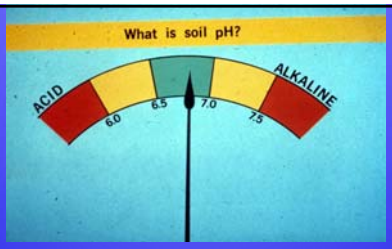
# Soil pH

Paulo Pagliari

Department of Soil, Water, and Climate

University of Minnesota



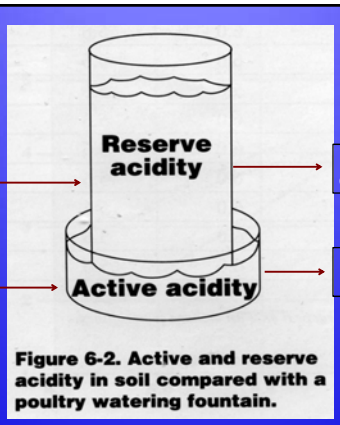

- pH = – log [$H^+$]

• pH decreases as [$H^+$] increases: 0.0001 g $H^+$ $kg^{-1}$ soil will have pH of 4; change [$H^+$] to 0.001 g $H^+$ $kg^{-1}$ soil pH will go to 3 – ACIDIC

• pH increases as [$H^+$] decreases: 0.0000001 g $H^+$ $kg^{-1}$ soil will have pH of 7; change [$H^+$] to 0.00000001 g $H^+$ $kg^{-1}$ soil pH will go to 8 – ALKALINE

Buffer pH Sikora

Soil pH water



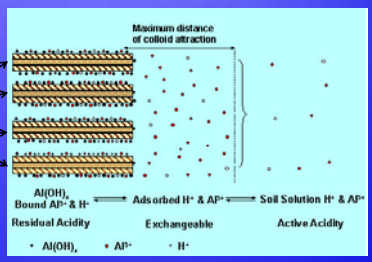

[$H^+$] and [$Al^{+3}$] on the CEC + OM

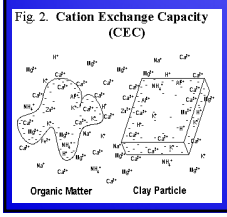
[$H^+$] and [$Al^{+3}$] in the soil solution

**Figure 6-2. Active and reserve acidity in soil compared with a poultry watering fountain.**

# $H^+$ and $Al^{3+}$ in the soil and OM

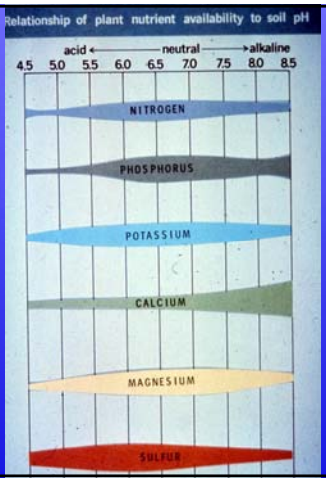
Clay particles

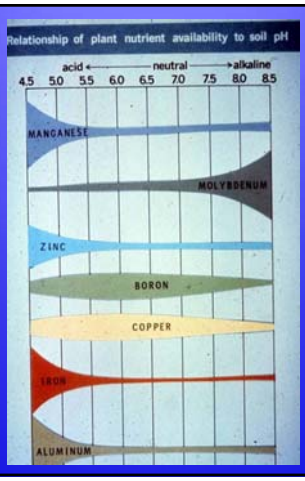


## Soil pH Effects on Soil Properties

- Availability of most essential and **non-essential elements**
- Activity of microorganisms
- Ability of soil to hold cations
- Herbicide performance



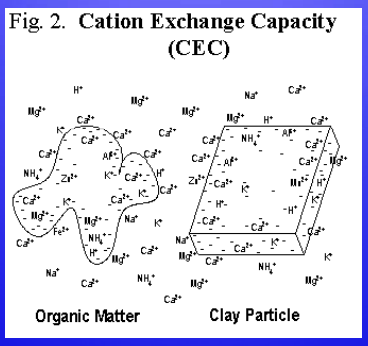

## Soil pH Effects on Soil Properties

- Availability of most essential and non-essential elements
- Activity of microorganisms
  - pH 5.5 - 6.5 best nitrification and OM decomposition rates
- Ability of soil to hold cations

## Soil pH Effects on Soil Properties

- Availability of most essential and non-essential elements
- Activity of microorganisms
  - pH 5.5 6.5 enhance nitrification and OM decomposition
- Ability of soil to hold cations
  - As pH decreases, soil exchange sites get saturated with $H^+$ and $Al^{+3}$
    - cations ($K^+$, $Ca^{+2}$, and $Mg^{+2}$) come off exchange sites and may leach out of soil

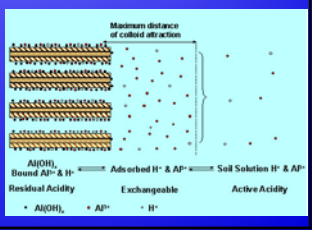
## Soil pH Effects on Soil Properties





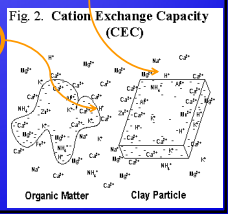
## Causes of Soil Acidification

- Acidic parent material
- Leaching of basic cations + Crop removal of cations
- Use of Nitrogen fertilizers
- Other- Acid rain, industrial emissions, internal combustion engines, etc



## Acid Forming Fertilizers

- Nitrification
  - $2NH_4 + 4O_2 \rightleftharpoons 2NO_3 + 2H_2O + 4H^+$
- $NH_4^+$ immobilization
  - $NH_4 + R\text{-}OH \rightleftharpoons R\text{-}NH_2 + H_2O + H^+$




## Effect of Nitrogen Fertilizer on Soil pH

| Nitrogen Applied each year for 5 years | Soil pH* | Aglime needed to return soil pH to 6.1 |
|---|---|---|
| (lbs/a) | | (ton/a) |
| 0 | 6.11 | 0.00 |
| 40 | 6.10 | 0.31 |
| 80 | 6.02 | 0.65 |
| 120 | 5.98 | 0.96 |
| 160 | 5.81 | 2.03 |
| 200 | 5.68 | 2.72 |

Nitrogen applied as ammonium nitrate, Walsh, L.M. 1965; * Soil was a Plano silt loam cropped to corn

## Aglime Required to Neutralize Acid Forming N Fertilizers

| Nitrogen source | Pounds of aglime needed per pound of Nitrogen[1] |
|---|---|
| Ammonium sulfate | 7.5 |
| Diammonium phosphate | 7.5 |
| Anhydrous ammonia | 5 |
| Urea | 5 |
| Solutions (28% - 41% N) | 4 |
| Ammonium nitrate | 4 |

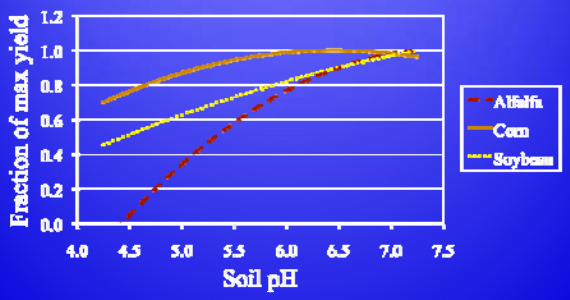
[1]Approximation

## Why do I Need Lime?


One year old stand

One year old stand

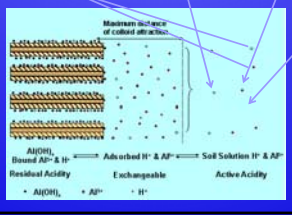

## Effect of Soil pH on Crop Yield Response




## Liming Reaction in Soil

- Calcium does not change soil pH, rather changes %BS
- The oxide, hydroxide, and carbonate present in the lime are the compounds responsible for changes in soil pH

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



[H+] decreased
pH increased

## $Al^{3+}$ Reaction Against pH Increase

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

$$H_2O + 1/3Al^{3+} \rightleftharpoons 1/3Al(OH)_3 + H^+$$

## What Factors Determine the Lime Needs of a Soil

- Soil pH (Active acidity) – determined by soil test (pH in water)
- Buffer pH (Residual acidity) – determined by soil test (pH in Sikora)
- Target pH – determined by crop and crop rotation

## Target pH

- Alfalfa – 6.8
- Red Clover – 6.3
- Soybean – 6.3
- Corn – 6.0
- Pasture – 6.0
- Oats – 5.8

## Target pH

- Rotation of Soybean, Corn, and Alfalfa
  - Soybean – 6.3
  - Corn – 6.0
  - Alfalfa – 6.8
- Alfalfa is the most sensitive so the target pH for the rotation is 6.8


## What Determines the Quality of a Liming Material

- Purity
  - measure of $CaCO_3$ equivalency
- Fineness – a dry sieving process is used
  - exact sieves used vary by state

## The Purity Factor ($CaCO_3$) Equivalent

**Table 6-5. Liming materials and their calcium carbonate ($CaCO_3$) equivalent**

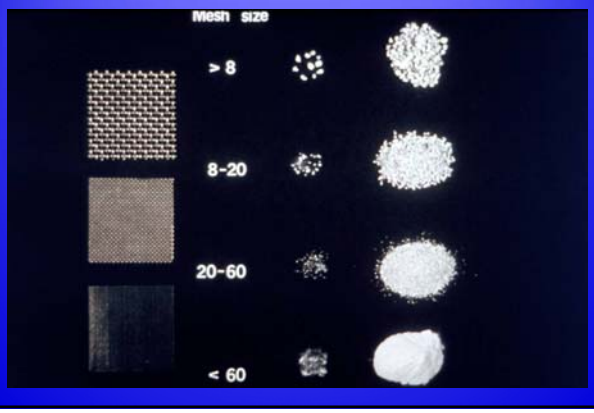
| Liming material | Neutralizing agent | $CaCO_3$ equivalent of pure material (%) |
|---|---|---|
| Dolomitic limestone | $CaCO_3 \cdot MgCO_3$ | 110–118 |
| Papermill lime sludge | Mainly $CaCO_3$ | * |
| Marl | Mainly $CaCO_3$ | variable |
| Calcitic limestone | $CaCO_3$ | 100 |
| Water treatment lime waste | $CaCO_3$ | variable |
| Wood ash | $K_2CO_3$, $CaCO_3$, $MgCO_3$ | 20–90 |
| Fly ash | CaO, $Ca(OH)_2$, $CaCO_3$ | variable |
| Hydrated lime | $Ca(OH)_2$ | 135 |
| Air-slaked lime | $Ca(OH)_2 + CaCO_3$ | 100–135 |

* *According to the Wisconsin Lime Law, one cubic yard of papermill lime sludge is equivalent to one ton of aglime having a neutralizing index of 60–69.*

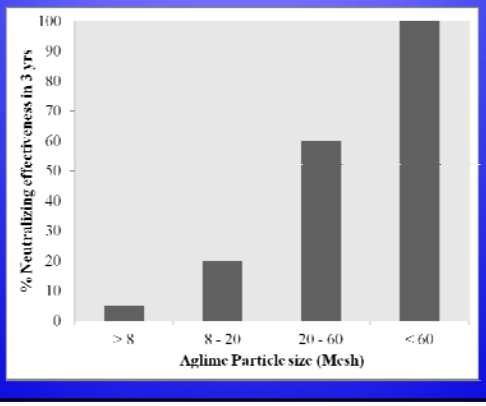
## What Determines the Quality of a Liming Material

- Purity
  - measure of $CaCO_3$ equivalency
- Fineness – a dry sieving process is used

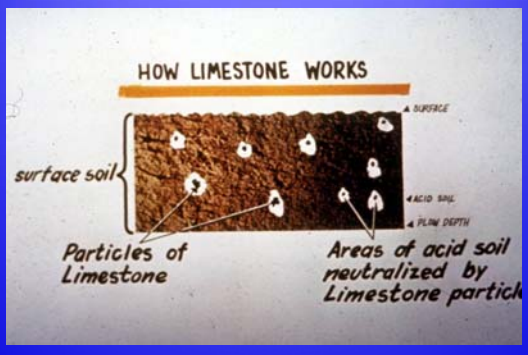
## Particle Size Distribution




## Particle Size Distribution Effect on Soil pH




## Limestone Behavior in Soil




Mixing is critical

**Table 2. Effect of various rates of dolomitic lime sizes on the pH of Withee silt loam**

| Fraction (mesh size) | Soil pH* 1 mo | 1 yr | 2 yr | 3 yr |
|---|---|---|---|---|
| **0 ton/a lime** | | | | |
| — | 4.96 | 5.18 | 5.23 | 5.30 |
| **2 ton/a lime** | | | | |
| 20-40 | 5.04 | 5.39 | 5.70 | 5.91 |
| 40-60 | 5.12 | 5.52 | 5.82 | 6.05 |
| 60-100 | 5.18 | 5.64 | 5.94 | 6.03 |
| < 100 | 5.44 | 5.58 | 5.97 | 6.03 |
| **6 ton/a lime** | | | | |
| 8-20 | 4.98 | 5.28 | 5.78 | 6.10 |
| 20-40 | 5.17 | 5.66 | 6.15 | 6.40 |
| 40-60 | 5.29 | 5.81 | 6.40 | 6.50 |
| 60-100 | 5.33 | 5.95 | 6.48 | 6.60 |
| < 100 | 5.73 | 6.19 | 6.59 | 6.61 |
| **16 ton/a lime** | | | | |
| 8-20 | 5.41 | 5.66 | 6.24 | 6.47 |
| 20-40 | 5.35 | 5.99 | 6.50 | 6.71 |
| 40-60 | 5.56 | 6.10 | 6.63 | 6.81 |
| 60-100 | 5.70 | 6.21 | 6.73 | 6.82 |
| < 100 | 6.17 | 6.45 | 6.97 | 6.98 |

** Each value represents the average of three replicates. Adapted from Love et al. (1960)*

## Calculating the Neutralizing Index (NI) of a Liming Material

**Example 2: Lime B (90% calcium carbonate equivalent)**

| Screen size | Screen analysis | | Effectiveness factor | | |
|---|---|---|---|---|---|
| | % | | | | |
| greater than 8 mesh | 5.0 | x | 0.0 | = | 0.0 |
| 8 to 20 mesh | 25.0 | x | 0.2 | = | 5.0 |
| 20 to 60 mesh | 20.0 | x | 0.6 | = | 12.0 |
| less than 60 mesh | 50.0 | x | 1.0 | = | 50.0 |
| | | | Total | = | 67.0 |

NI = 67.0 x 90% = 60.3

## Calculating Lime Rate

Soil pH in water (WpH) = 5.90
Soil pH in Buffer Sikora (BpH) = 6.79

LR for pH of 6.8 = 195 – 28.4(BpH) + 0.144(WpH)
$LR_{6.8}$ = 3.0 ton/a

**Table 6-7. Aglime conversion table for different neutralizing index zones**

| Lime recommendation* | Zones of lime quality according to neutralizing index values | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40-49 | 50-59 | 60-69 | 70-79 | 80-89 | 90-99 | 100-109+ |
| (ton/a) | tons lime to apply | | | | | | |
| 1 | 1.4 | 1.2 | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 |
| 2 | 2.9 | 2.4 | 2.0 | 1.7 | 1.5 | 1.4 | 1.2 |
| 3 | 4.3 | 3.5 | 3.0 | 2.6 | 2.3 | 2.1 | 1.9 |
| 4 | 5.8 | 4.7 | 4.0 | 3.5 | 3.1 | 2.7 | 2.5 |
| 5 | 7.2 | 5.9 | 5.0 | 4.3 | 3.8 | 3.4 | 3.1 |
| 6 | 8.7 | 7.1 | 6.0 | 5.2 | 4.6 | 4.1 | 3.7 |
| 7 | 10.1 | 8.3 | 7.0 | 6.1 | 5.4 | 4.8 | 4.3 |
| 8 | 11.6 | 9.5 | 8.0 | 6.9 | 6.1 | 5.5 | 5.0 |
| 9 | 13.0 | 10.6 | 9.0 | 7.8 | 6.9 | 6.2 | 5.6 |
| 10 | 14.4 | 11.8 | 10.0 | 8.7 | 7.6 | 6.8 | 6.2 |

* Soil test recommendations are made for lime having a neutralizing index zone of 60–69. To convert a recommendation to a liming material with a different grade, read across the table in the appropriate column.


## Choosing Between Liming Materials

- Example
  - 5 tons of 50-59 NI material at $ 13/ton results in a cost per acre of $ 65
  - 2 tons of 80-89 NI material at $ 16/ton results in a cost per acre of $ 32
  - The cheaper product may not always be the best buy

## Can the Soil pH be Lowered ?

- Some crops may have lower optimum pH range
- Soil pH can be lowered by addition of acid-forming fertilizers

Elemental Sulfur (S)

$2S + 3O_2 + 2H_2O \rightleftharpoons 2SO_4^{-2} + 4H^+$

Aluminum Sulfate $[Al_2(SO_4)_3]$

$Al_2(SO_4)_3 + 6H_2O \rightleftharpoons 2Al(OH)_3 + 3SO_4^{-2} + 6H^+$

Ammonium Nitrate $(NH_4)NO_3$

$NH_4NO_3 + 2O_2 \rightleftharpoons 2NO_3^- + H_2O + 2H^+$

## Thank you for attending!

Question?