### 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:

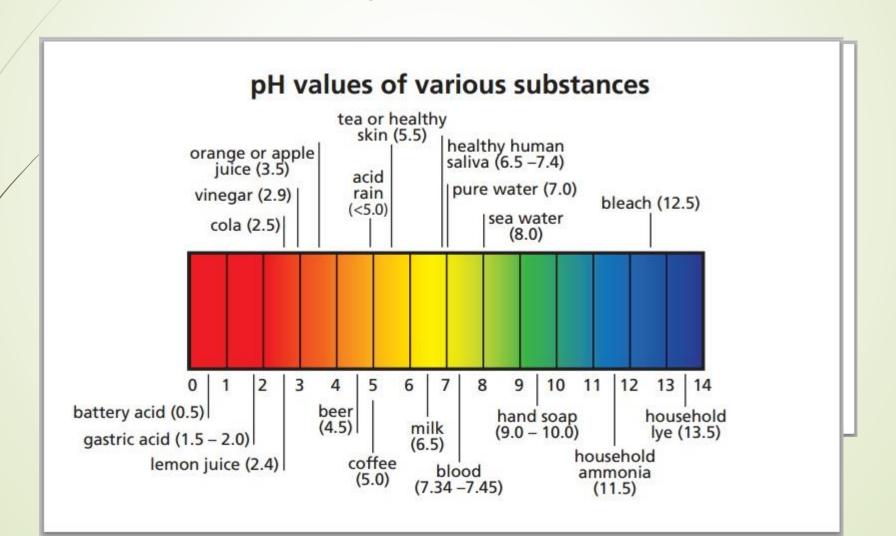
$$pH = log \frac{1}{|H^+|} = -log[H^+]$$

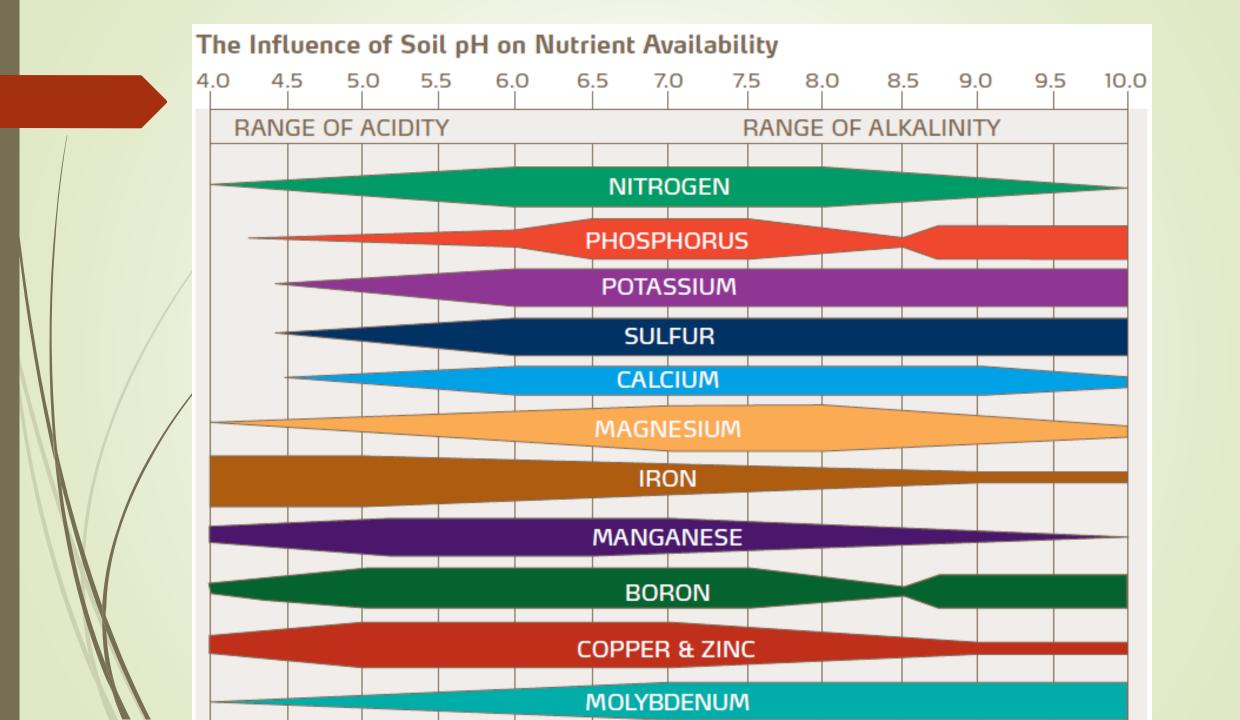
Thus, pure water, which has a concentration of H<sup>+</sup> = 10<sup>-7</sup> M (M = molarity, moles/liter) has a pH of 7.0, which is a neutral (neither acidic nor alkaline) pH.

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

Hydrogen Ion Concentration	pH	Interpretation
moles/liter		
.0000001	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?





### Some Plants Like Low pH

Those that developed in forests and highly weathered soils

#### Blueberries-Do Best in Acid Soil



- Mµλ
- 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 <sup>1</sup>	Aluminum Sulfate lb/100 sq ft¹
Light, Sandy	0.75	4.5
Medium, Sandy Loam	1.50	9.0
Heavy, Clay Loam	2.25	13.5

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.

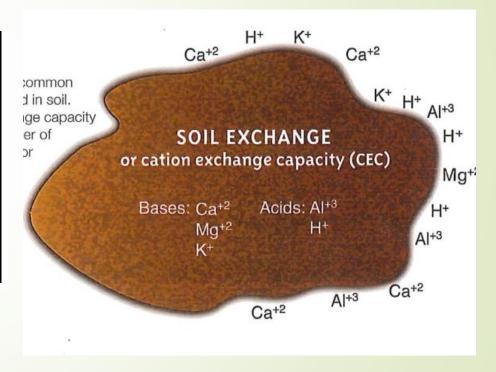
### Hydrangea-Pink vs Blue





### 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

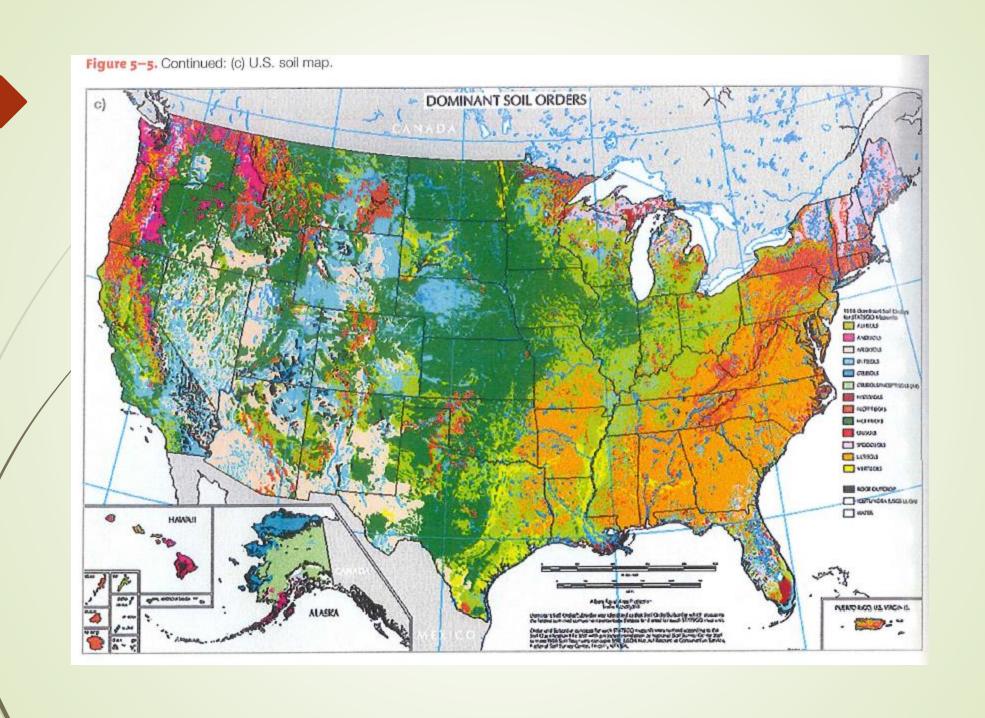




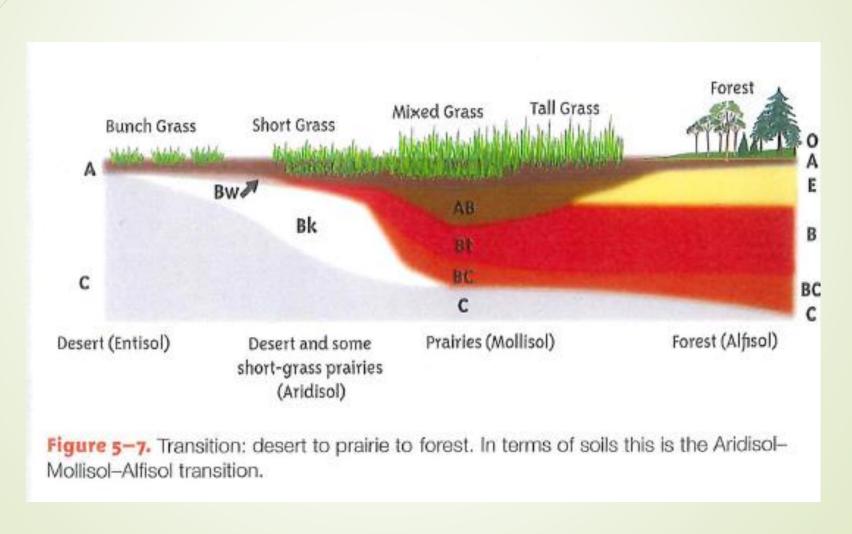
### What Is This And Why?



# How Do We Correct The pH? Raising pH With Lime



### Example of Soils-Mollisols and AlfisolspH increases as you move left



### 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

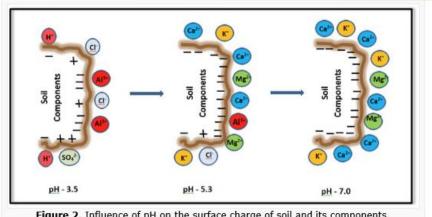
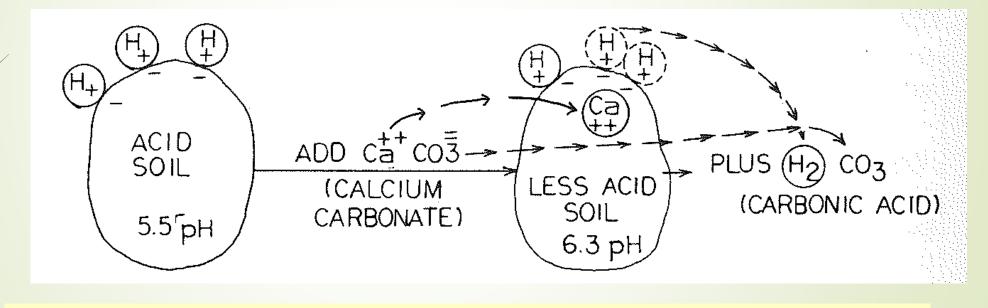


Figure 2. Influence of pH on the surface charge of soil and its components.

Lime Is Calcium Carbonate-CaCO<sub>3</sub> –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

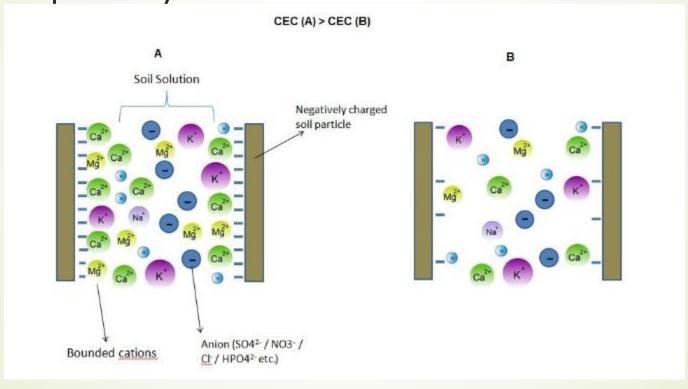


$$CaCO_3 + 2H^+ = Ca^{+2} + CO_2 \uparrow + H_2O$$

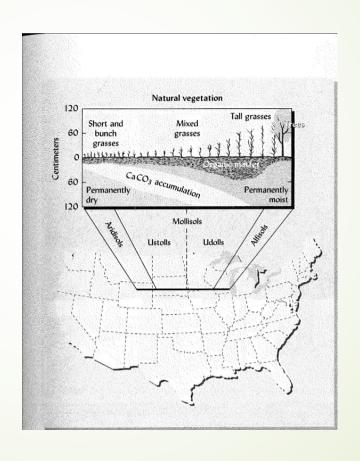
How Much Lime To We Need To Add?

Depends Upon The Cation Exchange

Capacity



### Alfisols Formed Under Forest, Mollisols Under Prairie



#### Alfisols and Mollisols

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 <sub>c</sub> /kg pH
Ultisols	3.5
Alfisols	9.0 6.00
Spodosols	9.3 4.93
Aridisols	15.2 7.26
Mollisols	18.7
Vertisols	35.6 6.72
Histosols	128.0 5.50

From Holmgren et al. (1002)



Soft, dark, semiarid to moist, grass-

lands

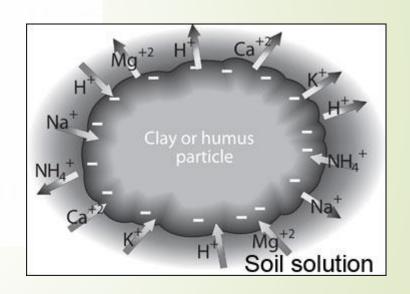
### pH is Then Like Air Pressure in Your Tire-It Doesn't Tell You How Much Hydrogen Is In the Soil



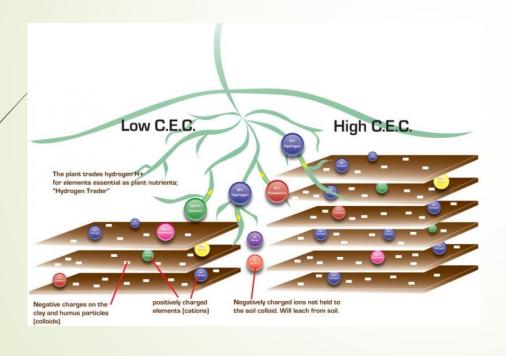


# Greater Clay Content=Higher Cation Exchange Capacity (CEC)

Soil texture	CEC (meq/100g soi)
Sands (light-colored)	3.5
Sands (dark-colored)	10-20
Loams	10-15
Silt Ioams	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

UNIVERS EX				Soil Repo		Soil Testing 23 Mumfore Columbia, I Phone 573- Fax 573-88-	d Hall, Mo 652 882-06 4-4288	MU 11 23		P.O. Porta Phon Fax 5	Box 10 geville e 573- i73-37	g Laborato 60 e, MO 638 379-5431 9-5875		
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Саррег	(Cu)						1		1					
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		_		-	NUTR	ENT REQUIR	EMENT	S	Bourse	fs per ac	-			
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117 SUNFLO		10			1500 lbs/A	20	20	20	0	0		Effective Neutralizing		585
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What Is ENM-Effective Neutralizable Material? Effective Calcium Carbonate?

- Lime is CaCO<sub>3</sub>
- But is it pure?
- What is the size of the particles?

# Effective Calcium Carbonate Equivalent-Based Upon Fineness

### How to Calculate Limestone ECCE (lowa)

	% 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 Fir	ieness Efficiency				70

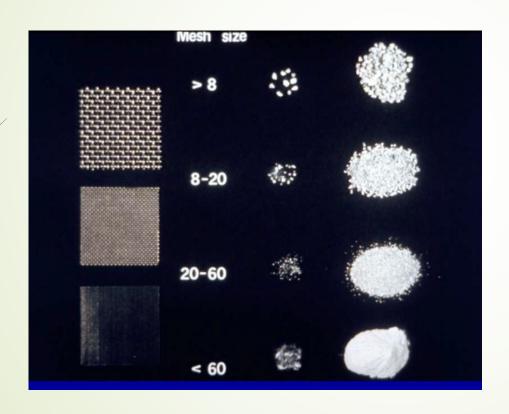
#### **Effective Calcium Carbonate Equivalent (ECCE):**

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

#### **Example:**

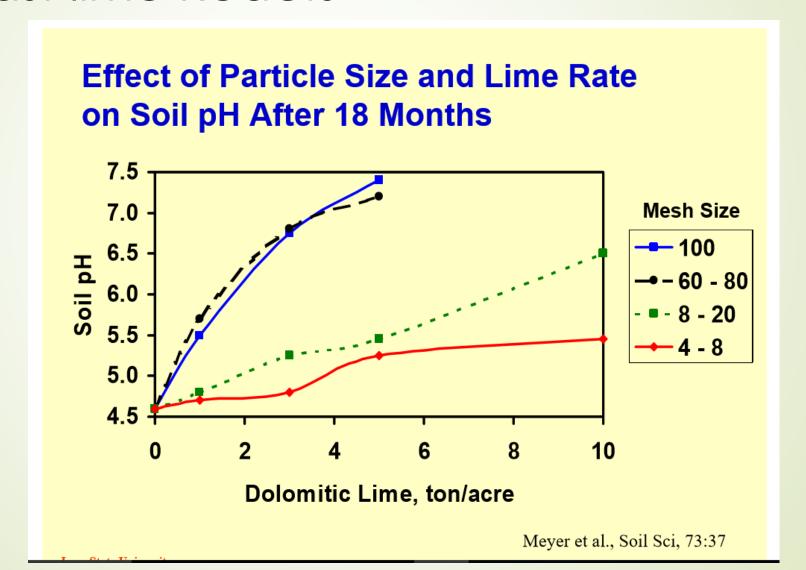
 $(70 \div 100) \times (92 \div 100) \times ([100 - 2] \div 100) \times 2,000 = 1,260 \text{ ECCE}$ 

#### 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	
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	lowa 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	2.060 lbs. to assist one standard top of agricultural
CAROLINA	2,069 lbs. to equal one standard ton of agricultural liming material
01110	ENP=1,638 lbs. per ton
OHIO OKLAHOMA	ECCE=86.0%
PENNSYLVANIA	ENV= 87.4%
TENNESSEE	RNV=86.8%
WISCONSIN	ECCE=86%
	Neutralizing Zone 80-89
	CCE=87.0%
	AND THE RESERVE TO THE PARTY OF

#### 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

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%

### Lime Vs Gypsum or Calcium Sulfate

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%

<b>Guaranteed Dry Weight Analysis (Element</b>	al)
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<sub>s</sub> preferences.

Category	Apply lime when	Limestone recommendation
Alkaline loving	$pH_{s} < 6.5$	Lime (lb/1000 sq ft) = neutralizable acidity $\times$ 25
Slightly acid loving	$pH_{s} < 6.0$	Lime (lb/1000 sq ft) = neutralizable acidity $\times$ 25
Medium acid loving	$pH_{s} < 5.0$	Lime ( $lb/1000 \text{ sq ft}$ ) = 50
Strong acid loving	$pH_{s} < 4.0$	Lime ( $lb/1000 \text{ sq ft}$ ) = 50

# Lowering the pH? Sulfur

At a CEC  $\leq$  10: Sulfur (lb/1000 sq ft) = (pH<sub>s</sub>Test - pH<sub>s</sub>Target)  $\times$  5 + 0.5

At a CEC 10 - 18: Sulfur (lb/1000 sq ft) =  $(pH_sTest - pH_sTarget) \times 10 + 0.5$ 

At a CEC > 18: Sulfur (lb/1000 sq ft) =  $(pH_sTest - pH_sTarget) \times 18 + 0.5$ 

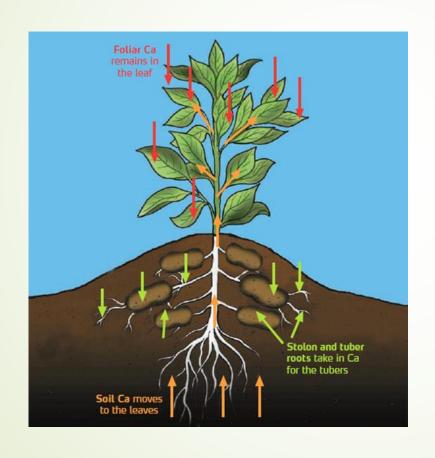
pH-8.5-7.0=1.5 x 10+0.5=15.5 lb S/1000 ft2

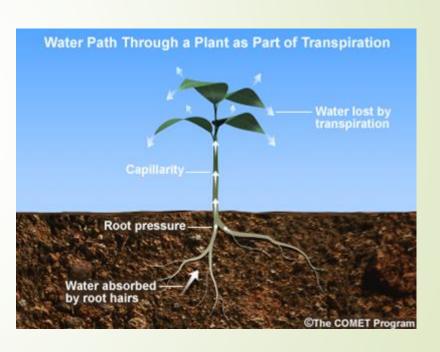
## Calcium and pH

■ 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





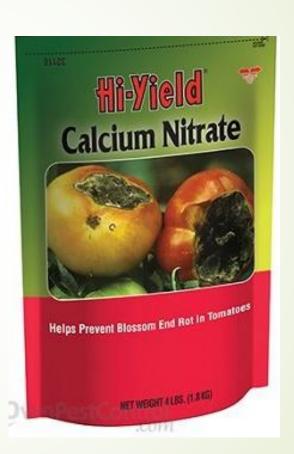
### What is This?





### The Cure?

Calcium Nitratealong the row during fruit set



# Let's Look At Some Soil Tests and Principles

			Report Soil Testing Labo 23 Mumford Hall. Columbia, Mo 65. Phone 573-882-06 Fax 573-884-4288				Hall, o 652 32-06:	1, MU P.O. 5211 Porta 623 Phor				oil Testing Laboratory CO. Box 160 ortageville, MO 63873 hone 573-379-5431 ax 573-379-5875				
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Calcium	(Ca)	3500 lbs/A	****	***	*******		******		*	****						
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O . !! T . . 4 | Sail Testing Laboratory

Soil Testing Laboratory

Effective

Neutralizing Material (ENM) Effective Magnesium(EMg)

117 SUNFLOWERS

LIMIVEDSITY OF MISSOURI

- ---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.
  ---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.

1500 lbs/A

	Extension   Soil Test			Soil Testing 23 Mumfor Columbia, Phone 573- Fax 573-88		Soil Testing Laboratory P.O. Box 160 Portageville, MO 63873 Phone 573-379-5431 Fax 573-379-5875							
	FIELD INFOR	RMATION					County Na	me Boon	e Reg	ion 3			
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This report is	for:												
		40					Rat	ing					
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Phosphorus	(P)	40 Ibs/A	****	***	*****	***	****						
Potassium	(K)	250 lbs/A	****	***	*****	***	***						
Calcium	(Ca)	3500 lbs/A	*****		******	***	*****	****					
Magnesium	(Mg)	200 lbs/A	*****		*****	***	k						
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Manganese	(Mn)												
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							_	L	Rati						
	Soil Test Informati	ion	Very Lo	w I	Low		Med	lium	Rati	ng High		Very I	ligh	Excess	
pHs	(salt pH)	5.5	_			****	**		_	i ii bii	_	V ci j I	iigii	Linevas	
Phosphorus	(P)	40 lbs/A	****	***	***	****	**	***	***			$\vdash$		$\vdash$	
Potassium	(K)	250 lbs/A	****	****	***	****	* ***		***					$\vdash$	
Calcium	(Ca)	1500 lbs/A	****	****	***	******		*****		****				$\vdash$	
Magnesium	(Mg)	200 lbs/A	****	****	******		******								
Sulfur	(SO <sub>4</sub> -S)														
Zinc	(Zn)														
Manganese	(Mn)														
Iron	(Fe)						Т								
Copper	(Cu)						Г			7 2 2 2 2 2					
Organic Matt	er 2.5%		Neutralia	zable Acidi	ity 4 r	neq/100g	_		Ca	tion Exch	. Capa	city 8.9	meq/100g		
pH in water			Electrica	l Conducti	vity	mmho/cm			So	dium (Na	) 1	bs/a			
Nitrate(NO3-	N) topsoil	ppm	subs			sampli	_	_		top i	nches		subsoil	inches	
				NUT	RIEN	T REQUIRE	MEN	TS		Pounds	nore	oro			
	0			VI-II O	N	1	P <sub>2</sub> O <sub>5</sub>		K <sub>2</sub> O	Zn	S	CIE		ESTONE	
117 SUNFLO	Cropping Opt	tions		Yield Go 1500 lbs//	_	0	20		20	0	0		Effective Neutralizing	GESTION	1175
					+		$\vdash$		_	+	+		Material (El		-
					$\pm$						$\perp$		Magnesium	(EMg)	0
as a guide. I	: picide labels list re f you wish to have t using dolomitic li	soil pH in wat	er analyz	zed, conta	ct yo	ur dealer or	Exten	sion	specia	list listed	ater o	f6.Us w.	e this estima	ited pH i	n wate

What Does Calcium Do In the Soil?

### Calcium Influence on Soil Structure

### Soil Structure

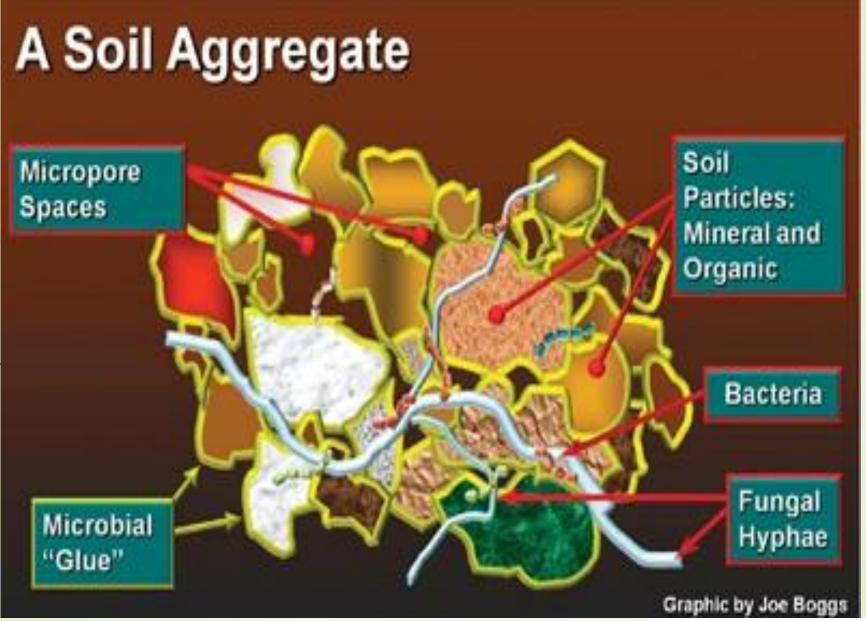
The grouping or arrangement of individual soil properties into a larger grouping.

(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.







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

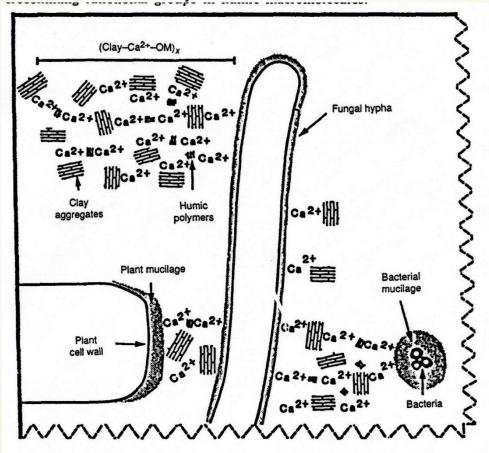
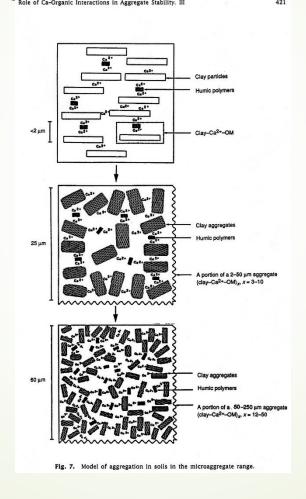


Fig. 8. Model of aggregation in soils showing a portion of an aggregate greater than 250  $\mu$ m.



# Aggregate Stability:Interaction with Ca, Humus Clav





# 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



# Change In Aggregate Stability After 3 Years of Calcium Treatments

<u>Treatment</u>	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

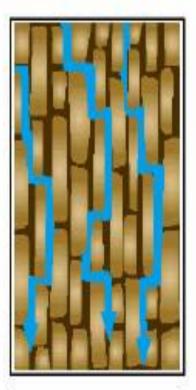
Granular
Flocculated by Ca
Enhanced by OM

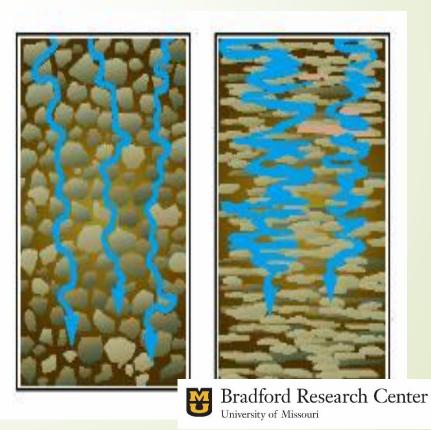
Prismatic

**Blocky** 

Platey Restricted Movement









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

### **Water Infiltration**

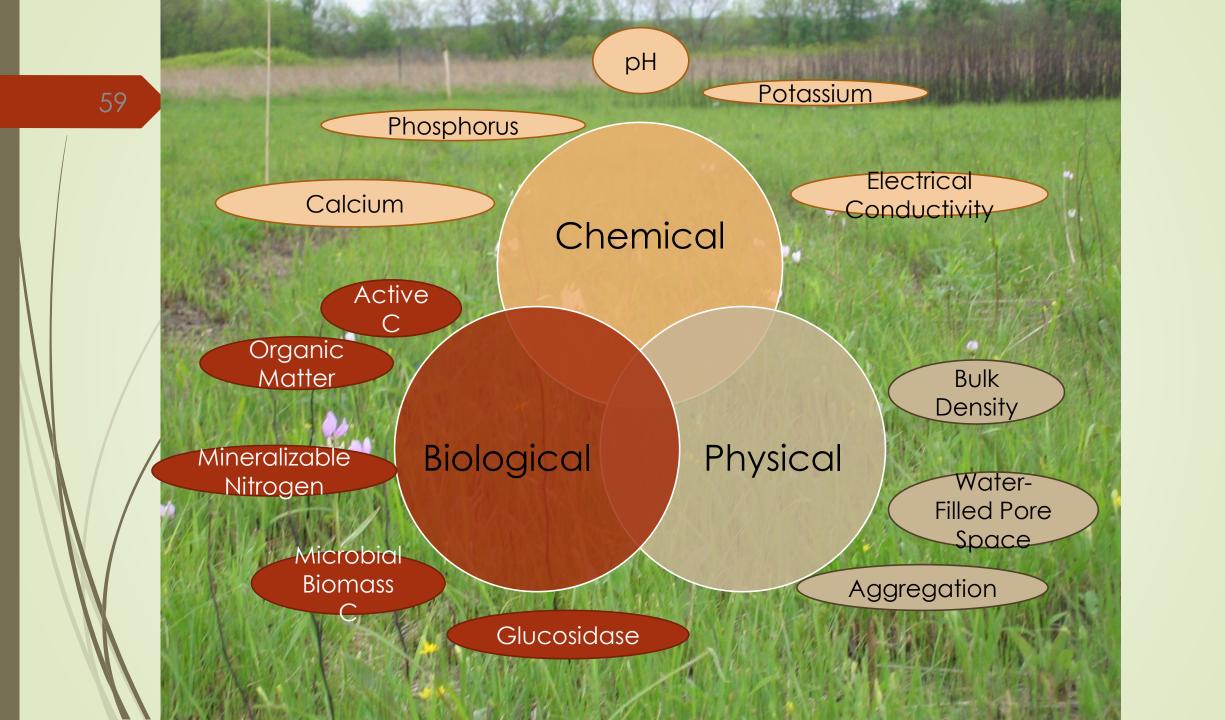
Good infiltration allows for less runoff and erosion





# Adding Calcium Also Increased the Biological Activity

<u>Treatment</u>	Mycorr.	<u>Fungi</u>
Control	3832	2504
Calcium	4219*	3135*



### The Slake Test Video



