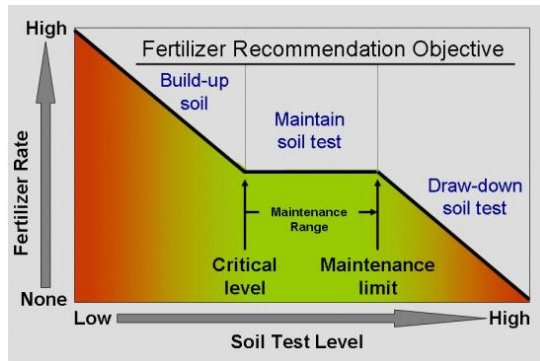


AGVISE Demonstration Project Update



Vitosh et al. (1995)

- Agvise Seminars
- March 14 and 16, 2023
- Brent Jaenisch, Ph.D.

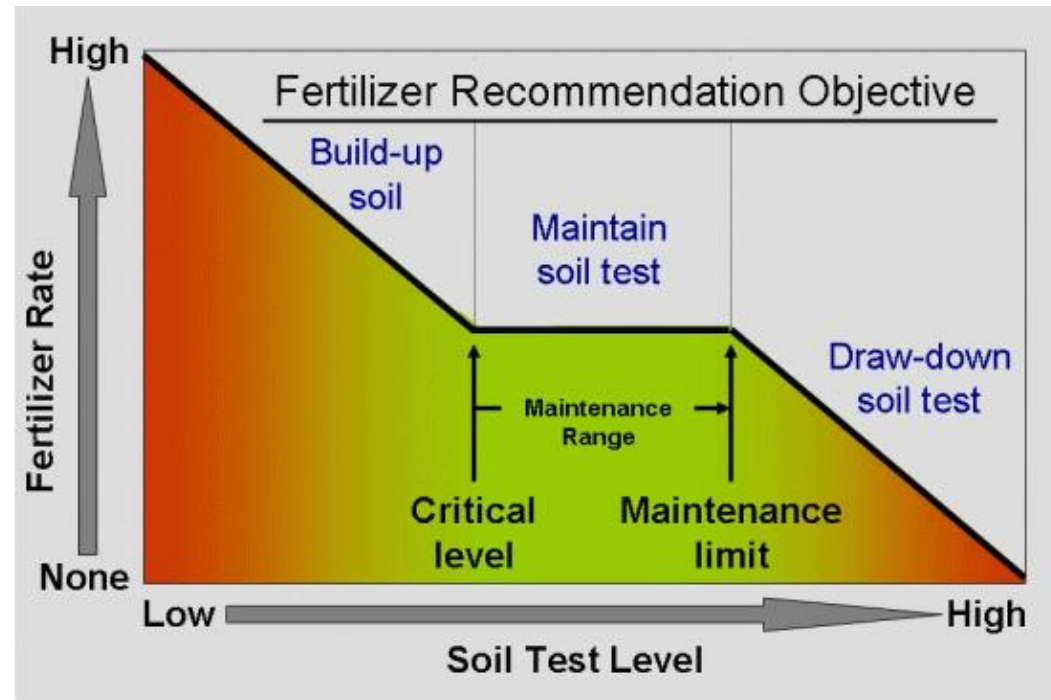


- Increasing soil test P and K values
- Decreasing soil pH with elemental sulfur
- Summary

Nutrient In The Soil		Interpretation			
		VLow	Low	Med	High
Nitrate	0-6"				
	6-24"				
	0-24"				
Phosphorus	Olsen				
Potassium					

Background – Why build soil test P and K values?

- Reduce fertilizer rates when prices are high
- Risk management



Vitosh et al. (1995)

Questions from growers about P

- Can you actually increase soil test phosphorus on high pH and calcareous soils?
 - We know high pH and calcium carbonate do increase phosphorus fixation.
- How much P does it actually take to move these soil test numbers in our upper Midwest soils?
- How many years will it take to raise soil test P to the optimal level?

Questions from growers about K

- Are you able to increase potassium saturation (%K) or base cation saturation ratios?
 - We know soils with high clay content have higher K buffering capacity.
 - We know soils with high pH, calcium carbonate, or salinity have inflated CECs and screwy BS calculations.
 - We know %K saturation is not important for soil potassium availability or crop uptake, so why do we still keep getting these questions?
- How much K does it actually take to move these soil test numbers in our upper Midwest soils?

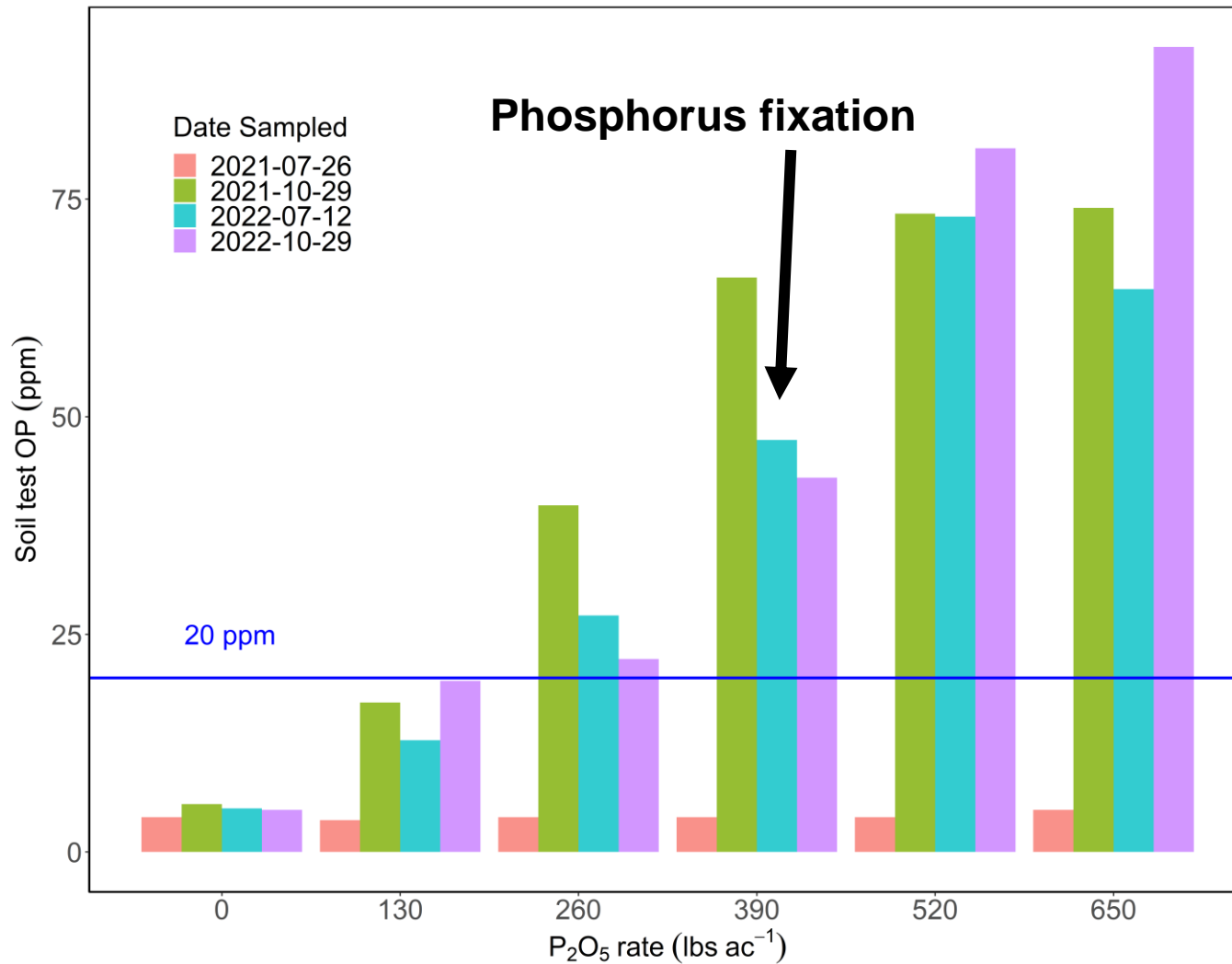
Long-term phosphorus and potassium fertilizer rate trial

- **Site:** Northwood, ND
 - Bearden silty clay loam
 - Soil pH: 7.9
 - Carbonate: 4.5% CCE
 - Initial soil test OP: 4 ppm
 - Initial soil test K: 226 ppm
 - Initial %K: 1.1%
- **Treatments:**
 - 0 to 1,250 lb/acre MAP (11-52-0)
 - 0 to 8,500 lb/acre potash (0-0-60)
 - rototilled to 6 inches after application

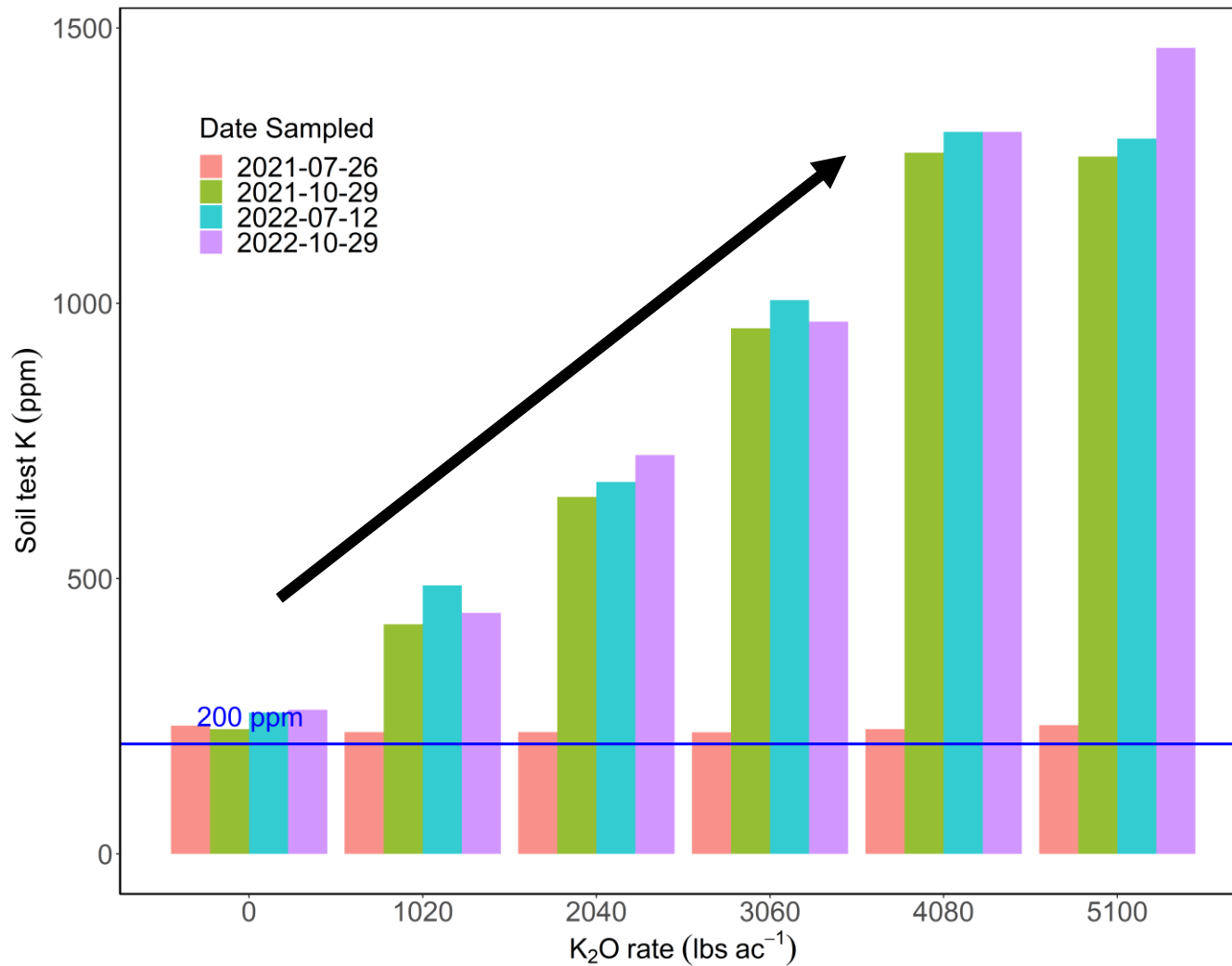


Trial initiated: September 1, 2021

Building soil test phosphorus

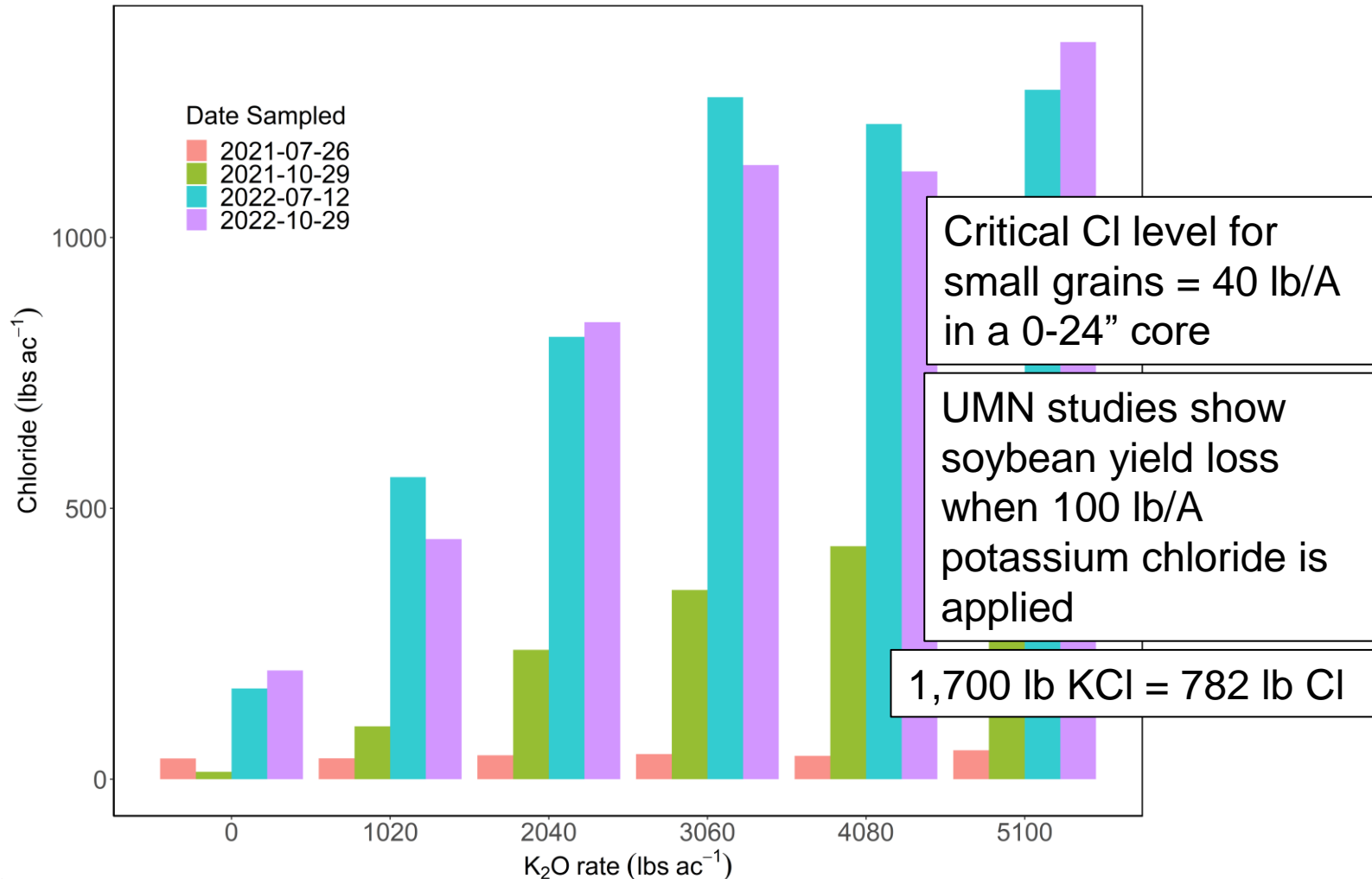


Building soil test potassium

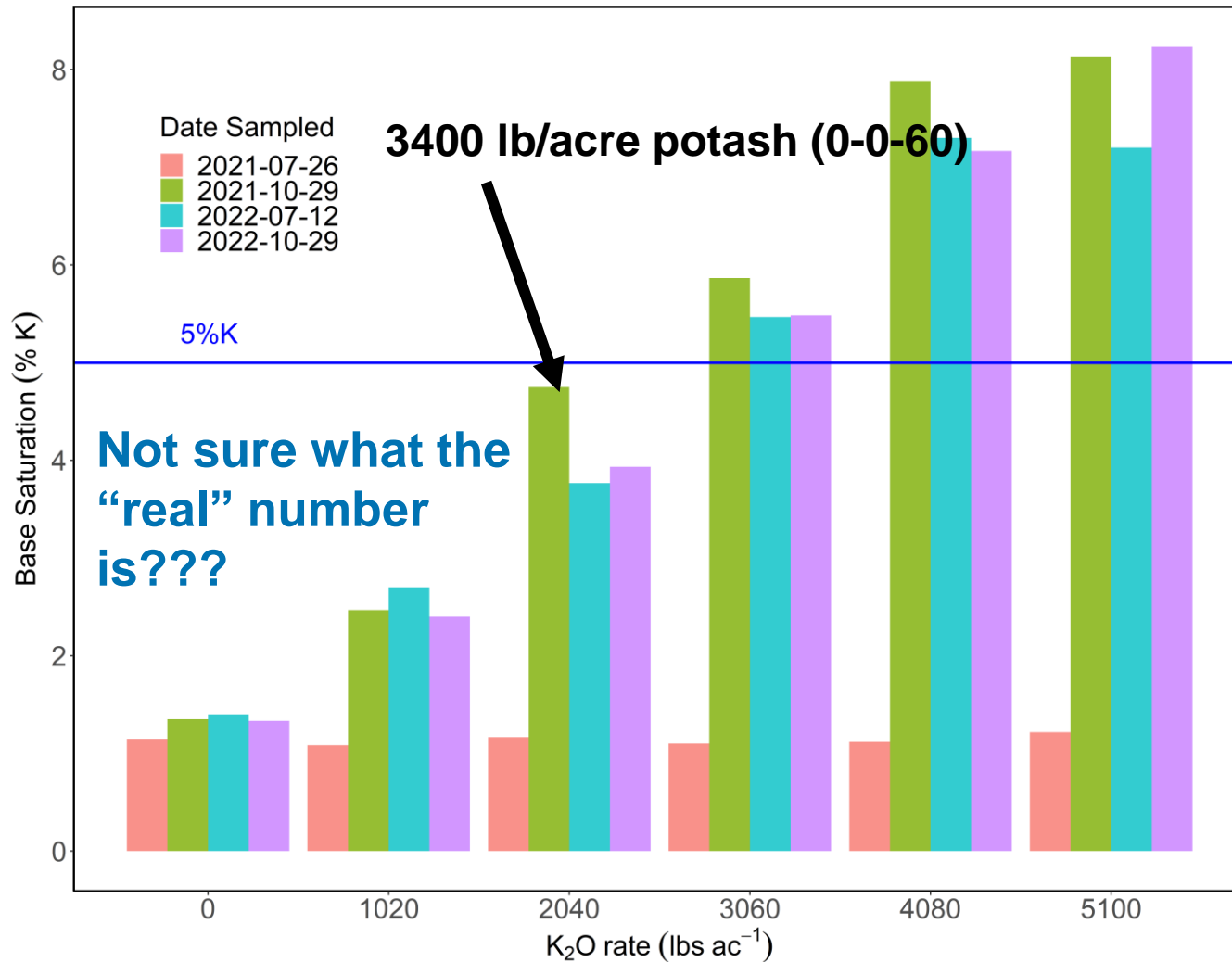


Effect of potash rate on soil chloride (lb/acre)

October 29, 2022



Building potassium base saturation



Soil buffering capacity, so far

Soil buffering capacity (building factor) describes how much added nutrient (fertilizer) is required to increase the soil test level. Factors include soil pH, soil texture, mineralogy, carbonate, and others.

Bearden silty clay loam, pH 7.9, 4.5% CCE.

Parameter	General range	Unit	Oct. 2021 (2 months)	July 2022 (10 months)	Oct. 2022 (14 months)
Soil test P (Olsen)	15-20 lb/ 1 ppm	P ₂ O ₅	7.2 lb/ppm	8.1 lb/ppm	9.3 lb/ppm
Soil test K	5-10 lb/ 1 ppm	K ₂ O	4.2 lb/ppm	4.4 lb/ppm	4.2 lb/ppm
K saturation	soil dependent	K ₂ O	660 lb/%	770 lb/%	772 lb/%

Take home message for Phosphorus

- Soil test P increased quickly from “fresh” P
- Phosphorus fixation is occurring and decreasing soil test P
 - Typical range - 15-20 lb P_2O_5 /ppm.

Take home message for Potassium

- Many soils in the northern Great Plains have high soil test K ppm
- There isn't a real %K value
- Concept of “ideal” BSCRs still floating around, despite no replicated research
- %K increased to 4-8% when high rates of K were applied
 - 3,400 – 8,500 lbs./ acre potash
- 100 years worth of K
- Typical range - 5-10 lb K₂O/ppm.

Take home message for Potassium

% Base Saturation (Typical Range)				
% Ca	% Mg	% K	% Na	% H
(65-75) 71.3	(15-20) 26.2	(2-5) 0.9	(0-5) 1.6	(0-5) 0.0

Nutrient In The Soil			Interpretation			
			VLow	Low	Med	High
Nitrate	0-6"	15 lb/ac				
	6-24"	15 lb/ac	*****			
	0-24"	10 lb/ac				
Phosphorus	Olsen	33 ppm	*****	*****	*****	*****
Potassium		619 ppm	*****	*****	*****	*****

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)

- Sandy soils - test low in K and are prone to leaching
- Fine texture – test high in K and deficiency can develop if soil is compacted or if soil contains high proportion of smectitic clays
- Potassium deficiency occurs when water is limiting.

Excessive Potash Fertilization Negatively Impacted Corn Growth and Grain Yield in Eastern South Dakota

Andrew Ahlersmeyer¹, Jason Clark²

¹M.S. Student, South Dakota State University

²Assistant Professor and Extension Soil Fertility Specialist, South Dakota
State University

Objectives

- 1. Investigate the negative implications of this practice on corn growth and yield**
- 2. Provide possible explanations for this occurrence**



Materials and Methods

- Soil samples were collected prior to treatment application
 - Various physical, chemical, and biological parameters tested
 - Sample depths of 0-10, 0-15, 15-30, and 30-60 cm
- Treatments of potash (0-0-60) were manually broadcast applied prior to VE
 - Conventional and excessive rates
- Response parameters:
 - V6 stand estimates, vegetative K content, and dry matter
 - NDVI imagery (Brookings-2022)
 - Grain yield
- Statistics analyzed in Excel and R



Materials and Methods

Conventional K Rates

Applied as part of the primary potassium rate study

- 0 kg K₂O ha⁻¹
- 34 kg K₂O ha⁻¹
- 67 kg K₂O ha⁻¹
- 101 kg K₂O ha⁻¹
- 134 kg K₂O ha⁻¹
- 168 kg K₂O ha⁻¹



Excessive K Rates

Applied to increase base saturation K to 40 and 70 g kg⁻¹

Yankton-2021

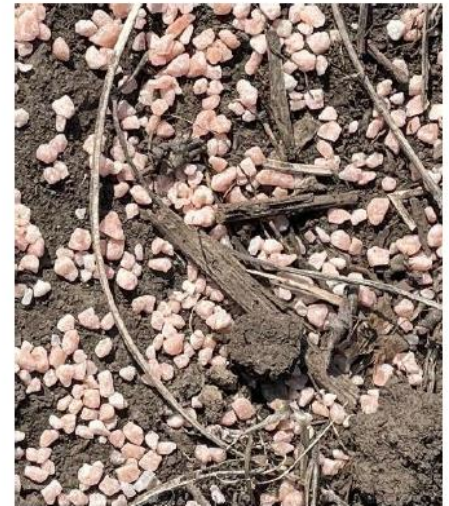
- 1434 kg K₂O ha⁻¹
- 2509 kg K₂O ha⁻¹

Brookings-2022

- 1553 kg K₂O ha⁻¹
- 2718 kg K₂O ha⁻¹

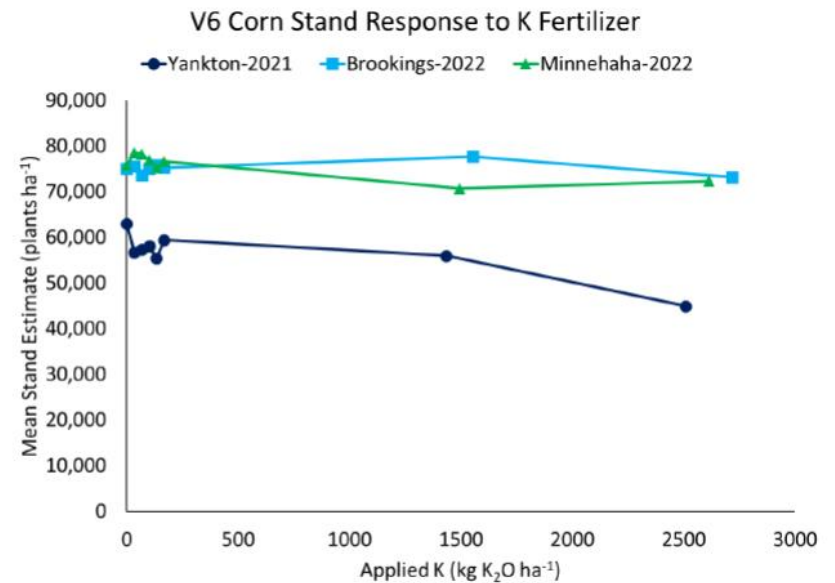
Minnehaha-2022

- 1493 kg K₂O ha⁻¹
- 2613 kg K₂O ha⁻¹



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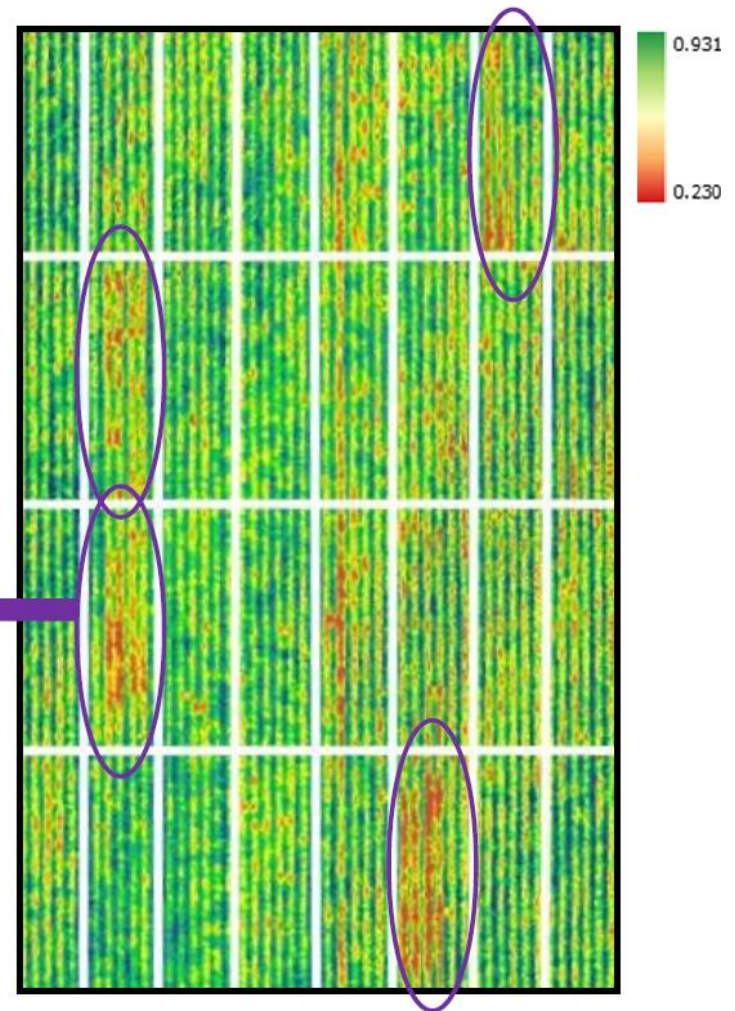
V6 Stand Estimates



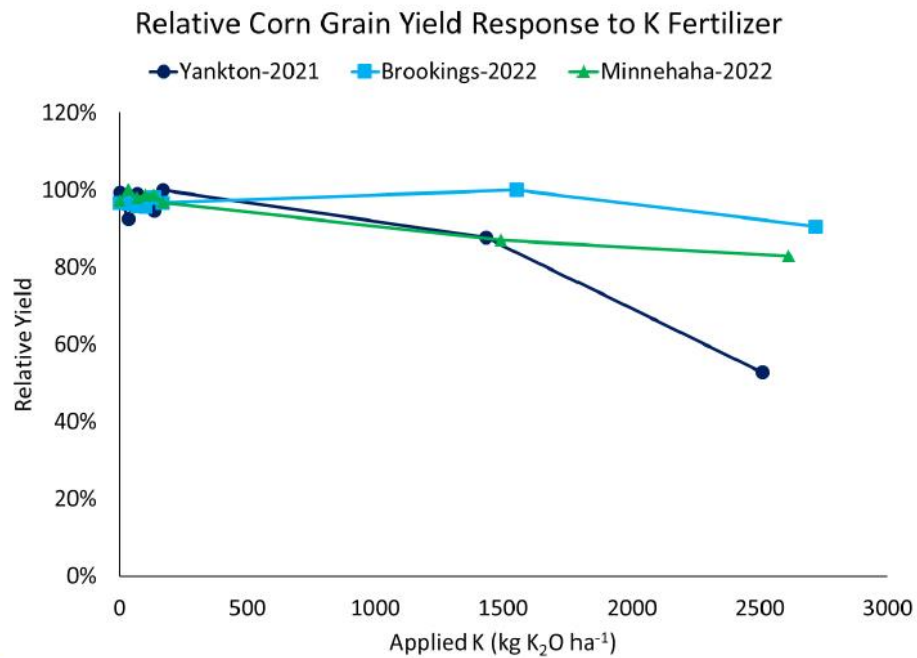
NDVI Imagery



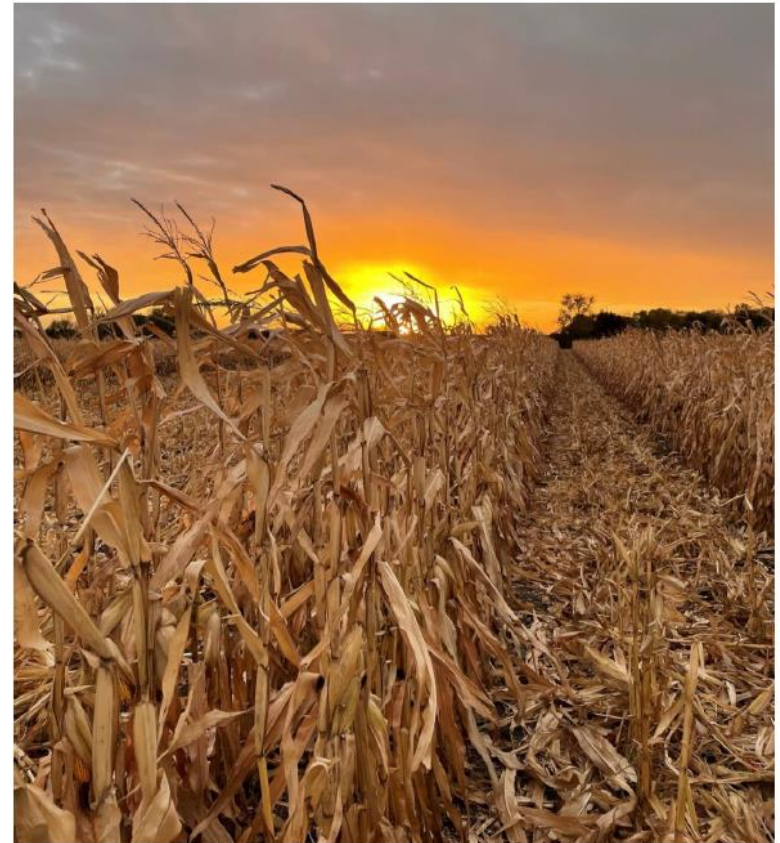
Circled plots:
 $2718 \text{ kg K}_2\text{O ha}^{-1}$



Grain Yield



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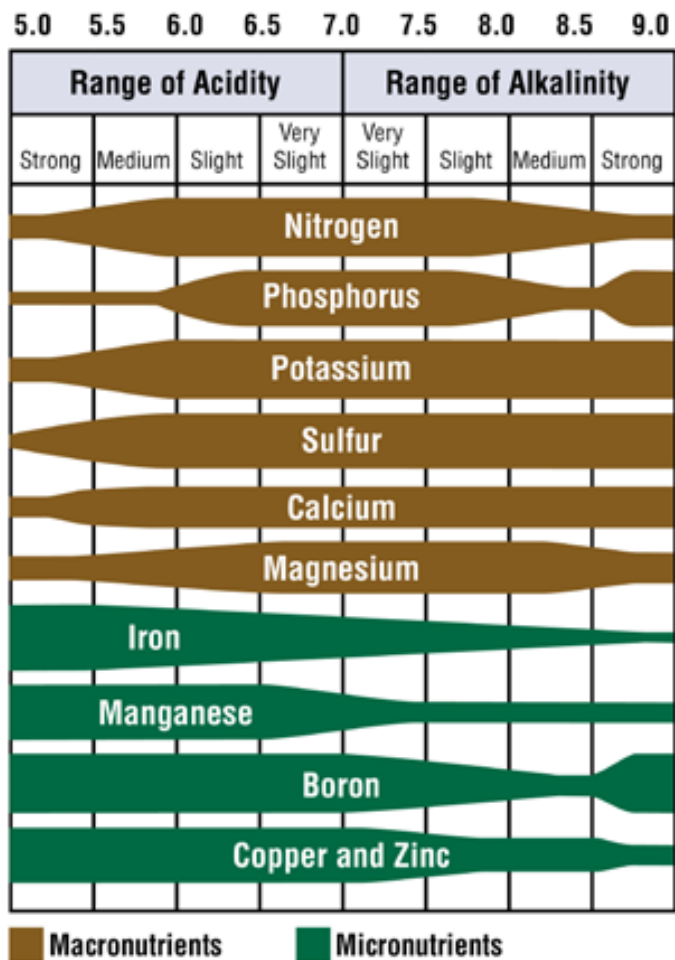


Conclusions

- In addition to being uneconomical, these excessive potash rates:
 - Reduced early season corn stands at all sites
 - Reduced corn dry matter at all sites
 - Reduced corn vegetative K content at two of three sites
 - Reduced final grain yield at all sites
- Likely due to a combination of factors, including:
 - Inadequate precipitation during V stages at Yankton and Minnehaha sites
 - Excessive salts from high rates of potash



Soil pH



Purdue Extension publication ID - 179

Atrazine carryover at pH > 6.8

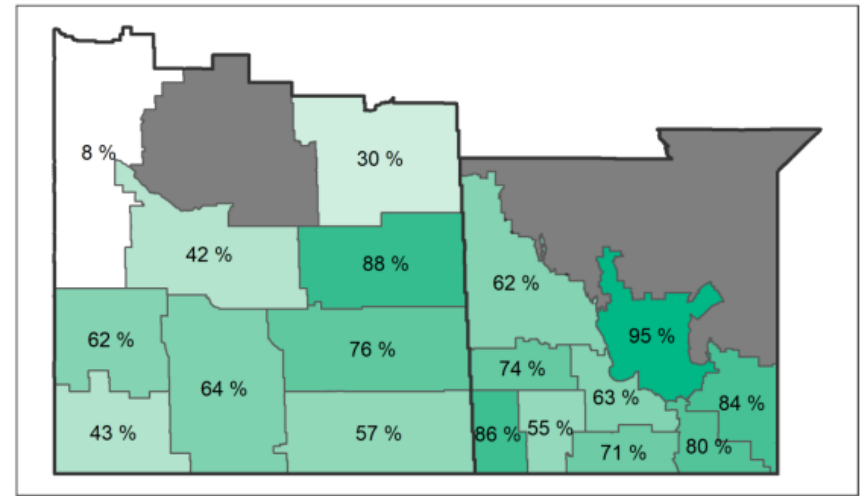


Purdue Extension publication ID – 2018.13

Is there an easy way to lower high pH?

- Soils in the Northern Great Plains often have soils with high pH (>7.3)
 - Soils with free calcium carbonate (CaCO_3) will have a pH buffered around 8
- Soil pH controls availability of plant nutrients
 - Lowering soil pH may increase nutrient availability
- Elemental sulfur often marketed as an “easy solution” to reduce pH

Soil samples with soil pH above 7.3 in 2022



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



Soil pH

Table 3-3 Soil Acidity Produced by N and S Fertilizers

Fertilizer Source	Soil Reaction	$\text{mole H}^+ / \text{mole N+S}$	$\text{CaCO}_3 \text{ Equiv.}^*$
Anhydrous ammonia	$\text{NH}_3 + 2\text{O}_2 \rightarrow \text{H}^+ + \text{NO}_3^- + \text{H}_2\text{O}$	1	3.6
Urea	$(\text{NH}_2)_2\text{CO} + 4\text{O}_2 \rightarrow 2\text{NO}_3^- + 2\text{H}^+ + \text{CO}_2 + \text{H}_2\text{O}$	1	3.6
Ammonium nitrate	$\text{NH}_4\text{NO}_3 + 2\text{O}_2 \rightarrow 2\text{NO}_3^- + 2\text{H}^+ + \text{H}_2\text{O}$	1	3.6
Ammonium sulfate	$(\text{NH}_4)_2\text{SO}_4 + 4\text{O}_2 \rightarrow 2\text{NO}_3^- + 4\text{H}^+ + \text{SO}_4^{-2} + \text{H}_2\text{O}$	2	7.2
Monoammonium phosphate	$\text{NH}_4\text{H}_2\text{PO}_4 + \text{O}_2 \rightarrow 2\text{NO}_3^- + 2\text{H}^+ + \text{H}_2\text{PO}_4^- + \text{H}_2\text{O}$	2	7.2
Diammonium phosphate	$(\text{NH}_4)_2\text{HPO}_4 + \text{O}_2 \rightarrow 2\text{NO}_3^- + 3\text{H}^+ + \text{H}_2\text{PO}_4^- + \text{H}_2\text{O}$	1.5	5.4
Elemental S	$2\text{S} + 3\text{O}_2 + 2\text{H}_2\text{O} \rightleftharpoons 2\text{SO}_4^{-2} + 4\text{H}^+$	2	7.2
Ammonium thiosulfate	$(\text{NH}_4)_2\text{S}_2\text{O}_3 + 6\text{O}_2 \rightarrow 2\text{SO}_4^{-2} + 2\text{NO}_3^- + 6\text{H}^+ + \text{H}_2\text{O}$	1.5	5.4

* CaCO_3 equivalent \rightarrow lbs CaCO_3 required per lbs N applied to neutralize acidity in the fertilizer.

SOURCE: Adams, 1984, *Soil Acidity and Liming*, No. 12, p. 234, ASA.

Table 3-3 shows the theoretical quantity of CaCO_3 needed to neutralize the acidity produced per unit of N or S fertilizer applied. For example with $(\text{NH}_4)_2\text{SO}_4$, 7.2 lbs CaCO_3 are needed to neutralize the H^+ produced per lb of N applied. The method used to determine the CaCO_3 equivalent for $(\text{NH}_4)_2\text{SO}_4$ is as follows:

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 (*Thiobacillus*). Thus, forming sulfuric acid



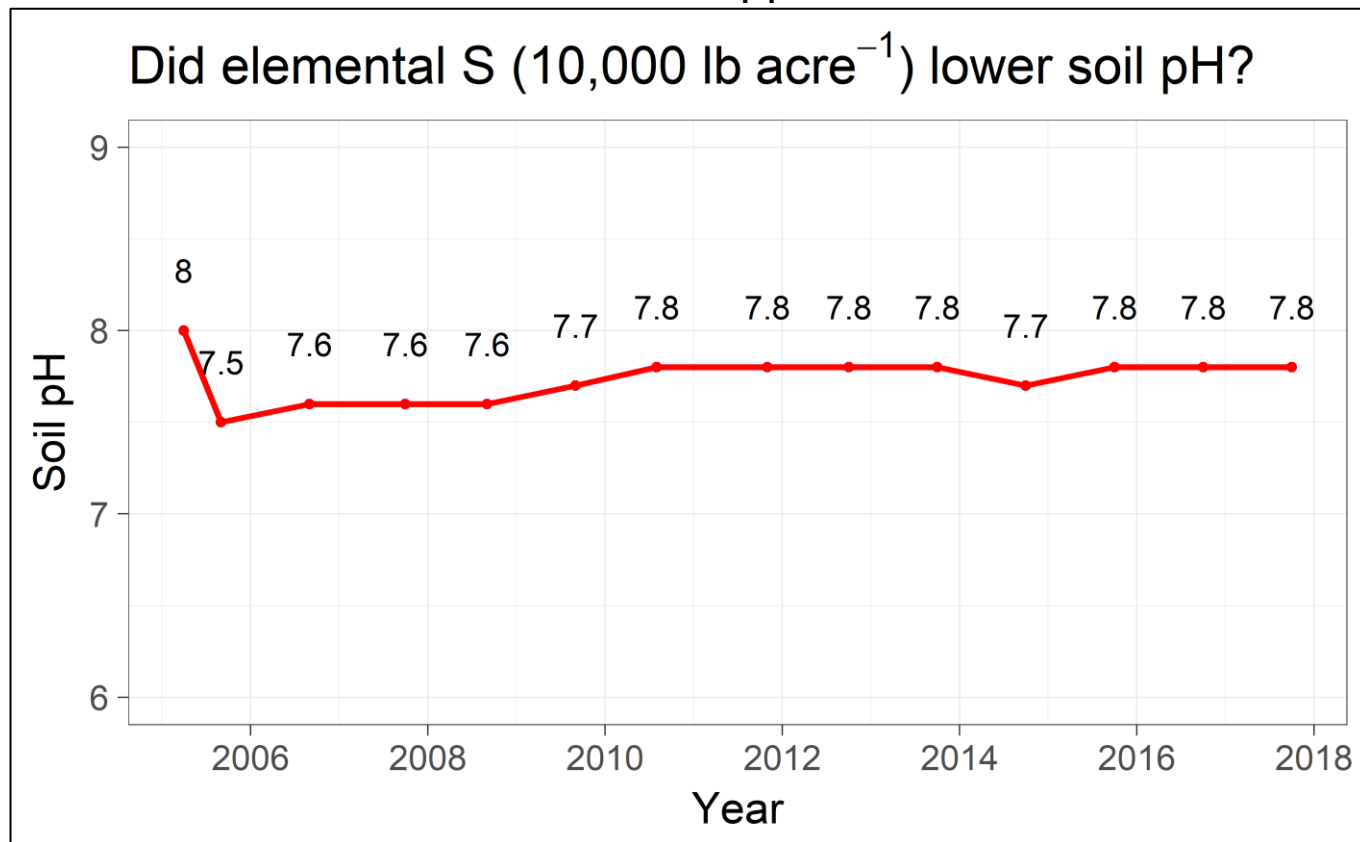
- Sulfuric acid produces H^+ ions, which can neutralize free lime in the soil
- Any sulfur fertilizer (e.g. gypsum) in the sulfate form CAN NOT neutralize free lime

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

AGVISE Demonstration 2005-2017

Soil had 1.5% CCE, starting pH was 8

Elemental S applied in 2005

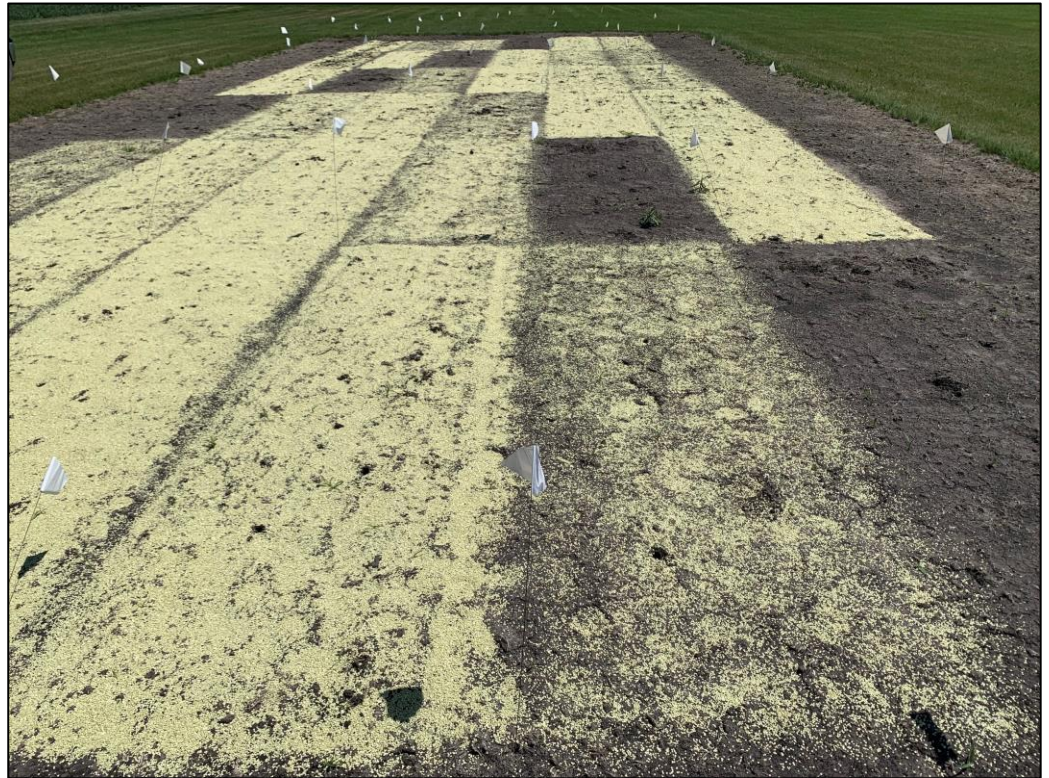


Again starting in 2020, with higher rates!

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

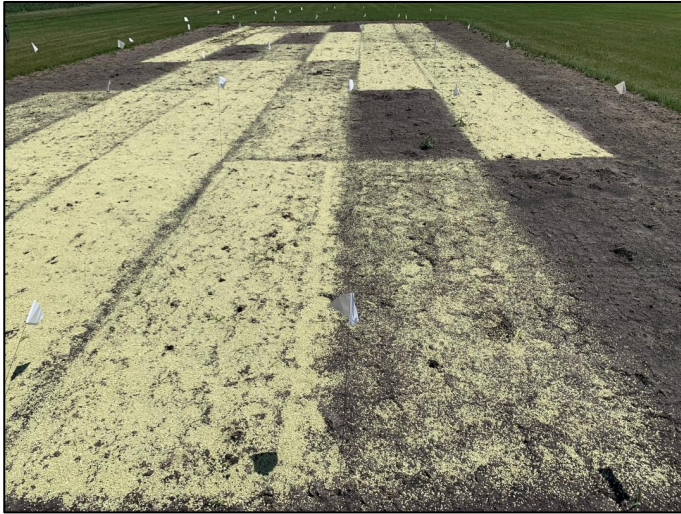
Site: Northwood, ND
Bearden silty clay loam,
soil pH 8.0,
average **CCE: 4.5%**

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

Sampling almost 2 years later...



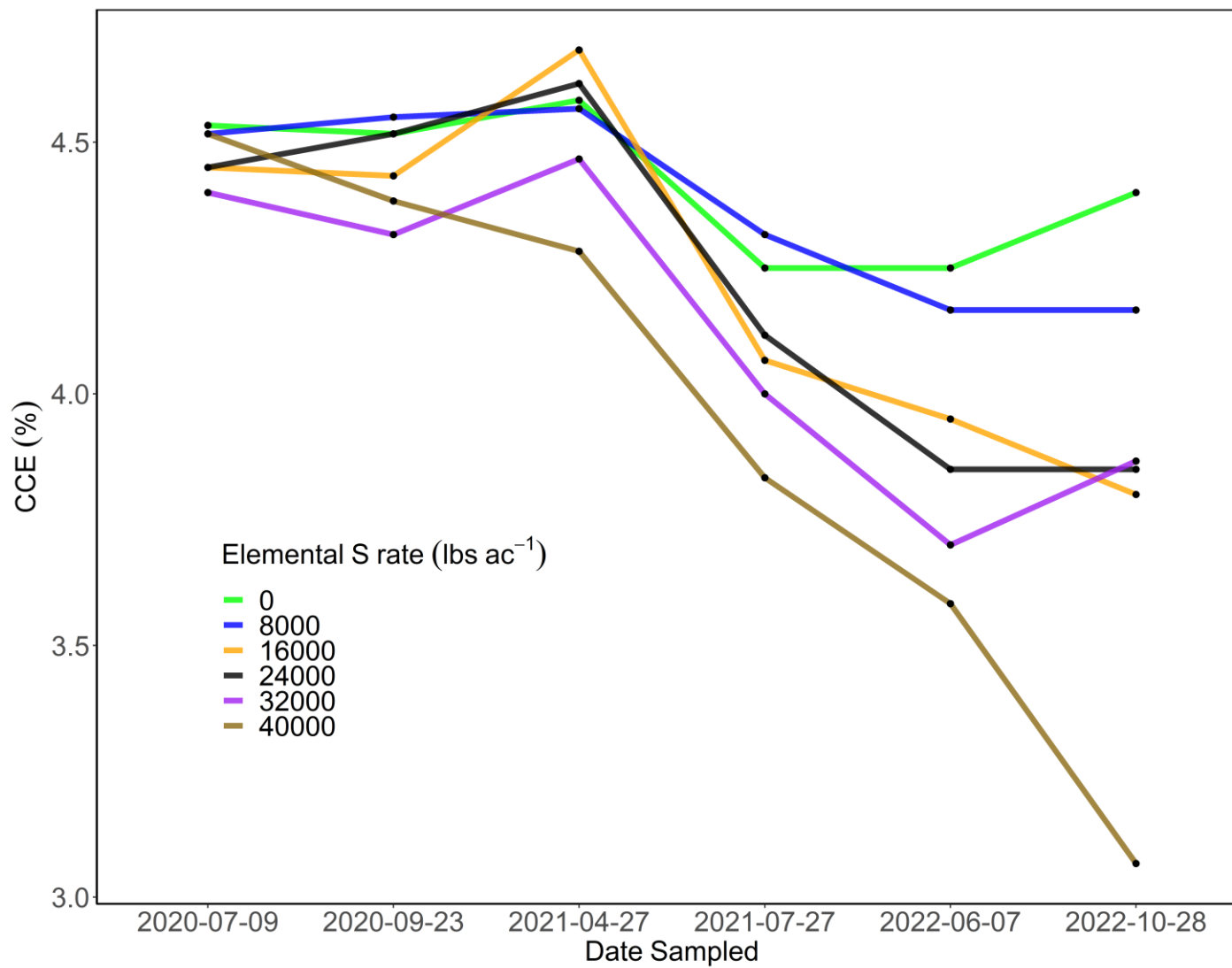
August 2020



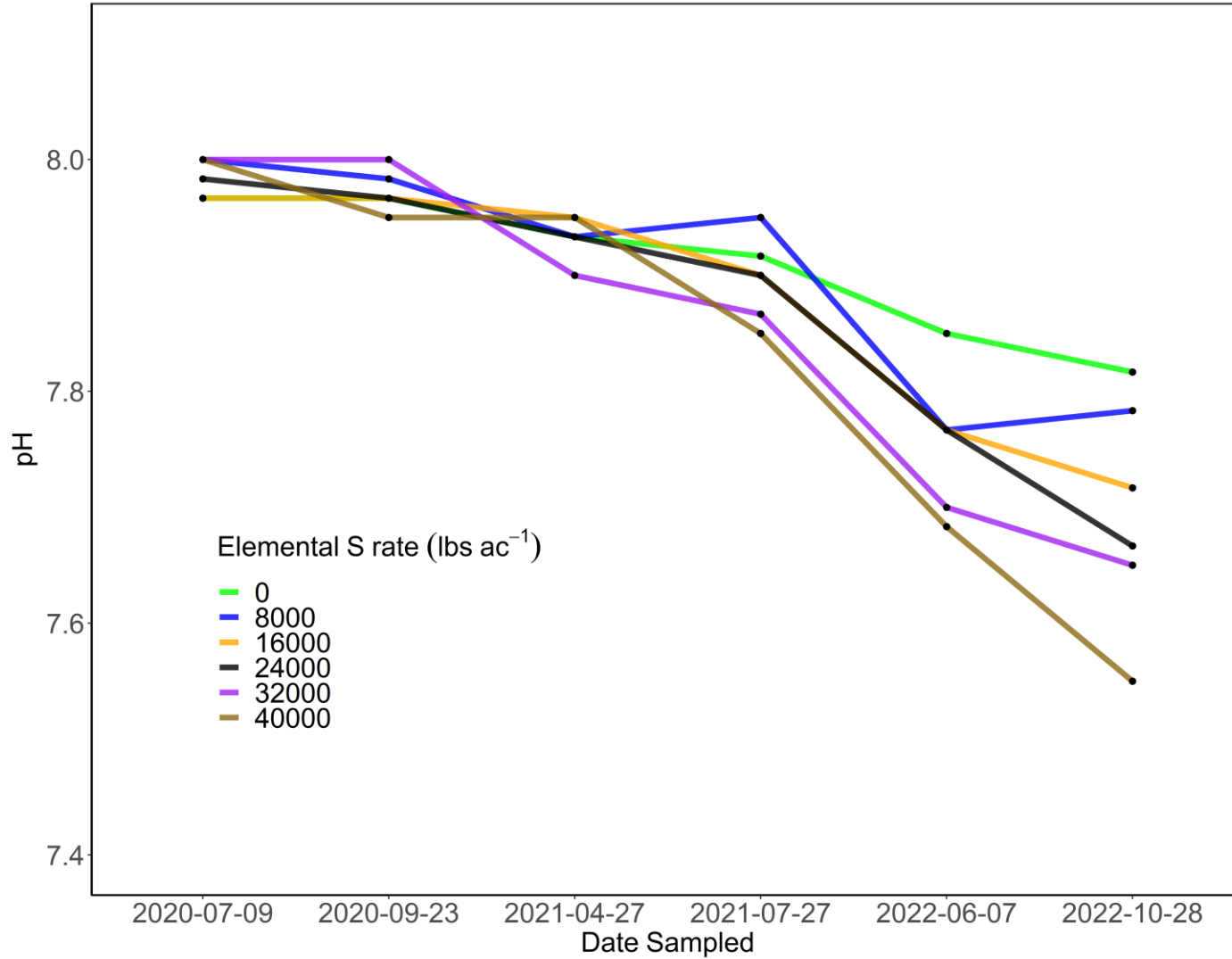
June 2022



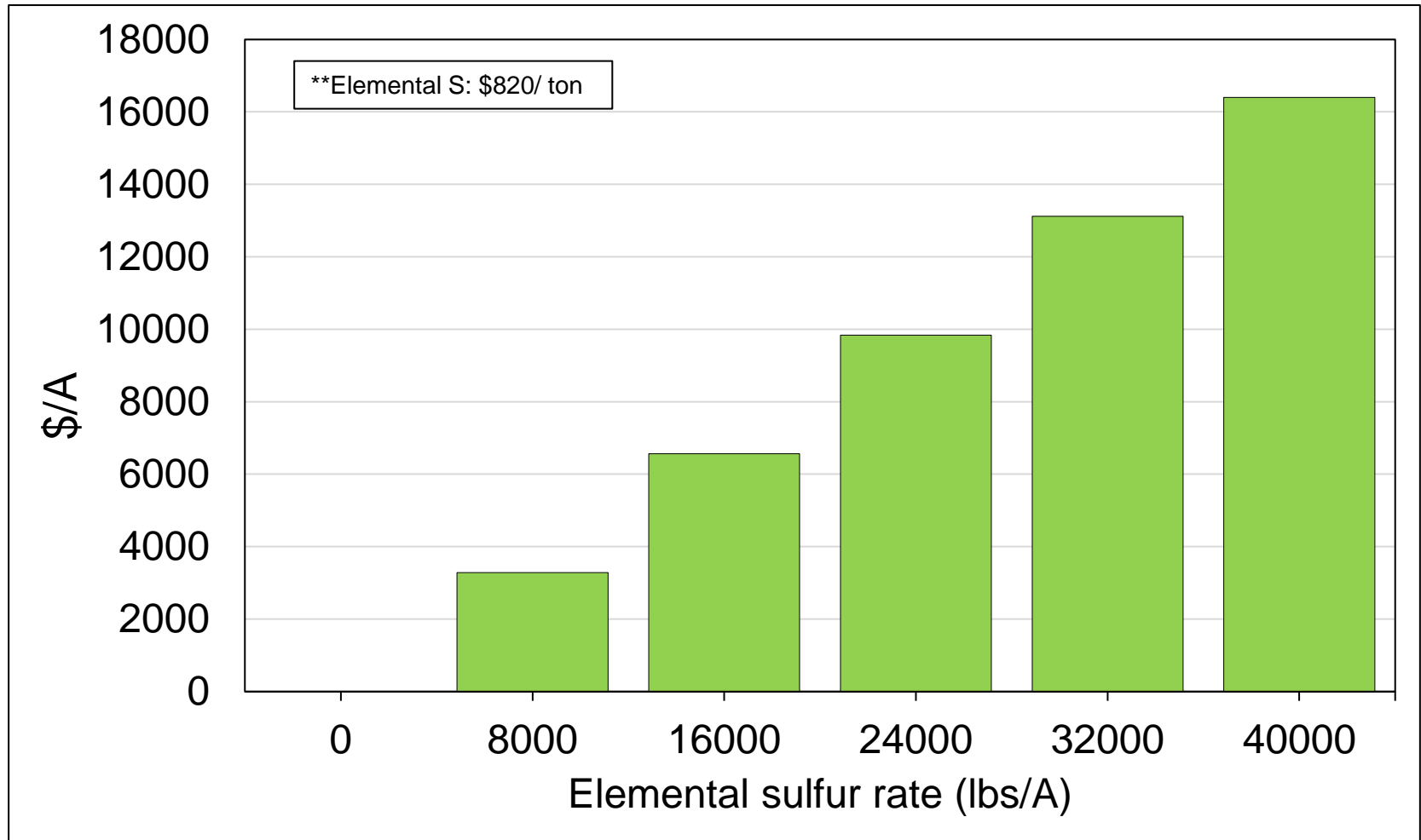
% CCE



Soil pH



Cost



Conclusion

- The process that turns elemental sulfur into sulfuric acid is biology driven; dry conditions in 2020 through 2021 slowed down any CCE% neutralization.
- Applying enough elemental sulfur to neutralize CCE and reduce pH is impractical on a field scale

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

Know the problem

- It's important to know exactly what problem you're trying to solve in a field. Get your problem area tested before you start adding things.

Final Thoughts

- We do this research, so you don't have to
 - High K rates
 - High elemental S rates

Questions



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