# Basic Soil Fertility

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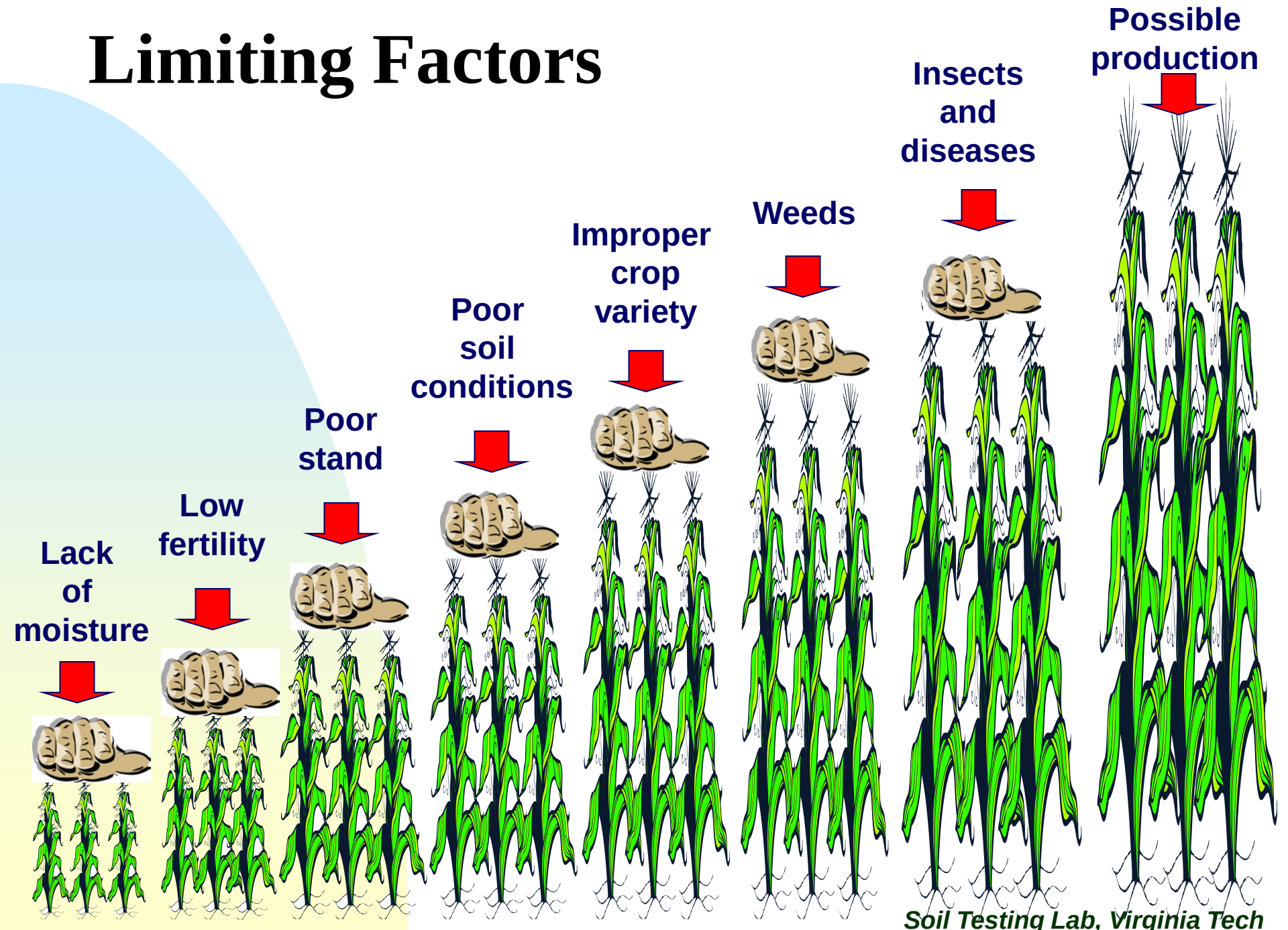
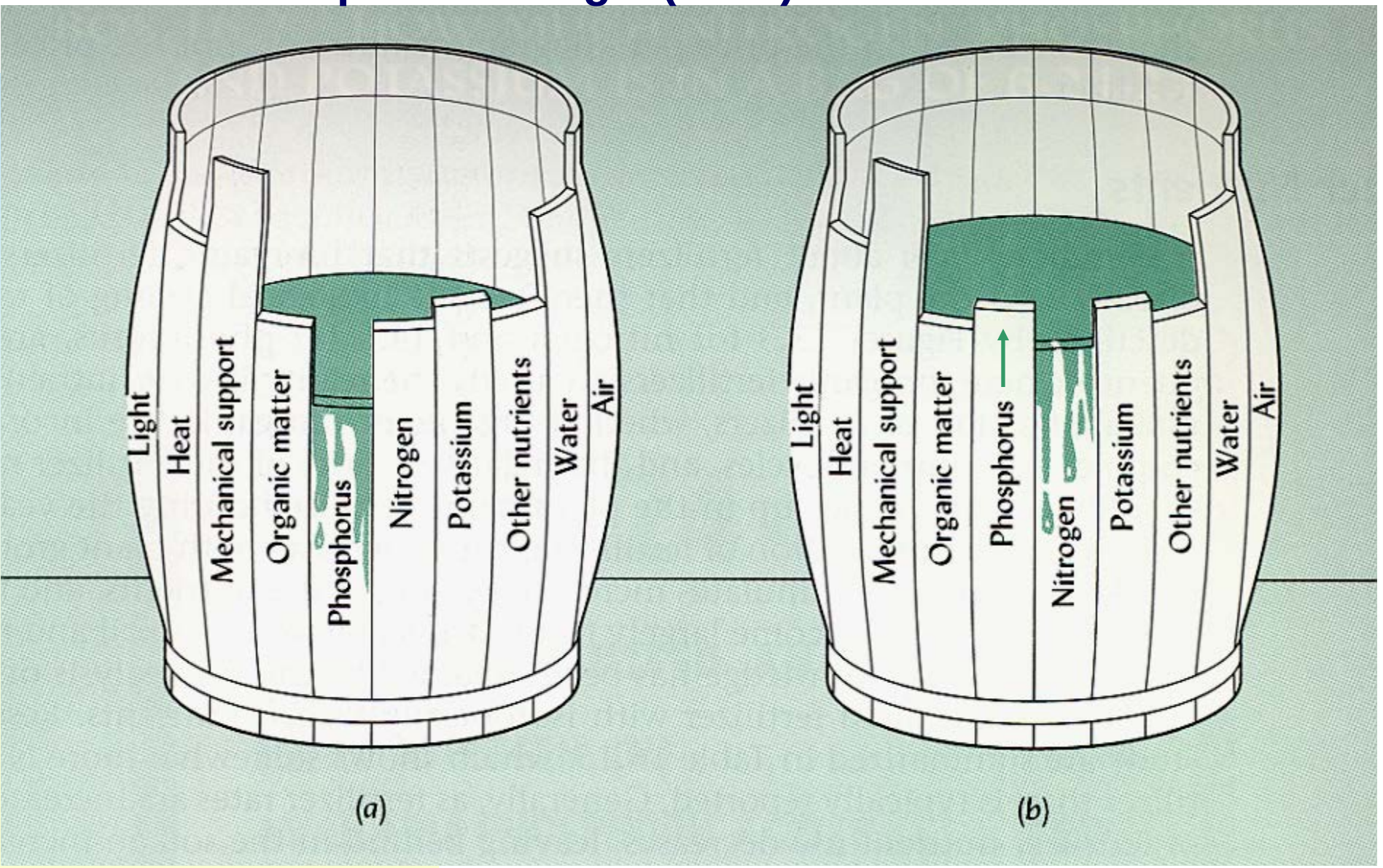
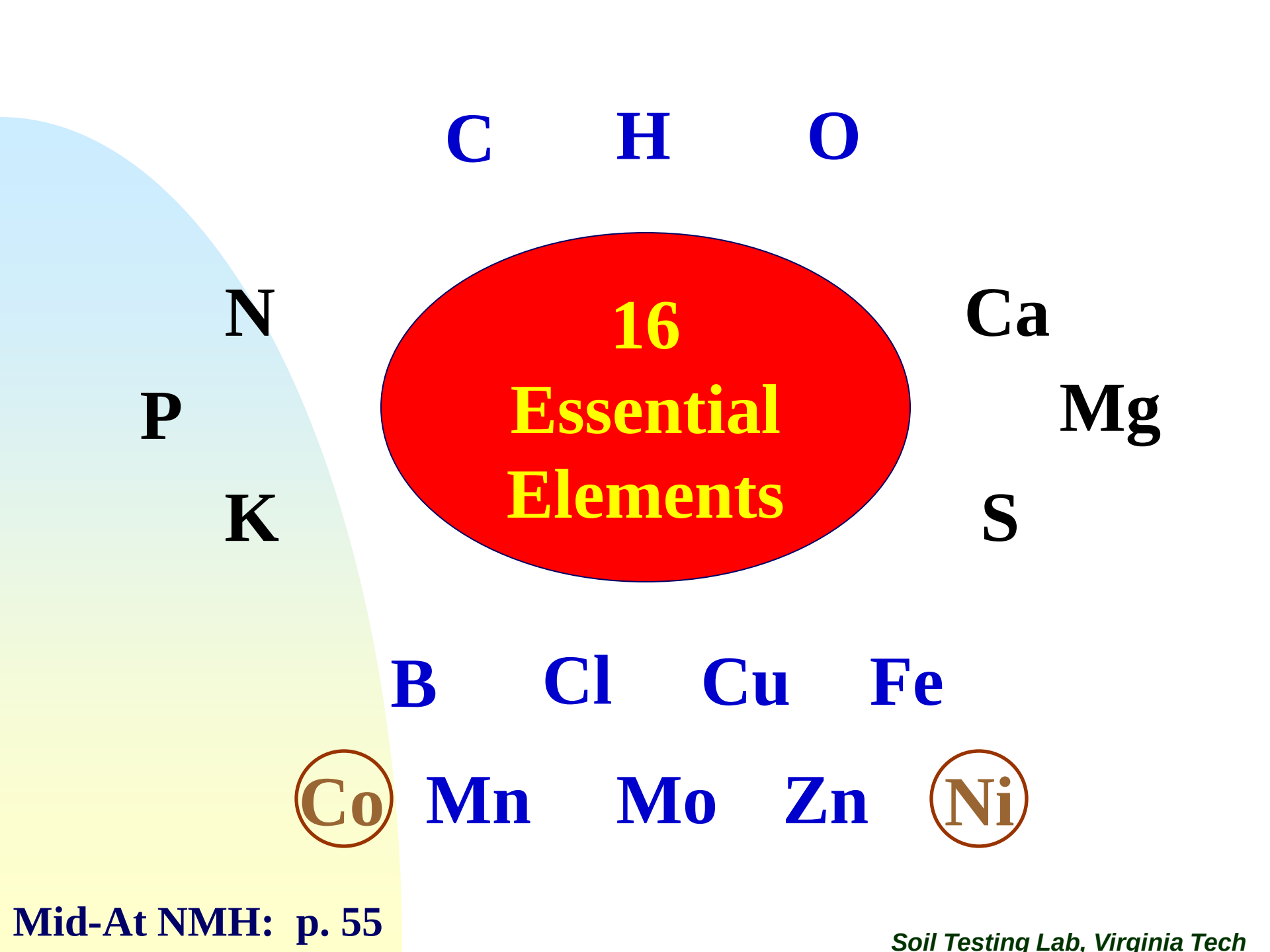
# Limiting Factors



# Example of Liebig's (1842) law of the minimum.




**Yield potential and reproduction are constrained by the essential element (or other Factor) that is the most limiting.**




Mid-At NMH: p. 55

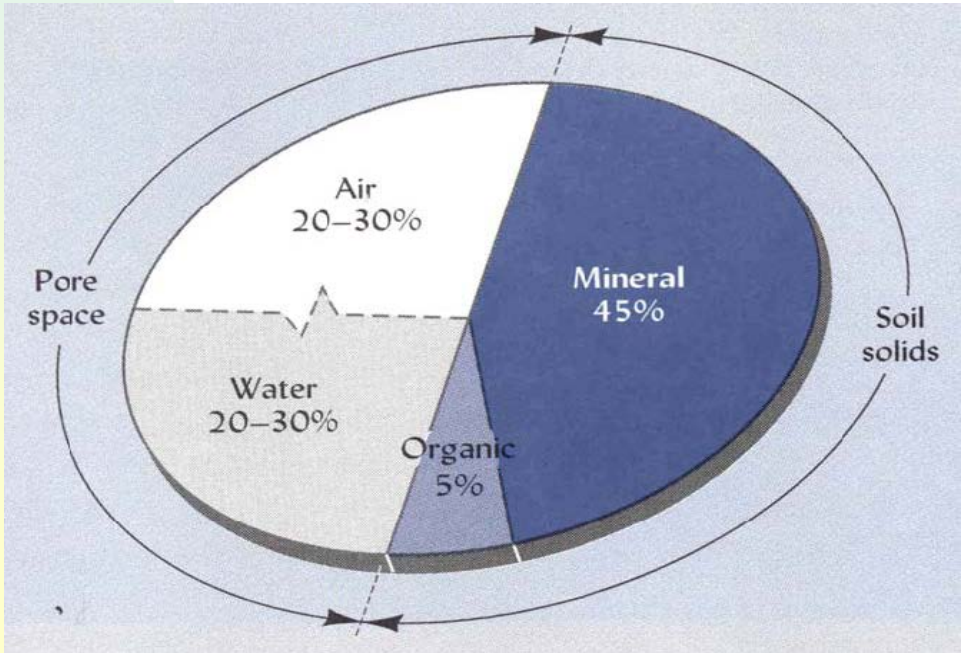
# Non-Mineral Nutrients

- **Non-Mineral Elements**
  - **Carbon (C)**
  - **Hydrogen (H)**
  - **Oxygen (O)**

**Sources:**

**Air ($CO_2$; $O_2$)**

**Water ($H_2O$)**

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# Mineral Nutrients

- **Primary / Major Nutrients**
  - Nitrogen (N)
  - Phosphorus (P)
  - Potassium (K)


- **Secondary Nutrients**
  - Calcium (Ca)
  - Magnesium (Mg)
  - Sulfur (S)

- **Micronutrients or Trace Elements**
  - Boron (B)
  - Chlorine (Cl)
  - Copper (Cu)
  - Iron (Fe)
  - Manganese (Mn)
  - Molybdenum (Mo)
  - Zinc (Zn)

**MANMH: p. 56**

# Mineral Nutrients:
## Alfalfa Hay (4 T/A)

- Major Nutrients
  - Nitrogen: **180 lb**
  - Phosphorus: **40 lb**
  - Potassium: **180 lb**
- Secondary Nutrients
  - Calcium: **107 lb**
  - Magnesium: **12 lb**
  - Sulfur: **19 lb**

- Micronutrients
  - Boron (B)
  - Chlorine (Cl)
  - Copper: **0.07 lb**
  - Iron (Fe)
  - Manganese: **0.43 lb**
  - Molybdenum (Mo)
  - Zinc: **0.41 lb**

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# Plant Available Forms

## Non-Mineral Nutrients

- **Element Available forms**
  - **Carbon: $CO_2$**
  - **Hydrogen: $H^+$, $OH^-$**
  - **Oxygen: $O_2$**

**MANMH: p. 55**

**www.mawaterquality.org/Publications/pubs/manhcomplete.pdf**

# Plant Available Forms:

## Mineral Nutrients

- **Primary Nutrients**
  - **Nitrogen:** $NH_4^+$; $NO_3^-$
  - **Phosphorus:** $HPO_4^{-2}$; $H_2PO_4^-$
  - **Potassium:** $K^+$

- **Secondary Nutrients**
  - **Calcium:** $Ca^{+2}$
  - **Magnesium:** $Mg^{+2}$
  - **Sulfur:** $SO_3^{-2}$; $SO_4^{-2}$

**MANMH: p. 55**

# Plant Available Forms:

## Mineral Nutrients

- **Micronutrients**
  - **Boron:** $BO_3^{3-}$; $H_3BO_3$
  - **Chlorine:** $Cl^-$
  - **Copper:** $Cu^{2+}$; $Cu^+$
  - **Iron:** $Fe^{+2}$; $Fe^{+3}$
  - **Manganese:** $Mn^{+2}$; $Mn^{+4}$
  - **Molybdenum:** $MoO_4^{2-}$
  - **Zinc:** $Zn^{2+}$

**MANMH: p. 55**

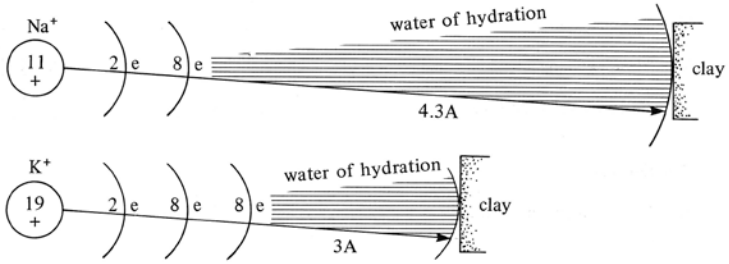
# Normal Sources of Plant Nutrients

- **Nitrogen (N) – Soil/Fertilizer**
- **Phosphorus (P), Potassium (K ) – Soil/Fertilizer**
- **Calcium (Ca), Magnesium (Mg) – Soil/Lime**
- **Sulfur (S) - Soil**
- **Micronutrients (boron, chlorine, copper, iron, manganese, molybdenum & zinc) - Soil**

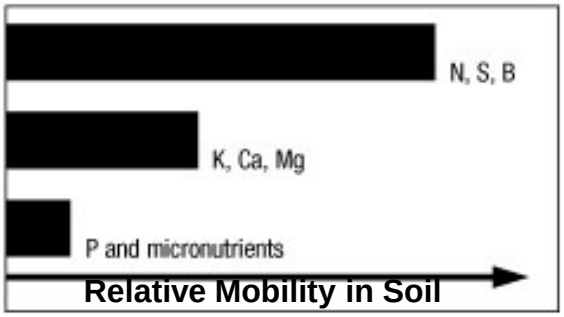
**Supplement with Fertilizers & Amendments**

# Nutrient Mobility in Soils

- **Depends on a number of factors**
  - **Charge of the ion**
  - **Size or diameter of ion**




    - **High charge + small diameter = high retention**
  - **Type of charge:**
    - **Anions (e.g. $NO_3^-$) in general leach more easily than cations**
    - **Phosphate is an exception**

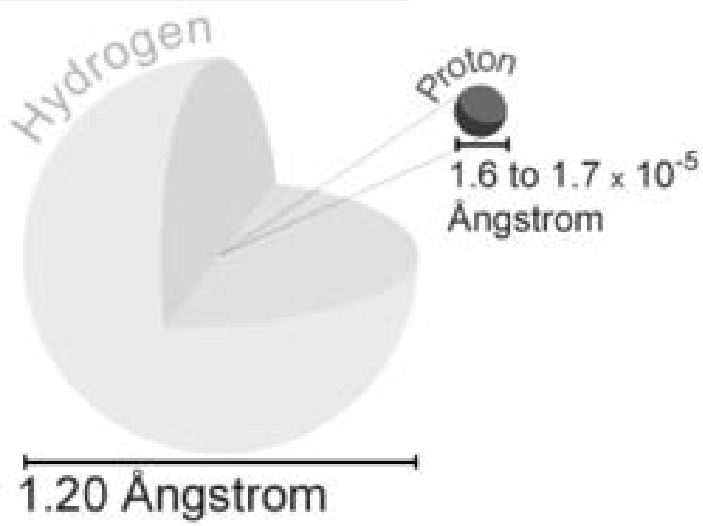



**MANMH: p.48**

# Nutrient Mobility in Soils

- **Degree or strength of retention:**

  **$(H^+)Al^{3+} >> Ca^{2+} > Mg^{2+} > K^+ = NH^{4+} > Na^+$**




**MANMH: p.48**

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# Translocation of Nutrients in the Plant

- **Mineral nutrients taken up from the soil are absorbed through the root system**
- **Nutrients differ in their mobility in the plant:**
- **Mobile Nutrients are elements that can move within the plant, and the plant has the ability to translocate the element from one part of the plant to another**
- **Mobile Nutrients – Generally move from older parts of the plant to the growing point to permit proper plant growth and development**

# Translocation of Nutrients in the Plant

- **Mobile Nutrients:**
  - Nitrogen
  - Phosphorus
  - Potassium
  - Magnesium
  - Sulfur (somewhat immobile)
- **Immobile Nutrients:**
  - Calcium
  - Boron
  - Copper
  - Iron
  - Manganese
  - Zinc
  - Molybdenum
  - Chlorine (mobile)

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**MANMH: p. 60-63**

# Translocation of Nutrients in the Plant

- **Visual diagnosis of nutrient deficiencies is risky**
- **Visual diagnosis can be confusing due to confounding effects of more than one deficient nutrient**
- **Should combine with soil and tissue testing before investing in additional fertilizer applications**

**MANMH: p. 59**

# IPNI's $30 CD (item # 82-8290) on Nutrient Deficiency Images http://store.ipni.net


**MANMH: p. 60-63**

INTERNATIONAL PLANT NUTRITION INSTITUTE

*Soil Testing Lab, Virginia Tech*

# www.plantmanagementnetwork.org


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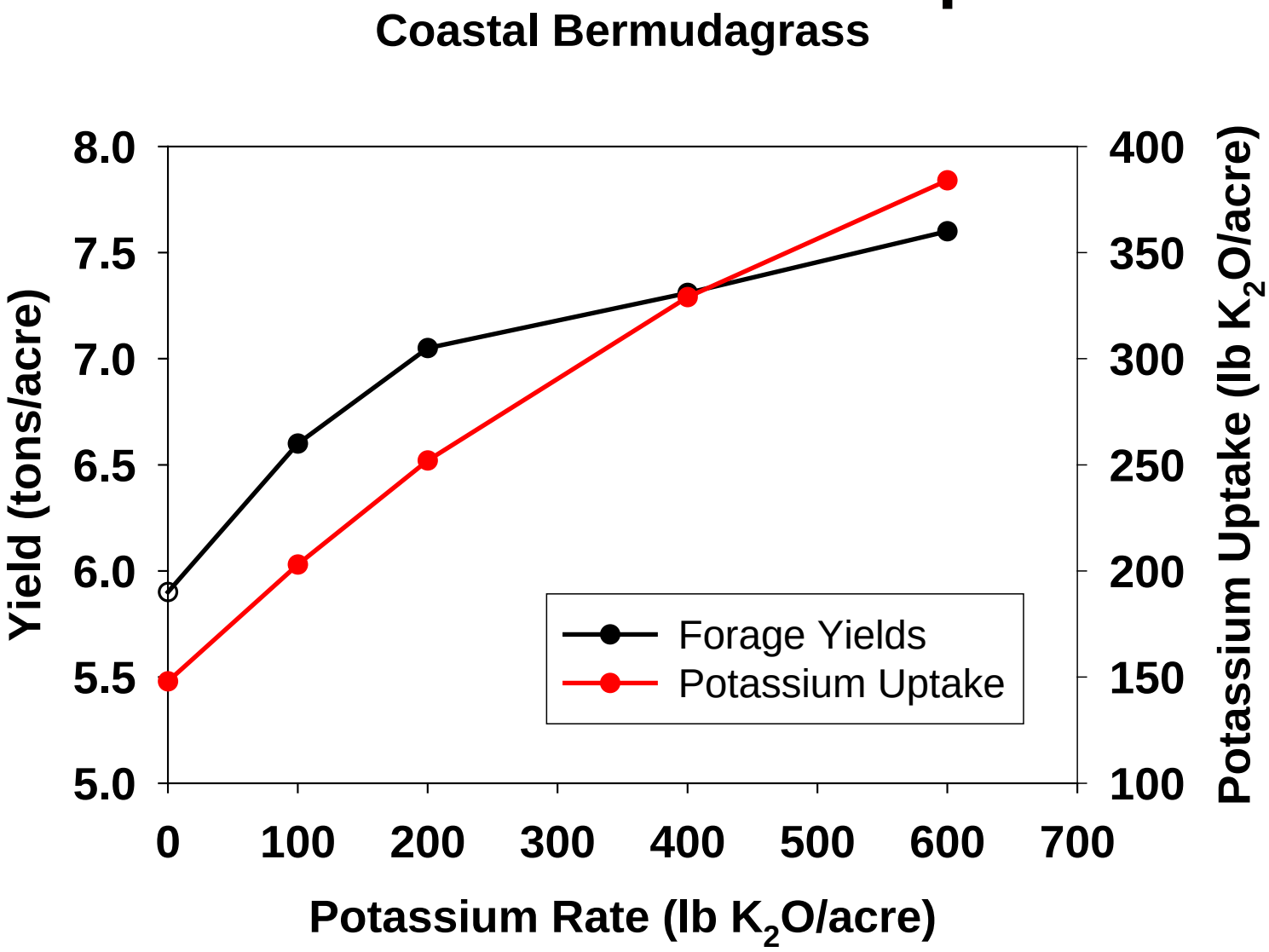
# Potassium

Potassium Deficient Corn

# K Deficient Soybean

# Potassium Yield Response




(Eichhorn, 1982)

# Potassium

- Taken up by the plant as $K^+$
- Does not form organic compounds in the plant
- Is vital to photosynthesis and protein synthesis
- Reduces Lodging
- Increases winter hardiness
- Increases resistance to diseases

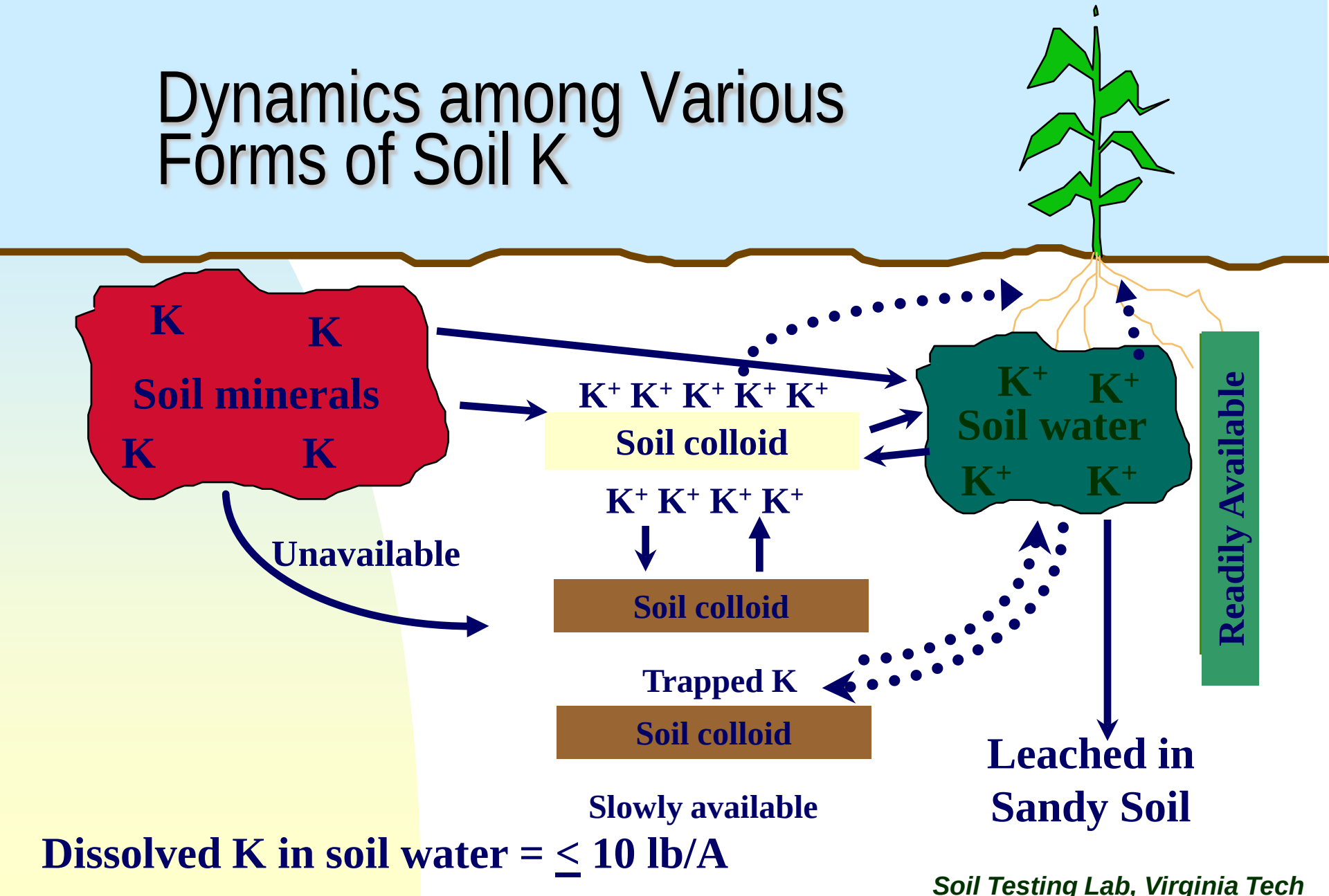
**MANMH: p. 82-84**

# Potassium in Soils

- **Soils may contain 20,000 lb/A of K, or more**
- **Only a small amount is available during the growing season**

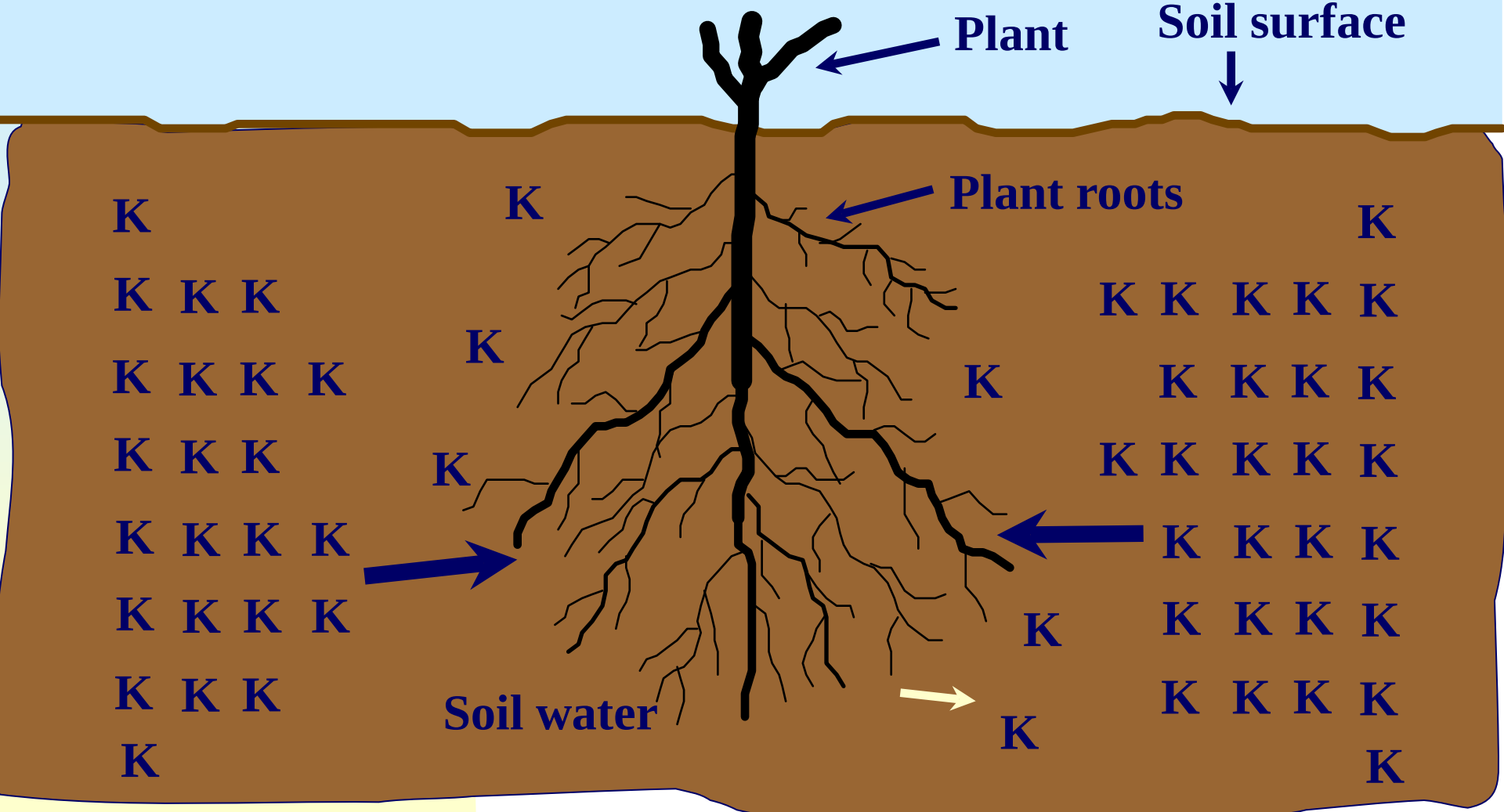
MANMH: p. 84

# Dynamics among Various Forms of Soil K




**Dissolved K in soil water = ≤ 10 lb/A**

# Potassium Moves to Plant Roots By Diffusion



# Potassium Timing & Placement

- **K fertilizers are completely water-soluble & have a high salt index – placement too close to seed or transplants can result in plant injury**
  - **Sandy soils**
  - **Dry soils**
  - **High fertilizer rates**
  - **3”x 2” placement**

- **Row placement of K: more efficient than broadcast application for low K rates and low soil K levels**

# Potassium Fertilizers

| Fertilizer Material | Chemical Formula | $K_2O$ (%) |
|---|---|---|
| Potassium Chloride (Muriate of Potash) | KCl | 60-62 |
| Potassium Sulfate (Sulfate of Potash) | $K_2SO_4$ | 50-53 |
| K-Mg-Sulfate (Sulphate of Potash-Magnesia) | $K_2SO_4 \cdot 2MgSO_4$ | 22 |
| Potassium Nitrate | $KNO_3$ | 44 |

**MANMH: p. 193-194**

# Secondary Nutrients: Ca, Mg & S

- **Includes Ca, Mg & S**
- **Just as important to plant nutrition as primary nutrients – some plants may not take up as much**
- **Commonly applied as soil amendments or applied along with materials which contain primary nutrients.**

**MANMH: p. 85**

# Secondary Nutrients: Ca, Mg, S

| | | Pounds in total Crop | | |
|---|---|---|---|---|
| Crop | Yield level | Ca[1] | Mg | S |
| Alfalfa | 8 tons | 175 | 40 | 40 |
| C. Bermudagrass | 8 tons | 52 | 26 | 44 |
| Corn | 160 bu | 39 | 52 | 27 |
| Cotton | 1000 lb lint | 14 | 23 | 20 |
| Grain Sorghum | 8000 lb | 60 | 40 | 39 |
| Peanuts | 4000 lb | 20 | 25 | 21 |
| Soybeans | 60 bu | 26 | 24 | 20 |
| Tomatoes | 40 tons | 30 | 36 | 54 |
| Wheat | 60 bu | 16 | 18 | 15 |

[1] Estimated

Soil Fertility Manual: Potash Phosphate Institute

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# Soil Ca & Mg

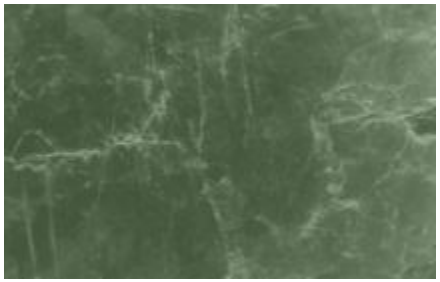
- **Calcium & Magnesium have similar behavior in soils:**
  - **<u>Cations</u>: $Ca^{+2}$ & $Mg^{+2}$**
  - **<u>Mobility</u>: relatively low compared to other ions (i.e., leaching losses - relatively low)**
  - **Quantities: Soils usually contain less Mg than Ca**
    - **Mg is not adsorbed as tightly as Ca**
    - **Most parent materials contain less Mg than Ca**

# Virginia Tech Soil Test Calibration for Calcium & Magnesium (Extractant = Mehlich I)

| Soil Test Rating | STCa lb/A | STMg lb/A |
|---|---|---|
| L- | 0-240 | 0-24 |
| L | 241-480 | 25-48 |
| L+ | 481-720 | 49-72 |
| M- | 721-960 | 73-96 |
| M | 961-1200 | 97-120 |
| M+ | 1201-1440 | 121-144 |
| H- | 1441-1680 | 145-168 |
| H | 1681-1920 | 169-192 |
| H+ | 1921-2160 | 193-216 |
| VH | 2161-2400+ | 217-240 |

# Soil Ca & Mg

- **Calcium**: Soil Ca < 0.1 – 30% (NC: 0.7-1.5%)
  - Mineral Ca: (very slowly available)
    - ☞calcite, dolomite, apatite & Ca-feldspars
  - Exchangeable Ca (←↓available)
  - Soil Solution Ca: $Ca^{+2}$
- **Magnesium**: Soil Mg 0.1 to 4%
  - Mineral Mg: (very slowly available)
    - ☞dolomite, biotite, hornblende & chlorite
  - Exchangeable Mg (←↓available)
  - Soil Solution Mg: $Mg^{+2}$



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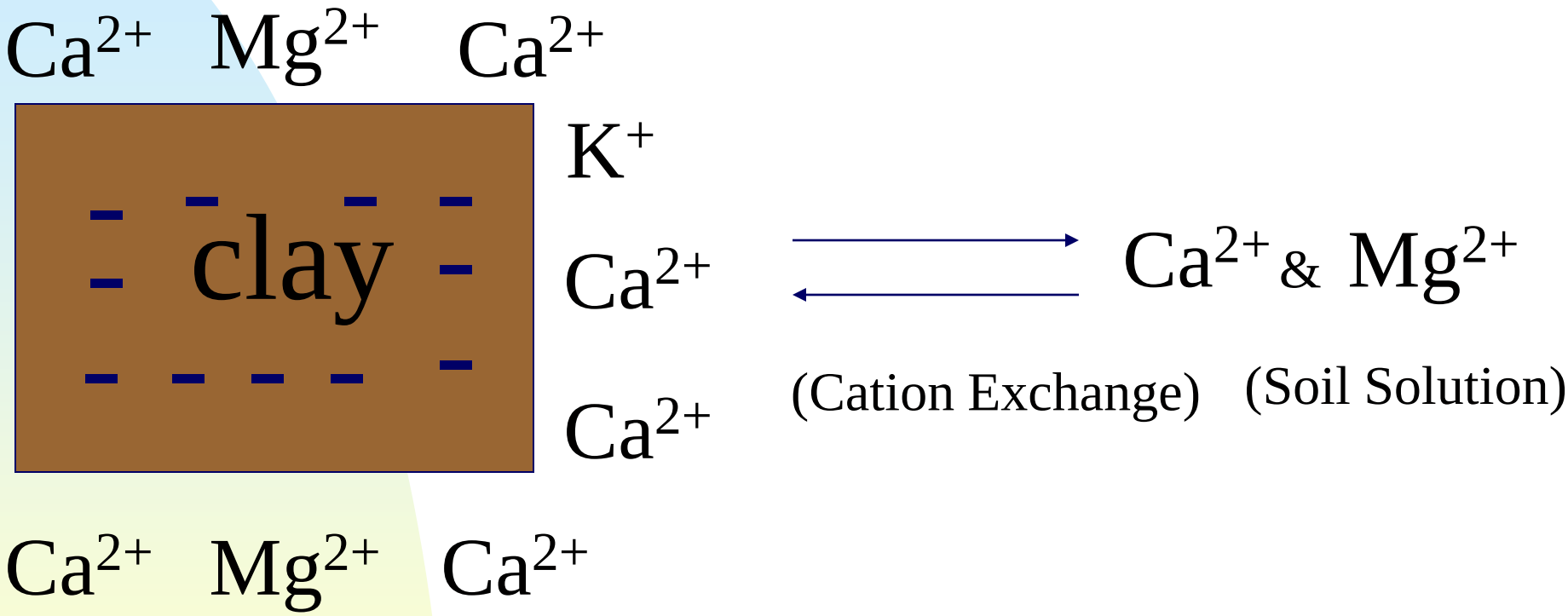
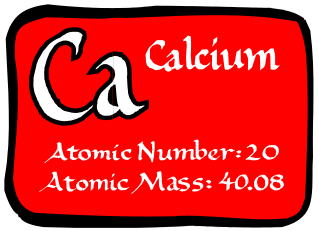
# Available Soil Ca & Mg




{Ca usually = 70-90% of CEC}

# Benefits of Calcium




- **Reduces soil acidity:**

  **Lowers solubility and toxicity of manganese and aluminum**

- **Improves root growing conditions:**

  **Microbial activity**

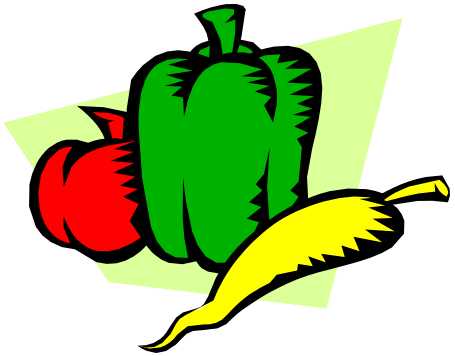
  **Molybdenum availability**

  **Availability & uptake of other nutrients**

**MANMH: p. 69**

# Calcium: Deficiency

- Poor root growth:  Ca deficient plants turn black and rot
- Except for peanuts & some vegetables, Ca deficiency seldom shows up in the field.



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# Magnesium



# Magnesium: Deficiencies

**Most Frequently Occur On:**

- **Coarse Texture Soils**
- **Acid Soils**
- **Areas of High Rainfall**

# Magnesium: Deficiencies

**Accentuated by:**

- **High Ca, Low CEC**
- **High K Rates**
- **High Available Ammonium-N**

**Magnesium**
**12**
**Mg**
**24.3050**

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# Calcium Sources

- **In general, Ca deficient soils are acid**
- **Good means of correcting low pH & Ca deficiencies is to apply lime**
- **Calcitic and dolomitic limestone are excellent sources**

**MANMH: p. 70**

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# Calcium Sources

| Material | Percent Ca | Neut. Value |
|---|---|---|
| Calcitic Limestone | 32 | 85-100 |
| Dolomitic Limestone | 22 | 95-108 |
| Basic Slag | 29 | 50-70 |
| Gypsum | 22 | None |
| Marl | 24 | 15-85 |
| Hydrated Lime | 45 | 120-135 |
| Burned Lime | 55 | 150-175 |
| Single superphosphate | 18 - 21 | ---- |
| Triple superphosphate | 12 - 14 | ---- |
| Calcium Nitrate | 19 | ---- |
| Animal/Municipal Waste | 2 – 5 | Variable |

**MANMH: p. 194-195**

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# Magnesium Fertilizers

| Material | Percent Mg | |
|---|---|---|
| Dolomitic limestone (Mg Carbonate) | 3-12 | slowly available |
| Magnesia (Mg oxide) | 55-60 | |
| Basic Slag | 3 | |
| Magnesium sulphate (Epsom salts) | 9-20 | rapidly available |
| K-Mg-Sulphate | 11 | |
| Magnesium Nitrate | 16-19 | |
| Magnesium Chloride | 8 - 9 | |

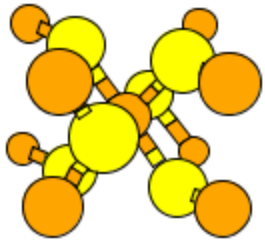
**MANMH: p. 194-195**

# Sulfur *(PPI)*

# Soil Sulfur

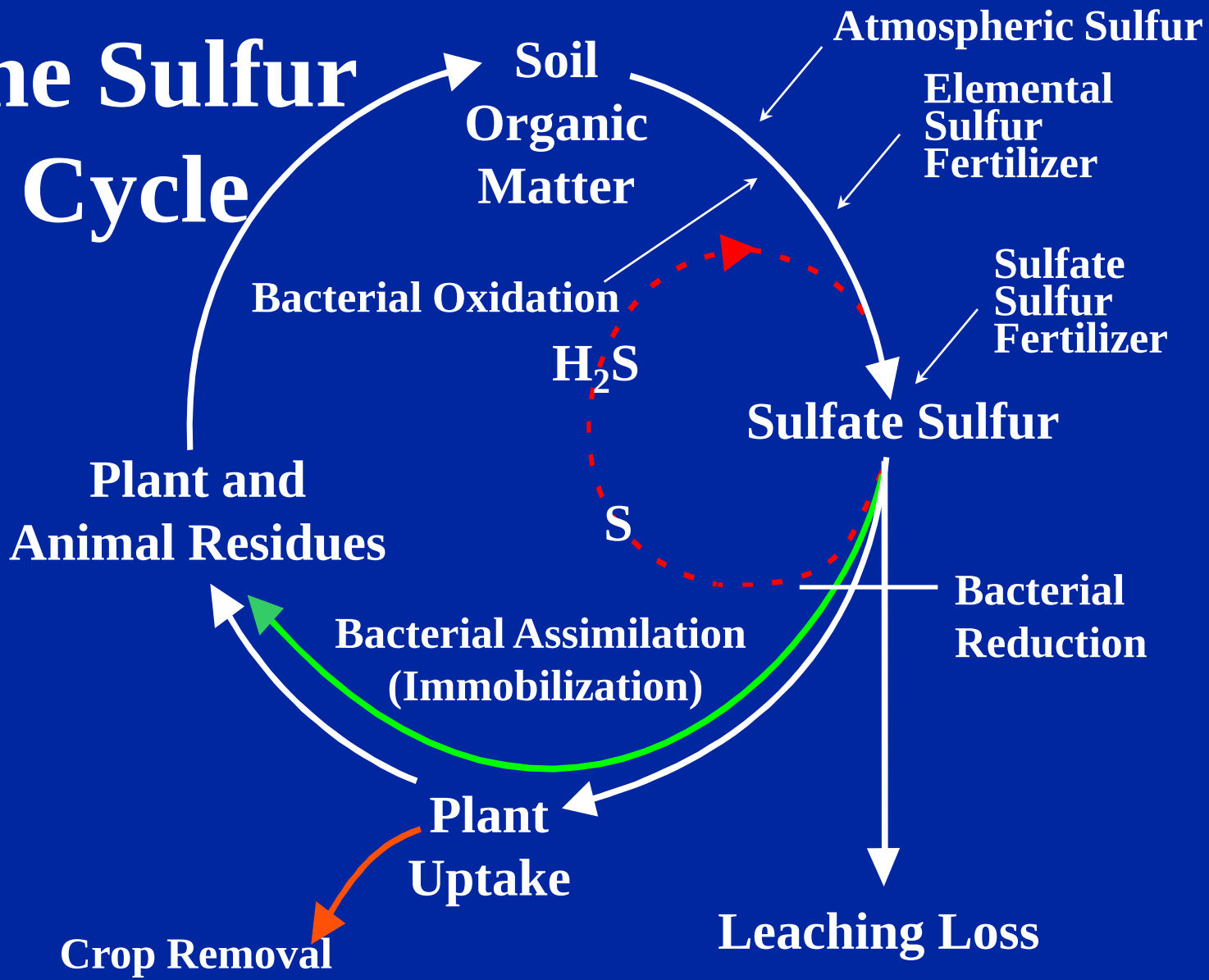
- **Form available to plants:**
  - **Inorganic Sulfate-Sulfur: $SO_4^{2-}$**
  - **Negative Charged**
  - **Not attracted to soil clay or OM**

- **Sulfate - Subject to leaching**
  - **Sulfate often accumulates in subsurface horizons (Positively charged soil colloids)**
- **Sulfate - Adsorbed to clay with Fe & Al oxide coatings**
- **Soil S - Most is bound in soil organic matter (>90%)**



**MANMH: p. 86**

# The Sulfur Cycle




MANMH: p. 87

# Factors Affecting Availability

- Crop to be grown
- Soil Texture
- Soil organic matter

# Sulfur Fertilizers

| Fertilizer Material | Chemical Formula | S (%) | |
|---|---|---|---|
| Ammonium Sulfate | $(NH_4)_2SO_4$ | 24 | rapidly available |
| Ammonium Thiosulfate | $(NH_4)_2S_2O_3 \cdot 5H_2O$ | 26 | |
| Potassium Sulfate | $K_2SO_4$ | 18 | |
| K-Mg-Sulfate | $K_2SO_4 \cdot MgSO_4$ | 22 | |
| Elemental Sulfur | S | >85 | slowly available |
| Gypsum | $CaSO_4 \cdot H_2O$ | 12-18 | |
| Magnesium Sulfate | $MgSO_4 \cdot 7H_2O$ | 14 | |

**MANMH: p. 194-195**

# Micronutrients

**Zn Deficient Corn**

**Mn Deficient Soybean**

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# Micronutrients

**Mn Toxic Soybean**

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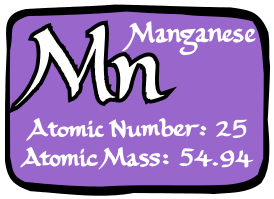
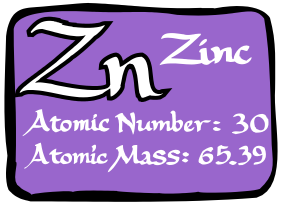
# Micronutrient Needs - VA

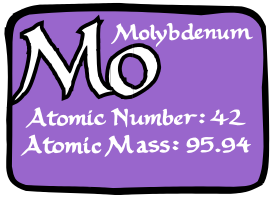
- Manganese
  - Soybean & Peanuts



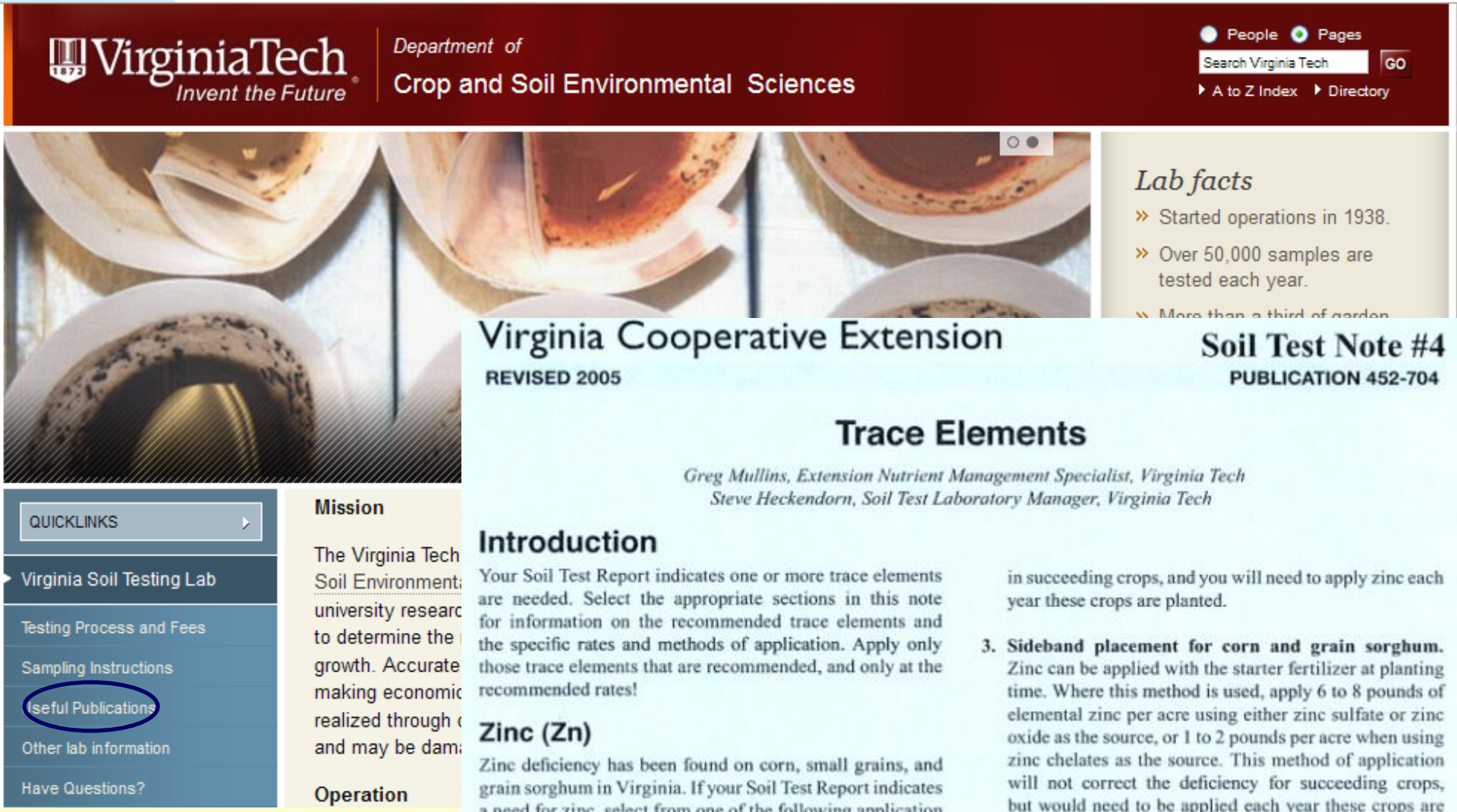

- Boron
  - Alfalfa
  - Certain Vegetables:
    - Asparagus, Broccoli, Peppers, White Potatoes, etc.
  - Cotton
  - Peanuts


- Zinc
  - Corn, Small Grains & Grain Sorghum
- Molybdenum
  - Alfalfa
  - Soybeans
  - Broccoli & Cauliflower



# Soil Test Notes are on-line at www.soiltest.vt.edu. See Note #4

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# Application of Micronutrients

- **Can be soil or foliar applied**
- **Sulfates, chelates & most organics are soluble and better adapted for foliar applications as compared to fritz & oxides**
- **Foliar applications – sufficient to meet crop needs**
- **Solution fertilizers – compatibility problems with P**

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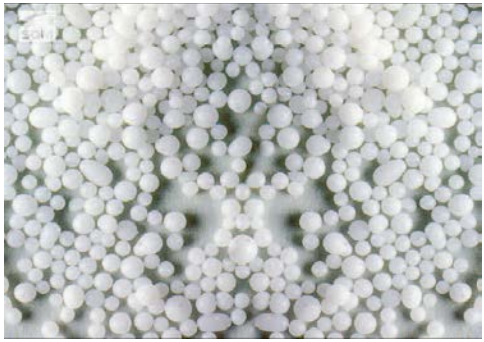
# Application of Micronutrients

- **Micronutrients can be added to commercial fertilizers and/or mixed into bulk blends**



- **Band applications of fertilizer materials containing micronutrients increases efficiency**
- **Over applications – may result in toxic soil levels**

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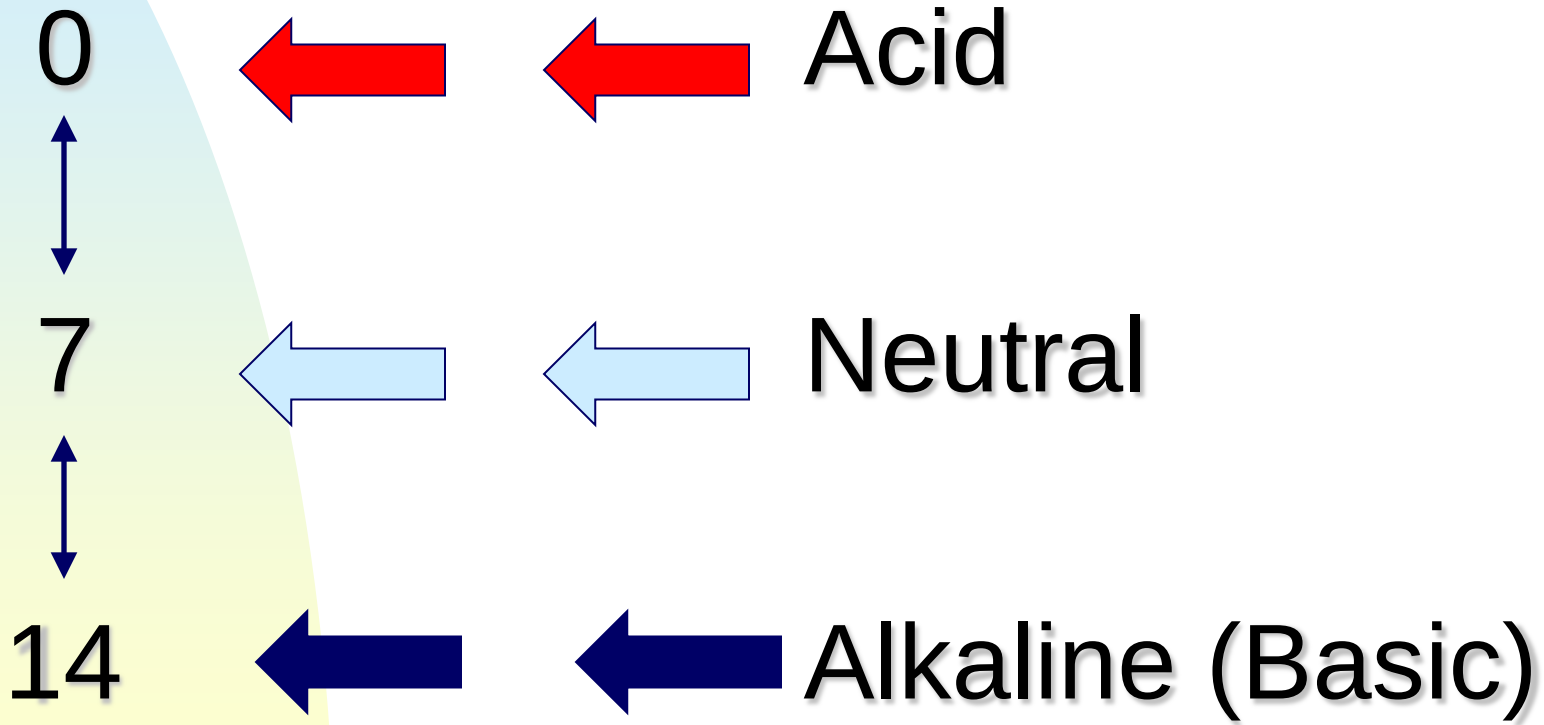
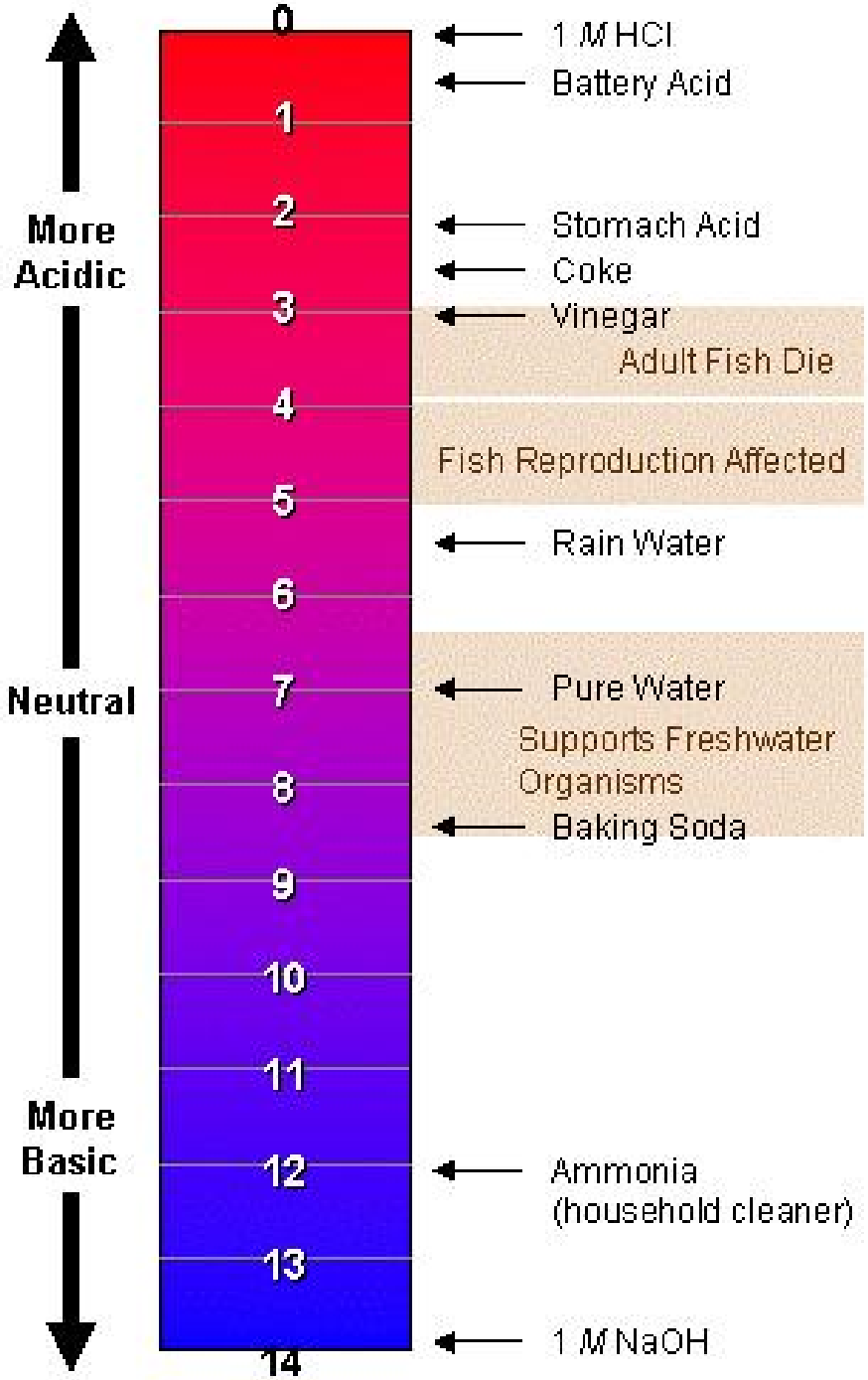
# Selected Micronutrient Sources

| Material | Element | % Element |
|---|---|---|
| Borax | B | 11.3 |
| Solubor | B | 20.0 |
| Boron Frits | B | 2.0 – 6.0 |
| Iron Sulfate | Fe | 19 – 23 |
| Iron Frits | Fe | Variable |
| Iron Chelates | Fe | 5 – 14 |
| Manganease Sulfate | Mn | 26 – 28 |
| Manganese Chelates | Mn | 12 |
| Zinc Sulfate | Zn | 23 – 35 |
| Zinc Chelates | Zn | 9 – 14 |
| Sodium Molybdate | Mo | 39 – 41 |

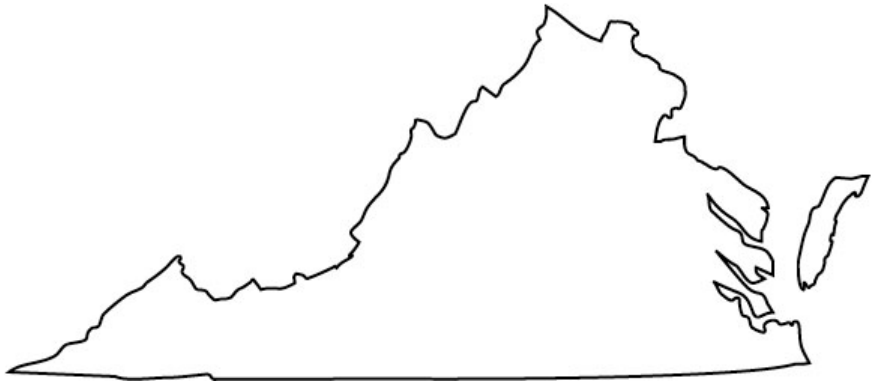
**MANMH: p. 195-196**

# pH Scale






# For Virginia Most Mineral Soils have a pH from 4.0 to 8.0



5.1 -5.3 most common for unlimed soils

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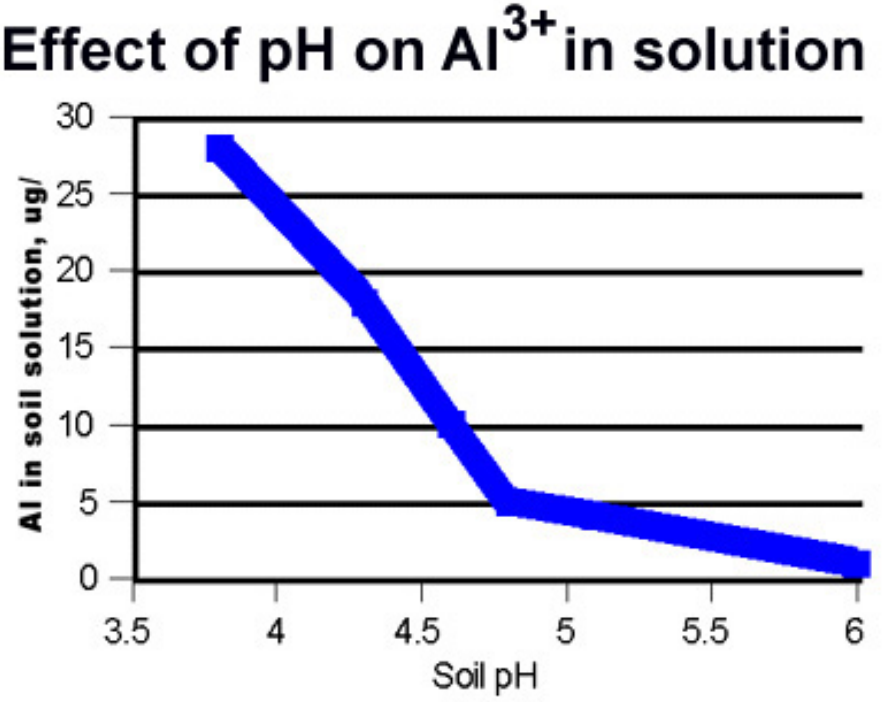
# Desired Soil pH

- **Critical Levels:**
  - **<5.0 – 5.5: Non-Leguminous crops**
    - **Corn: 6.2**
    - **Tobacco: 5.8**
  - **<6.5: Legumes**
    - **Alfalfa: 6.8**




**MANMH: p. 66-68**

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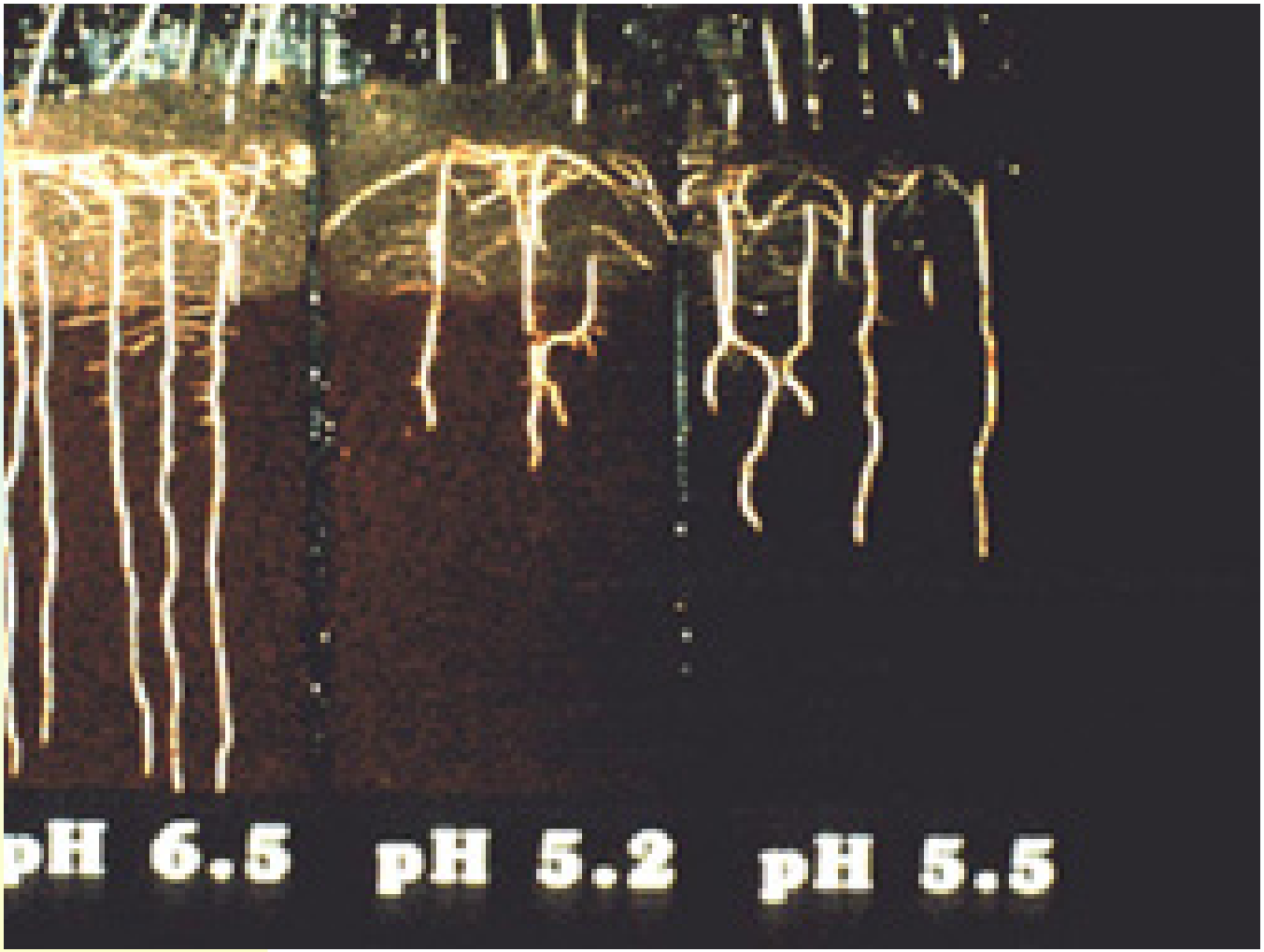
# Root Growth Restricted by Al




**MANMH: p. 171**

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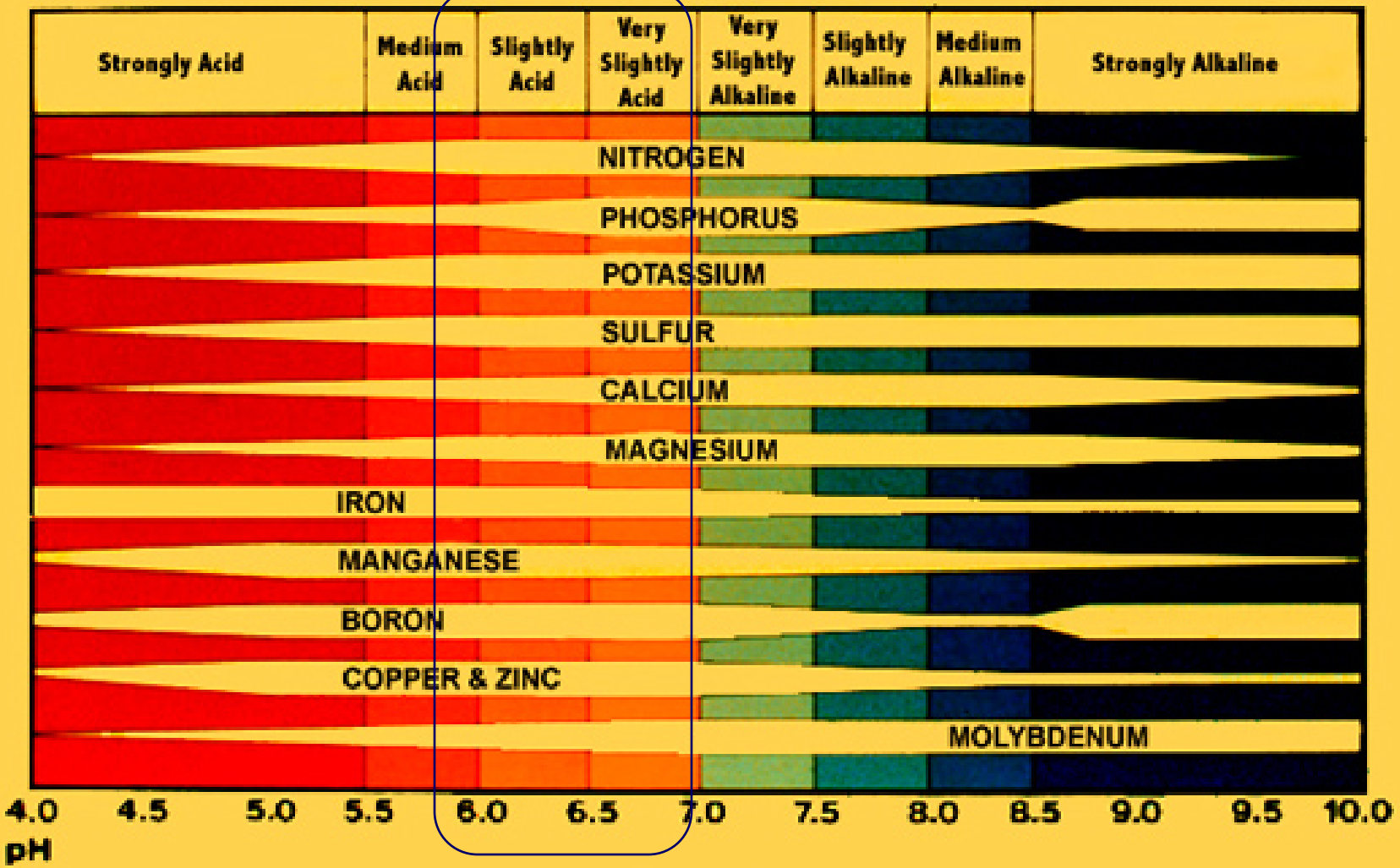
# How Soil pH Affects Availability of Plant Nutrients

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## Virginia Cooperative Extension

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Agriculture and Natural Resources >

### Agriculture and Natural Resources

**Advice You Can Trust**

Agriculture and natural resources (ANR) programs help sustain the profitability of agricultural and forestry production and enhance and protect the quality of our land and water resources. Virginia Cooperative Extension strives to improve the well-being of Virginians and increase producers' profitability through programs that help put research-based knowledge to work in people's lives.

**Meeting Diverse Needs**

Extension faculty -- agents and specialists -- work together to meet the ever-changing needs of the agriculture industry. Follow the links to the right to explore the work we are doing in a particular area.

Extension agents serve as important links to a broad base of research, much of which occurs at 13 agricultural research and Extension centers (ARECs). Located throughout the commonwealth, these field laboratories allow scientists to tailor projects to Virginia's varied soil, vegetation, climate, and communities.

**Drawing on Local Expertise**

Extension program involve many partners to assure that our programs are relevant and responsive to the issues of our communities. Some of those partners include:

**ANR Topic Areas**

- Agricultural Business, Finance, & Marketing
- Agricultural Systems
- Animal Agriculture
- Crops & Soils
- Environment & Natural Resources
- Lawn & Garden
- Nursery, Greenhouse, & Turf
- Specialty Agriculture

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- What's Happening in ANR Today (See Topic Calendars)
- Certifications & Trainings

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