

Basic Soil Fertility

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Limiting Factors

Possible production

Insects and diseases

Weeds

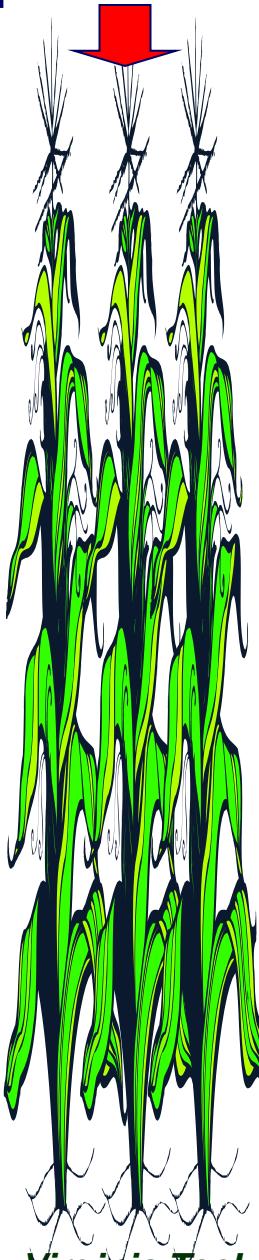
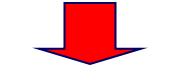
Improper crop variety

Poor soil conditions

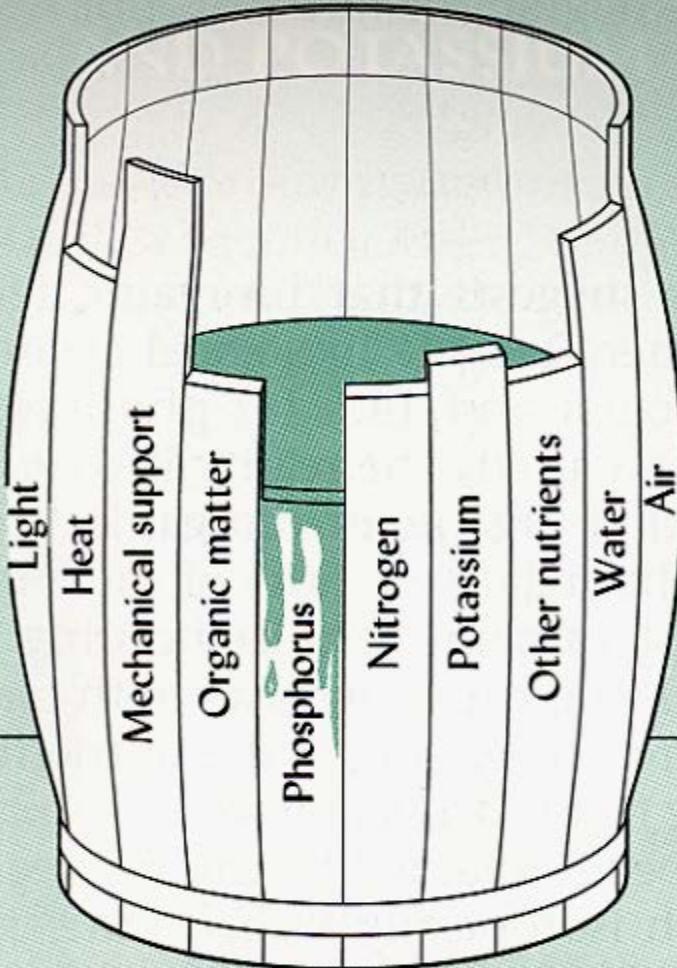
Poor stand

Low fertility

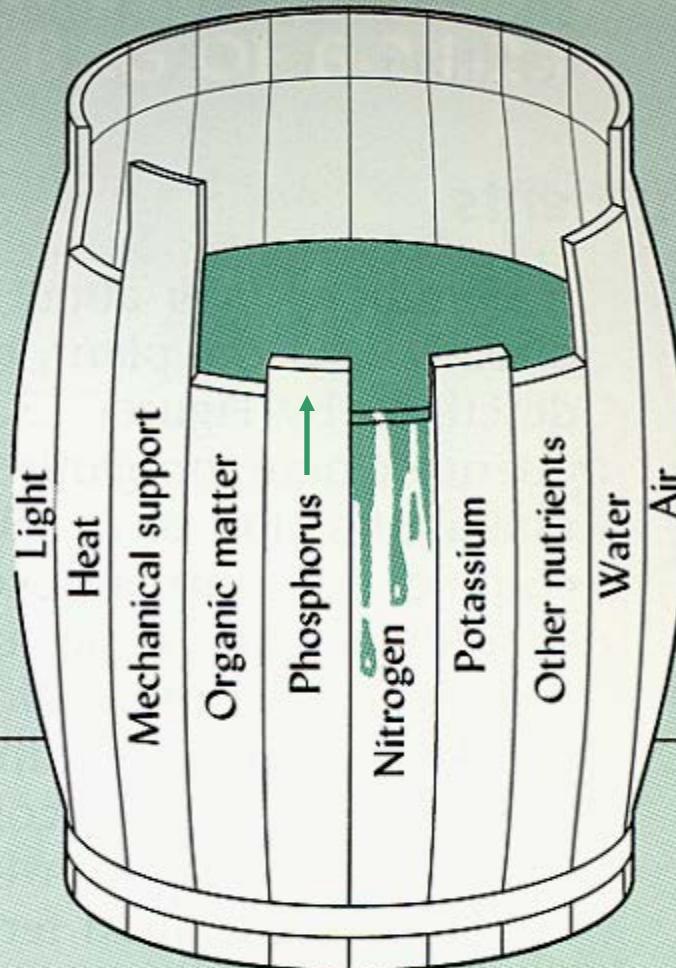
Lack of moisture



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



Co

Ni

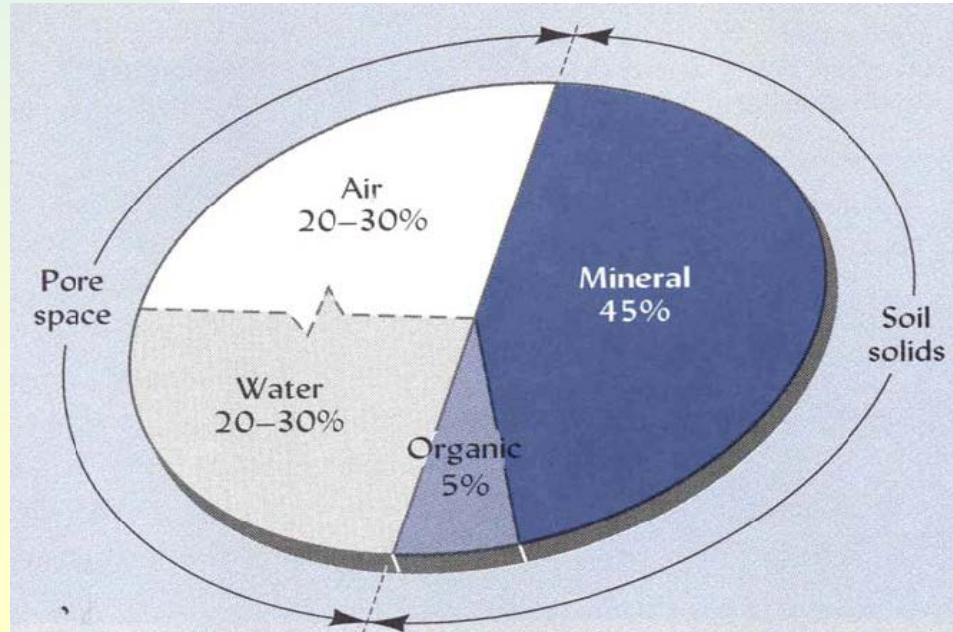
Non-Mineral Nutrients

Non-Mineral Elements

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

Sources:

Air (CO_2 ; O_2)
Water (H_2O)



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: 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-}

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+}

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

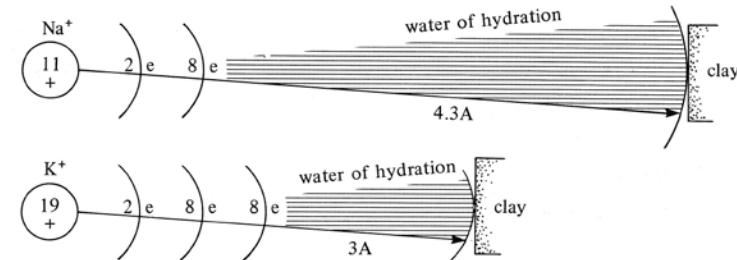
- ◆ Size or diameter of ion

- ☞ High charge + small diameter = high retention

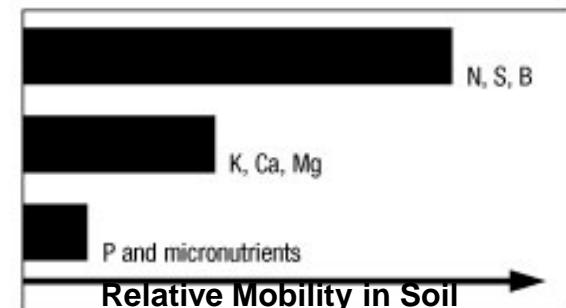
- ◆ Type of charge:

- ☞ Anions (e.g. NO_3^-) in general leach more easily than cations

- ☞ Phosphate is an exception



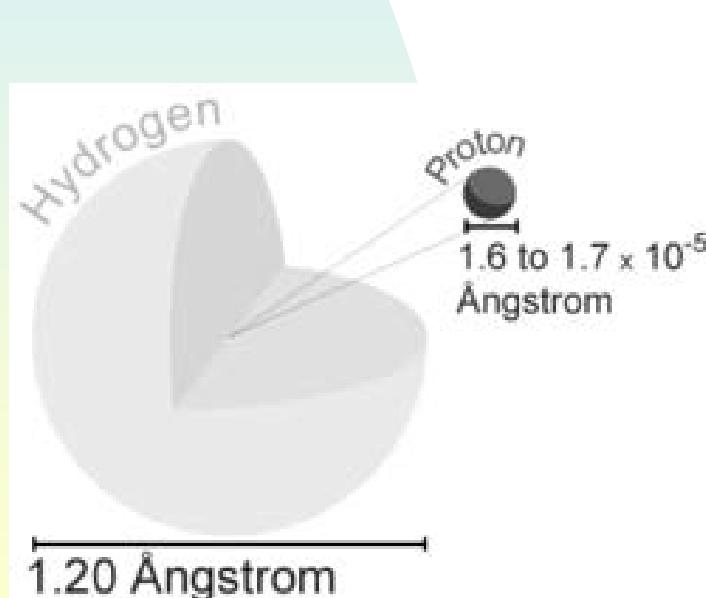
MANMH: p.48



Nutrient Mobility in Soils

- Degree or strength of retention:

$(H^+)Al^{3+} \gg Ca^{2+} > Mg^{2+} > K^+ = NH_4^+ > Na^+$



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

Manganese

Boron

Zinc

Copper

Molybdenum

Iron

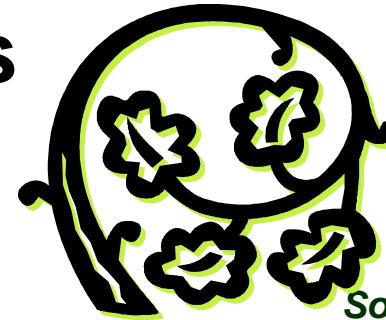
Chlorine (mobile)





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

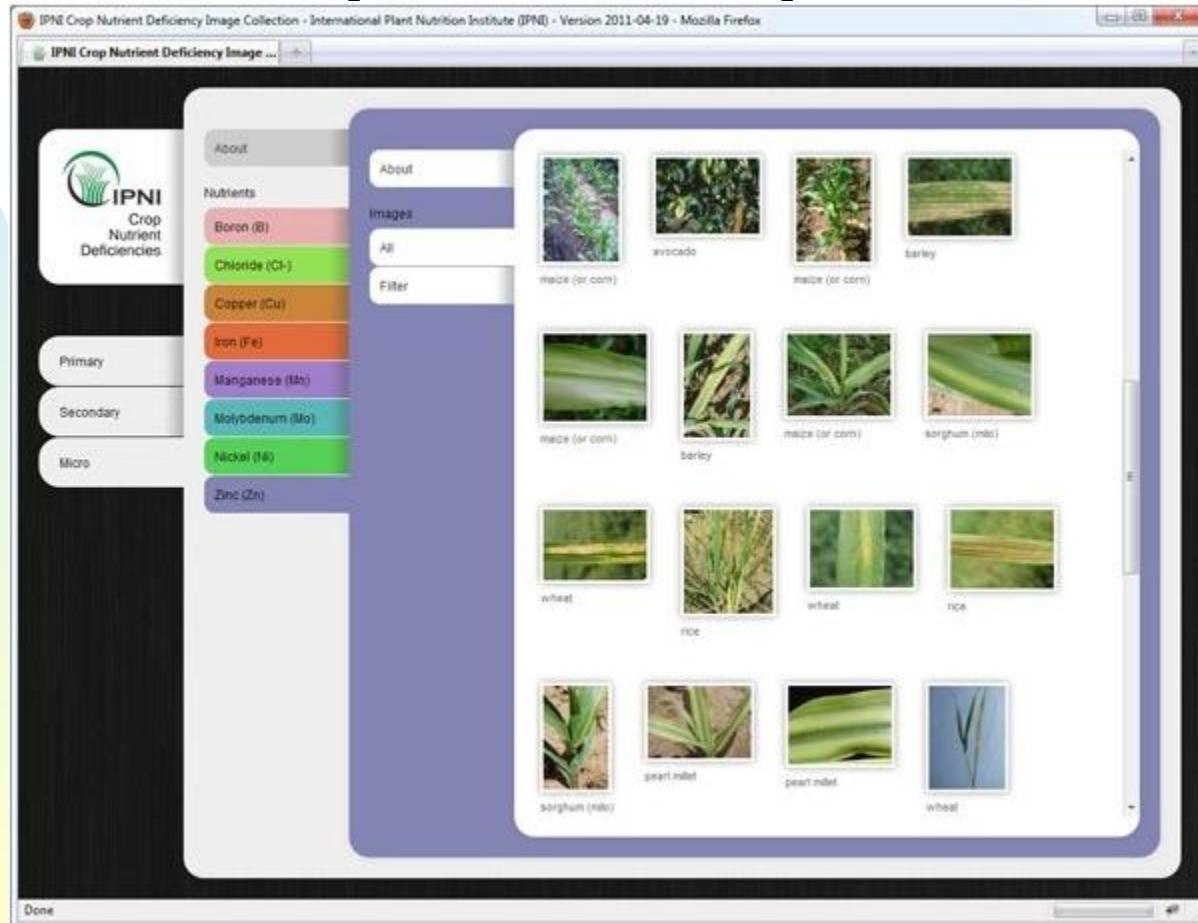


MANMH: p. 59



IPNI's \$30 CD (item # 82-8290) on Nutrient Deficiency Images

<http://store.ipni.net>



MANMH: p. 60-63



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Potassium



A close-up photograph of a green corn leaf exhibiting potassium deficiency. The leaf shows distinct horizontal yellowish-green streaks running parallel to the veins, indicating the lack of potassium. The edges of the leaf appear slightly browned and curled. The background is dark, making the green and yellow colors stand out.

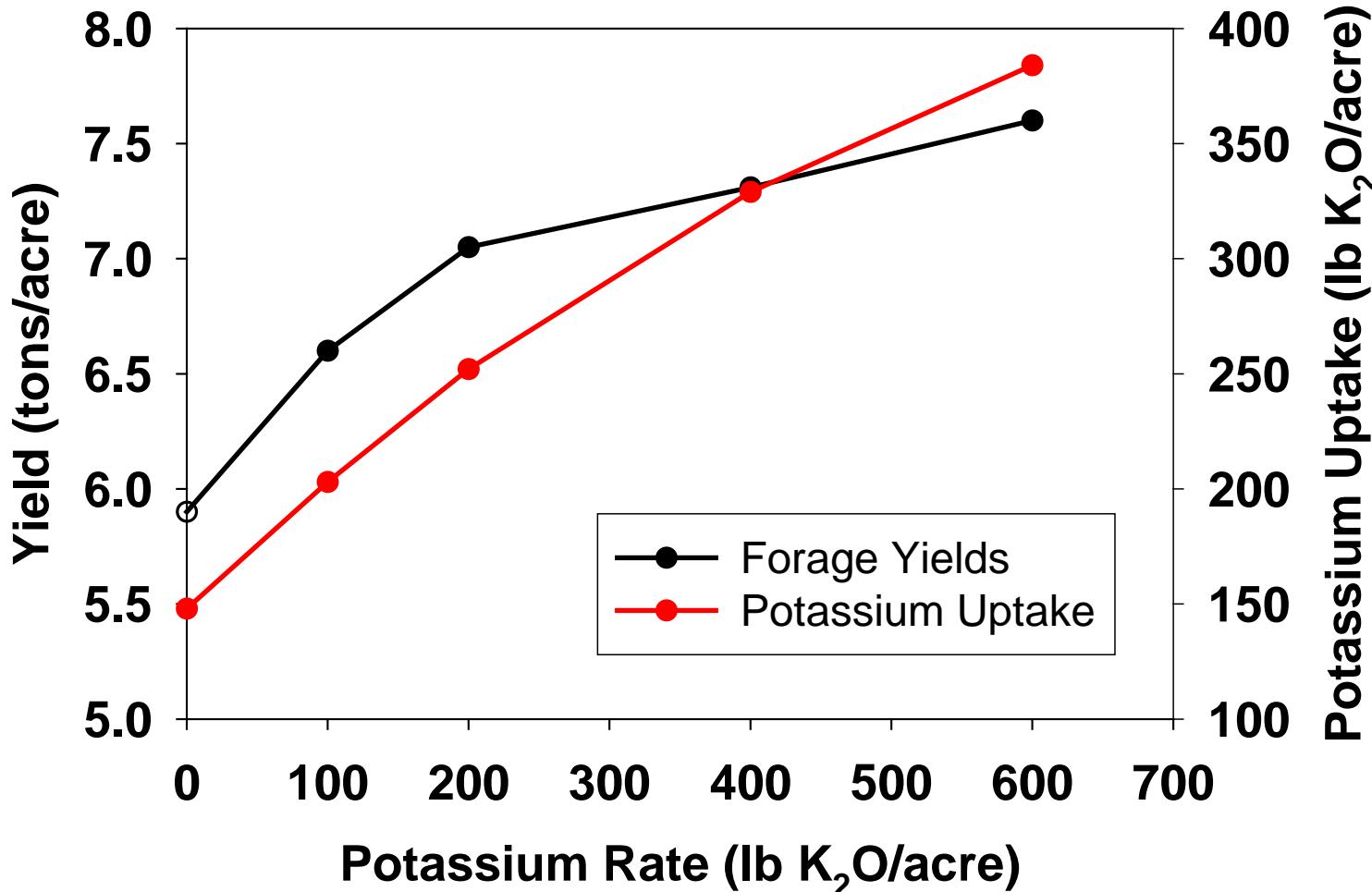
Potassium Deficient Corn

K Deficient Soybean



Potassium Yield Response

Coastal Bermudagrass



(Eichhorn, 1982)

Potassium

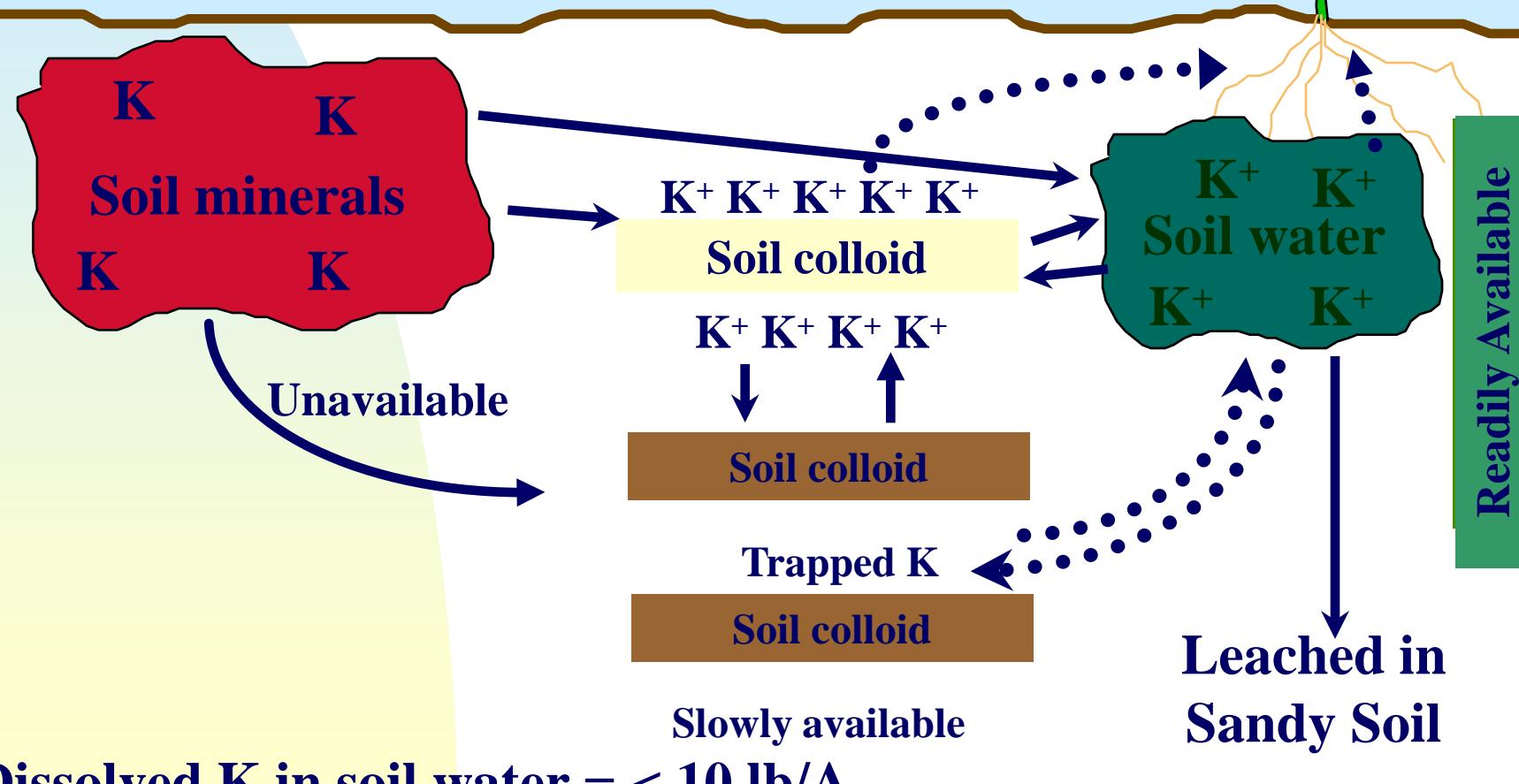
- Taken up by the plant as K⁺
- Does not form organic compounds in the plant
- Is vital to photosynthesis and protein synthesis
- Reduces Lodging
- Increases winter hardiness
- Increases resistance to diseases

MANMH: p. 82-84

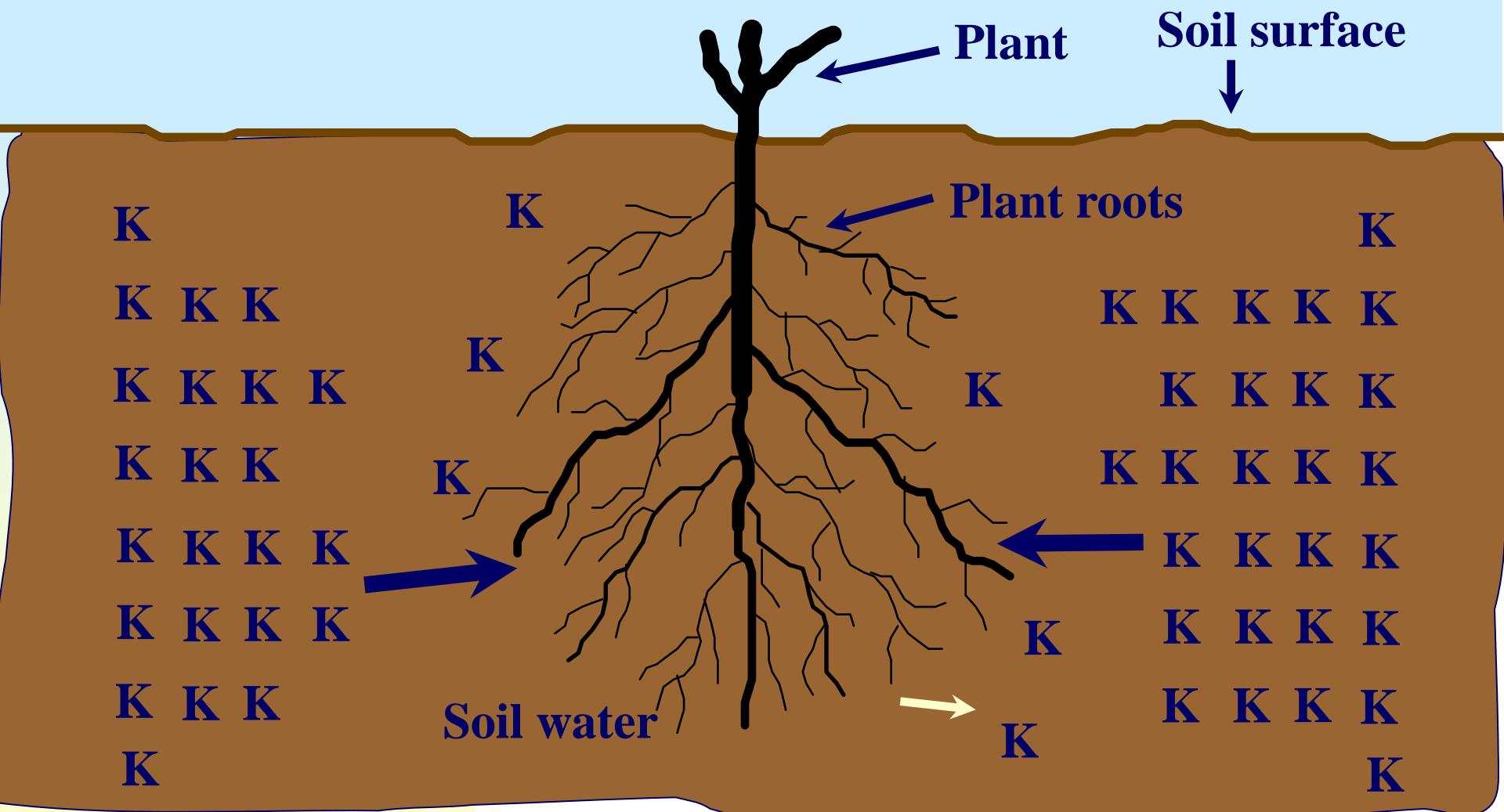
Potassium in Soils

- 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



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 ₂ O (%)
Potassium Chloride (Muriate of Potash)	KCl	60-62
Potassium Sulfate (Sulfate of Potash)	K ₂ SO ₄	50-53
K-Mg-Sulfate (Sulphate of Potash-Magnesia)	K ₂ SO ₄ ·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.

Secondary Nutrients: Ca, Mg, S

Crop	Yield level	Pounds in total Crop		
		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 Ca & Mg

- Calcium & Magnesium have similar behavior in soils:
 - ◆ Cations: Ca^{+2} & 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)

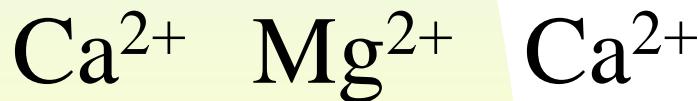
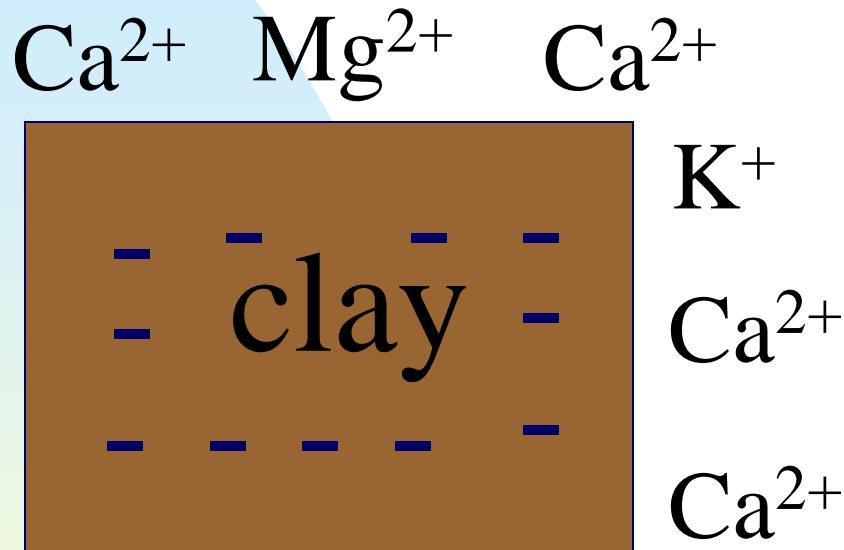
Soil Test Rating	STCa lb/A	STMg lb/A
L-	0-240	0-24
L	241-480	25-48
L+	481-720	49-72
M-	721-960	73-96
M	961-1200	97-120
M+	1201-1440	121-144
H-	1441-1680	145-168
H	1681-1920	169-192
H+	1921-2160	193-216
VH	2161-2400+	217-240

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 ($\leftarrow \downarrow$ available)
 - ◆ Soil Solution Ca: Ca^{+2}
- **Magnesium:** Soil Mg 0.1 to 4%
 - ◆ Mineral Mg: (very slowly available)
 - ☞ dolomite, biotite, hornblende & chlorite
 - ◆ Exchangeable Mg ($\leftarrow \downarrow$ available)
 - ◆ Soil Solution Mg: Mg^{+2}

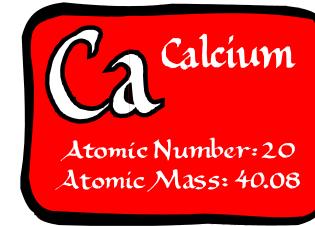


Available Soil Ca & Mg



{Ca usually = 70-90% of CEC}

Benefits of Calcium



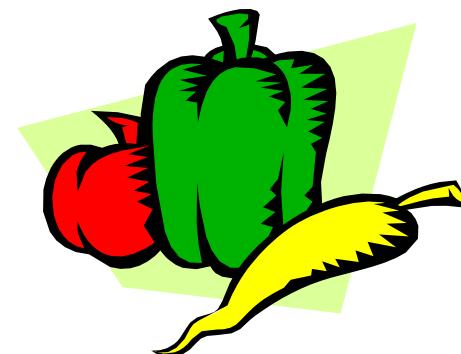
- Reduces soil acidity:
Lowers solubility and toxicity of
manganese and aluminum

- Improves root growing conditions:
Microbial activity
Molybdenum availability
Availability & uptake of other
nutrients

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.



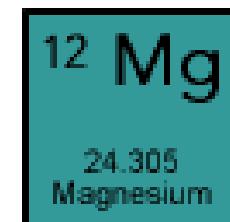
Magnesium



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



MANMH: p. 70

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



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

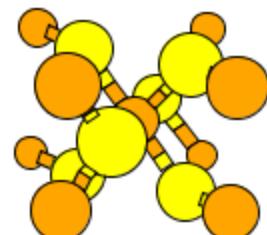


■ Sulfate - Subject to leaching

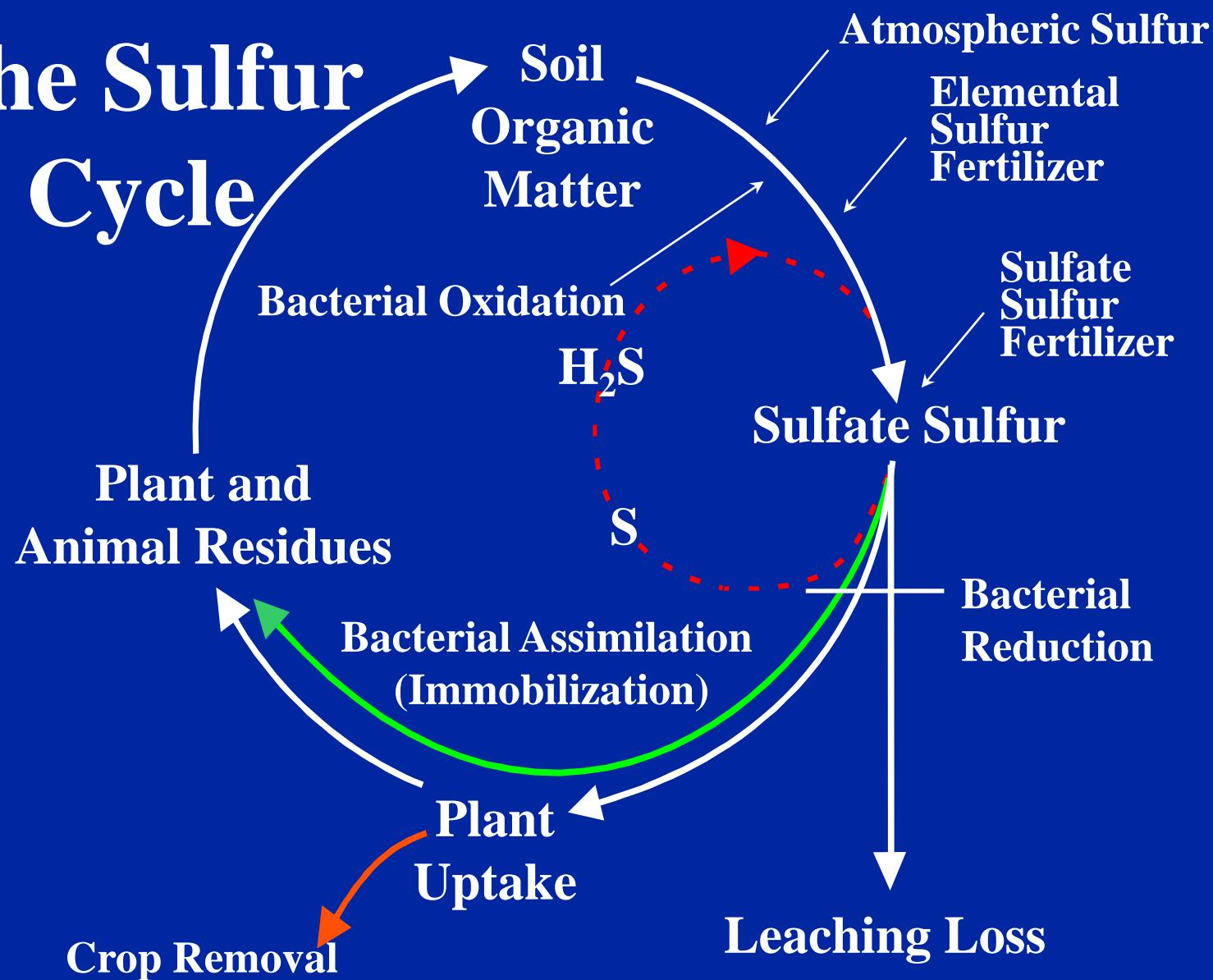
- ◆ Sulfate often accumulates in subsurface horizons (Positively charged soil colloids)

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

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

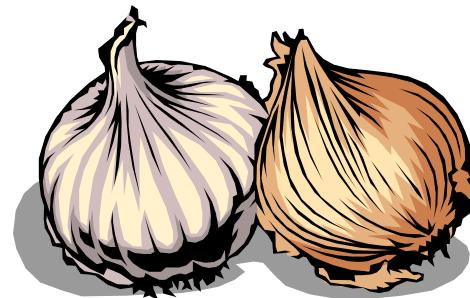


The Sulfur Cycle



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	K_2SO_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

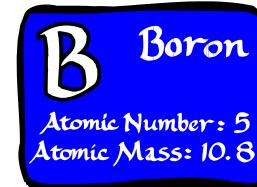
- ◆ Soybean & Peanuts



■ Boron

- ◆ Alfalfa
- ◆ Certain Vegetables:

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



- ◆ Cotton

- ◆ Peanuts

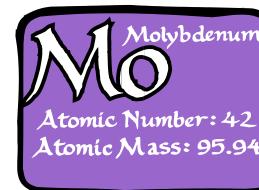
■ Zinc

- ◆ Corn, Small Grains & Grain Sorghum



■ Molybdenum

- ◆ Alfalfa
- ◆ Soybeans
- ◆ Broccoli & Cauliflower

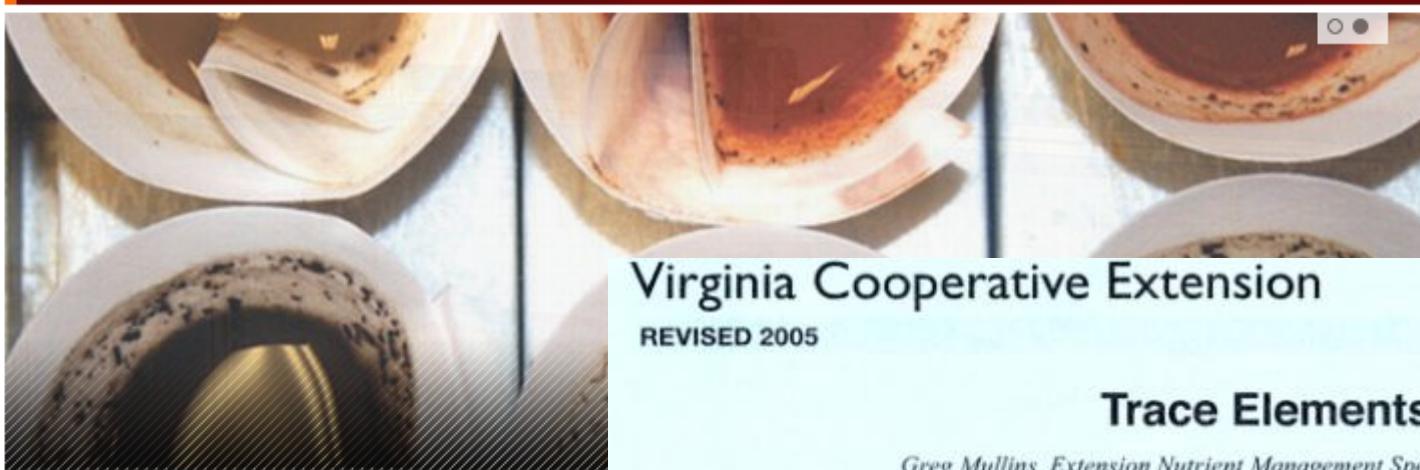


Soil Test Notes are on-line at www.soiltest.vt.edu. See Note #4



Department of
Crop and Soil Environmental Sciences

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Virginia Cooperative Extension REVISED 2005



Lab facts

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

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*

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.

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

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



Application of Micronutrients

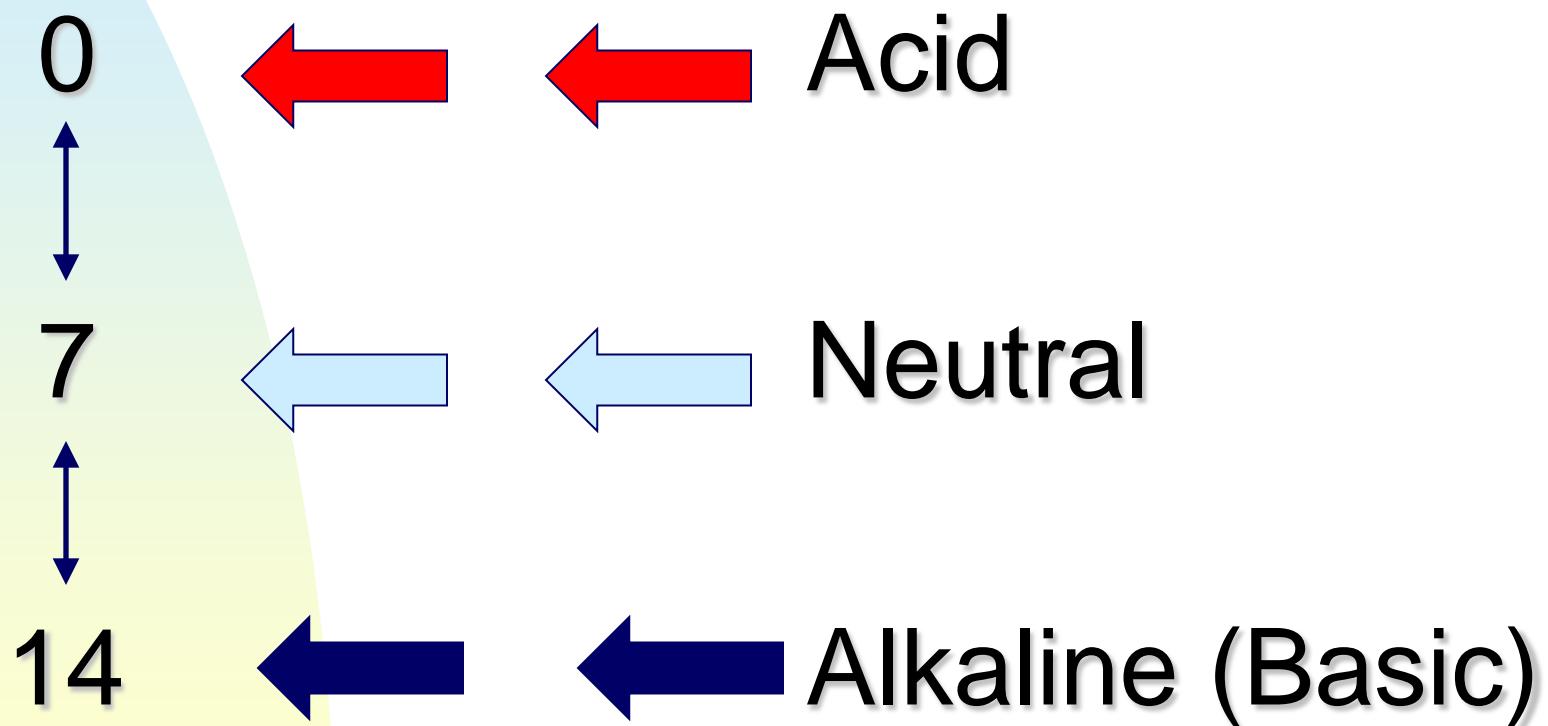
- Micronutrients can be added to commercial fertilizers and/or mixed into bulk blends
- Band applications of fertilizer materials containing micronutrients increases efficiency
- Over applications – may result in toxic soil levels

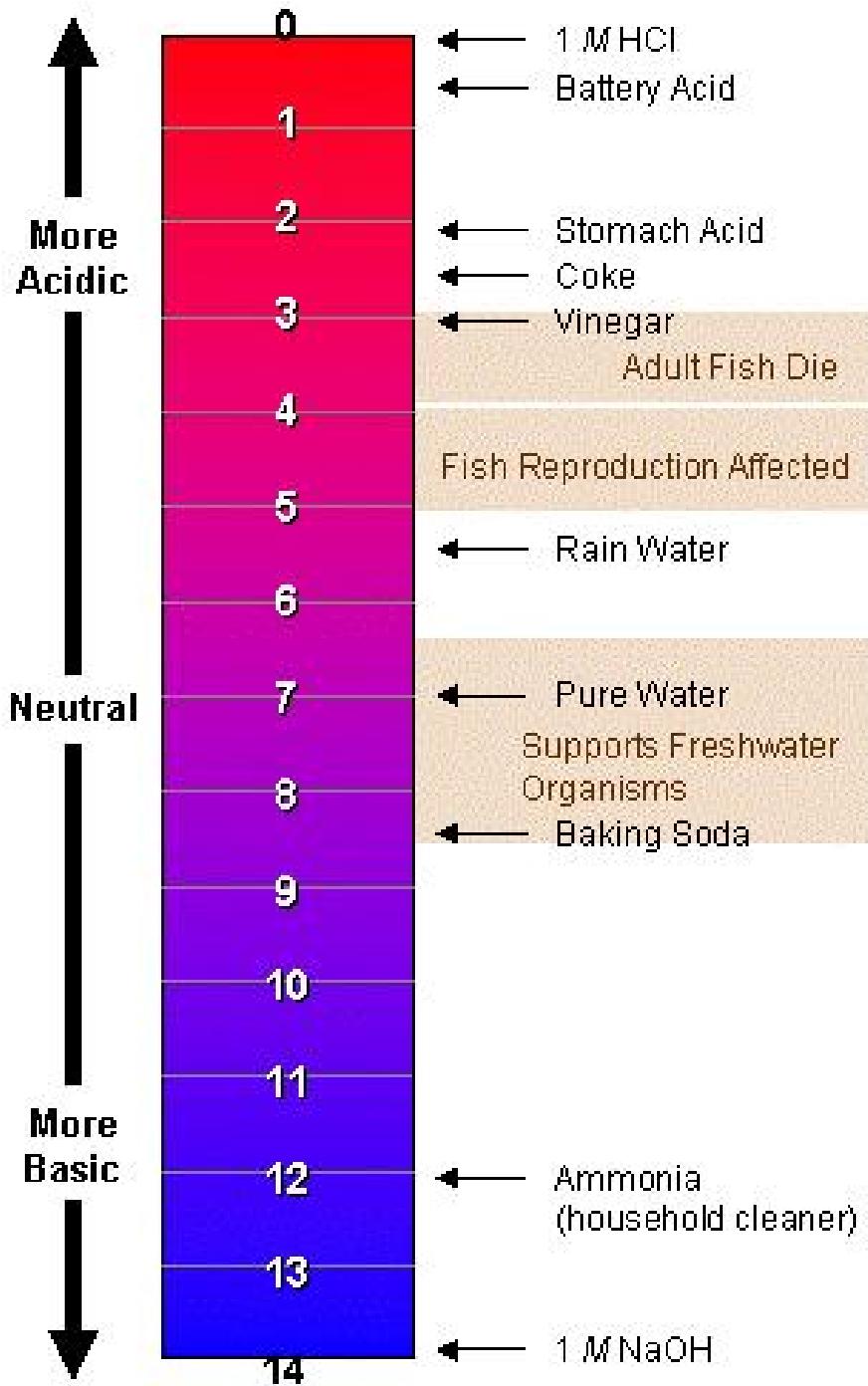


Selected Micronutrient Sources

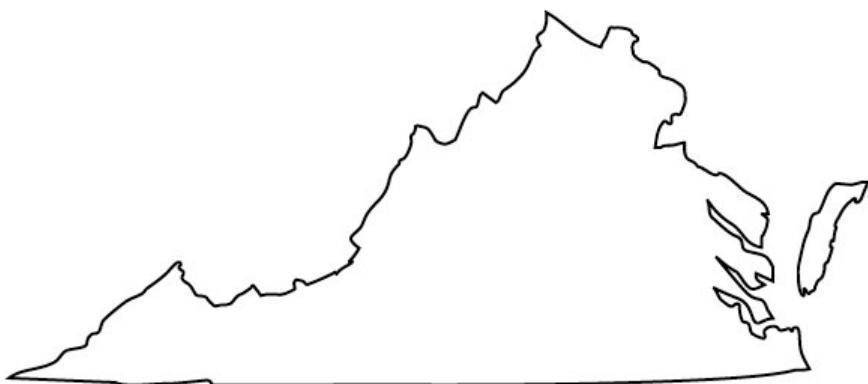
Material	Element	% Element
Borax	B	11.3
Solubor	B	20.0
Boron Frits	B	2.0 – 6.0
Iron Sulfate	Fe	19 – 23
Iron Frits	Fe	Variable
Iron Chelates	Fe	5 – 14
Manganese Sulfate	Mn	26 – 28
Manganese Chelates	Mn	12
Zinc Sulfate	Zn	23 – 35
Zinc Chelates	Zn	9 – 14
Sodium Molybdate	Mo	39 – 41

pH Scale





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



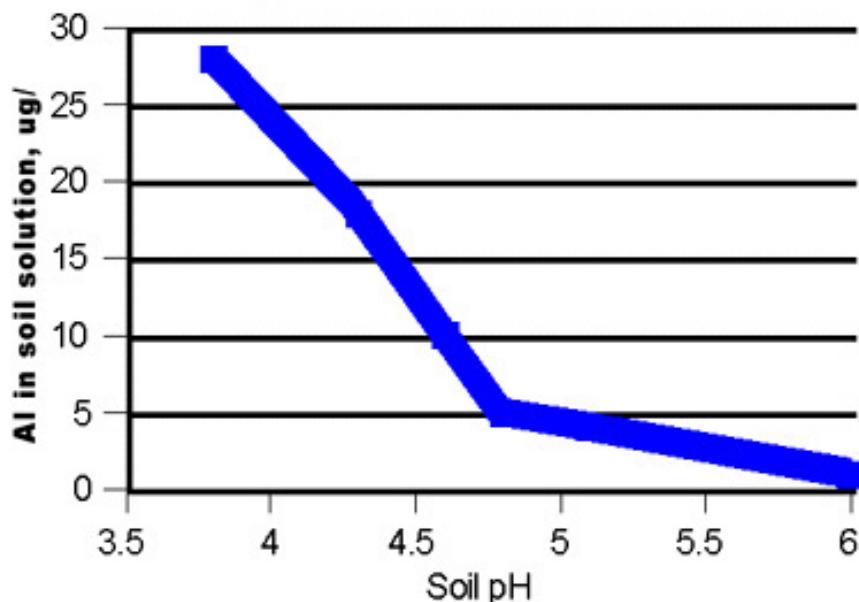
**5.1 -5.3 most common
for unlimed soils**

Desired Soil pH

■ Critical Levels:

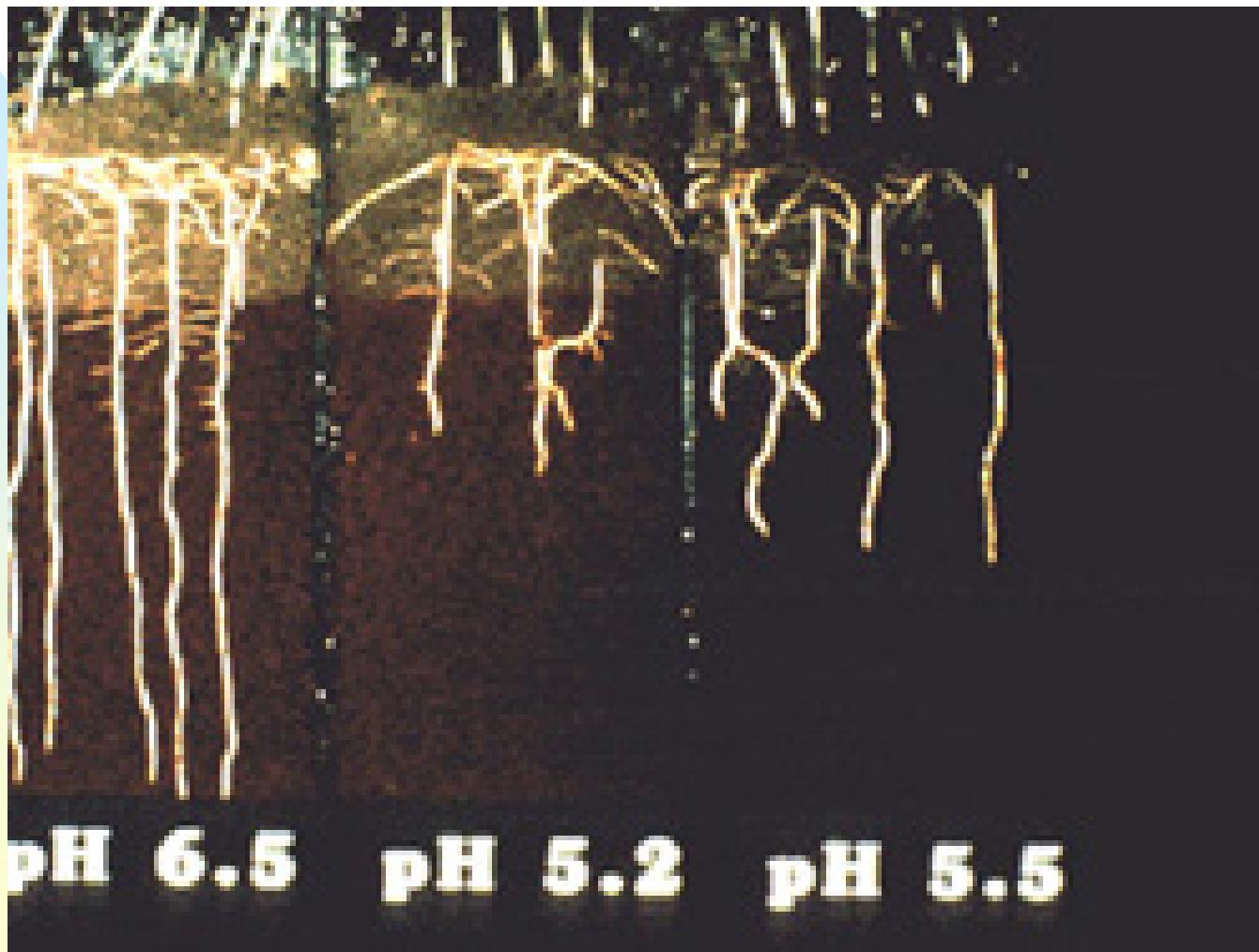
- ◆ <5.0 – 5.5: Non-Leguminous crops
 - 👉 Corn: 6.2
 - 👉 Tobacco: 5.8
- ◆ <6.5: Legumes
 - 👉 Alfalfa: 6.8

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

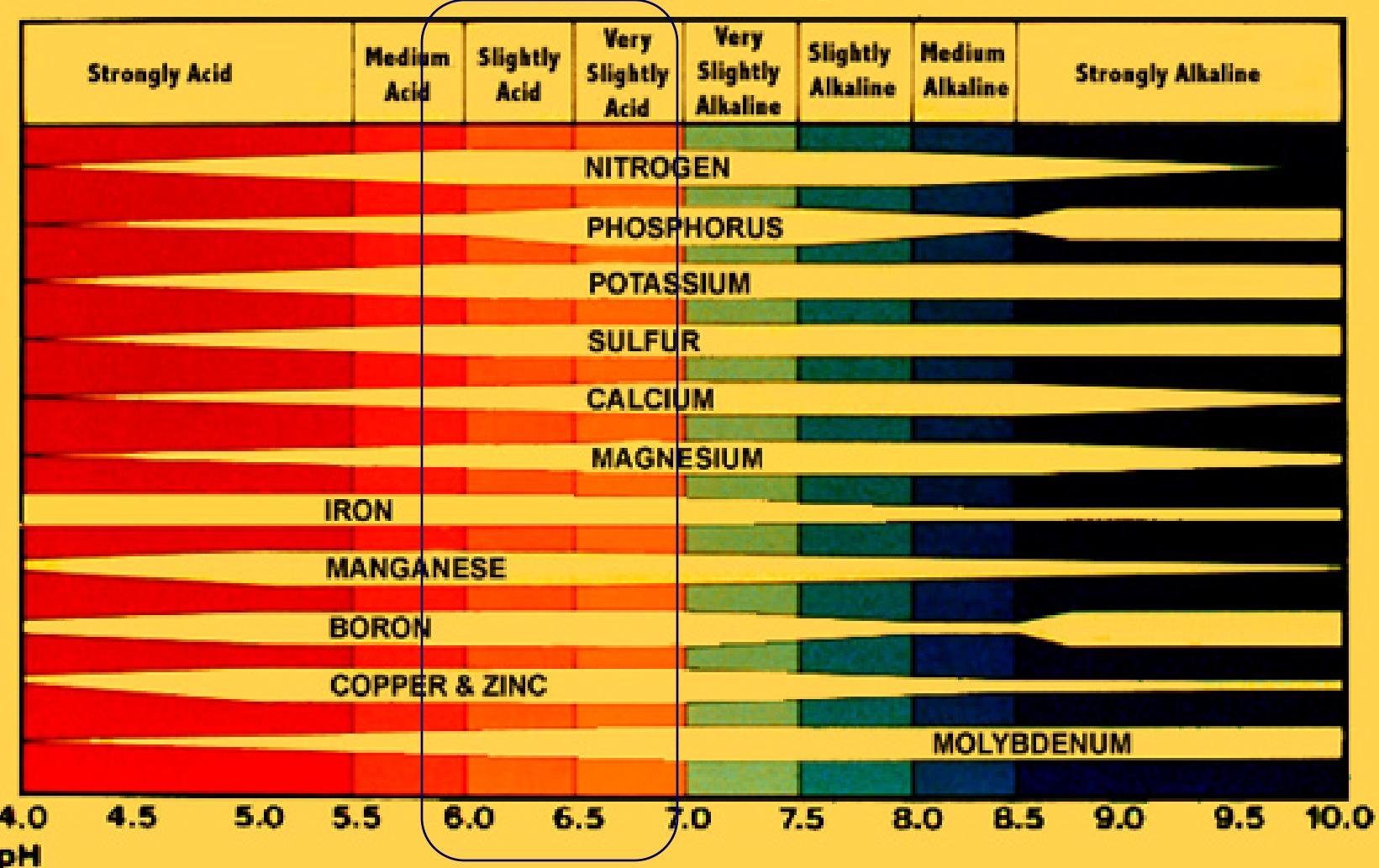


MANMH: p. 66-68

Root Growth Restricted by Al



How Soil pH Affects Availability of Plant Nutrients



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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:



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- 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](#)