

# Basic Soil Fertility

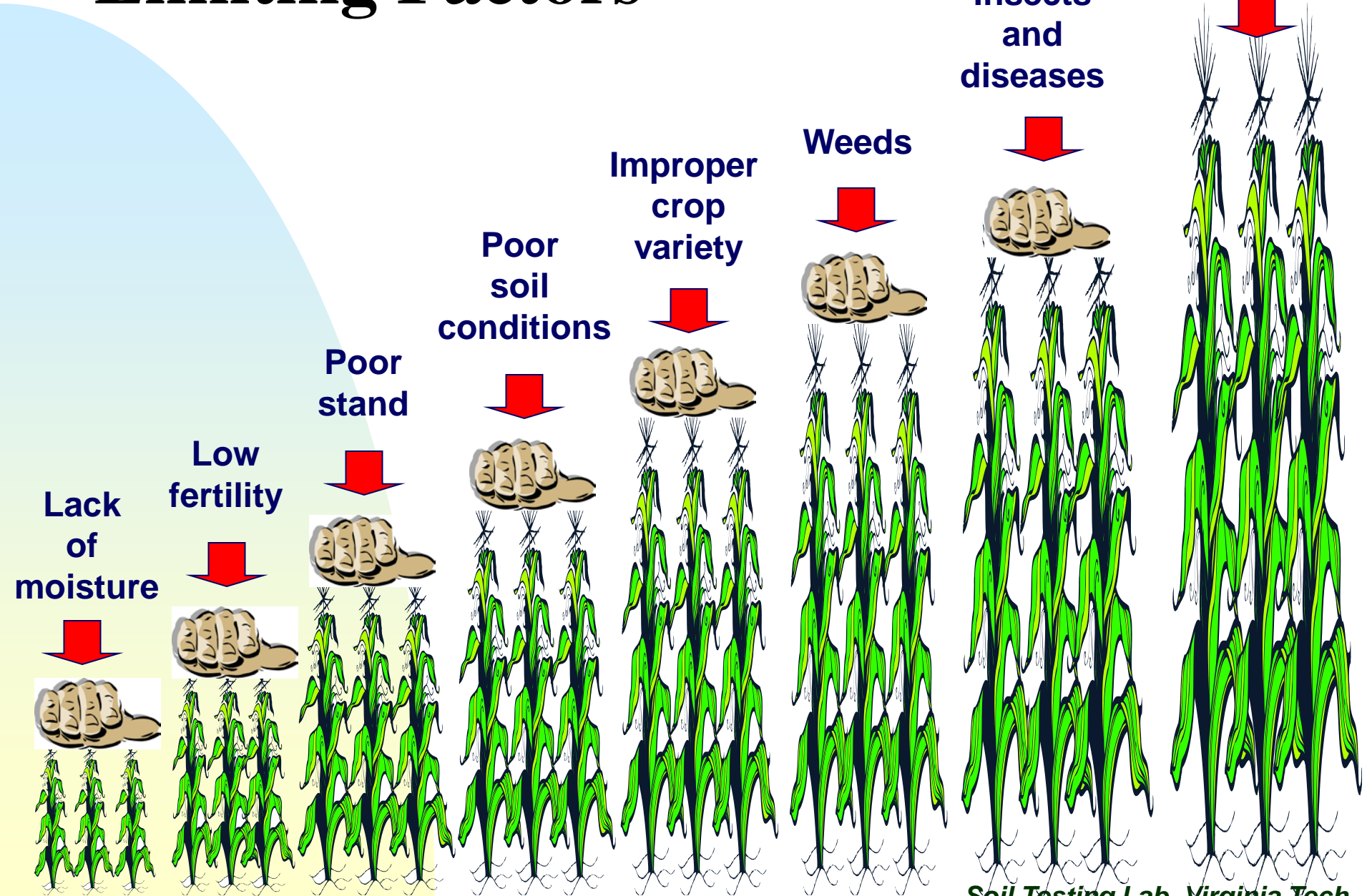
---

Steve Heckendorn  
Virginia Tech  
Soil Testing Lab

Lab Phone: 540-231-6893  
Desk Phone: 540-231-9807  
Email: [soiltesting@vt.edu](mailto:soiltesting@vt.edu)

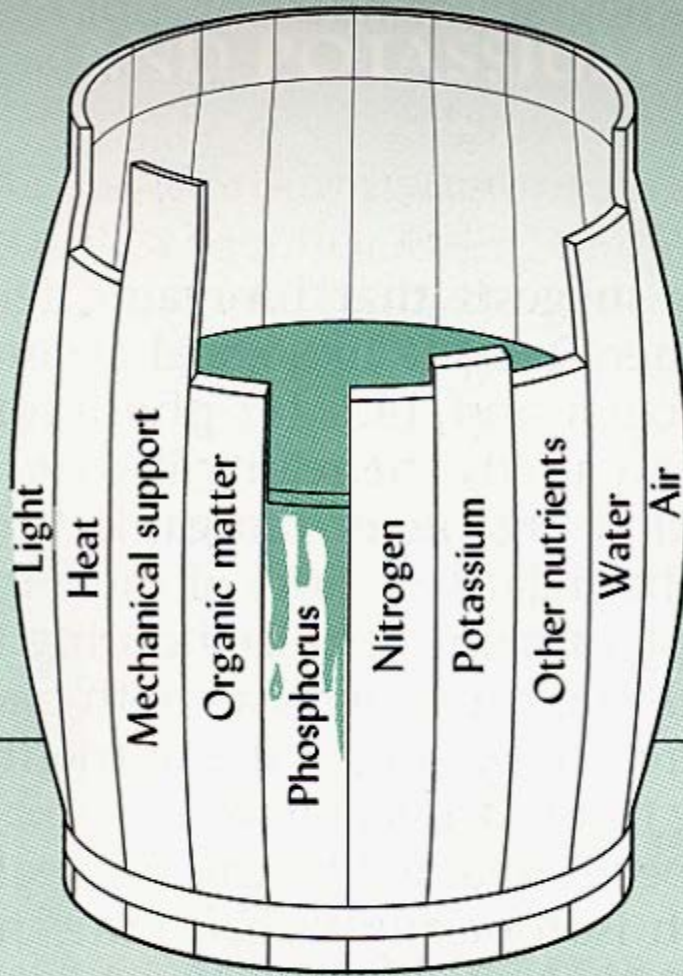


# Limiting Factors

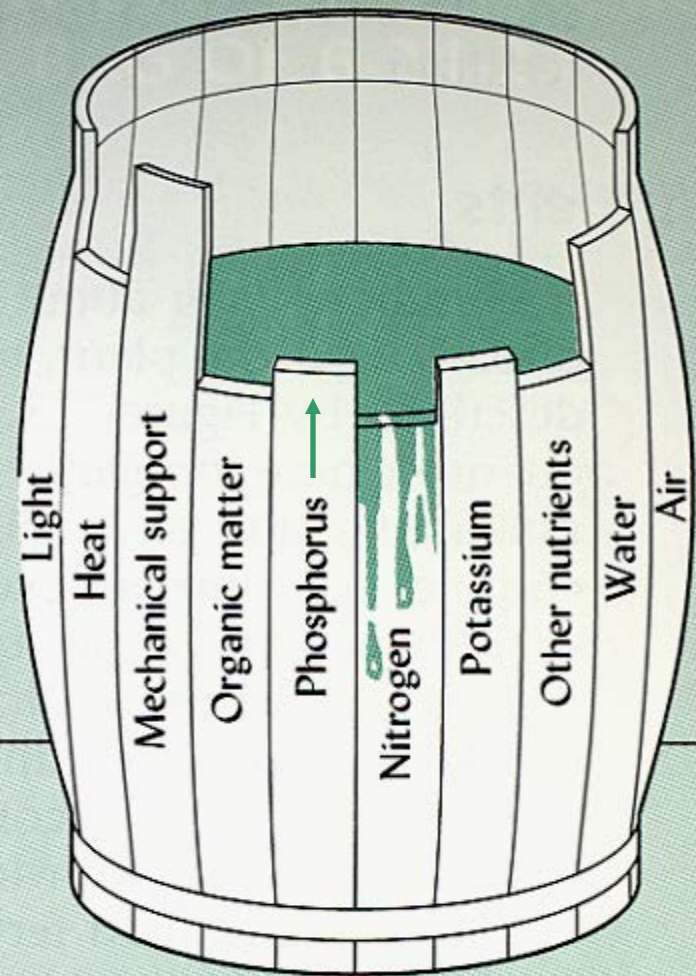




# Example of Liebig's (1842) law of the minimum.



(a)



(b)

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

**C H O**

**N**

**Ca**

**P**

**16  
Essential  
Elements**

**Mg**

**K**

**S**

**B**

**Cl**

**Cu**

**Fe**

**Co**

**Mn**

**Mo**

**Zn**

**Ni**

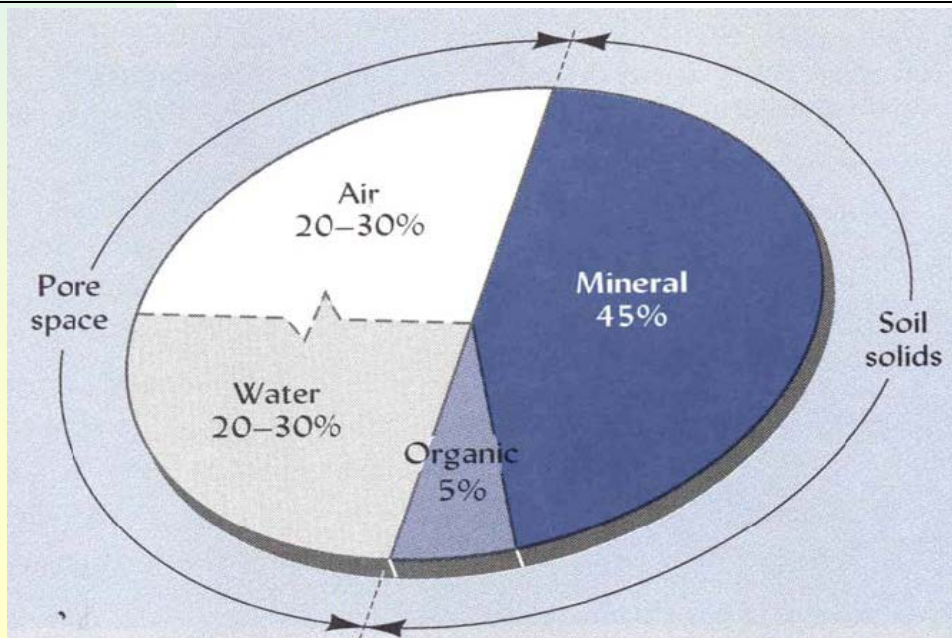
# Non-Mineral Nutrients

## ■ Non-Mineral Elements

- ◆ Carbon (C)
- ◆ Hydrogen (H)
- ◆ Oxygen (O)

## Sources:

Air ( $\text{CO}_2$ ;  $\text{O}_2$ )  
Water ( $\text{H}_2\text{O}$ )



# 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)

# 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**



# Plant Available Forms

## Non-Mineral Nutrients

- Element Available forms

- ◆ Carbon:  $\text{CO}_2$

- ◆ Hydrogen:  $\text{H}^+$ ,  $\text{OH}^-$

- ◆ Oxygen:  $\text{O}_2$



# Plant Available Forms: Mineral Nutrients

## ■ Primary Nutrients

- ◆ Nitrogen:  $\text{NH}_4^+$ ;  $\text{NO}_3^-$
- ◆ Phosphorus:  $\text{HPO}_4^{-2}$ ;  $\text{H}_2\text{PO}_4^-$
- ◆ Potassium:  $\text{K}^+$

## ■ Secondary Nutrients

- ◆ Calcium:  $\text{Ca}^{+2}$
- ◆ Magnesium:  $\text{Mg}^{+2}$
- ◆ Sulfur:  $\text{SO}_3^{-2}$ ;  $\text{SO}_4^{-2}$

# Plant Available Forms: Mineral Nutrients

## ■ Micronutrients

◆ Boron:



◆ Chlorine:



◆ Copper:



◆ Iron:



◆ Manganese:



◆ Molybdenum:



◆ Zinc:



# 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

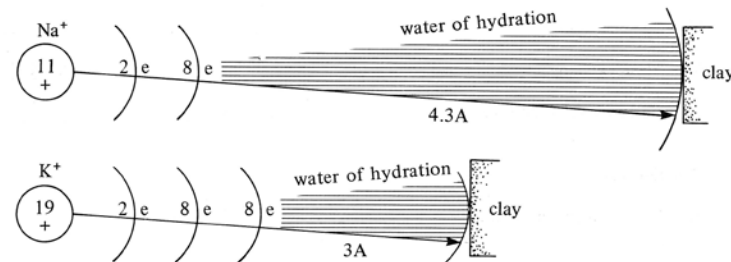
◆ Size or diameter of ion

☞ High charge + small diameter = high retention

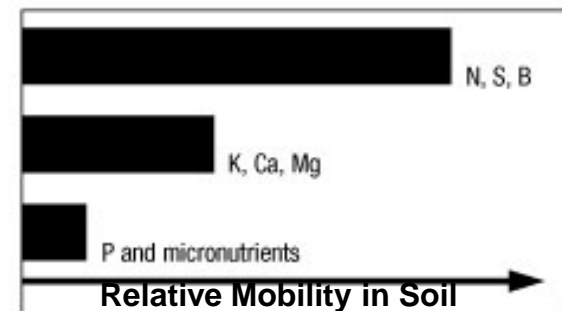
◆ Type of charge:

☞ Anions (e.g.  $\text{NO}_3^-$ ) in general leach more easily than cations

☞ Phosphate is an exception

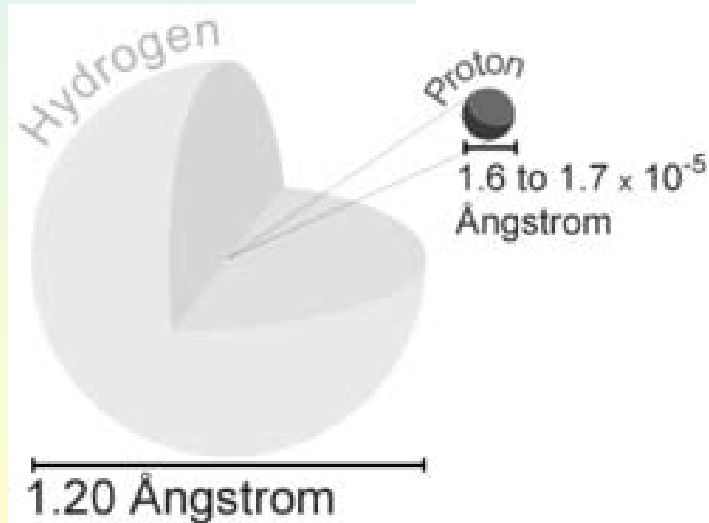


MANMH: p.48



# Nutrient Mobility in Soils

- Degree or strength of retention:



**MANMH: p.48**



# 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)





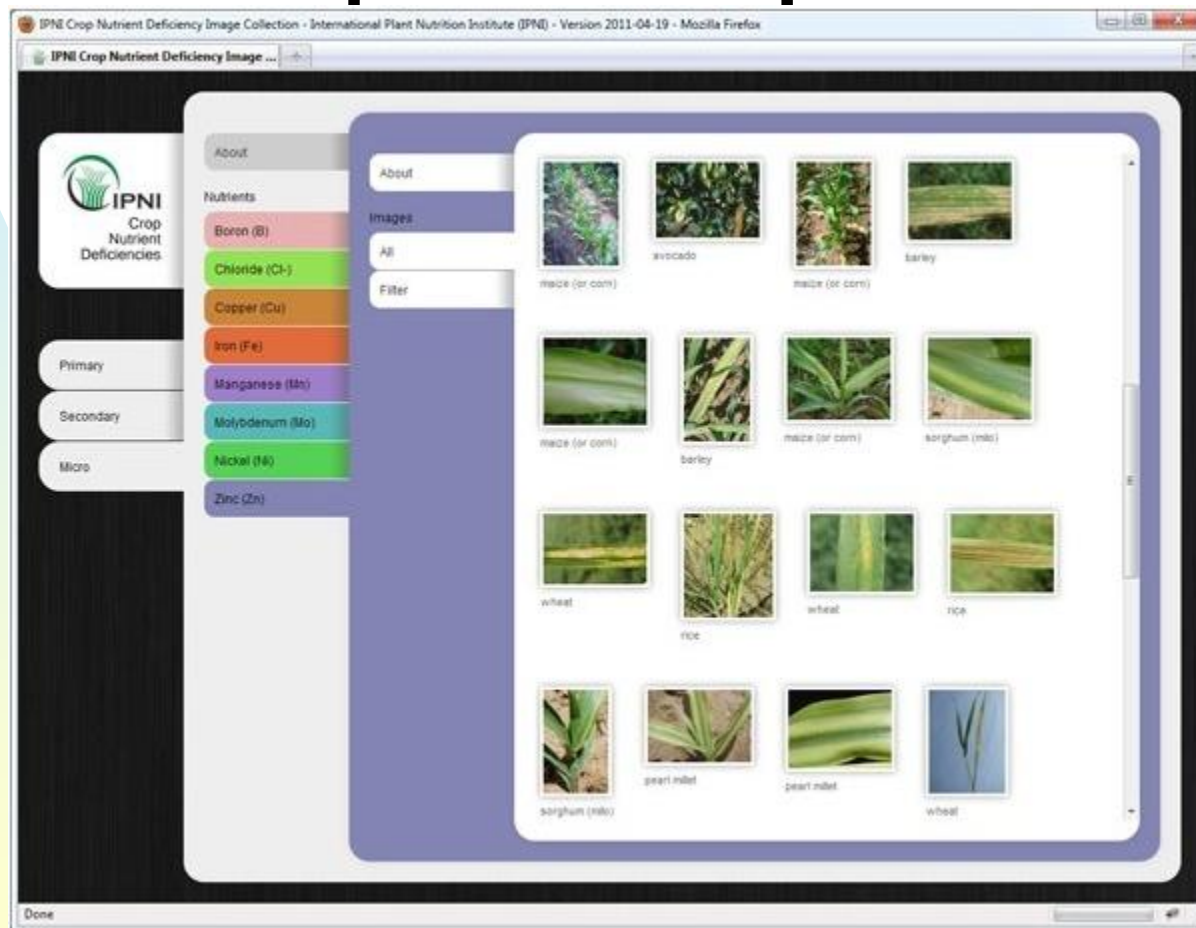
# Translocation of Nutrients in the Plant

- **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**





# 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

Brought to You by:



## Plant Management Network International

Log In | About Us | Partners | Journals | Resources | Subscribe | \* Find \*

**NEW:**  
Focus on Ag Practitioners

**Useful Resources:**  
[Free Newsletter Sign Up](#)  
[Journals](#)  
[Cross-Journal Search](#)  
[Images](#)  
[Online Learning](#)  
[Proceedings](#)  
[Insect Management Tests](#)  
[Plant Disease Management Reports](#)  
[Extension Information](#)  
[Employment/Internships](#)



### Science-Based Solutions in Agriculture and Horticulture

*Applied Turfgrass Science*    *Crop Management*  
*Forage and Grazinglands*    *Plant Health Progress*



#### Featured Partners



Show All Partners  
Be a Partner



Focus on Soybean



Focus on Potato

**Sign Up for Updates**  
  
Receive free monthly notices of new articles and network news

**Become a Partner**  
  
Enroll in the PMN partner program and give your organization its benefits

**Get Access**  
**Subscribe**  
Purchase personal or institutional subscriptions to access all PMN content

**Continue Access**  
**Renew**  
**New:** Renew your Plant Management Network subscription online.

Privacy Policy | Copyright © 2011 | Disclaimer | Viewing Tips | Contact Us



# Potassium





**Potassium Deficient Corn**

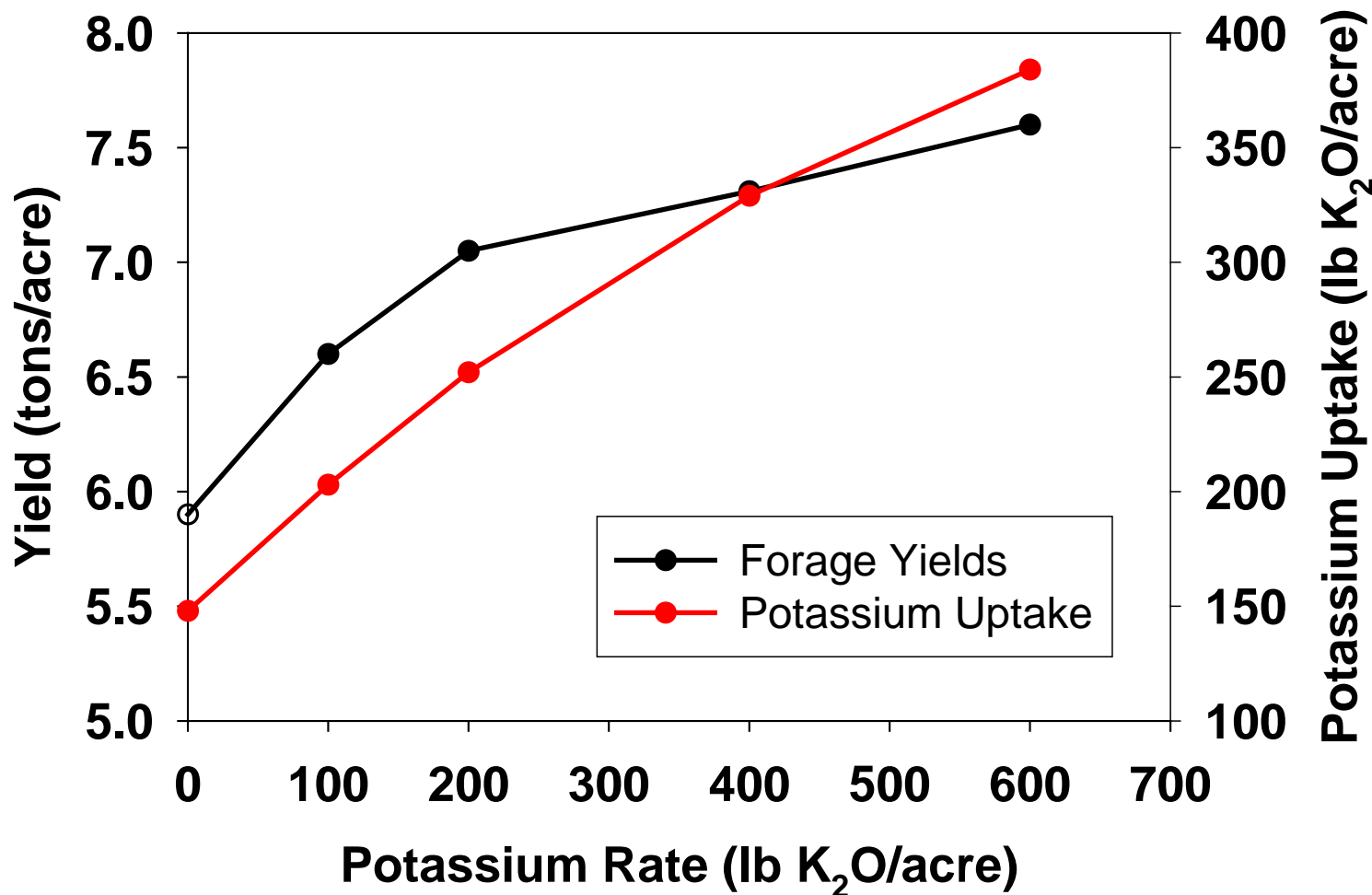


# K Deficient Soybean



# Potassium Yield Response

Coastal Bermudagrass



(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

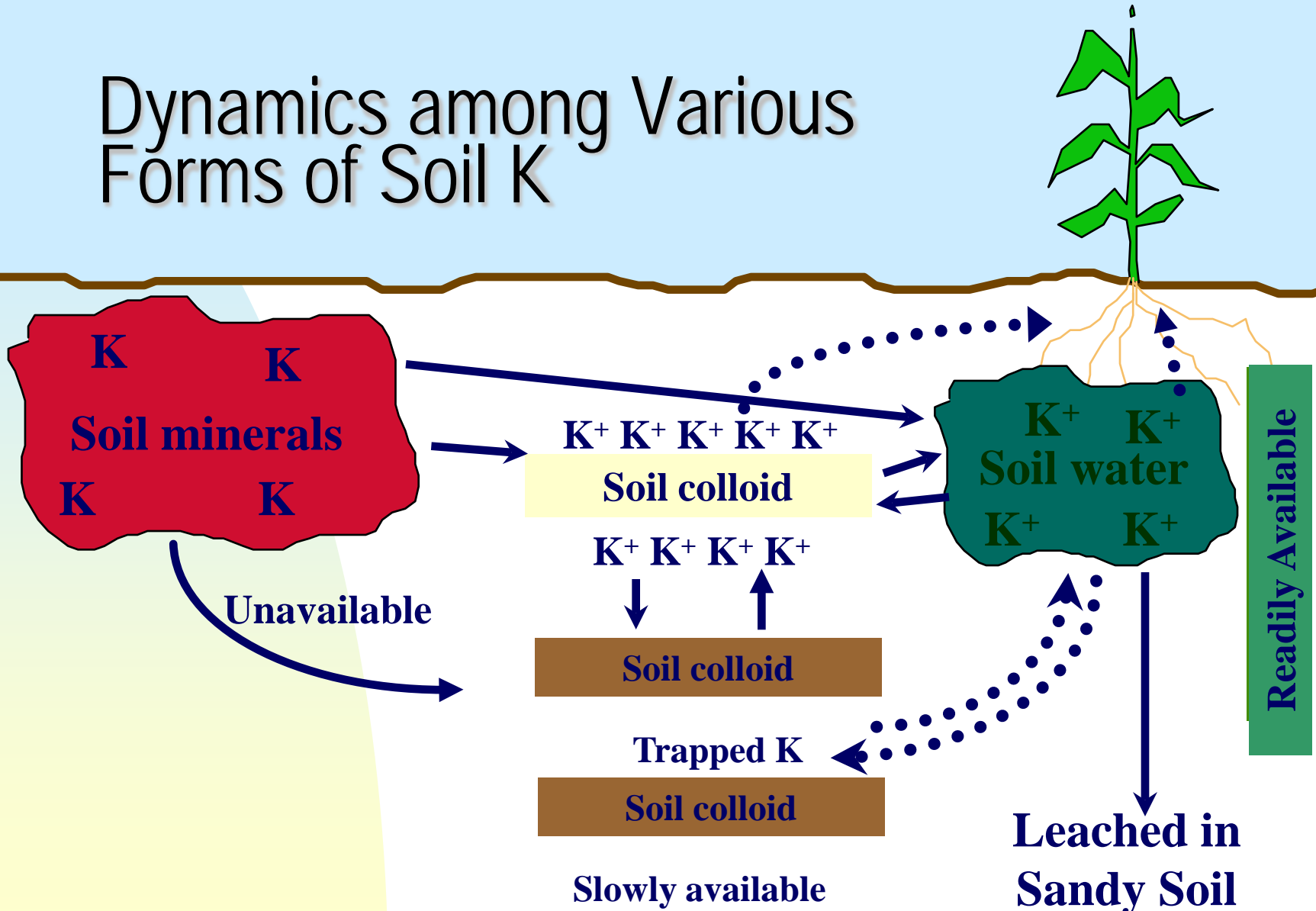
**MANMH: p. 82-84**



# Potassium in Soils

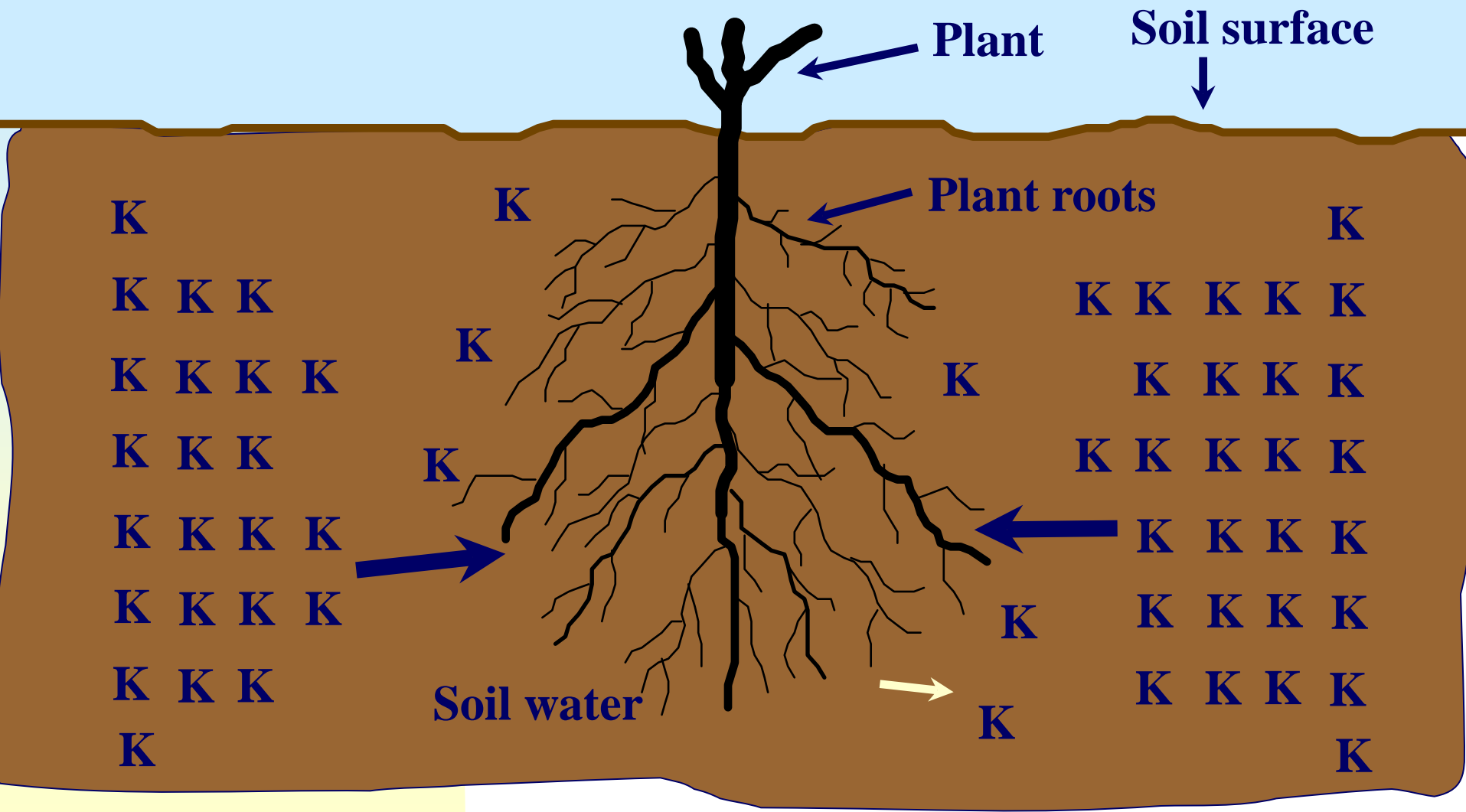
- **Soils may contain 20,000 lb/A of K, or more**
- **Only a small amount is available during the growing season**

# Dynamics among Various Forms of Soil K



Dissolved K in soil water =  $\leq 10$  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

<b>Fertilizer Material</b>	<b>Chemical Formula</b>	<b>K<sub>2</sub>O (%)</b>
<b>Potassium Chloride (Muriate of Potash)</b>	<b>KCl</b>	<b>60-62</b>
<b>Potassium Sulfate (Sulfate of Potash)</b>	<b>K<sub>2</sub>SO<sub>4</sub></b>	<b>50-53</b>
<b>K-Mg-Sulfate (Sulphate of Potash-Magnesia)</b>	<b>K<sub>2</sub>SO<sub>4</sub>·2MgSO<sub>4</sub></b>	<b>22</b>
<b>Potassium Nitrate</b>	<b>KNO<sub>3</sub></b>	<b>44</b>

**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.**

# Secondary Nutrients: Ca, Mg, S

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

<sup>1</sup> Estimated

# Soil Ca & Mg

---

- **Calcium & Magnesium have similar behavior in soils:**
  - ◆ **Cations:  $\text{Ca}^{+2}$  &  $\text{Mg}^{+2}$**
  - ◆ **Mobility: 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)

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

# 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: $\text{Ca}^{+2}$



## ■ Magnesium: Soil Mg 0.1 to 4%

### ◆ Mineral Mg: (very slowly available)

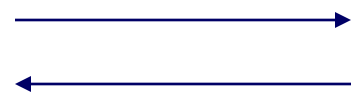
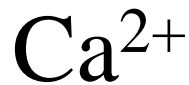
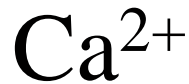
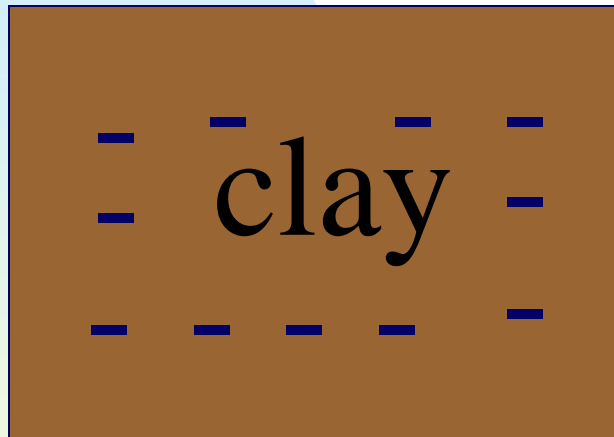
☞ dolomite, biotite, hornblende & chlorite

### ◆ Exchangeable Mg (←↓available)

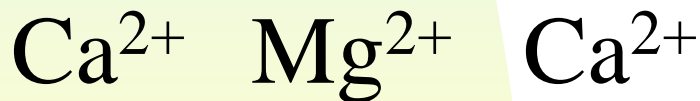
### ◆ Soil Solution Mg: $\text{Mg}^{+2}$



# Available Soil Ca & Mg



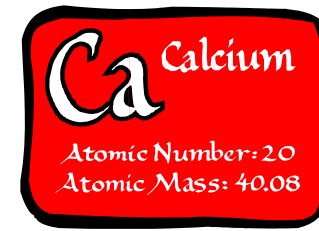
(Cation Exchange) (Soil Solution)



{ Ca usually = 70-90% of CEC }



# Benefits of Calcium

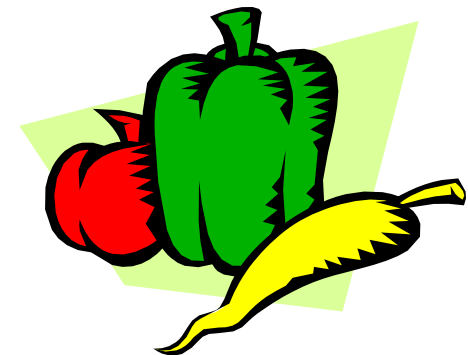


- **Reduces soil acidity:**
  - Lowers solubility and toxicity of manganese and aluminum**
- **Improves root growing conditions:**
  - Microbial activity**
  - Molybdenum availability**
  - Availability & uptake of other nutrients**

# 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.**





# Magnesium

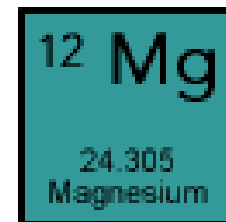


# Magnesium: Deficiencies

---

## 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**



# 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



# Calcium Sources



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





# Magnesium Fertilizers

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

**MANMH: p. 194-195**



# Sulfur (*PPI*)





# Soil Sulfur

---

## ■ Form available to plants:

- ◆ Inorganic Sulfate-Sulfur:  $\text{SO}_4^{2-}$
- ◆ Negative Charged
- ◆ Not attracted to soil clay or OM

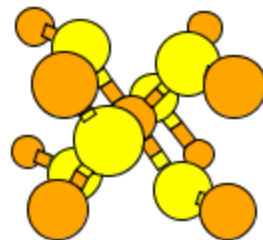


## ■ Sulfate - Subject to leaching

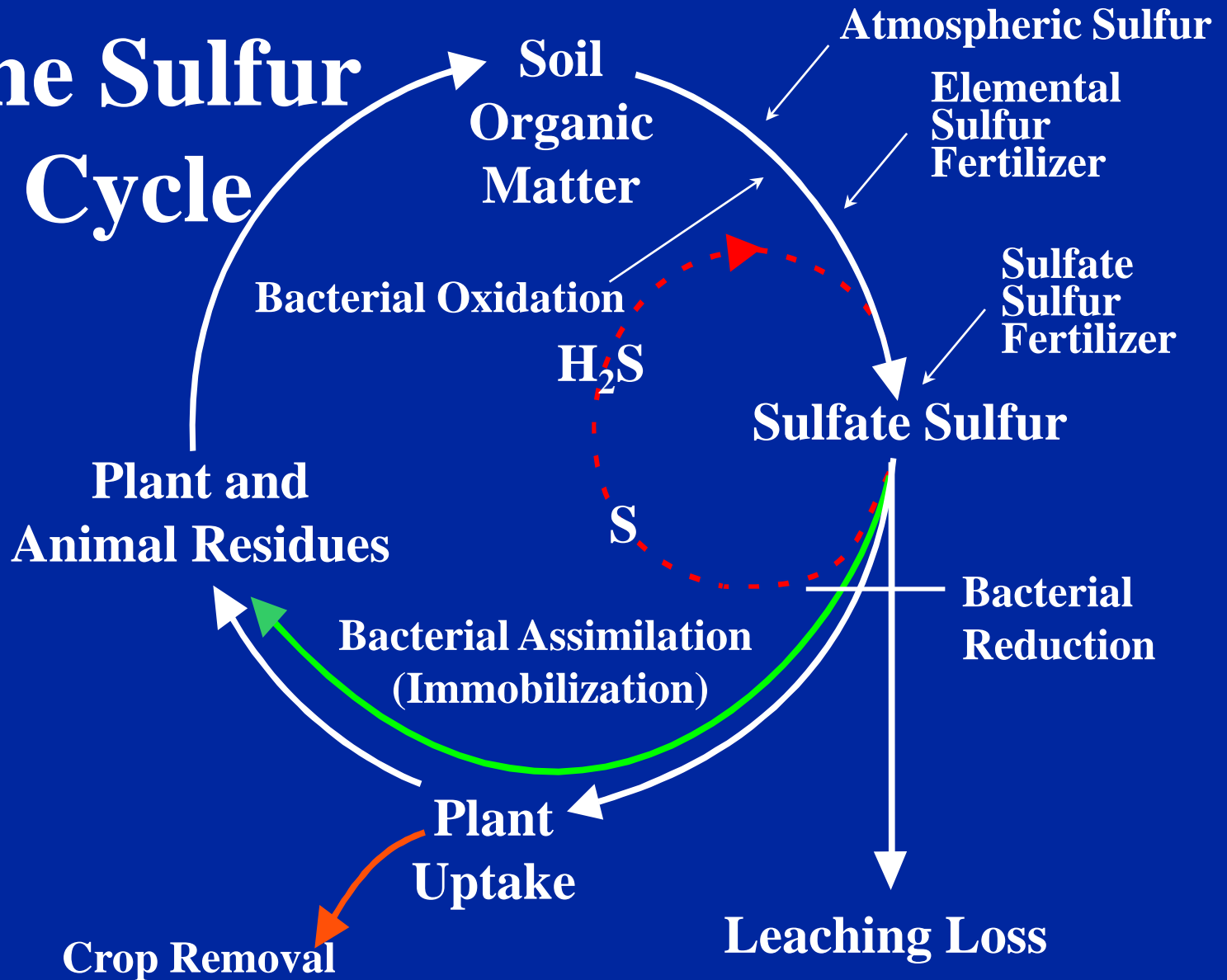
- ◆ Sulfate often accumulates in subsurface horizons (Positively charged soil colloids)

## ■ Sulfate - Adsorbed to clay with Fe & Al oxide coatings

## ■ Soil S - Most is bound in soil organic matter (>90%)



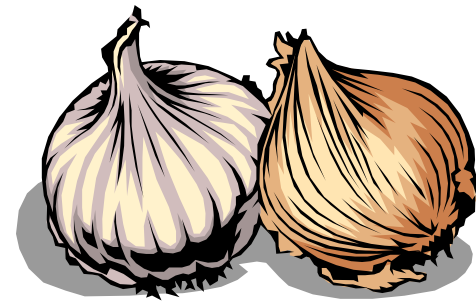
# The Sulfur Cycle



# Factors Affecting Availability

---

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



# Sulfur Fertilizers



Fertilizer Material	Chemical Formula	S (%)
Ammonium Sulfate	$(\text{NH}_4)_2\text{SO}_4$	24 rapidly available
Ammonium Thiosulfate	$(\text{NH}_4)_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$	26
Potassium Sulfate	$\text{K}_2\text{SO}_4$	18
K-Mg-Sulfate	$\text{K}_2\text{SO}_4 \cdot \text{MgSO}_4$	22
Elemental Sulfur	S	>85 slowly available
Gypsum	$\text{CaSO}_4 \cdot \text{H}_2\text{O}$	12-18
Magnesium Sulfate	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	14

MANMH: p. 194-195



# Micronutrients

**Zn Deficient  
Corn**



**Mn Deficient  
Soybean**



# Micronutrients

**Mn Toxic  
Soybean**



# Micronutrient Needs - VA

## ■ Manganese

- ◆ Soybean & Peanuts



## ■ Boron

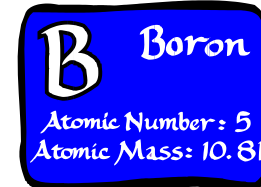
- ◆ Alfalfa

- ◆ Certain Vegetables:

☞ Asparagus, Broccoli, Peppers, White Potatoes, etc.

- ◆ Cotton

- ◆ Peanuts



## ■ Zinc

- ◆ Corn, Small Grains & Grain Sorghum

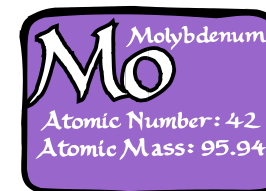


## ■ Molybdenum

- ◆ Alfalfa

- ◆ Soybeans

- ◆ Broccoli & Cauliflower



# Soil Test Notes are on-line at [www.soiltest.vt.edu](http://www.soiltest.vt.edu). See Note #4



## Lab facts

- » Started operations in 1938.
- » Over 50,000 samples are tested each year.
- » More than a third of garden

## Virginia Cooperative Extension

REVISED 2005

## Soil Test Note #4

PUBLICATION 452-704

## Trace Elements

*Greg Mullins, Extension Nutrient Management Specialist, Virginia Tech*  
*Steve Heckendorn, Soil Test Laboratory Manager, Virginia Tech*

### QUICKLINKS

Virginia Soil Testing Lab

Testing Process and Fees

Sampling Instructions

Useful Publications

Other lab information

Have Questions?

### Mission

The Virginia Tech Soil Environment: university research to determine the growth. Accurate making economic realized through and may be dam:

### Operation

## Introduction

Your Soil Test Report indicates one or more trace elements are needed. Select the appropriate sections in this note for information on the recommended trace elements and the specific rates and methods of application. Apply only those trace elements that are recommended, and only at the recommended rates!

## Zinc (Zn)

Zinc deficiency has been found on corn, small grains, and grain sorghum in Virginia. If your Soil Test Report indicates a need for zinc, select from one of the following application methods:

in succeeding crops, and you will need to apply zinc each year these crops are planted.

- 3. Sideband placement for corn and grain sorghum.** Zinc can be applied with the starter fertilizer at planting time. Where this method is used, apply 6 to 8 pounds of elemental zinc per acre using either zinc sulfate or zinc oxide as the source, or 1 to 2 pounds per acre when using zinc chelates as the source. This method of application will not correct the deficiency for succeeding crops, but would need to be applied each year these crops are grown.



# Application of Micronutrients

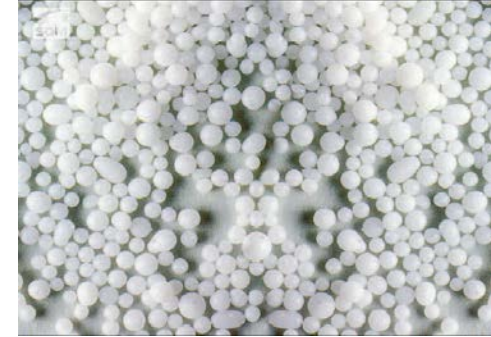
- Can be soil or foliar applied
- Sulfates, chelates & most organics are soluble and better adapted for foliar applications as compared to frits & oxides
- Foliar applications – sufficient to meet crop needs
- Solution fertilizers – compatibility problems with P





# Application of Micronutrients

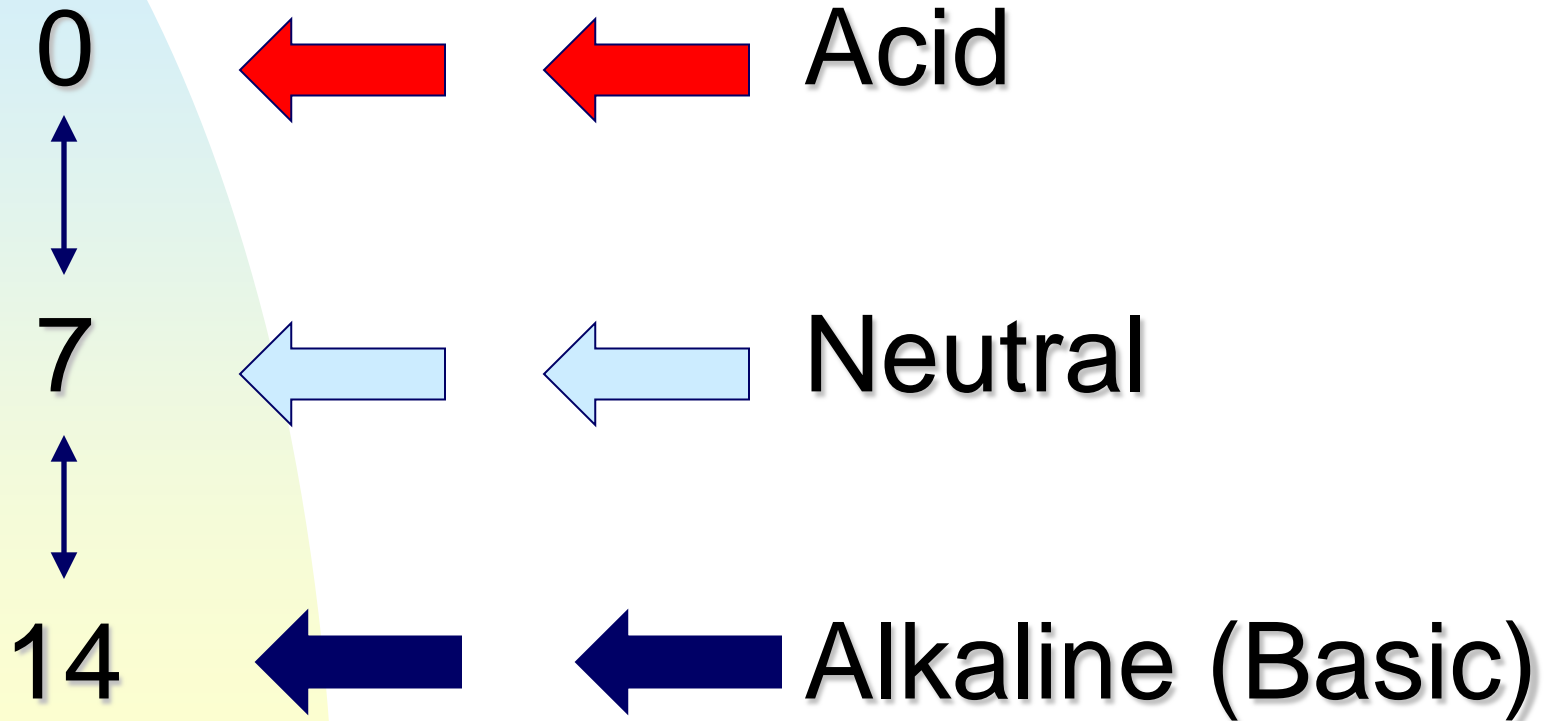
- **Micronutrients can be added to commercial fertilizers and/or mixed into bulk blends**
- **Band applications of fertilizer materials containing micronutrients increases efficiency**
- **Over applications – may result in toxic soil levels**

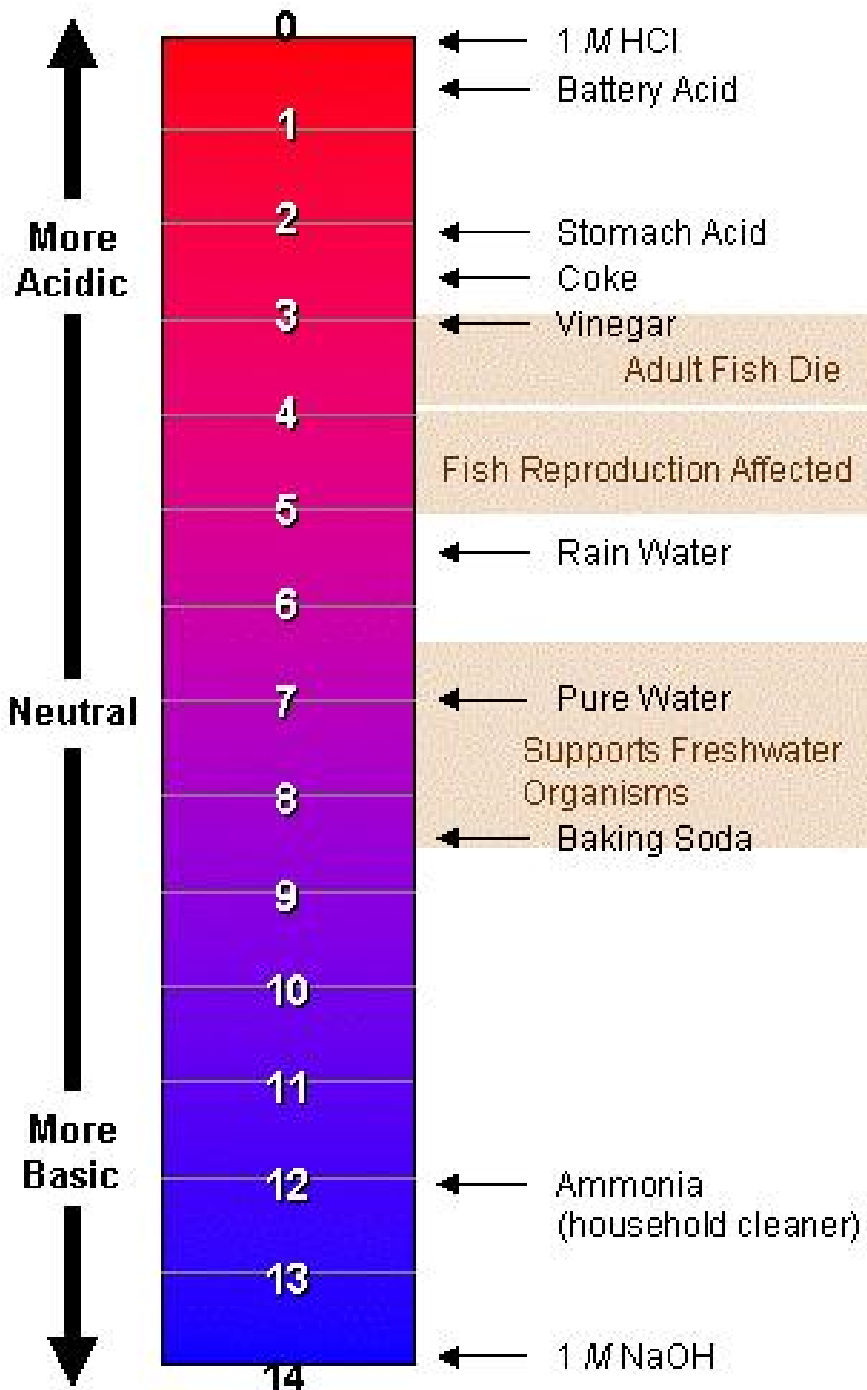


# Selected Micronutrient Sources

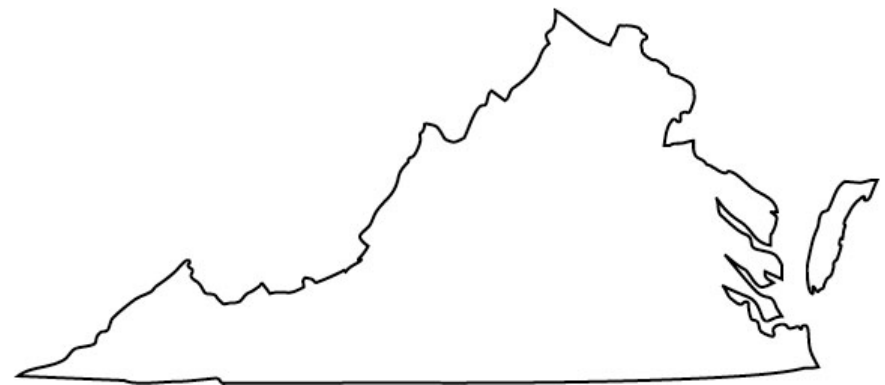
<b>Material</b>	<b>Element</b>	<b>% Element</b>
<b>Borax</b>	<b>B</b>	<b>11.3</b>
<b>Solubor</b>	<b>B</b>	<b>20.0</b>
<b>Boron Frits</b>	<b>B</b>	<b>2.0 – 6.0</b>
<b>Iron Sulfate</b>	<b>Fe</b>	<b>19 – 23</b>
<b>Iron Frits</b>	<b>Fe</b>	<b>Variable</b>
<b>Iron Chelates</b>	<b>Fe</b>	<b>5 – 14</b>
<b>Manganese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

# 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**

# Desired Soil pH

## ■ Critical Levels:

◆ <5.0 – 5.5: Non-Leguminous crops

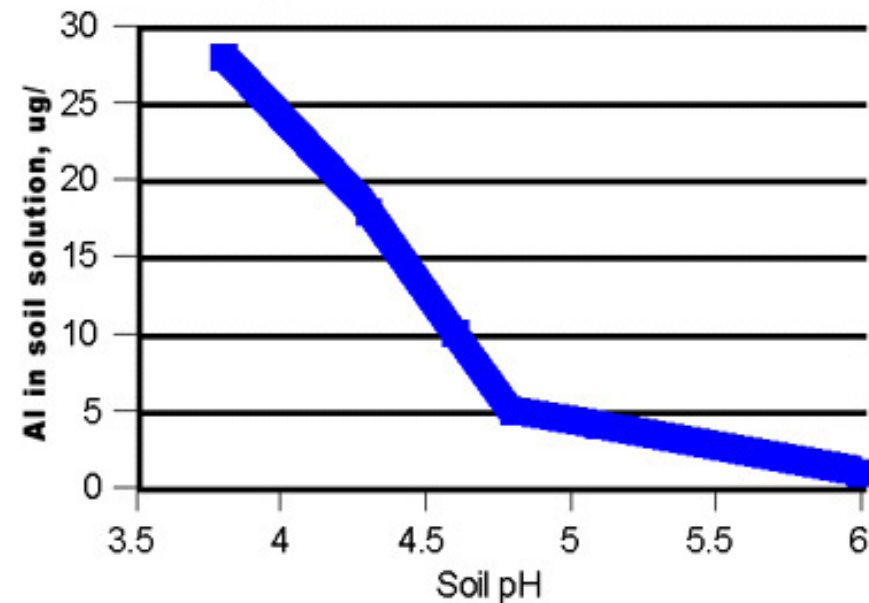
☞ Corn: 6.2

☞ Tobacco: 5.8

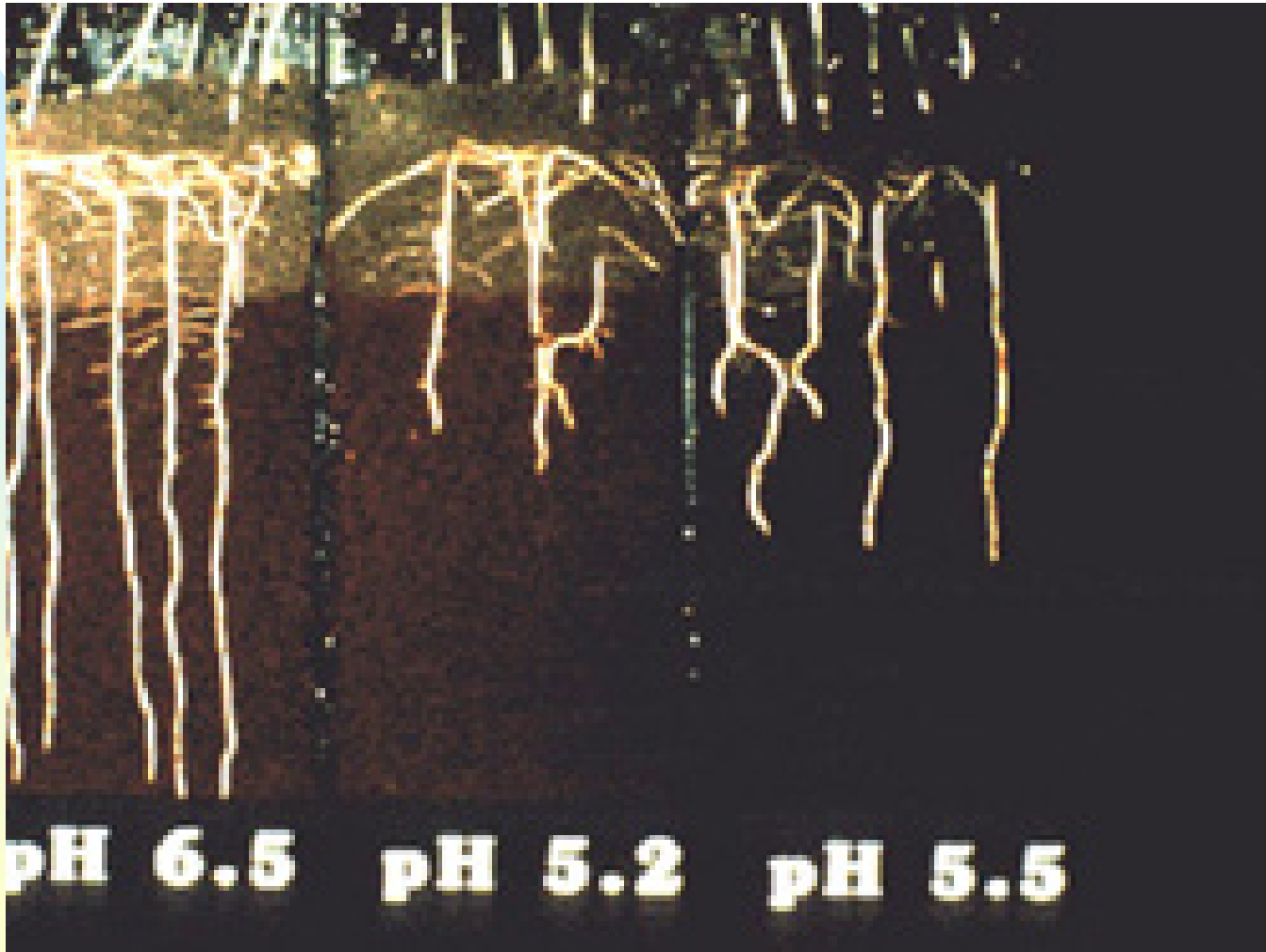
◆ <6.5: Legumes

☞ Alfalfa: 6.8

Effect of pH on  $\text{Al}^{3+}$  in solution

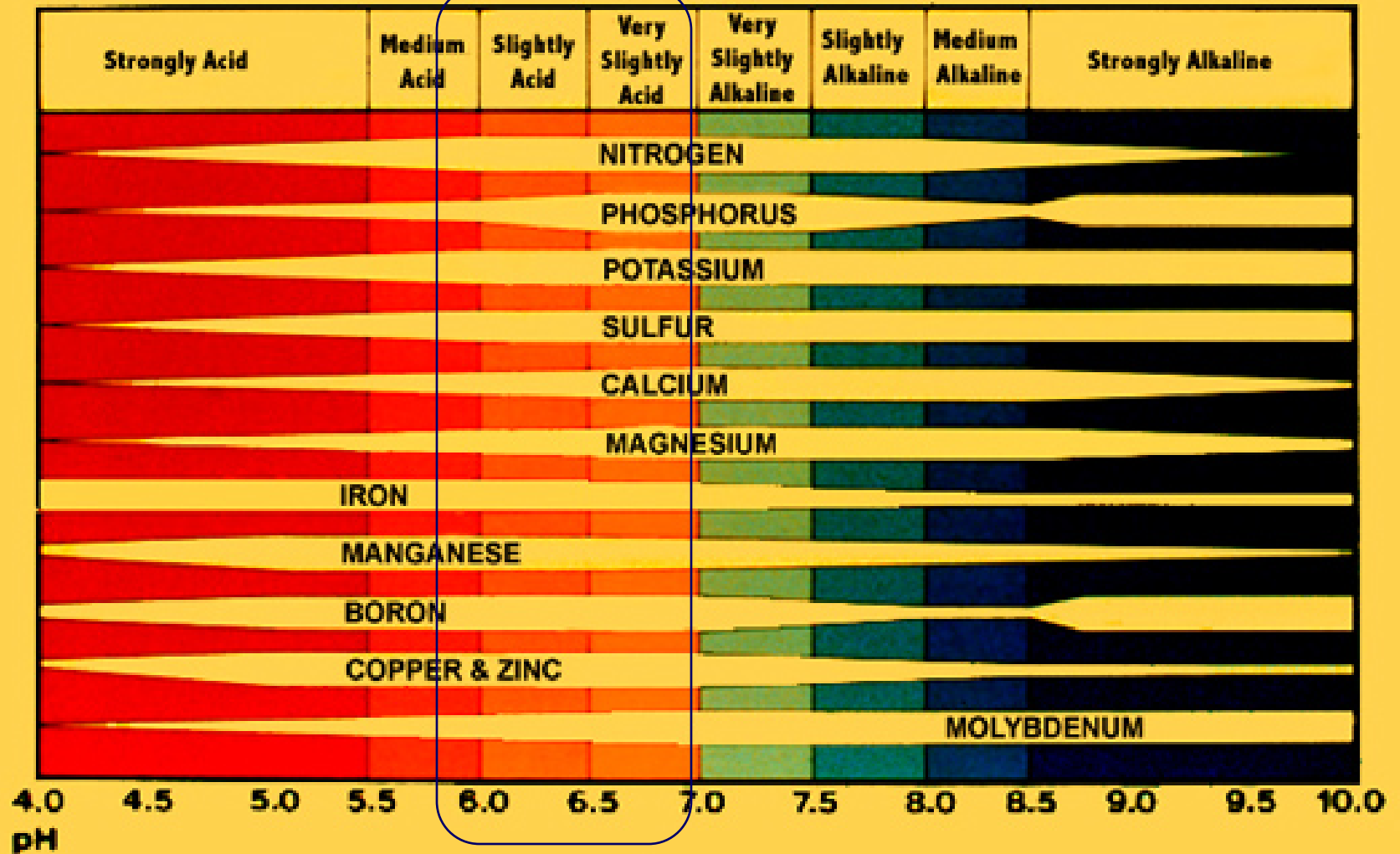


# Root Growth Restricted by Al





# How Soil pH Affects Availability of Plant Nutrients



# VCE's web site → [www.ext.vt.edu](http://www.ext.vt.edu)

The screenshot shows the homepage of the Virginia Cooperative Extension website. At the top, there is a green navigation bar with links for 'VCE', 'People', and 'Office By ZIP', along with a 'Google™ Custom Search' box and a 'GO' button. Below this is the main header area with the 'Virginia Cooperative Extension' logo on the left, and the logos for 'Virginia Tech' (with the tagline 'Invent the Future') and 'VIRGINIA STATE UNIVERSITY' on the right. A dark blue navigation bar contains links for 'Home', 'Publications & Resources', 'Local Offices & Research Ctrs.', 'Program Areas', 'News', 'Calendar', and 'About'. Below the navigation bar, the page title 'Agriculture and Natural Resources >' is displayed. The main content area features a large green heading 'Agriculture and Natural Resources'. Underneath, there is a section titled 'Advice You Can Trust' with a photograph of two men in a market setting. To the right of the photo is a paragraph about ANR programs. Below the photo is a sub-section 'Meeting Diverse Needs' with a paragraph about extension faculty. Further down is another paragraph about extension agents and their role. To the right of the text is a photograph of a person in an orange shirt working in a greenhouse. On the far right, there is a vertical sidebar titled 'ANR Topic Areas' containing a list of nine topics, each preceded by a blue circular bullet point.

VCE People Office By ZIP  Google™ Custom Search GO

Virginia Cooperative Extension Virginia Tech *Invent the Future* VIRGINIA STATE UNIVERSITY

Home Publications & Resources Local Offices & Research Ctrs. Program Areas News Calendar About

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

---

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