pH and Liming Practices

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Research and Extension

Outline

- What is pH
- Normal pH ranges
- Acid Soil
- Importance of soil pH
- Factors affecting soil pH
- Acid types and measurement
- Neutralizing value of materials
- Soil sampling and pH analysis
- Summary

What is pH

- A measure of the relative acidity of a substance
- Negative logarithm of the hydrogen ion concentraion

pH	H^+Concentration
5.0	0.00001 or 10^{-5}
6.0	0.000001 or 10^{-6}
7.0	0.0000001 or 10^{-7}
8.0	0.00000001 or 10^{-8}

What is pH

- pH is a convenient notation
  - (5.0 is easier to use than 0.00001 or 10^{-5})
- The H in pH stands for hydrogen ions
- A change in pH of one unit equals a 10 fold change in H^+ concentration
- A change of pH 6.0 to 5.7 doubles the acidity

pH Range

< 7.0 Acid

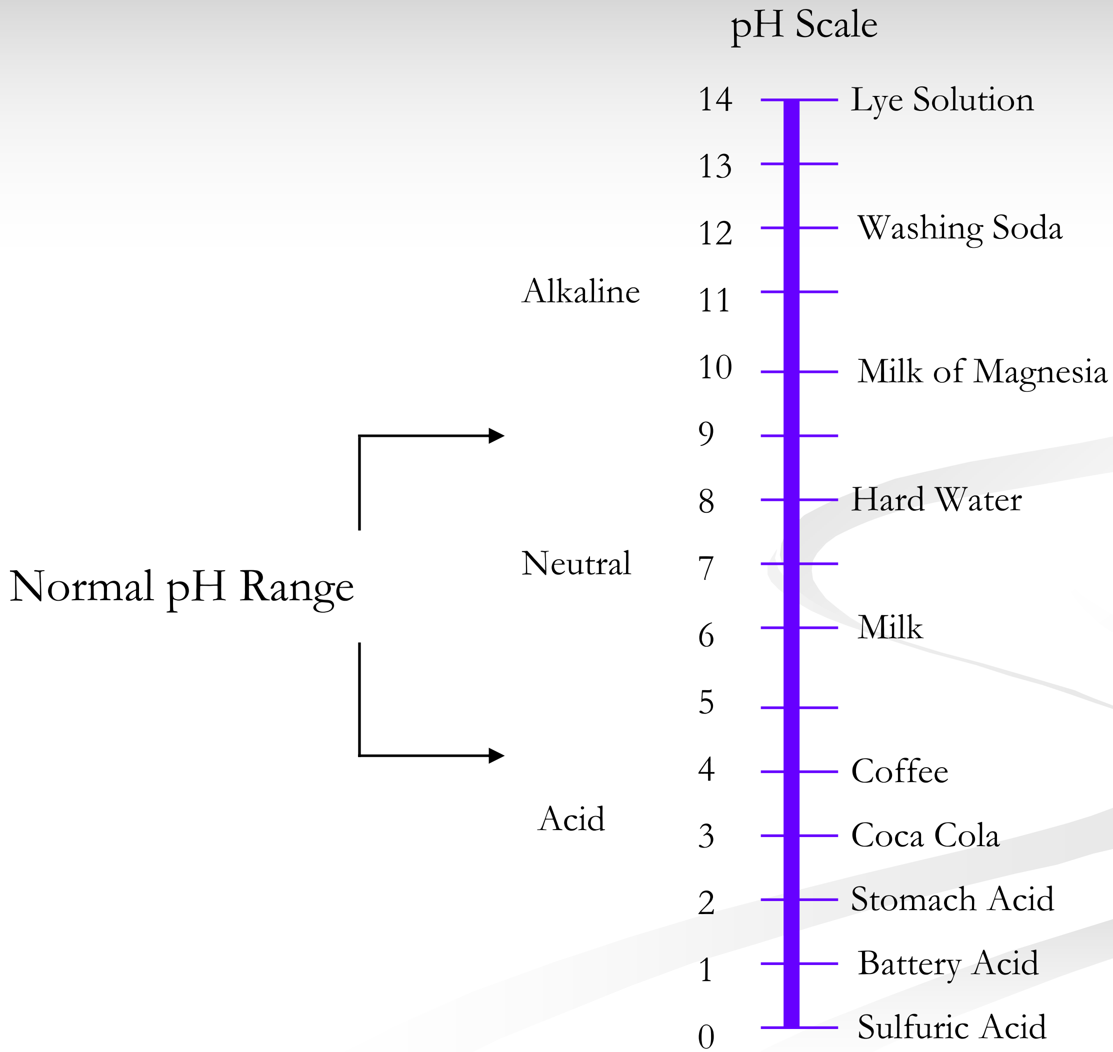
>7.0 Alkaline

0

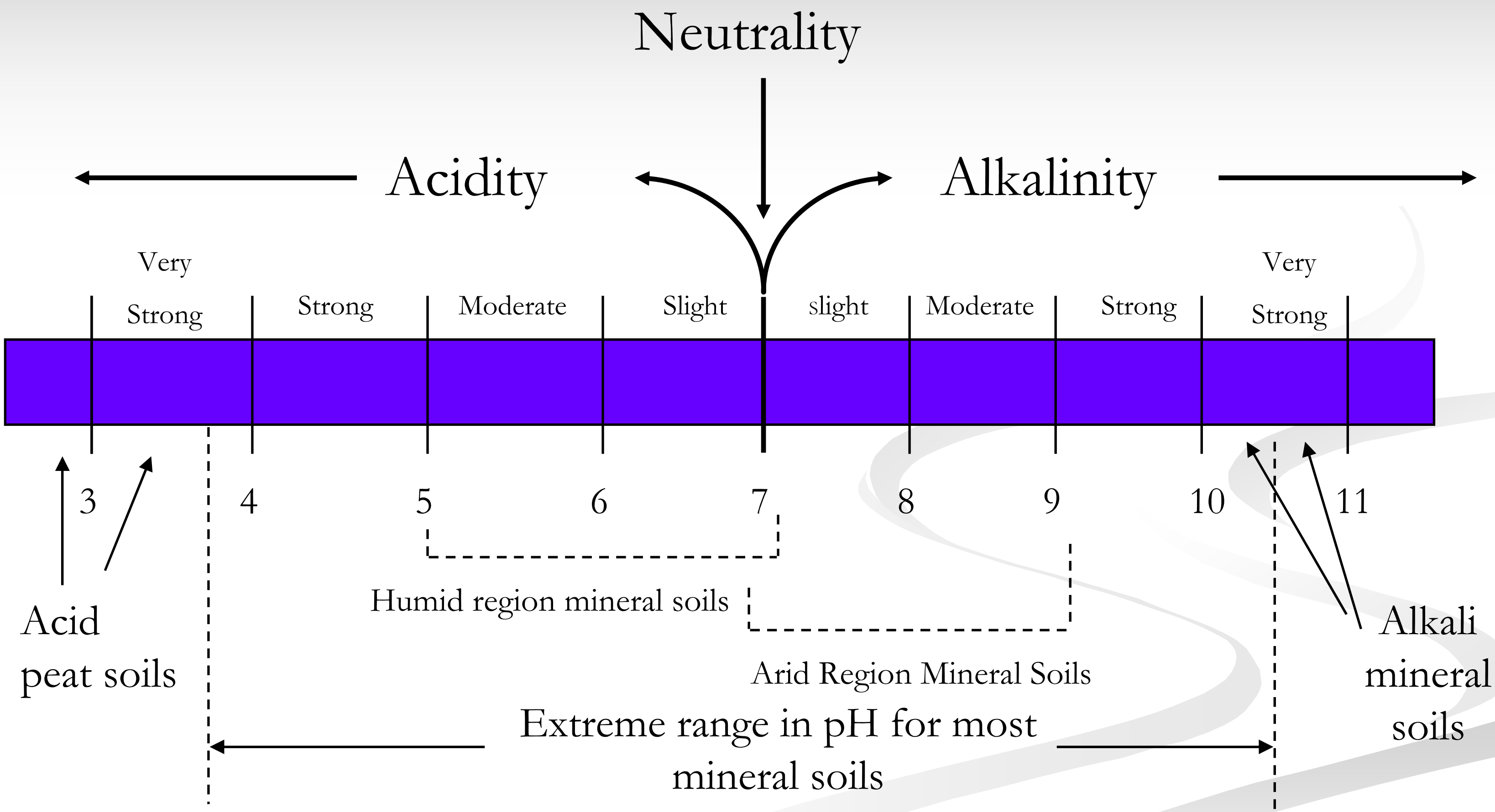
7

14

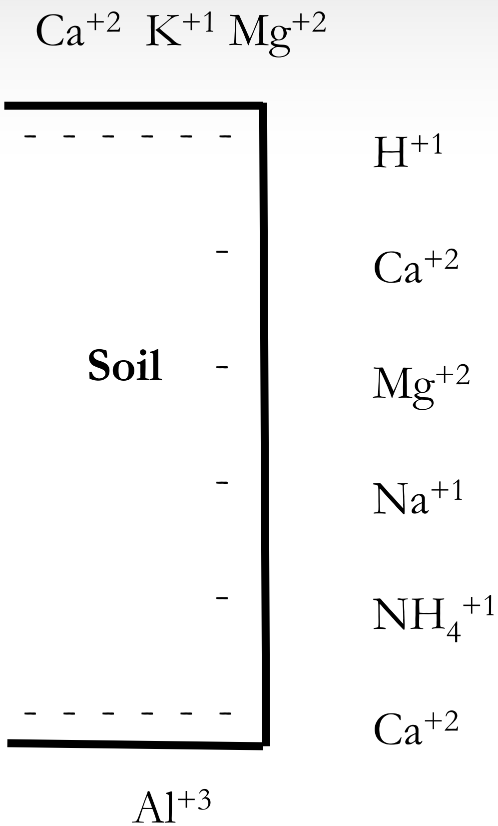
Normal pH Range



Normal pH Range



What is Acid Soil



- Soils have a net negative charge
- Positively charged ions, cations, are retained, preventing their leaching.
- The balance of acidic and basic ions determines soil pH

Importance of Soil pH

- Low pH: Dissolves Al^{+++}
  - 1000 times more soluble at 4.5 pH than 5.5 pH
  - Causes plant toxicity
  - Interferes with microbe activity, which affects:
    - Nutrient cycling
    - Legume nodulation
    - Residue decomposition
    - Diseases
    - Herbicide breakdown and carryover
- High pH: Low nutrient availability
  - P, Zn, Fe

Importance of Soil pH

Low soil pH and Al toxicity

pH 5.2 **pH 4.5**

Reno County, KS 2008

Importance of Soil pH

Wheat response to lime

Lime (ECC/a)	pH	Yield (bu/a)	Al (ppm)
0	4.6	14	102
3000	5.1	37	26
6000	5.9	38	0
12000	6.4	37	0

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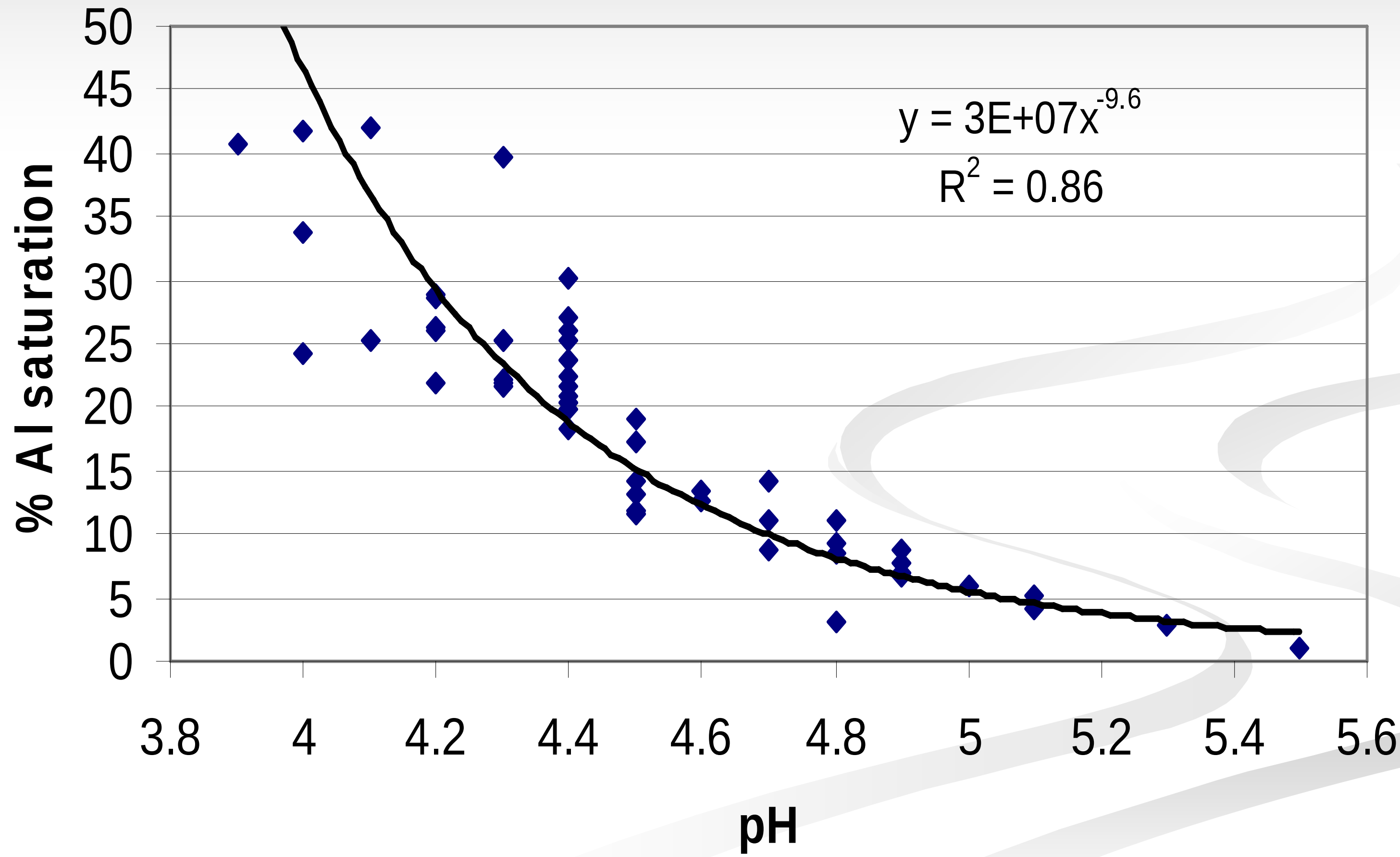
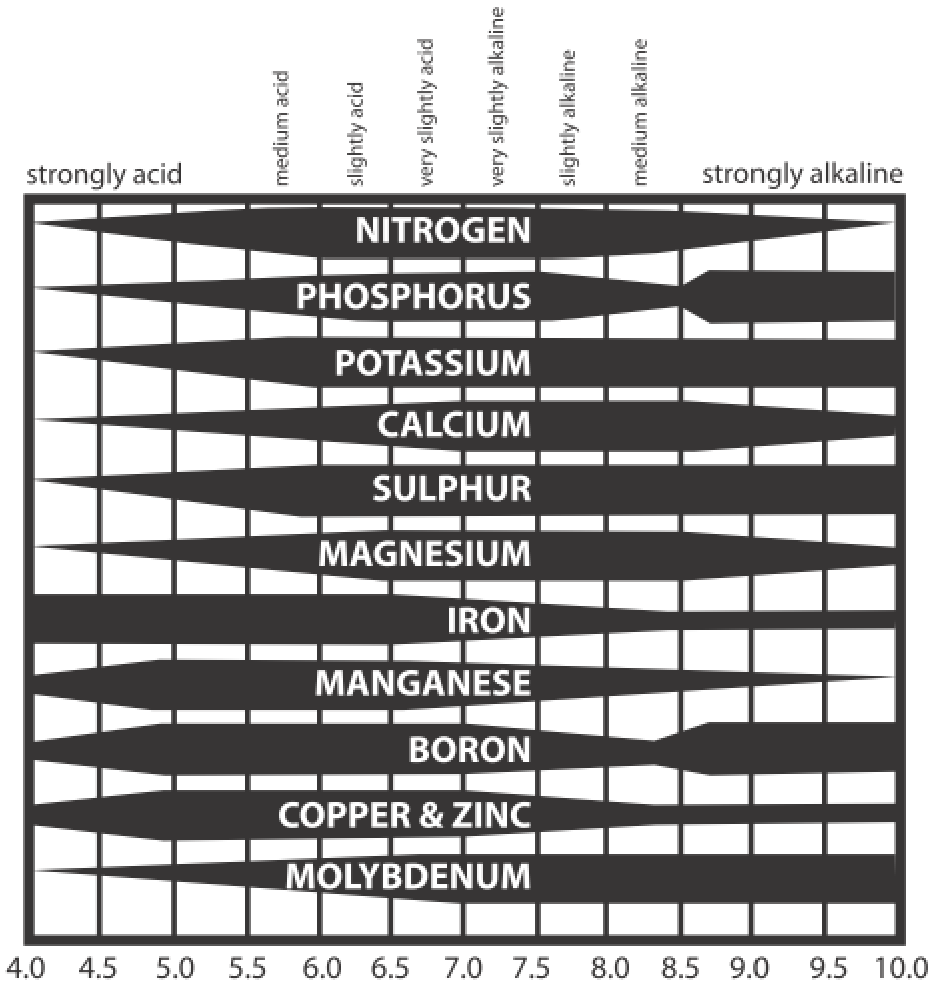
Importance of Soil pH

Active Al Increased by Soil Acidity



Importance of Soil pH



NUTRIENT AVAILABILITY VS. SOIL pH

Colorado State University Extension

Factors Affecting Soil pH

- Parent Material
- Annual Precipitation
  - Higher rainfall → Lower pH
- Native Vegetation
- Crop Grown
  - Legumes remove more Ca and Mg than nonlegumes
- Microbial Nitrification
  - 1-2 lbs of lime to neutralize 1 lb N

Factors Affecting Soil pH

- The process of nitrification creates soil acidity
  - Ammonium conversion to nitrate = H^+ released

$$NH_4^+ + 2O_2 \xrightarrow{\text{Nitrifying Bacteria}} NO_3^- + 2H^+ + H_2O$$

Ammonium **Oxygen** **Nitrate** **Hydrogen** **Water**

- Lime required to neutralize acidity from N application

N Source	Lb ECC/lb N
Ammonia, Urea, UAN	1.8
Ammonium Sulfate	5.4
DAP	3.6
MAP	7.2

Factors Affecting Soil pH

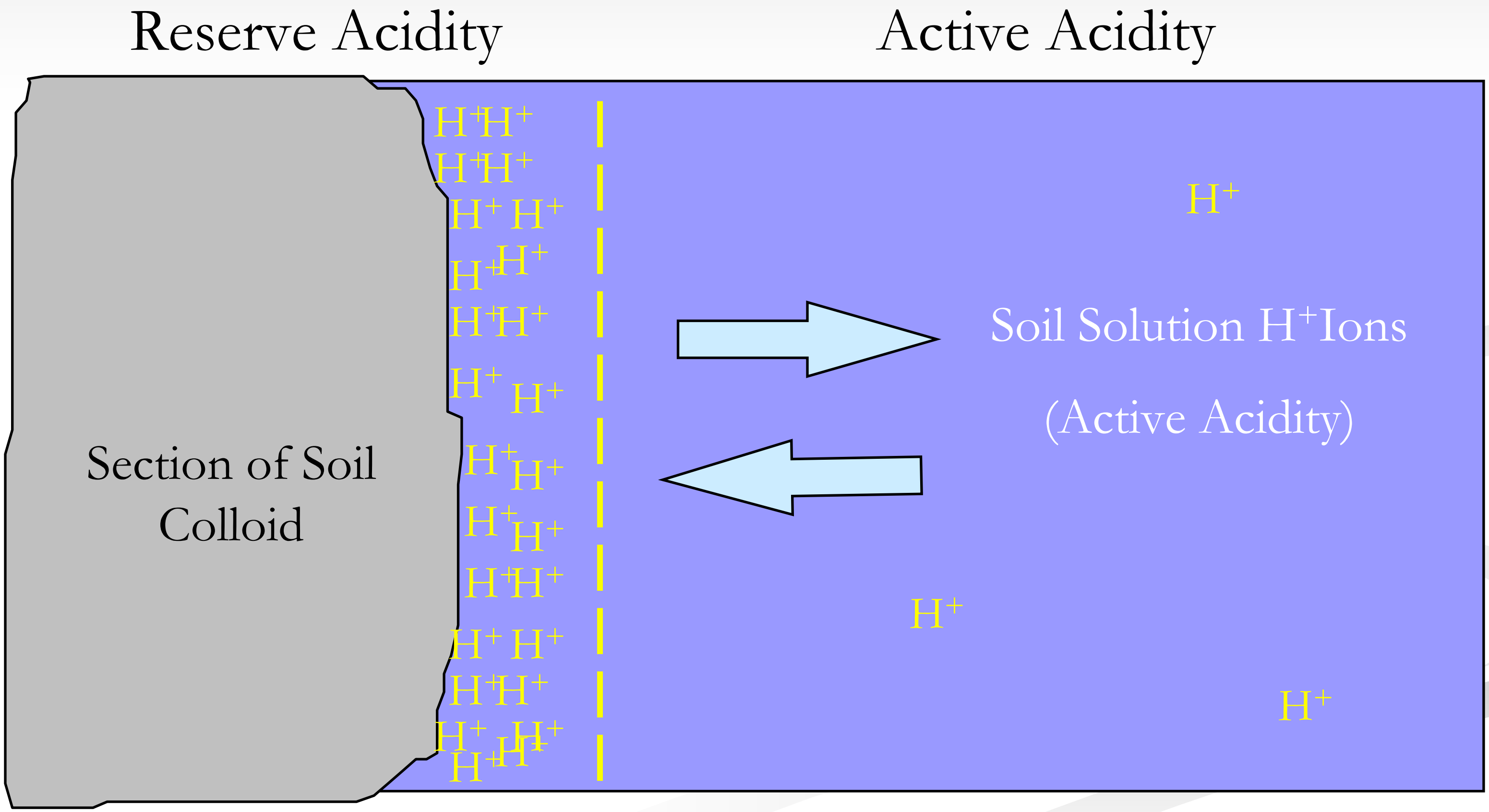
N Rate	Continuous Corn	Sorn/Soybean
	---------------Soil pH---------------	
0	6.5	6.5
50	6.0	6.4
100	5.5	6.3
200	4.8	5.8

North Central Kansas Experiment Field, Dr. Barney Gordon

Acid Types and Measurement

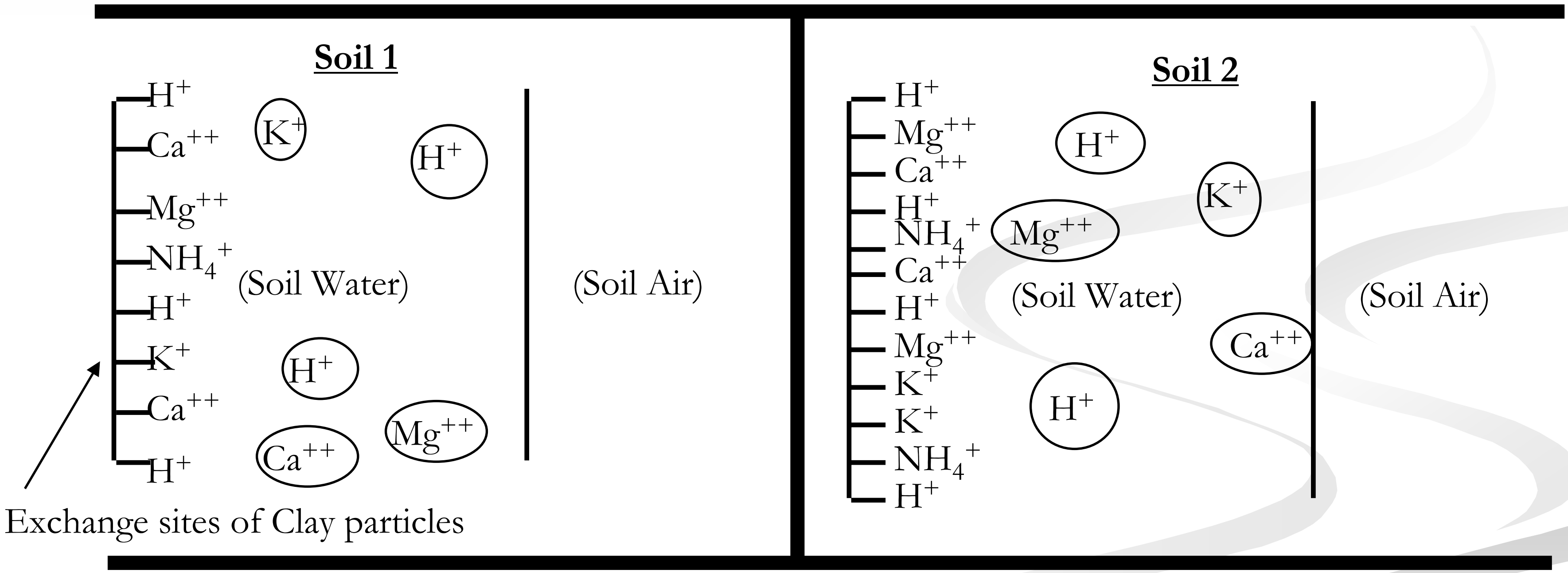
- Active Acidity
  - Affects soil chemical reactions and plant growth
  - Measured as soil or water pH
  - Neutralized by <1 pound calcium carbonate/acre
- Reserve Acidity
  - The total acidity
  - Affects the quantity of lime required
  - Measured by buffer pH (buffer index)

Acid Types and Measurement



Acid Types and Measurement

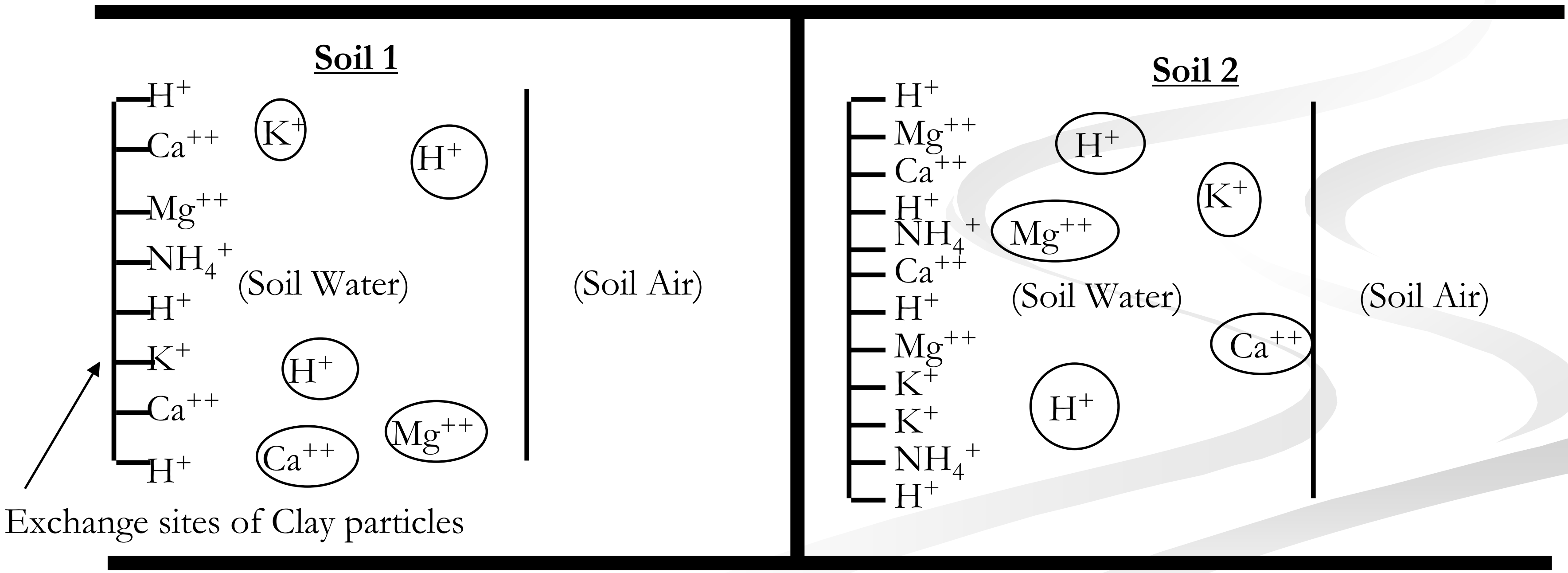
- Soil pH is a measure of the acidity of the soil solution
- Buffer pH is a measure of the potential acidity due to the soil solution and the exchange sites



- Same soil pH values, but different buffer pH; soil 2 will require more lime than soil 1.

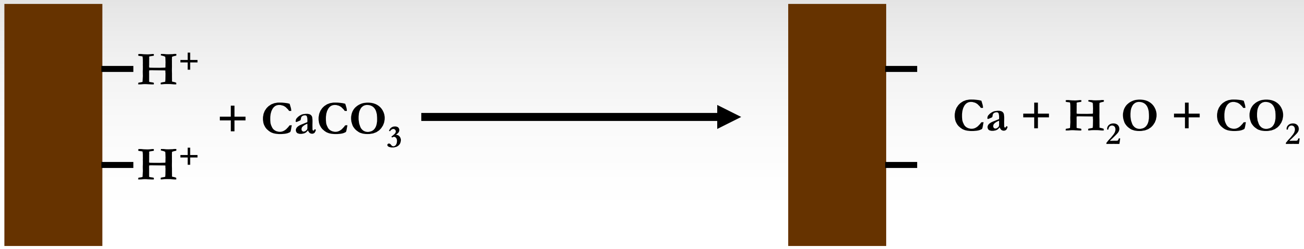
Acid Types and Measurement

- Could we use this as an example of sandy loam vs. clay loam

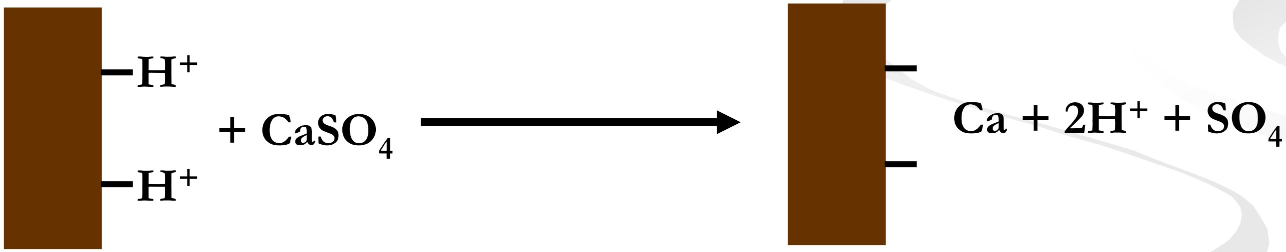


How Does Lime Work?

Calcium Carbonate



Gypsum



Neutralizing Value of Materials

Liming Material	Composition	Relative Neutralizing Value
Calcium Carbonate	$CaCO_3$	100
Calcitic Lime	$CaCO_3$ + Impurities	50-100
Dolomitic Lime	$CaCO_3$ + $MgCO_3$ +Impurities	90-109
Quicklime (burned lime)	CaO	150-180
Hydrated lime (slaked lime)	$Ca(OH)_2$	115-135
Ground shells		80-90
Wood ashes		40-80

Neutralizing Value of Materials

- Determined by:
  - Purity – calcium carbonate equivalent
    - % liming agent vs. % inert materials
  - Fineness – particle size
    - Determined by dry sieves (8 and 60 mesh)
    - Fine particles dissolve more quickly than coarse
  - Expressed as Effective Calcium Carbonate Equivalent (ECCE)

Neutralizing Value of Materials

Size Fraction	Dissolved After 1 Year (%)
< 60 mesh	100
60-8 mesh	50
>8 mesh	0

Neutralizing Value of Materials

Example:

Size Fraction	Material (%)	Effectiveness Factor	Effectiveness
>8	0	0.0	0
8-60	60	0.5	30
<60	40	1.0	40

Fineness = 70

If a quarry has 80% CCE, the ECC is $70 \times 0.86 = 60.2$

(Combination of purity and fineness)

Neutralizing Value of Materials

Pros	Cons
Ag Lime	
Typically lowest cost	Difficulty of uniform application
Residual benefits	Hard on equipment
Highest producer profitability	Small margins for vendors
Fluid Lime	
Uniform application	Higher cost than ag lime
Quick effect on pH	High rates not practical
Profit for vendors	Applied as fluid slurry
Pel-Lime	
Uniform application	Highest cost
Quick effect on pH	Adequate rates not practical
Profit for vendors	Too attractive marketing

Soil Sampling and pH Analysis

- Soil sampling should match the depth of incorporation
  - No-till depth should be about 3 inches
- Sample analysis
  - 1:1 water slurry measured with pH probe
  - Buffer pH measured after addition of solution (SMP, Mehlich, Sikora)
- Soil test results: pH and buffer pH (if pH < 6.0)

Soil Sampling and pH Analysis

	1:1 Soil pH (% of total samples submitted)							
	5.0 or lower	5.1 to 5.5	5.6 to 6.0	6.1 to 6.4	6.5 to 7.0	7.1 to 7.5	7.6 to 8.3	8.4 or higher
North Central	4.1	12.4	31.4	17.4	16.7	8.0	9.0	0.9
Central	6.9	13.4	25.5	14.6	15.6	9.7	13.4	0.9
South Central	8.1	13.2	24.1	15.8	15.4	9.9	12.2	1.3

KSU Soil Testing Lab, 2002-2006

Soil Sampling and pH Analysis

Lime Recommendations (Lb ECC/A)[1]

Buffer pH	Target pH = 6.8	Target pH = 6.0	Target pH = 5.5
	- - - - - -	lb ECC/acre	- - - - -
7.4	0	0	0
7.2	750	375	250
7.0	1,750	875	500
6.8	3,000	1,500	750
6.6	4,500	2,250	1,125
6.4	6,250	3,125	1,625
6.2	8,250	4,125	2,000
6.0	10,250 [2]	5,125	2,625
5.8	12,500 [2]	6,250	3,125
5.6	15,250 [2]	7,625	3,750
5.4	18,000 [2]	9,000	4,500
5.2	20,000 [2]	10,375 [2]	5,250

[1] *Based on 6.67 inch soil depth. Soil Depth is the depth of incorporation through rotation. For No-Till systems, alfalfa and grass –assume 2 inch depth of incorporation (≈1/3 of rate for 6-7 inch depth).*

[2] *When lime recommendation exceeds 10,000 lb ECC/A, we suggest applying one-half rate, incorporate, wait 12 to 18 months and then retest.*

Target pH of 6.8 = [25,620 – (6,360 × Buffer pH) + (Buffer pH × Buffer pH × 391)] × Depth (inches)

All crops in Southeast Kansas –east of Flinthills & south of Highway 56
Alfalfa and clover in Northeast Kansas
Lime Rec if pH < 6.4

Target pH of 6.0 = [12,810 – (3,180 × Buffer pH) + (Buffer pH × Buffer pH × 196)] × Depth (inches)

All crops in Northeast Kansas except alfalfa and clover
All crops in Central and Western Kansas
Lime Rec if pH < 5.8

Target pH of 5.5 = [6,405 – (1,590 × Buffer pH) + (Buffer pH × Buffer pH × 98)] × Depth (inches)

Cash flow/lime availability problem areas in Central and Western Kansas

Lime Rec if pH < 5.5

Soil Sampling and pH Analysis

Know and adjust for incorporation depth

Incorporation Depth (inch)	Adjustment Factor
3	0.43
5	0.71
7	1.00
9	1.29
11	1.57

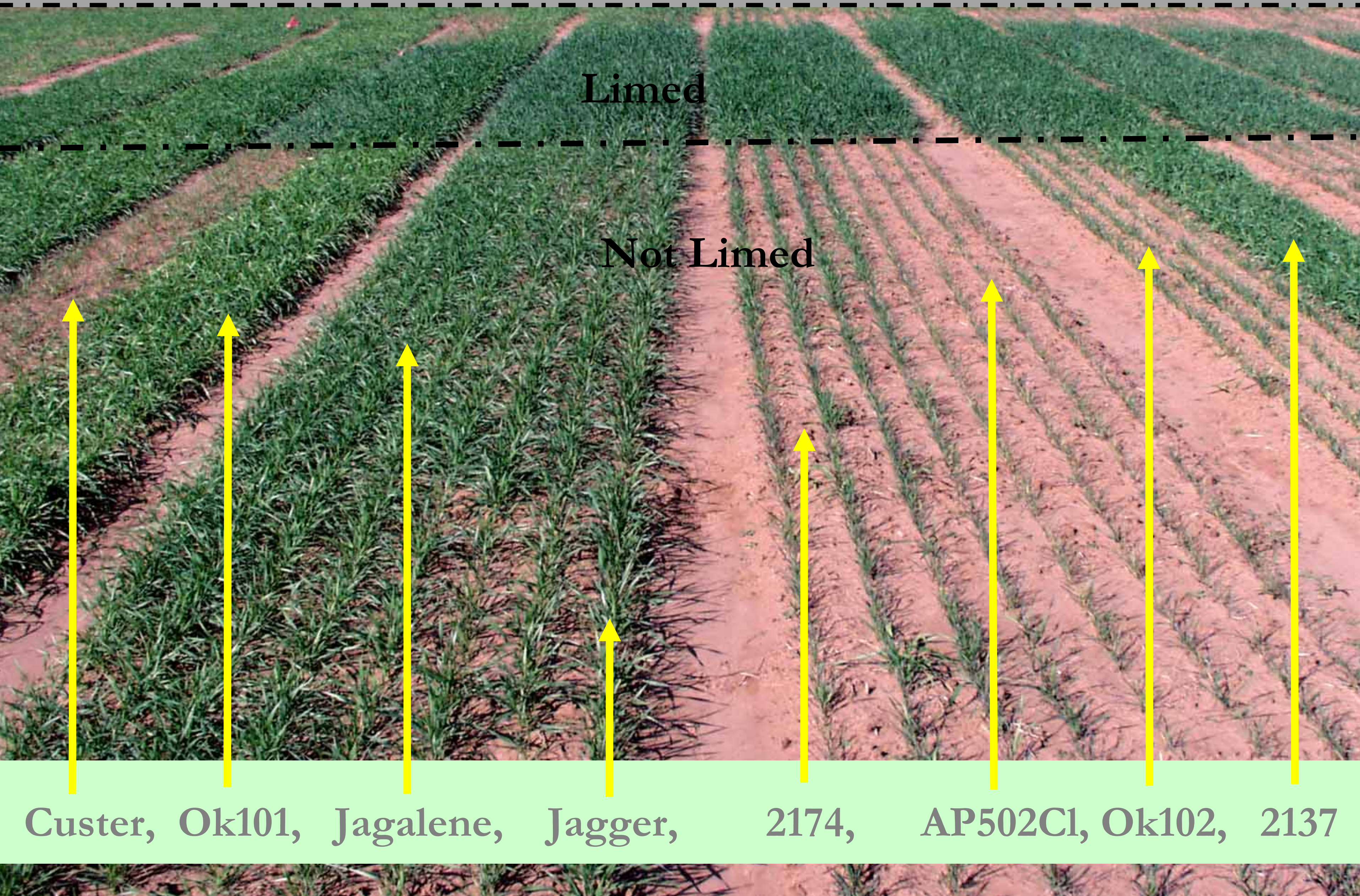
Soil Sampling and pH Analysis

- Timing and application of lime
  - Apply 3-12 months before planting
  - Mix with soil if possible (if no-till, allow more time for activity)
  - Adjust for tillage depth

Soil Sampling and pH Analysis

- Know assumptions of lime recommendations
  - Lime quality
  - Incorporation depth
    - Rotational tillage
    - No-till
    - Crop
  - Target pH
    - Crop
    - Geography
    - Financial considerations

Variety Response to Soil pH



Soil Acidity Effect on Wheat

pH	Relative Yield	Yield bu/a
3.8	0	0
4.1	30%	12
4.5	60%	24
5.0	85%	34
5.5	95%	38
6.0	100%	40

Oklahoma State University

Effect of pH on Alfalfa

Summary

- Soil pH is dropping in Kansas, in large part due to the use of N and P fertilizers
- Soil pH is becoming low enough to cause crop issues in many areas, but especially in Central Kansas
- Current fertilizer prices and production economics suggest liming, even if lime has to be hauled some distance should be considered.