

SDSU EXTENSION



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Using Soil Health to Stabilize pH

Anthony Bly, Soils Field Specialist
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What is pH????

Soil pH is a soil health indicator.

pH = -log [H⁺]

Really ? What does this all mean???

Power of hydrogen = negative log transformation of hydrogen ion concentration in solution

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Water is H₂O

Pure water has equal concentrations of H⁺ and OH⁻ (hydroxide) and absolutely will not conduct electricity.

A strong acid (battery acid) has 100 million, million (100,000,000,000,000) times more hydrogen ions than a strong base (sodium hydroxide).

A logarithmic scale was created because of all the numbers. Therefore, a change in 1 pH unit is 10 times acidic or basic.

The scale ranges from 0-14 (notice all those zeros above, 14)

It is a lot easier to use a scale of 0-14 than all those zeros!



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$$\text{pH} = -\log[\text{H}^+]$$

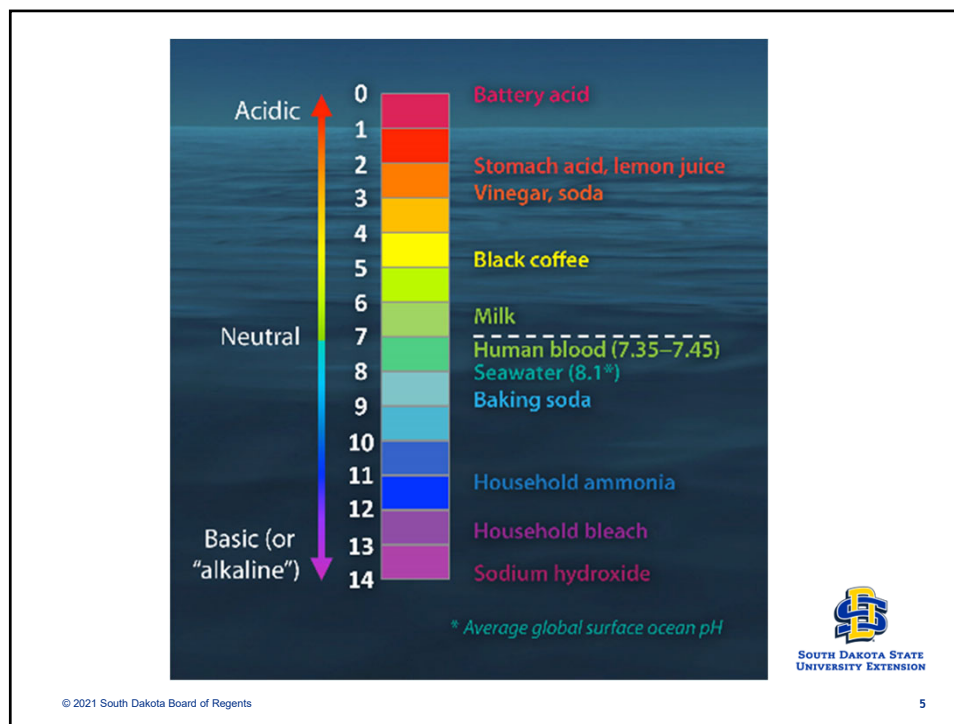
0	10 ⁰	1
1	10 ⁻¹	0.1
2	10 ⁻²	0.01
3	10 ⁻³	0.001
4	10 ⁻⁴	0.0001
5	10 ⁻⁵	0.00001
6	10 ⁻⁶	0.000001
7	10 ⁻⁷	0.0000001
8	10 ⁻⁸	0.00000001
9	10 ⁻⁹	0.000000001
10	10 ⁻¹⁰	0.0000000001
11	10 ⁻¹¹	0.00000000001
12	10 ⁻¹²	0.000000000001
13	10 ⁻¹³	0.0000000000001
14	10 ⁻¹⁴	0.00000000000001



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How is soil pH measured ?



Hydrogen (H^+) ion selective probe

1:1 soil and pure water slurry

Buffer pH (BpH) :
Buffer added to 1:1 soil/water slurry
pH measured

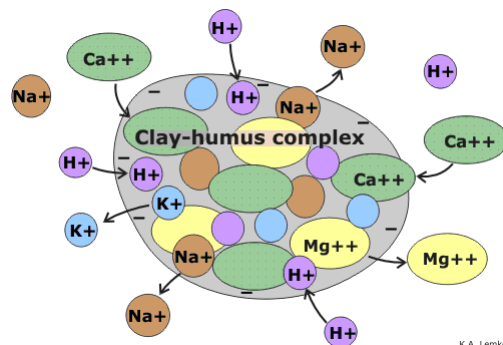
Sikora, SMP, Woodruff ect.

BpH most always higher than pH for our soils.

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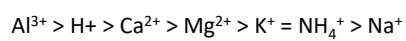
Soil Cations: Ca, Mg, K, Na, NH₄, Cu, Mn, Fe, Zn, Co, Ni

Soil Cation Exchange: Comes from clay particles and organic matter



K.A. Lemke

Cation absorption strength:



Acidic / Alkaline

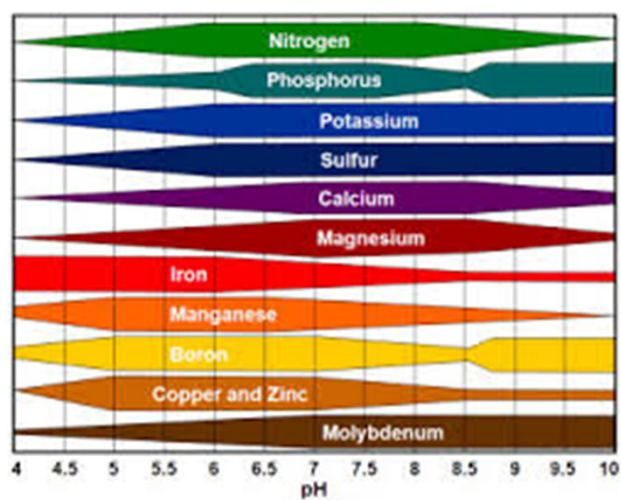


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Why is pH important in precision soil management?



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How do soils become basic (pH > 7)?

Glaciated soils typically neutral to alkaline.

White concretions are lime.

Ethan Soil Series

Add:

Lime CaCO_3

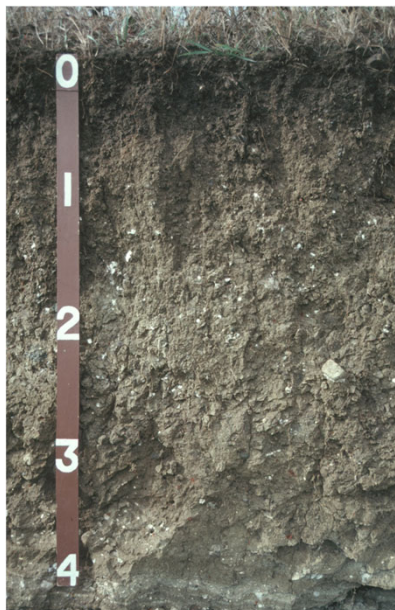
Calcium oxide CaO

Calcium hydroxide Ca(OH)_2

Wood ash

Water treatment plant

By-products.



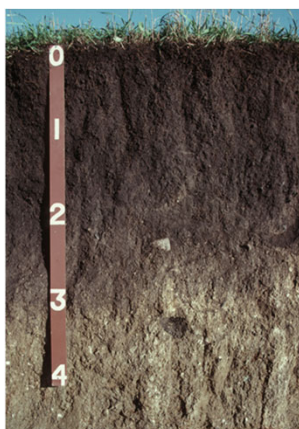
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Soil pH by depth

Brookings Soil Series



Site 1 Soil Depth	Soil Test Parameter			
	P	K	OM	pH
	---- ppm ----		%	
0-6	35(VH)	164(VH)	3.6	6.5
6-12	46(VH)	102(M)	3.0	7.2
12-18	12(H)	129(H)	2.1	7.6
18-24	3(VL)	110(M)	1.5	7.9

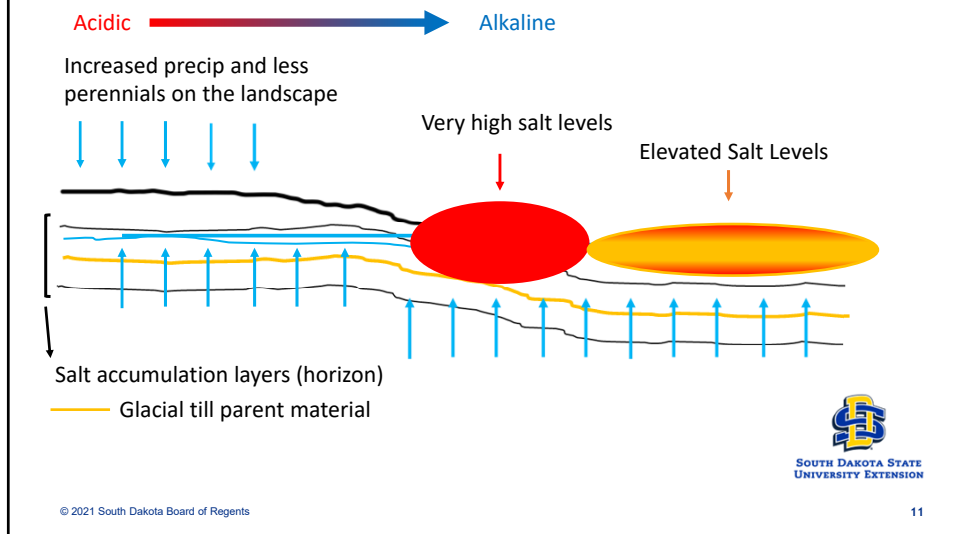


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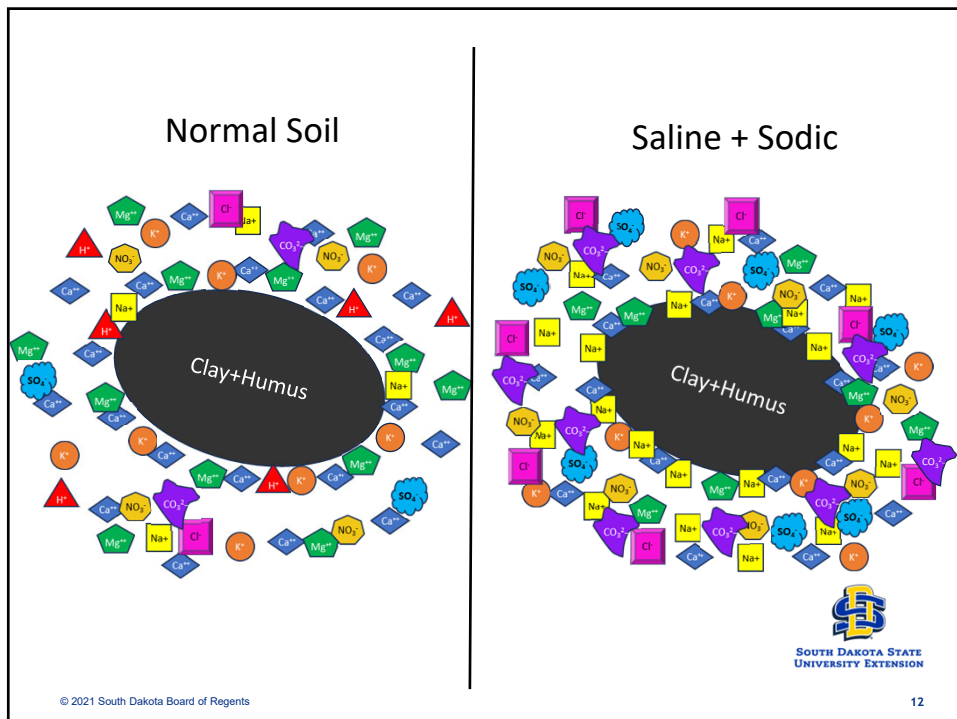
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Saline and Sodic Soils Development



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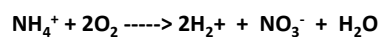


How do soils become acidic? (pH <7)

Soil weathering, leaching and organic acids created from organic processes do contribute, however the largest cause is :

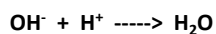
Nitrate-N not used by plants leaves H^+ ions that are not neutralized.

Nitrification of fertilizer N:



Neutralization of acidity by plant root uptake of Nitrate-N.

Plant / Root uptake of nitrate-N releases OH^-



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Table 1. Influence of N rate management on surface soil pH (0-6 inch), SE Research Farm, 2006, Beresford, SD.

Nitrogen Treatment ^A	N Rate ^C lbs/a	pH (0-6 inch)
		-log[H ⁺]
check-no nitrogen	0	6.3
Spring -Rec. N ^B	110	6.0
Split - Rec. N ^B	110	5.7
Fall - Rec. N ^B	110	6.0
Spring 200	200	5.5
Spring 400	400	5.0

^A N rate applications made for corn in rotation with soybean from 1988 to 2006. (broadcast urea, conventional tillage)

^B Rec N = Recommended N for corn (corn/soybean rotation) determined from yield goal and 0-24 inch soil test.

^C 2006 N application rates

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Increasing Soil pH with amendments.

Increasing pH in acidic soils.

Low pH soils (4.5-6.0) apply lime.

Adding Lime (based on BpH).

Buffer Index	Lime required (6 inch depth)
	tons/acre
>6.5	0
6.1 – 6.499	2.0
5.9 – 6.099	2.5
5.7 – 5.899	3.0
< 5.699	3.5
Calcium carbonate equivalent = 90%, total effectiveness = 70%	
-adapted from SDSU Fertilizer Recommendation Guide, EC750	

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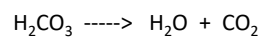
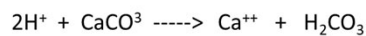


What is lime ?

Calcium carbonate (CaCO_3)



How does lime neutralize acidity ?



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Lime Sources

Ag Lime – extracted from a mine, maybe crushed. Can be calcitic (Ca based) or dolomitic (higher Mg concentration). Universities of MN and WI have found no advantage in manipulating the Ca:Mg ratio.

Pelletized Lime – finely ground lime (glued – stuck) together with water soluble, synthetic tree sap. (expensive)

Water treatment lime – produced from softening municipal water sources.

Process: Limewater (CaOH solution) is added to raw water. The pH increases resulting in a shift of carbonate species producing calcium and magnesium carbonate. Iron, manganese and other metals are removed.

Other lime sources: CaO, MgO, MgCO₃, and Ca(OH)₂

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Lime Effectiveness

CCE (Calcium Carbonate Equivalent) – effectiveness of a lime source determined by the amount of acid it neutralizes.

Important for lime sources containing impurities.
Lime sources with lower CCE require higher application rates.

Mesh size – finer materials neutralize acidity more quickly.

Mesh size – wires/inch	Opening size (inches)
4	0.1870
8	0.0937
60	0.0098

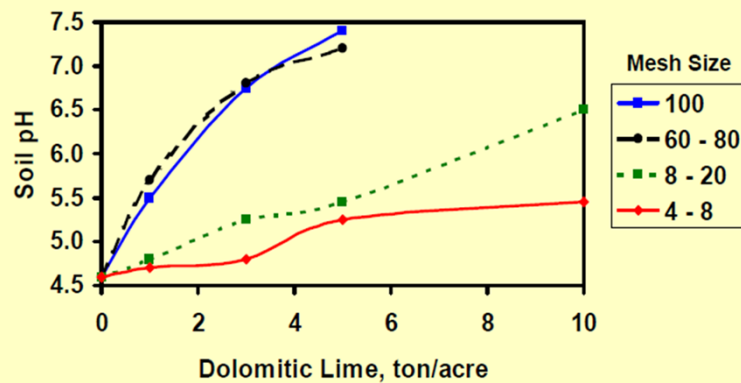
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Effect of Particle Size and Lime Rate on Soil pH After 18 Months



Meyer et al., Soil Sci, 73:37

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Effective Calcium Carbonate Equivalent (ECCE):

$$(\text{Total Fineness Efficiency} \div 100) \times (\% \text{ CCE} \div 100) \times ([100 - \% \text{ Moisture}] \div 100) \times 2000 = \text{ECCE}$$

Mesh size	% of particles passing through	Fineness Factor	% Available
4	100	X 0.1 =	10
8	90	X 0.3 =	27
60	55	X 0.6 =	33
Total Fineness Efficiency =			70

Example:

$$(70 \div 100) \times (92 \div 100) \times ([100 - 2] \div 100) \times 2,000 = 1,260 \text{ ECCE}$$

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Tillage System Effectiveness

Table 4. Soil pH of conventional and no-till plots with applied rates of Super Cal and Brookings city water treatment lime sludge at Aurora, SD, in 2005.

Lime Source	Rate ^A tons/a	Soil pH ^E							
		Conventional tillage				No-Till			
		0-2"	2-4"	4-6"	0-6"	0-2"	2-4"	4-6"	0-6"
Check	0	5.3 b	5.5 b	5.6 b	5.4 b	5.2 b	5.4 b	5.5	5.3 b
Brookings ^B	1	7.6 a	7.4 a	6.3 a	7.1 a	7.3 a	6.4 a	5.9	6.5 a
Super Cal ^C	1	7.4 a	7.2 a	6.2 a	7.0 a	7.3 a	6.5 a	5.9	6.6 a
Super Cal ^D	4	7.5 a	7.5 a	6.3 a	7.1 a	7.4 a	6.5 a	6.4	6.8 a
LSD _(.10)		0.3	0.4	0.5	0.4	0.2	0.4	NS	0.3

^A dry weight basis.

^B Applied in 1998, 1999, 2000, 2001, 2002, 2003, 2004, and 2005. (Brookings City water treatment plant lime sludge)

^C Applied in 1998, 1999, 2000, 2001, 2002, 2003, 2004, and 2005. (Calcium Products Inc., Gilmore City IA)

^D Applied in 1998 and 2002. (Calcium Products Inc., Gilmore City IA)

^E Samples taken prior to 2005 lime application.

LSD = least significant difference between treatment means.

-means with similar lower case letter are not significantly different within a comparison column.

NS = non-significant difference

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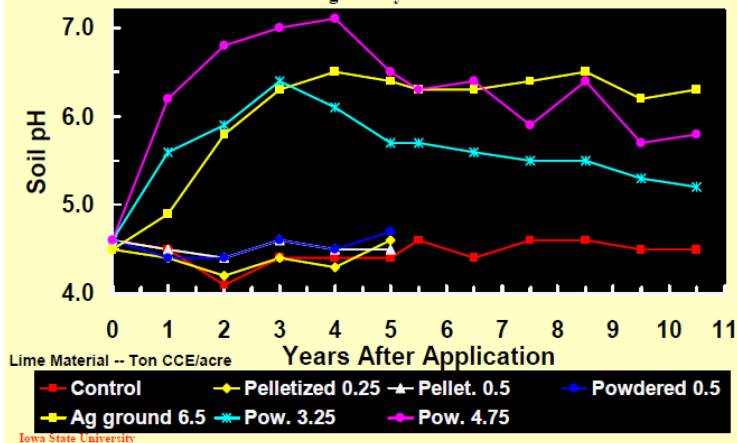


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Source and Rate Effects

Long-Term Liming Practices Cisne sil soil, 0-6 Inch Sample Depth

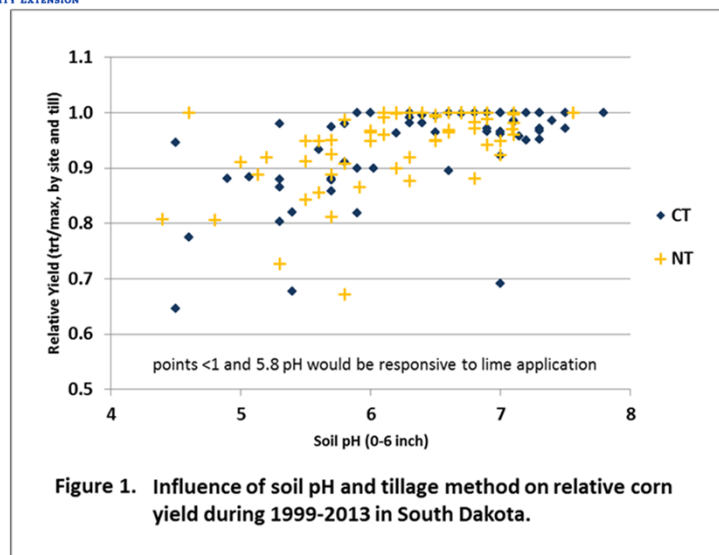
Brownstown Agronomy Research Center



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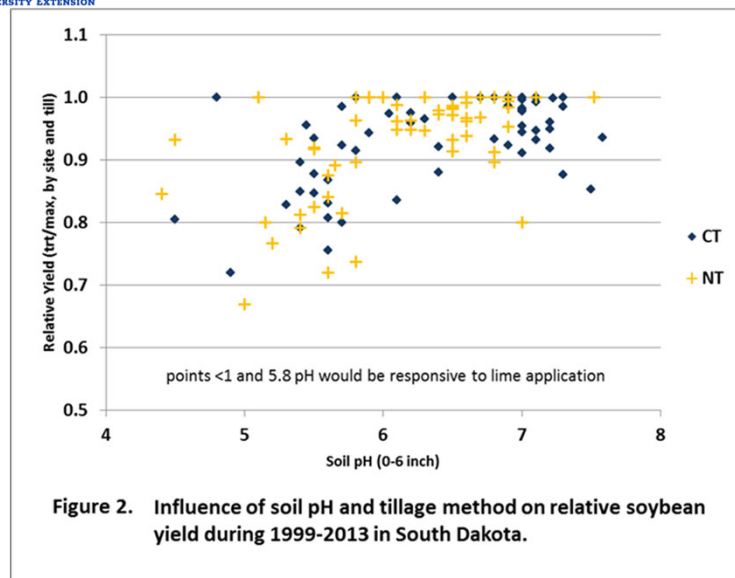
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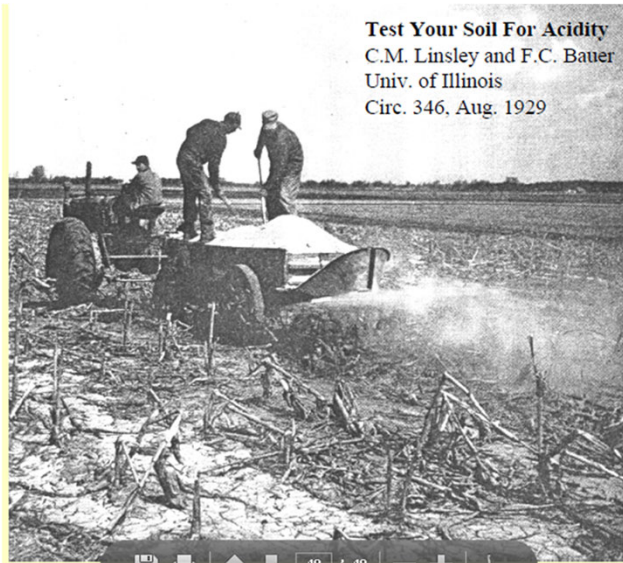
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Precision Soil Management - lime



Test Your Soil For Acidity
C.M. Linsley and F.C. Bauer
Univ. of Illinois
Circ. 346, Aug. 1929

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Test Your Soil For Acidity

C.M. Linsley and F.C. Bauer

- **University of Illinois Circular 346
August, 1929**
- **In a 40-Acre Field Measure pH & Carbonates**
 - ❖ 23 Surface Samples (2 inch depth)
 - ❖ 5 subsurface (12 inch depth)
 - ❖ 5 subsoil (20 inch depth)
- **Completed Acidity Map Shows Where and
How Much Limestone Is Needed**
- **Good Plan to Test After Six Years**

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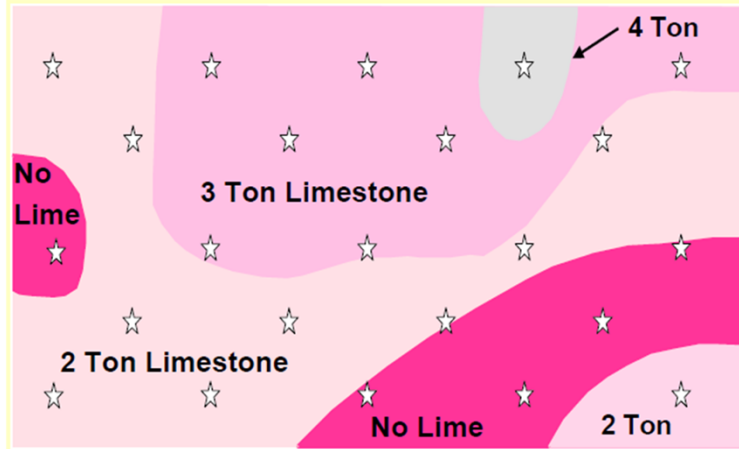
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Test Your Soil For Acidity

Adapted from C.M. Linsley and F.C. Bauer



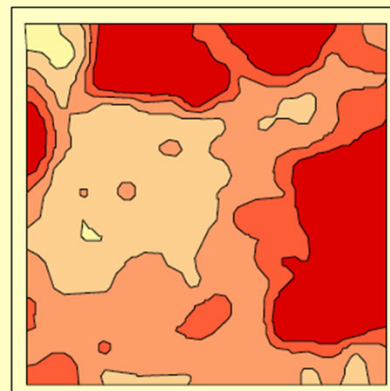
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September 1991 Soil pH



Soil pH

- < 5.5
- 5.5 - 6.0
- 6.0 - 6.5
- 6.5 - 7.0
- > 7.0

40 acres
16 x 16 grid
0.156 acres/sample

Mansfield Test Field

Data From:
T. Peck, Univ. of Illinois

0 400 800 1200 Feet

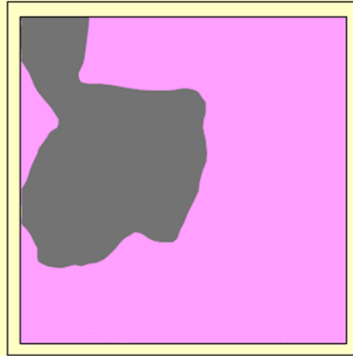
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Agricultural Limestone Application 4 Ton/acre -- October 1991



Lime Rate

- 4 ton/acre
- 0 ton/acre

40 acres
16 x 16 grid
0.156 acres/sample

Mansfield Test Field

Data From:
T. Peck, Univ. of Illinois

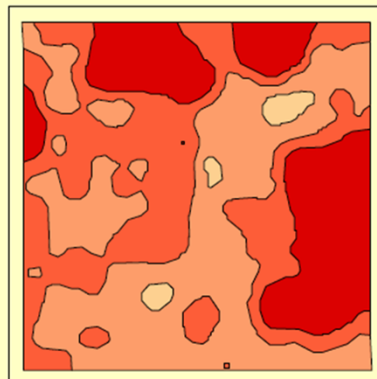
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September 1992 Soil pH



Soil pH

- < 5.5
- 5.5 - 6.0
- 6.0 - 6.5
- 6.5 - 7.0
- > 7.0

40 acres
16 x 16 grid
0.156 acres/sample

Mansfield Test Field

Data From:
T. Peck, Univ. of Illinois

0 400 800 1200 Feet

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Ok, it seems like everyone is concerned about increasing pH?

What about lowering pH, is it possible?

Clemson University:

Present pH	Desired pH				
	6.5	6.0	5.5	5.0	4.5
	----- lbs elemental S/a -----				
8.0	1300	1750	2400	3050	3500
7.5	1100	1525	1960	2200	3050
7.0	435	871	1525	2175	2600
6.5	---	435	1100	1750	1950
6.0	---	---	435	1100	1525
For sandy soil reduce by 1/3, clayey soil increase by 1/2					

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Research in South Dakota

High pH soil (> 7.5) apply elemental sulfur.

No clear recommendations due to soil variability.

Only limited research available in South Dakota.

Influence of elemental sulfur on surface soil pH, 1991-1995				
Year	Elemental Sulfur Rate (lbs/a)			
	0	2000	4000	8000
	----- pH (0-3 inch) -----			
1991	7.8	7.5	7.2	6.5
1992	7.9	6.6	6.4	5.4
1993	7.7	6.6	6.2	5.0
1994	7.5	6.7	6.4	5.1
1995	7.8	7.2	6.6	5.7
Applied April 1991 and sampled Nov. each year.				
Gerwing and Gelderman, 1996				

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Influence of soil pH on soil test levels.

	Soil Test (0-3 inch)				
Sulfur Rate	pH	Olsen P	Zn	Fe	Mn
lbs/a		----- ppm -----			
0	7.8	27	1.57	20	16
2000	7.2	33	1.8	46	29
4000	6.6	39	2.13	68	40
8000	5.7	52	2.09	58	94

Applied April 1991, sample November 1995. Gerwing and Gelderman 1996.

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Influence of Elemental Sulfur on subsoil pH.

	Sulfur Rate (lbs/a)			
Depth	0	2000	4000	8000
inches	----- pH -----			
0-3	7.8	7.2	6.6	5.7
3-6	7.8	7.4	7.1	6.6
6-9	7.9	7.7	7.6	7.3
9-12	8.0	7.9	7.8	7.8
12-24	8.2	8.1	8.0	8.0

Applied April 1991 and sampled November 1995.

Gerwing and Gelderman, 1996

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Soil Analysis of Sulfur Treated Soil

Sulfur	Brookings	Yankton M-8	Yankton G-4
lbs/a	pH (0-6 inch)		
0	7.8	7.1	7.7
1000	----	----	7.7
2000	6.9	5.8	7.5
4000	6.5	4.6	7.5
6000	----	----	7.5
8000	5.3	4.4	----
16000	----	3.8	----
CaCO ₃ (%)	1.8	0.6	6.8
CEC	31	20	15
OM (%)	4.1	2.3	1.3
Texture	loam	loam	loam
Sand, silt clay (%)	42,25,33	39,33,28	46,31,23

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What about Soil Health practices influence on soil pH?

Rotations: Reduce N use, provide opportunities for cover crops and grazing that will help to increase pH (alkaline minerals converted to organic forms).

Cover Crops: Convert NO₃-N from inorganic to organic form and therefore neutralizing any extra acidity (H⁺).

Perennials: Convert inorganic alkaline minerals (calcium and magnesium) to organic forms that can offset acidity. Water use increases which can bring alkaline minerals near to soil surface.

Grazing: Livestock help to convert carbon stocks more to humus that can hold more alkaline minerals (CEC increases).

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Summary

1. Soil pH is a very important soil health indicator.
Nutrient availability and microbial activities are greatly affected.
2. Our soils are/were naturally very alkaline.
3. Nitrogen applications above yield levels have decreased soil pH.
4. Lime is a very effective way to increase soil pH.
5. Reducing soil pH is very difficult and cost prohibited.
6. Elemental S can lower soil pH but only when free CaCO_3 is low.
7. Following soil health practices are the best way
to keep soil pH at optimal levels.

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CONTACT INFORMATION

anthony.bly@sdstate.edu

1-605-690-4563

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