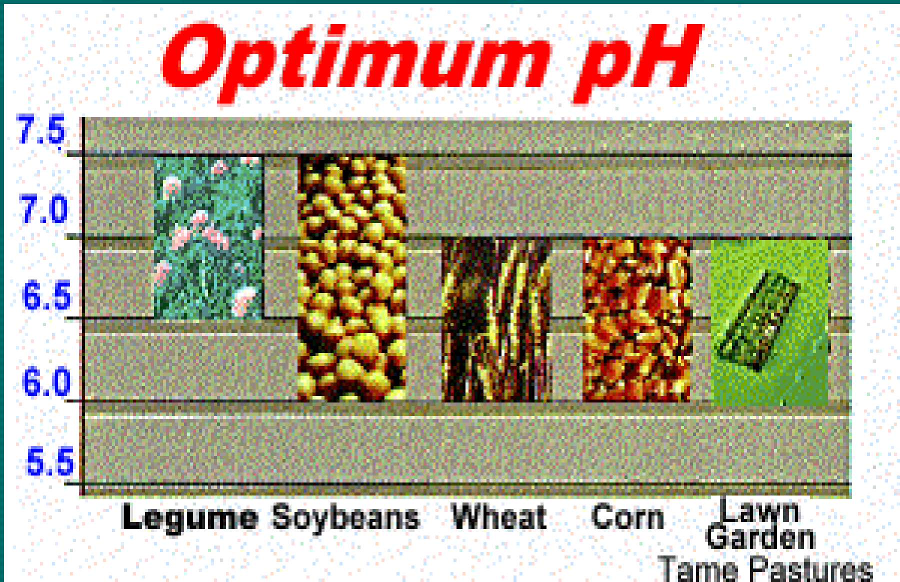
SOIL ACIDITY, ALKALINITY AND SALINITY

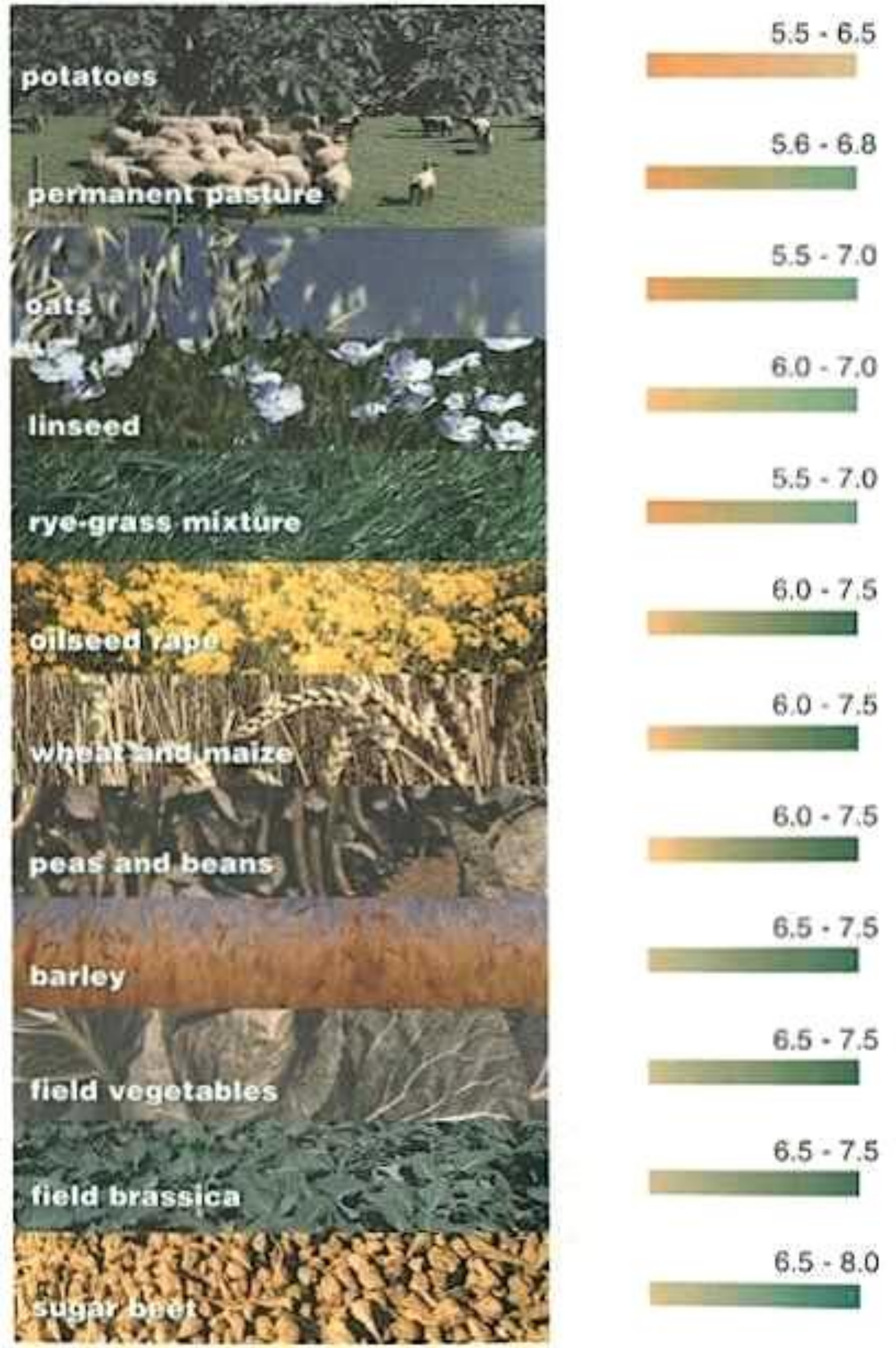
INTRODUCTION

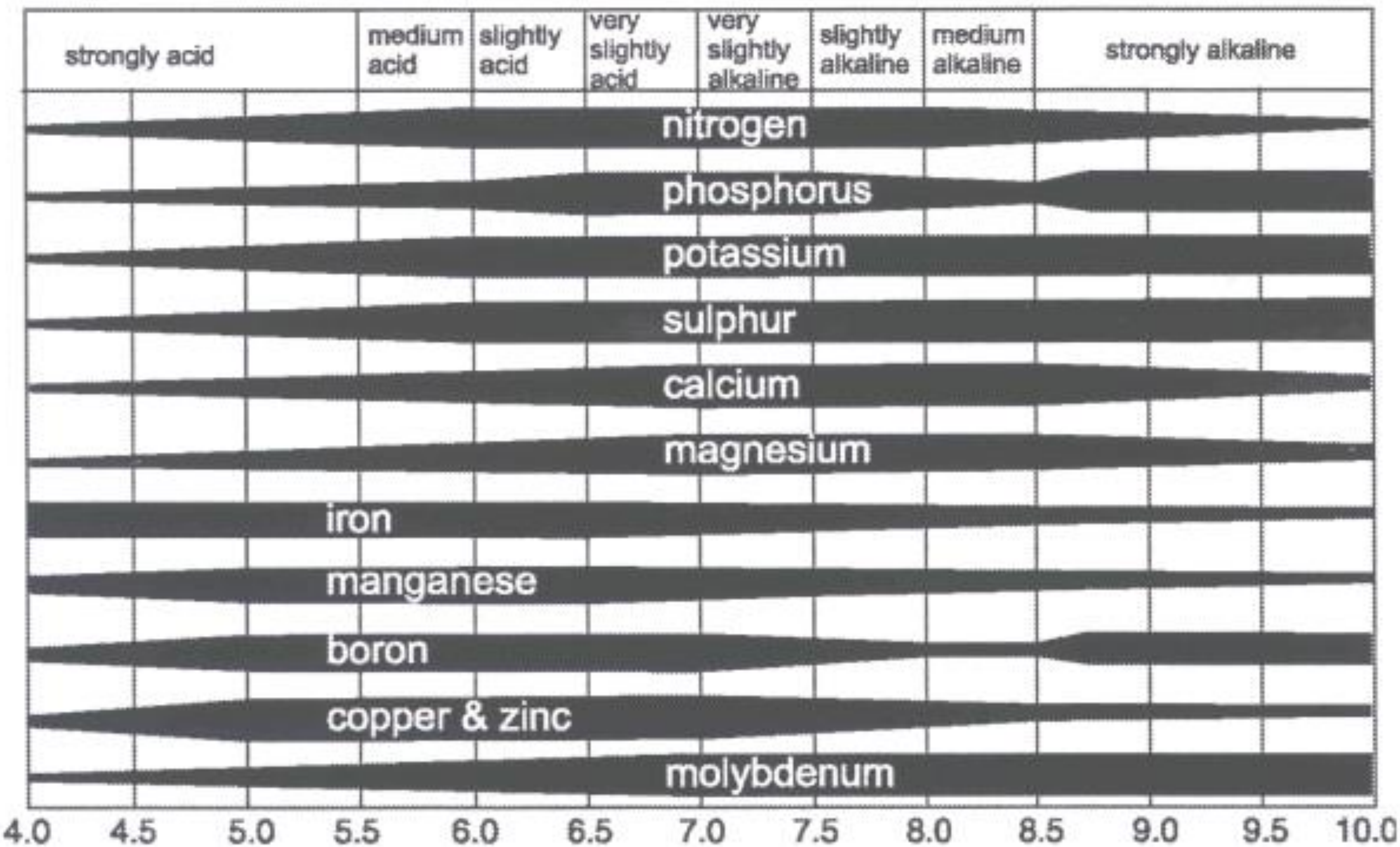
- pH is considered the master variable:
  - Chemical soil properties
  - Biological soil properties



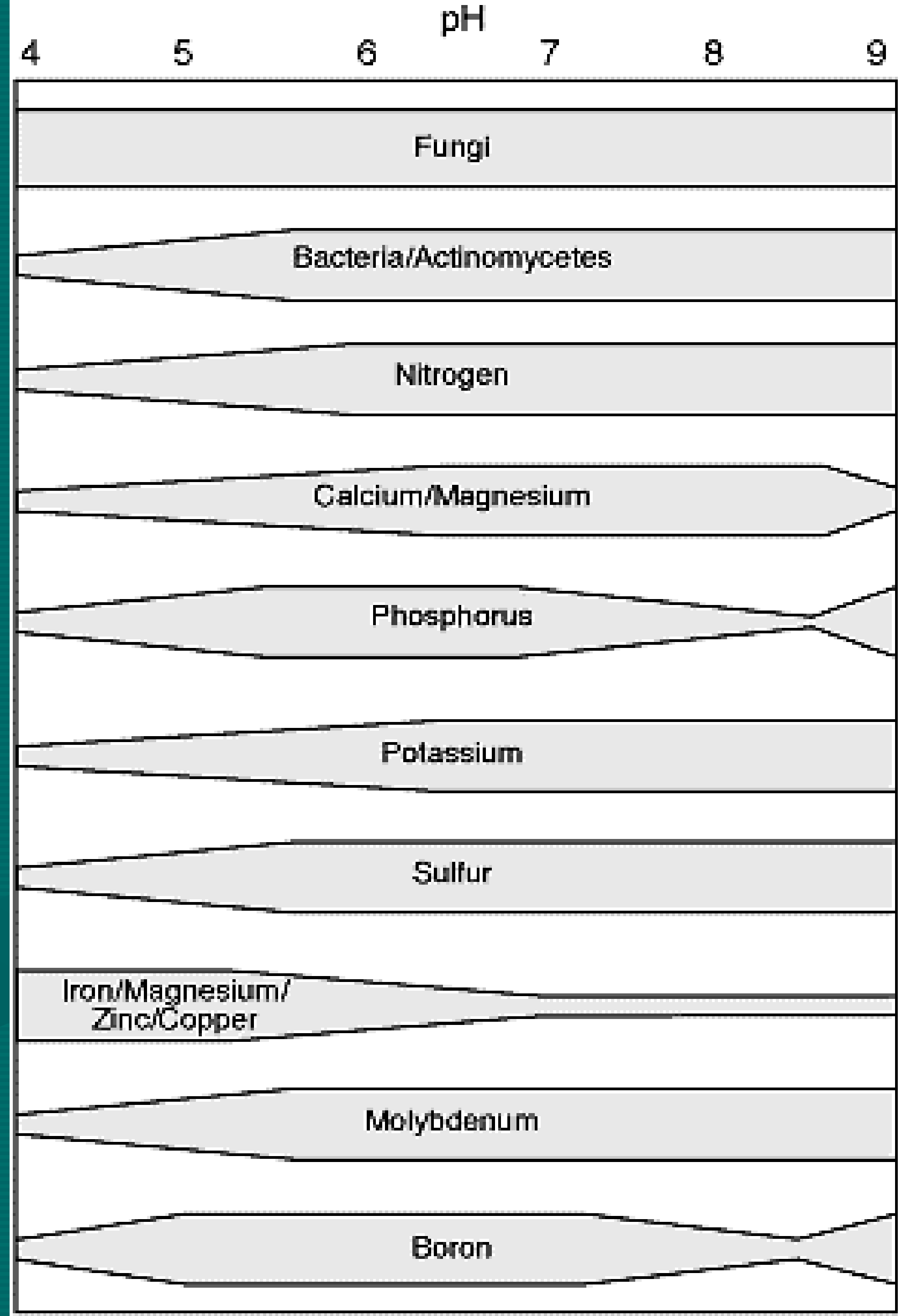
OPTIMUM pH

- Physical soil properties
- Nutrient uptake




strongly acid
medium acid
slightly acid
very slightly acid
very slightly alkaline
slightly alkaline
medium alkaline
strongly alkaline
nitrogen
phosphorus
potassium
sulphur
calcium
magnesium
iron
manganese
boron
copper & zinc
molybdenum
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0

- Microbial activity
- Plant species
- Mobility of pollutants
- Build-up of acids



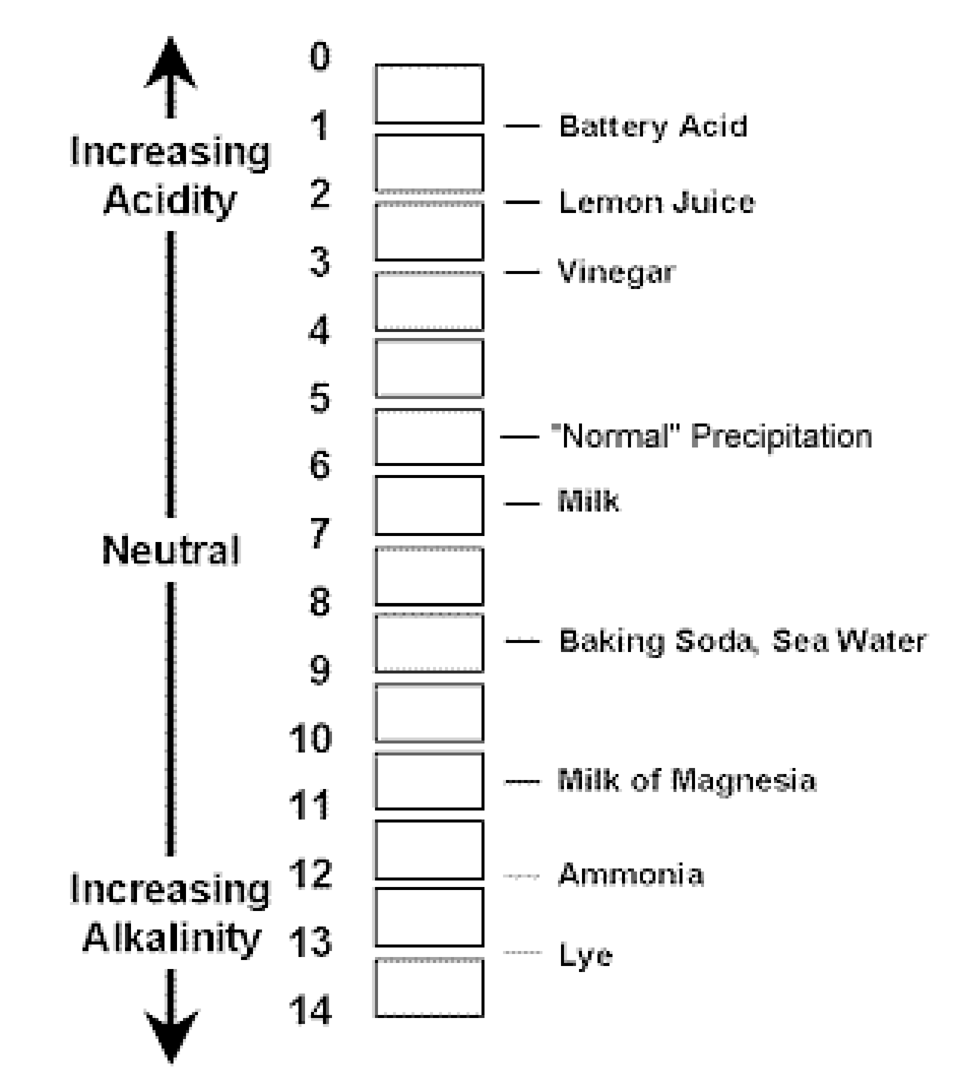
INTRODUCTION

- **Factors affecting soil pH**
  - Balance between acid and non-acid cations on colloid surfaces
  - Balance between H^+ and OH^- in soil solution
  - Supply of macronutrients (Ca, Mg, and Al)

PROCESS OF SOIL ACIDIFICATION

- Quantified using a pH scale

- Expresses the concentration of H+ ions present in solution



PROCESS OF SOIL ACIDIFICATION

- Source of H+ ions?
- How they enter the soil system?
- How they may be lost from the soil system?

SOURCES OF HYDROGEN IONS

- **Acids**
  - **Carbonic acid** = $CO_2 + H_2O$
    - Considered a weak acid
    - Negligible source of H+ at pH's <5
  - **Citric** and **malic acids** from breakdown of organic matter
  - **Carboxylic** and **phenolic acids** in humic substances

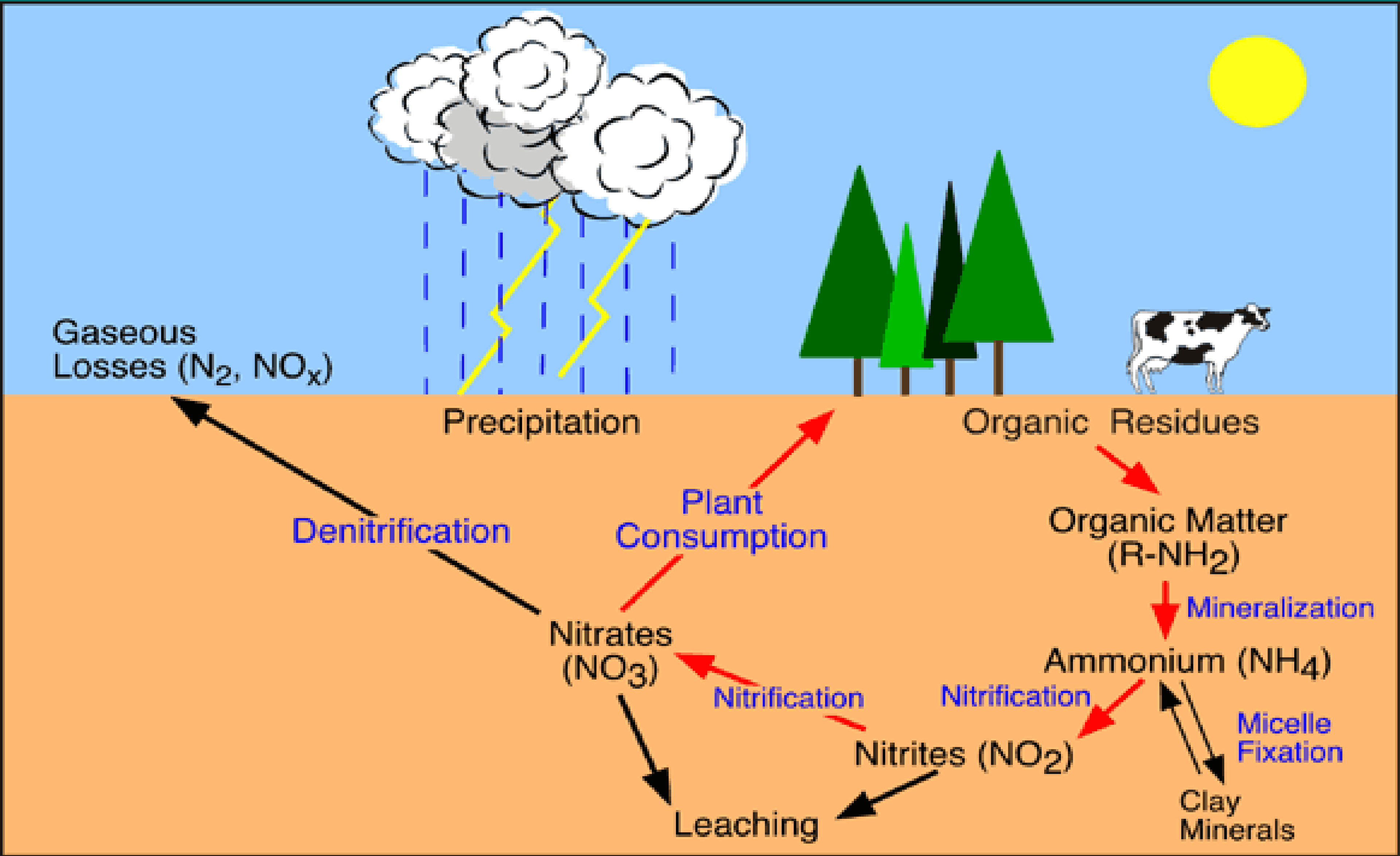
SOURCES OF HYDROGEN IONS

- **Accumulation of organic matter**
  - OM forms soluble complexes with Ca and Mg resulting in loss of cations by leaching

SOURCES OF HYDROGEN IONS

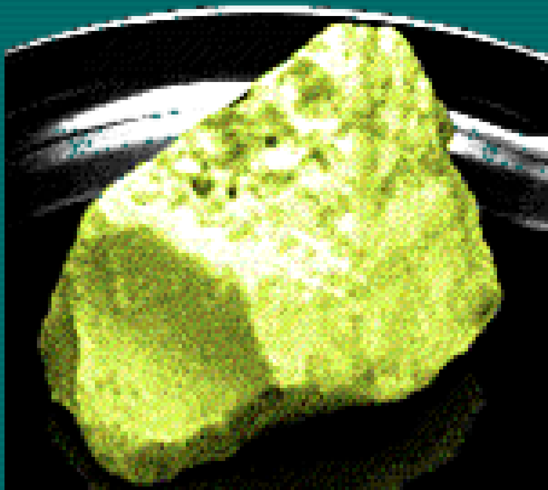
- **Oxidation of nitrogen (nitrification)**
  - Produces H^+ ions
  - **Nitrification** is the reaction of ammonium ions (NH_4^+) which react releasing two H^+ ions resulting in NO_3
  - NO_3 is the anion of a strong acid (**nitric acid**)

NITROGEN CYCLE



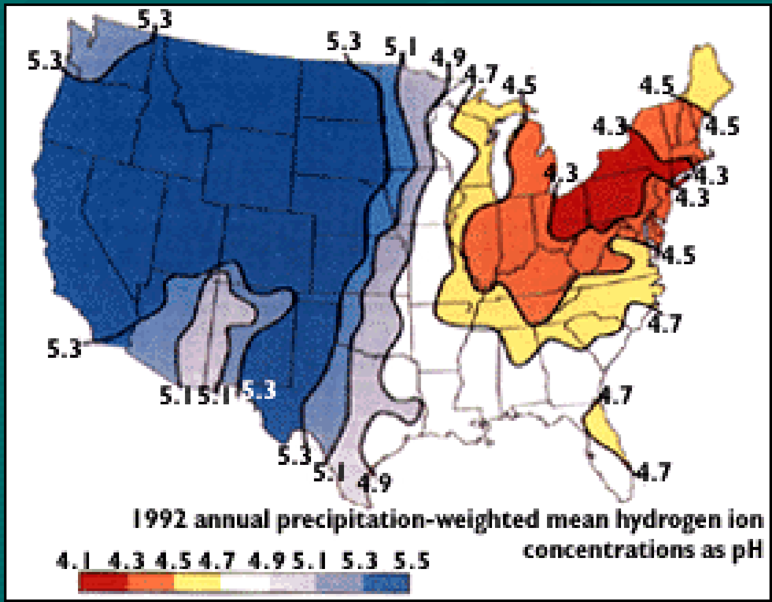
SOURCES OF HYDROGEN IONS

- **Oxidation of sulfur**
  - Results from decomposition of plant residues
  - Involves oxidation of organic **–SH group** yielding **sulfuric acid** (H_2SO_4)
  - Oxidation of reduced sulfur in minerals (i.e. **pyrite**)



SOURCES OF HYDROGEN IONS

- Acids Rain
  - Carbonic acid
  - Nitric and sulfuric acids
    - Lightning
    - Volcanic eruptions
    - Forest fires
    - Combustion of fossil fuels

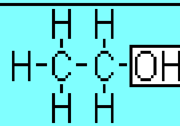
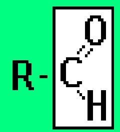
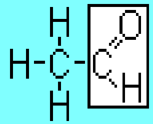
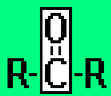
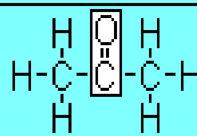
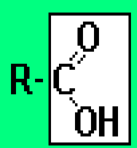
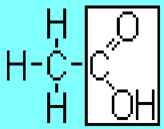
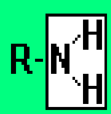
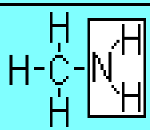
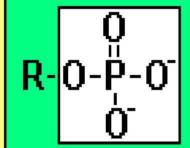
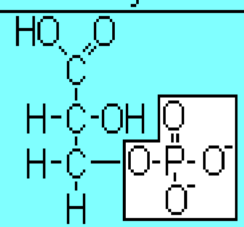
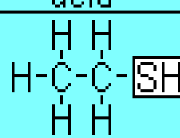


EFFECTS OF ACID RAIN

SOURCES OF HYDROGEN IONS

- **Plant uptake of cations**
  - H^+ ions are exuded into the soil when plants take up more **cations** (K, NH_4, Ca) than **anions** (NO_3, SO_4)

FUNCTIONAL GROUPS

Functional group	Class of compounds	Structural formula	Example
Hydroxyl -OH	Alcohols	R -OH	 Ethanol
Carbonyl -CHO	Aldehydes		 Acetaldehyde
Carbonyl >CO	Ketones		 Acetone
Carboxyl -COOH	Carboxylic acids		 Acetic acid
Amino $-NH_2$	Amines		 Methylamine
Phosphate $-OPO_3^{2-}$	Organic phosphates		 3-phosphoglyceric acid
Sulfhydryl -SH	Thiols	R- SH	 Mercaptoethanol

BALANCE OF H^+ PRODUCTION AND CONSUMPTION

- **Degree of acidification** is determined by:
  - Balance between processes that produce H^+ ions
  - Other processes that consume them

BUFFERING OF pH IN SOILS

- **Buffering** – resistance to change in soil solution pH when either an acid or base is added

MECHANISMS OF BUFFERING

- ***Soils with higher clay and organic matter content are better buffered due to involvement of residual and exchangeable acidity***

- ***Reactions that either consume or produce H ions provide mechanisms to buffer the soil solution and prevent rapid changes in soil pH***

MECHANISMS OF BUFFERING

- Aluminum hydrolysis
- Organic matter reactions
- Cation exchange

IMPORTANCE OF SOIL BUFFERING CAPACITY

- **Ensure some stability in soil pH**
  - Prevents drastic fluctuations that are harmful to plants and soil organisms
  - **Example:** well-buffered soils resist the acidifying effect of acid rain
- **Influences amount of amendments (i.e. lime/sulfur) required to change soil pH**

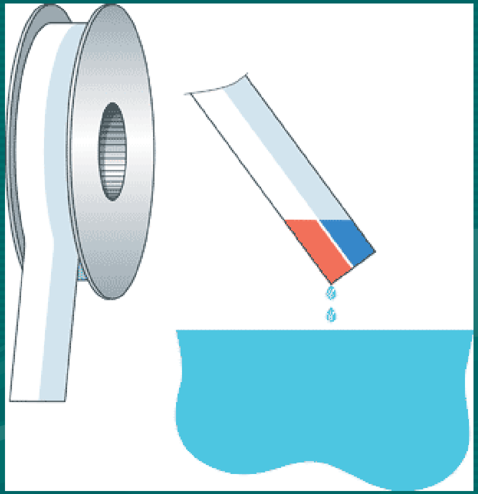
IMPORTANCE OF SOIL BUFFERING CAPACITY

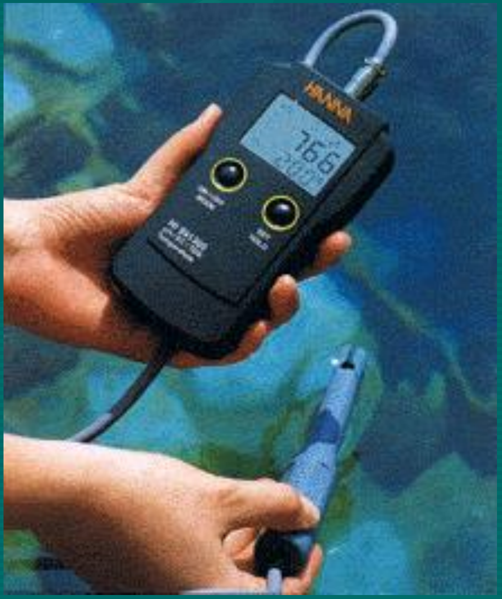
- Soils vary greatly in the buffering capacity

- The higher the CEC of a soil, the greater its buffering capacity

DETERMINATION OF SOIL pH

- **Dye method**
  - Accurate within 0.2 to 0.5 pH units
- **pH meter** (involves electrodes)
  - Most accurate





pH VARIABILITY IN THE FIELD

- Provides major information on the chemical and biological conditions in a given soil

- Correct **interpretation** of pH results is important due to variability within a field

pH VARIABILITY IN THE FIELD

- **Spatial variation** – variability over very small distances, depth, and time
  - Unfavorable effects on soil microorganisms
  - Concentrations of fertilizers and ash from fires affect soil pH
  - Erosion
  - Drainage

HUMAN-INFLUENCED SOIL ACIDIFICATION

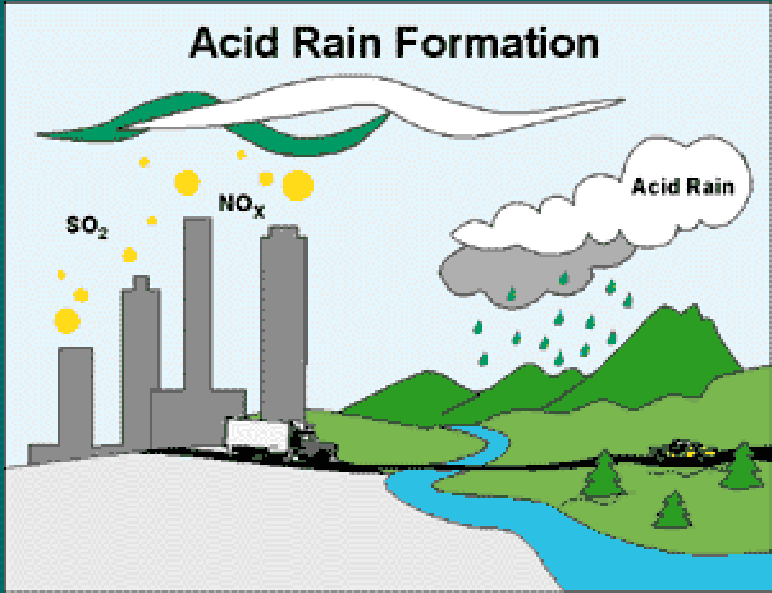
- **Nitrogen amendments**
  – Excessive nitrogen fertilizer rates contribute to soil acidification

HUMAN-INFLUENCED SOIL ACIDIFICATION

- **Acid-forming organic materials**
- Application of **sewage sludge/manures** can lower soil pH
- Addition of lime may be needed to counteract acidification
- **Lime stabilized sludge** has lime added (20-30% by weight) to control pathogens and odor

HUMAN-INFLUENCED SOIL ACIDIFICATION

- **Acid rain**
  - Results from N and S containing gases
  - Normal rainfall: pH=5.5
  - Acid rain: pH=2.0-4.5



HUMAN-INFLUENCED SOIL ACIDIFICATION

- **Soil acidification**
  - Mobiles Al and leaches Ca
- **Effects on forests**
  - Al toxicity
  - Reduction in Ca levels in soil
  - Ca is required for synthesizing wood

HUMAN-INFLUENCED SOIL ACIDIFICATION

- **Effects on aquatic ecosystems**
  - Al is toxic to fish damaging gill tissues

  - pH values of 5.0 or lower are lethal to fish

  - Lake and streams are clear, but are "biologically dead"

LOWERING SOIL pH

- Essential for growing azaleas, rhododendrons, blueberries, and conifers

- **Acid organic matter**
  - Pine needles, pine sawdust, peat moss

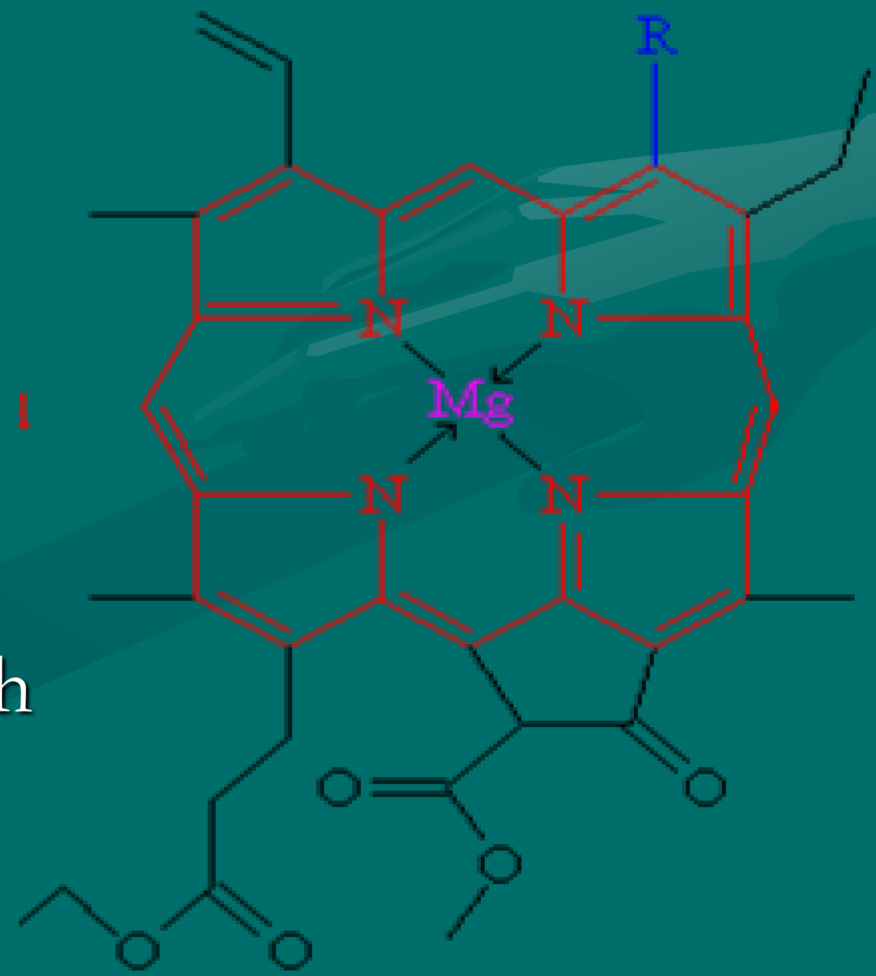
LOWERING SOIL pH

- **Inorganic chemicals**
  - Aluminum sulfate or ferrous sulfate
  - Elemental sulfur and sulfuric acid
  - Sulfur is more effective than ferrous sulfate

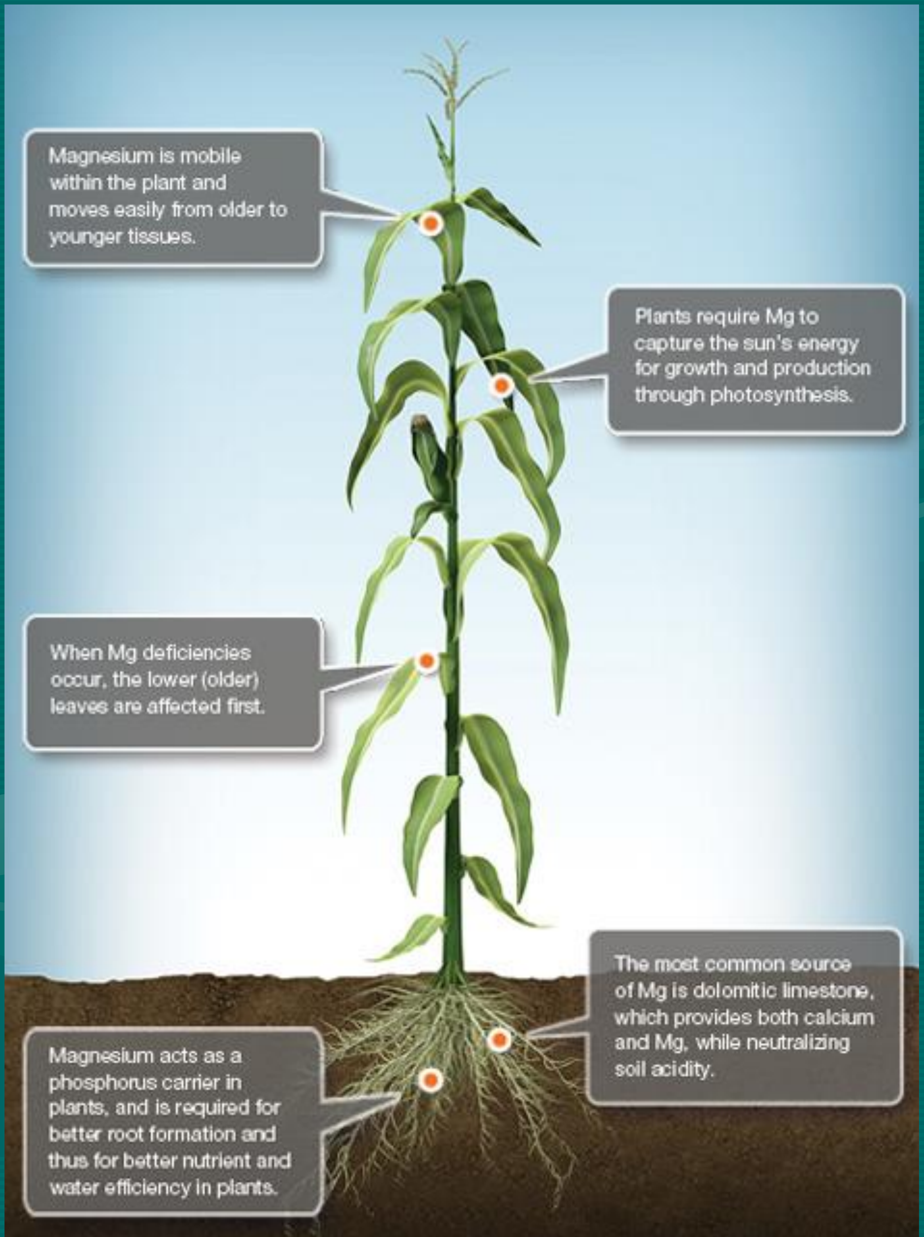
  - **Example:** 218 lbs./acre is required for a one unit drop in pH

MAGNESIUM (MG) AS A PLANT NUTRIENT

- Plants take up smaller amounts
- Component of **chlorophyll** molecule
- Intimately involved with **photosynthesis**



MG AND PLANT HEALTH



MAGNESIUM (MG) AS A PLANT NUTRIENT

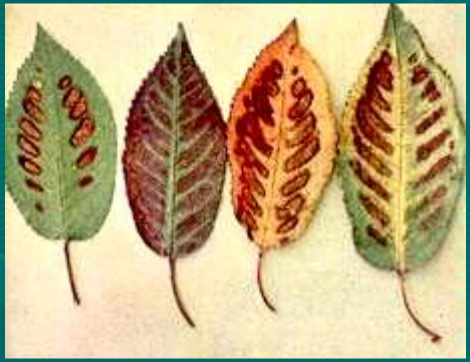
- Important in **energy metabolism**
  - Synthesis of oils and proteins
  - Activation of enzymes
- More easily **leached** (CEC_{sat}=5-20%)

MAGNESIUM (MG) AS A PLANT NUTRIENT

- **Deficiency symptoms**
  - More common than Ca
  - **Interveinal chlorosis** on older leaves
  - **Mottling** and yellowing in dicots
  - **Striping** in monocots
  - Readily **translocated** from older to younger tissues
    - **Older tissues affected first**

SYMPTOMS OF MG DEFICIENCY

(Cauliflower, Cherry, Corn Plants)



SYMPTOMS OF MG DEFICIENCY

RATIO OF CALCIUM TO MAGNESIUM

- Ca/Mg ratios of 1:1 to 15:1 are needed by plants for optimum growth

IRRIGATION-INDUCED SALINITY AND ALKALINITY

- Irrigation water brings in salts to soil
- **In arid regions a grower may need to apply 36 inches of irrigation per year with 3 tons of salt added per acre per year**
- If Na ions exceed Ca and Mg ions, **sodic soils** may result

CLASSES OF SALT-AFFECTED SOILS

- Saline soils
- Saline-Sodic soils
- Sodic soils

SALINE-SODIC SOILS

- Plant growth is adversely affected by high salt and sodium levels
- Rapid changes in soil condition can occur due to leaching

SODIC SOILS

- Most troublesome of salt-affected soils
- ***pH > 8.5 up to 10***

SODIC SOILS

- Soil can become **dispersed** resulting in a breakdown of **soil aggregates**
- Large pores are lacking resulting in reduced **hydraulic conductivity** and **water infiltration**

SODIC SOILS

- Water tends to **puddle**
- Thin A horizons overlying a clayey B horizon
- Few plants can tolerate the Na, OH, and HCO_3 toxicities and very poor soil physical conditions

GROWTH OF PLANTS IN SALT-AFFECTED SOILS

- **Osmotic effects**
  - Lower **osmotic potential** of soil water
  - Plant expend energy to lower osmotic potential inside their root cells to counteract low osmotic potential of soil solution
  - May prevent germination
  - Kills younger plants

GROWTH OF PLANTS IN SALT-AFFECTED SOILS

- Specific ion effects
  - Type of salt makes a big difference in plant response
  - Na, Cl, HCO_3 are quite toxic to many plants
  - High Na can affect uptake of K and Ca

GROWTH OF PLANTS IN SALT-AFFECTED SOILS

- Oxygen may become deficient because of breakdown in soil structure

- Water relations are poor due to slow **infiltration** and **percolation** rates

PLANT SYMPTOMS IN SALT-AFFECTED SOILS

- Severe stunting

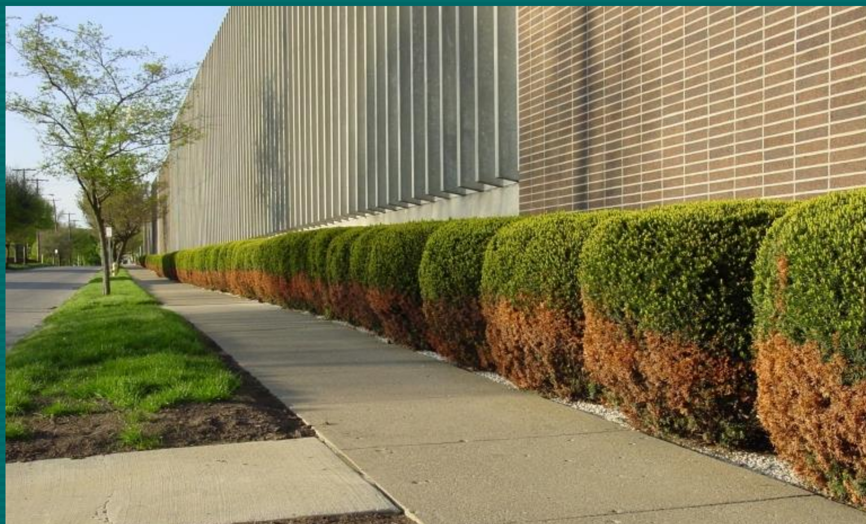
- Small, dark bluish green leaves with dull surfaces

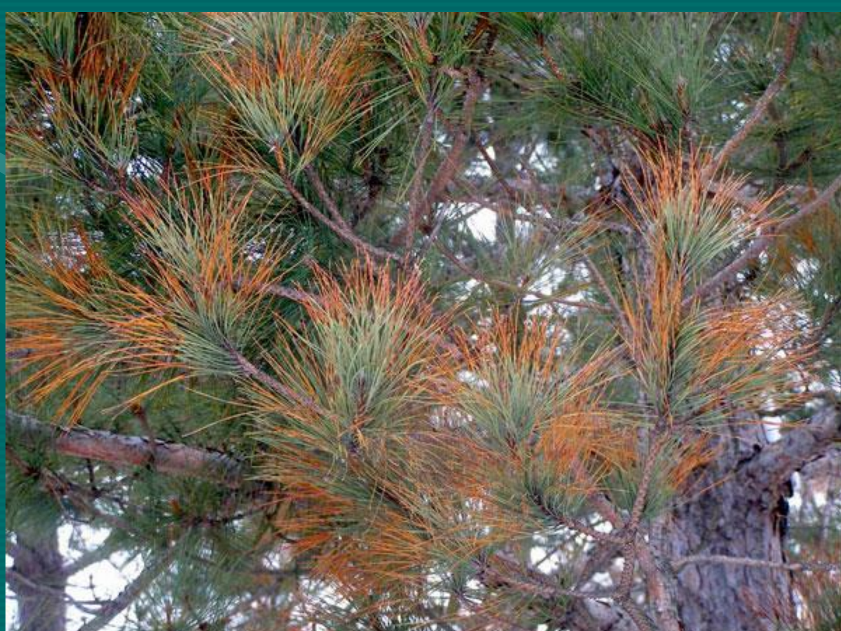
- Scorching of leaf margins and tips

SALT DAMAGE TO PLANTS

- Necrosis of leaf margins and tips
- Premature leaf drop

SALT DAMAGE TO PLANTS





DE-ICING SALTS AND CONTAINERIZED PLANTS

- Can build up over years
- Decreases with distance from roadway
- KCl can be substituted for NaCl
- Use sand instead of salt
- Container grown perennials can be affected
- Irrigation water and fertilizers contribute to salt build up

WATER QUALITY AND IRRIGATION

- A proper salt balance must be maintained
- Proper soil drainage is critical
- Quality and disposition of **waste irrigation waters** must be carefully monitored

WATER QUALITY AND IRRIGATION

- **Toxic elements** must be monitored
  - Mo, As, B, and Se
  - Can be toxic to humans and animals

END OF PRESENTATION