Soil Salinity and pH: What Are They and Why/How Do We Measure Them?

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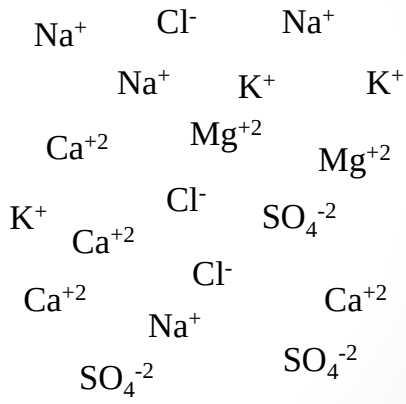
What are SALINITY and pH?

- SALINITY
  - Refers to the concentration of soluble mineral ions in solution
    - As minerals weather and dissolve over time, they release ions:
      - Cations (positive) and Anions (negative)

Salts Dissolve – Release Ions

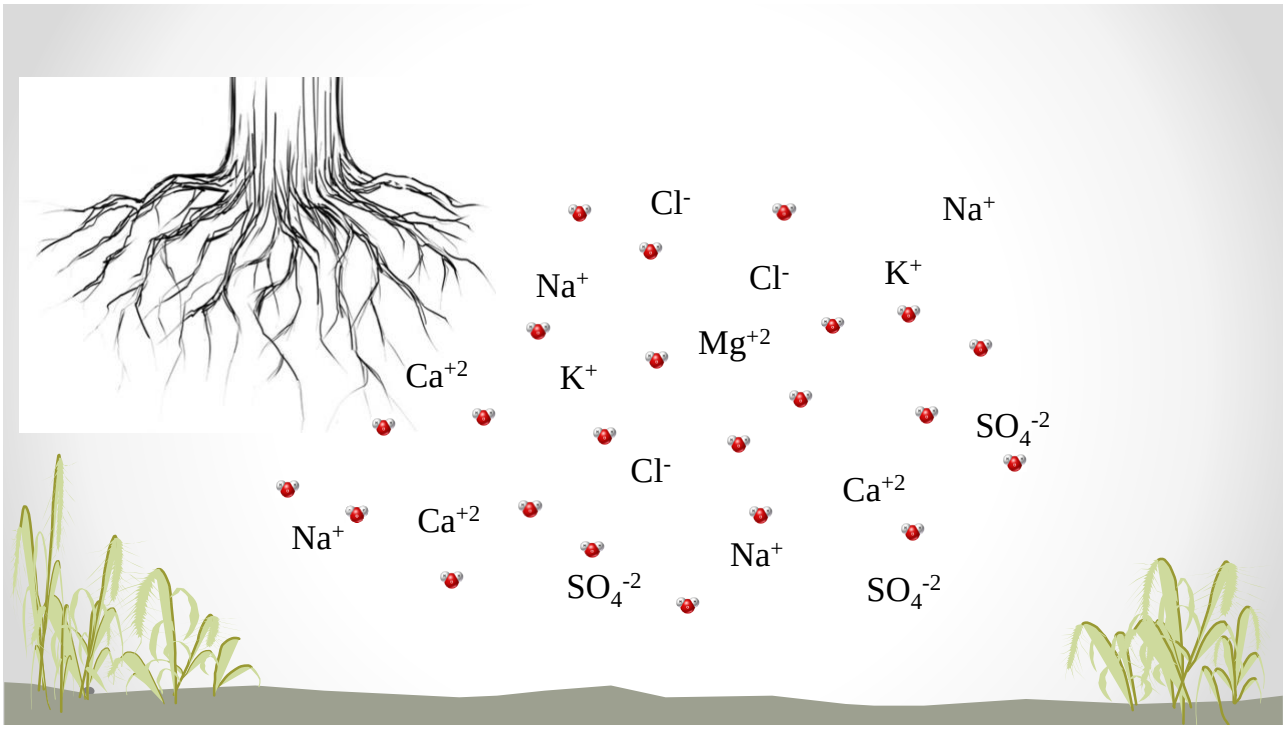
Salts:

$CaSO_4$ (gypsum)
Na_2SO_4 (glauber's)
$MgSO_4$ (epsom)
NaCl (table salt)
KCl (Muriate of Potash)
$CaCl_2$
$MgCl_2$



What are SALINITY and pH?

- SALINITY
  - As water is Evapo-transpired over time, the ions can concentrate (especially in semi-arid areas)
  - Water molecule is also charged (has both positive and negative poles)
  - Excessive solute ion concentration can reduce the free energy of the water, reducing the ability of the plant to take it up.
  - Referred to as "Chemical Drought"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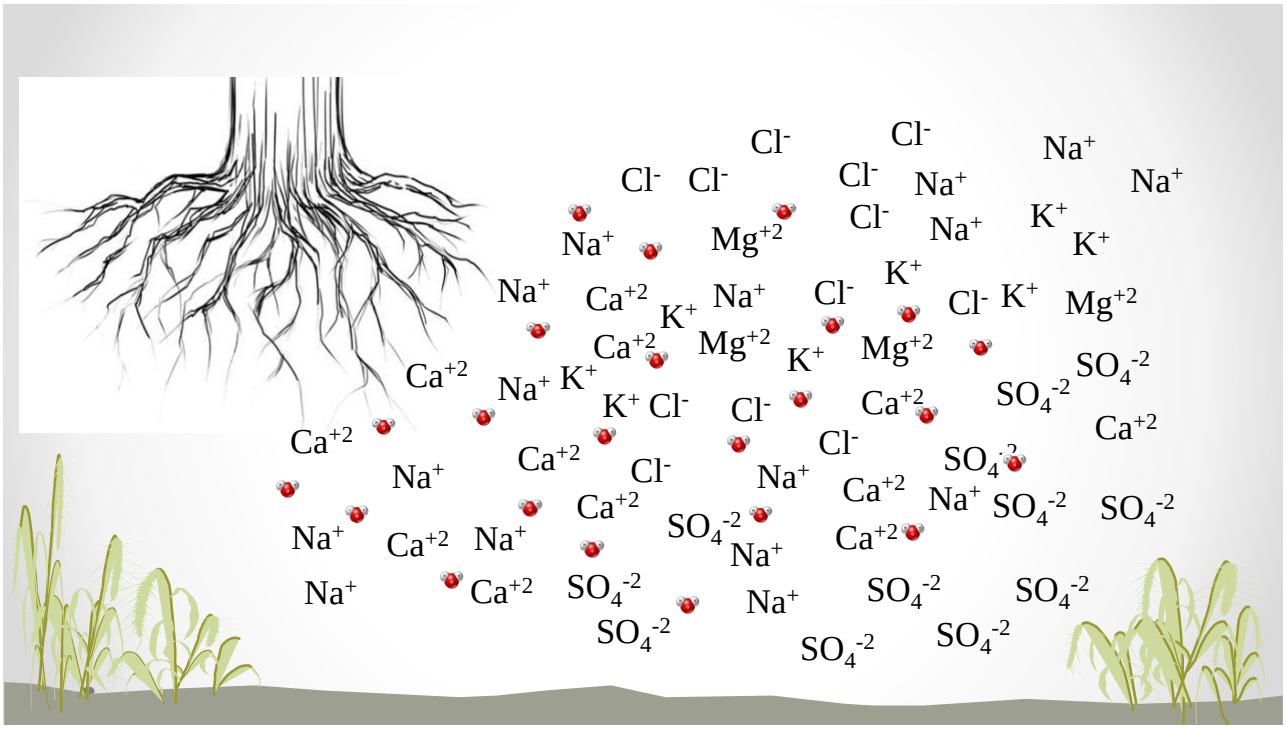
Na+
Na+
Cl-
K+
Mg+2
Ca+2
K+
SO4-2
Cl-
Ca+2
Na+
Ca+2
Na+
SO4-2
SO4-2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K+
Mg+2
K+
Ca+2
Mg+2
Mg+2
SO4-2
Ca+2
Na+
K+
K+
Cl-
Cl-
Ca+2
SO4-2
Ca+2
Ca+2
Cl-
Cl-
SO4-2
Ca+2
Na+
Cl-
Na+
Ca+2
Na+
SO4-2
SO4-2
Na+
Ca+2
Na+
SO4-2
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Ca+2
SO4-2
SO4-2
SO4-2
SO4-2
SO4-2

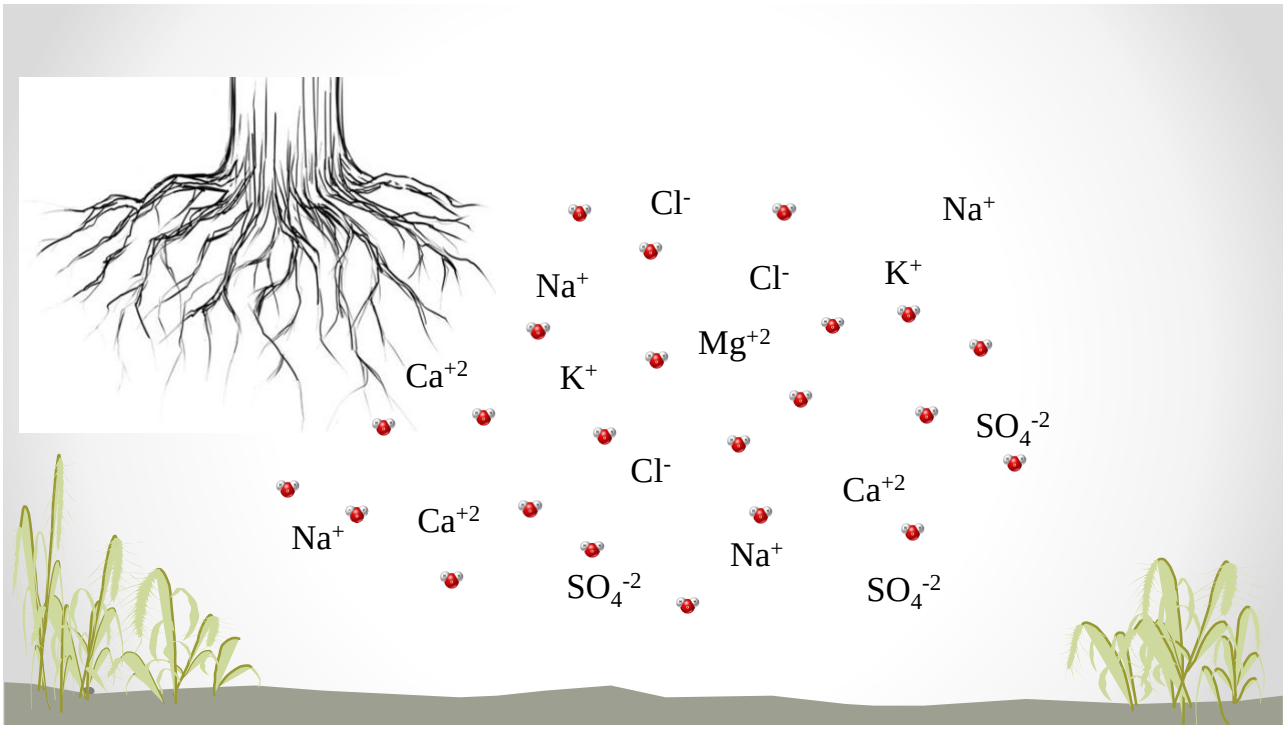
What are SALINITY and pH?

- SALINITY
  - "Chemical Drought"
    - Symptoms (stunting, reduced vigor, wilting leaves, leaf margin burn and necrosis)

What are SALINITY and pH?

- SALINITY
  - Refers to the concentration of soluble mineral ions in solution
    - Measured as the Electrical Conductivity (EC) of the soil solution, or irrigation water

Measuring EC: Simple Conductivity Measurement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Na+
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K+
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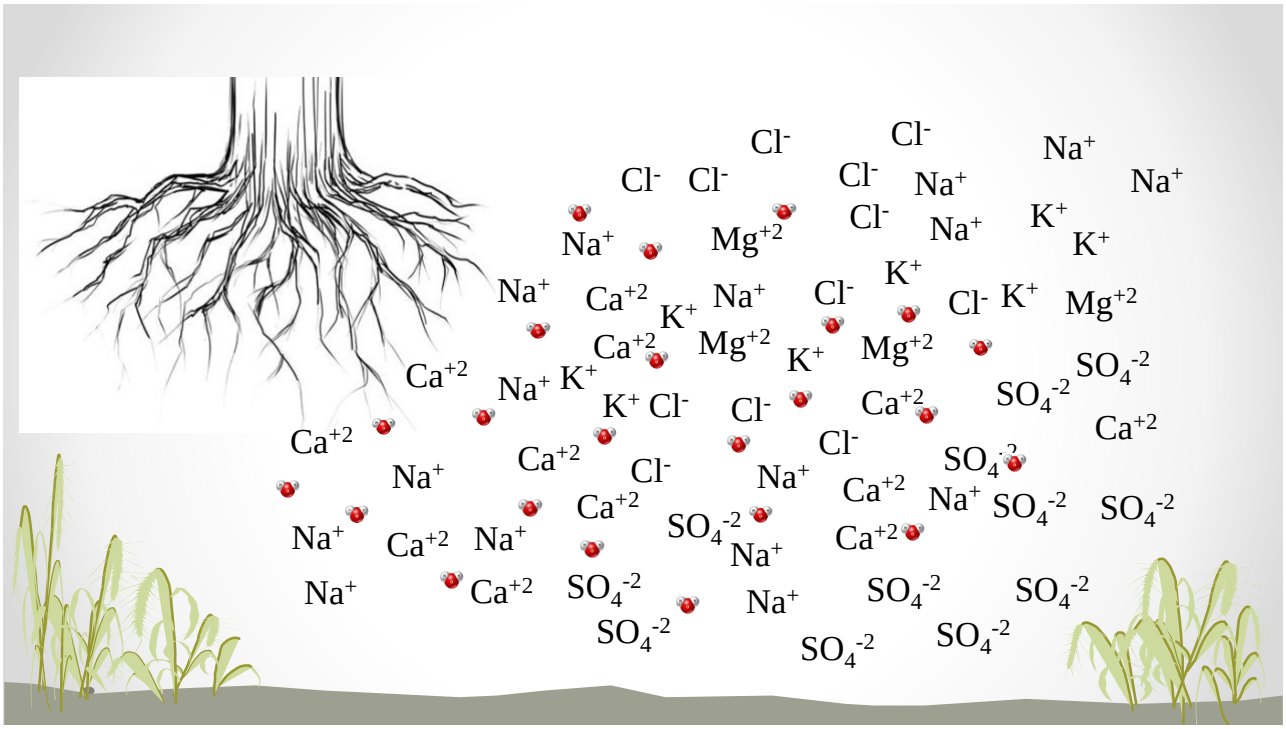
Cl-
Ca+2
Na+
Ca+2
Na+
SO4-2
SO4-2


Cl-
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Mg+2
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Na+
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Cl-
Ca+2
SO4-2
Ca+2
Ca+2
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Cl-
SO4-2
Ca+2
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SO4-2
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SO4-2
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SO4-2
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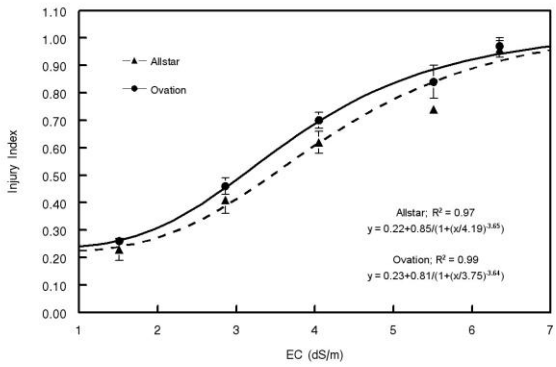
SO4-2
SO4-2
SO4-2

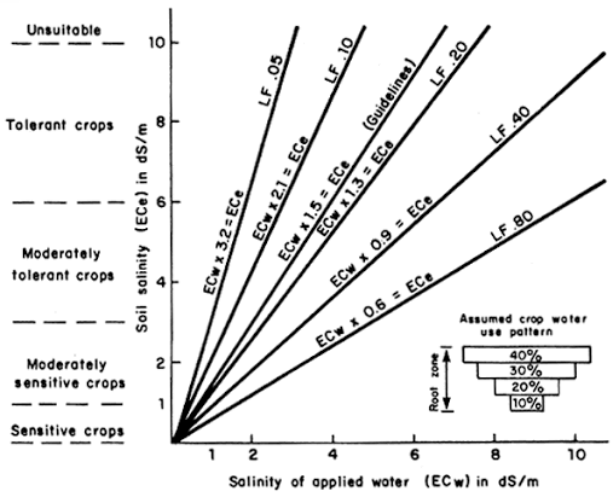
Plant Tolerance to Salinity

Crop	Threshold value	Yield loss		
		10%	25%	50%
	---------- EC_e (dS/m) ----------			
Apple	1.7	2.3	3.3	4.8
Almond	1.5	2.0	2.8	4.1
Apricot	1.5	2.0	2.6	3.7
Blackberry	1.0	2.0	2.6	3.8
Boysenberry	1.3	2.0	3.0	4.0
Cherries, Sweet and Tart	0.9	1.9	2.2	3.1
Grape	1.5	2.5	4.1	6.7
Nectarines	1.6	2.0	2.6	3.7
Peach	1.7	2.2	2.9	4.1
Pear	1.7	2.3	3.3	4.8
Pecan	1.9	2.5	3.5	4.9
Plum	1.5	2.1	2.9	4.3
Raspberry	1.0	1.4	2.1	3.2
Strawberry	1.0	1.3	1.8	2.5
Walnut	1.7	2.3	3.3	4.8



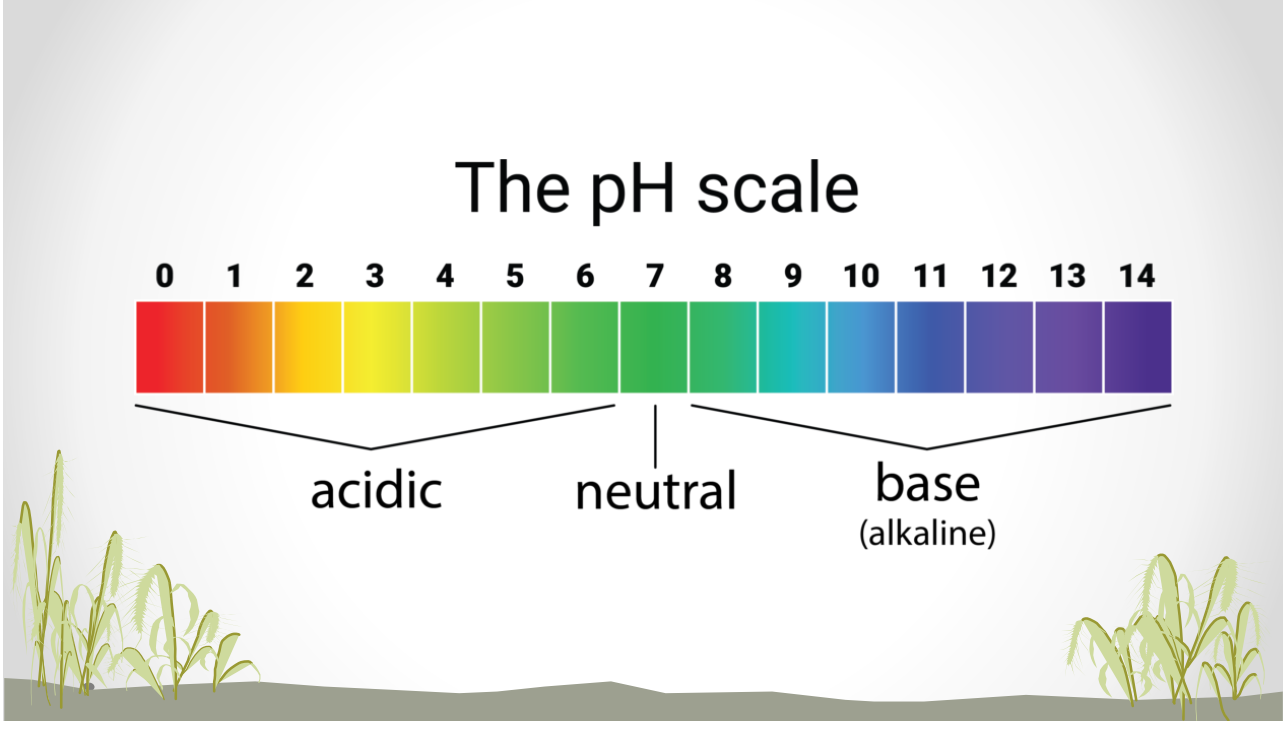
Salt injury progression

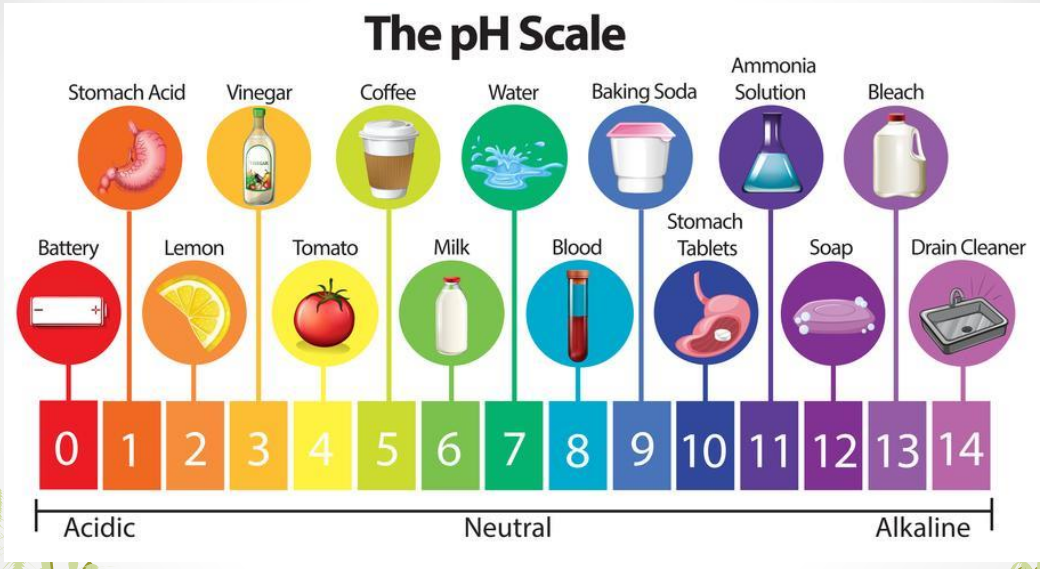
Soil vs Irrigation Water Salinity



What are SALINITY and pH?

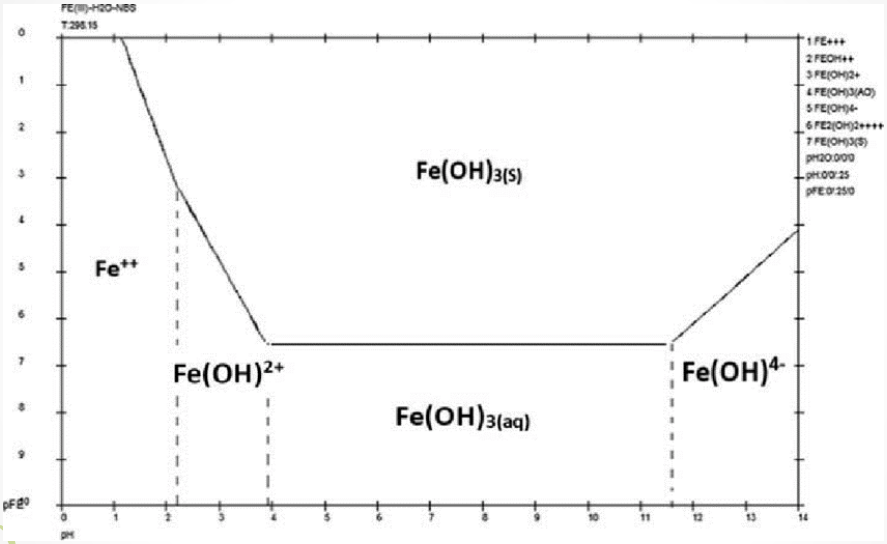
- pH
  - Refers to the concentration (activity) of Hydrogen (H+) in solution vs Hydroxide (OH-)
    - Acidity/Alkalinity
    - More H+ = acidic
    - More OH- = basic or alkaline
    - Measured as the –log(H+) in solution on a scale of 1 to 14 (7 is mid-scale, or neutral)
      - Remember water – H2O (or H-OH) – small amount of water splits half/half, so the H+ activity of pure water is balanced, or neutral.
      - "Low" pH is smaller numbers – acidic below 7
      - "High" pH is larger numbers – alkaline above 7
      - Every whole number step is 10x change (above or below) the previous value





What are SALINITY and pH?

- pH
  - Don't confuse ALKALINE with ALKALI
    - Alkaline = "high" pH, above 7 on pH scale
    - Alkali = archaic term referring to salts in the soil
  - pH controls the solubility of minerals in the soil (some minerals more soluble in acidic conditions, some in basic conditions


FE(III)-H2O-NBS
T:298.15
1 FE+++
2 FEOH++
3 FE(OH)2+
4 FE(OH)3(AQ)
5 FE(OH)4-
6 FE2(OH)2++++
7 FE(OH)3(S)
pH:0:0:10
pH:0:0:25
pFE:0:25:0
Fe(OH)3(S)
Fe++
Fe(OH)2+
Fe(OH)3(aq)
Fe(OH)4-
pH
pFE0


9.11
pH
25.6°C
Read
Cal
pH/mV

Questions?

Salinity and pH: Effects on Plant Nutrient Availability and Uptake

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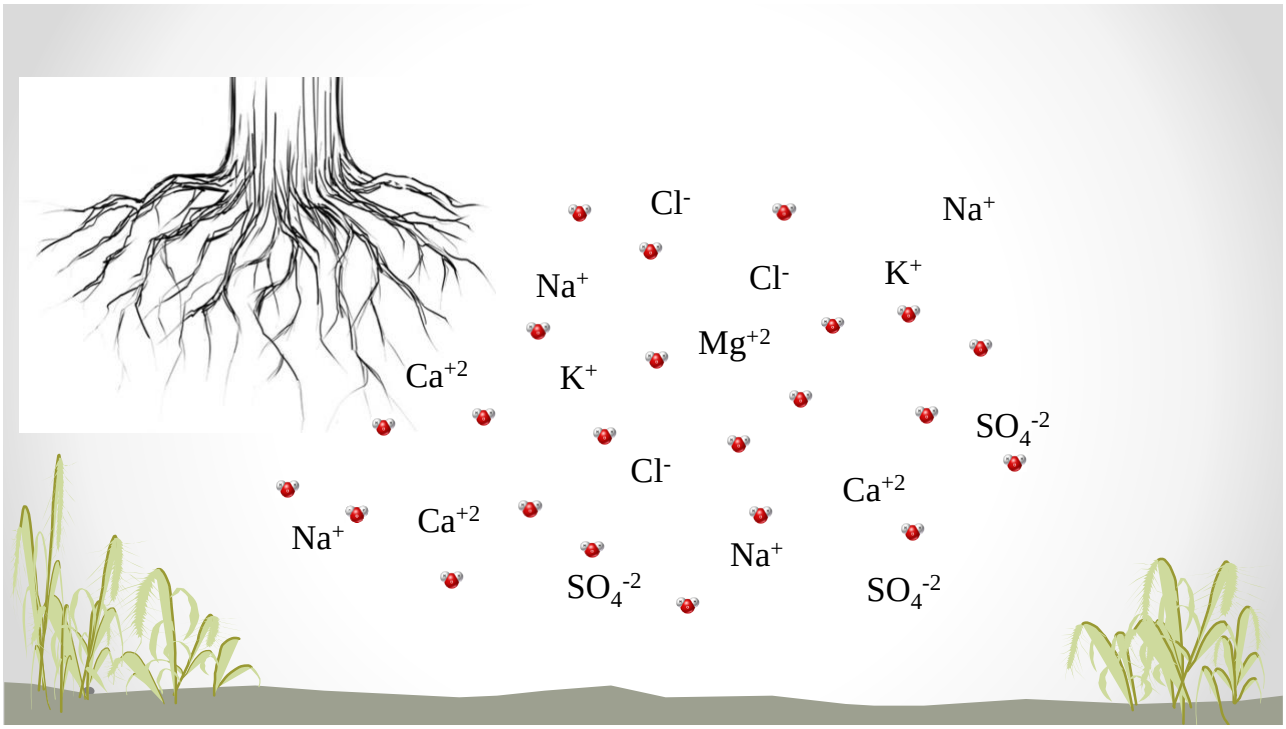
USU Extension Soils Specialist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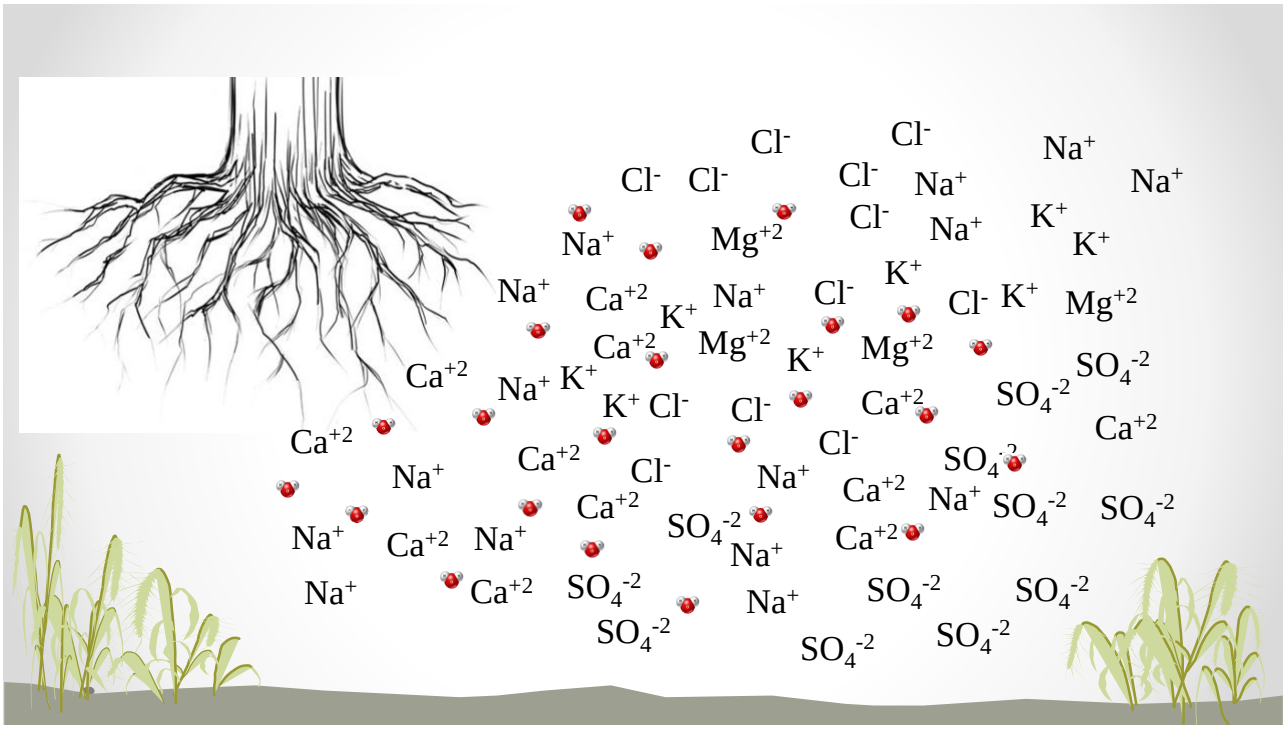
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Ca+2
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SO4-2
SO4-2
SO4-2
SO4-2

Uptake Competition

Ca^{+2} Ca^{+2} Ca^{+2} Ca^{+2} K^{+} Ca^{+2} Ca^{+2} Ca^{+2} SO_4^{-2} Ca^{+2}

Nutrient Precipitation

HCO_3^- Ca^{+2} Ca^{+2} HCO_3^- Ca^{+2} CO_3^{2-} CO_3^{2-} Ca^{+2} CO_3^{2-} Ca^{+2} Ca^{+2} Ca^{+2} CO_3^{2-} CO_3^{2-} Ca^{+2} Ca^{+2} HCO_3^-

$CaCO_3$ (lime)

Precipitation

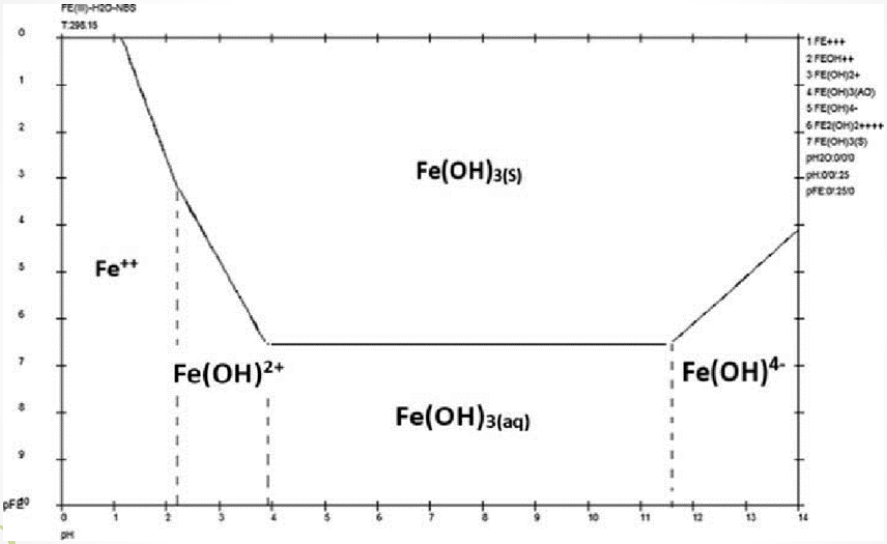
Salts:
$CaSO_4$ (gypsum)
Na_2SO_4 (glauber's)
$MgSO_4$ (epsom)
NaCl (table salt)
KCl (Muriate of Potash)
$CaCl_2$
$MgCl_2$

Two Way Street

Na^+ Cl^- Na^+ Na^+ K^+ K^+ Ca^{+2} Mg^{+2} Mg^{+2} K^+ Cl^- SO_4^{-2} Ca^{+2} Cl^- Ca^{+2} Ca^{+2} Na^+ SO_4^{-2} SO_4^{-2}

Nutrient Precipitation Effect

Calcium deficiency in greenhouse experiment at high salinity conditions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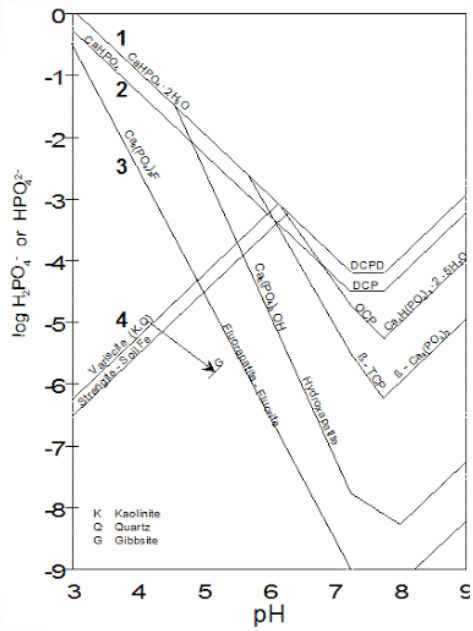
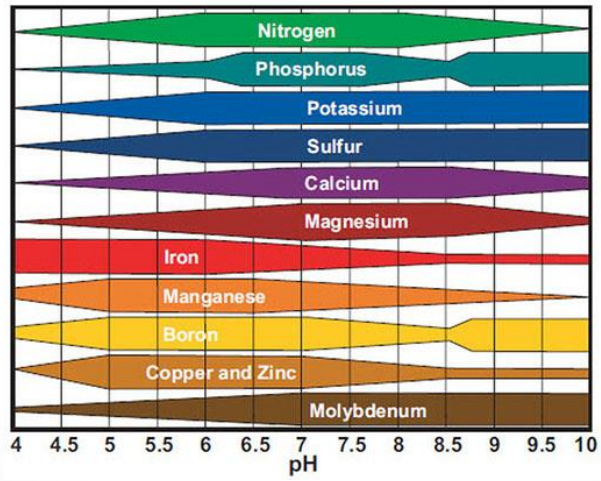
2 FEOH++
3 FE(OH)2+
4 FE(OH)3(AQ)
5 FE(OH)4-
6 FE2(OH)2++++
7 FE(OH)3(S)
pH2O:0/0
pH:0/0:25
pFE:0/25/0
Fe(OH)3(S)
Fe++
Fe(OH)2+
Fe(OH)3(aq)
Fe(OH)4-
pFE
pH


log H2PO4- or HPO42-
pH
1
2
3
4
CaHPO4
CaHPO4.2H2O
Ca4PO4F
Variscite (K-G)
Strengite - Soil Fe
G
Fluorapatite - Fluorite
Ca5(PO4)3OH
Hydroxyapatite
DCPD
DCP
OCP
Ca8H(PO4)5.2.5H2O
ß - TCP
ß - Ca3(PO4)2
K Kaolinite
Q Quartz
G Gibbsite

Nutrient Availability vs pH



Mineral Precipitation

- pH-related soil reactions reduce nutrient availability
  - High concentration coupled with high pH forces formation of insoluble solids:
    - Calcium and P react to form Ca-Phosphate (Apatitie)
    - Zinc and P react to form ZnPO4 (Zn-phosphate)
    - Iron and Sulfate react to form FeSO4 (Iron Sulfate)
  - So why not just adjust pH to solubilize minerals?
    - Buffer compounds that regulate pH change
      - Calcareous soils issues (high lime conditions)
    - Problem of scale

Soil Acidification

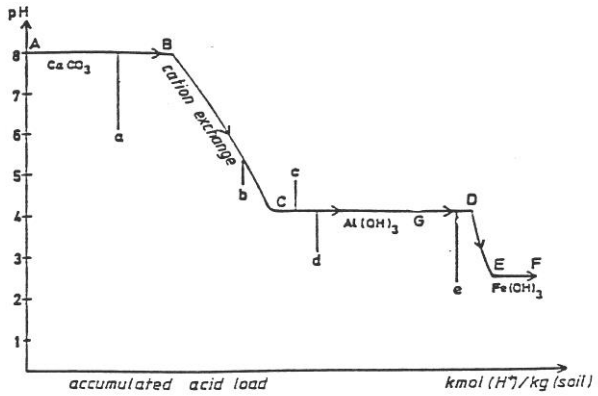


Figure A. Model of soil acidification.

Problem of scale to change pH

- High soil lime ($CaCO_3$) content
  - As it dissolves with acid application, produces CO_3 which reacts almost immediately with H^+ to produce $CO_2(g)$ and H_2O (water) – Acid is consumed and pH remains constant
  - Leaves additional Ca in soil which can react with other nutrients or simply increase solute concentrations
  - All lime would have to be dissolved before pH will begin to drop
  - Soils in Utah contain 15-40% lime by weight, or 300-800 tons of lime per acre (upper foot)

Reaction

- https://youtu.be/IvyIkmf9WVY

Managing nutrients in high pH and Salinity Conditions

- Reduce salinity through "washing" or leaching solutes out of the soil
- Don't over-apply fertilizers (mineral salts of nutrients)
- Manage soil moisture at optimum levels (reduces concentrations, potential reduction in water uptake and salt precipitation)
- Better to apply chelated or foliar forms of nutrients (e.g., Fe, Zn, K) if soil pH conditions causing issues with uptake, than trying to regulate soil pH
  - Except in low lime conditions, coarse/rocky soils – may be opportunity to slightly lower pH
    - Acid injection in drip irrigation
    - Sulfur burners
- Well water high in Bicarbonate or Carbonate can be acid treated to remove these compounds and reduce their activity in the soil

Questions?