

Choosing a Test: Differences in Buffer pH Methods

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Acknowledgements

- [Frank Sikora](#)
- FRST – Fertilizer Recommendation Support Tool
- Amber Moore

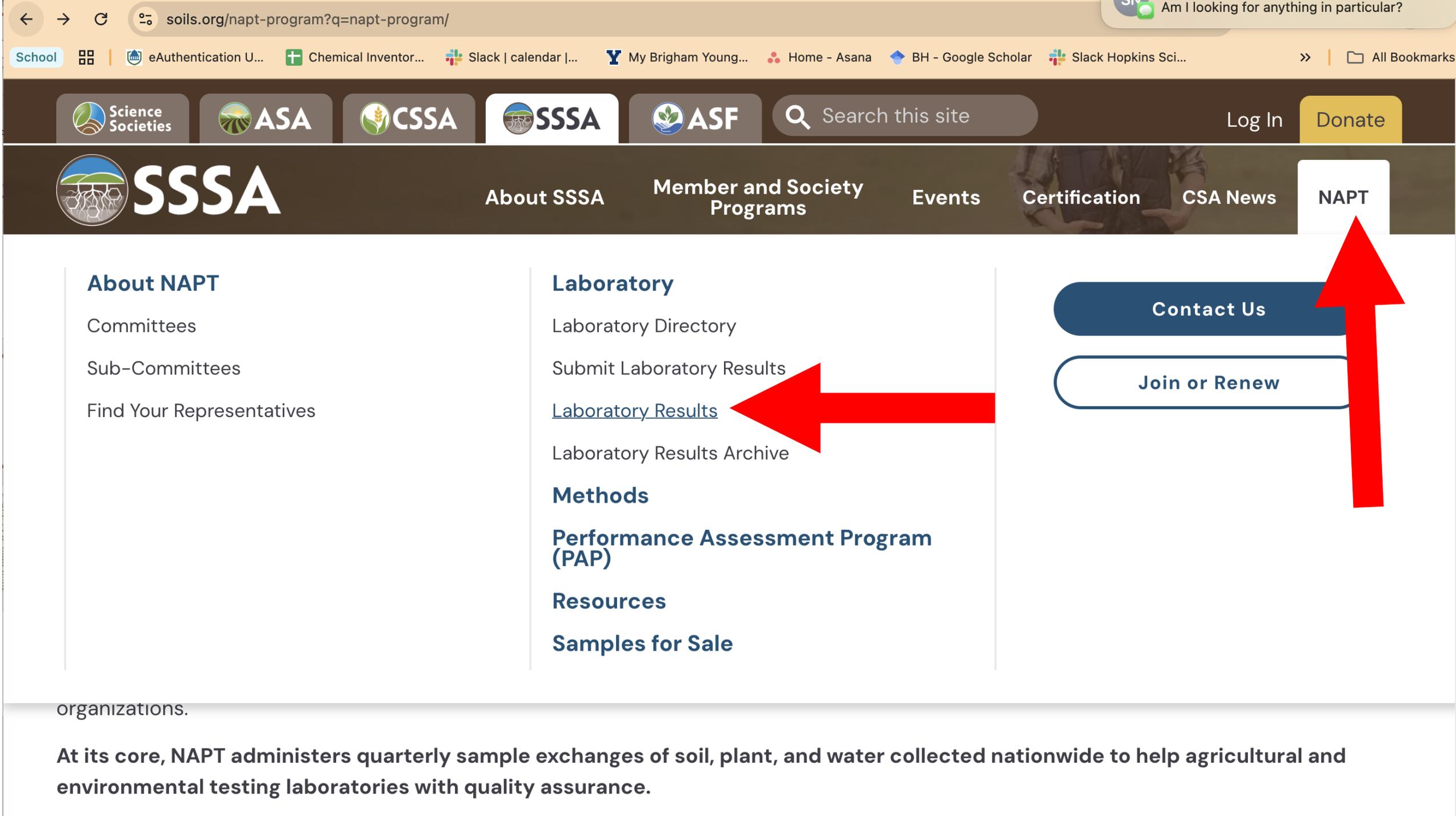


Buffer pH test is needed to more accurately predict lime recommendations

- **Soil pH alone is not enough (active vs. reserve acidity)**
 - **CEC colloids**
 - **Clay**
 - **Organic Matter**
 - **Mineralogy**

Buffer pH methods

- SMP (Shoemaker-McLean-Pratt)
- Sikora
- Sikora2
- Adams-Evans
- Moore-Sikora
- Woodruff
- Mehlich (original)
- Mehlich (modified)
- CaOH titration



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At its core, NAPT administers quarterly sample exchanges of soil, plant, and water collected nationwide to help agricultural and environmental testing laboratories with quality assurance.



2025 North American Proficiency Testing Program
 Quarter 1 Report - 4/24/2025

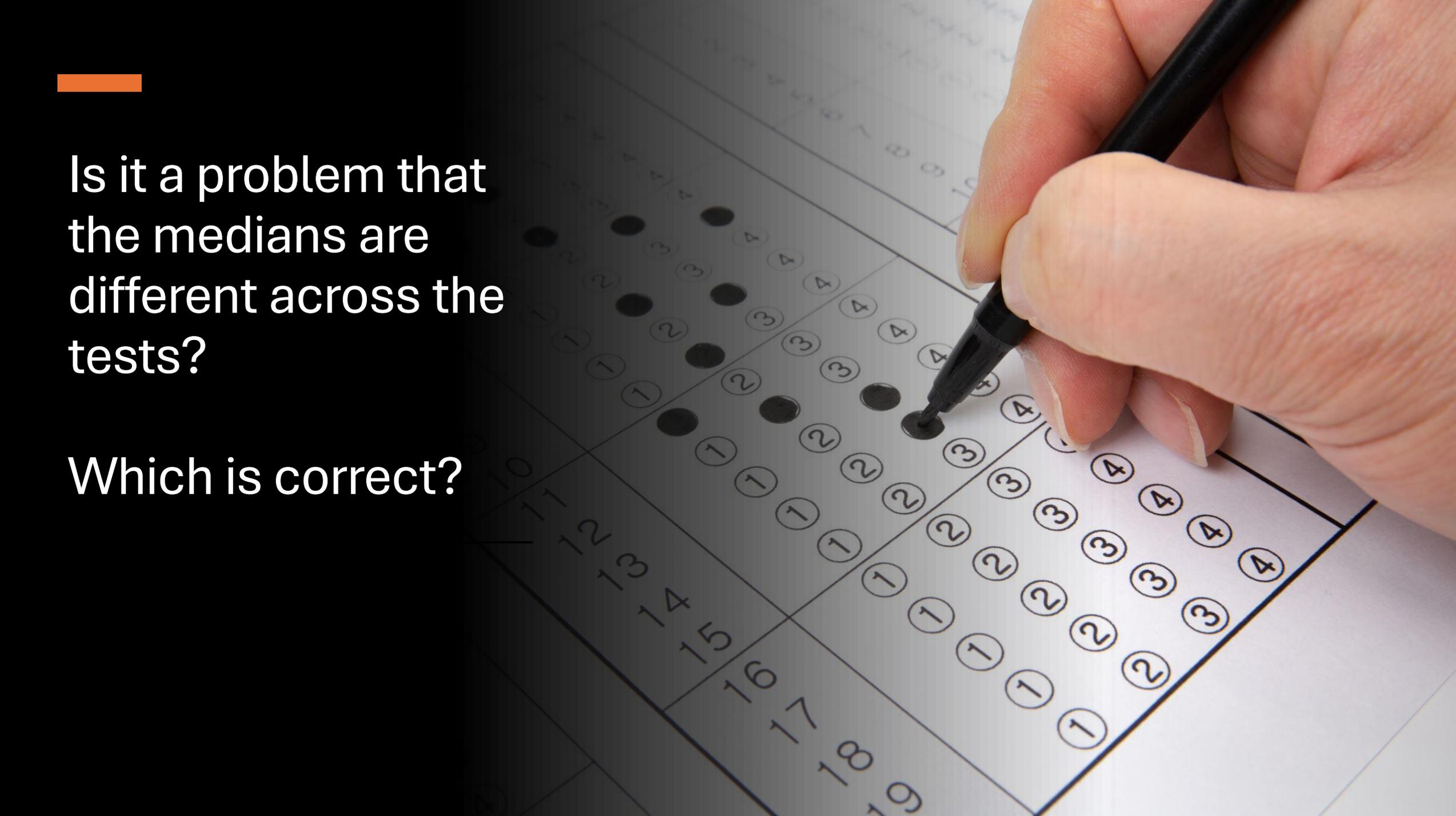
Select a quarter to view

Soil	Soil 2025-101				Soil 2025-102			Soil 2025-103			
Analysis - Modus Code	Units	n	Median	MAD	Lab Result	Median	MAD	Lab Result	Median	MAD	Lab Result
Saturated Paste											
Moisture - sp	%	13	51.2	3.70		49.7	5.70		49.5	2.00	
pH - sp	Unit	21	7.76	0.16		7.38	0.15		7.10	0.14	
ECe - sp	dS/m	18	0.92	0.057		1.56	0.17		1.08	0.059	
HCO3 - sp	mmolc/L	13	6.00	0.58		4.50	1.15		3.52	0.62	
Ca - sp	mmolc/L	19	5.82	0.50		8.90	1.12		7.94	0.78	
Mg - sp	mmolc/L	19	2.55	0.19		6.30	0.84		1.97	0.25	
Na - sp	mmolc/L	17	1.21	0.098		1.93	0.23		0.25	0.020	
SAR - sp	value	14	0.60	0.025		0.70	0.050		0.12	0.020	
Cl - sp	mmolc/L	12	0.62	0.11		0.82	0.18		0.40	0.029	
SO4 - sp	mmolc/L	15	1.66	0.17		1.83	0.50		1.04	0.23	
NO3 - sp	mmolc/L	9	1.51	1.28		5.34	2.27		4.63	1.17	
B - sp	mg/L	10	0.32	0.055		0.20	0.050		0.060	0.037	
pH & EC (1:1 or 1:2)											
EC (1:1)	(dS/m)	28	0.59	0.060		0.73	0.044		0.57	0.045	
EC (1:2)	(dS/m)	35	0.34	0.043		0.49	0.040		0.35	0.029	
pH (1:1) Water	Unit	75	8.00	0.16		7.48	0.15		7.24	0.15	
pH (1:2) Water	Unit	19	8.10	0.16		7.61	0.15		7.36	0.15	
pH (1:1) 0.01M CaCl2	Unit	20	7.62	0.15		7.20	0.14		6.90	0.14	
pH (1:2) 0.01M CaCl2	Unit	10	7.52	0.15		7.16	0.14		6.95	0.14	
Lime Req.											
SMP Buffer pH	Unit	17	7.51	0.15		7.34	0.15		7.28	0.15	
Adams-Evans Buf pH	Unit	5	7.70	N/A		7.64	N/A		7.75	N/A	
Woodruff Buf. pH	Unit	19	7.13	0.14		7.07	0.14		7.00	0.14	
Mehlich Buffer pH	Unit	7	6.90	N/A		6.72	0.13		6.60	0.13	
Sikora Buffer pH	Unit	37	7.54	0.15		7.33	0.15		7.30	0.15	

Buffer pH methods

Buffer pH tests offered by NAPT

	<i>n</i>	Median	MAD
Lime Req.			
SMP Buffer pH	17	7.51	0.15
Adams-Evans Buf pH	5	7.70	N/A
Woodruff Buf. pH	19	7.13	0.14
Mehlich Buffer pH	7	6.90	N/A
Sikora Buffer pH	37	7.54	0.15

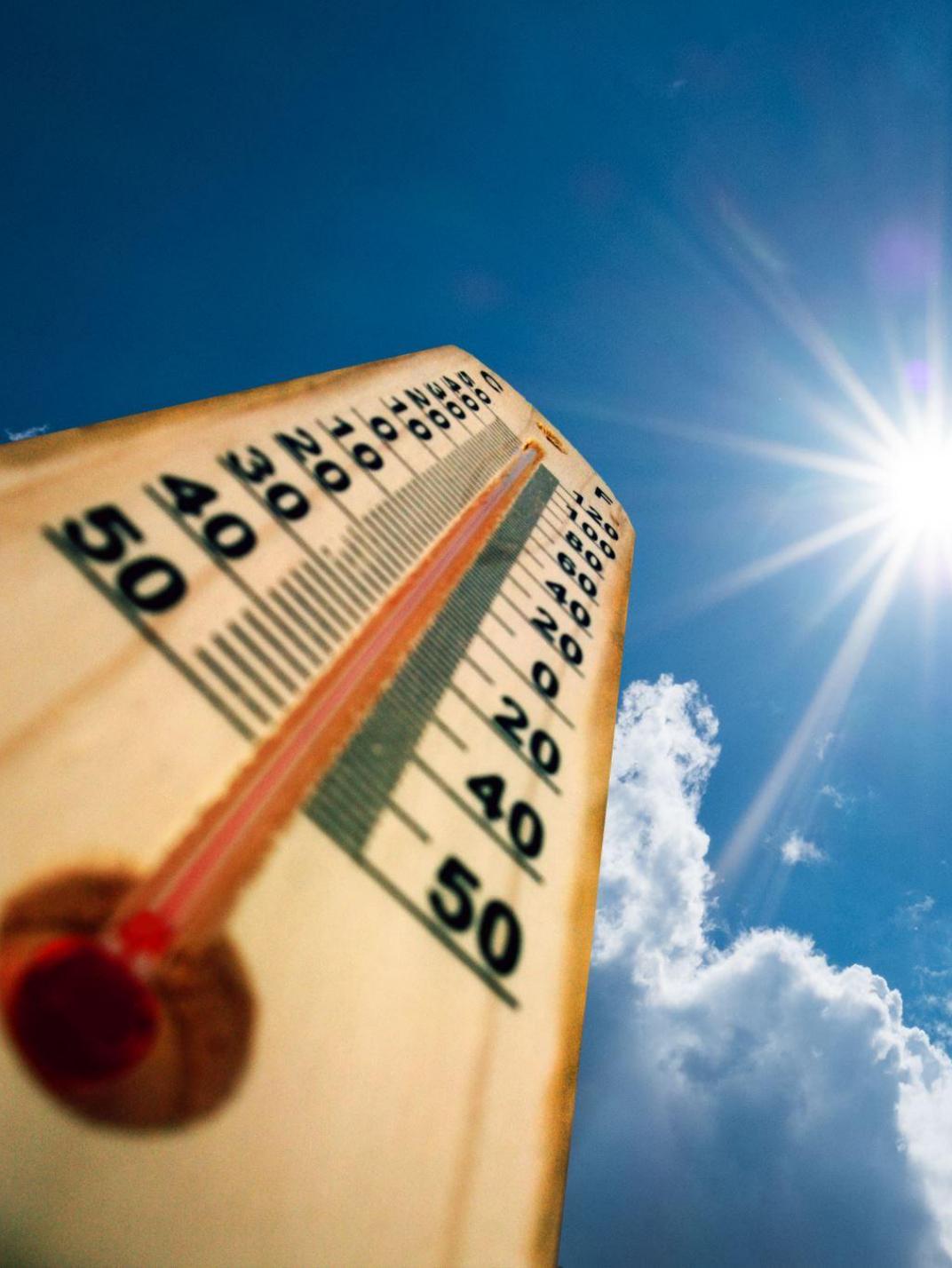
A close-up photograph of a hand holding a black pen, marking a dot on a grid of numbers. The grid consists of rows and columns of numbers, with some cells containing a solid black dot. The numbers are arranged in a pattern that suggests a sequence or a specific data set. The hand is positioned over the grid, and the pen is in the process of marking a dot in one of the cells. The background is slightly blurred, focusing attention on the hand and the pen.

Is it a problem that
the medians are
different across the
tests?

Which is correct?

Buffer pH tests offered by NAPT

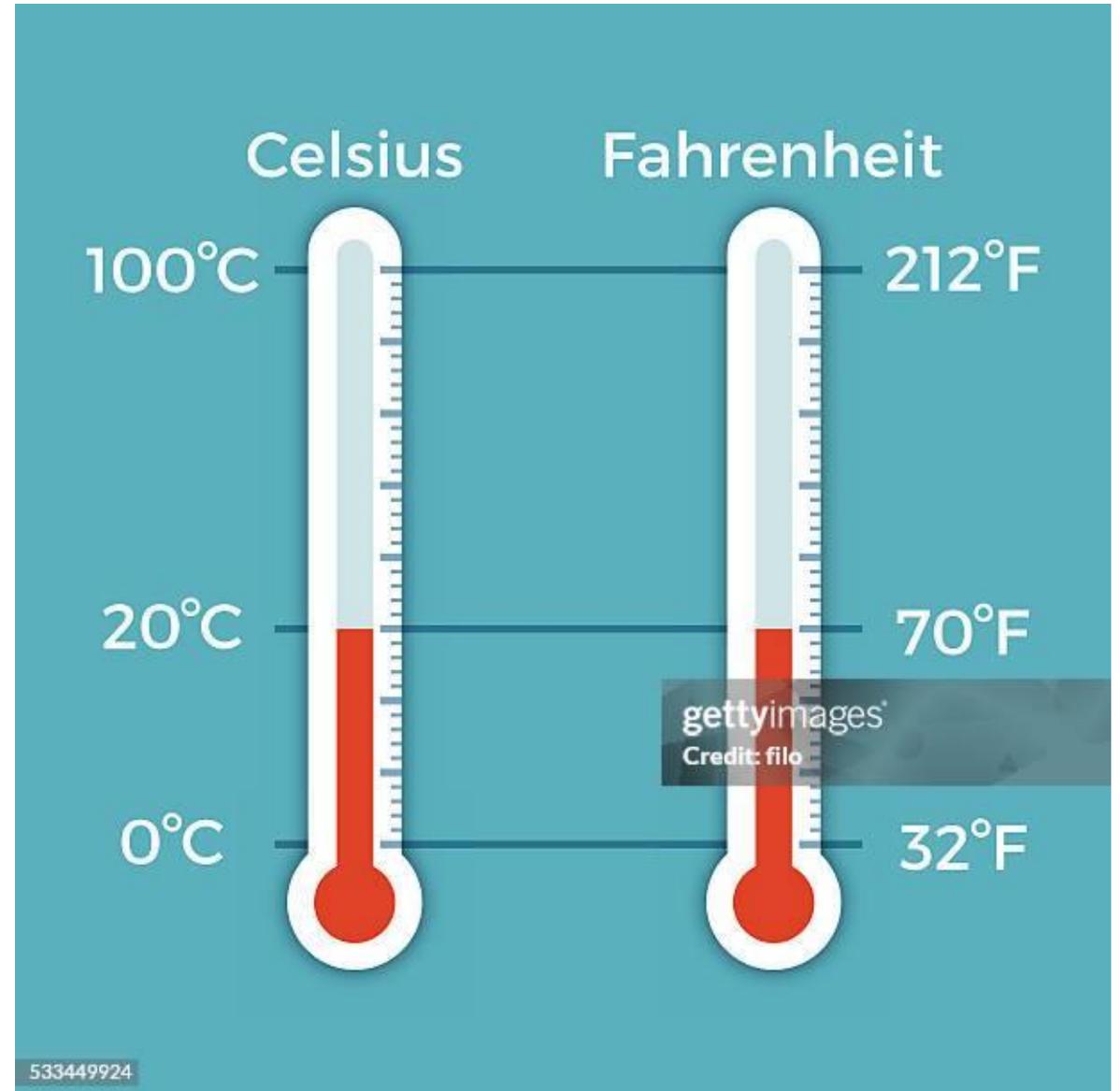
	<i>n</i>	Median	MAD
Lime Req.			
SMP Buffer pH	17	7.51	0.15
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Woodruff Buf. pH	19	7.13	0.14
Mehlich Buffer pH	7	6.90	N/A
Sikora Buffer pH	37	7.54	0.15



If you told me that it is 30 degrees, is that cold or hot?

- **The answer depends on which temperature scale you are using?**
 - **Fahrenheit**
 - **Celsius**

Both are perfectly accurate and correct (as long as you use the correct scale to interpret)



Not as simple for buffer pH

- Acid soils
 - aluminum & manganese (other?) toxicities
 - Reduced nutrient solubility (especially phosphorus)
- Need to increase the pH to above ~6.
- How much limestone or other liming agent does it take to effectively increase the pH?



Lime recommendations

- BpH lime recommendation table
- Algorithm base on pH_{H_2O} and BpH
 - i. Soil depth adjustment
 - ii. Target final pH
 - iii. Adjustment for mineral vs organic soils
 - iv. Lime neutralizing value (NV) adjustment

Iowa State University

Buffer pH	Depth of Soil to be Neutralized								
	2 inches			3 inches			6 inches		
	pH 6.0	pH 6.5	pH 6.9	pH 6.0	pH 6.5	pH 6.9	pH 6.0	pH 6.5	pH 6.9
	Amount of Calcium Carbonate to Apply (pounds/acre) ‡								
7.0	0	0	400	0	0	600	0	0	1,100
6.9	0	0	600	0	0	1,000	0	0	1,900
6.8	0	200	900	0	300	1,400	0	600	2,700
6.7	0	400	1,200	0	700	1,800	0	1,300	3,500
6.6	0	700	1,500	0	1,100	2,200	0	2,100	4,400
6.5	100	900	1,700	100	1,400	2,600	200	2,800	5,200
6.4	300	1,200	2,000	400	1,800	3,000	800	3,500	6,000
6.3	500	1,400	2,300	700	2,100	3,400	1400	4,200	6,800

University of Wisconsin

Target pH	Lime requirement formula ^a (tons/a 60–69 lime to apply ^b)
5.2	36.1 – (3.29 x BpH) – (2.67 x WpH)
5.4	48.2 – (4.84 x BpH) – (3.03 x WpH)
5.6	51.0 – (5.40 x BpH) – (2.67 x WpH)
5.8	57.2 – (5.55 x BpH) – (3.50 x WpH)
6.0	72.7 – (7.59 x BpH) – (3.78 x WpH)
6.3	103 – (12.6 x BpH) – (3.18 x WpH)
6.5	134 – (17.2 x BpH) – (2.73 x WpH)
6.6	152 – (20.3 x BpH) – (2.17 x WpH)
6.8	195 – (28.4 x BpH) + (0.144 x WpH)

^a Abbreviations: BpH = buffer pH, WpH = water pH.

^b Buffer Method – SMP/Sikora. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin (A2809).

University of Delaware

Water pH	Adams-Evans Buffer pH						
	7.60	7.55	7.50	7.45	7.40	7.35	7.30
5.9	0.00	0.00	0.00	0.50	0.50	0.50	0.50
5.8	0.50	0.50	0.50	0.50	0.50	0.50	0.50
5.7	0.50	0.50	0.75	0.75	0.75	1.00	1.00
5.6	0.75	0.75	0.75	1.00	1.00	1.00	1.25
5.5	0.75	0.75	1.00	1.00	1.25	1.25	1.25
5.4	1.00	1.00	1.00	1.25	1.25	1.50	1.50
5.3	1.00	1.25	1.25	1.50	1.50	1.50	1.75
5.2	1.00	1.25	1.50	1.50	1.75	1.75	2.00
5.1	1.25	1.25	1.50	1.75	1.75	2.00	2.00
5.0	1.25	1.50	1.75	1.75	2.00	2.00	2.25

Target pH 6.5 (0-8"), Lime Rate tons per acre 67% ECCE.

Comparison of lime recommendations



Soil ID ¹	SRS-1910	SRS-2001	SRS-2006	SRS-2003
pH _{H2O}	5.78	5.19	5.48	6.01
Sikora BpH	6.87	6.65	6.50	6.85
AE BpH	7.54	7.44	7.30	7.45

	Calculated lime rate lbs/ac ²			
Kansas St Univ	1000	1600	2100	200
Tri-State (OH-MI-IN)	500	2100	3200	700
Mid West LGU	200	16700	22300	0
Clemson Univ	1100	1900	2100	1100
Univ Delaware	1400	2500	2800	1400

¹ Soil data source ALP program 2019-2020, population median values.

² Recommendations based on a 3" depth, target pH of 6.5, and 100% ECCE.

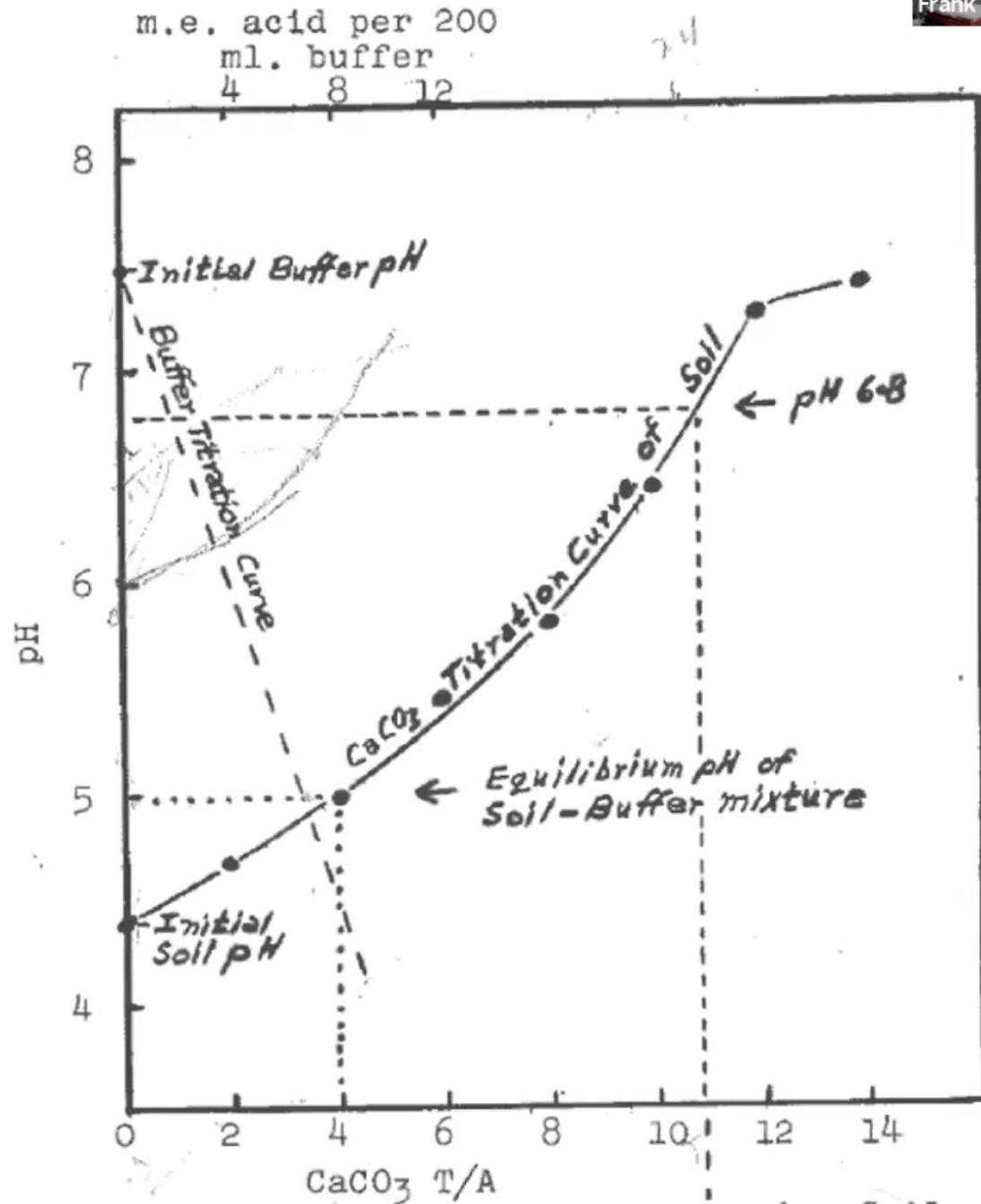
THE DETERMINATION OF ACIDITY IN OHIO SOILS BY USING LIME
ADDITION, BASE TITRATION, AND BUFFER EQUILIBRATION METHODS

DISSERTATION

Presented in Partial Fulfillment of the Requirements
for the Degree Doctor of Philosophy in the
Graduate School of The Ohio State
University

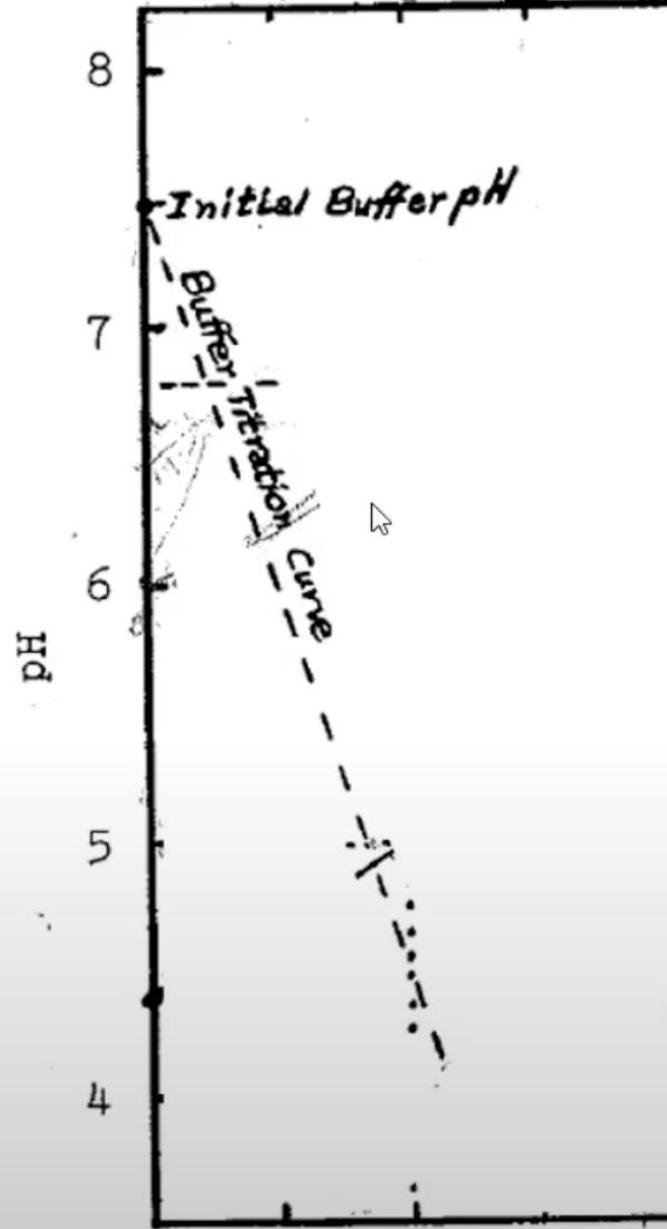
by

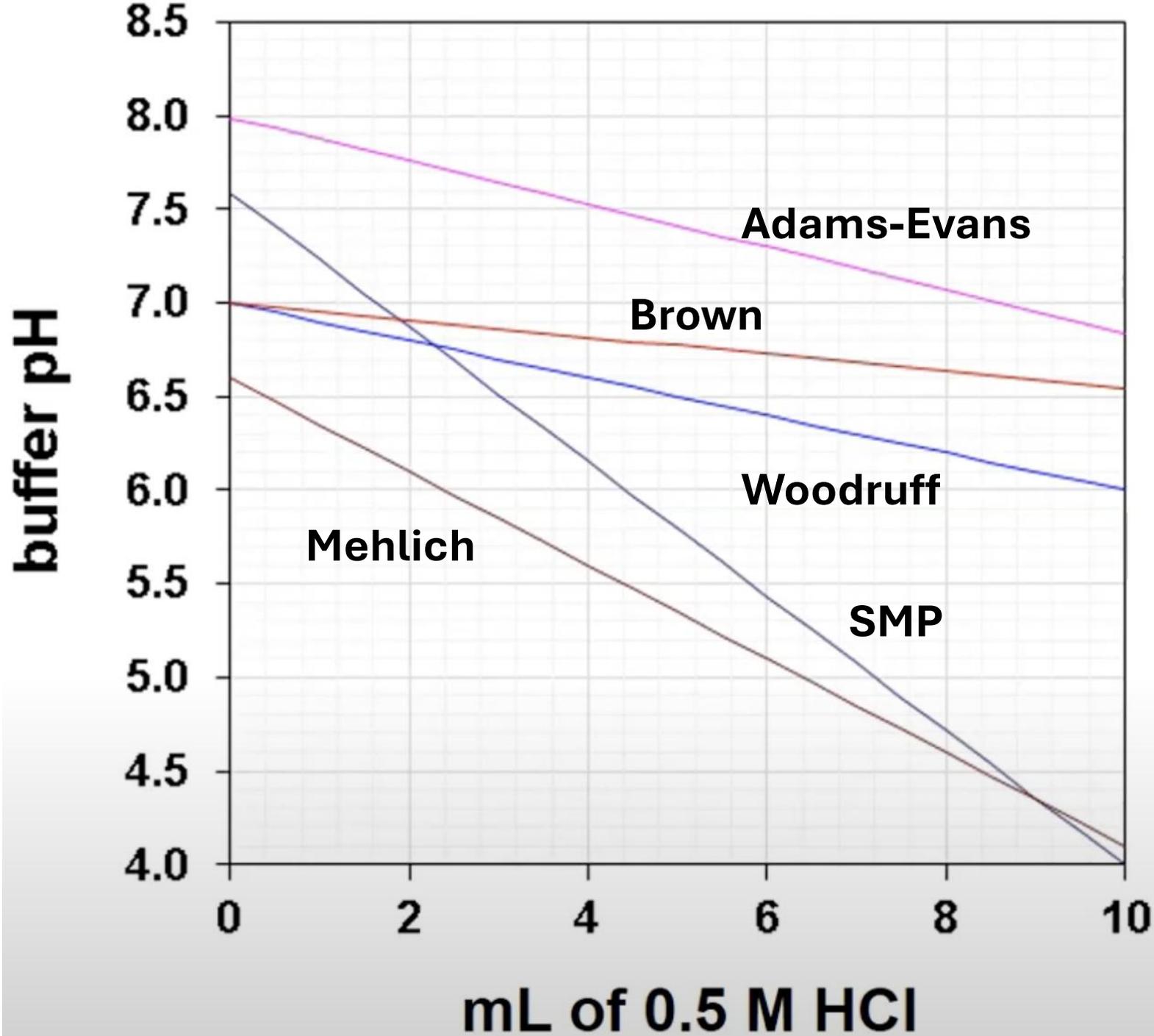
Harold Earl Shoemaker, B.S., M.S.
The Ohio State University
1959



m.e. acid per 200
ml. buffer

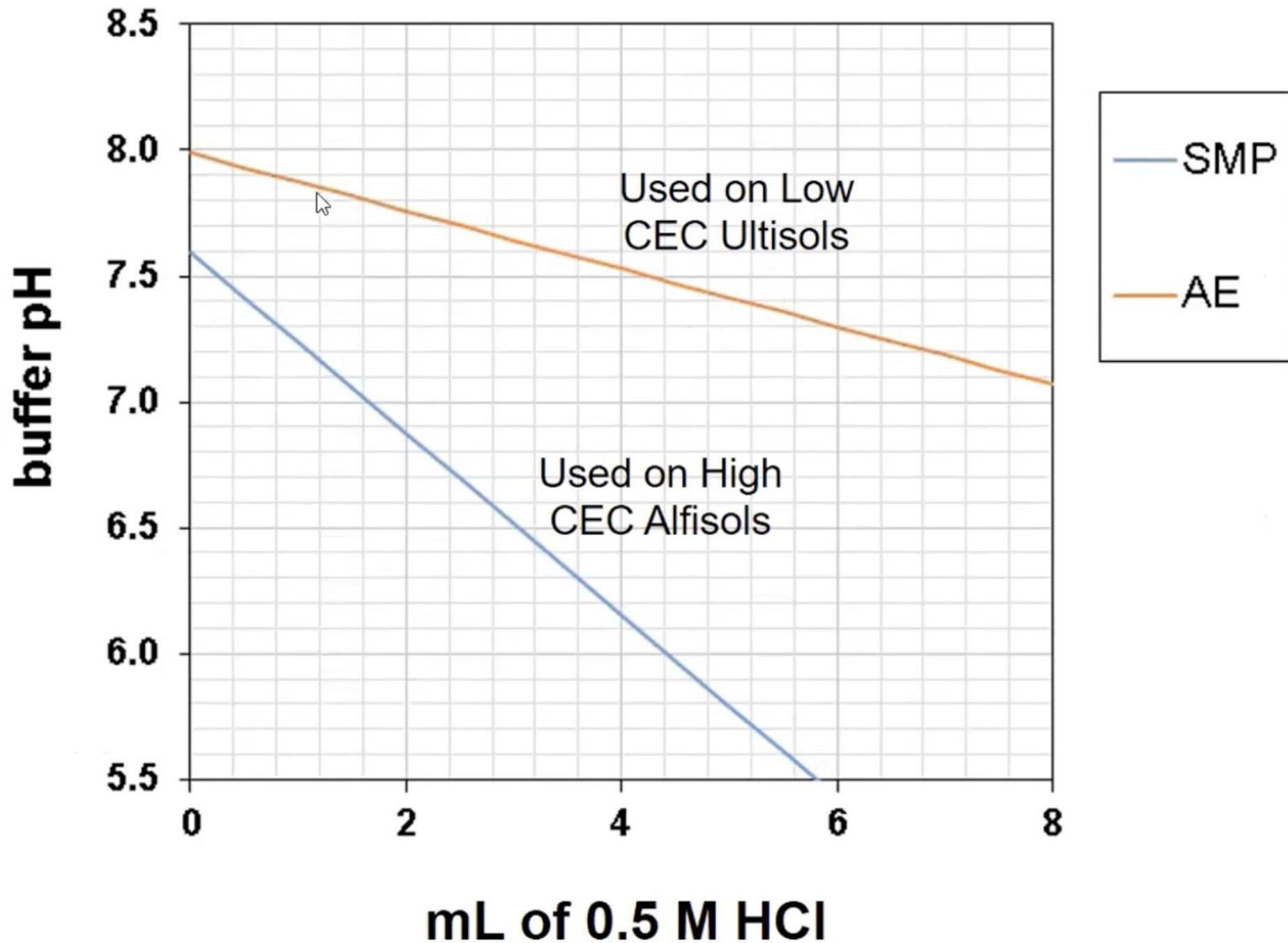
4 8 12



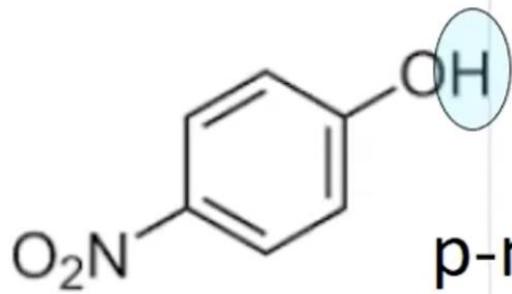


Notice that they are linear, which is important

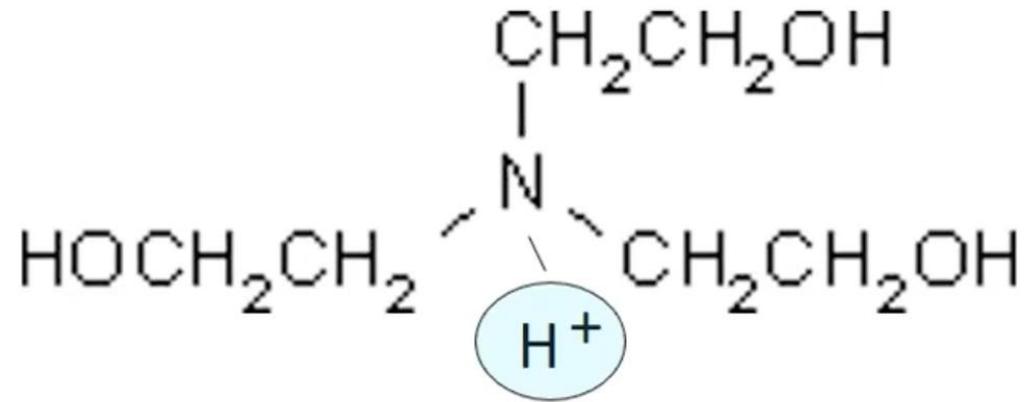
Some are more buffered than others



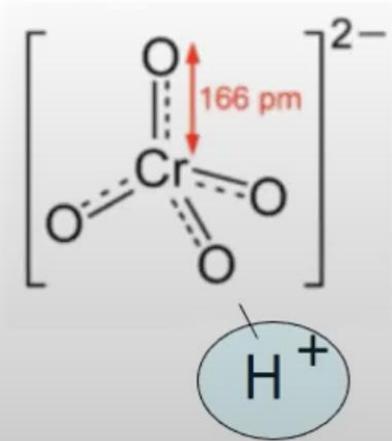
Components of SMP buffer



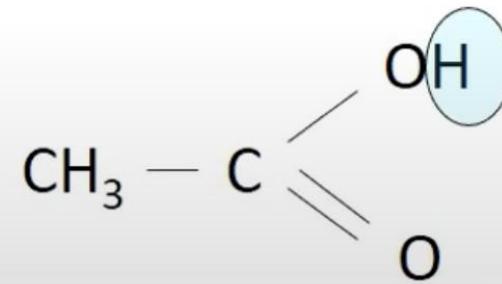
p-nitrophenol
pKa = 6.2



triethanolamine
pKa = 8.0



chromate
pKa = 5.9

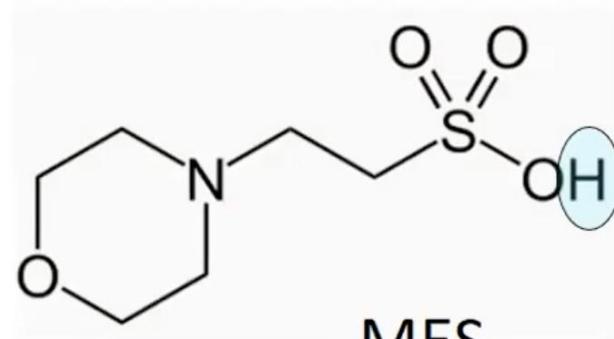


acetate
pKa = 4.6

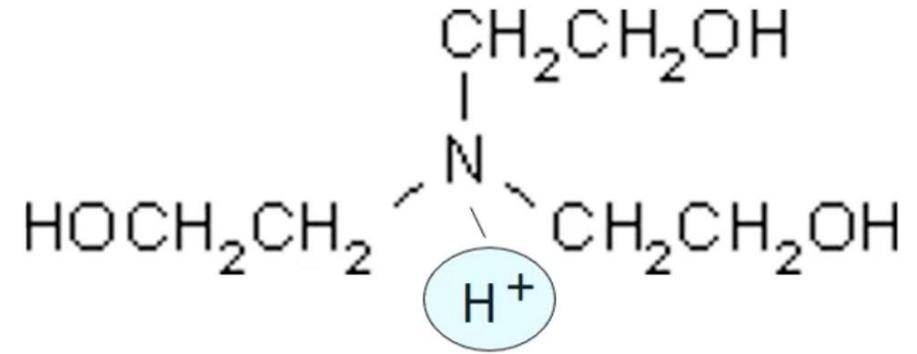
Toxins

Components of Sikora buffer

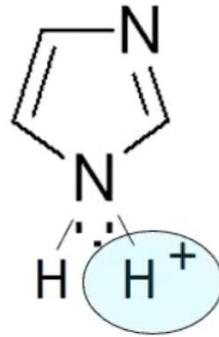
Sikora
mimics
SMP



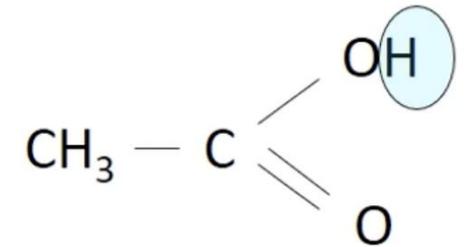
MES
pKa = 6.2



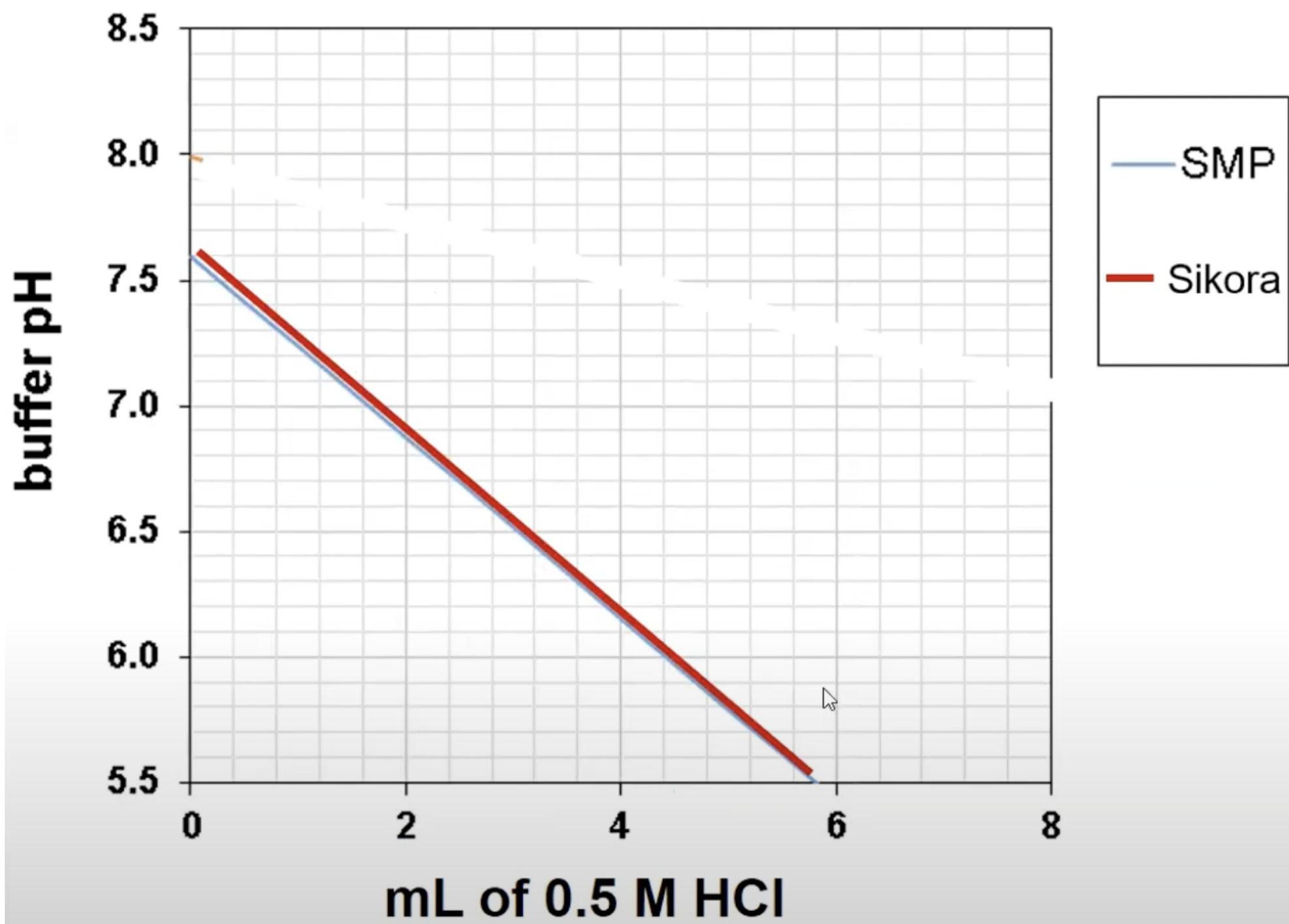
triethanolamine
pKa = 8.0

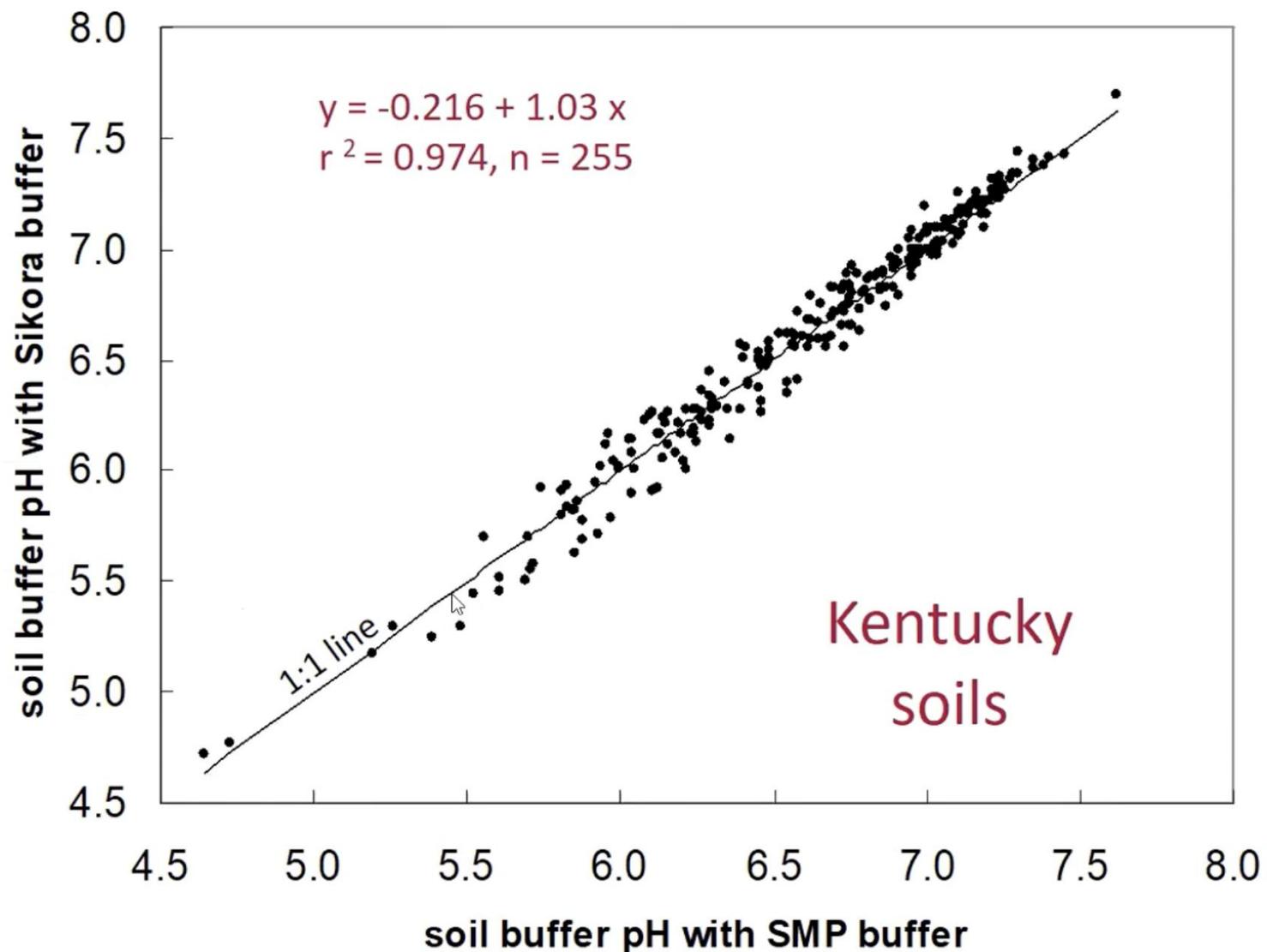


Imidazole
pKa = 7.1



acetic acid
pKa = 4.6



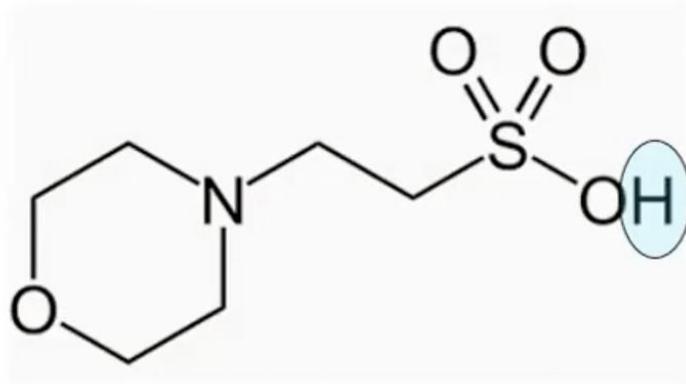


A Buffer that Mimics the SMP Buffer for Determining Lime Requirement of Soil

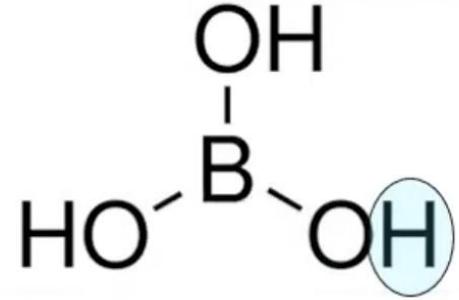
F. J. Sikora*

Published in Soil Sci. Soc. Am. J. 70:474–486 (2006).

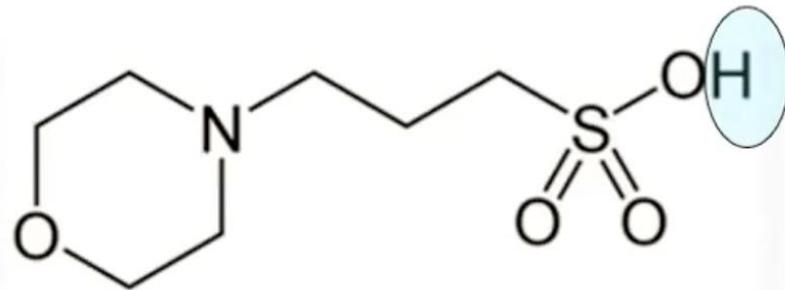
Components of Moore-Sikora buffer



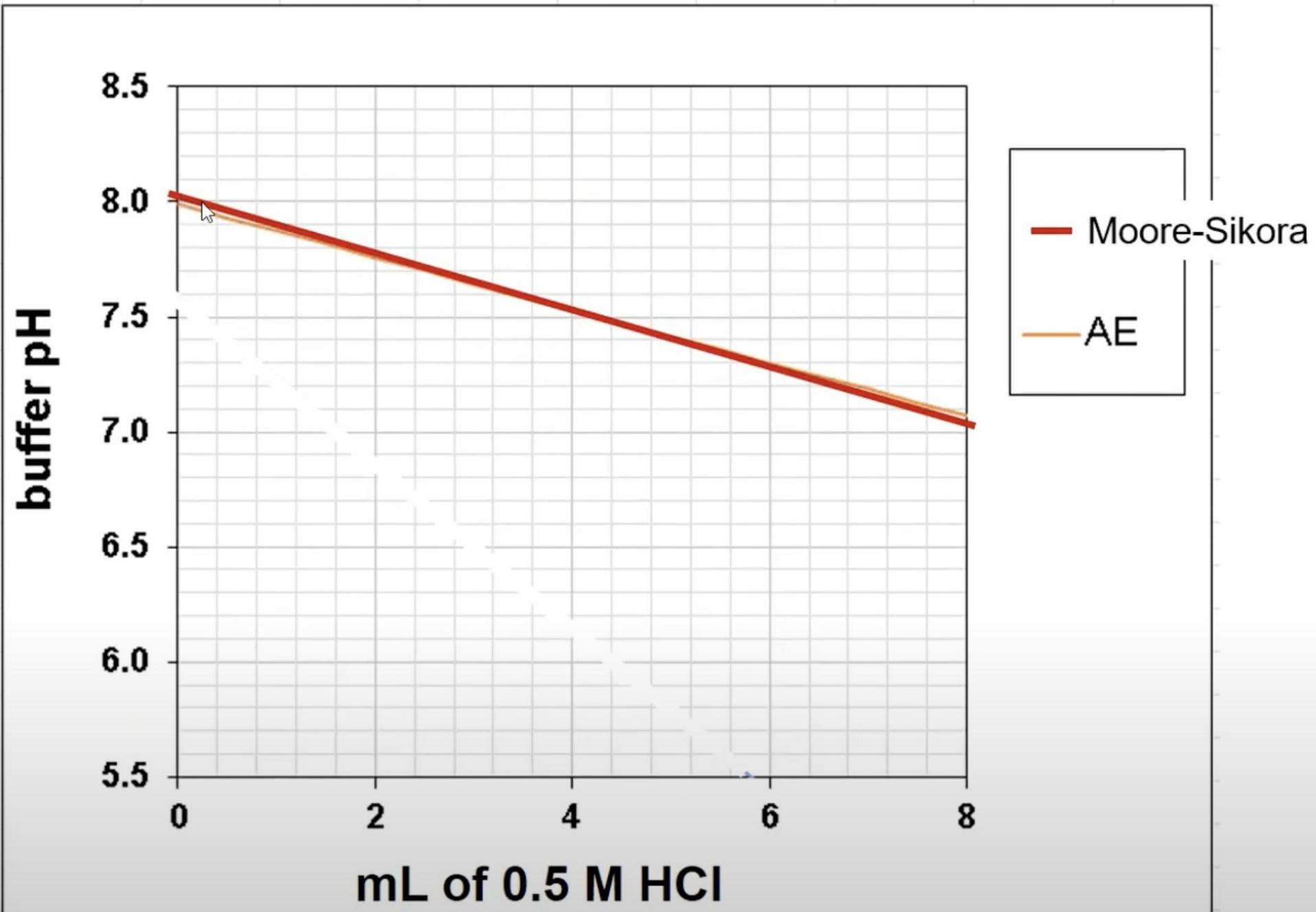
MES
pKa = 6.2



Boric acid
pKa = 9.2

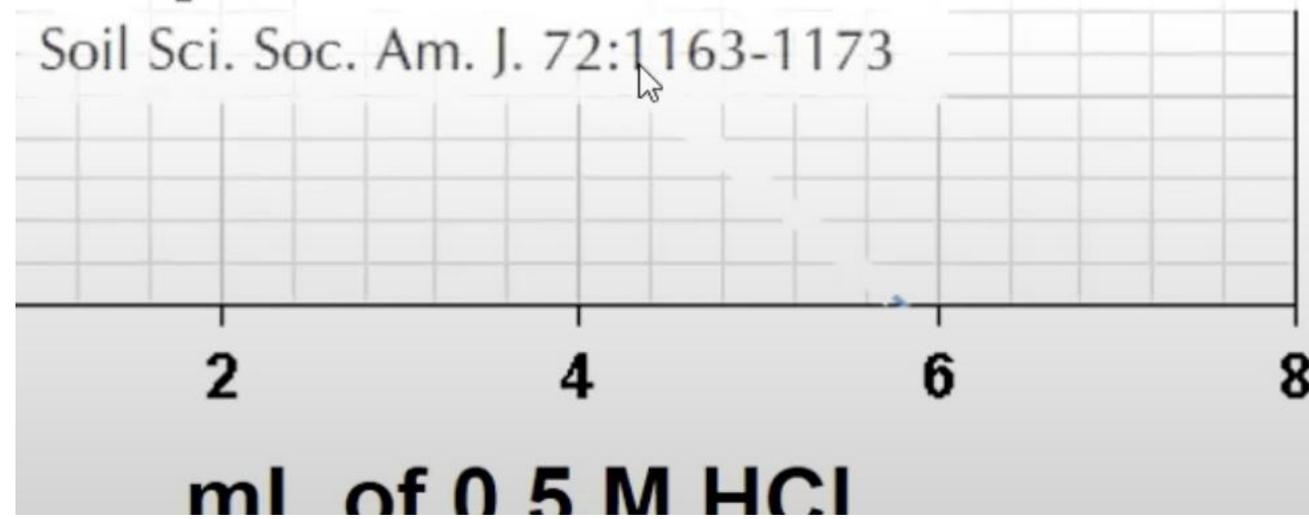


MOPS
pKa = 7.2



The Moore–Sikora Buffer for Lime Requirement Determinations

Soil Sci. Soc. Am. J. 72:1163-1173



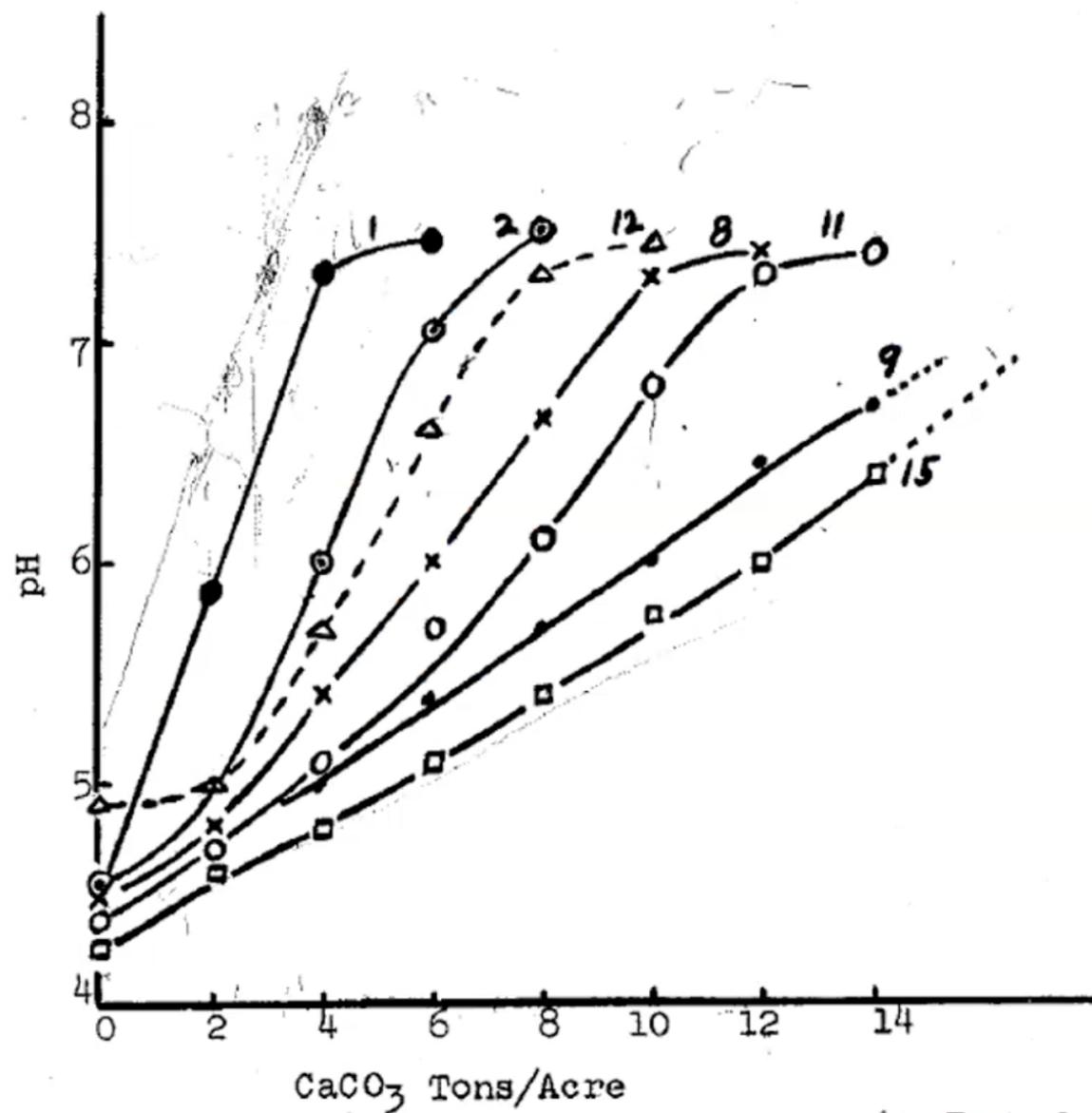
F. J. Sikora*

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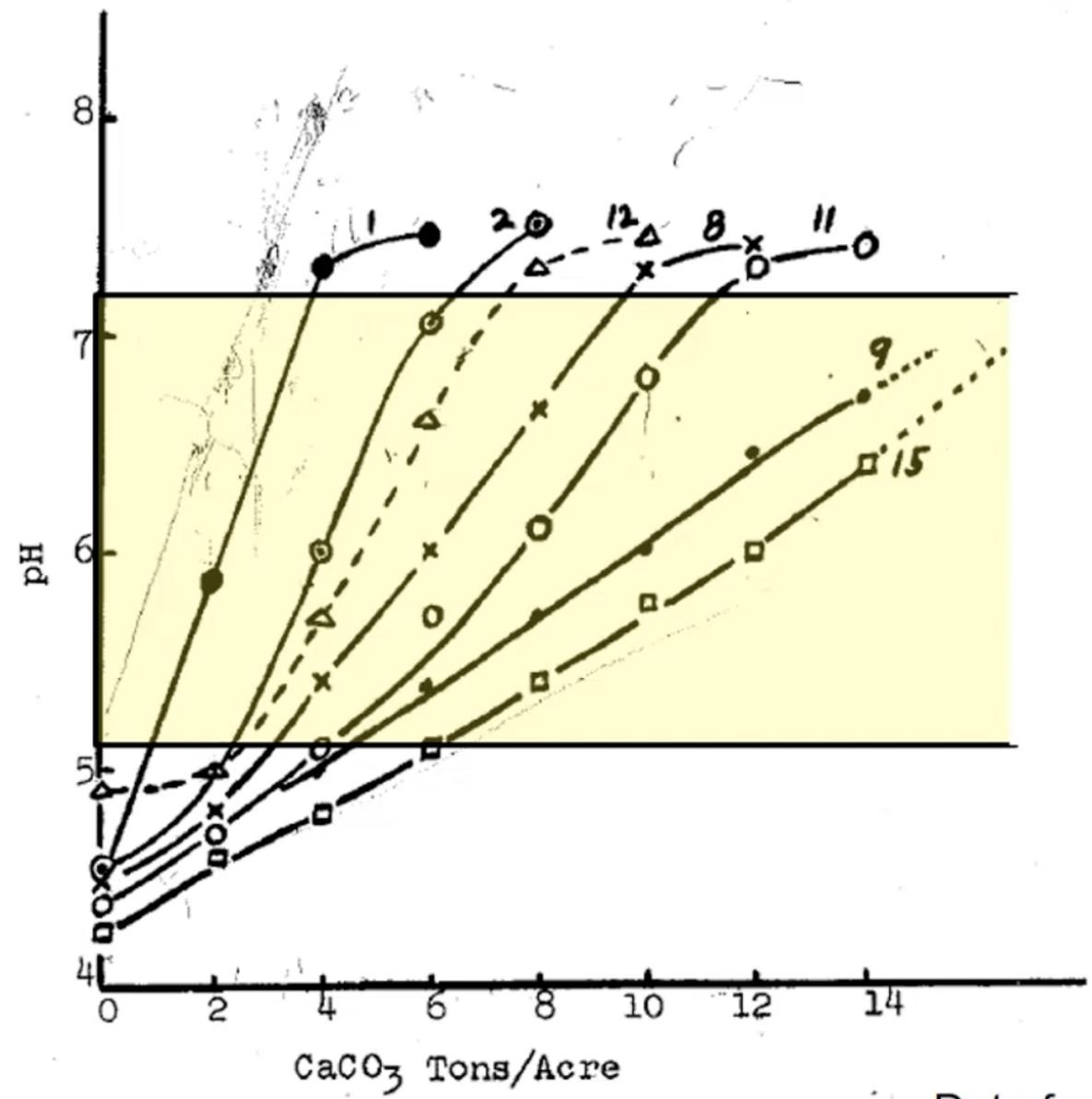
Figure 4. CaCO_3 titration curves for seven representative soils. (Moist incubation for 17 months plus 3 months dry storage)



Data from Shoemaker's Thesis

5

Figure 4. CaCO_3 titration curves for seven representative soils. (Moist incubation for 17 months plus 3 months dry storage)



The slope is the important parameter sought

Ok at pH 5.2-7.2

Very low pH =
aluminum
impacts
buffering

Very high pH =
carbonates
impact

Table 2. Lime requirement with pure CaCO_3 to raise soil-water pH to target values of 6.0, 6.4, and 6.8 based on SMP soil-buffer pH.

CaCO_3 (tons acre ⁻¹) to increase soil-water pH to the following values			
Soil-buffer pH	pH 6.0	pH 6.4	pH 6.8
6.7	1.0	1.2	1.4
6.6	1.4	1.7	1.9
6.5	1.8	2.2	2.5
6.4	2.3	2.7	3.1
6.3	2.7	3.2	3.7
6.2	3.1	3.7	4.2
6.1	3.5	4.2	4.8
6.0	3.9	4.7	5.4
5.9	4.4	5.2	6.0
5.8	4.8	5.7	6.5
5.7	5.2	6.2	7.1
5.6	5.6	6.7	7.7
5.5	6.0	7.2	8.3
5.4	6.5	7.7	8.9
5.3	6.9	8.2	9.4

U. Kentucky table prior to Sikora method



Table 5. Rate of agricultural limestone (T/A) needed to raise soil pH to 6.4.

Water pH of Sample	Buffer pH of Sample								If Buffer pH Is Unknown
	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	
4.5	7.0	6.0	6.0	5.0	4.0	4.0	3.0	3.0	4.0
4.7	7.0	6.0	6.0	5.0	4.0	4.0	3.0	3.0	4.0
4.9	7.0	6.0	6.0	5.0	4.0	4.0	3.0	3.0	4.0
5.1	7.0	6.0	5.0	5.0	4.0	3.0	3.0	2.0	4.0
5.3	7.0	6.0	5.0	4.0	4.0	3.0	3.0	2.0	3.5
5.5	6.0	5.0	5.0	4.0	4.0	3.0	2.0	2.0	3.0
5.7	6.0	5.0	4.0	4.0	3.0	3.0	2.0	2.0	2.5
5.9	—	5.0	4.0	3.0	3.0	2.0	2.0	1.0	2.0
6.1	—	—	3.0	3.0	2.0	2.0	1.0	1.0	1.5
6.3	—	—	—	2.0	1.0	1.0	1.0	1.0	1.0

Agricultural Limestone with 67% effective neutralizing ability

Salt (KCl) concentration of soil pH and buffer pH impacts interpretation equation

- Sikora
 - Use water soil pH & 2 M KCl in buffer pH = 1 M KCl in final solution for buffer
- Sikora2
 - Use 1 M KCl for soil pH & 1 M KCl in buffer pH = 1 M KCl in final solution for buffer

2020-2021 Lime and Nutrient Recommendations



AGR-1
University of Kentucky
College of Agriculture,
Food and Environment
Cooperative Extension Service



Sikora-2 soil-buffer pH
and 1 M KCl pH



Lab incubation lime requirement (tons acre⁻¹)
to reach target pH_w =

$$\frac{(1.10 \times (\text{target pH}_w) - 1.47 - \text{pH}_{\text{KCl}}) \times (\text{soil-buffer pH} - 7.55) \times 5 \div (\text{g soil})}{[(\text{soil-buffer pH} - \text{pH}_{\text{KCl}}) \times (-0.364)]}$$

2020-2021 Lime and Nutrient Recommendations

AGR-1



University of Kentucky
College of Agriculture,
Food and Environment
Cooperative Extension Service

Sikora-2 soil-buffer pH
and 1 M KCl pH



Lab incubation lime requirement (tons acre⁻¹)
to reach target pH_w =

$$\frac{(1.10 \times (\text{target pH}_w) - 1.47 - \text{pH}_{\text{KCl}}) \times (\text{soil-buffer pH} - 7.55) \times 5 \div (\text{g soil})}{[(\text{soil-buffer pH} - \text{pH}_{\text{KCl}}) \times (-0.364)]}$$

Sikora soil-buffer pH
and soil-water pH



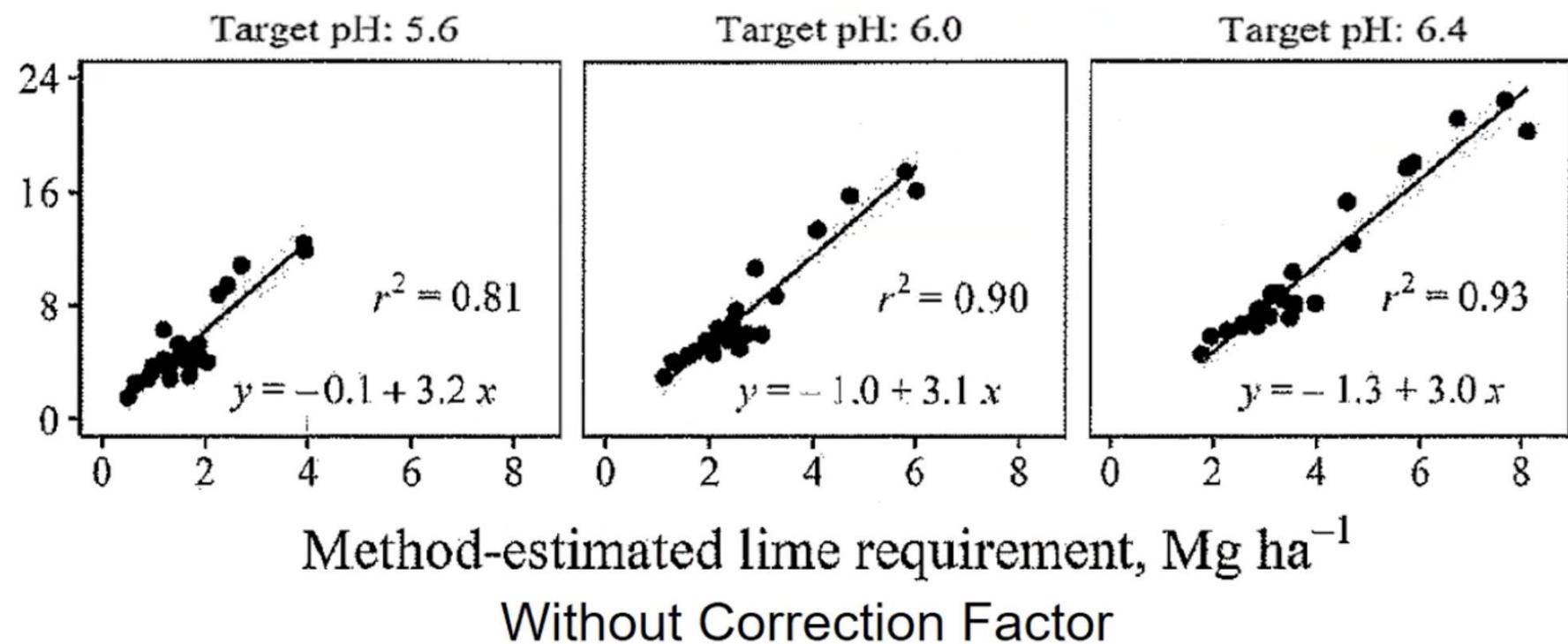
Lab incubation lime requirement (tons acre⁻¹)
to reach target pH_w =

$$\frac{-1.10 \times (\text{target pH}_w - \text{pH}_w) \times (\text{soil-buffer pH} - 7.55) \times 13.75 \div (\text{g soil})}{[\text{soil-buffer pH} - (1.10 \times \text{pH}_w) + 1.47]}$$

Table 6. Rate of 100% effective limestone (tons/A) needed to raise soil pH to 6.4.

Water pH of Sample	Buffer pH of Sample								If Buffer pH is Unknown
	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	
4.5	4.50	4.25	4.00	3.50	3.00	2.50	2.00	1.50	2.75
4.7	4.50	4.25	4.00	3.50	3.00	2.50	2.00	1.50	2.75
4.9	4.50	4.25	3.75	3.25	2.75	2.25	1.75	1.25	2.75
5.1	4.50	4.25	3.75	3.25	2.75	2.25	1.75	1.25	2.75
5.3	4.50	4.25	3.75	3.25	2.50	2.00	1.50	1.00	2.25
5.5	4.50	4.25	3.50	3.00	2.50	2.00	1.50	1.00	2.00
5.7	4.50	4.00	3.50	2.75	2.25	1.75	1.25	1.00	1.75
5.9		4.00	3.25	2.50	2.00	1.50	1.00	0.75	1.25
6.1			2.75	2.00	1.50	1.00	0.75	0.50	1.00

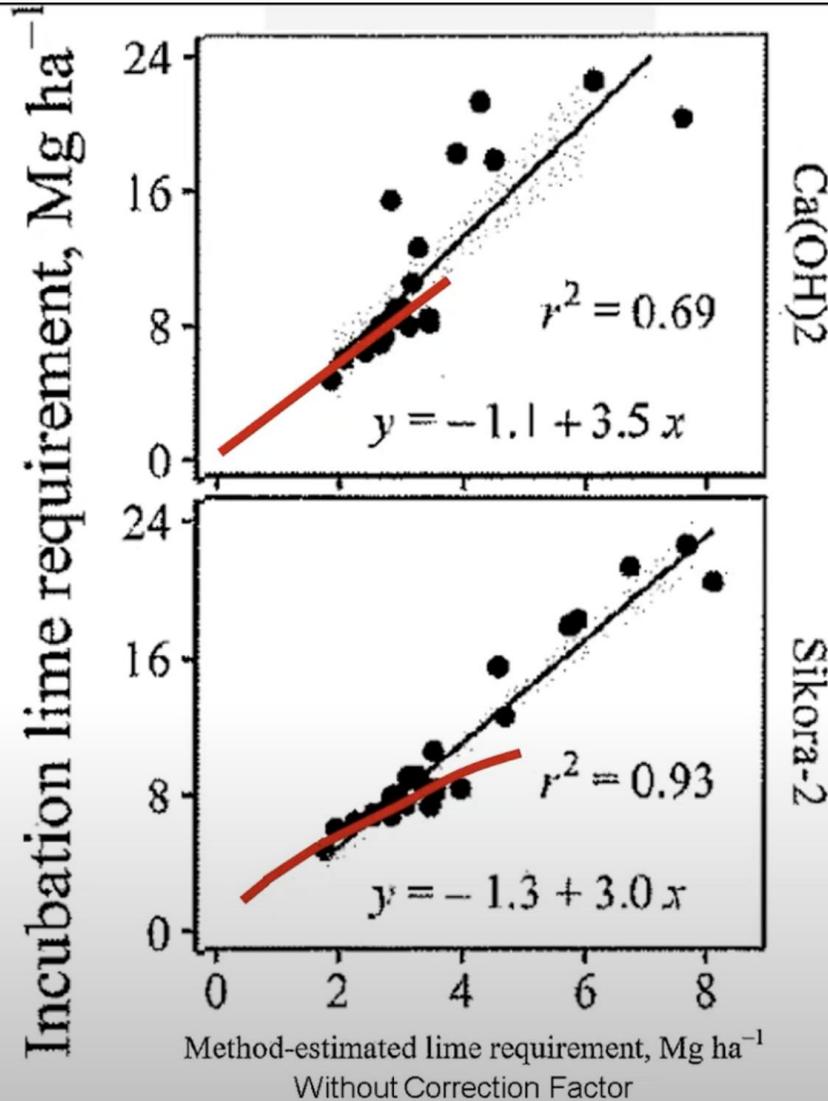
Incubation lime requirement, Mg ha^{-1}



Data from Makepeace and Moore, Oregon State Univ.

Comparable across soils (OR, GA, KY)

Target pH: 6.4



Georgia's Ca(OH)₂ correction factor

Kentucky's Sikora-2 correction factor

NAPT data

- Sikora and Woodruff > SMP

Publications

Single addition Ca(OH)₂, Sikora, and Sikora-2 buffer methods:

<http://aesl.ces.uga.edu/sera6/PUB/MethodsManualFinalSERA6.pdf>

Univ of KY Lime and Nutrient Recommendations, AGR1

<http://www2.ca.uky.edu/agcomm/pubs/agr/agr1/agr1.pdf>

Comparison of Sikora and SMP buffer methods:

Sikora, F.J. 2006. A buffer that mimics the SMP buffer for determining lime requirement of soil. Soil Sci. Soc. Am J. 70:474-486.

Theoretical study on Sikora-2 and double buffer methods:

Sikora, F.J. 2012. Double buffer methods revisited with focus on ionic strength and soil/solution ratio. Soil Sci. Soc. Am. J. 76:718-732.



Questions?

