Soil pH and Soil Fertility

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Environmental factors influencing plant growth – Which can we manage?

1. Temperature
2. Moisture Supply
3. Radiant Energy (Sunlight: quality, intensity & duration)
4. Composition of the atmosphere
5. Gas content of the soil
6. **Soil reaction (Soil pH) Degree of acidity or alkalinity**
7. Biotic factors (Plant variety type- genetics, soil biology)
8. Supply of mineral nutrient elements

What is pH?

- pH can be viewed as an abbreviation for **Power** of concentration of **Hydrogen** ion in solution
- pH = - [log (H+)] in solution, The pH of a soil is a measure of hydrogen ion activity or concentration ([H+]) in the soil solution.

Impact of soil PH changes

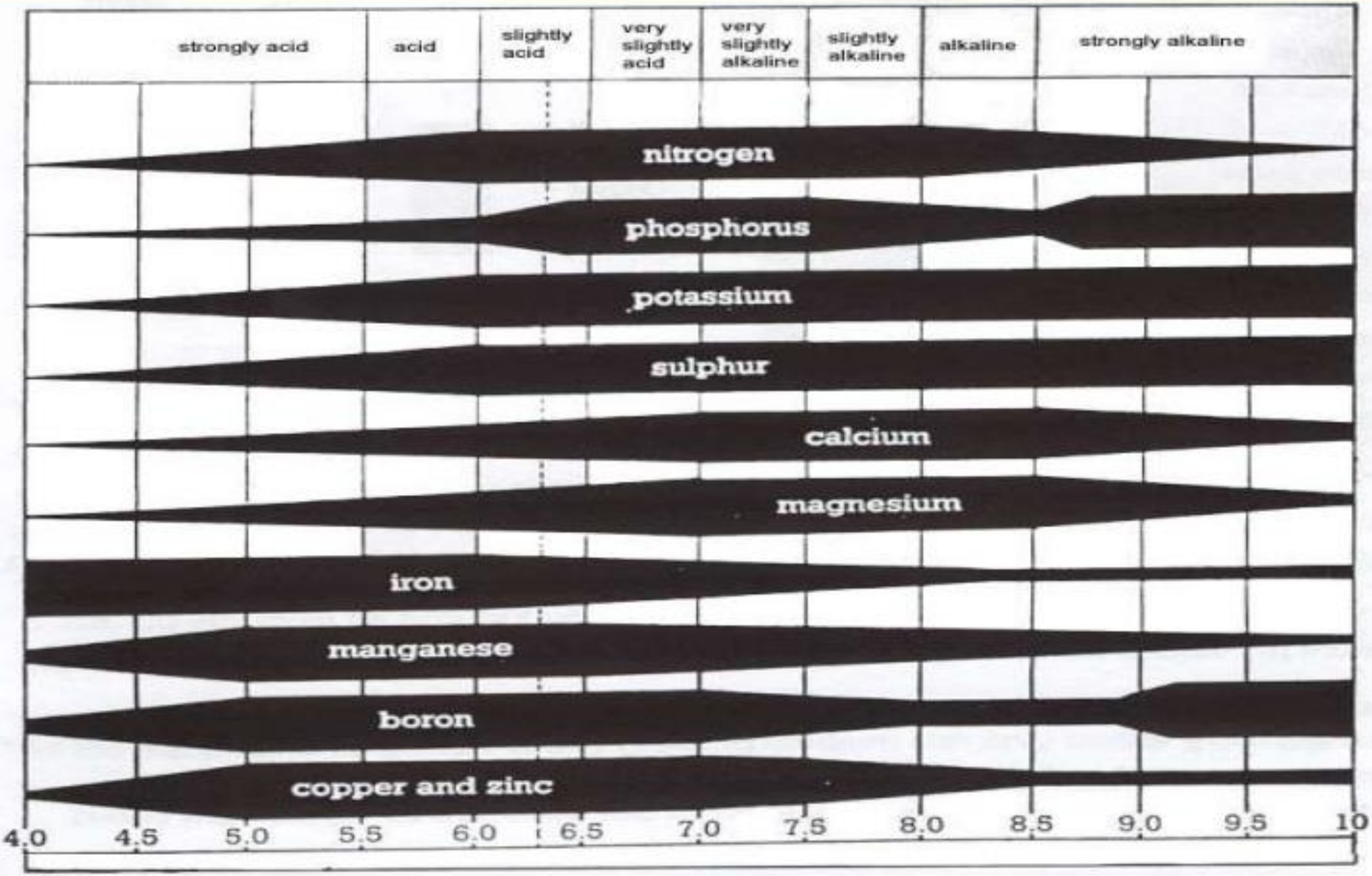
As the H+ activity increases, soil pH decreases.

As the soil pH decreases, most desirable crop nutrients become less available while others, often undesirable, become more available and can reach toxic levels.

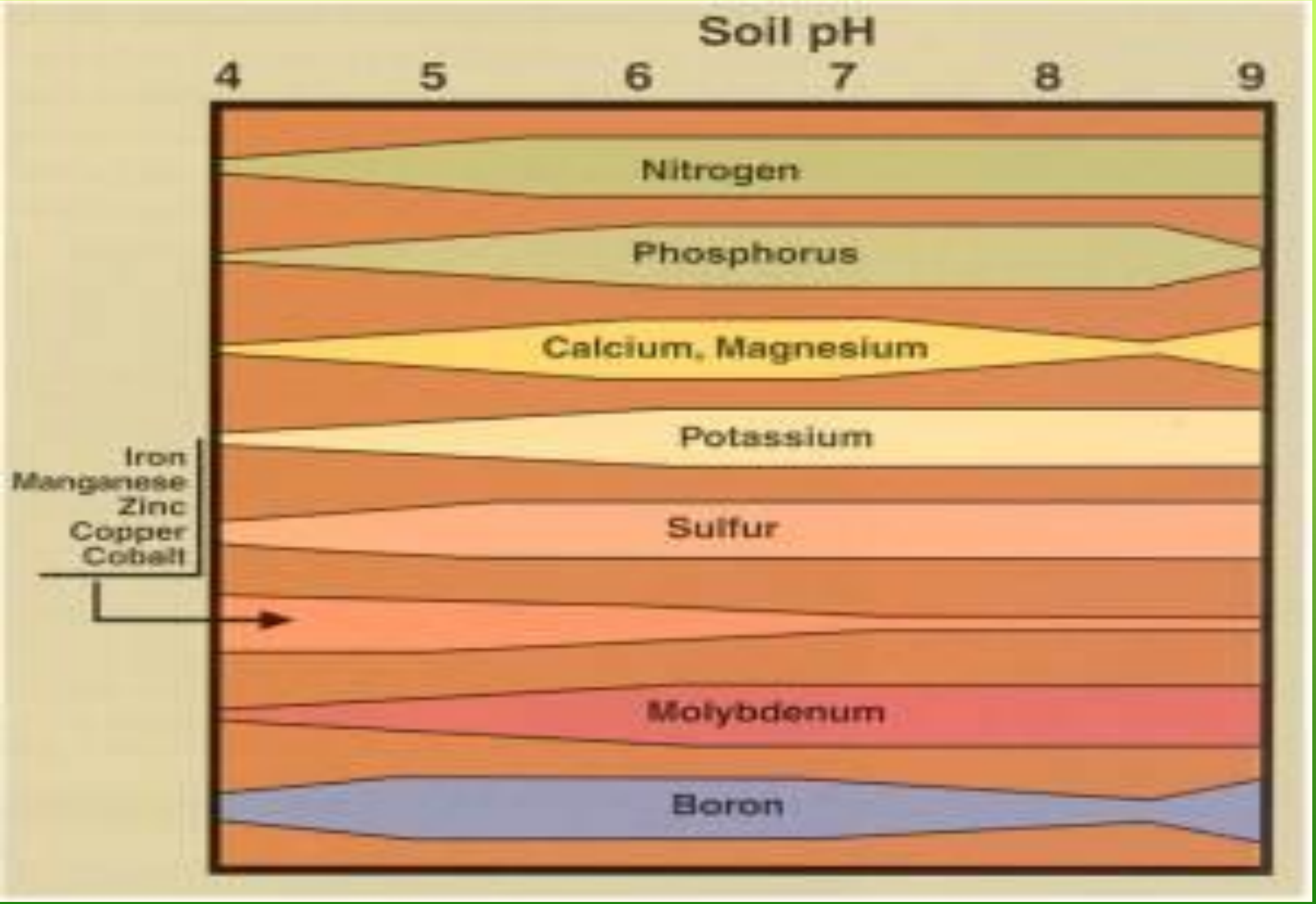
Total pH scale: 0 ------------------------------ 7 -------------------------------- 14

Acid Neutral Basic or Alkaline

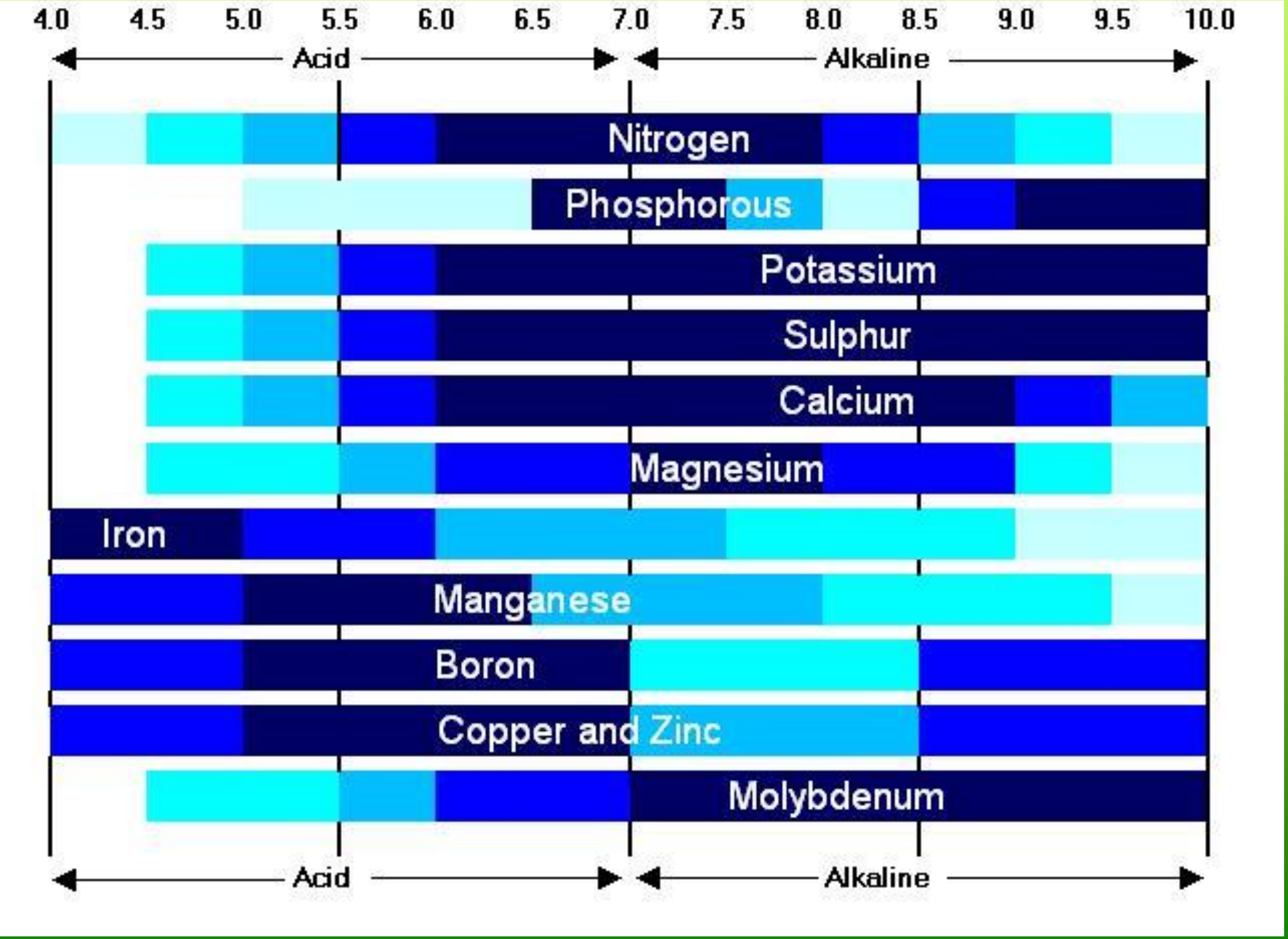
pH & Nutrient Availability



The relative availability of Nutrients as a function of pH



Color coded chart of relative nutrient availability with change in pH. The darker the blue the more available the nutrient



Logarithmic Scale of pH

Total pH scale:

10x

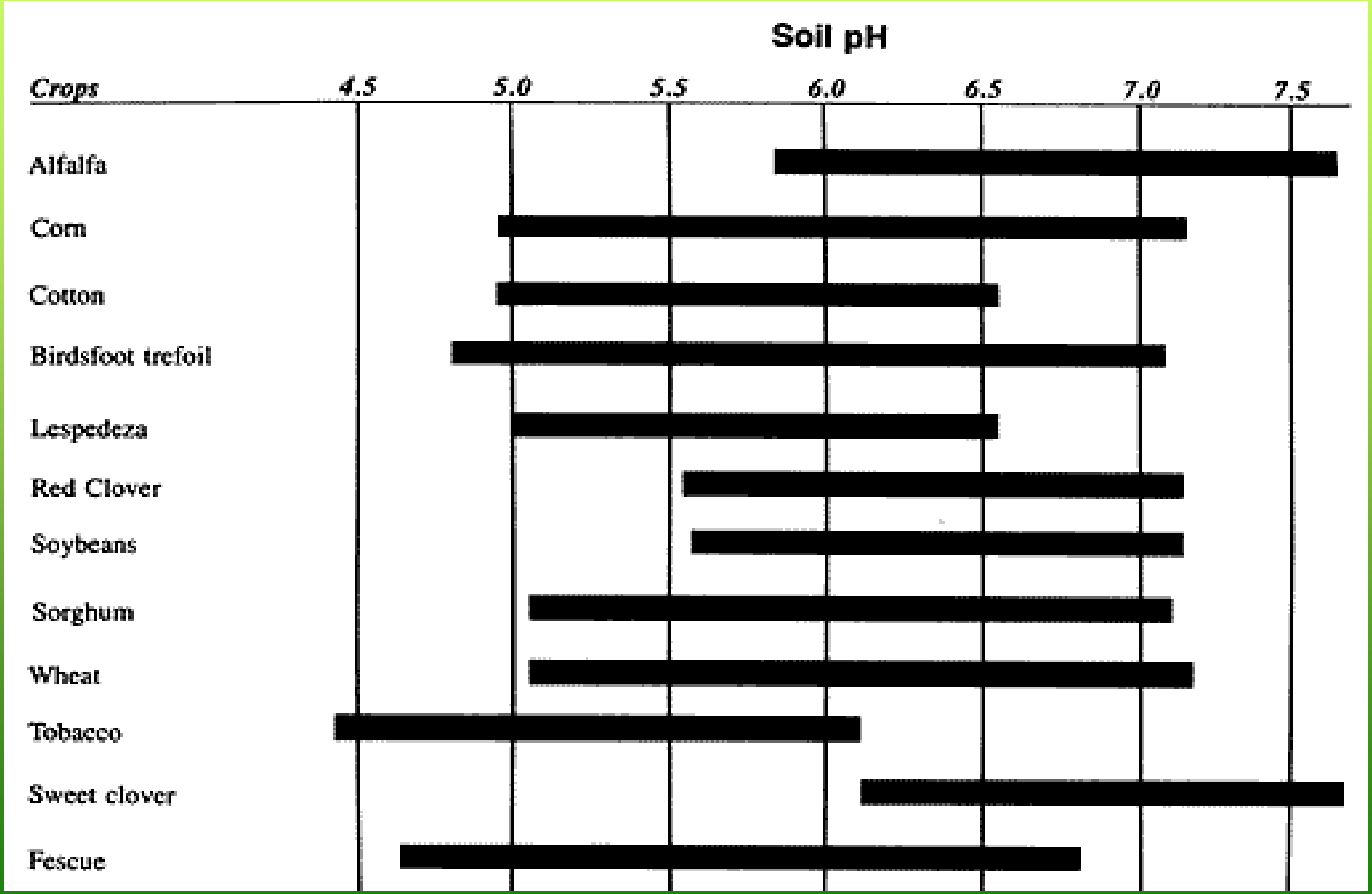
0 ---1----2----3----4-----5-----6----- 7 -----8-----9----10-----11-----12-----13--- 14

100x

Acid Neutral Basic or Alkaline

- Hydrogen activity is mathematically expressed as a negative logarithm:
- pH = -log[H+]. Because of the logarithmic scale, one unit decrease in pH implies a 10 time increase in acidity.
- So a soil with a pH of 5.0 is 10 times more acid than a soil with a pH of 6.0 and 100 (10 x 10) times more acid than a soil with pH 7.0

Soil pH Range for Crops



pH scale and common pH range of New York soils

New York agricultural soils: 4.5 ------------- 7 --------- 8.5 (Range)

Total pH scale: 0 ------------------------------ 7 -------------------------------- 14

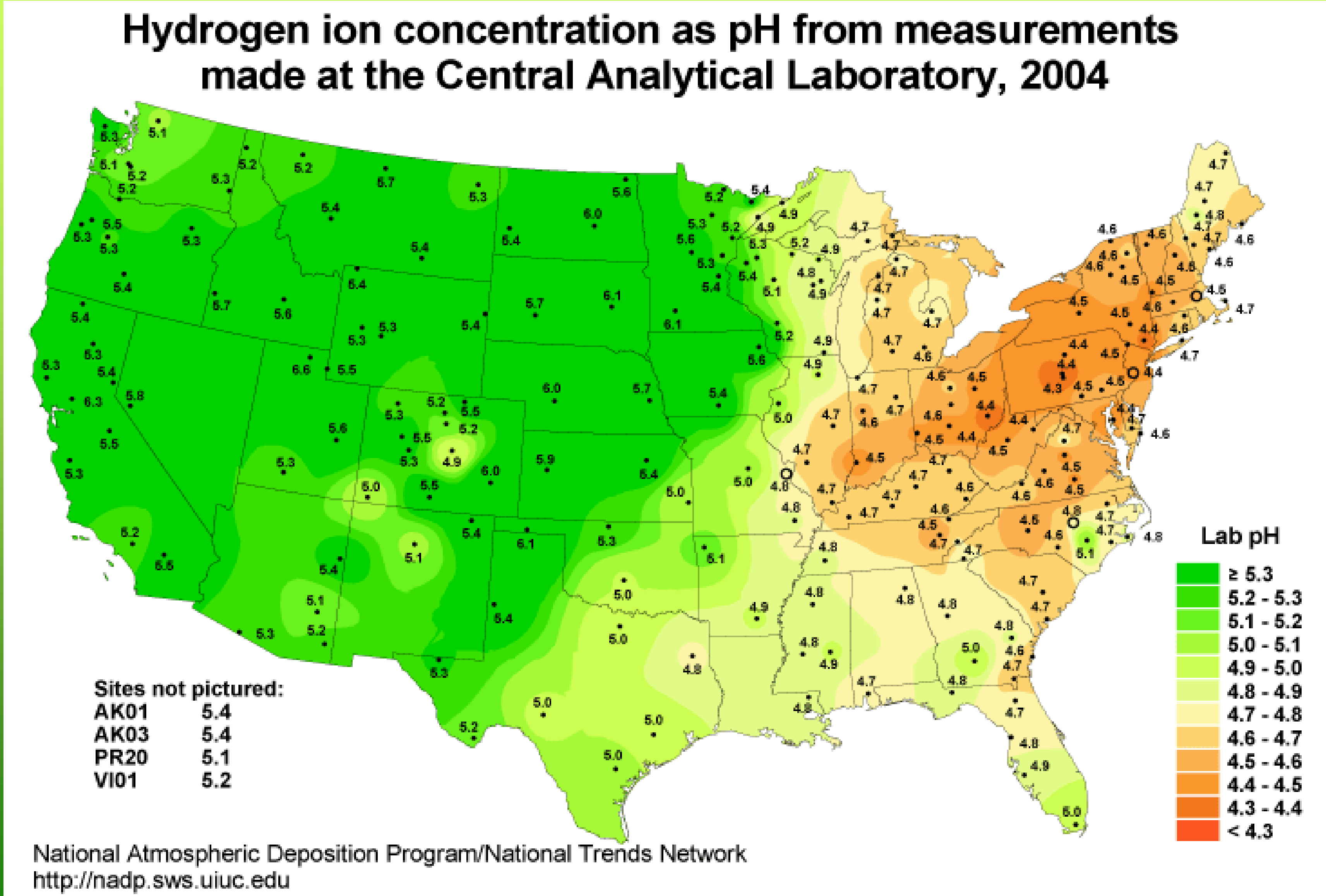
Acid Neutral Basic or Alkaline

NY Climate leads to Leaching of Soils

In humid climates such as found in New York, the leaching of calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+) ions leads to an increase of active hydrogen (H^+) and aluminum (Al^{3+}) in the soil and results in a decrease in pH.

Typically, the addition of inorganic fertilizers and organic nutrient sources (compost and manure) leads to a decrease in pH due to the formation of two strong inorganic acids, nitric acid (HNO_3) and sulfuric acid (H_2SO_4).

The average pH of precipitation in New York tends to be acidic and range from pH 4.4 to 4.6, about as low as any in the US



Ammonium forming fertilizers

$2\ NH_3$ (**ammonia**)	$+\ 4\ O_2$ (oxygen)	→	**$2\ NO_3^-$** (nitrate)	+ **$2\ H^+$** ("acid")		$+\ 2\ H_2O$ (water)
NH_4NO_3 (**ammonium nitrate**)	$+\ 2\ O_2$ (oxygen)	→	**$2\ NO_3^-$** (nitrate)	+ **$2\ H^+$** ("acid")		$+\ H_2O$ (water)
$(NH_2)_2CO$ (**urea**)	$+\ 2\ O_2$ (oxygen)	→	**$2\ NO_3^-$** (nitrate)	+ **$2\ H^+$** ("acid")		$+\ H_2O$ (water)
$(NH_4)_2SO_4$ (**ammonium sulfate**)	$+\ 4\ O_2$ (oxygen)	→	**$2\ NO_3^-$** (nitrate)	$+\ SO_4^{2-}$ (sulfate)	+ **$4\ H^+$** ("acid")	$+\ 2\ H_2O$ (water)

Ammonium fertilizers are acid forming (they ultimately decrease the soil pH)

Liming Materials

CaO - Calcium oxide

(Lime, Burned lime, Quick lime)

$Ca(OH)_2$ - Calcium hydroxide

(Hydrated lime, slaked lime)

$CaCO_3$ - Calcium carbonate

(Calcitic limestone)

$CaCO_3$, $MgCO_3$ - Ca and Mg carbonates

(Dolomitic limestone)

Additional Tips

- Lime before you fertilize

pH	N	P	K
5.0	53%	34%	52%
6.0	89%	52%	100%
7.0	100%	100%	100%

Approximate % availability of mineral fertilizer elements

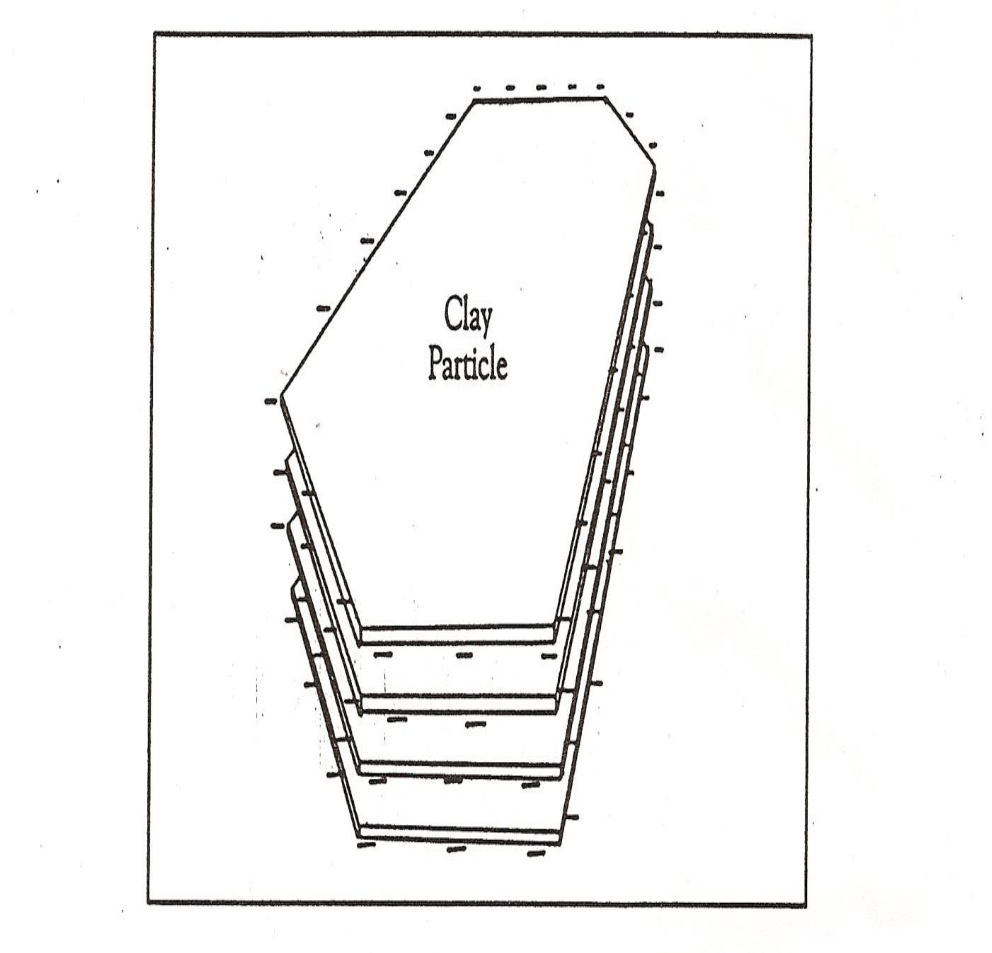
As the pH increase from an acidic pH (5.0) toward a more neutral pH (7.0) then the availability of mineral fertilizer elements become more available

Critical Values

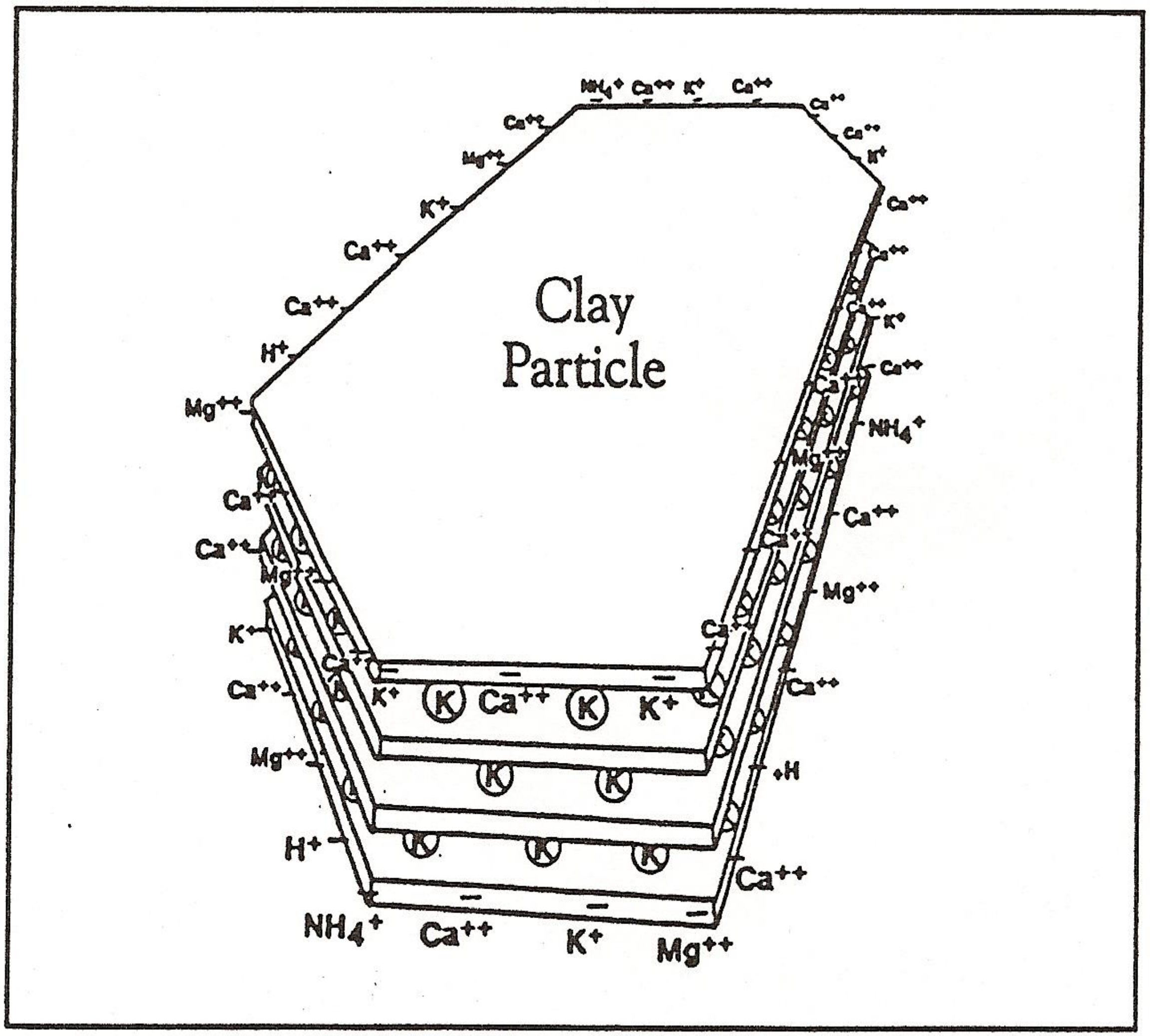
- Below pH 6.2 in surface 2” –Triazine Herbicides effectiveness reduced.
- Below pH 5.5 – Elevated levels of Manganese & Aluminum can seriously reduce crop growth
- Above pH 7.0 – The availability of most micronutrients is reduced

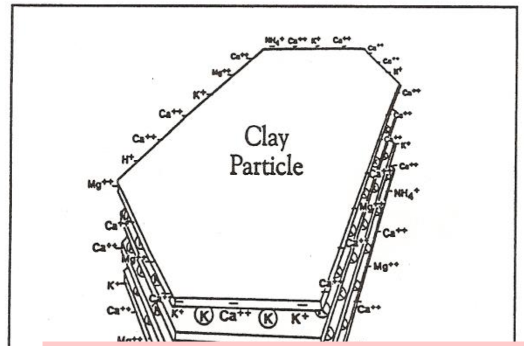
Clay Particles

clay minerals



Clay Particles have a net negative surface charge and therefore attract cations.
(Negative attracts positive)



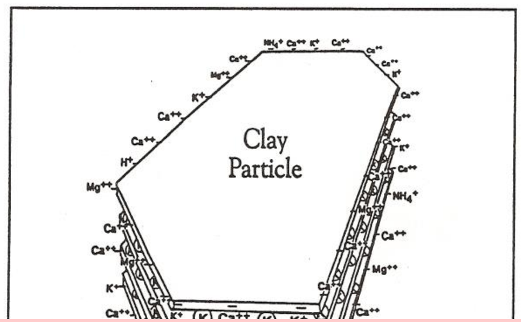


Acid Soil

H^+

Al^{3+}

$+ CaCO_3$
(Calcium Carbonate)



Neutral Soil

Ca^{2+}

$+ H^+ + Al^{3+} + CO_3^{2-}$

Ca^{2+}

$Al(OH)_3 + CO_2 + H_2O$

Gypsum

It is a fairly common misconception that gypsum is a liming material. Gypsum is calcium sulfate ($CaSO_4$). The Ca in gypsum can displace the H+ and Al3+ on the soil's exchange complex but the sulfate cannot neutralize the acidity.

Ions (Cations & Anions)

- An **ion** is an atom or molecule in which the total number of electrons is not equal to the total number of protons, giving it a net positive or negative electrical charge.
- An **anion** (-) is an ion with more electrons than protons, giving it a net **negative charge.**
- A **cation** (+) is an ion with fewer electrons than protons, giving it a **positive charge**.

Plant Nutrients (mineral elements)

Major Nutrients

(Primary- Need in Large Quantities)

- Nitrogen (N)
- Phosphorous (P)
- Potassium (K)

(Secondary – Need in Intermediate Quantities

- Calcium (Ca)
- Magnesium (Mg)
- Sulfur (S)

Micronutrients

- Boron (B) **
- Iron (Fe)
- Maganese (Mn)
- Copper (Cu)
- Zinc (Zn) **
- Molybdenum (Mo)
- Chlorine (Cl)
- Cobalt (Co)
- Vandium (V)
- Sodium (Na)
- Silicon (Si)

** May be deficient in some soils

Plant Mineral Nutrients Come from Multiple Sources

- Soil Reserves (attached to clay particles & humus)
- Added Fertilizers or Manures
- Crop Residues (Nutrient Recycling)
- Cover Crops (Nutrient recycling, N Fixation and Bio-accumulation)

Soil Analysis

- Different labs use different extractants
  - Extractants are selected based on local soil conditions
    - Mehlich 3
    - Mehlich 1/Double Acid
    - Bray P1 & Bray P2
    - Morgan
    - Modified Morgan
    - Olsen
  - Important to use appropriate test for local conditions
  - Be careful comparing soil test results from different labs. Different labs may not use the same extractants which will give different results.

Soil Test Interpretation

- Below Optimum

  (Very Low, Low, Medium, etc.)

  - Nutrient is deficient
  - High probability of a profitable response
- Optimum

  (Medium, High, etc.)

  - Nutrient is adequate
  - Low probability of a profitable response
- Above Optimum

  (High, Very High, Excessive, etc.)

  - Nutrient is more than adequate
  - Very low probability of a profitable response

Soil Test Recommendations

- Basic Cation Saturation Ratios

- Conceptually ok
- Ideal ratios (Bear, et al., 1947)
  - 65 % Ca
  - 10% Mg
  - 5 % K
  - 20 % Acidity
- Still used by some labs but has some problems
  - Doesn't work very well
  - May result in some unreasonable recommendations

- General range of cation balance

  60 - 90 % Ca **(65-75%)**

  5 - 40 % Mg **(12-18%)**

  2 - 5 % K

  Na < 2.5% (less than 2.5%)

  0 - 20 % Acidity
- If cation levels and pH are in the optimum range the ratios will usually be ok and no further adjustment is necessary.
- Only worry about the ratios in the extreme
  - Mg ≥ Ca
  - K ≥ Mg

Soil Potassium

- Deficient or low potassium fertility levels will most assuredly reduce forage growth, e.g., can become first limiting nutrient and decrease overall yields. Potassium is assimilated in luxury amounts by most forage species. Forages, typically, will accumulate two to 20 times sufficient/required levels of potassium when it is available in the soil.

Soil Phosphorous

- Like potassium, low soil phosphorus can be growth limiting. Phosphorus is typically not consumed in luxury amounts like potassium and will generally show on forage analysis as 0.2 to 0.3% composition on a dry matter basis. Phosphorus may be low enough in forage plant tissue that it becomes deficient in the grazing livestock diet. When phosphorus is this low in the soil, plant growth will most definitely be reduced/limited. In terms of animal nutrition phosphorus should be fed to the livestock in a mineral supplement to correct the deficiency. In the long run however, the soil phosphorus levels must be adjusted for adequate forage growth.

Soil Nitrogen

- **Soil nitrogen level/fertility does not (directly) affect digestibility but does directly affect forage crude protein levels in grasses, with much less effect on crude protein levels in legumes.** Within reason, the greater the nitrogen fertilizer applied the higher the forage grass crude protein; there is, of course, an upper limit to this affect. Nitrogen fertility levels should be based on realistic yield expectations however, and forage crude protein levels should be managed by plant maturity at harvest, whether by haying or grazing management.

Where does soil fit into the big picture?
Environmental factors influencing plant growth

1. Temperature, (**Soil Temperature**)
2. Moisture Supply (**Ability to percolate and hold moisture in the soil)**
3. Radiant Energy (Sunlight, quality, intensity & duration)
4. Composition of the atmosphere
5. Gas content of the **soil**
6. **Soil reaction** (Soil pH) Degree of acidity or alkalinity
7. Biotic factors (Plant variety type- genetics, **soil biology**)
8. **Supply of mineral nutrient elements**

Questions/Discussion?