Soil pH and Liming Sources

John Jemison
Extension Professor

Competency Area 5: Soil pH and Liming

39. Define:
    a. Soil pH
    b. Buffer pH
    c. Exchangeable acidity
    d. Alkalinity

40. Describe the long-term change in soil pH from applying N.

41. Describe how applying N in a no-till or long term perennial forage crop results in pH stratification (acid roof) and how this impacts, root growth, herbicide activity, soil sampling, and liming management.

42. Describe how cation exchange capacity (CEC), soil texture, exchangeable acidity and soil organic matter affect lime requirements.

43. Describe how soil pH affects the availability of each nutrient.

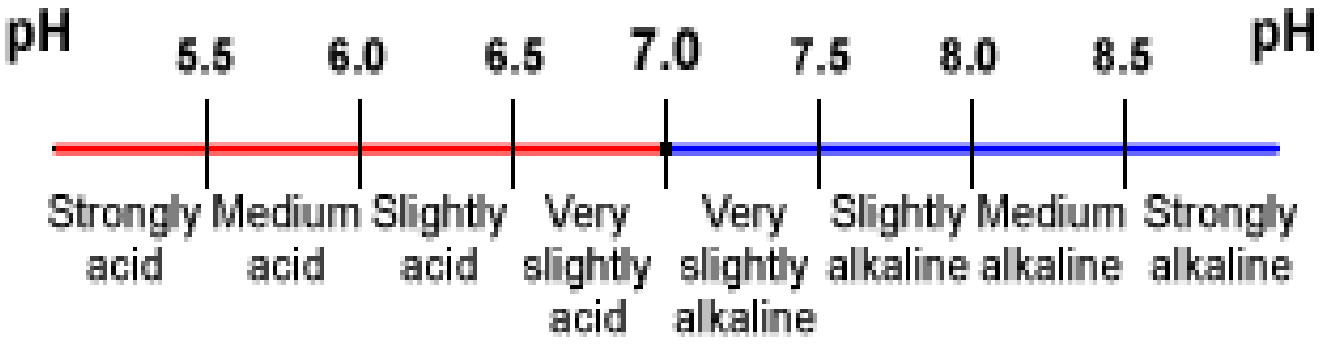
44. Describe how liming materials increase soil pH.

45. Describe how purity, fineness, and calcium carbonate equivalent (CCE) affect the neutralizing ability of liming materials.

46. Calculate lime application rates to meet lime requirements

47. Understand how biosolid application and soil pH affect availability of heavy metals to plants.

Soil pH



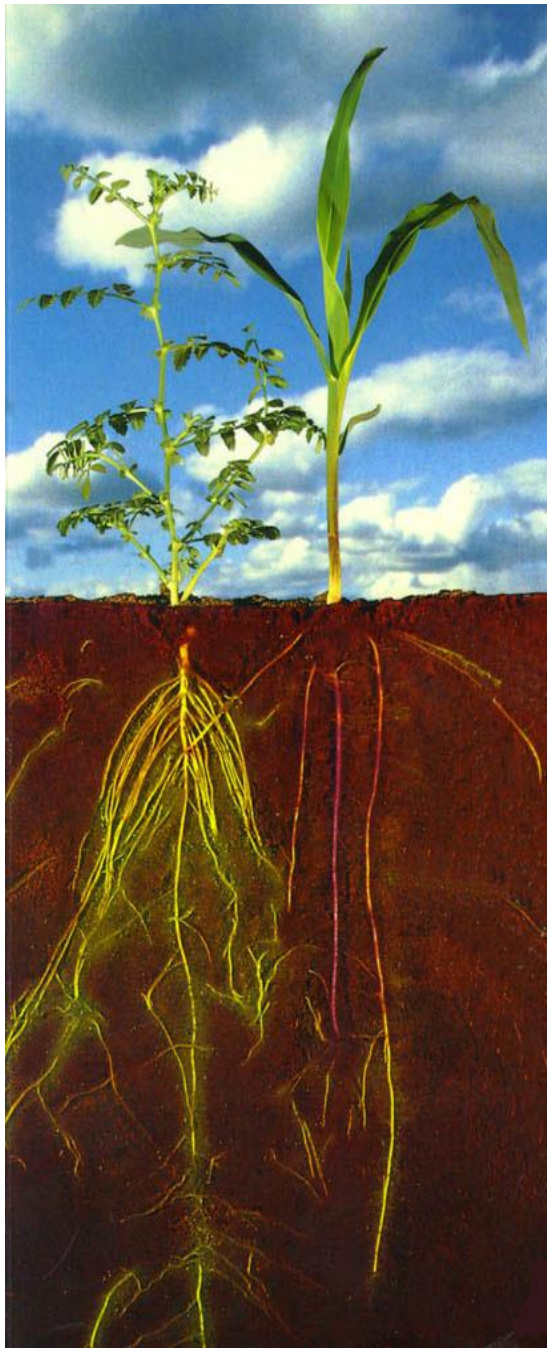
Measure of amount of H^+ and Al^{+++} in soil

Each unit change .. 10 factor

SF: 5-39

Causes of Soil Acidity

- Leaching of basic cations: Ca^{+2} Mg^{+2} K^{+}
- Leaves behind Al^{+3}
  - Toxic to many plants roots
- Role of N fertilizer
- Acid rain – used to be more important
- Plant electrical balance

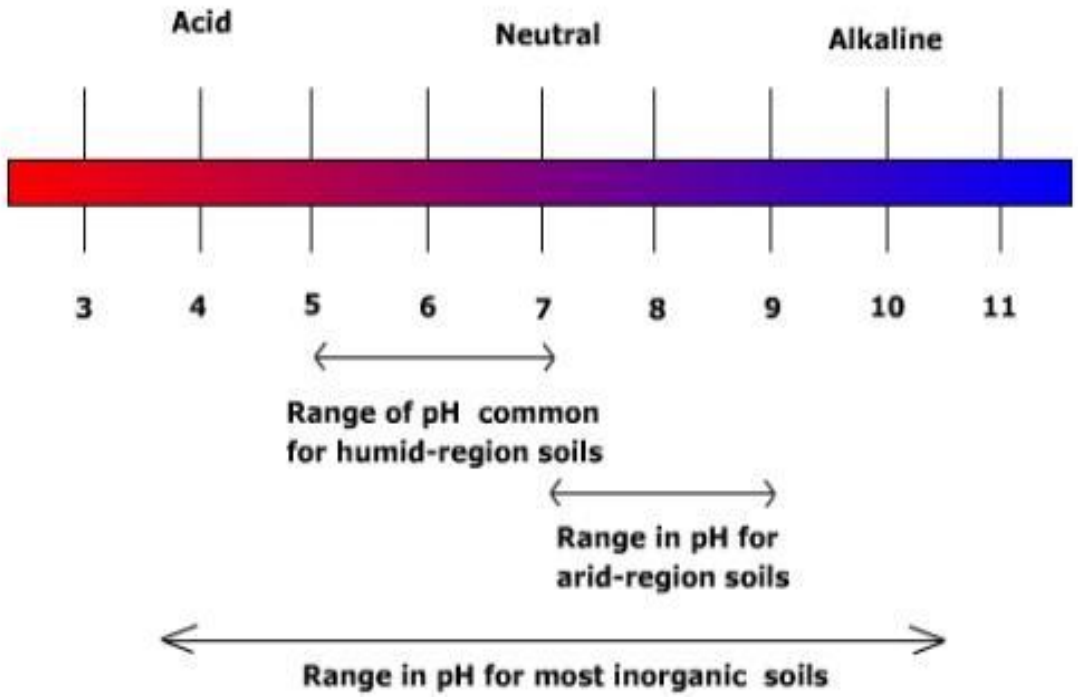


Factors that lead to acidification of soils

nutrient balance

K^+ in … H^+ out

Crop plants and weeds


Acid
Neutral
Alkaline
3
4
5
6
7
8
9
10
11
Range of pH common for humid-region soils
Range in pH for arid-region soils
Range in pH for most inorganic soils

???


Proper
SOIL pH

Acidity caused by N Fertilizer

- Reaction:
  - $2NH_4 + 4O_2 \rightarrow 2NO_3 + 4H + H_2O$


$NH_3 + H^+ \rightarrow NH_4^+$
M37

Acidity caused by N Fertilizer

- Reaction:
  - $2NH_4 + 4O_2 \rightarrow 2NO_3 + 4H + H_2O$
- Sources affect amount of acidity
  - NH_4^+ based fertilizers … most acidifying
    - ammonium sulfate, MAP
    - DAP - 1 OH produced per 2 N's
    - urea … 2NH4 + 2OH …
    - $CaNO_3$ – not acidifying … already oxidized
- Lbs lime / lb N … 1.8 (u) to 5.4 (s)

- **Acidity from Oxidation of NH_4^+ to NO_3^- by microbes**
  - **Base required to neutralize the acidity**

N Source	Official (AOAC) lb $CaCO_3$/lb N*
Anhydrous Ammonia	1.8
Urea	1.8
Ammonium Nitrate	1.8
Ammonium Sulfate	5.4
Monoammonium Phosphate	5.4
Diammonium Phosphate	3.6

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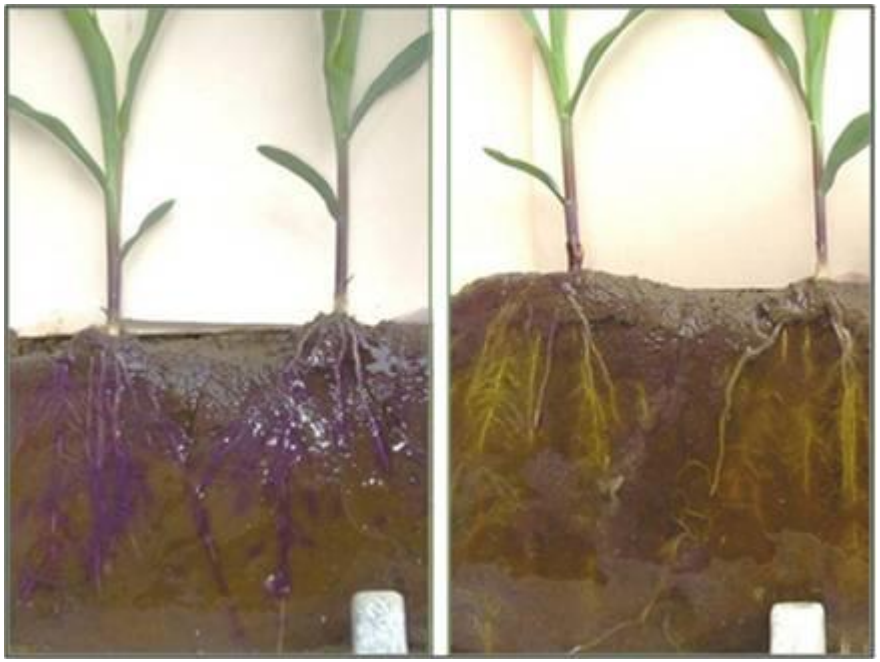
***Accounts for anion uptake effects on pH**

NO_3^- → OH^- ↑pH NH_4^+ → H^+ ↓pH



pH 7

pH 4

Heckman, Rutgers

Acid Roof Issue

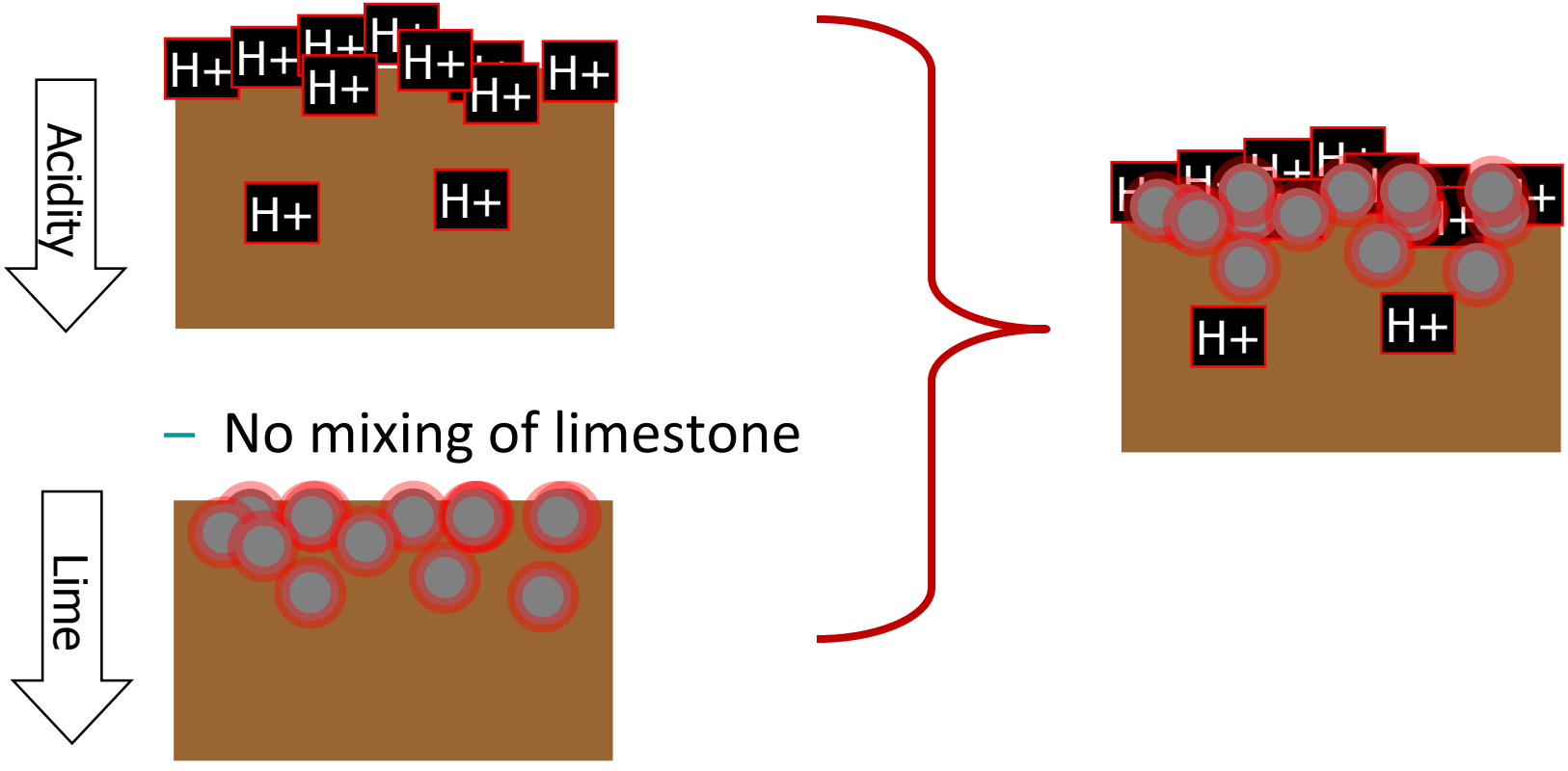
Table 1. The effect of four years of no-till corn production upon soil test levels in an irrigated Tedrow loamy sand soil (Gratiot County).

Soil Sample Depth *(in)*	Soil pH	Soil Test P *(ppm)*
0-2	5.6	220
2-4	5.9	104
4-6	6.4	47
6-8	6.6	35

http://www.spectrumanalytic.com/support/library/ff/Soil_Sampling_Instructions.htm

Tillage and pH

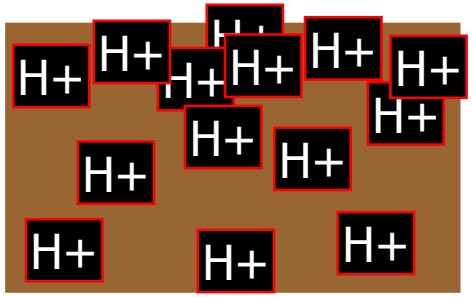
- No Tillage/perennial forages = Stratification & no mixing
- **Lime regularly** – no special management required
  - Acid Roof



  - No mixing of limestone

Tillage and pH

- No Tillage = Stratification & no mixing
- **Not** limed regularly – very difficult to correct quickly
  - Acid soil



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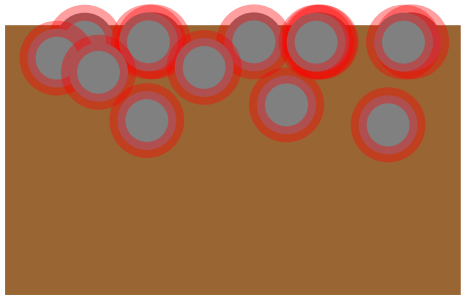
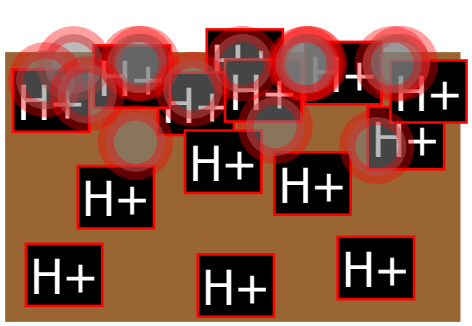
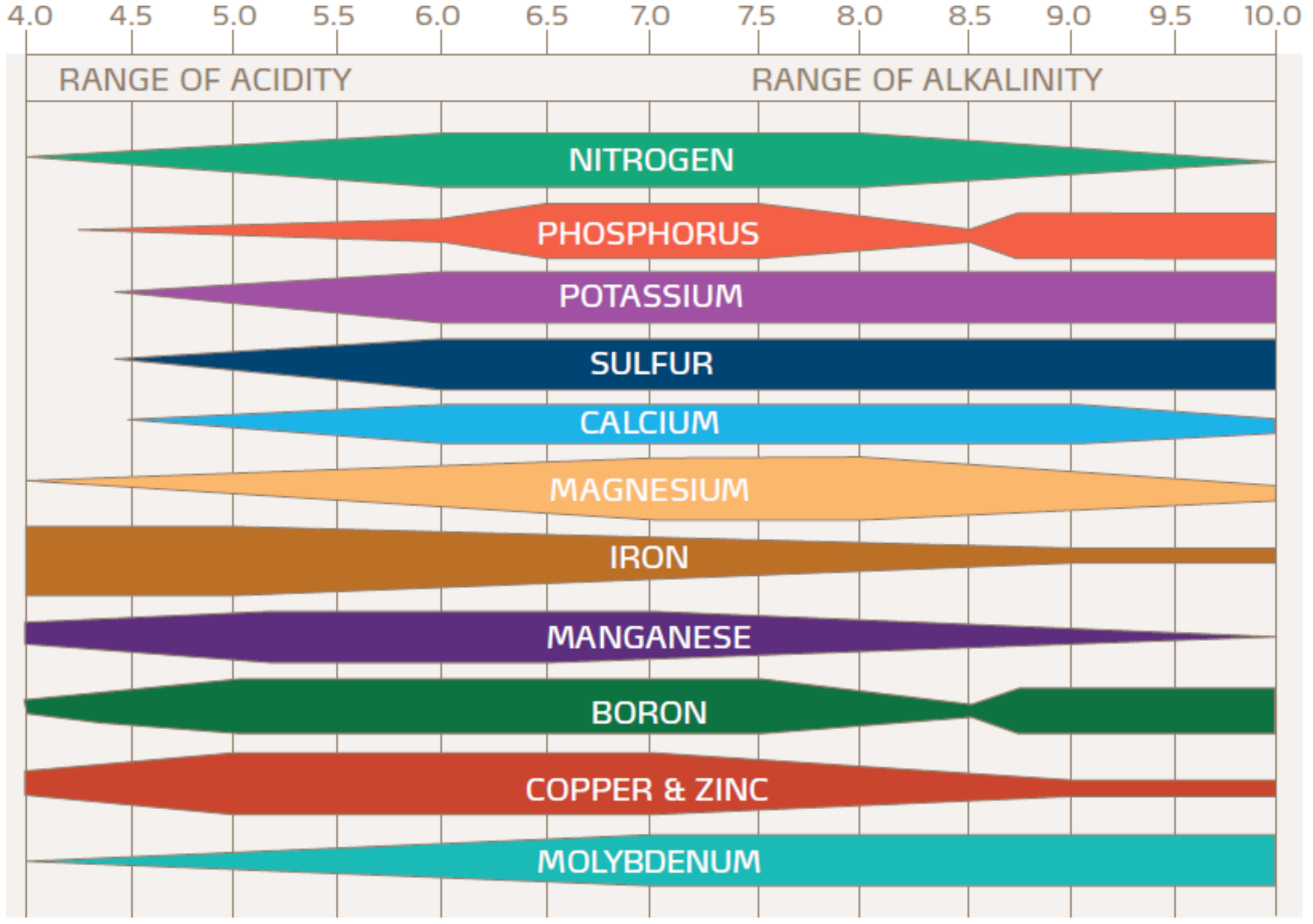




Benefits of Liming

- Reduces effect of toxic aluminum
- Increases availability of essential nutrients
- Important for microorganism activity
- Important for herbicide function
- Improves soil structure
- Supplies Ca and often Mg to soil

The Influence of Soil pH on Nutrient Availability

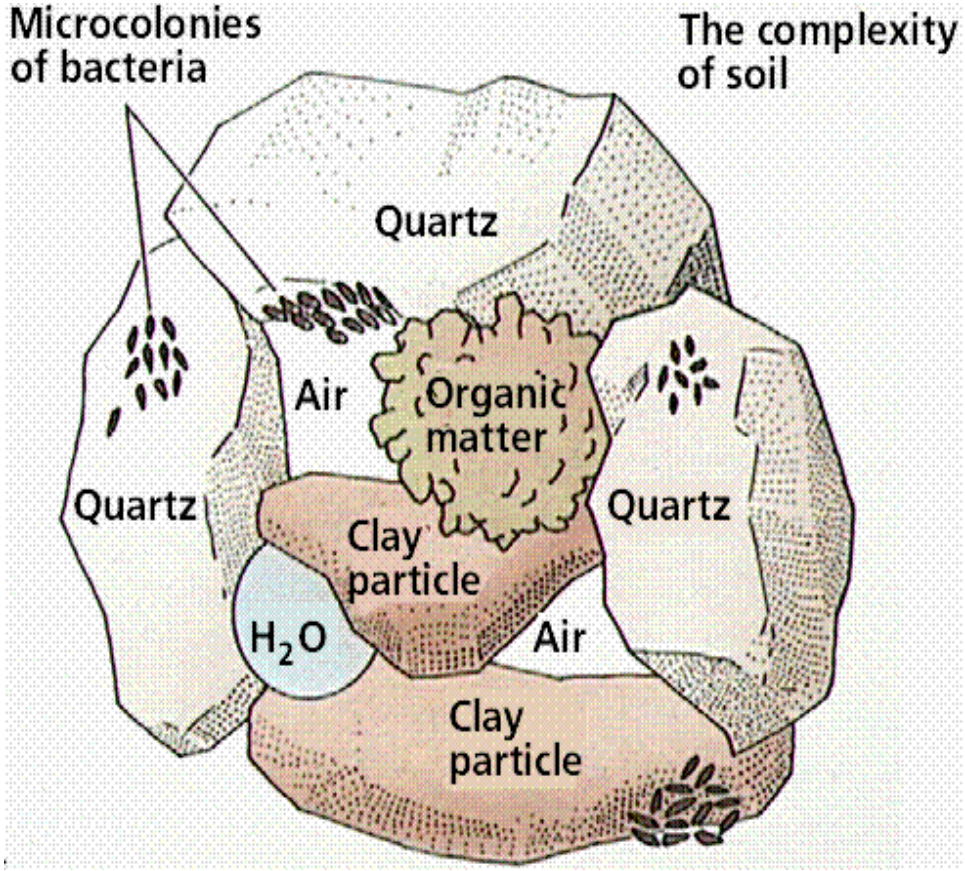


Favorable pH range for common crops

	Soil pH				
	5.0	5.5	6.0	6.5	7.0
Corn			**********		
Alfalfa				**********	
Soybeans				**********	
Wheat				**********	
Oat			**********		
Barley				**********	
Red Clover			**********		
Grasses			**********		

So you want to add lime

Active and Reserve Acidity



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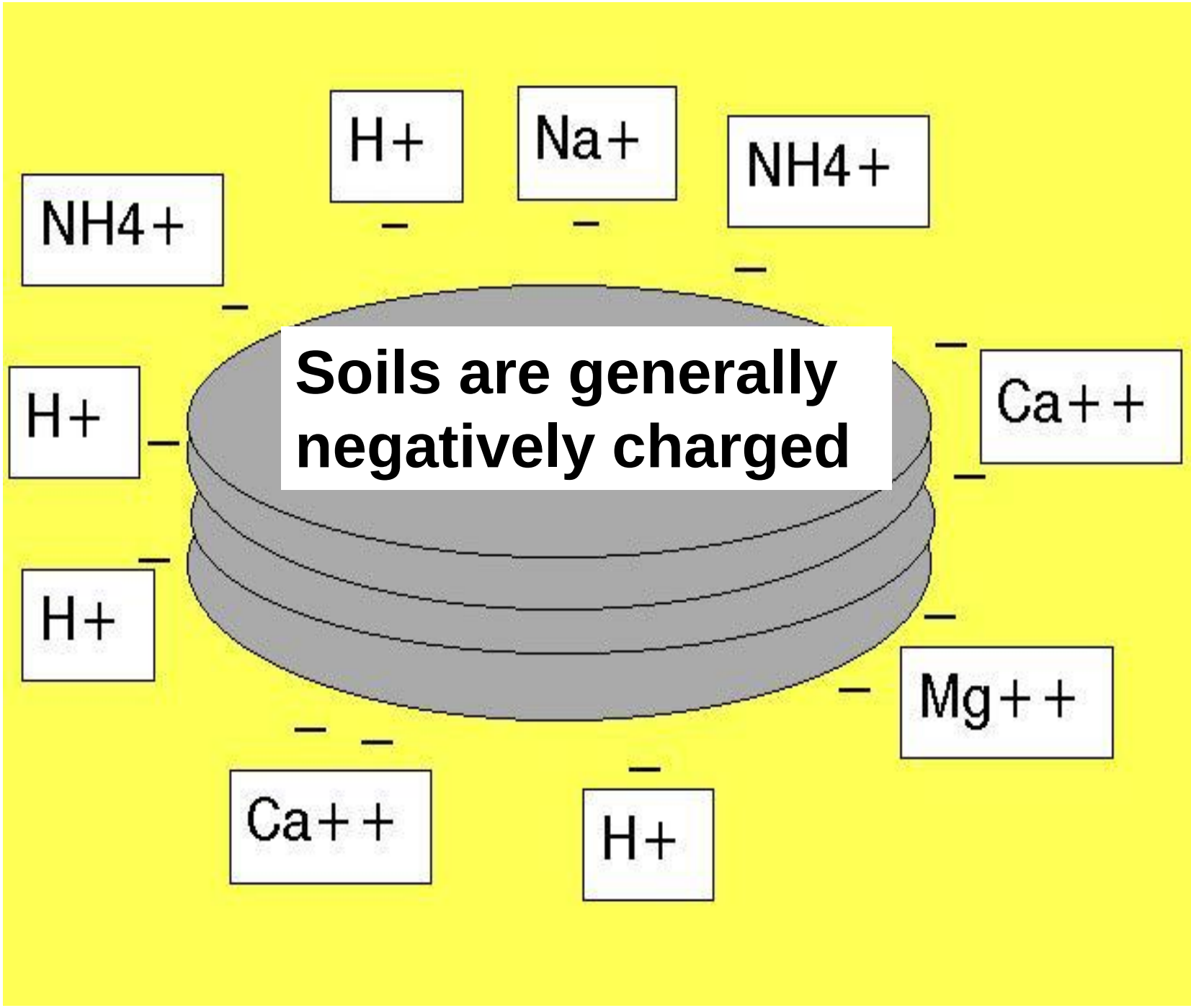
H+
Na+
NH4+
NH4+
Soils are generally negatively charged
H+
Ca++
H+
Mg++
Ca++
H+

pH and Lime Requirement

- pH is a measure of *active acidity*
  - Property of the soil
  - Tells you if you need to add lime
- Lime requirement - *reserve acidity*
  - Buffer pH …
  - Meaningless by itself
  - But … key to how much lime to add

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For information on micronutrient management and recommendations, see enclosed form.

NUMERICAL RESULTS

(Test methodology: pH in water and Mehlich buffer, available nutrients by modified Morgan extract)
(Organic matter measured by LOI, P determined colorimetrically, all others measured by ICP-OES)

CEC and nutrient balance calculations are based on present pH of 6.7

Level Found	6.7	6.26	252	648	947	6006	13.4(A)	6.2	19.4	74.4	0.0
	Soil pH	Lime Index 2	Phosphorus (lb/A)	Potassium (lb/A)	Magnesium (lb/A)	Calcium (lb/A)	CEC (me/100 g)	K	Mg (% Saturation)	Ca	Acidity
Optimum Range	6.0-7.0	N/A	20-40	see % Saturation levels			> 5	3.5-5.0	10-20	60-80	< 10

Level Found	9.3	11	0.12	3.2	7.6	5.0
	Organic Matter (%)	Sulfur (ppm)	Copper (ppm)	Iron (ppm)	Manganese (ppm)	Zinc (ppm)
Normal Range	5 - 8	> 15	.25-.60	6 - 10	4 - 8	1 - 2

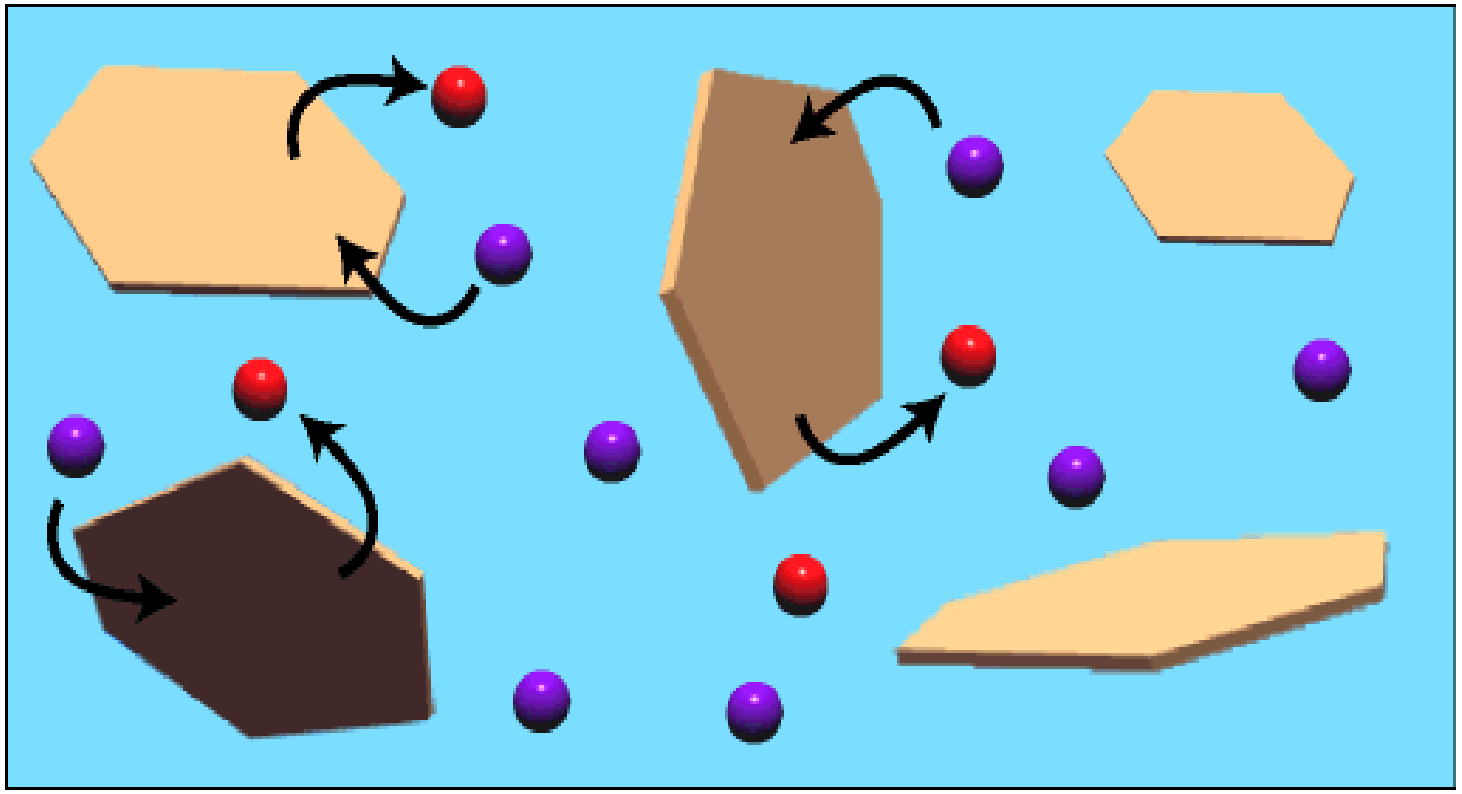
Level Found	N/A	N/A	N/A	N/A	N/A
(Extras)	Boron (ppm)	Sodium (ppm)	Soluble Salts (mmhos/cm)	Nitrate-N (ppm)	Ammonium-N (ppm)
Normal Range					

Additional Results or Comments:

Lead scan: NORMAL BACKGROUND LEVEL - no health risk.

Till in 5 lb yellow sulfur/1000 sq ft. This rate will cause only minor acidity.

Cation Exchange



= cation exchanging IN TO clay

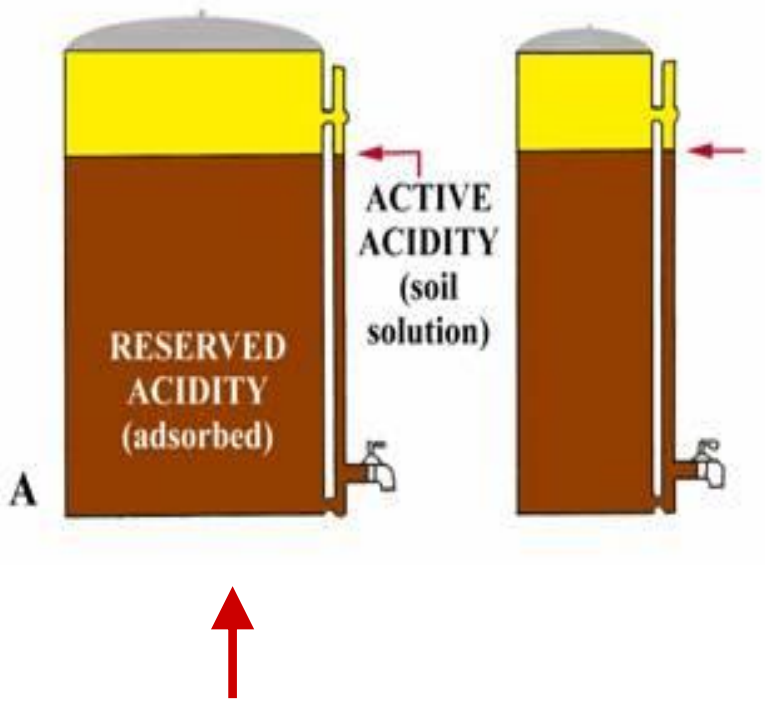
= cation exchanging OUT OF clay

= clay minerals

Frequently adding tons of lime ?

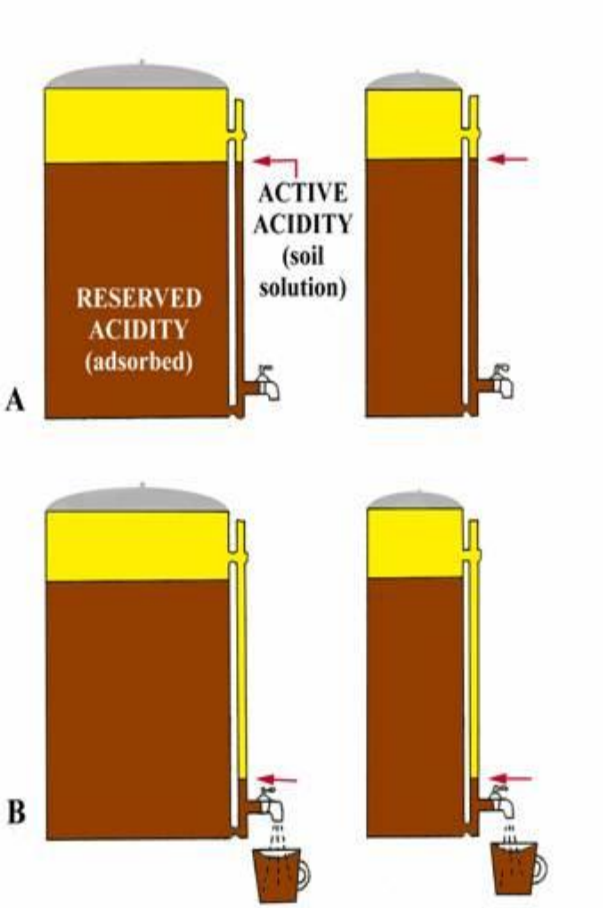
Why so much?

Potato soil

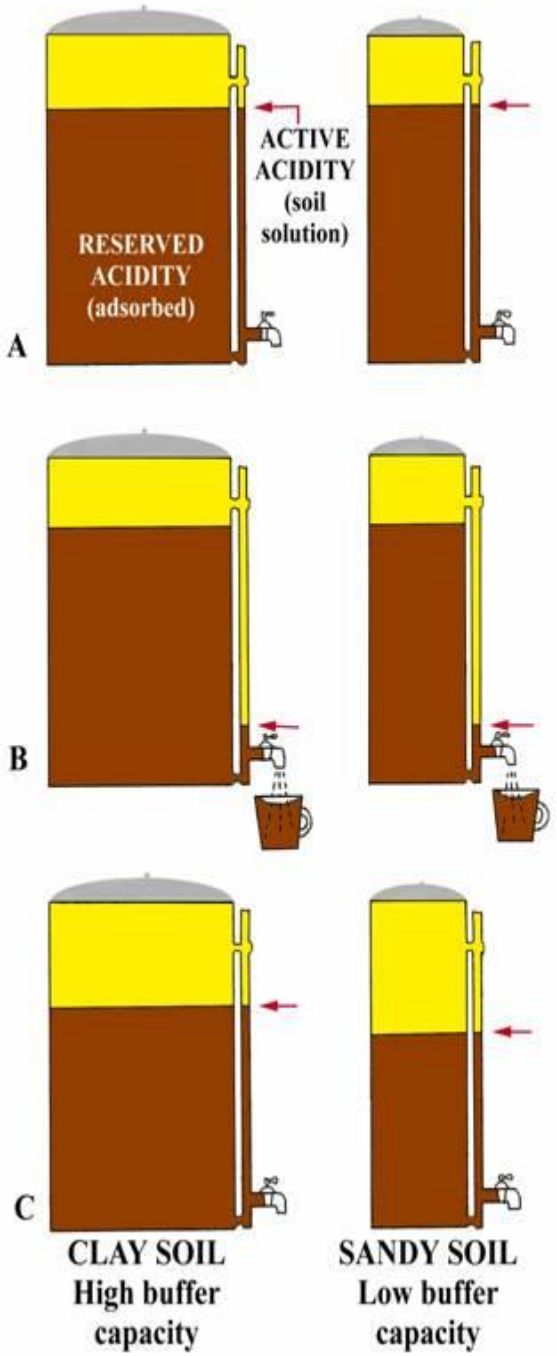


Agronomic soil

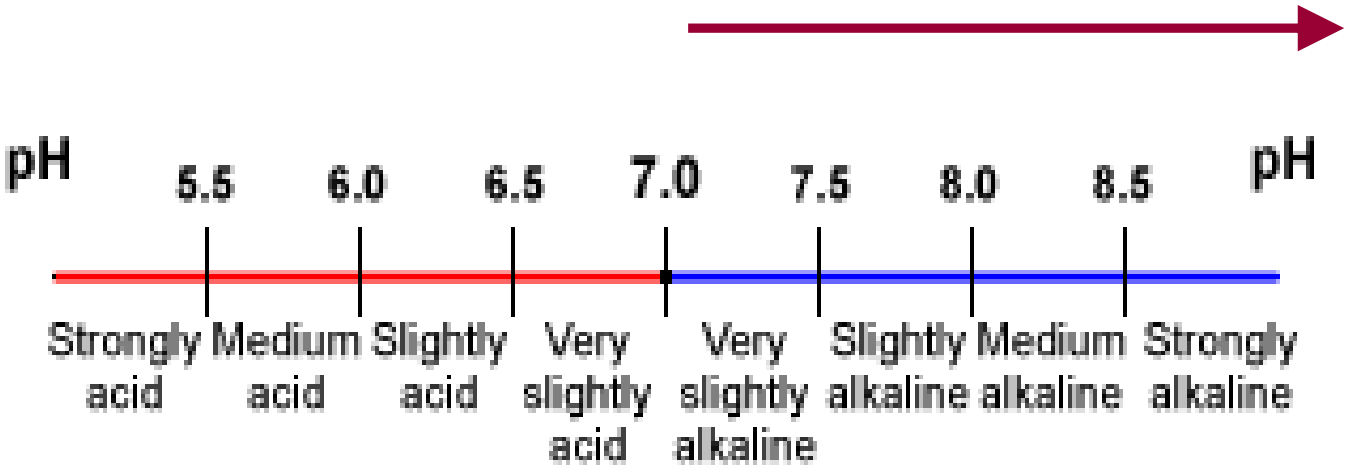
As we add lime … initially reduce H^+ in the soil water



More or less lime to neutralize H in the potato soils ?



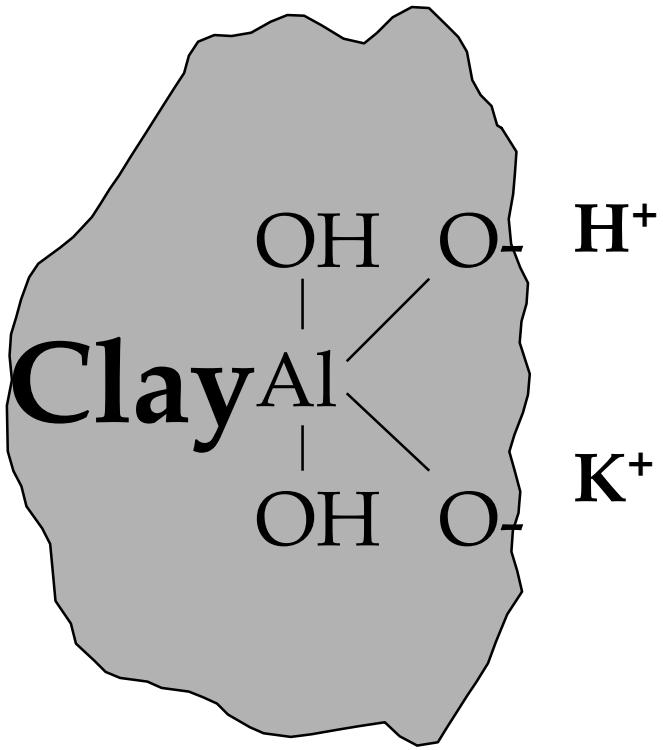
Soil pH



Alkalinity: amount of base in
Higher pH soils … not relevant here …

Sources of Negative Charge

pH dependent



permanent

OH O-

Al^{+++}

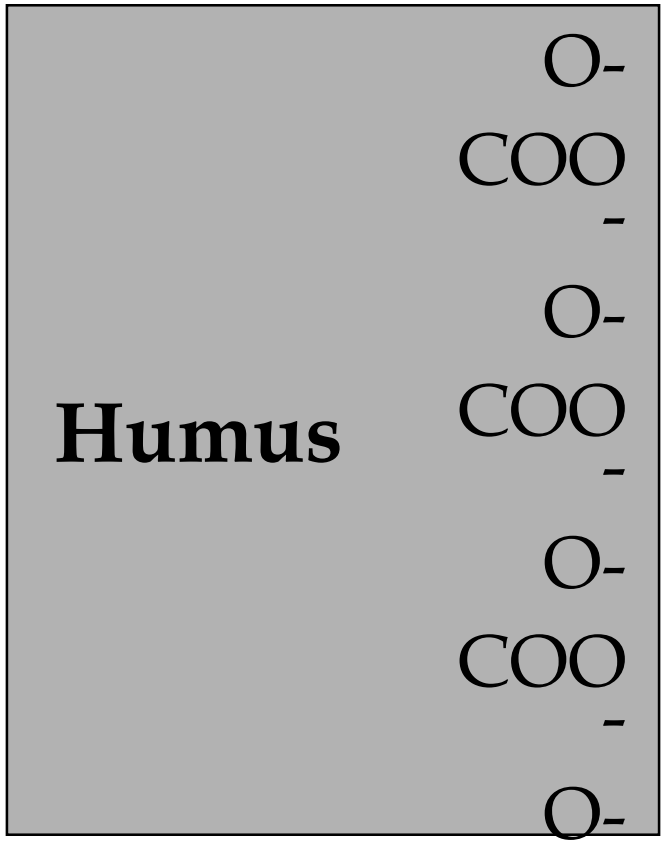
OH O-

OH O-

Mg^{++}

OH O-

Sources of Negative Charge

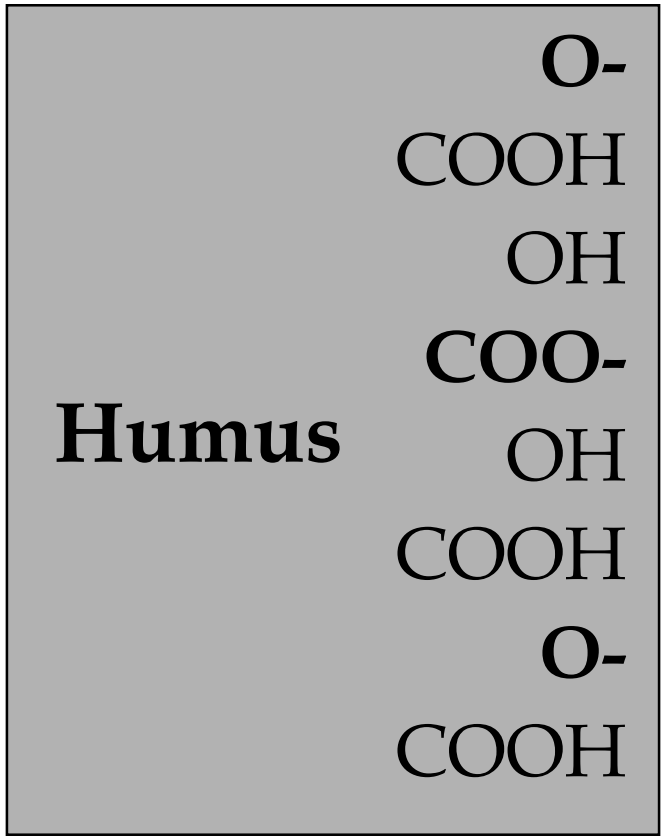


The CEC of humus is 300 meq/100g

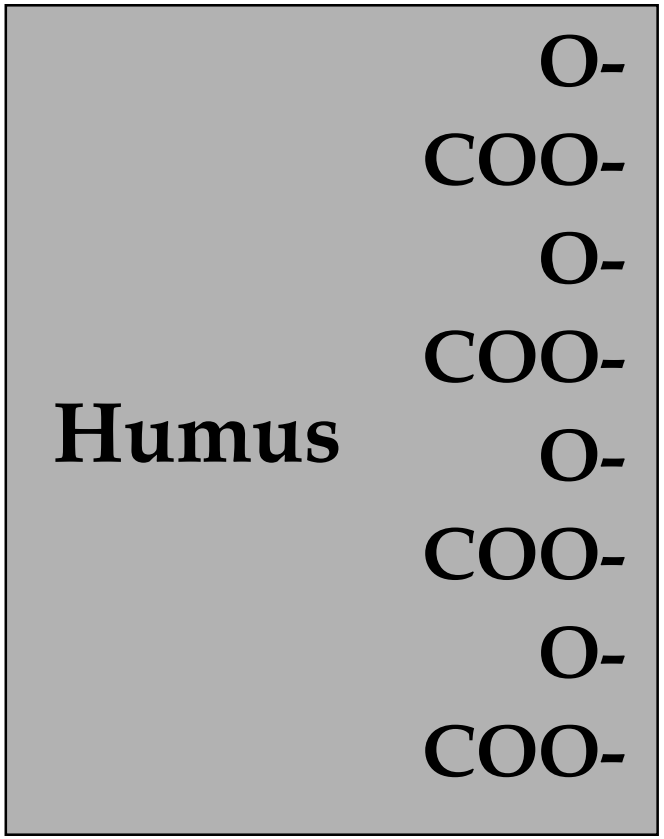
SF: 5-42

pH Dependent Charge

pH = 5.2



pH = 6.8



SF: 5-42

General Relationships: High Nutrient Availability and Soil pH

- ***Phosphorus: midrange pH***
- ***Micronutrients: low pH***
  - ***exception: Mo***
- ***Ca, Mg, S, K … near neutral***

Agricultural Lime Materials

- Any product whose Ca and Mg compounds can neutralize acidity
  - CaO – calcium oxide
  - $Ca(OH)_2$ – slaked lime – hydrated lime
  - $CaCO_3$ – calcium carbonate
  - $CaCO_3$ and $MgCO_3$ – dolomitic lime

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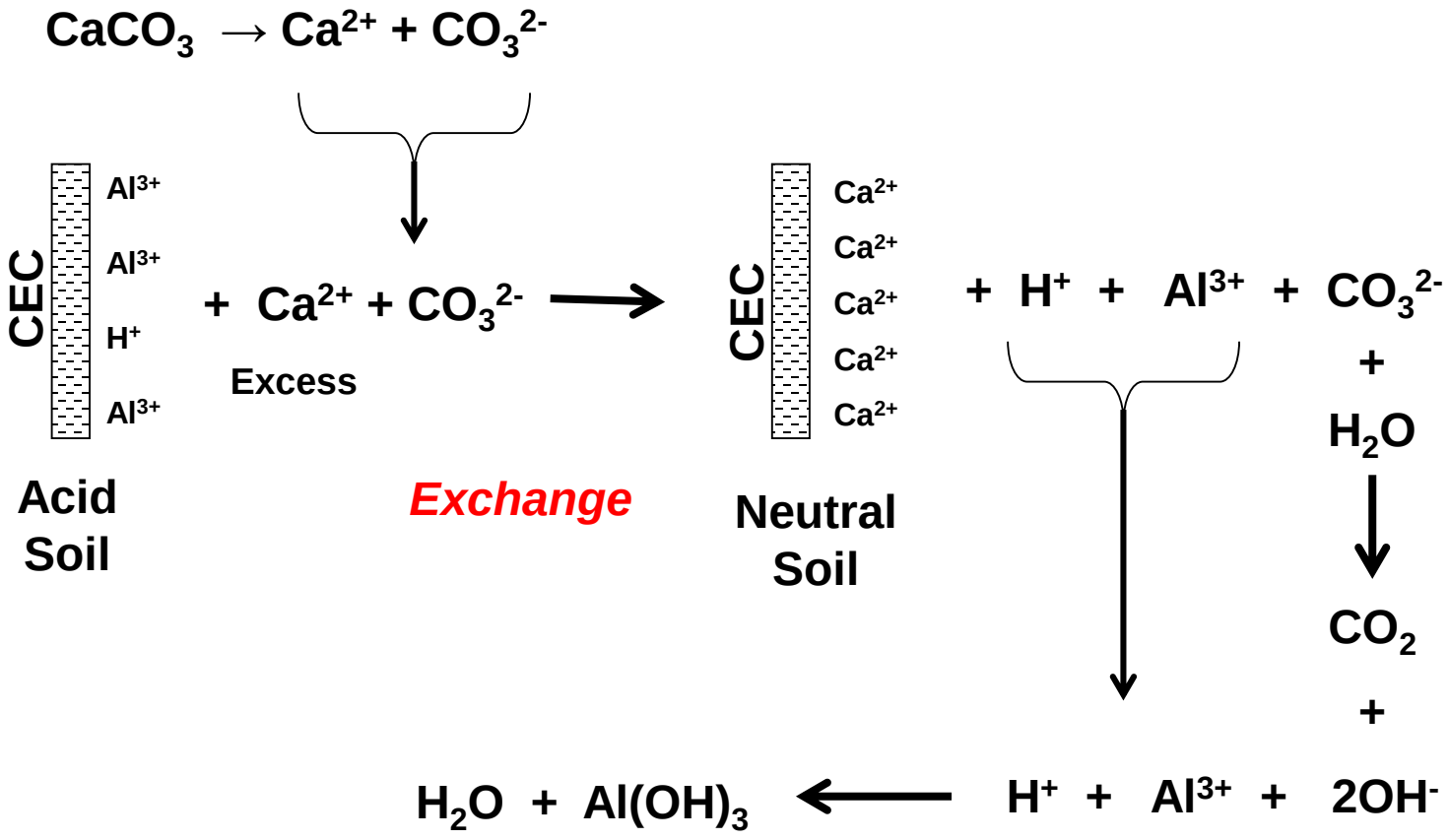
Liming Reaction



Gypsum

$CaSO_4$

Good source of Ca – not lime

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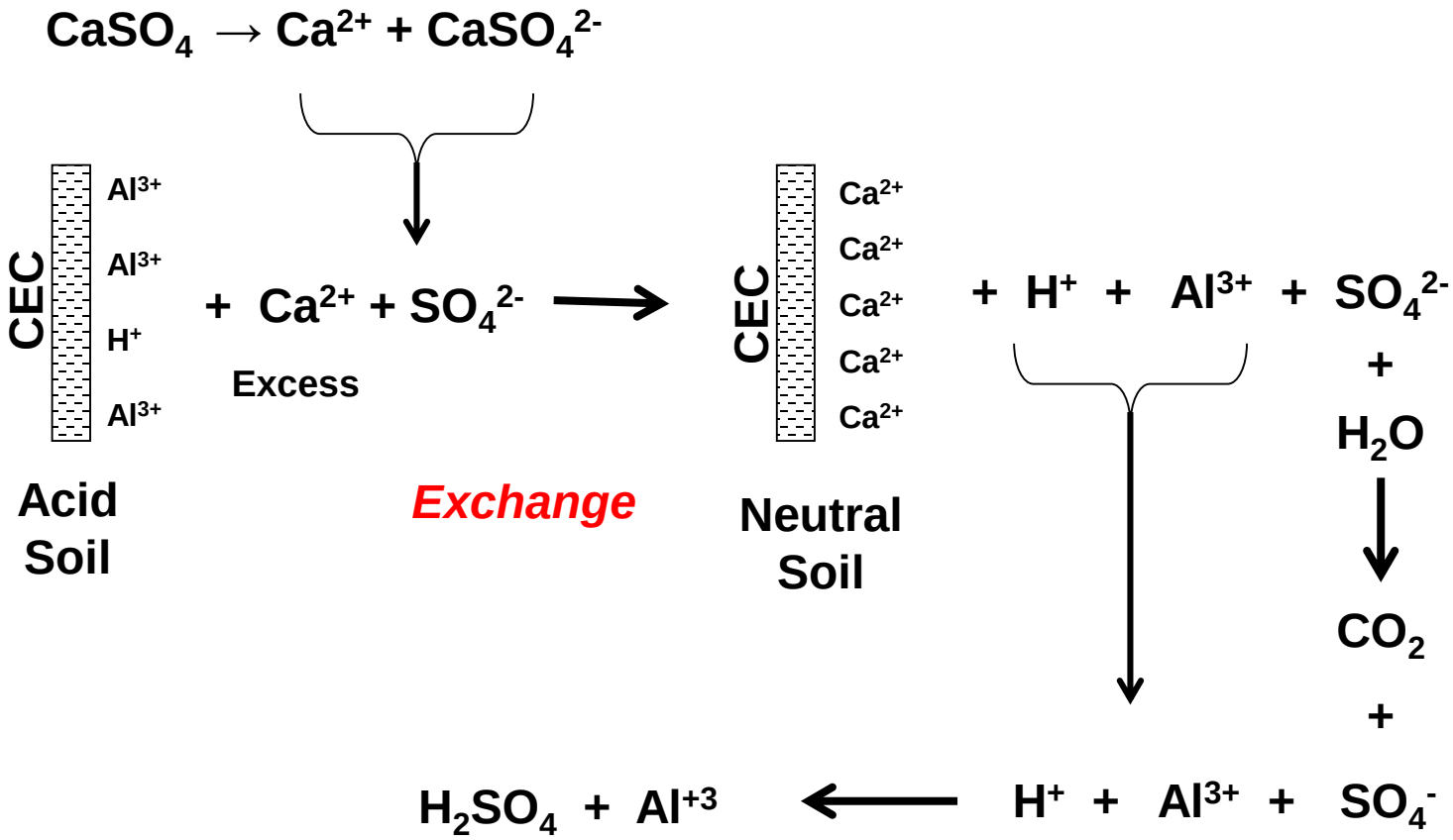
Gypsum Reaction

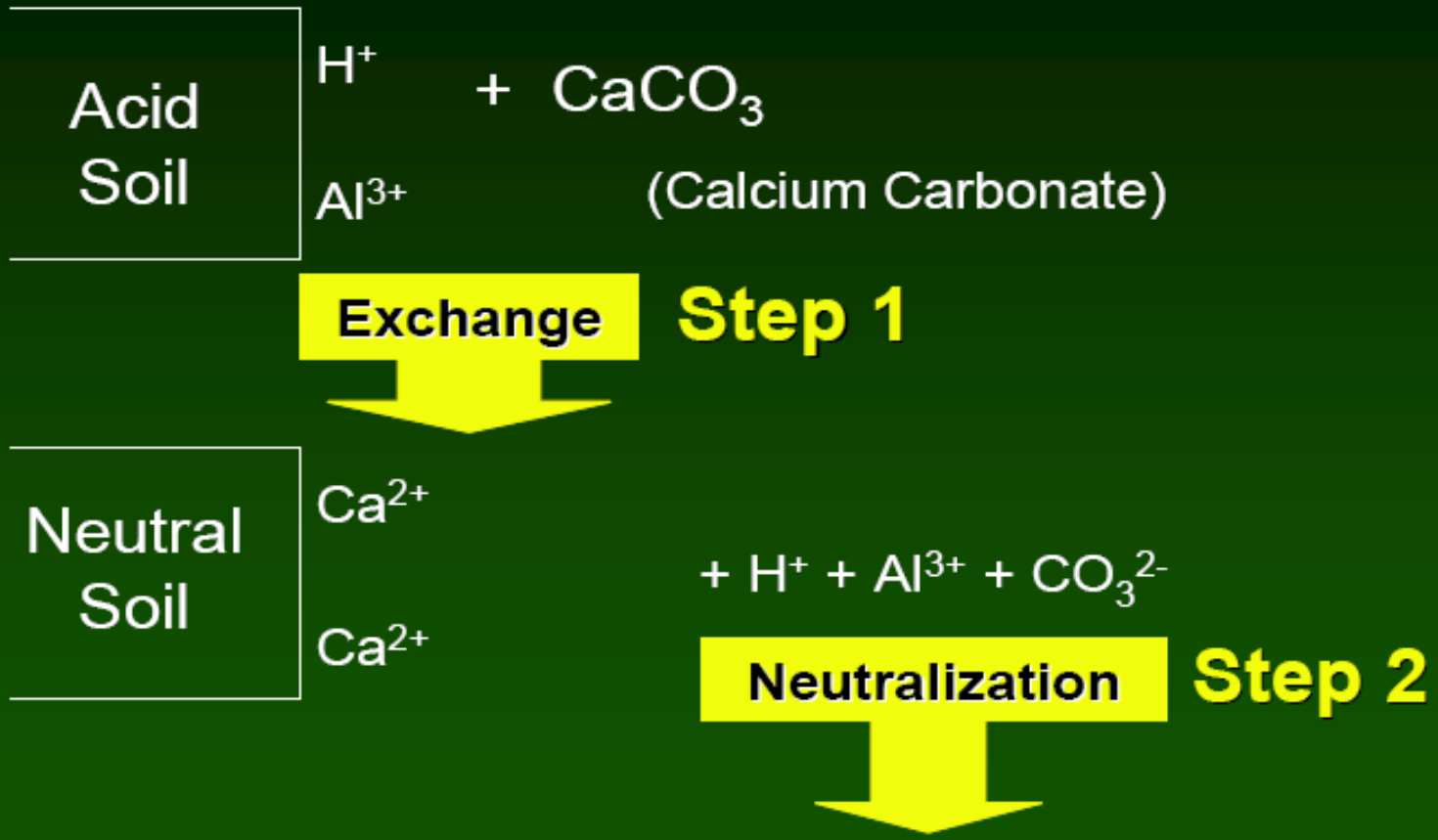


No Neutralization !

Gypsum Promoted as Soil Conditioner

- Ca helps affect soil aggregations
  - $CaCO_3 = CaSO_4$
  - Source is not important
- Gypsum is not a liming agent!
- Usually if you need Ca – you need aglime

Aglime – Reactions in Soil



SF: 5-44

Calcium Carbonate Equivalence - CCE

Calcite - $CaCO_3$ Standard

100

based on MW

Kelly's

CAPSULATED™ PELLETS

LIMESTONE

DOLOMITIC

MICRO & FAIRWAY PELLETS

FOR TURF, LAWN & GARDEN

- Neutralizes Acid Soils
- Not recommended for use as a fertilizer substitute.

Most plants produce better in a neutral ph range. This product increases ph on acid soils by replacing hydrogen and aluminum with calcium, which allows plan to utilize other nutrients more efficiently.

RECOMMENDATIONS:
Follow soil test results. Without test results, follow these guidelines.

CORRECTIVE APPLICATION:
Apply 100 lbs. per 1/10 pH correction per acre.

ESTABLISHED TURF & LAWN:
Apply 10-50 lbs., per 1,000 sq. ft.

NEW TURF & LAWN:
New seeding apply 50 lbs. per 1,000 sq. ft.

GARDENS:
Apply 10-50 lbs. per 1,000 sq. ft. Incorporate into top 2-5 inches of soil.

MAINTENANCE APPLICATION:
Apply 2-4 lbs. Kelly's Limestone for each lb. of actual nitrogen applied.

APPROXIMATE SPREADER SETTING:
Actual settings depend on type, model and condition of spreader.

	CYCLONE/ SPIKER	SCOTTS DROP
FAIRWAY		
10 lbs. per 1,000 sq. ft.	4	6.5
50 lbs. per 1,000 sq. ft.	7*	8.5*
MICRO		
10 lbs. per 1,000 sq. ft.	3	4
50 lbs. per 1,000 sq. ft.	10*	12*

*Make 2 criss cross passes.

These spreader settings are approximate. Age, condition of spreader, spee of operation and contour of terrain may cause settings to vary. Always calibrate your spreader before use.

FLORIDA
Registration No. 1072
This product requires 2093 lbs. to be equal to one ton of standard liming material. One standard ton of lime is 90% Calcium Carbonate Equivalent.
IOWA
Iowa Secretary of Agriculture
Certified 1258 lbs. ECCE per ton
KANSAS
ECC=66.1%
MINNESOTA
1416 lbs. Minimum ENP per ton
MISSOURI
525 lbs. E.N.M. per ton
NEBRASKA
ECCE=62.9%
1258 lbs. ECCE per ton

NORTH CAROLINA
2093 lbs. of this material equals one ton standdard liming material. One standard of lime is 90% Calcium Carbonate Equivalent.
OKLAHOMA
ECCE=60.9%
PENNSYLVANIA
Effective Neutralizing Value = 59.5%
WISCONSIN
Neutralizing Index = 56.5%
Neutralizing Index Zone = 50.59

PRODUCT PRODUCED BY:
KELLY LIME & ROCK CO., INC.
P.O. BOX 725
KIRKSVILLE, MO 63501

FOR INCORPORATION, AFTER APPLICATION, WET THOROUGHLY 30 MINUTES BEFORE TILLING.

DRY WEIGHT*
GUARANTEED ANALYSIS

TOTAL CALCIUM (Ca)	18%
TOTAL MAGNESIUM (Mg)	10.1%
CALCIUM CARBONATE EQUIV	86%
Derived from Mined Calckum Carbonate & Magnesium Carbonate	
ALSO CONTAINS NON PLANT FOOD	
INGREDIENT	2% Lignosulfonates
Moisture	approx. 1%
EQUIVALENT OXIDES	
Min. Calcium Oxide (CaO)	25.2%
Min. Magnesium Oxide (Mg)	16.8%
TOTAL OXIDES	42%
SOURCES	
Calcium Carbonate ($CaCO_3$)	45%
Magnesium Carbonate ($MgCO_3$)	35%
TOTAL CARBONATES	80%

*Sieve Mesh below does not apply in California.
*SIZING BEFORE CAPSULATING
*DOES NOT APPLY IN CALIFORNIA

***SIZING BEFORE PELLETIZING**
FINE SIZE

99.8% PASSING	8 MESH SIEVE
98.0% PASSING	10 MESH SIEVE
95.0% PASSING	20 MESH SIEVE
86.0% PASSING	40 MESH SIEVE
63.0% PASSING	50 MESH SIEVE
61.0% PASSING	60 MESH SIEVE
50.0% PASSING	100 MESH SIEVE

This product is NON-BURNING if used according to the directions.
STORE IN A DRY PLACE

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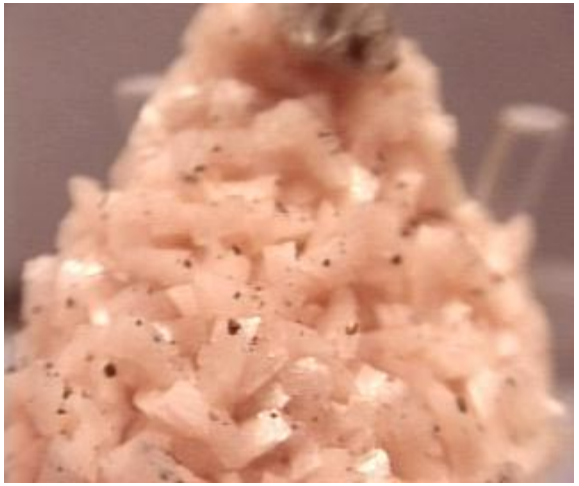
CCE:

The neutralizing ability of a liming material compared to pure calcium carbonate

Dolomite - $MgCO_3$



Lighter

2000 lbs of pure calcite – 1700 lbs of dolomite

$CaCO_3$ - $MgCO_3$

Not particularly pure

Clays … other junk

2000 lbs of pure calcite – 2400 lbs of lime

Neutralizing Value of Liming Materials

	CCE
$CaCO_3$	100
$MgCO_3$	119
CaO	179
$Ca(OH)_2$	136
$(Ca,Mg)CO_3$	109
$CaSiO_3$	86

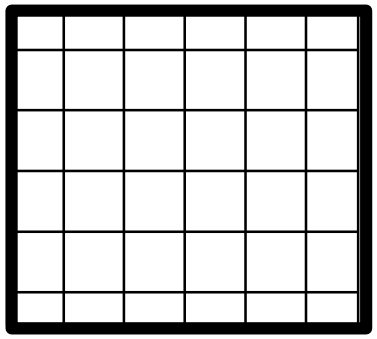
Liming materials are not usually pure, but may be mixtures and usually contain some impurities

Measure Calcium Carbonate Equivalent (CCE)

Aglime Quality – Fineness / Particle Size

- Fineness affect reaction time
  - Want a mix of size particles
  - Fine particles react quickly

Mesh Size = Wires/in on a sieve



Standard Mesh Sizes

20 mesh sieve - Coarse

60 mesh sieve - Medium

100 mesh sieve - Fine

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525 lbs. E.N.M. per ton
NEBRASKA
ECCE=62.9%
1258 lbs. ECCE per ton

NORTH CAROLINA
2093 lbs. of this material equals one ton standdard liming material. One standard of lime is 90% Calcium Carbonate Equivalent.
OKLAHOMA
ECCE=60.9%
PENNSYLVANIA
Effective Neutralizing Value = 59.5%
WISCONSIN
Neutralizing Index = 56.5%
Neutralizing Index Zone = 50.59

PRODUCT PRODUCED BY:
KELLY LIME & ROCK CO., INC.
P.O. BOX 725
KIRKSVILLE, MO 63501

FOR INCORPORATION, AFTER APPLICATION, WET THOROUGHLY 30 MINUTES BEFORE TILLING.

DRY WEIGHT*
GUARANTEED ANALYSIS

TOTAL CALCIUM (Ca)	18%
TOTAL MAGNESIUM (Mg)	10.1%
CALCIUM CARBONATE EQUIV	86%
Derived from Mined Calckum Carbonate & Magnesium Carbonate	
ALSO CONTAINS NON PLANT FOOD	
INGREDIENT	2% Lignosulfonates
Moisture	approx. 1%
EQUIVALENT OXIDES	
Min. Calcium Oxide (CaO)	25.2%
Min. Magnesium Oxide (Mg)	16.8%
TOTAL OXIDES	42%
SOURCES	
Calcium Carbonate ($CaCO_3$)	45%
Magnesium Carbonate ($MgCO_3$)	35%
TOTAL CARBONATES	80%

*Sieve Mesh below does not apply in California.
*SIZING BEFORE CAPSULATING
*DOES NOT APPLY IN CALIFORNIA

***SIZING BEFORE PELLETIZING**
FINE SIZE

99.8% PASSING	8 MESH SIEVE
98.0% PASSING	10 MESH SIEVE
95.0% PASSING	20 MESH SIEVE
86.0% PASSING	40 MESH SIEVE
63.0% PASSING	50 MESH SIEVE
61.0% PASSING	60 MESH SIEVE
50.0% PASSING	100 MESH SIEVE

This product is NON-BURNING if used according to the directions.
STORE IN A DRY PLACE

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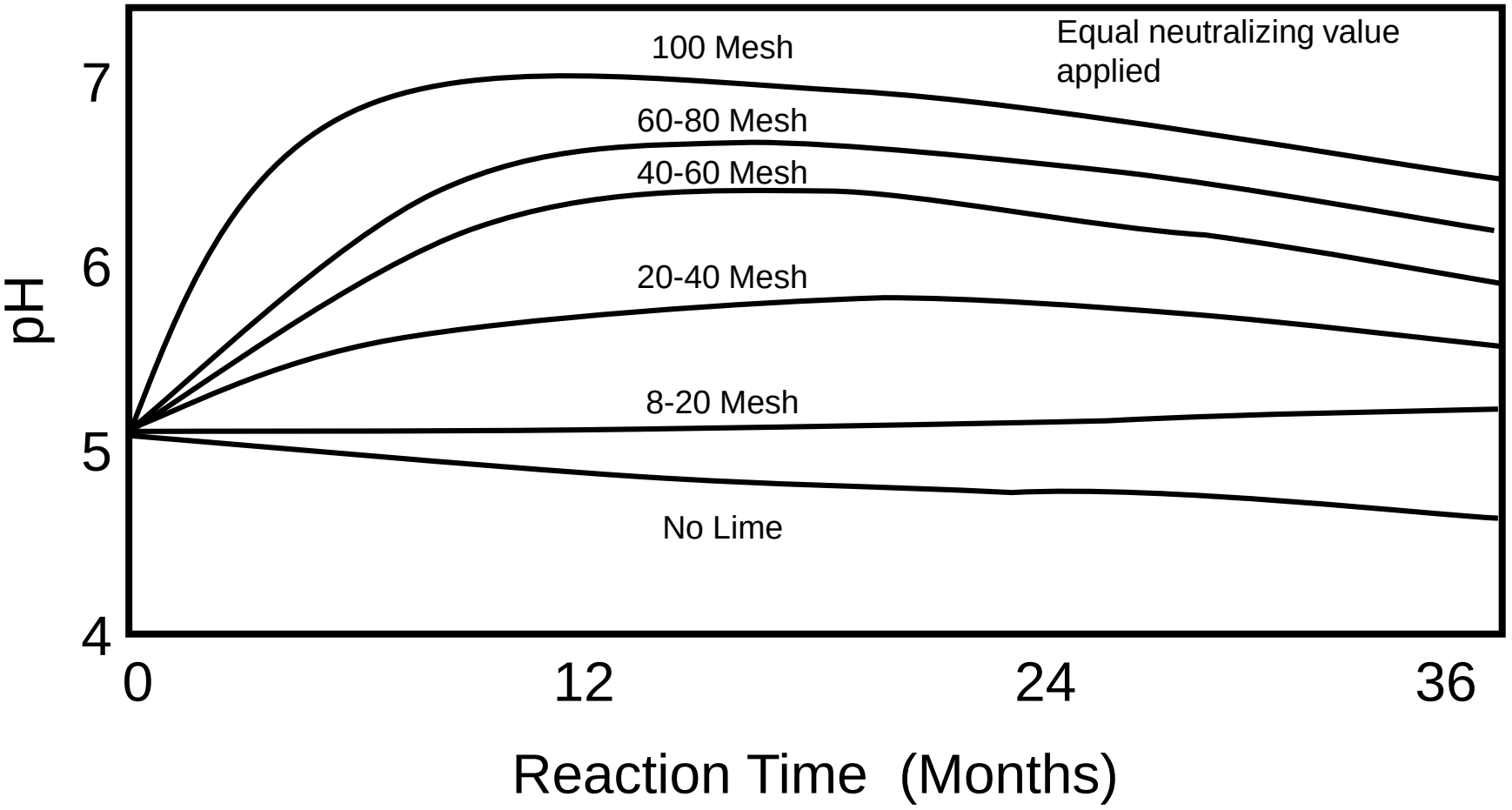
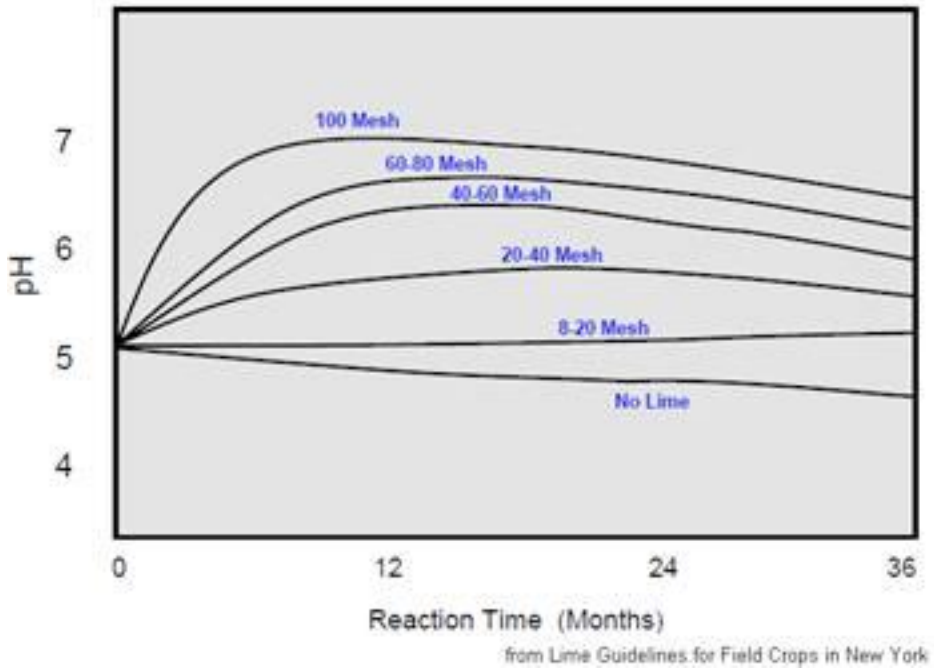
Effect of aglime fineness on speed of reaction



SF: 5-45

Desirable Degree of Fineness?

- Effective lime fineness
  - 95% pass 20 mesh
  - 60% should pass 60 mesh
  - 50% should clear a 100 mesh screen
- *Fast reaction + continued activity over time*



NY ENV Calculation

To determine the ENV of a limestone:

- Subtract the % passing 60 mesh from the % passing 20 mesh and multiply by 0.40.
- Subtract the % passing 100 mesh from the % passing 60 mesh and multiply by 0.60.
- Subtract the % passing 100 mesh by 1.00.
- Add the above 3 numbers to obtain the fineness factor. It should be less than 100%.
- Multiply the above number by the CCE in decimal form to get the ENV.
- The ENV should be between about 30 and 100 for pulverized limestones sold in NY.

SF: 5-45

Determining Liming Amounts

- Take CCE of the Lime and ENV …
- Lime recommendation is 2.5 tons/ac lime
  - assume 80% CCE lime …
- 3.125 tons lime
- Assume ENV for lime is 70.3%
- 3.125/.703 = 4.45 tons lime/ac

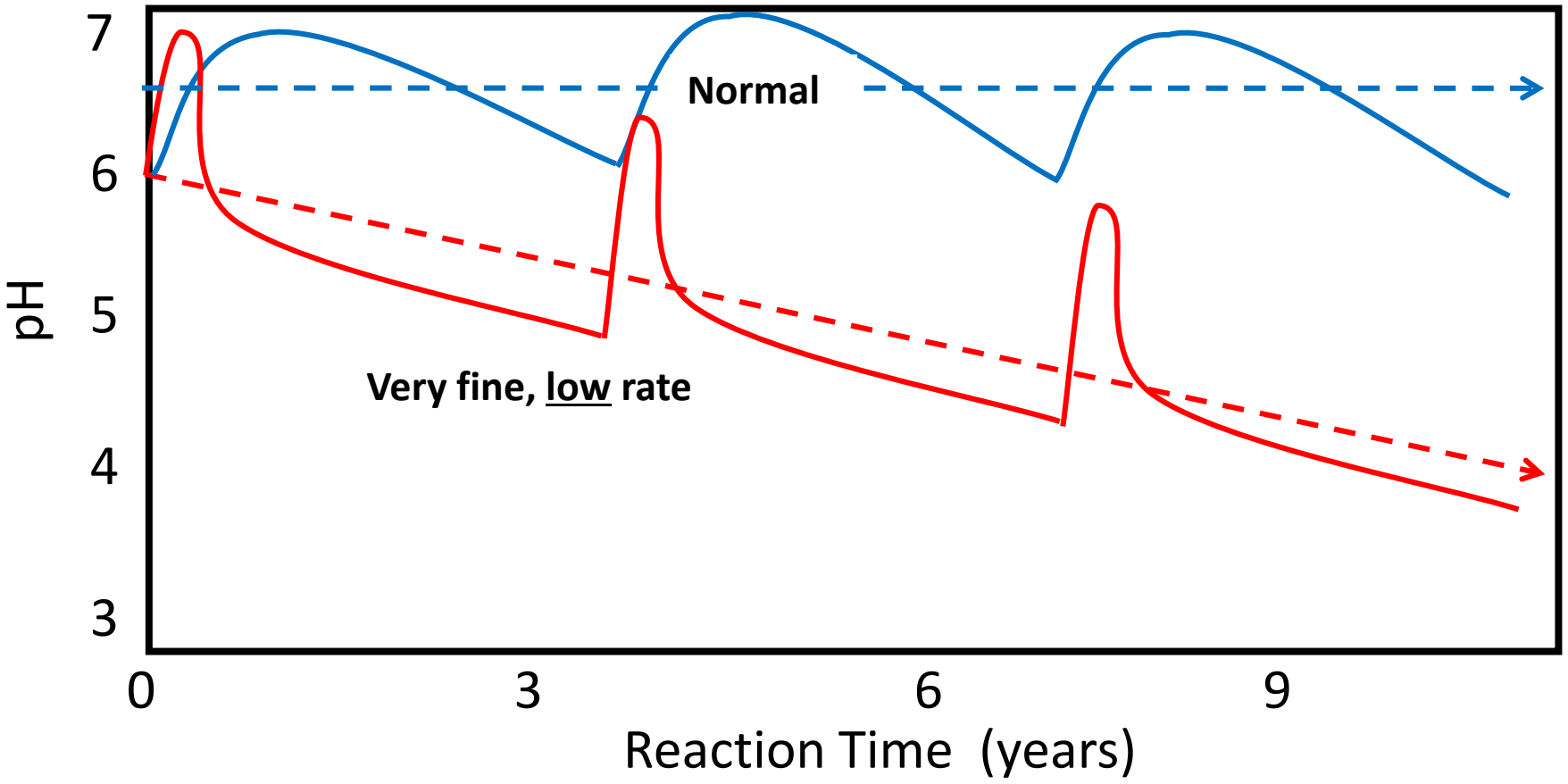
Aglime Quality - ENV

- Calculated value
  - CCE * Fineness
- Must be listed on bag and/or delivery slip

Cornell recommendations are for 100% ENV

$$\text{Actual lime required} = \frac{\text{Recommendation}}{\text{ENV of limestone}} * 100$$

Less than recommended very fine limestone applied compared to normal liming program



Pelleted lime

- Finely ground lime stone
- Glued together into water soluble pellets
- Advantages –
  - Ease of spreading
  - Uniformity
- *Disadvantage - cost*

Alternative Liming Materials

Wood ash
Lime mud

Inexpensive
Nutrient source
Recycling

Calcium Carbonate Equivalence - CCE

Wood ash

25 – 56%

Calcium Carbonate Equivalence - CCE

Lime mud

90 - 100%

Other Liming Agents

SF: 5-43

Other Liming Agents

- Lime stabilized sludge … helps boost pH
- Metals a concern
  - less available / mobile at higher (neutral) pH
- Different biosolids / different metal amounts
- Best use … low quality hay fields

Disadvantages of Other Materials

- Lime supplies adequate Ca and Mg
- Wood ash – good source of K – needed?
- Questionable liming products on market …

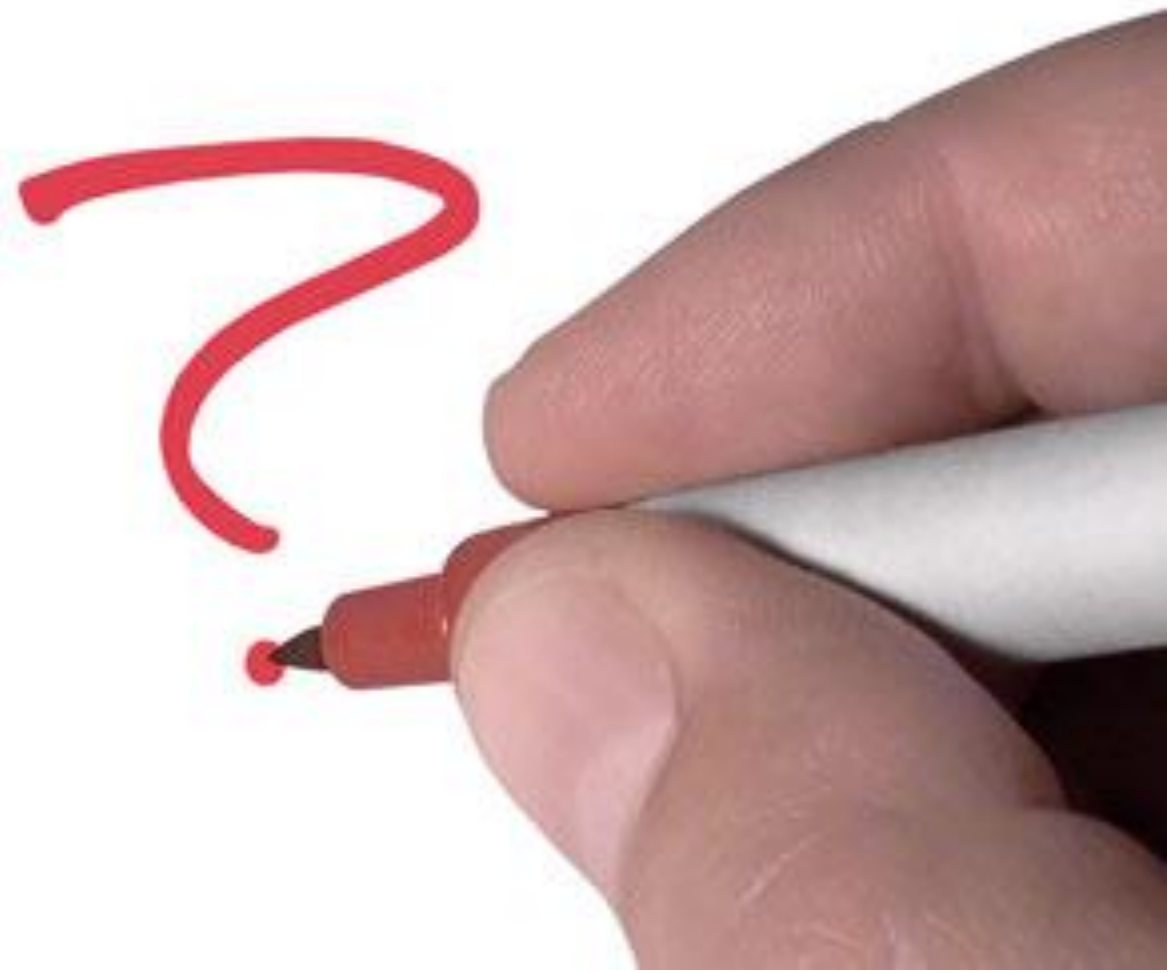
Promesol 30, Liquid Lime
Trihydroxy glutaric acid 25% Ca
1 gallon = 500-750 lb CCE?

Liqui-Til
Trihydroxy glutaric acid
Neutralizes pH in alkaline soil?

KK Organic Soil Builder
Neutralizes both acidic and alkaline soils?

Lime Management Tips

- Soil test … always start there
  - Apply lime 6 mo ahead of sensitive crop
  - Till in if possible
  - If moving to no-till, apply in last tilled yr
  - Split applications if need to apply > 4 t/a
  - Apply in fall
- *Pay attention to Aglime quality*



Question

- As pH decreases, _____ increases?
  - A) hydrogen ion concentration
  - B) hydroxyl ion concentration
  - C) alkalinity
  - D) cation exchange capacity

Answer: a: why ?

Question

- What is pH dependent charge ?
  - A) as pH is decreases – CEC rises?
  - B) as pH increases - CEC decreases
  - C) total alkalinity
  - D) net negativity is dependent on amount of free H in the soil

Answer: d: why ?

Question

- Which of the following soils would have the highest lime requirement to meet the same target pH?
  - A) pH 5, 35% clay, 2% organic matter
  - B) pH 5, 10% clay, 1% organic matter
  - C) pH 6.5, 40% clay, 3.5% organic matter
  - D) pH 6.5, 60% clay, 2.2% organic matter

Answer: a: why ?

Question

- ENV is the product of the CCE and _____?
  - A) ag lime content
  - B) neutralizing power
  - C) basicity
  - D) calcium carbonate equivalence
  - E) fineness of grind

Answer: e: why ?

Question

- Which of the following is least likely to change soil pH
  - A) elemental S
  - B) alum
  - C) ammonium sulfate
  - D) gypsum

Answer: d: why ?