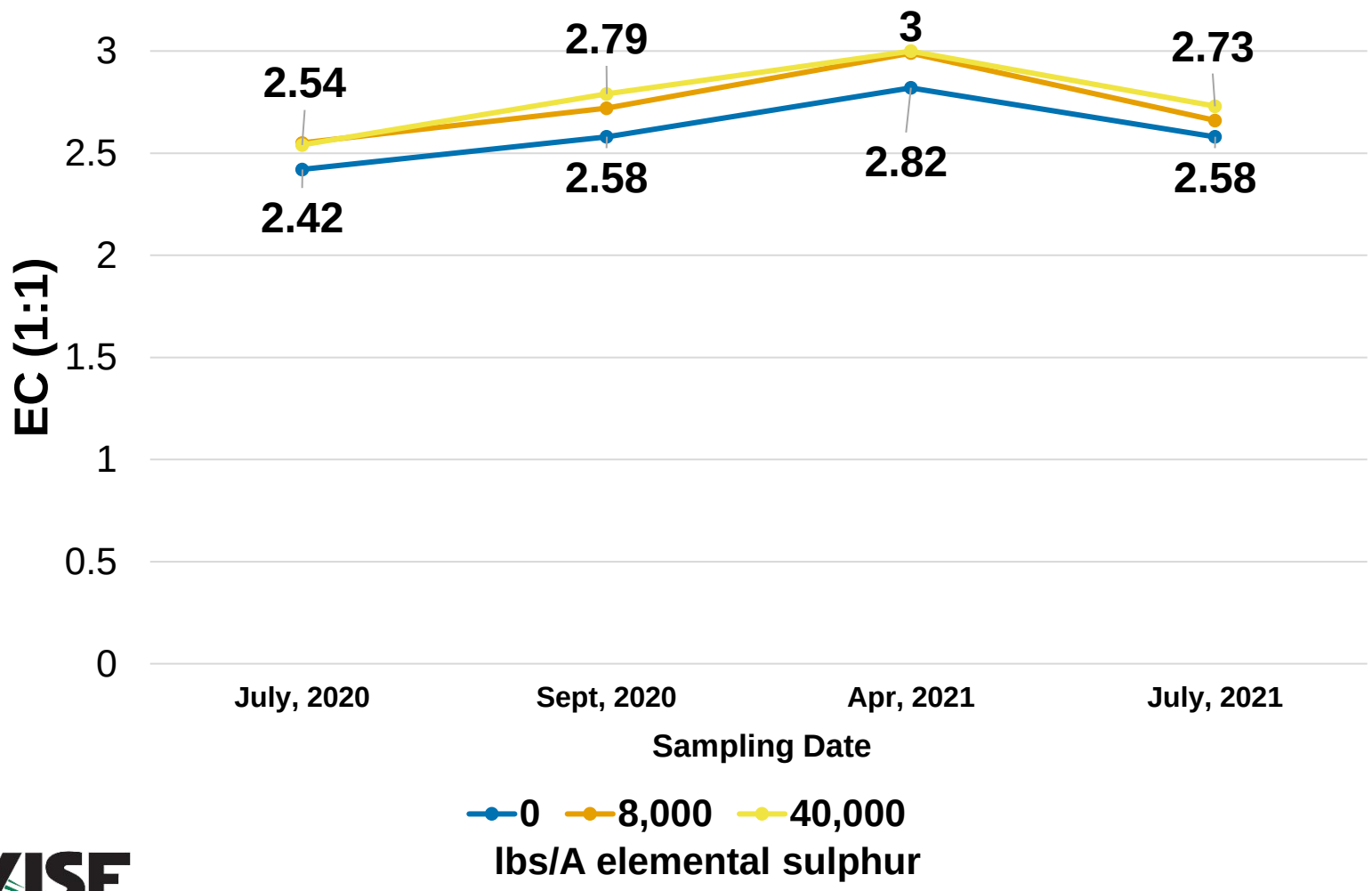
Effect of elemental sulphur rate on soil pH one year after application



Effect of elemental sulphur on %CCE over one year



Effect of elemental sulphur on EC (1:1) over one year

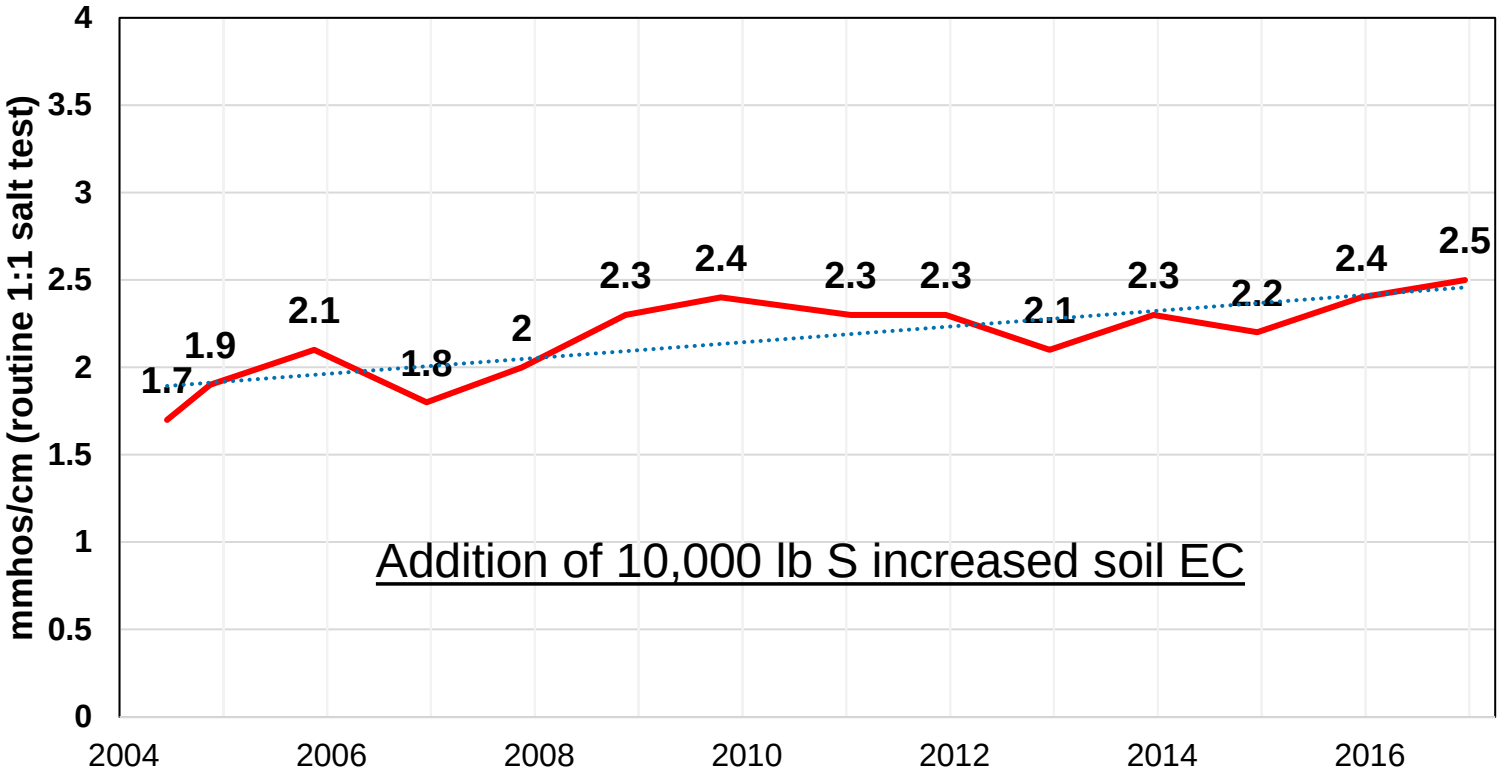


Effect of elemental sulphur on soil salinity

AGVISE Demonstration 2005-2017

Start EC was 1.7

Did elemental S (10,000 lb acre^{-1}) lower soil pH?



Elemental S reacts with $CaCO_3$ in the soil, creating gypsum ($CaSO_4$), which increases salinity

Is there an easy way to lower high pH?

Carbonate(CCE)	5.6 %	**********	Soil pH
0-6"	2.82 mmho/cm	**********	0-6" 7.9
Sol. Salts			

High pH and High Calcium Carbonate

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

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?

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

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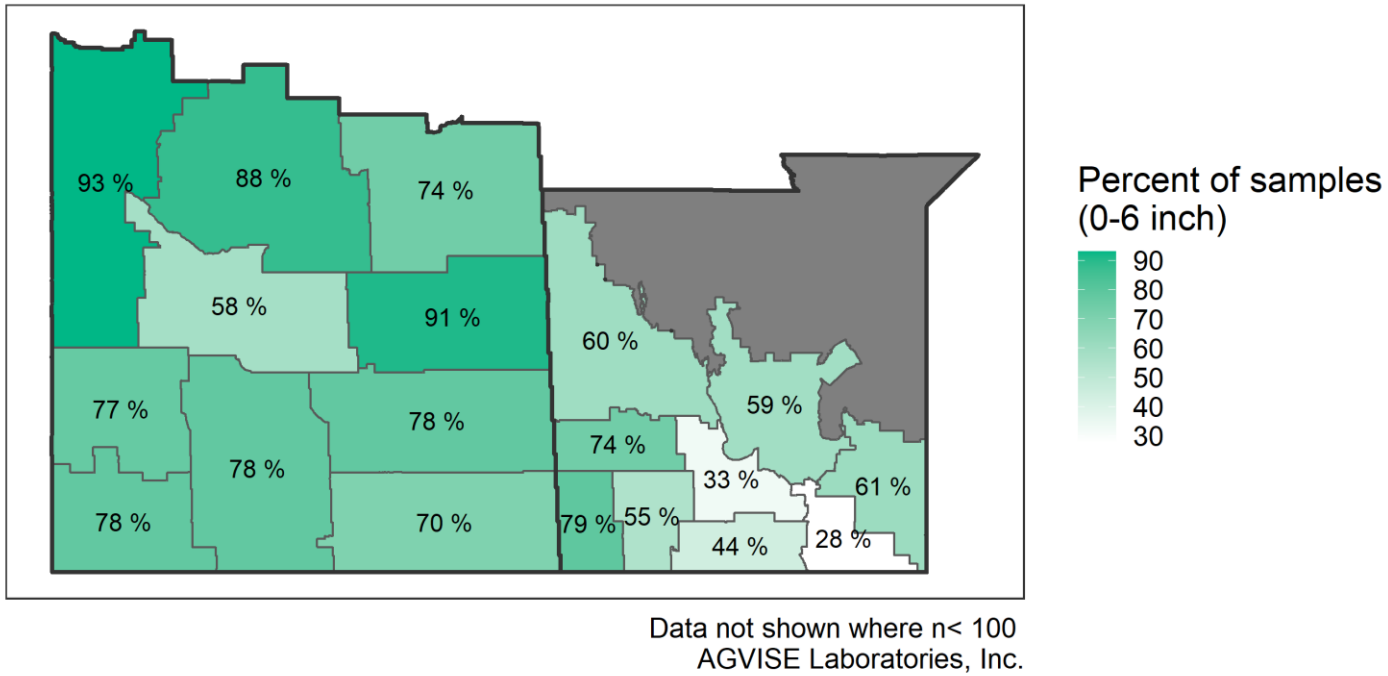
Is it possible to build soil test P levels in high pH soils?

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



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AGVISE long-term phosphorus project

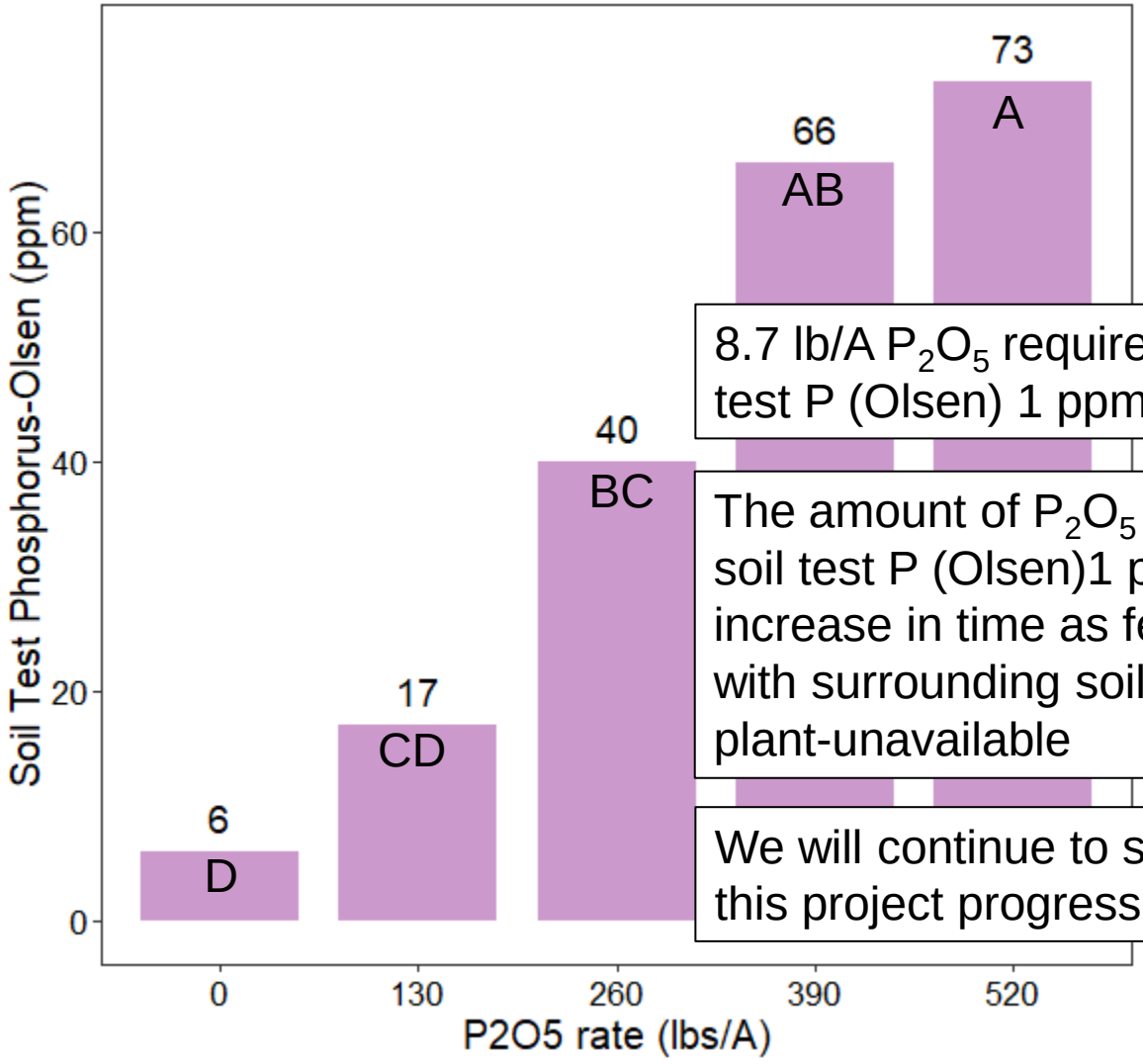
Objective: Determine rate of P needed to build soil test P levels; monitor over time

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 15 cm 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

We will continue to share results as this project progresses

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

Olsen Phosphorus	3 ppm	******				Soil pH
Carbonate(CCE)	2.1 %	**********				
0-6" Sol. Salts	2.86 mmho/cm	**********	**********	**********	**********	0-6" 7.8

Low soil test P

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

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?

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% 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**

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~~Can I increase soil %K?~~

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

Should I *acknowledge* %K?

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% 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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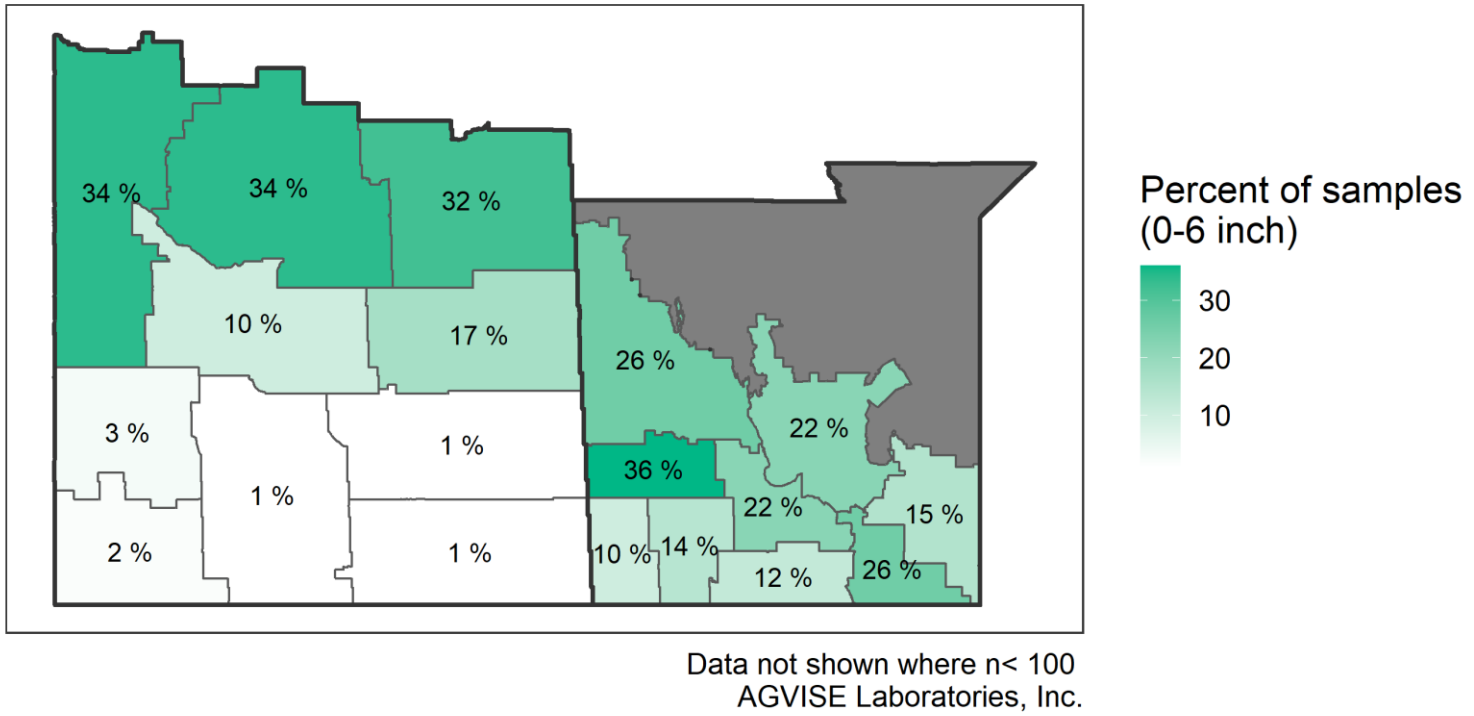
Should I acknowledge %K?

- 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>

How is %K calculated, anyway?

Potassium	211 ppm	**********
0-6" Chloride	52 lb/acre	**********
0-6" Sulfur	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

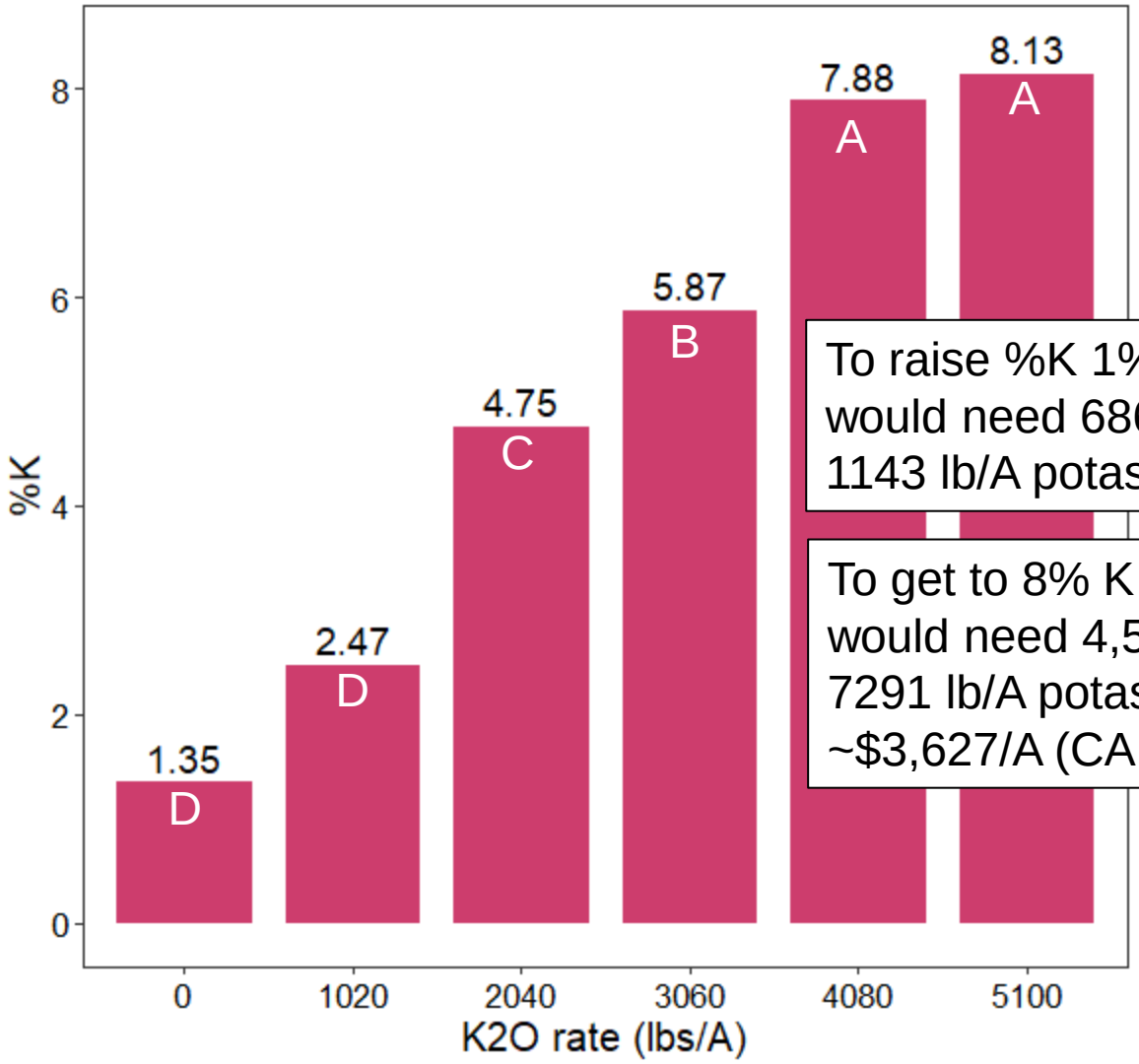
Objective: determine the amount of potash fertilizer required to raise imaginary %K in soil from 1.0% to 8.0%

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 15 cm after application

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

Effect of potash rate on soil %K

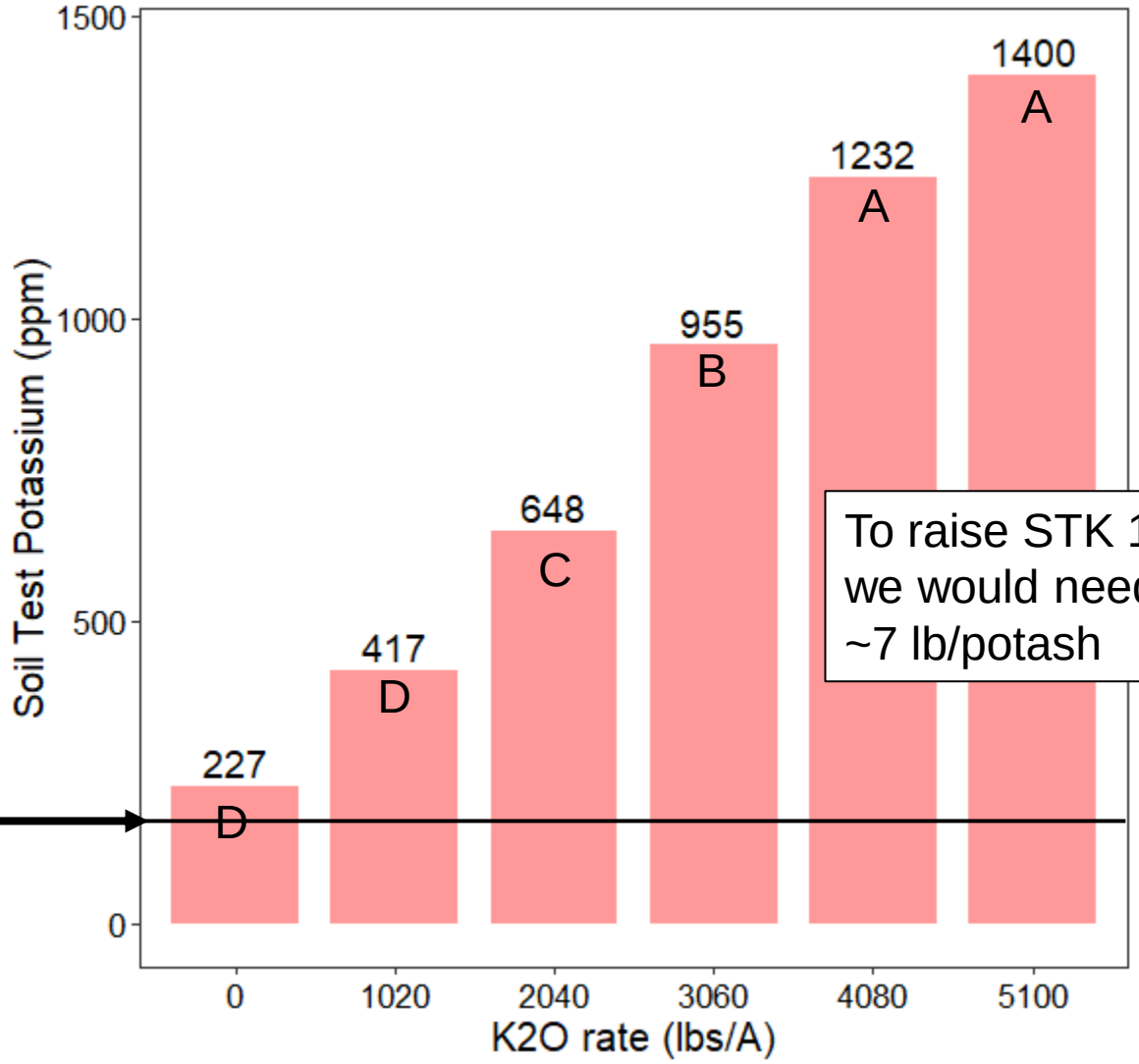


To raise %K 1% in this soil, we would need 686 lb/A K_2O, or 1143 lb/A potash (~0.5 MTs!)

To get to 8% K in this soil, we would need 4,521 lb/A K_2O, or 7291 lb/A potash (3.3 MTs!) ~$3,627/A (CAD)*

*Assuming price of $1,097 (CAD)/MT of potash

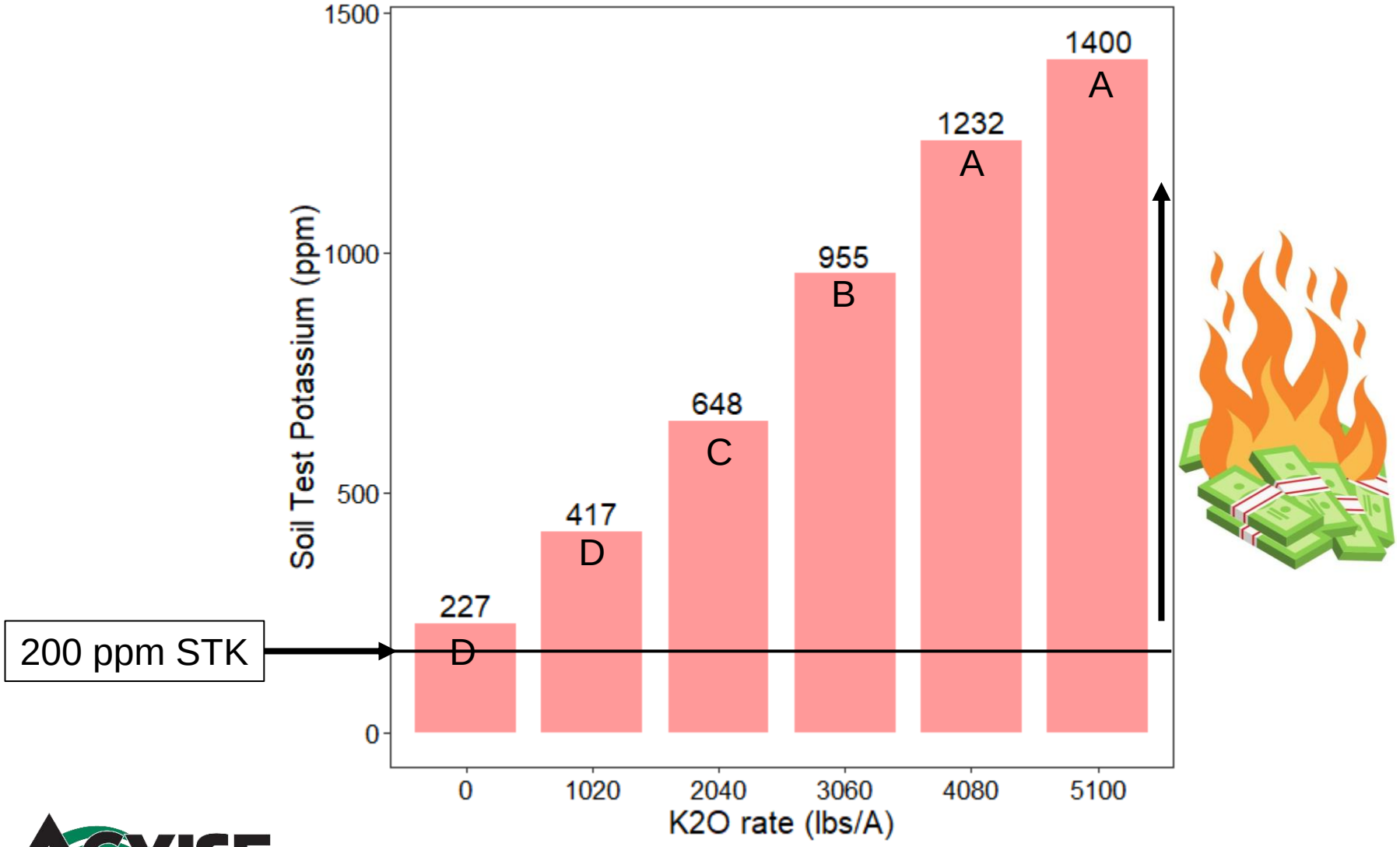
Effect of potash rate on soil-test K (ppm)



200 ppm STK

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

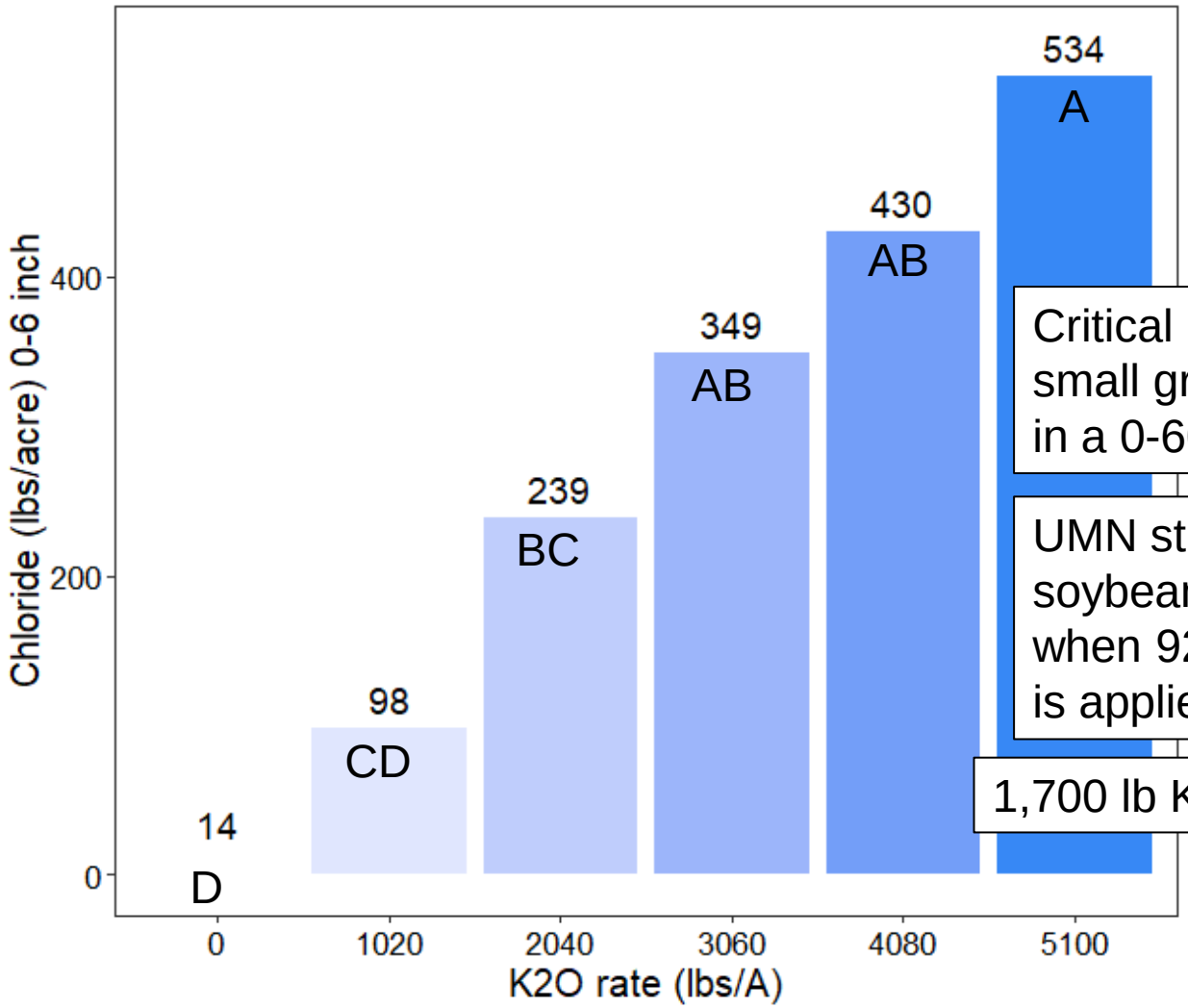
Effect of potash rate on soil-test K (ppm)



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

Effect of potash rate on soil chloride (lb/acre)



Critical Cl level for small grains = 40 lb/A in a 0-60 cm core

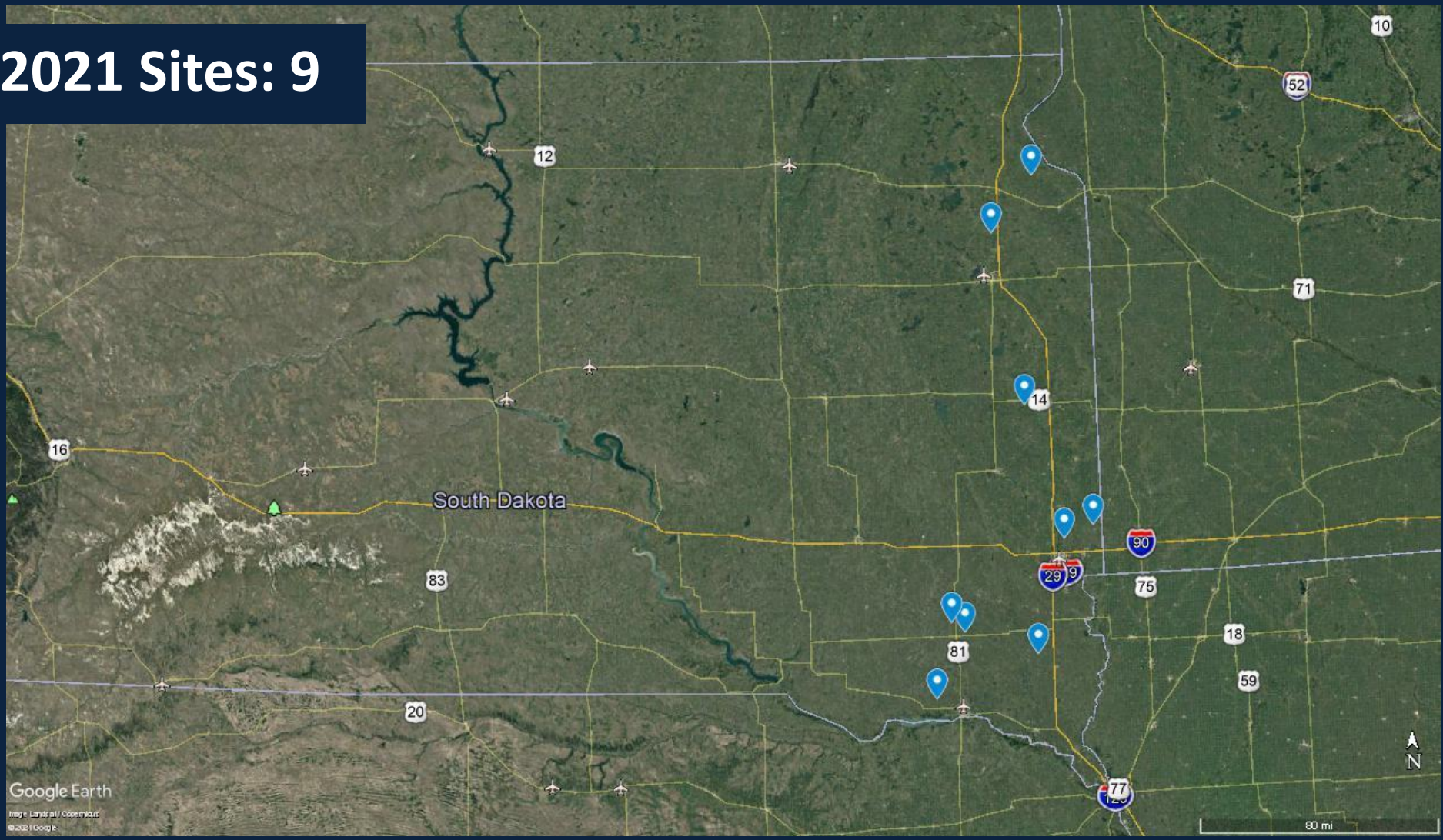
UMN studies show soybean yield loss when 92 lb/A chloride is applied

1,700 lb KCl = 782 lb Cl

What about yield?

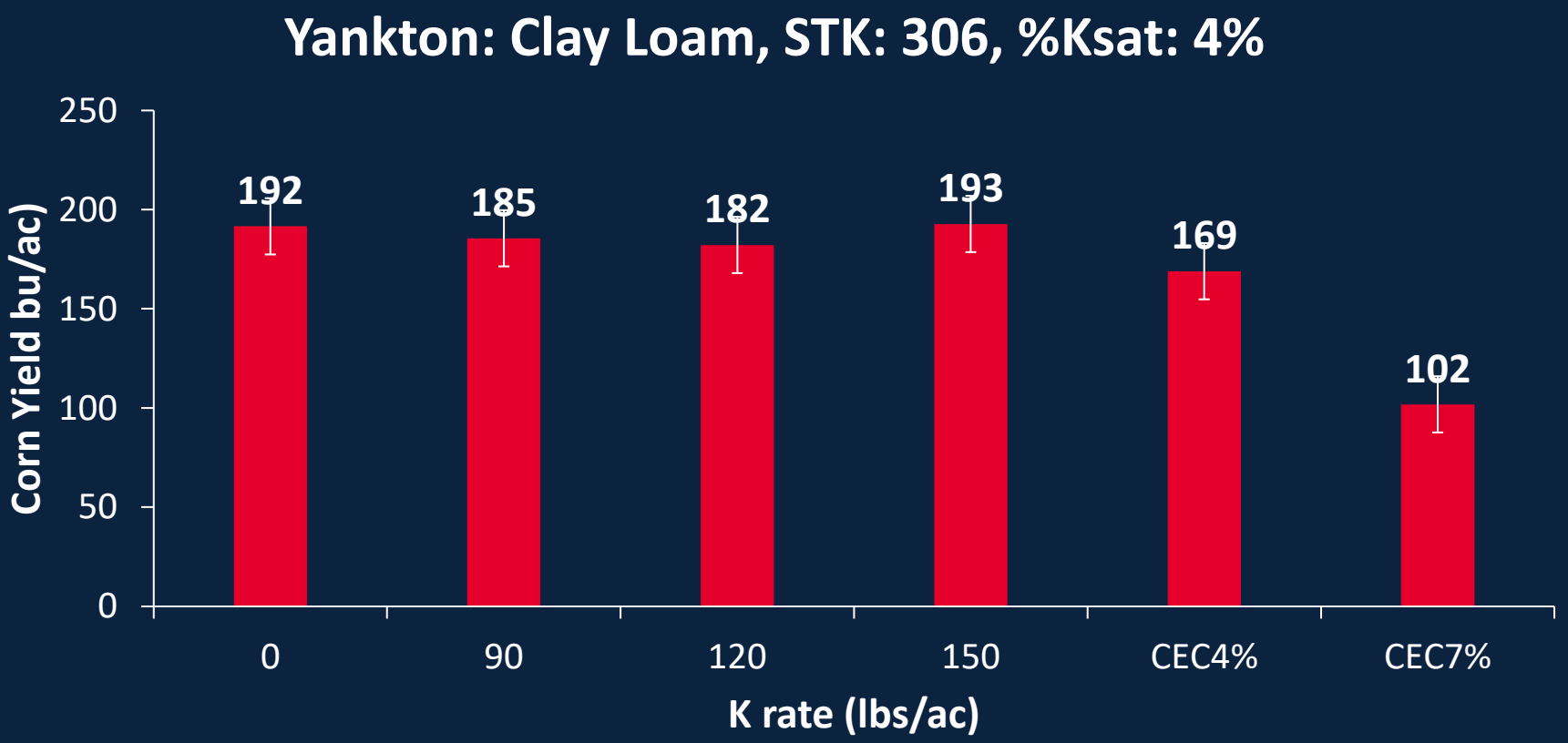
- The following slides are corn yield data from the 2021 growing season from Dr. Jason Clark at SDSU
- The goal was to measure yield response to differing rates of KCl fertilizer with differing soil-test K level
  - Rates: 0, 90, 120, 150 lbs K_2O plus two site-specific rates to reach %Ksat of 4% and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

2021 Sites: 9



Slide courtesy of Dr. Jason Clark, SDSU

2021 Corn Yield Data



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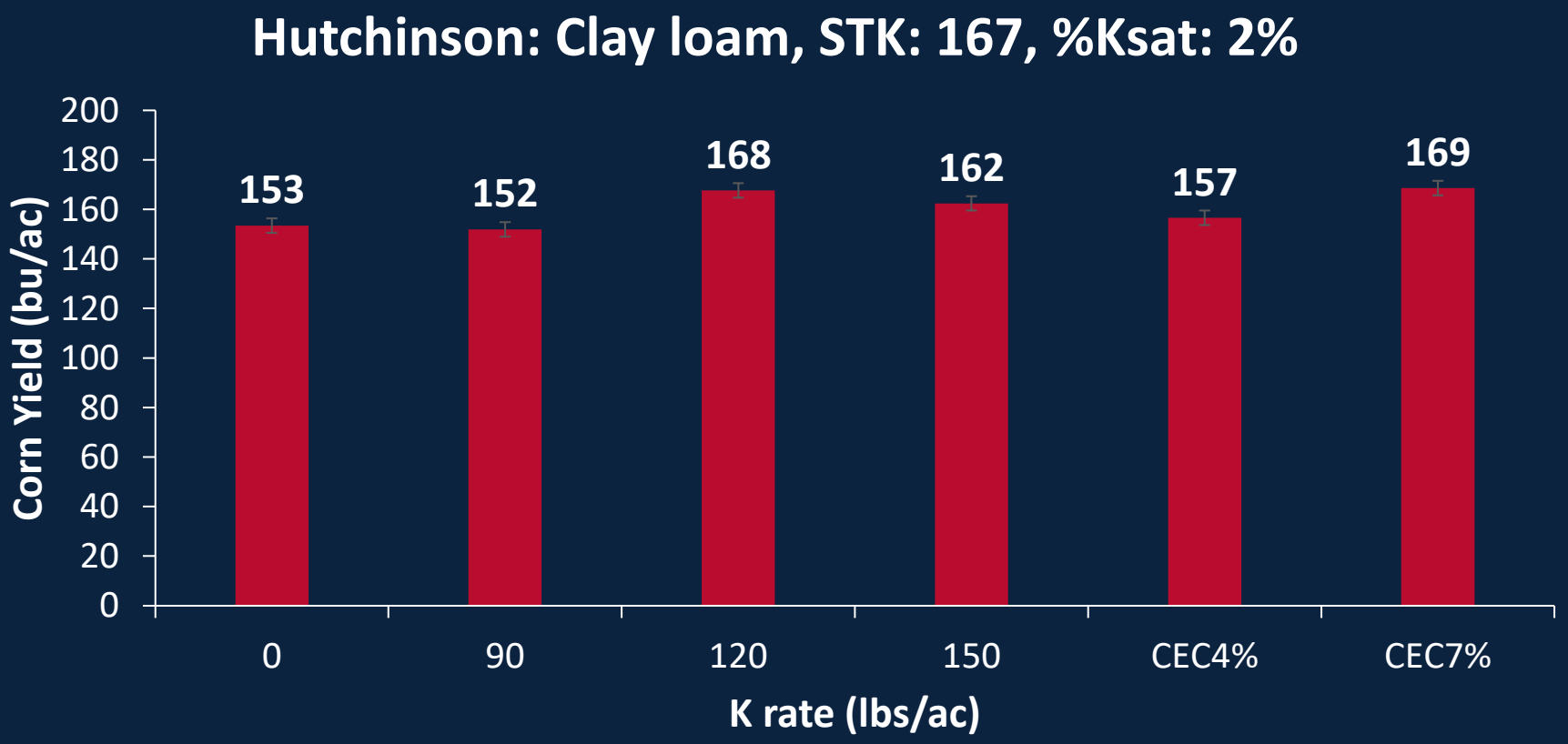

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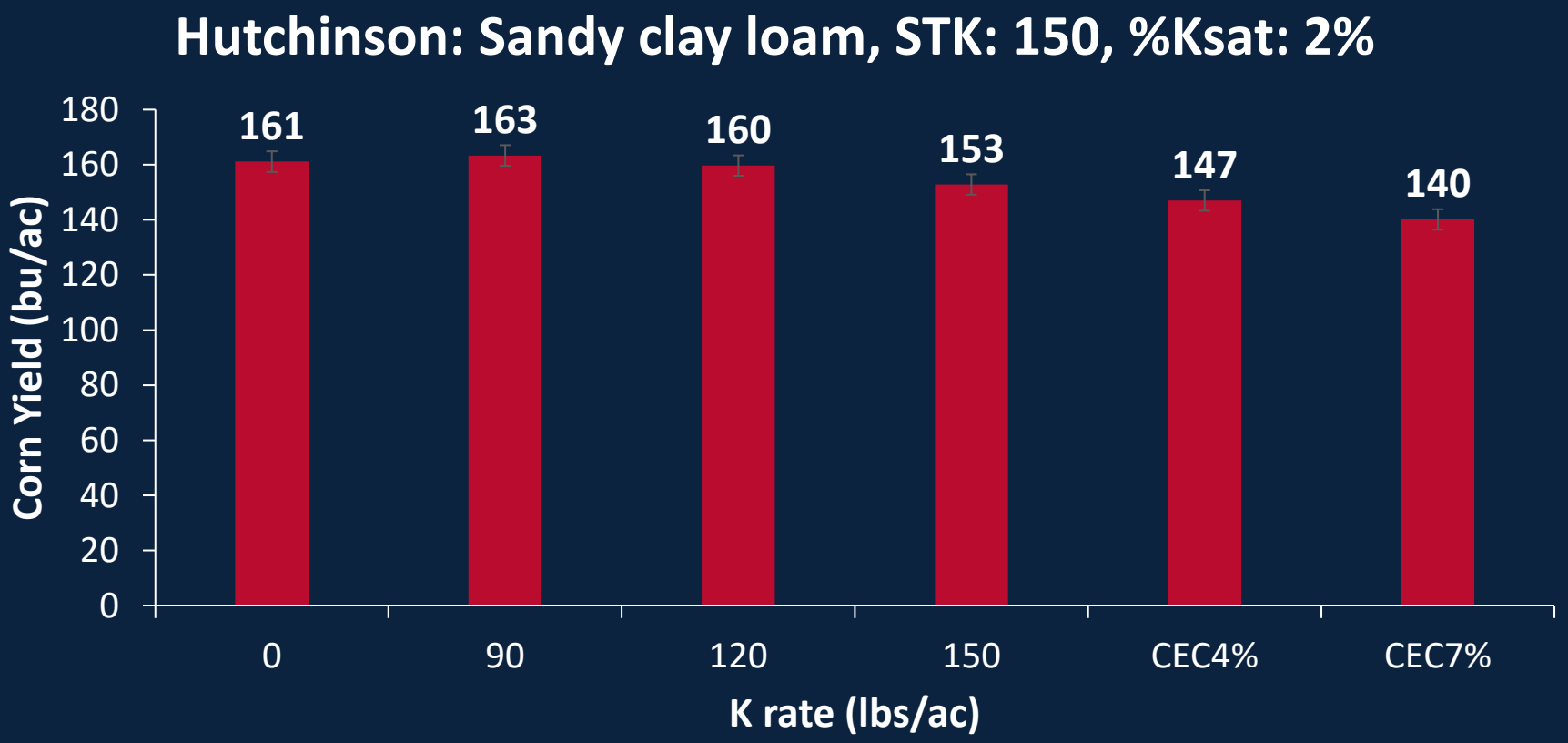

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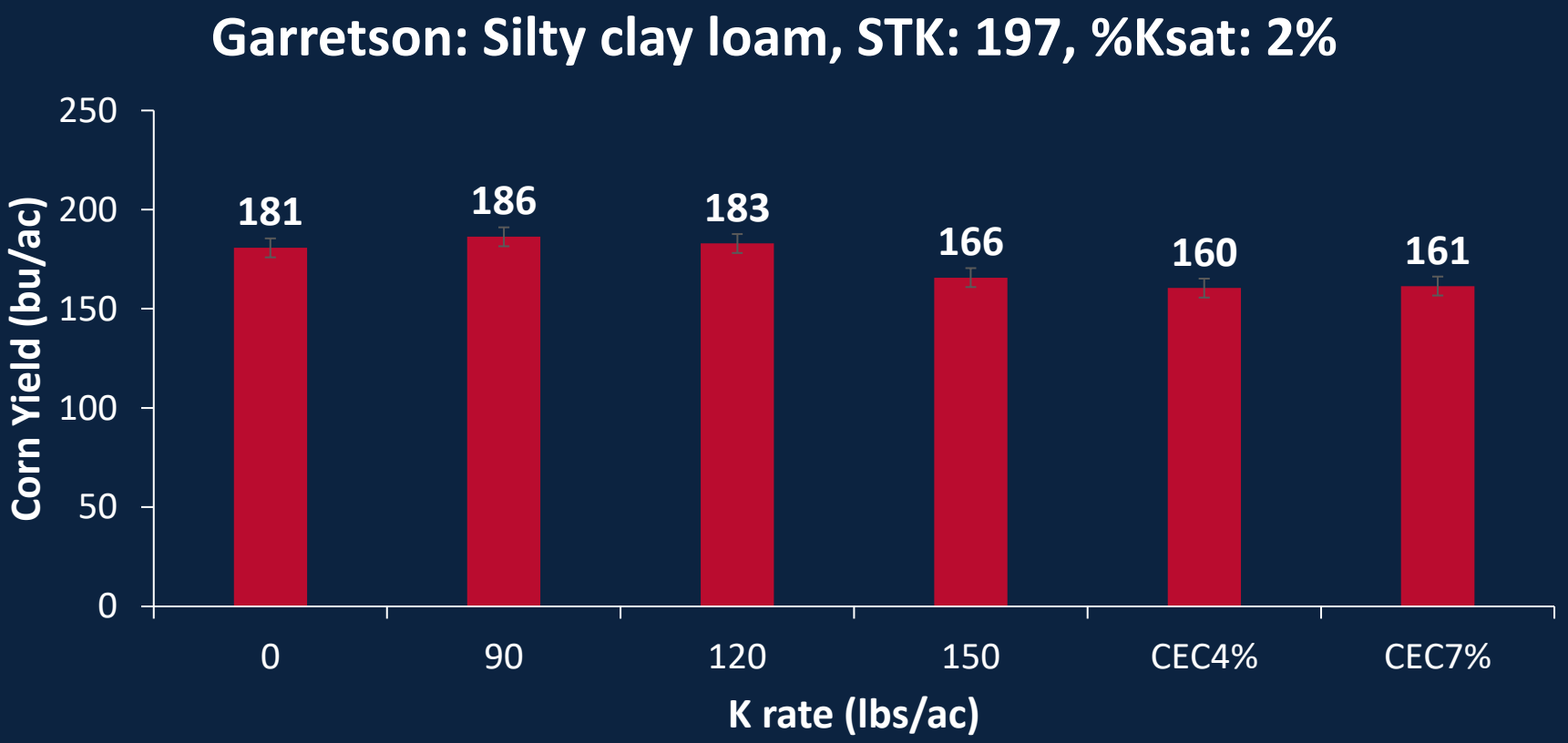

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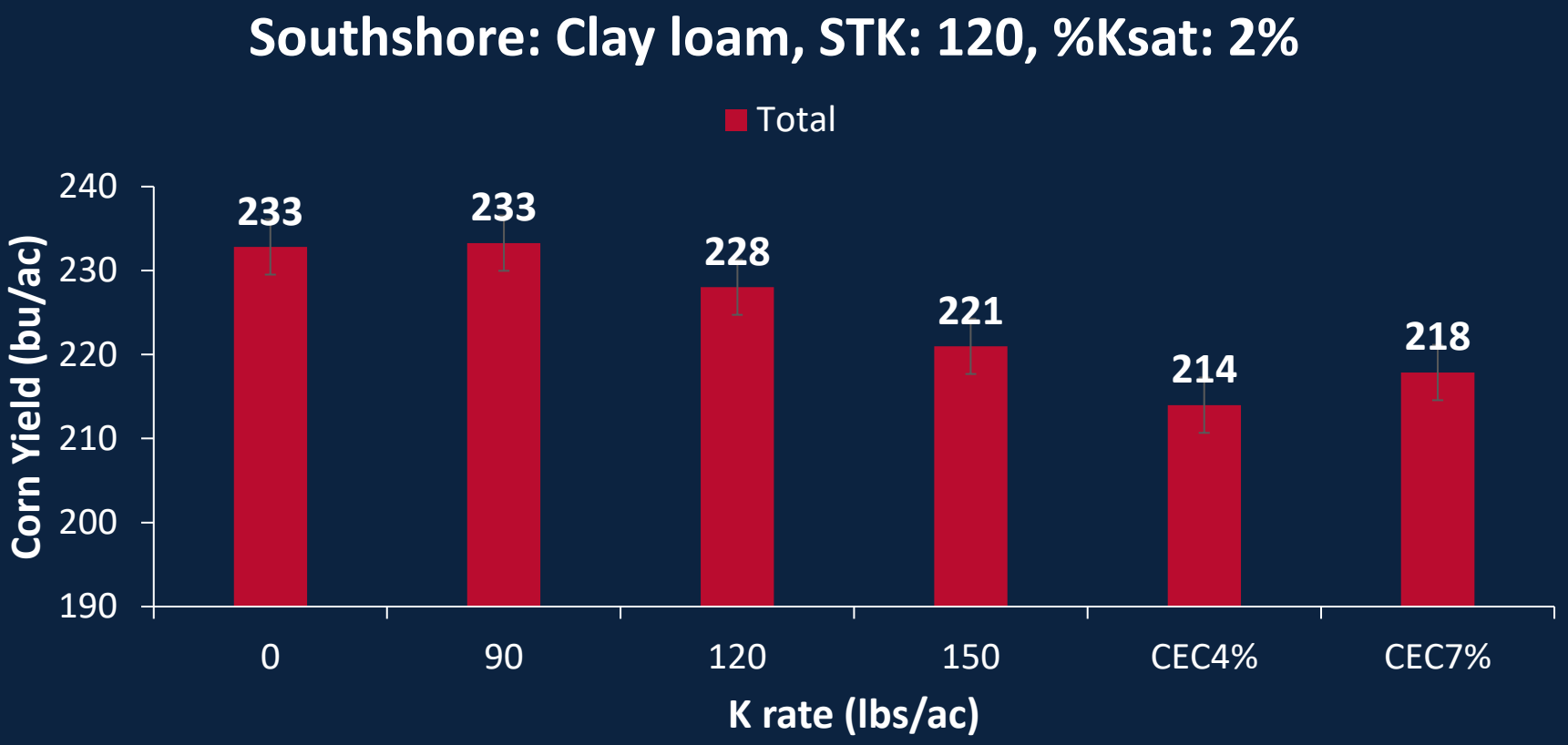

Slide courtesy of Dr. Jason Clark, SDSU

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

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

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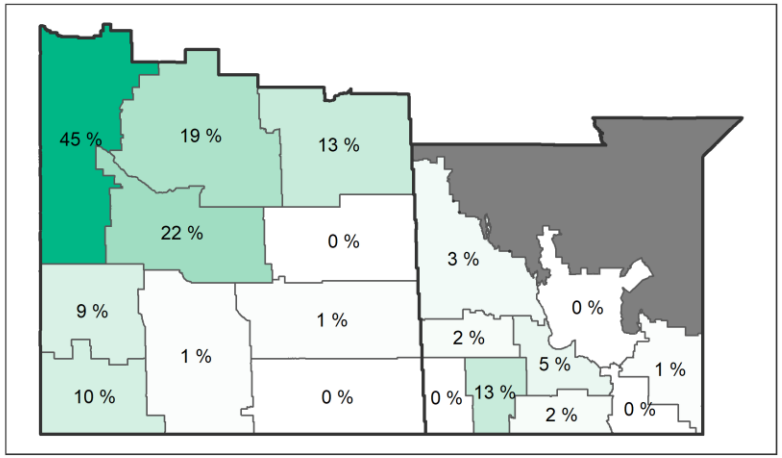
Soil acidity (pH <6.0) an emerging soil fertility issue on the Northern Plains

Soil samples with soil pH below 6.0 in 2021



Percent of samples (0-6 inch)

40
30
20
10
0

Data not shown where n< 100
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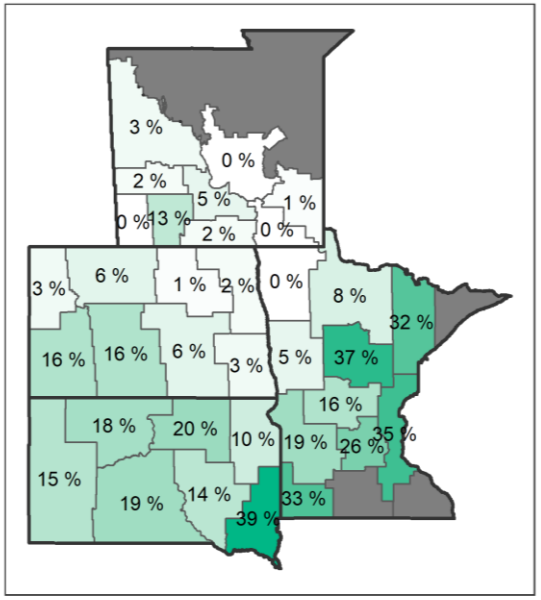
Soil samples with soil pH below 6.0 in 2021



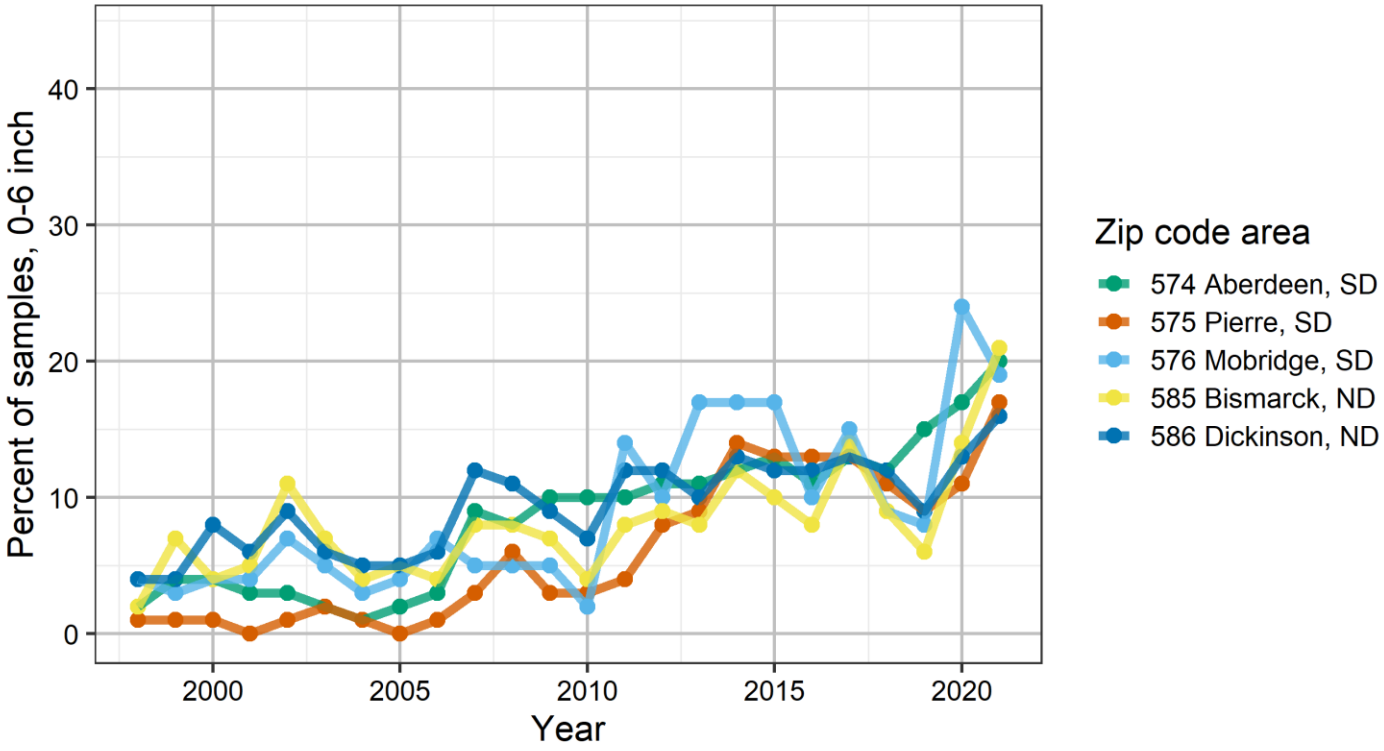
Percent of samples (0-6 inch)

30
20
10
0

Data not shown where n< 100
AGVISE Laboratories, Inc.

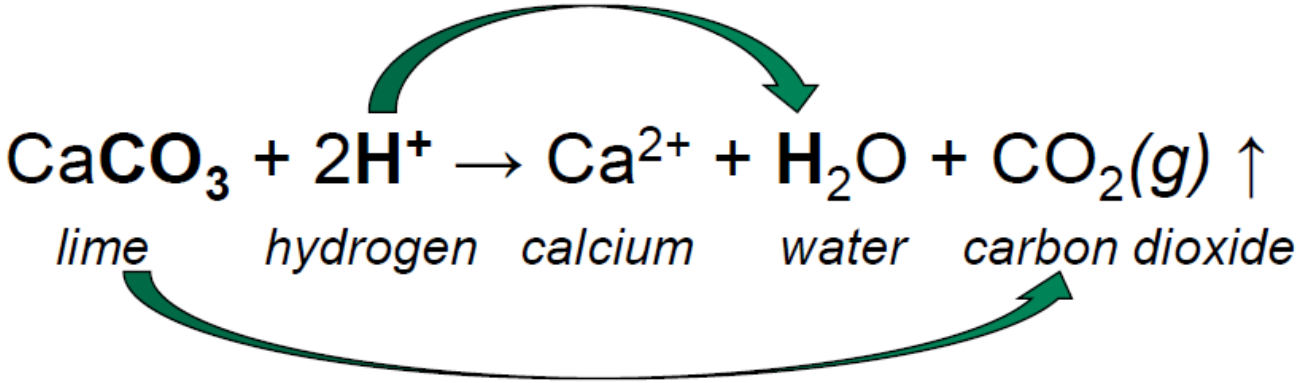
Managing soil acidity is an emerging soil fertility issue in North Dakota

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



- 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

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:

- 0-7.5 cm: 5.2
- 7.5-15 cm: 5.4

average initial buffer pH:

- 0-7.5 cm: 6.3
- 7.5-15 cm: 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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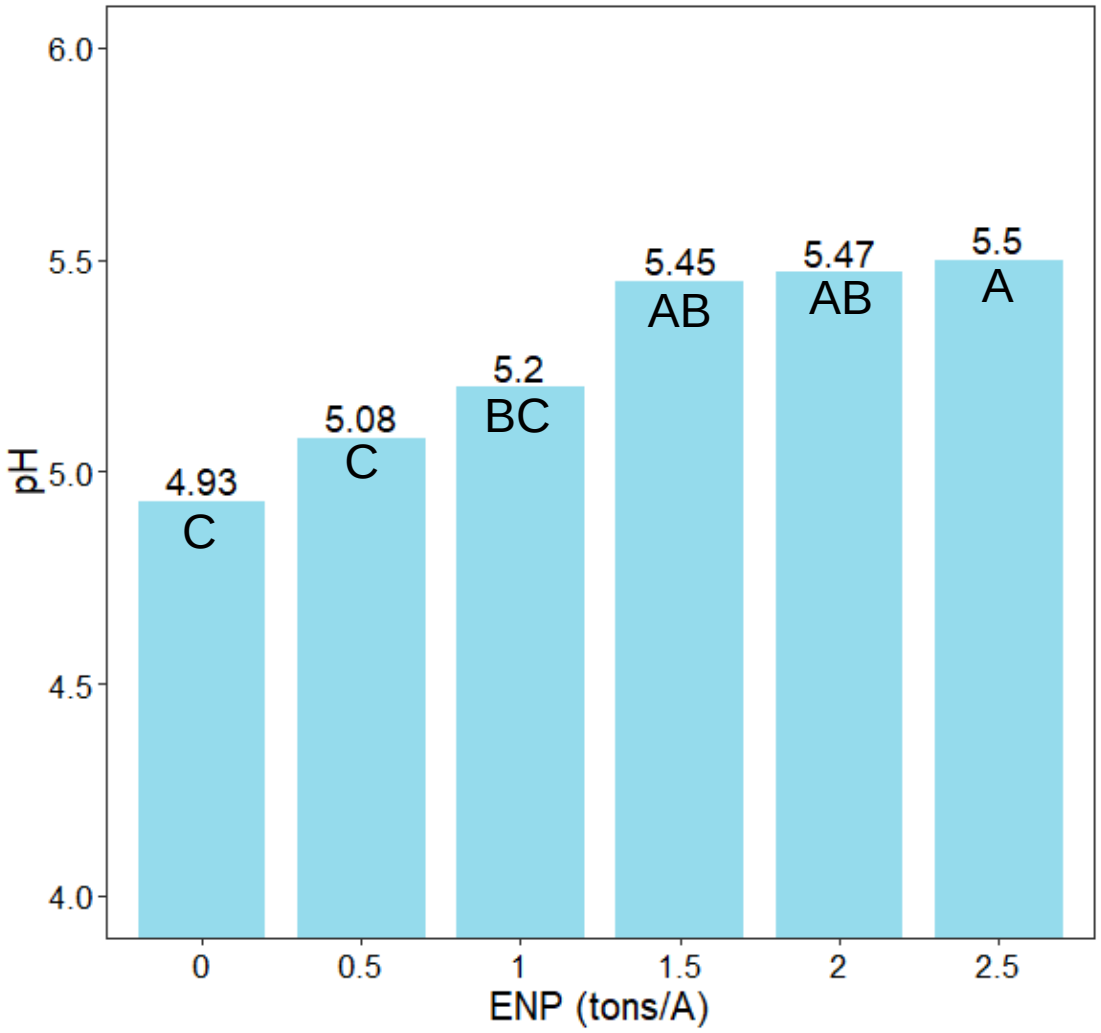
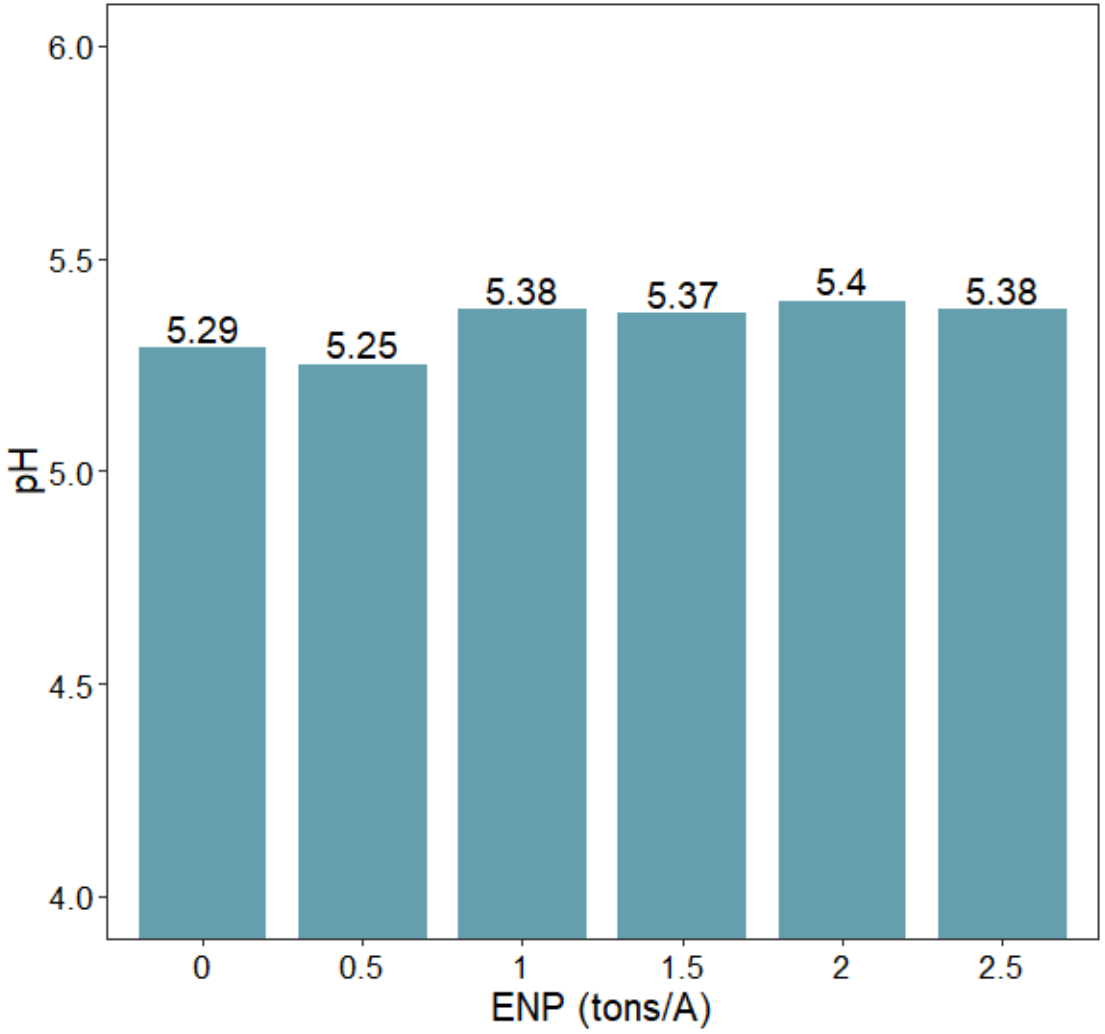
Effect of lime on soil pH, 3.5 months after application, 0-7.5 cm depth



Effect of lime on soil pH, 3.5 months after application, 7.5-15 cm 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.

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

AGVISE Projects:

1. Long-term elemental sulphur 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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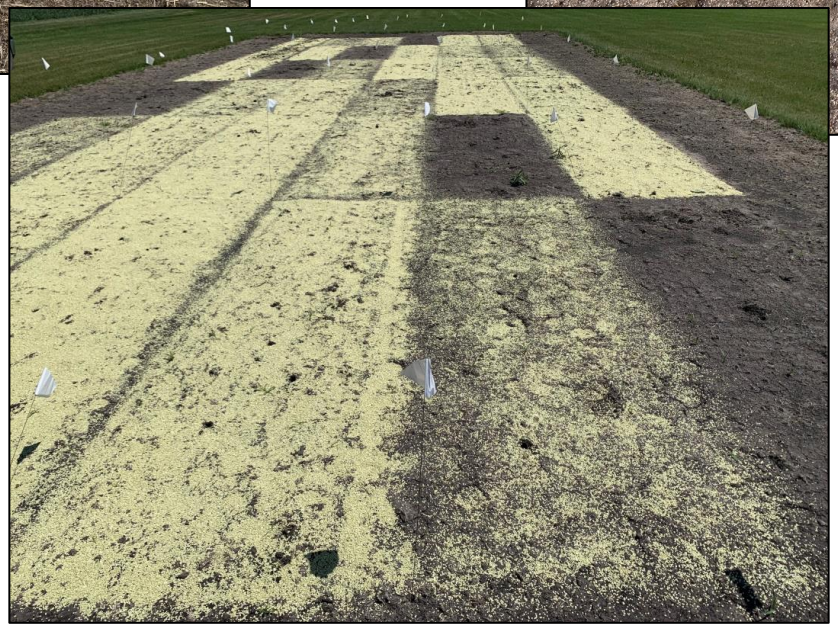
We look forward to continuing these projects in 2022!



Thank you!

Are there any questions?

Email me at jodi@agvise.com