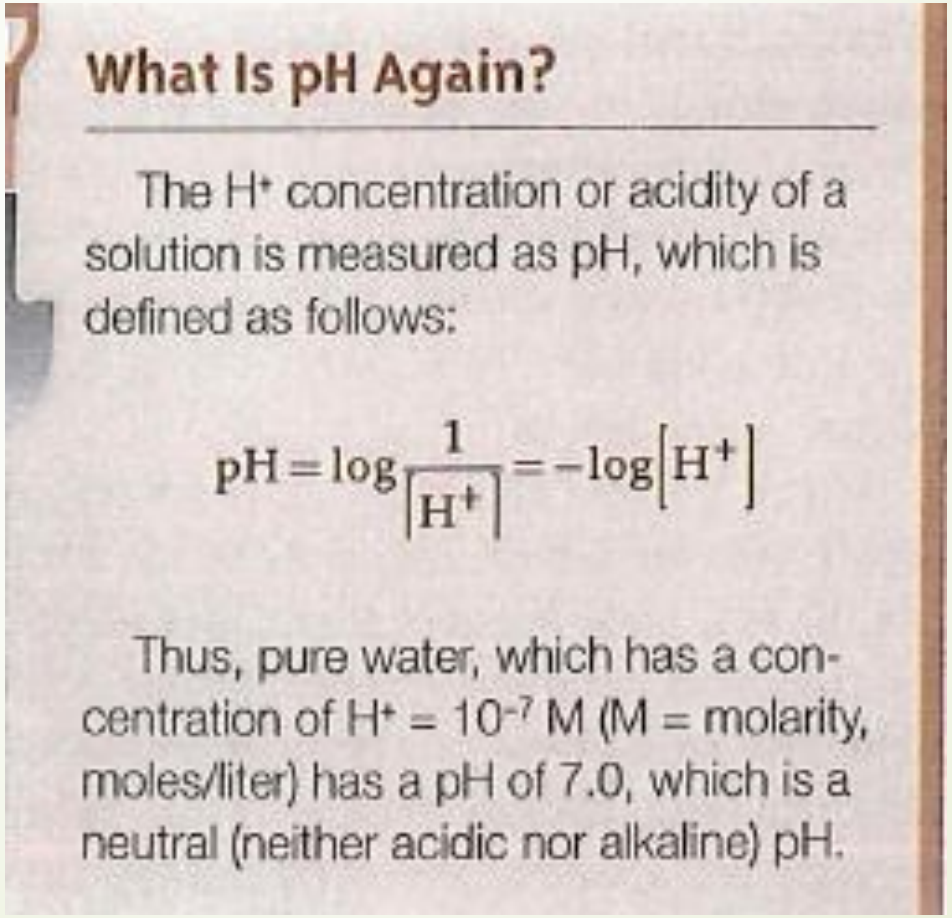
Calcium, pH and Soil Health

Tim Reinbott, MU Field Operations

Soil pH

Fix it First Before You Do Anything Else!

But What Is it?



What Is pH Again?

The H^+ concentration or acidity of a solution is measured as pH, which is defined as follows:

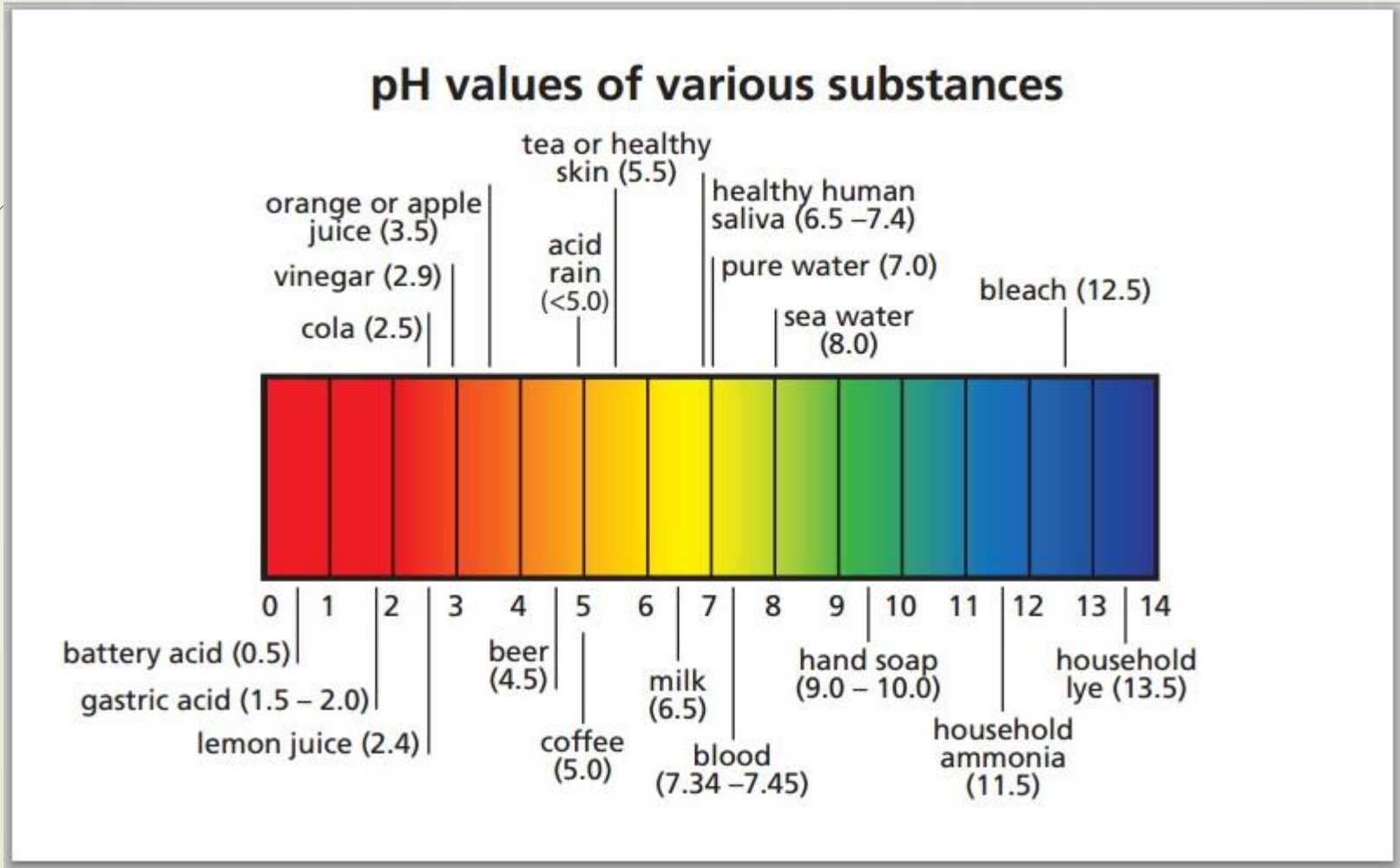
$$pH = \log \frac{1}{[H^+]} = -\log [H^+]$$

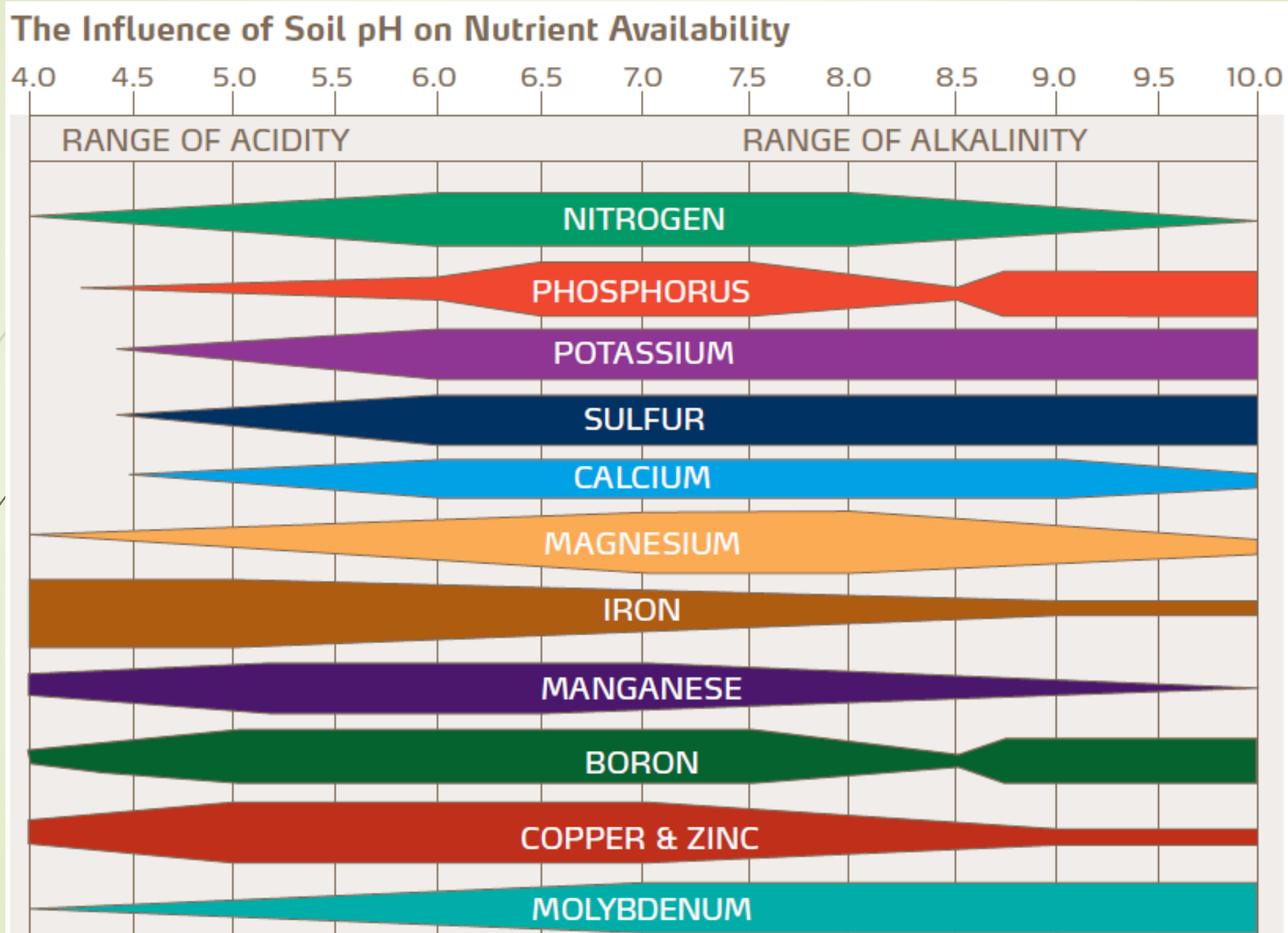
Thus, pure water, which has a concentration of $H^+ = 10^{-7}$ M (M = molarity, moles/liter) has a pH of 7.0, which is a neutral (neither acidic nor alkaline) pH.

What Is pH? The lower the pH the more Hydrogen is Present

Hydrogen Ion Concentration	pH	Interpretation
moles/liter		
.00000001	8	Strongly alkaline
.0000001	7	Neutral
.000001	6	Slightly acid
.00001	5	Strongly acid
.0001	4	Extremely acid

pH Scale-In Soils We Want to Be Slightly Acid-6.5-Why?




The Influence of Soil pH on Nutrient Availability
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
RANGE OF ACIDITY
RANGE OF ALKALINITY
NITROGEN
PHOSPHORUS
POTASSIUM
SULFUR
CALCIUM
MAGNESIUM
IRON
MANGANESE
BORON
COPPER & ZINC
MOLYBDENUM

Some Plants Like Low pH

Those that developed in forests and highly weathered soils

Blueberries-Do Best in Acid Soil

- Why?
- Evolved in Forest, Acid Soils
  - Interaction with soil microbes
- Root System Does Not Have Fine Roots
- Iron Availability

Too High pH in Blueberry-Iron Deficiency

How Do You Lower the pH?-Elemental Sulfur or Aluminum Sulfate- 6 months ahead of time.

Table 1. Amending soil to reduce pH.

To lower the pH one full pH unit (e.g., from 5.5 to 4.5), incorporate either finely ground sulfur or aluminum sulfate. Sulfur is usually the least expensive material. Use the water pH value rather than the buffer pH value to determine how much sulfur or aluminum sulfate to incorporate.

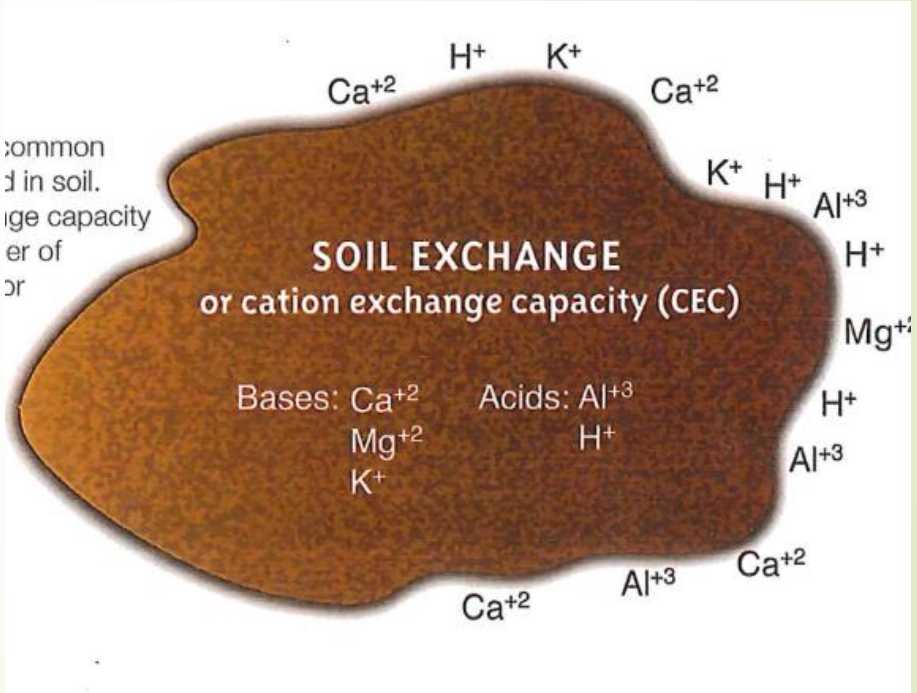
Soil Texture	Sulfur lb/100 sq ft[1]	Aluminum Sulfate lb/100 sq ft[1]
Light, Sandy	0.75	4.5
Medium, Sandy Loam	1.50	9.0
Heavy, Clay Loam	2.25	13.5

1	Because the soil's buffering capacity affects the degree to which a soil is acidified, apply the recommended amount well before planting. Then recheck the pH 60 to 90 days later.

Hydrangea-Pink vs Blue

The Lower The pH, The More Available Aluminum

Soil pH (H2O)	% Al Saturation
4.45	82
4.90	27
5.60	13
5.90	6



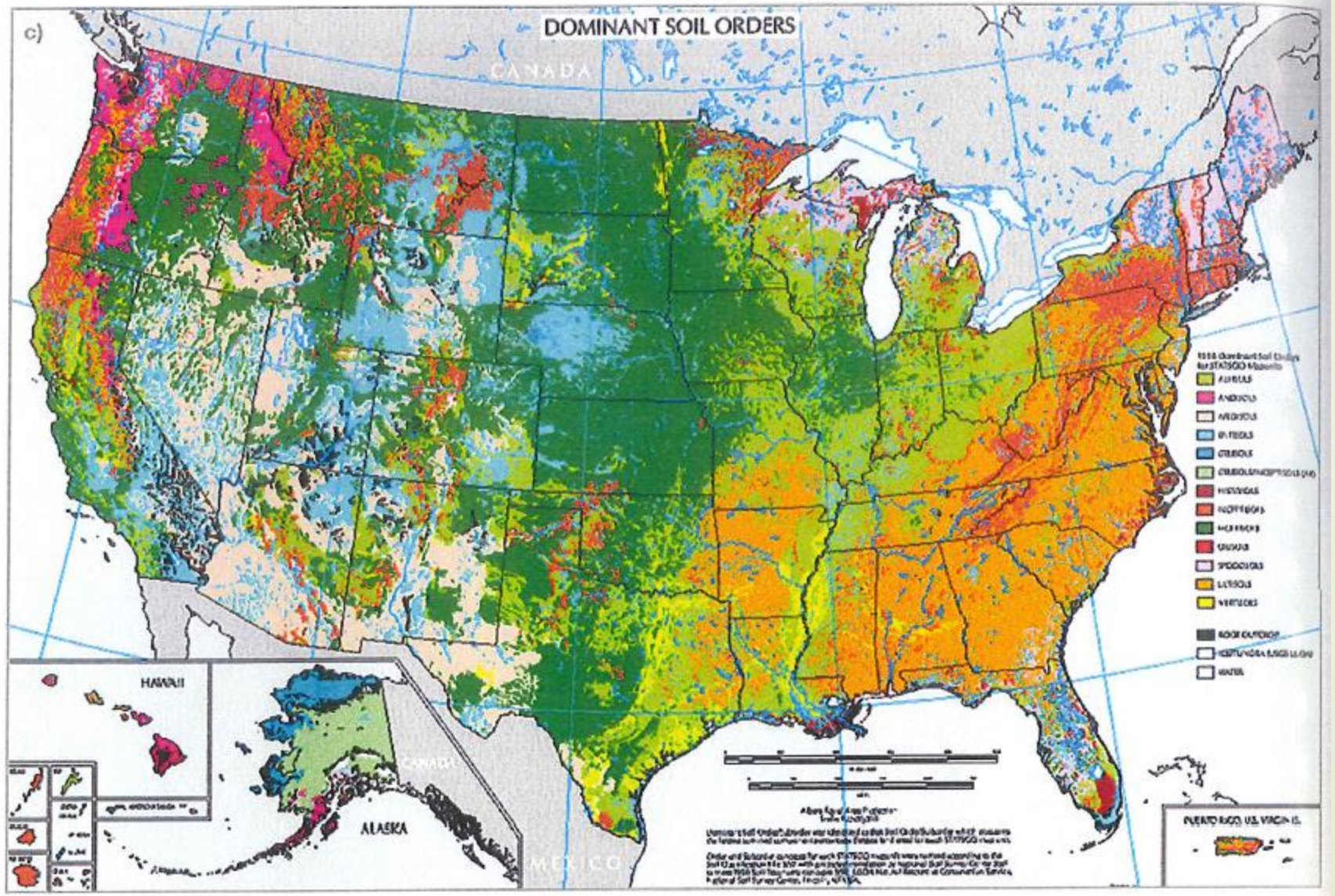
Hydrangea-Pink vs Blue-Aluminum Turns the Flower Blue

What Is This And Why?

How Do We Correct The pH?

Raising pH With Lime

Figure 5–5. Continued: (c) U.S. soil map.



Example of Soils-Mollisols and Alfisols-pH increases as you move left

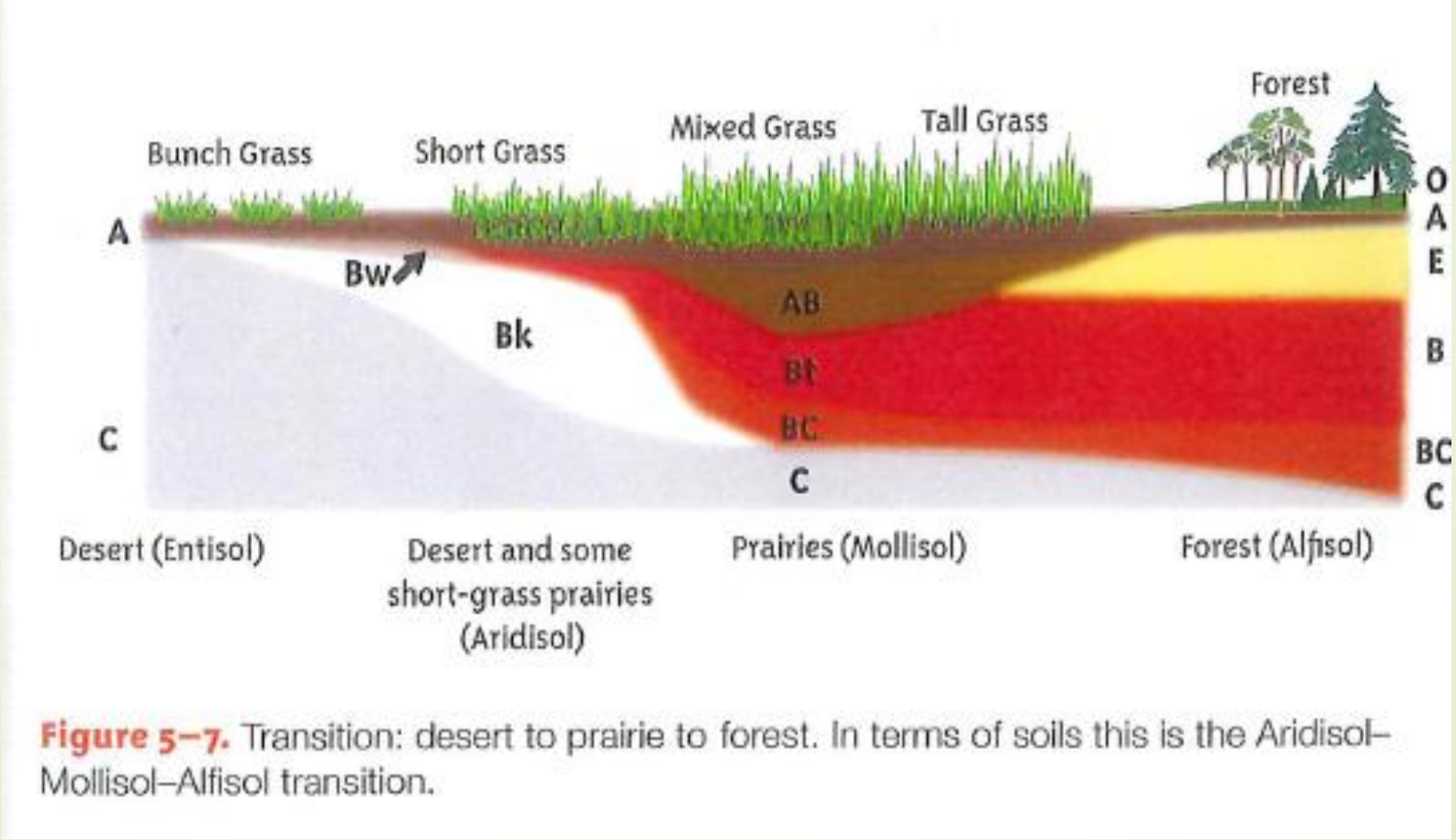


Figure 5–7. Transition: desert to prairie to forest. In terms of soils this is the Aridisol–Mollisol–Alfisol transition.

What Does Liming Do?

Lime Corrects Problems from Excessive Acidity

- Reduces Al and other metal toxicities
- Improves soil physical condition
- Stimulates microbial activity -Fungal
- Including symbiotic bacteria that fix N
- Improves availability of essential nutrients
- Supplies Ca and Mg for plants

Frequency of Liming Influenced By

- Soil texture-More Clay, More Lime
- Rate of N fertilization-increase N, decrease pH
- Rate of crop removal of Ca and Mg
- Amount of lime applied
- Quality of lime applied
- Soil buffer capacity-CEC-Clay
- Tillage Desired pH range

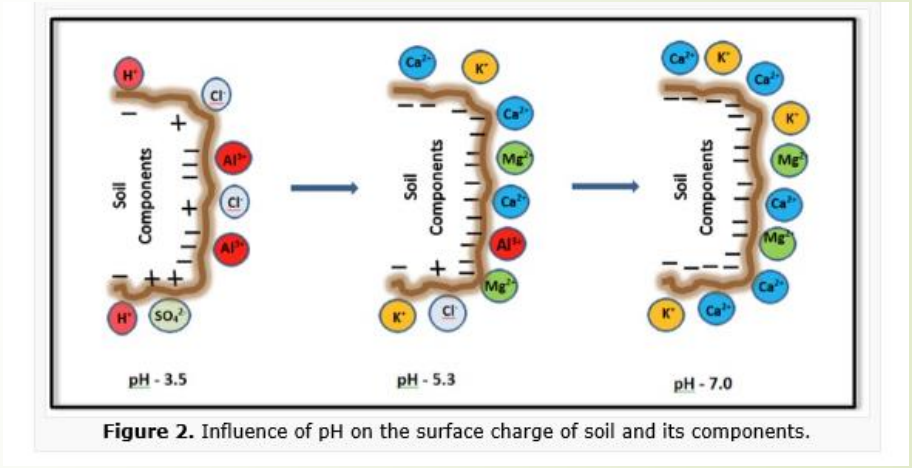
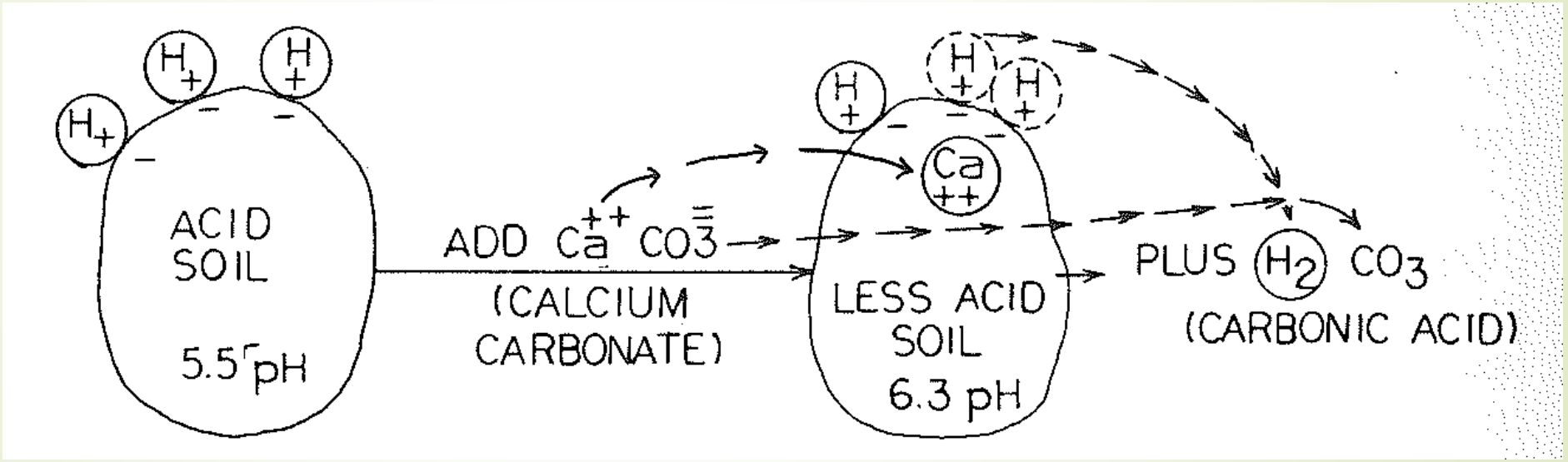


Figure 2. Influence of pH on the surface charge of soil and its components.

Lime Is Calcium Carbonate- $CaCO_3$ –It is Not the Ca That Corrects pH, but CO3

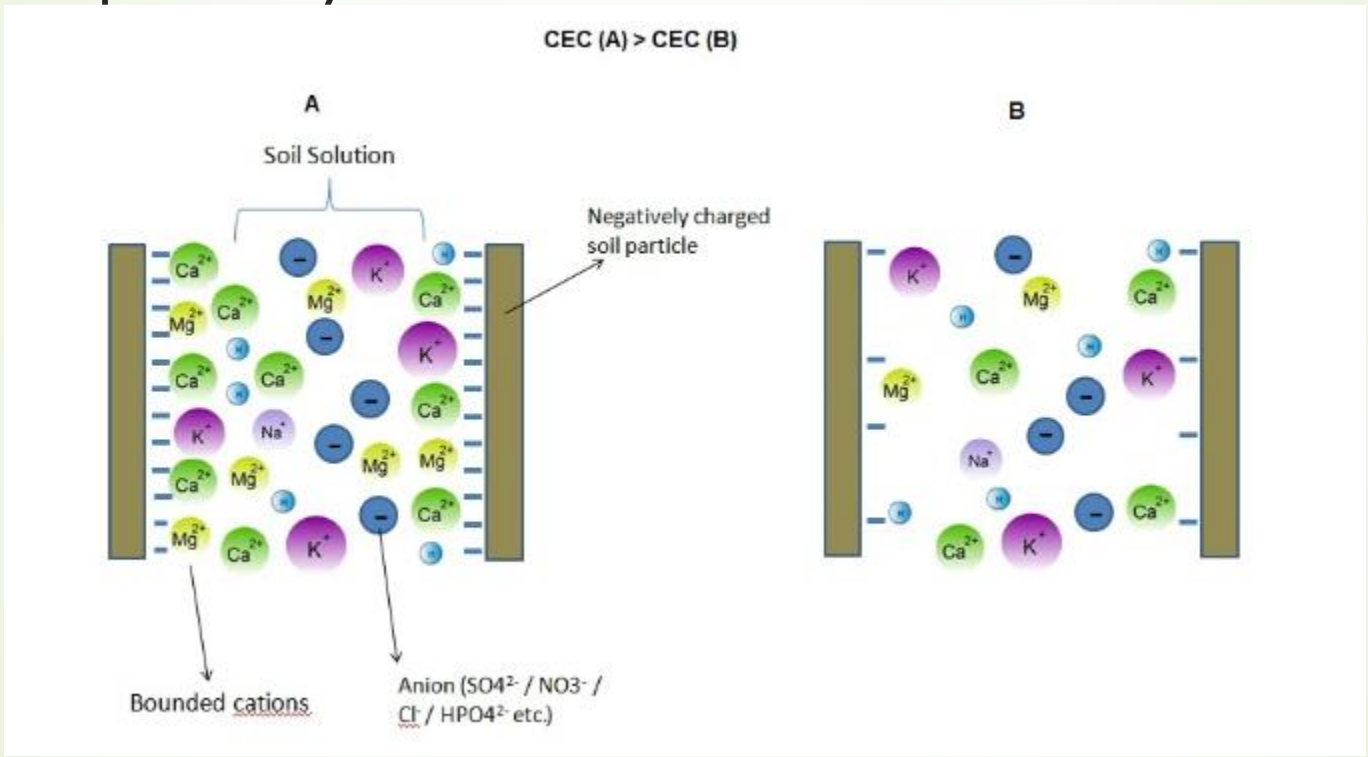
$$CaCO_3 + 2H^+ = Ca^{+2} + CO_2 \uparrow + H_2O$$

Slides showing Ca bumping off H

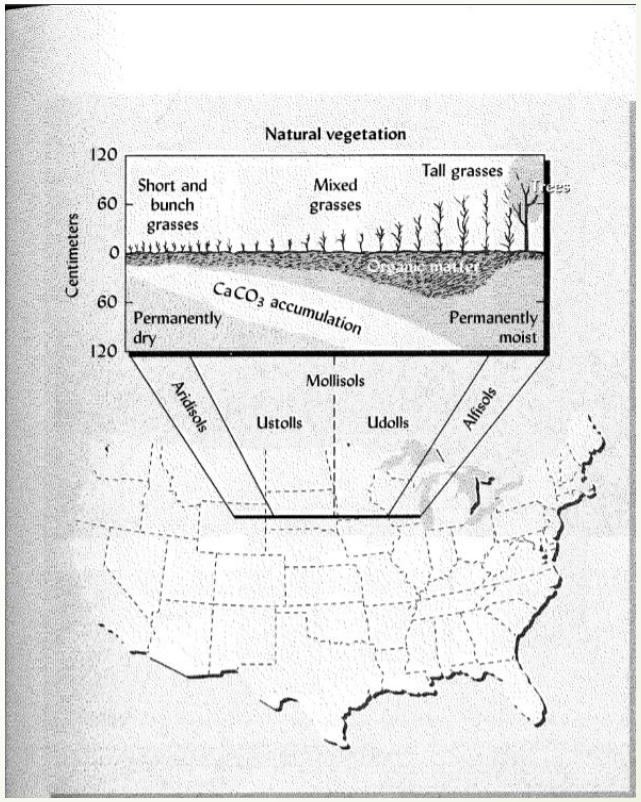


$$CaCO_3 + 2H^+ = Ca^{+2} + CO_2 \uparrow + H_2O$$

How Much Lime To We Need To Add? Depends Upon The Cation Exchange Capacity



Alfisols Formed Under Forest, Mollisols Under Prairie



Alfisols and Mollisols

TABLE 8.7 **The Average Cation Exchange Capacities (CEC) and pH Values of More Than 3000 Surface Soil Samples Representing Seven Different Soil Orders**

Organic colloids give Histosols a very high CEC. Compare to data in Tables 8.3 and 8.4 to see the relationship between the average CEC and the main types of colloids in the other soil orders.

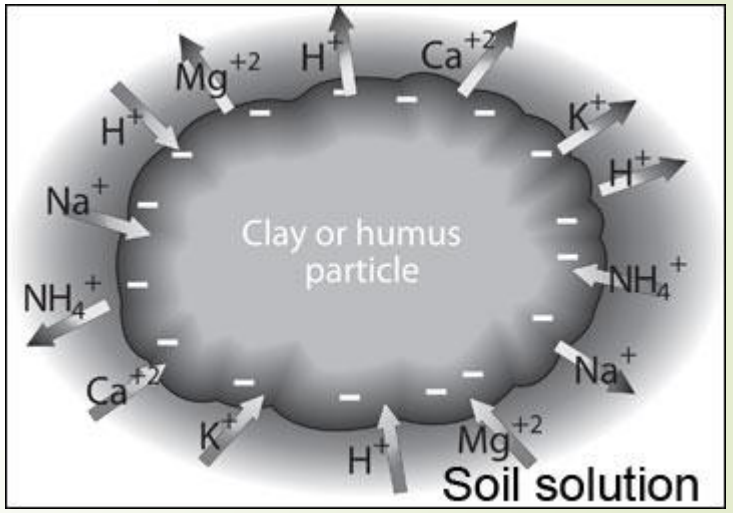
Soil order	*CEC, $cmol_c/kg$*	*pH*
Ultisols	3.5	5.60
Alfisols	9.0	6.00
Spodosols	9.3	4.93
Aridisols	15.2	7.26
Mollisols	18.7	6.51
Vertisols	35.6	6.72
Histosols	128.0	5.50

From Holmgren et al. (1993)

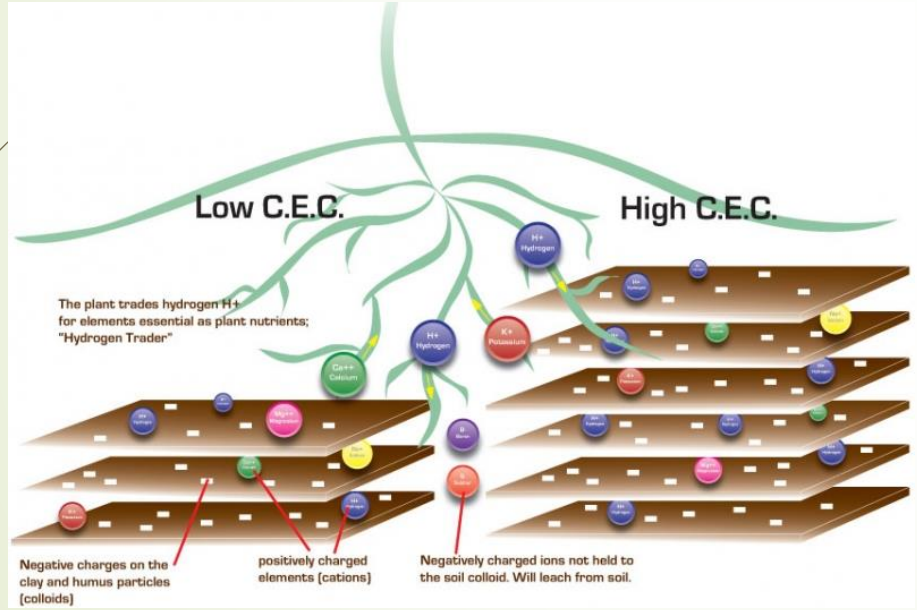
pH is Then Like Air Pressure in Your Tire-It Doesn't Tell You How Much Hydrogen Is In the Soil

Greater Clay Content=Higher Cation Exchange Capacity (CEC)

Soil texture	CEC (meq/100g soi)
Sands (light-colored)	3-5
Sands (dark-colored)	10-20
Loams	10-15
Silt loams	15-25
Clay and clay loams	20-50
Organic soils	50-100

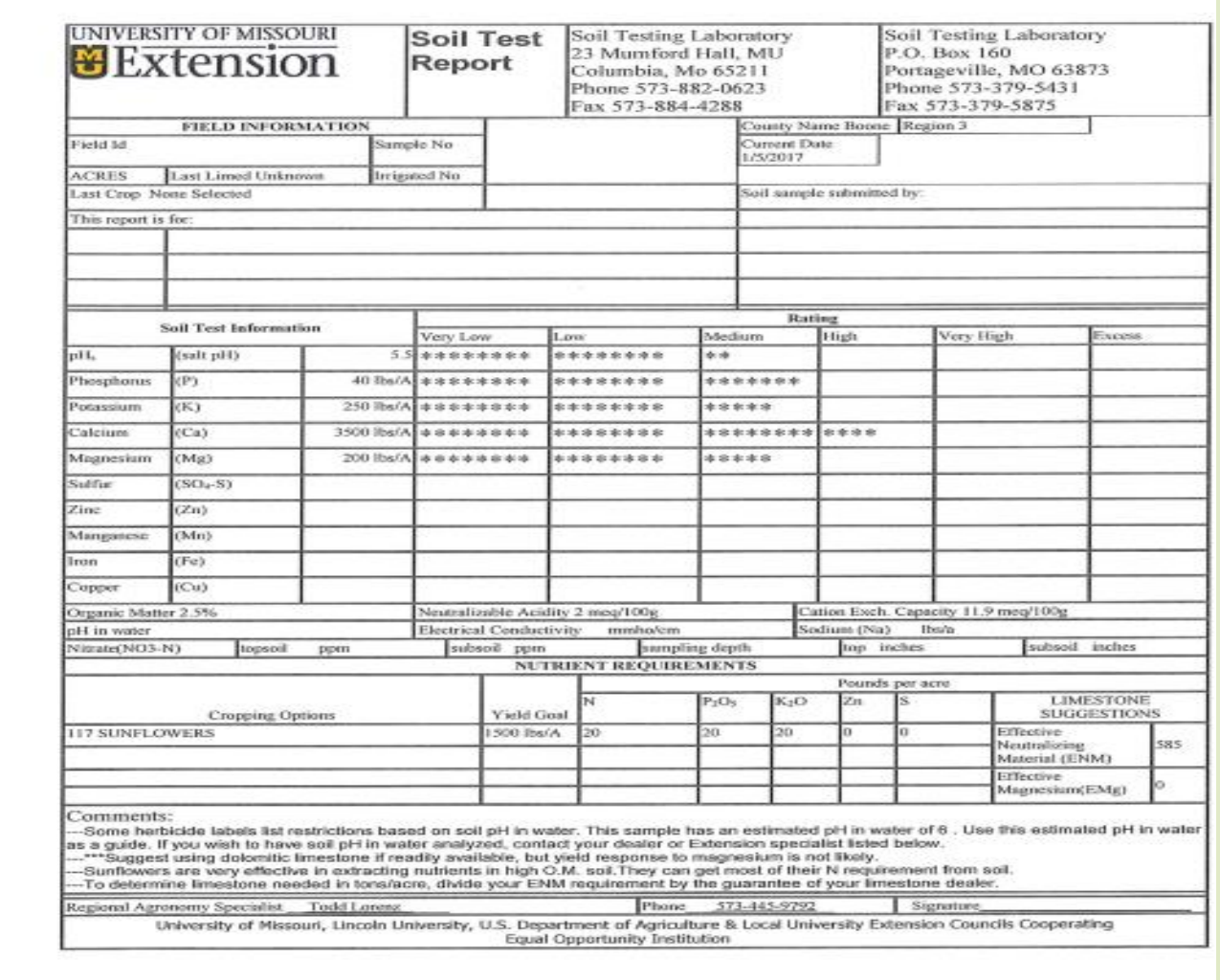


Soil Test Measure How Many Hydrogen Molecules are Attached to the Clay Particles



- Nuetralizable Acidity
- Buffer pH

Soil Test Reports Show You How Much Lime To Use



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FIELD INFORMATION

Field Id	Sample No	County Name Boone	Region 3
ACRES / Last Limed Unknown	Irrigated No	Current Date 1/5/2017	
Last Crop None Selected		Soil sample submitted by:	
This report is for:			

Soil Test Information			Rating						
			Very Low	Low	Medium	High	Very High	Excess
pH,	(salt pH)	5.5	********	********	**			
Phosphorus	(P)	40 lbs/A	********	********	*******			
Potassium	(K)	250 lbs/A	********	********	*****			
Calcium	(Ca)	3500 lbs/A	********	********	********	****		
Magnesium	(Mg)	200 lbs/A	********	********	*****			
Sulfur	(SO_4-S)							
Zinc	(Zn)							
Manganese	(Mn)							
Iron	(Fe)							
Copper	(Cu)							

Organic Matter 2.5%	Neutralizable Acidity 2 meq/100g	Cation Exch. Capacity 11.9 meq/100g	
pH in water	Electrical Conductivity mmho/cm	Sodium (Na) lbs/a	
Nitrate(NO3-N) topsoil ppm	subsoil ppm	sampling depth top inches	subsoil inches

NUTRIENT REQUIREMENTS

Cropping Options	Yield Goal	Pounds per acre N	P_2O_5	K_2O	Zn	S	LIMESTONE SUGGESTIONS	
117 SUNFLOWERS	1500 lbs/A	20	20	20	0	0	Effective Neutralizing Material (ENM)	585
							Effective Magnesium(EMg)	0

Comments:
---Some herbicide labels list restrictions based on soil pH in water. This sample has an estimated pH in water of 6 . Use this estimated pH in water as a guide. If you wish to have soil pH in water analyzed, contact your dealer or Extension specialist listed below.
---***Suggest using dolomitic limestone if readily available, but yield response to magnesium is not likely.
---Sunflowers are very effective in extracting nutrients in high O.M. soil.They can get most of their N requirement from soil.
---To determine limestone needed in tons/acre, divide your ENM requirement by the guarantee of your limestone dealer.

Regional Agronomy Specialist Todd Lorenz Phone 573-445-9792 Signature

What Is ENM-Effective Neutralizable Material? Effective Calcium Carbonate?

- Lime is $CaCO_3$
- But is it pure?
- What is the size of the particles?

Effective Calcium Carbonate Equivalent-Based Upon Fineness

How to Calculate Limestone ECCE (Iowa)

	% of Particles Passing Each Screen		Fineness Factor		Percent Available Based on Fineness
4-mesh	100	x	0.1	=	10
8-mesh	90	x	0.3	=	27
60-mesh	55	x	0.6	=	33
Total Fineness Efficiency					70

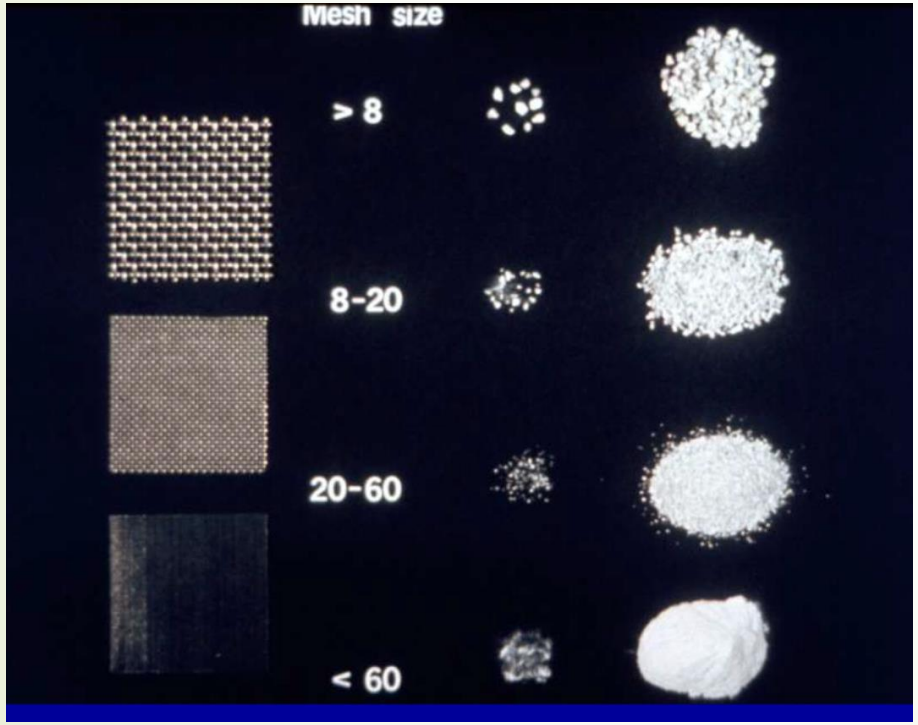
Effective Calcium Carbonate Equivalent (ECCE):

(Total Fineness Efficiency ÷ 100) x (% CCE ÷ 100)
x ([100 - % Moisture] ÷ 100) x 2000 = ECCE

Example:

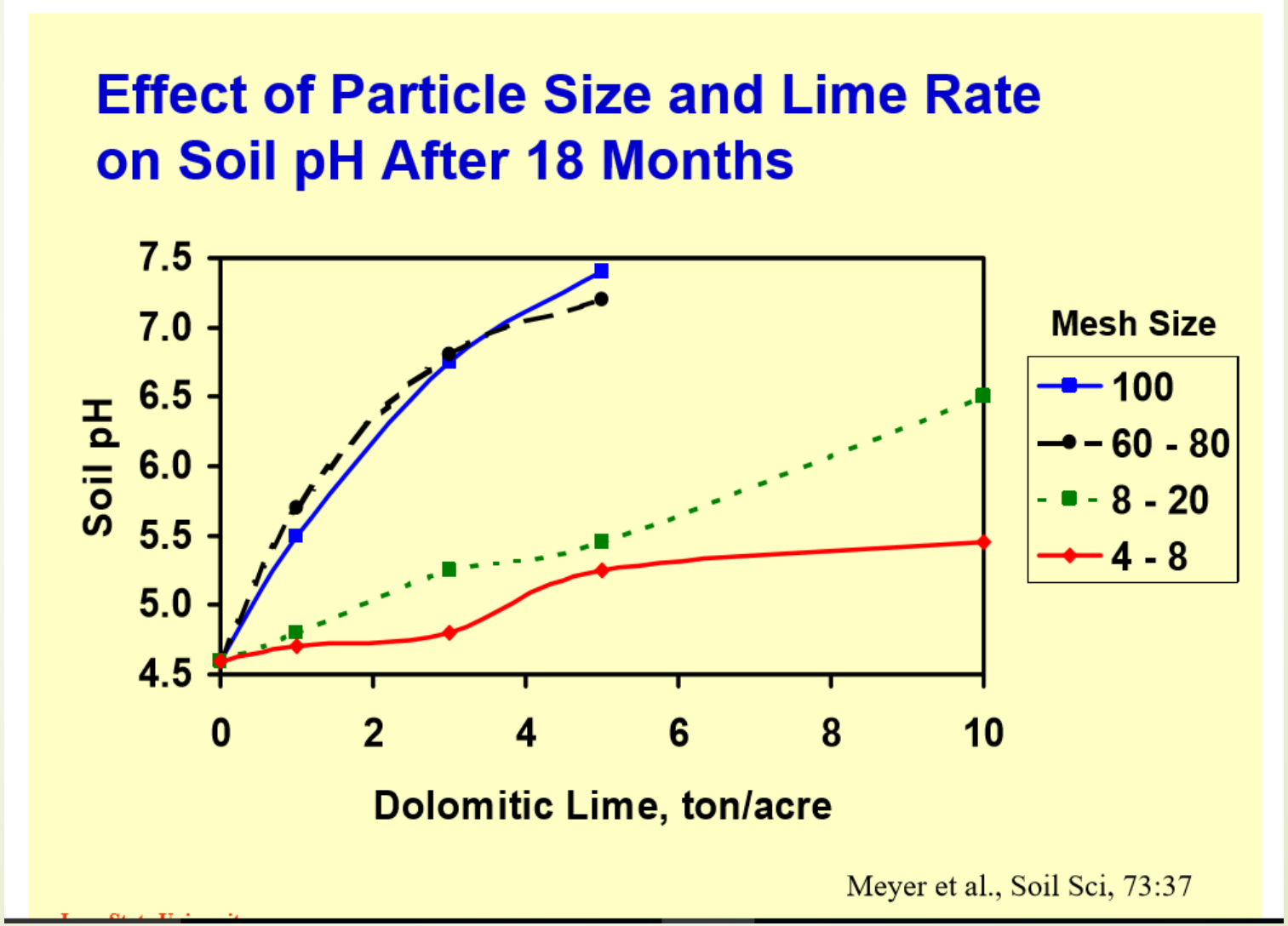
(70 ÷ 100) x (92 ÷ 100) x ([100 - 2] ÷ 100) x 2,000 = 1,260 ECCE

Fineness of Lime Scale-Pell Lime



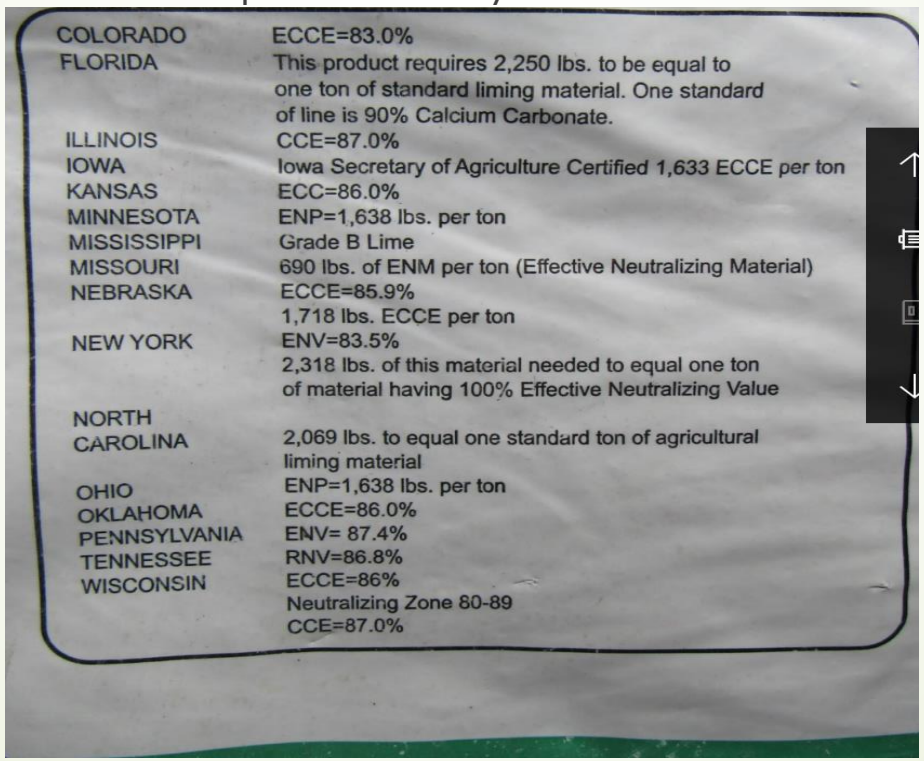
Sizing Before Pelietizing	
100% Passing	8 Mesh Sieve
100% Passing	10 Mesh Sieve
100% Passing	20 Mesh Sieve
100% Passing	40 Mesh Sieve
100% Passing	50 Mesh Sieve
98% Passing	60 Mesh Sieve
90% Passing	100 Mesh Sieve
70% Passing	200 Mesh Sieve

Particle Size Makes a Difference How Fast lime Reacts



Your State Will Have Different Measurement For Lime Quality

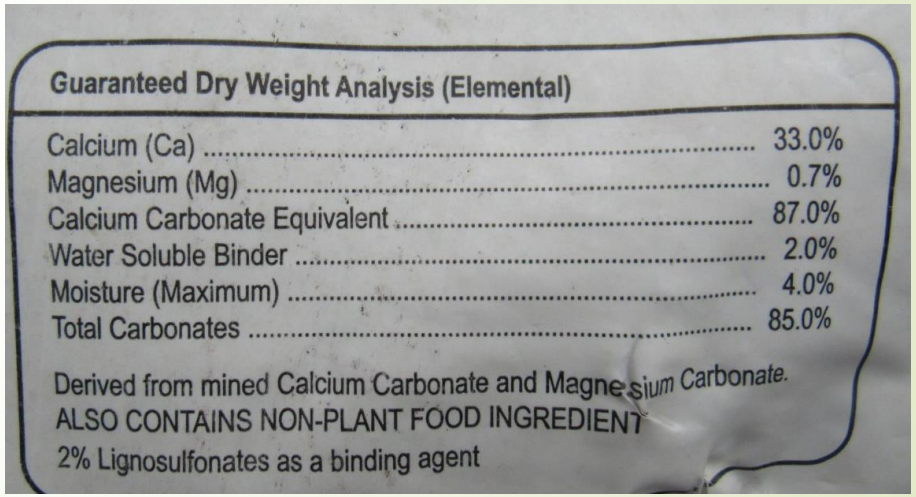
Essentially All Based Upon Quality of Lime and Fineness



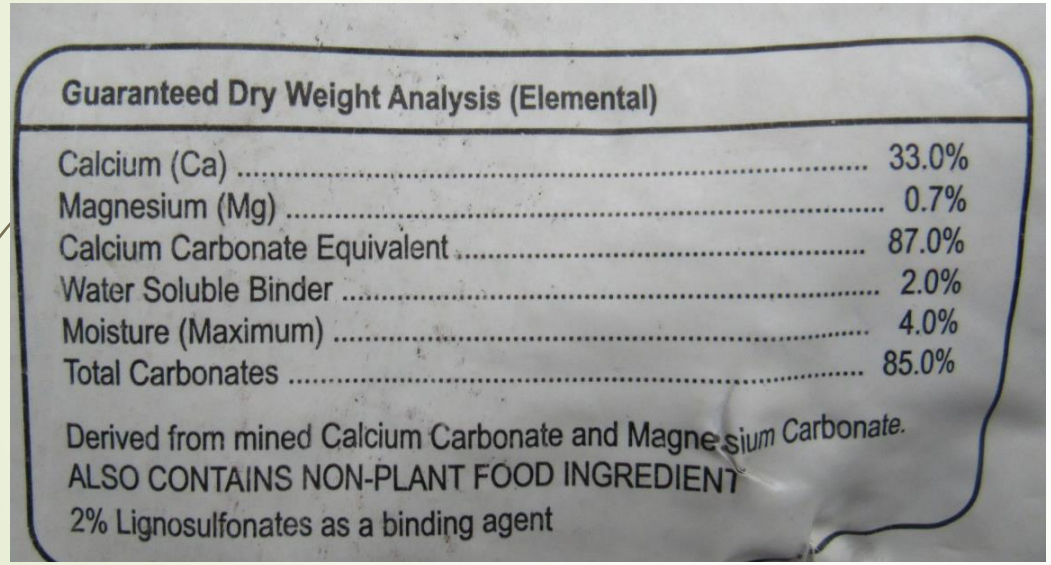
COLORADO	ECCE=83.0%
FLORIDA	This product requires 2,250 lbs. to be equal to one ton of standard liming material. One standard of line is 90% Calcium Carbonate.
ILLINOIS	CCE=87.0%
IOWA	Iowa Secretary of Agriculture Certified 1,633 ECCE per ton
KANSAS	ECC=86.0%
MINNESOTA	ENP=1,638 lbs. per ton
MISSISSIPPI	Grade B Lime
MISSOURI	690 lbs. of ENM per ton (Effective Neutralizing Material)
NEBRASKA	ECCE=85.9% 1,718 lbs. ECCE per ton
NEW YORK	ENV=83.5% 2,318 lbs. of this material needed to equal one ton of material having 100% Effective Neutralizing Value
NORTH CAROLINA	2,069 lbs. to equal one standard ton of agricultural liming material
OHIO	ENP=1,638 lbs. per ton
OKLAHOMA	ECCE=86.0%
PENNSYLVANIA	ENV= 87.4%
TENNESSEE	RNV=86.8%
WISCONSIN	ECCE=86% Neutralizing Zone 80-89 CCE=87.0%

Agriculture Lime vs Pell Lime

- Pell Lime-Dust with a sticker agent
  - Very Quick Change in pH, Available Calcium
    - May Have To Apply More Often
- Ag Lime
  - Can Take 18 months to get desired pH
  - Long Lasting Due to Various Sized Material



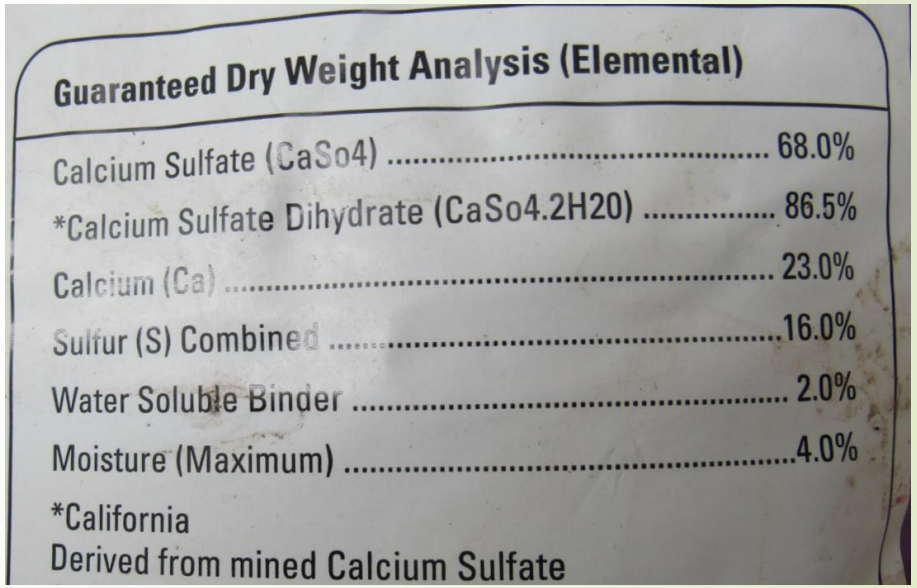
Lime Vs Gypsum or Calcium Sulfate



Guaranteed Dry Weight Analysis (Elemental)

Calcium (Ca)	33.0%
Magnesium (Mg)	0.7%
Calcium Carbonate Equivalent	87.0%
Water Soluble Binder	2.0%
Moisture (Maximum)	4.0%
Total Carbonates	85.0%

Derived from mined Calcium Carbonate and Magnesium Carbonate.
ALSO CONTAINS NON-PLANT FOOD INGREDIENT
2% Lignosulfonates as a binding agent



Guaranteed Dry Weight Analysis (Elemental)

Calcium Sulfate (CaSo4)	68.0%
*Calcium Sulfate Dihydrate (CaSo4.2H20)	86.5%
Calcium (Ca)	23.0%
Sulfur (S) Combined	16.0%
Water Soluble Binder	2.0%
Moisture (Maximum)	4.0%

*California
Derived from mined Calcium Sulfate

Rules of Thumb For Gardens

- pH

Table 3. Limestone recommendations for crops with different pH_s preferences.

Category	Apply lime when	Limestone recommendation
Alkaline loving	$pH_s < 6.5$	Lime (lb/1000 sq ft) = neutralizable acidity × 25
Slightly acid loving	$pH_s < 6.0$	Lime (lb/1000 sq ft) = neutralizable acidity × 25
Medium acid loving	$pH_s < 5.0$	Lime (lb/1000 sq ft) = 50
Strong acid loving	$pH_s < 4.0$	Lime (lb/1000 sq ft) = 50

Lowering the pH?
Sulfur

At a CEC ≤ 10:	Sulfur (lb/1000 sq ft) = (pH_sTest - pH_sTarget) × 5 + 0.5
At a CEC 10 - 18:	Sulfur (lb/1000 sq ft) = (pH_sTest - pH_sTarget) × 10 + 0.5
At a CEC > 18:	Sulfur (lb/1000 sq ft) = (pH_sTest - pH_sTarget) × 18 + 0.5

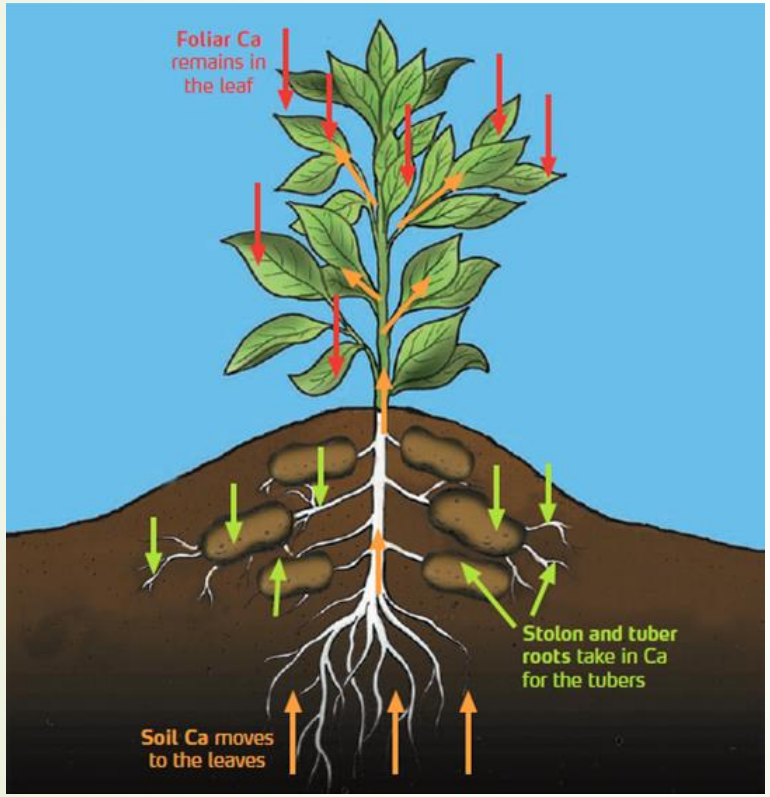
pH-8.5-7.0=1.5 x 10+0.5=15.5 lb S/1000 ft2

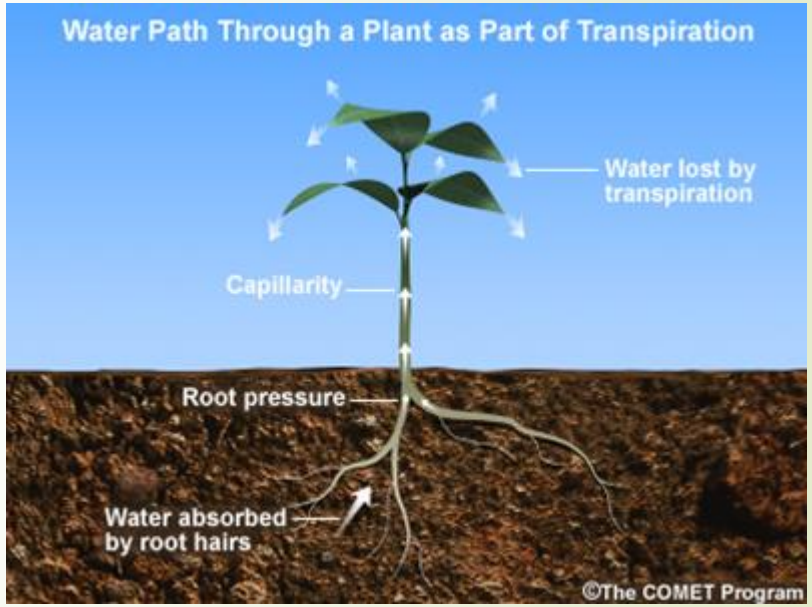
Calcium and pH

- Can You Have a Calcium Deficiency and High pH?

Calcium Deficiency

How Does Calcium Move in the Plant? Through the Water Stream-One Direction





Symptoms Are on New Growth Areas

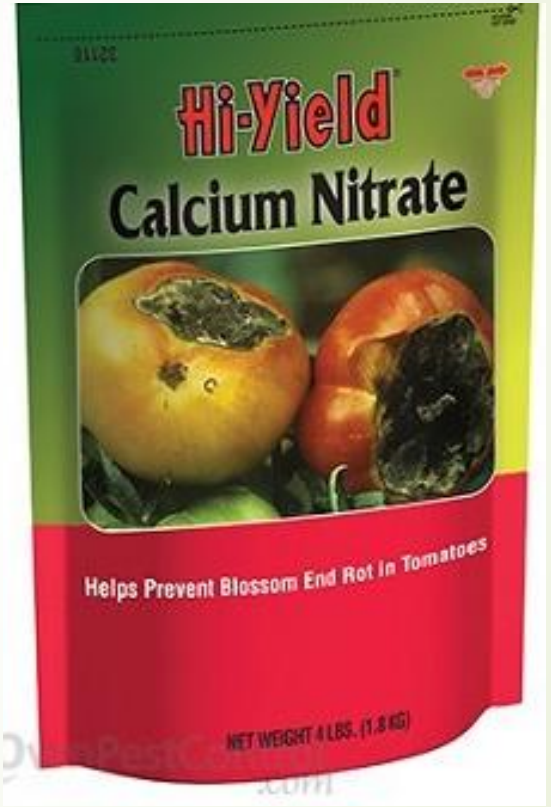
Also Black Heart In Potato

What is This?

The Cure?

- Calcium Nitrate

  along the row during fruit set



Let's Look At Some Soil Tests and Principles

UNIVERSITY OF MISSOURI Extension

Soil Test Report

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23 Mumford Hall, MU
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Phone 573-882-0623
Fax 573-884-4288

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone 573-379-5431
Fax 573-379-5875

FIELD INFORMATION

Field Id		Sample No	County Name Boone	Region 3
			Current Date 1/5/2017	
ACRES	Last Limed Unknown	Irrigated No		
Last Crop None Selected			Soil sample submitted by:	
This report is for:				

Soil Test Information			Rating					
			Very Low	Low	Medium	High	Very High	Excess
pH_s	(salt pH)	5.5	********	********	**			
Phosphorus	(P)	40 lbs/A	********	********	*******			
Potassium	(K)	250 lbs/A	********	********	*****			
Calcium	(Ca)	3500 lbs/A	********	********	********	****		
Magnesium	(Mg)	200 lbs/A	********	********	*****			
Sulfur	(SO_4-S)							
Zinc	(Zn)							
Manganese	(Mn)							
Iron	(Fe)							
Copper	(Cu)							

Organic Matter 2.5%	Neutralizable Acidity 2 meq/100g	Cation Exch. Capacity 11.9 meq/100g	
pH in water	Electrical Conductivity mmho/cm	Sodium (Na) lbs/a	
Nitrate(NO3-N)	topsoil ppm	subsoil ppm	sampling depth top inches subsoil inches

NUTRIENT REQUIREMENTS

Cropping Options	Yield Goal	Pounds per acre N	P_2O_5	K_2O	Zn	S	LIMESTONE SUGGESTIONS	
117 SUNFLOWERS	1500 lbs/A	20	20	20	0	0	Effective Neutralizing Material (ENM)	585
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Calcium	(Ca)	1500 lbs/A	********	********	********	****		
Magnesium	(Mg)	200 lbs/A	********	********	********	***		
Sulfur	(SO_4-S)							
Zinc	(Zn)							
Manganese	(Mn)							
Iron	(Fe)							
Copper	(Cu)							

Organic Matter 2.5%	Neutralizable Acidity 2 meq/100g	Cation Exch. Capacity 6.9 meq/100g	
pH in water	Electrical Conductivity mmho/cm	Sodium (Na) lbs/a	
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Fax 573-379-5875

FIELD INFORMATION					
Field Id		Sample No		County Name Boone	Region 3
ACRES	Last Limed Unknown	Irrigated No		Current Date 1/5/2017	
Last Crop None Selected				Soil sample submitted by:	
This report is for:					

Soil Test Information			Rating					
			Very Low	Low	Medium	High	Very High	Excess
pH_s	(salt pH)	5.5	********	********	**			
Phosphorus	(P)	40 lbs/A	********	********	*******			
Potassium	(K)	250 lbs/A	********	********	*****			
Calcium	(Ca)	3500 lbs/A	********	********	********	****		
Magnesium	(Mg)	200 lbs/A	********	********	***			
Sulfur	(SO_4-S)							
Zinc	(Zn)							
Manganese	(Mn)							
Iron	(Fe)							
Copper	(Cu)							

Organic Matter 2.5%	Neutralizable Acidity 4 meq/100g	Cation Exch. Capacity 13.9 meq/100g
pH in water	Electrical Conductivity mmho/cm	Sodium (Na) lbs/a

Nitrate(NO3-N)	topsoil ppm	subsoil ppm	sampling depth	top inches	subsoil inches

NUTRIENT REQUIREMENTS

Cropping Options	Yield Goal	Pounds per acre N	P_2O_5	K_2O	Zn	S	LIMESTONE SUGGESTIONS	
117 SUNFLOWERS	1500 lbs/A	20	20	20	0	0	Effective Neutralizing Material (ENM)	1175
							Effective Magnesium(EMg)	0

Comments:
---Some herbicide labels list restrictions based on soil pH in water. This sample has an estimated pH in water of 6 . Use this estimated pH in water as a guide. If you wish to have soil pH in water analyzed, contact your dealer or Extension specialist listed below.
---***Suggest using dolomitic limestone if readily available, but yield response to magnesium is not likely.
---Sunflowers are very effective in extracting nutrients in high O.M. soil.They can get most of their N requirement from soil.
---To determine limestone needed in tons/acre, divide your ENM requirement by the guarantee of your limestone dealer.

Regional Agronomy Specialist Todd Lorenz Phone 573-445-9792 Signature

UNIVERSITY OF MISSOURI Extension

Soil Test Report

Soil Testing Laboratory
23 Mumford Hall, MU
Columbia, Mo 65211
Phone 573-882-0623
Fax 573-884-4288

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone 573-379-5431
Fax 573-379-5875

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Manganese	(Mn)							
Iron	(Fe)							
Copper	(Cu)							

Organic Matter 2.5%	Neutralizable Acidity 4 meq/100g	Cation Exch. Capacity 8.9 meq/100g
pH in water	Electrical Conductivity mmho/cm	Sodium (Na) lbs/a

Nitrate(NO3-N)	topsoil ppm	subsoil ppm	sampling depth	top inches	subsoil inches

NUTRIENT REQUIREMENTS

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What Does Calcium Do In the Soil?

Calcium Influence on Soil Structure

Soil Structure

- The grouping or arrangement of individual soil properties into a larger grouping.

(Also called aggregate, ped)

Formation of Soil Structure

- Flocculation: Bringing the particles close together, enhanced by polyvalent cations (Al+++, Ca++, etc.). Mg is not as good as Ca in flocculation.

- Stabilization: Providing durability to maintain the arrangement. Some clay; organic matter; oxides of Fe and Al.

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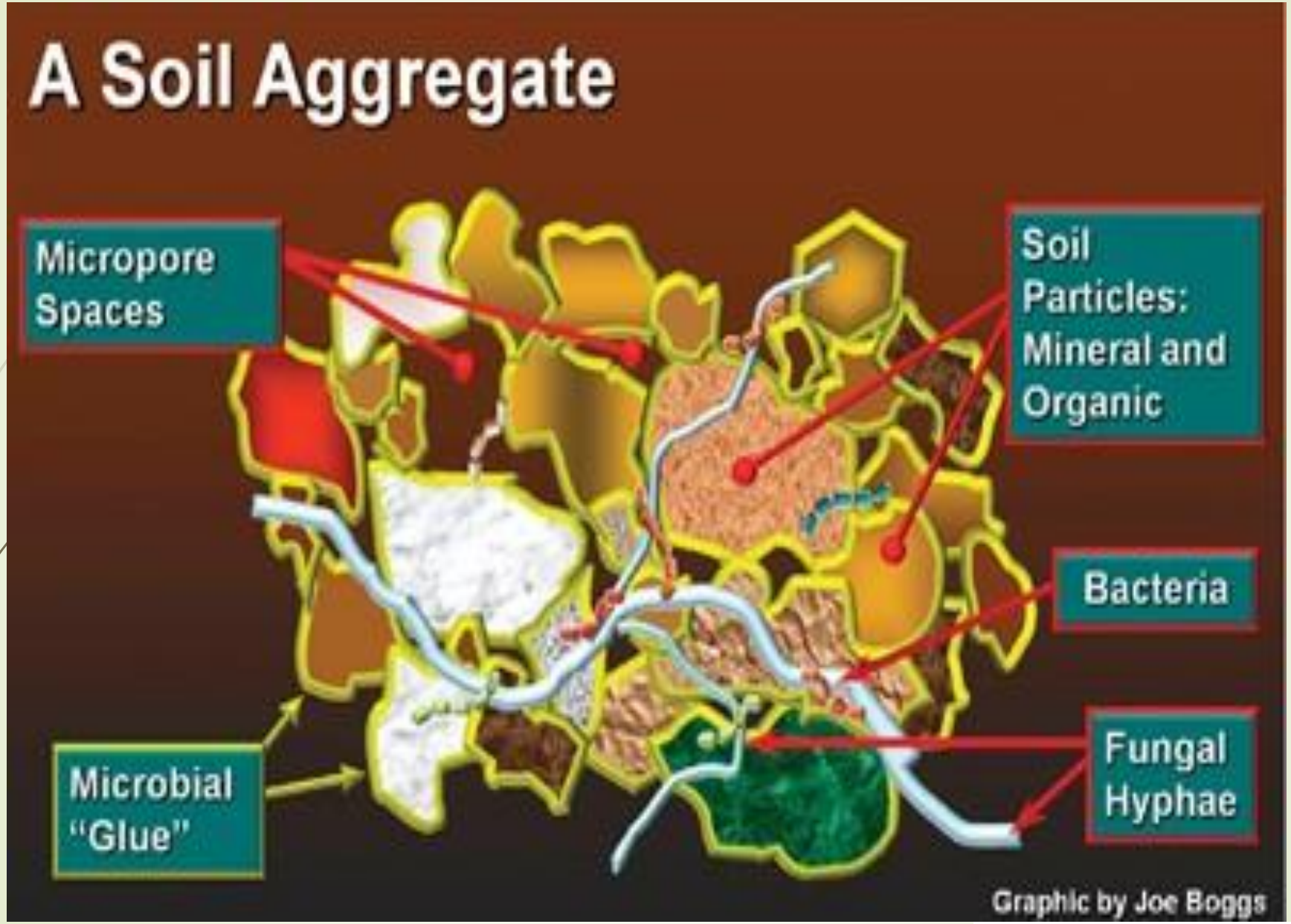
A Soil Aggregate
Micropore Spaces
Soil Particles: Mineral and Organic
Bacteria
Fungal Hyphae
Microbial "Glue"
Graphic by Joe Boggs

Aggregate Stability: Interaction of Soil Microbes, Clay, Ca, and Humus

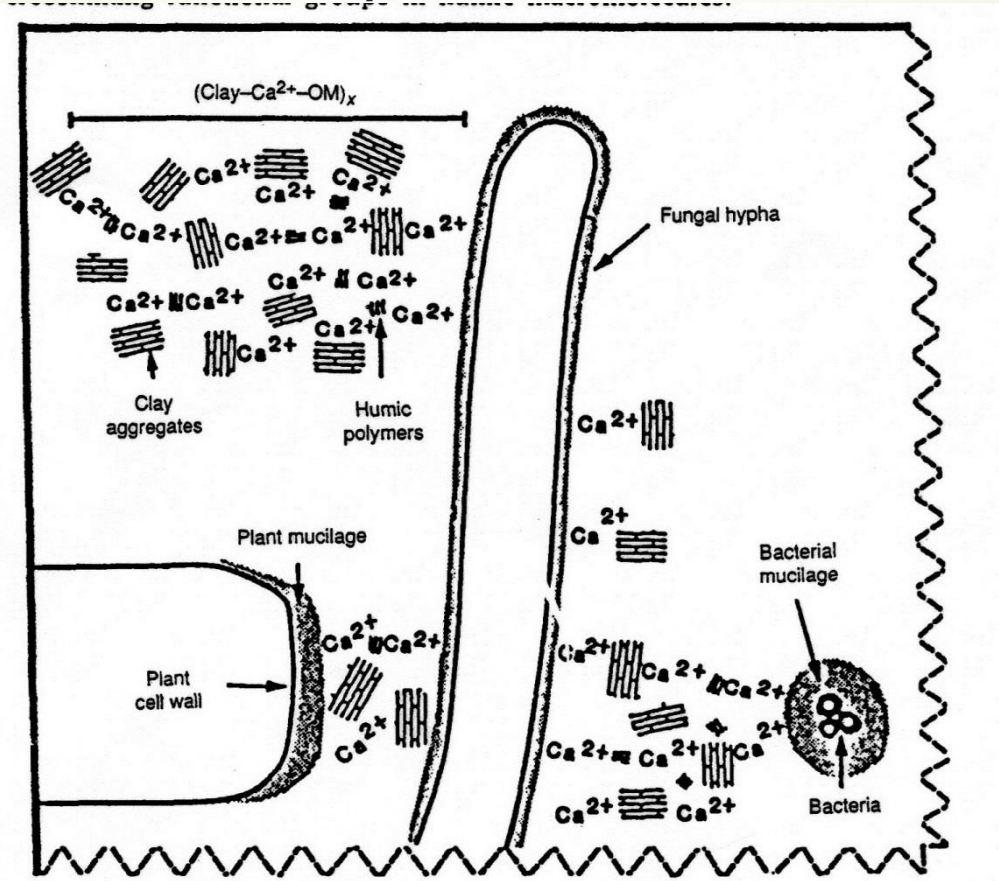

Fig. 8. Model of aggregation in soils showing a portion of an aggregate greater than 250 μm.

From Muneer and Oades, 1989

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Aggregate Stability:Interaction with Ca, Humus, Clay

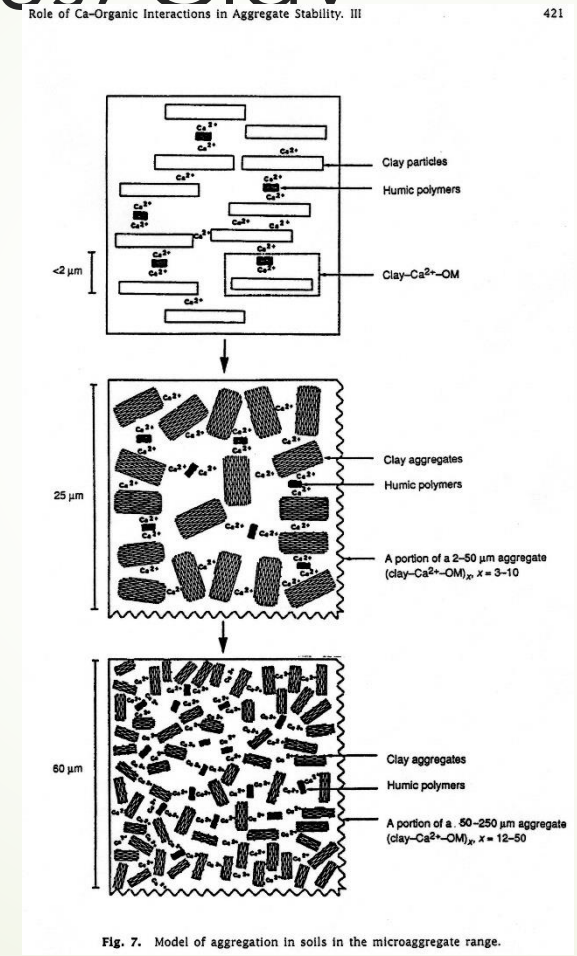

Fig. 7. Model of aggregation in soils in the microaggregate range.

From Muneer and Oades, 1989

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Aggregate Stability-How Quick Can it Change?

Water Aggregate Stability After Two Years

Rotation	Water Aggregate Stability (g/g)
Corn/Soybean	38 b
Corn/rye/Soybean/rye	41 a
Corn/rye/Soybean/hairy vetch	43 a
Corn/rye/Soybean/HV+rye	44 a

Letters indicate significant difference at the 0.10 probability level

From Villamil, et al., 2006

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Change In Aggregate Stability After 3 Years of Calcium Treatments

Treatment	percent
N only	31.0 b
NPKS and Calcium	33.3 a
NPKS only	30.4 b
NPKS, no Calcium, Mg instead	25.1 c
No P, K and Ca- Micros Only	30.5 b
NPK only	28.7 bc

- Different Letters Indicate Significance at the 0.05 probability Level

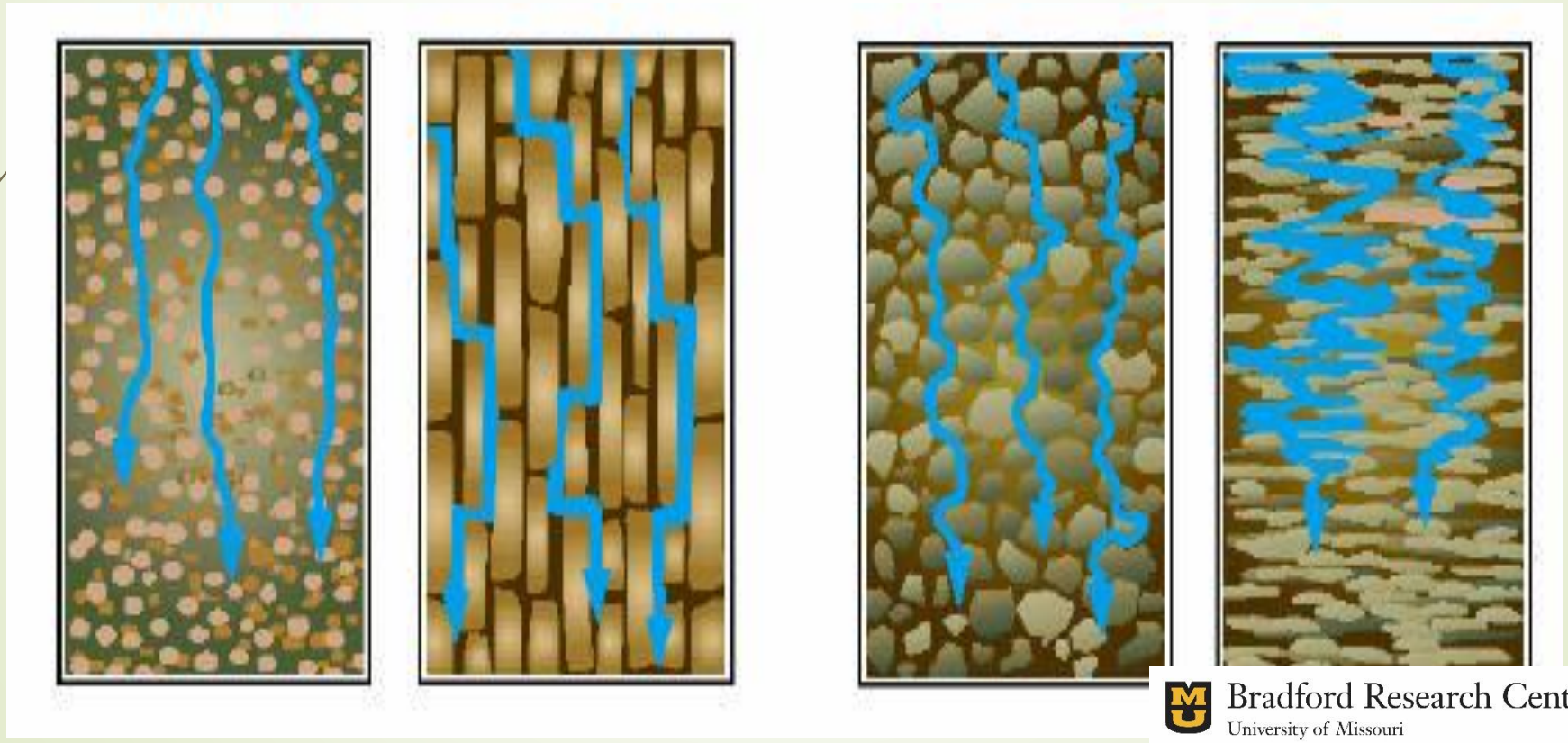
Influence of Structure on Water Movement

Granular
Flocculated by Ca
Enhanced by OM

Prismatic

Blocky

Platey
Restricted
Movement



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Water Infiltration

Good infiltration allows for less runoff and erosion

Soils with poor aggregate stability will crust, damaging emerging seedlings and increasing runoff

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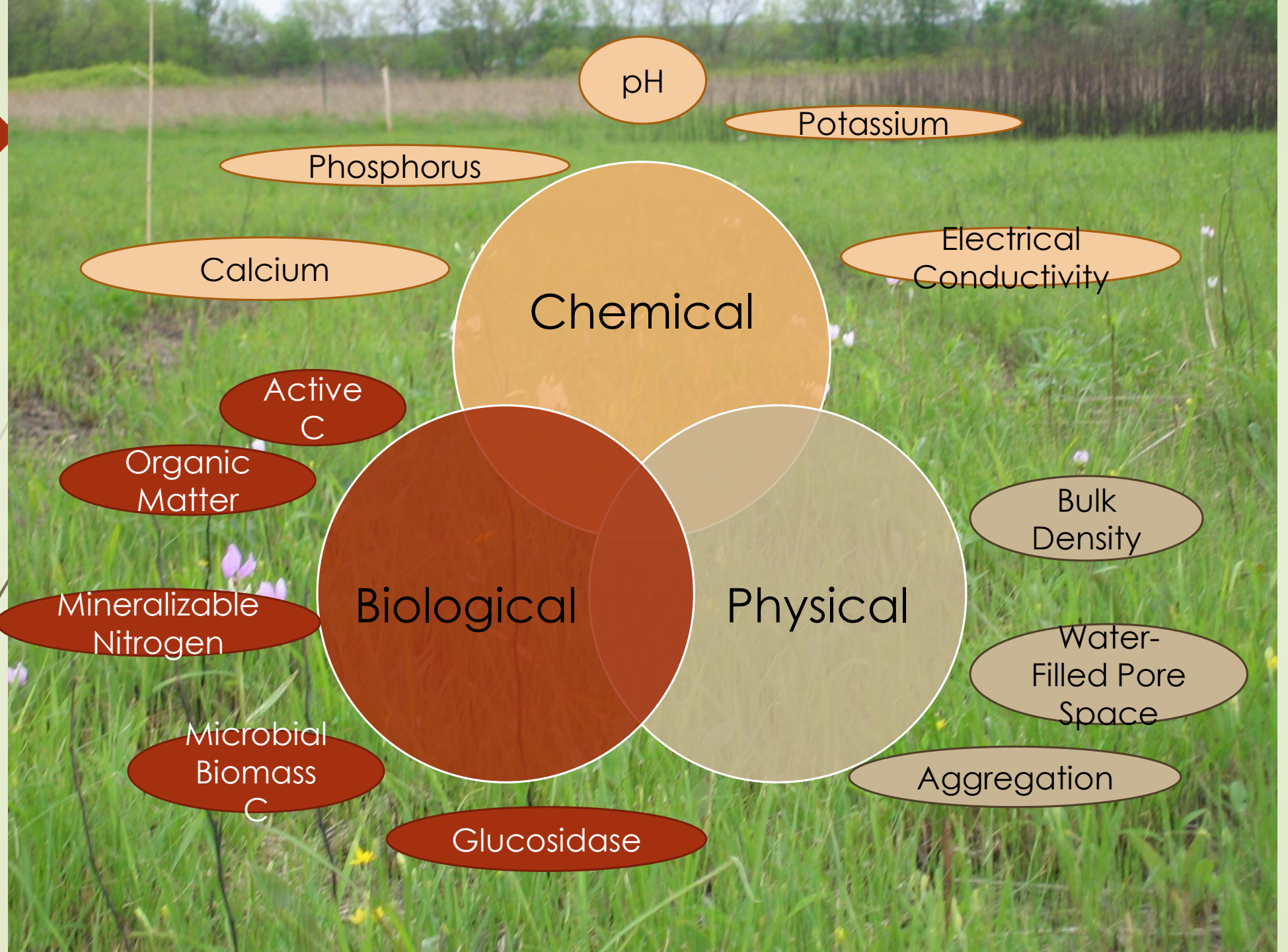
Adding Calcium Also Increased the Biological Activity

Treatment	Mycorr.	Fungi
Control	3832	2504
Calcium	4219*	3135*


pH
Potassium
Phosphorus
Calcium
Electrical Conductivity
Chemical
Active C
Organic Matter
Bulk Density
Biological
Physical
Mineralizable Nitrogen
Water-Filled Pore Space
Microbial Biomass C
Aggregation
Glucosidase

The Slake Test Video

Questions?