SOIL CHEMISTRY

Reading Materials:

•Brady NC, 1990. The Nature and Properties of Soils

•Supardi, 1989. Sifat dan Ciri Tanah

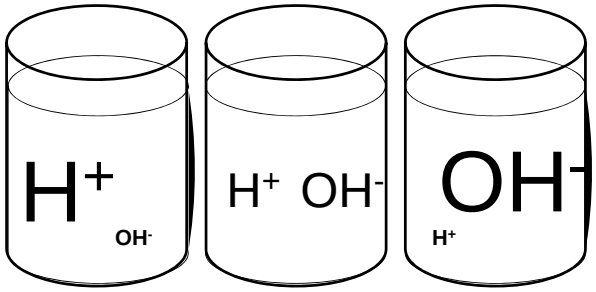
Foto: Reza Nugroho

Objectives

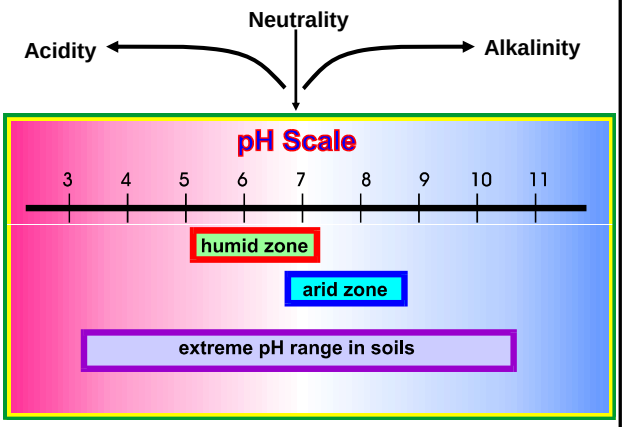
- Soil pH
- Cation exchange
  - Cation Exchange Capacity (CEC)
  - Base saturation
- Plant Nutrients

$H_2O \rightleftharpoons 2\ H^+ + O^{-2}$

$pH = - \log [\ H^+\ ]$



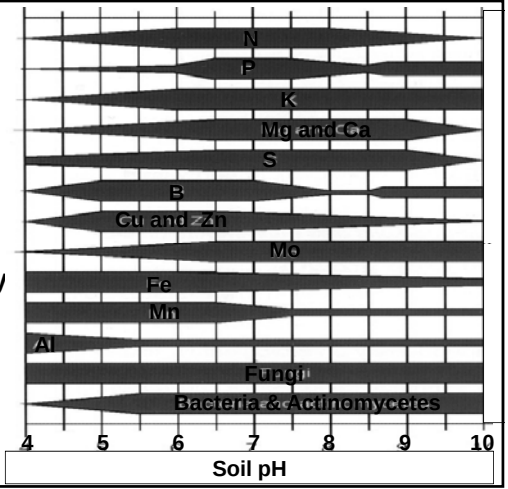
Acid pH = 6.0 | Neutral pH = 7.0 | Alkaline pH = 8.0



Why is pH important?

- **Nutrient availability**
- **toxicity in the soil**
- **Microbial activity**

Soil pH & nutrient availability



Cation Exchange

Exchange process

Ca^{+2}-colloid + 2 H^+ ⟷ 2 H^+-colloid + Ca^{+2}

= H^+ replaces Ca^{+2} adsorbed to soil colloids

Ca-x + 2 H^+ ⟷ 2 H-x + Ca^{+2}

x = the soil solid phase

$Ca_{(ad)}$ + 2 H^+ ⟷ 2 $H_{(ad)}$ + Ca^{+2}

$X_{(ad)}$ = "adsorbed" cation X

Adsorption: the attraction of ions (Ca^{2+}, Mg^{2+}, K^+ on the surface of colloidal clay and humus.

Adsorbed cations

(a) arid region soils = "basic" cations

Ca^{+2}, Mg^{+2}, K^+, Na^+

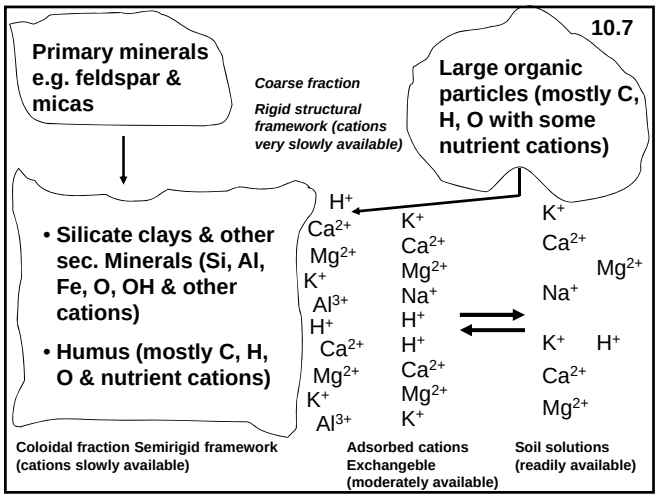
(b) humid region soils

= "acidic" cations as well

Ca^{+2}, Mg^{+2}, H^+ and Al^{+3}

(c) strength of adsorption

$Al^{+3} > Ca^{+2} = Mg^{+2} > K^+ = NH_4^+ > Na^+$



Sumber-sumber penyebab kemasaman tanah

1. **Humus atau bahan organik**
   - ✓**Gugus-gugus karboksil**
     gugus-gugus phenolik
     gugus-gugus amino ⟶ **Timbunan ion H^+**
   - ✓**Proses dekomposisi**
     H_2CO_3 ⟶ **mencuci basa-basa terus-menerus**
     H_2SO_4, HNO_3 ⟶ **tambahan ion H^+**

2. Garam-garam yang larut
   - Pemupukan
   - Pelapukan mineral
   - Dekomposisi BO

   } **menambah kation-kation**

   menggantikan Al teradsorbsi

   Al masuk ke larutan tanah

   penyebab tambahnya H+

3. Intensitas pencucian

Tanah di daerah humid : basa-basa tercuci, tertinggal H^+ dan Al^{+++}

$Al^{+++} + H_2O$ ⟶ **$Al(OH)^{++} + H^+$**

$Al(OH)^{++} + H_2O$ ⟶ **$Al(OH)_2^+ + H^+$**

$Al(OH)_2^+ + H_2O$ ⟶ **$Al(OH)_3 + H^+$**

4. Mineral klei (*clay*) alumino silikat oleh pelapukan dari oktahedral Al membebaskan Al dengan 2 kemungkinan :
   - Al teradsorbsi

     $Al + 3H_2O$ ⟷ $Al(OH)_3$ + MISEL ⟷ H^+
   - Al dalam larutan

5. Karbon dioksida (CO_2)

CO_2 dihasilkan oleh adanya respirasi akar dan jasad hidup dalam tanah,

$CO_2 + H_2O \rightarrow H_2CO_3$ mencuci basa-basa

Factor of Acid forming in Soil

1. Nitrification:

Ammonium to Nitrate (oxidation of NH_4^+)

$NH_4^+ + 2O_2 \dashrightarrow NO_3^- + H_2O + 2\ H^+$

2. **O.M. decomposition**

organic acids ionized :

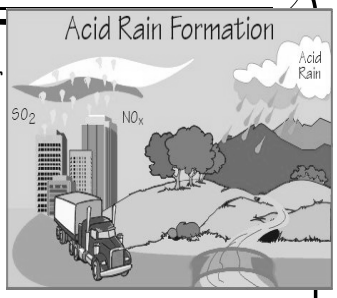
$R\text{-}COOH \dashrightarrow R\text{-}COO^- + H^+$

respiration:

$CO_2 + H_2O \dashrightarrow H_2CO_3 = H^+ + HCO_3^-$

3. Acid rain

- Acid rain is caused by the burning of fossil fuels.
- Burning oil, gas and coal in power stations releases Sulfuric Dioxide (SO2) into the atmosphere.
- Burning oil and gasoline in motor vehicles puts nitrogen oxides (NOX) into the atmosphere.
- These gases mix with water droplets in the atmosphere creating weak solutions of nitric and sulfuric acids.
- When precipitation occurs these solutions fall as acid rain.

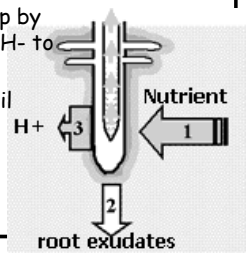


$SO_2 + OH \dashrightarrow H_2SO_4 \dashrightarrow SO_4^- + 2\ H^+$

$NO_2 + OH \dashrightarrow HNO_3 \dashrightarrow NO_3^- + H^+$

4. Uptake of basic cations by plants.

- Basic cations are sources of OH- to the soil solution.
- **Ca++, Mg++, K+,**
- Basic cations that are taken up by plants no longer contribute OH- to the soil solution.
- H+ ions are released to the soil solution.

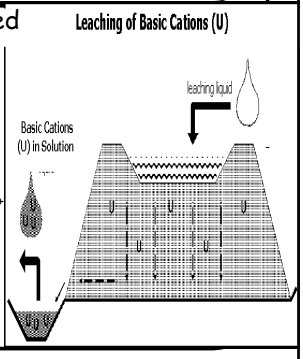


5. Leaching of basic cations

as basic cations are removed from the soil solution by leaching they no longer contribute the OH- ions to neutralize the ever increasing amounts of H+

$Ca^{++} + 2\ H_2O \dashrightarrow Ca(OH)_2 + 2H^+$

$\dashrightarrow Ca^{++} + 2OH^-$



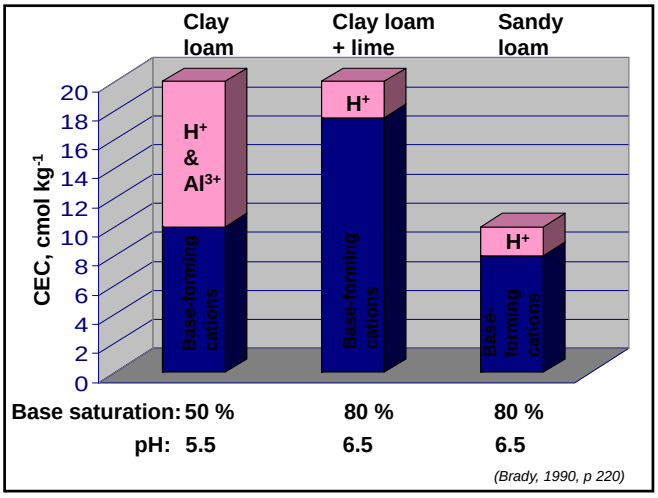
Cation Exchange Capacity, CEC

(KAPASITAS TUKAR KATION, KTK)

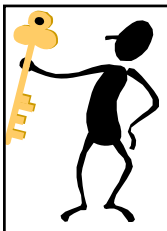
- Sum total of the exchangeable cations (K^+, Ca^{2+}, Mg^{2+}, Na^+, NH_4^+) that a soil can adsorb
- Unit: **$cmol_c\ kg^{-1}$** used to be **me/100 g** of soil
- Measurement:Extraction of 1 M NH_4Oac. pH 7.0

Soil CEC, clay mineral type & humus

Clay Mineral	Type	CEC,cmol$_c$ kg^{-1}
Kaolinite	1:1	30-150
Halloysite	1:1	60-100
Hidrous mica	2:1	200-400
Montmorilonite	2:1	800-1200
Vermiculite	2:1	1000-1500
Iron Hydroxide Aluminium oxide		30-50
Humus		2000-4500



(Brady, 1990, p 220)



Why is CEC important?

Nutrient availability

- Cation released during mineralisation
- Cation exchangeable (e.g KCl application➔ release another cations into soil solution)
- Nutrient buffer ~ it reduces nutrients losses through leaching

Level of Soil Fertility based on its CEC

Category	Ca	Mg	K	Na	KTK
	----------cmol$_c$ kg^{-1}----------				
Very high	**>200**	**>80**	**>12**	**>20**	**>400**
High	**100-200**	**30-80**	**6-12**	**7-20**	**250-400**
Medium	**50-100**	**10-30**	**3-6**	**3-7**	**120-250**
Low	**20-50**	**3-10**	**2-3**	**1-3**	**60-120**
Very low	**<20**	**<3**	**<2**	**<1**	**<60**

Exchangeable cations in soils

- The predominant exchangeable cations either ***"basic"*** (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) or ***"acidic"*** (Al^{3+} and H^{+}). It is useful in identifying the relative proportions of sources of alkalinity and acidity in soil solution.
- ***Percentage base saturation***: The percentage of the CEC is satisfied by base-forming cations.

% base saturation =

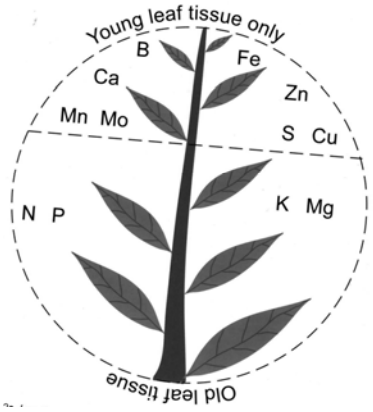
$$\frac{\text{Exchangeable base-forming cations (cmol kg}^{-1}\text{)}}{\text{CEC (cmol kg}^{-1}\text{)}}$$

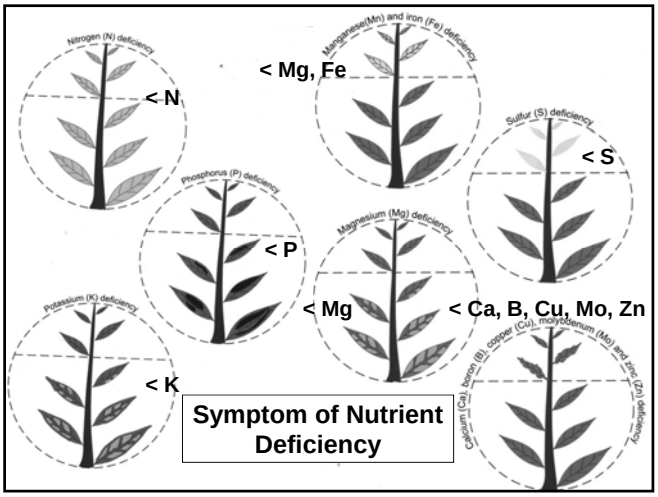
Cation exchange data for representative mineral surface soils in different areas

Characteristics	Humid region soil (Alfisol)	Semiarid region soil (Aridisol)	Arid region soil (Natrargids)
Exchangeable Ca (cmol/ kg)	6-9	14-17	12-14
Other exchangeable bases (cmol/ kg)	2-3	5-7	8-12
Exchangeable H and/or Al (cmol/ kg)	4-8	1-2	0
CEC (cmol/ kg)	12-18	20-26	20-26
Base saturation (%)	66.6	90-95	100
Probable pH	5.6-5.8	~ 7	8-10

(Brady, 1990, p 205)

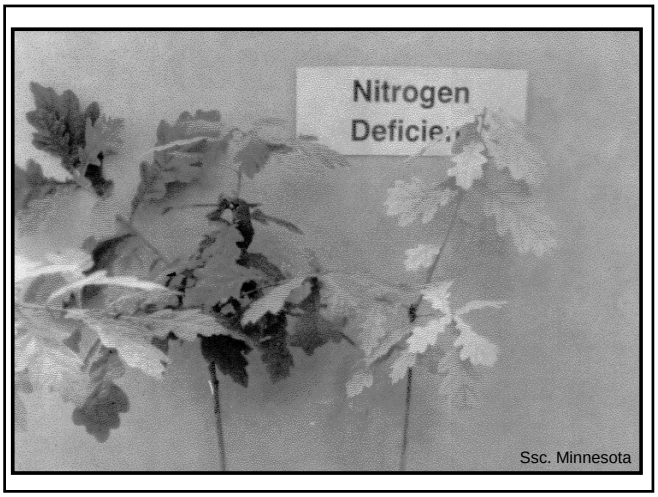
Symptom of Nutrients deficiency





Influence of Nitrogen on Plant growth

- Absorbed by plants in NH_4^+ and NO_3^-
- N as an integral component of many component such as: Chlorophyl & enzymes.
- As an essential component of amino acids and related proteins ~ critical for building blocks for plant tissue, the cell nuclei & protoplasm.
- It encourages vegetative growth & gives a deep green color to the leaves.
- Symptom of N deficiency is shown by yellow color or yellowish green of older leaves and tend to drop off.



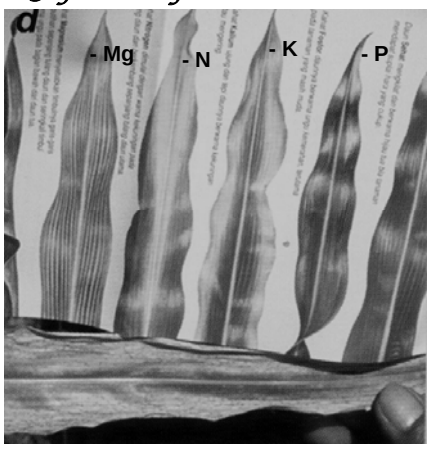
Phosphorus

It absorbed by plants in $H_2PO_4^-$, HPO_4^{2-} or PO_4^{3-}

Function

- Photosynthesis
- Nitrogen fixation
- Crop maturation: flowering & fruiting including seed formation
- Root development
- Strength of straw in cereal crops
- Improvement of crop quality

Gejala Defisiensi Unsur



Symptom of Potassium (K) Deficiency

(Ssc. Minnesota)

Cassava

Cassava

Pueraria