pH and Soil Acidifying Processes

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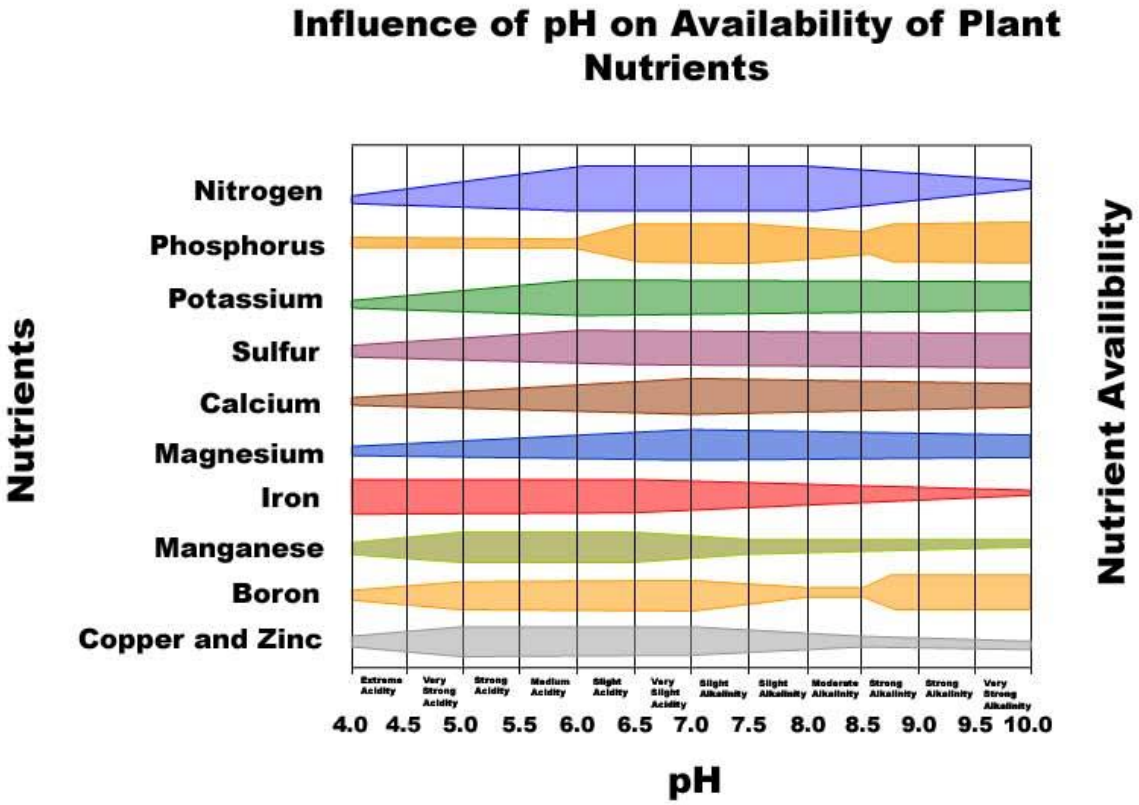
Advanced Crop Advisors Workshop

February 12, 2019

Pfffffffffffffffffffffffff! *or*, pH!

Why are we concerned with soil pH?

- **pH is the "master soil variable"**
  - **Controls solubility and thus plant availability of plant nutrients**



http://www.luresext.edu/photos/soilpHnutavlg.jpg

(S.S.S.A.P., 1946. 11:305.)

What is pH?

- By definition pH is the negative $\log_{10}$ of the hydrogen ion concentration
- Ranges from 0 to 14

$$pH = -\log [H^+] \quad \text{or} \quad \log 1/[H^+]$$

$$pH + pOH = 14$$

H^+ also written as H_30^+

Why this scale?

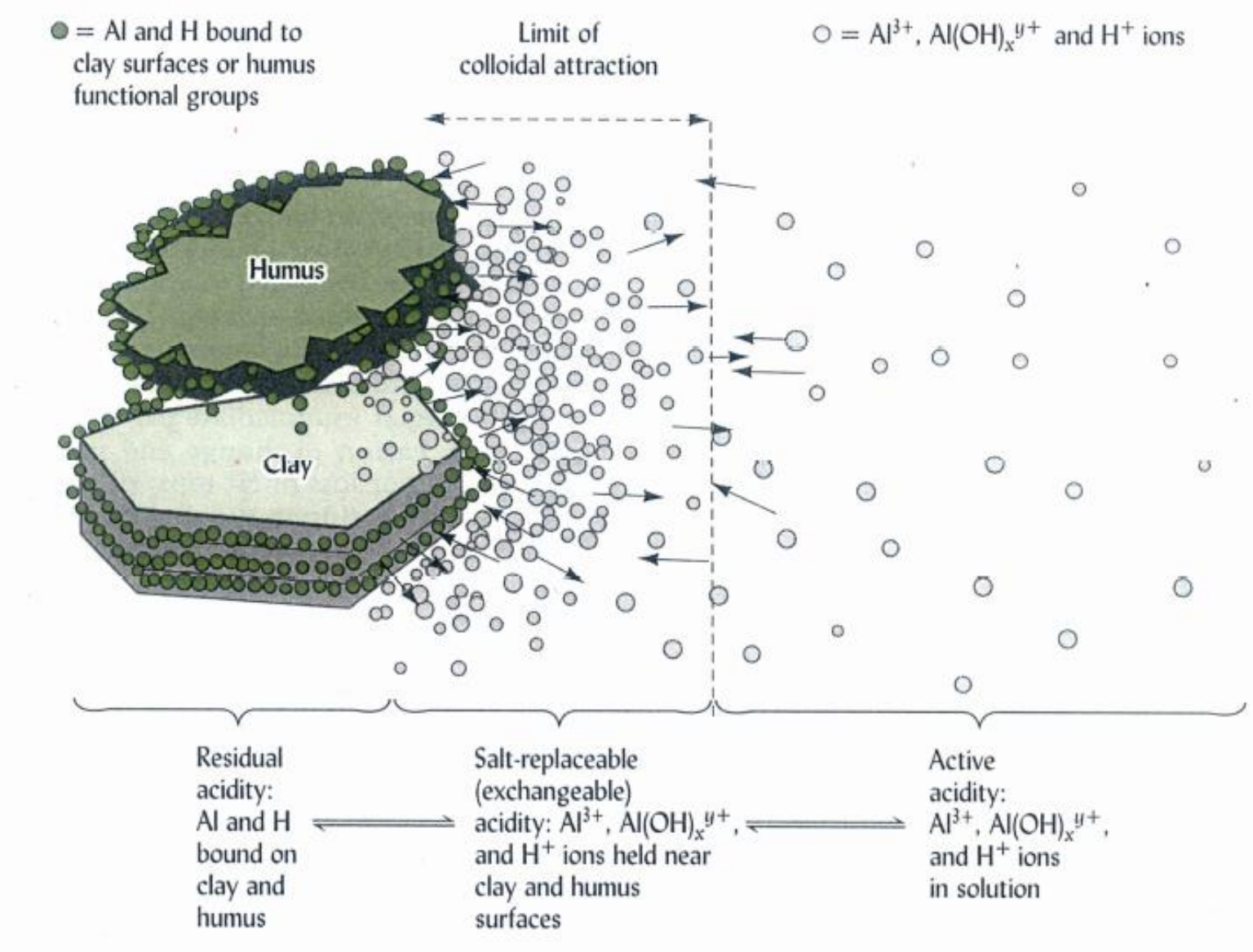
- **First proposed in 1909 by Danish scientist Soren P.L. Sörenson**
- **Scale ranges from 0 to 14:**
  - **0, which is 1 M HCl**
  - **14, which is 1 M NaOH**

So…

$[H^+]$	pH
1	0
0.01	2
0.000001	6
0.0000001	7
0.00000001	8
0.0000000001	10
0.000000000000001	14

Types of soil acidity (n = 3)

- **1. Active acidity**
- **2. Potential acidity**
  - **Also called “reserve” or “exchangeable” acidity**
  - ***In* ‘reserve’ but also ‘exchangeable’**
- **3. Residual acidity**



(Brady and Weil, 14th ed; figure 9.9)

Types of soil acidity (n = 3)

- **1. Active acidity**
  - **H^+ in the soil solution**
  - **Measured as soil pH in the lab**
  - **Reflects what plants experience**
  - **Determines solubility of many substances**
  - **Not very hard to neutralize**
    - **“teaspoon of lime”**

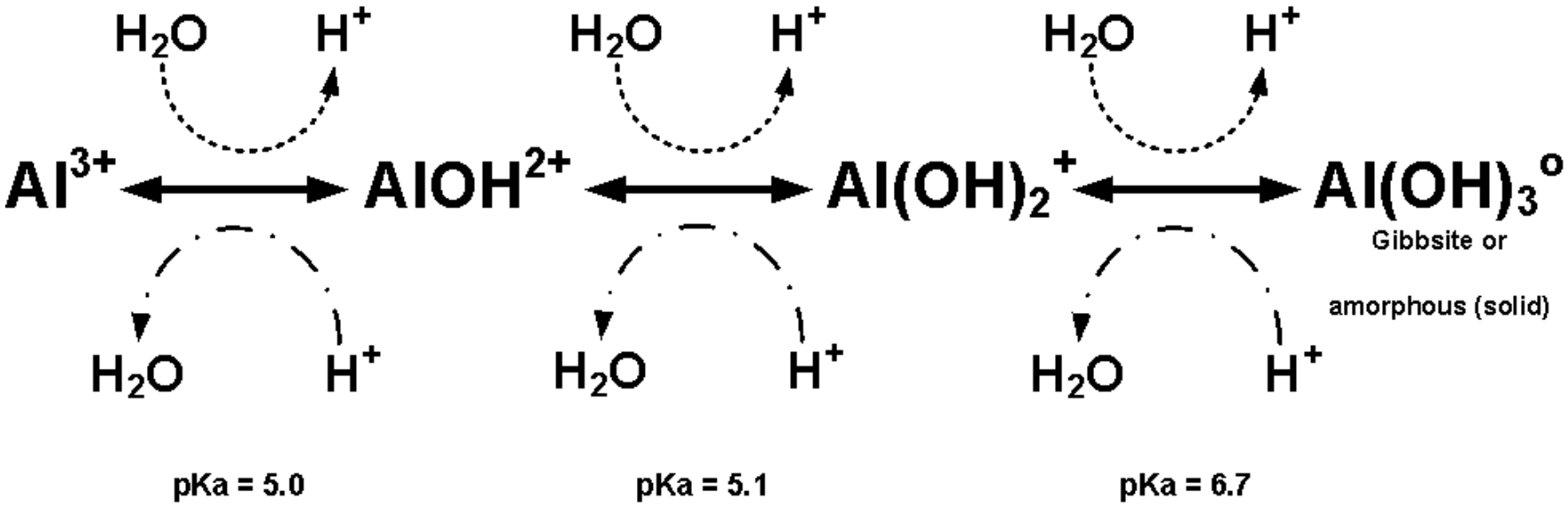
Types of soil acidity

- **2. Potential acidity**
  - **Exchangeable Al species and H**
    - **Released through cation exchange**
  - **Hydrolysis of Al^{3+} releases more H^{+}**
  - **In moderately acid soils (pH 5 to 6), about 100 times more than active acidity**
  - **In a sandy soil, 1000X of active acidity**
  - **In a soil with high clay and OM, 50,000 to 100,000 greater than active acidity**

Aluminum

- Released into solution through mineral destruction by H^+
- Absorbed to exchange sites
- Toxic to plant roots
- One Al^{3+} ion can release up to three H^+ through hydrolysis
- Al^{3+} and H^+ are considered “acid cations”
- Key source when pH is $\leq$ 4.8

Hydrolysis of Al species



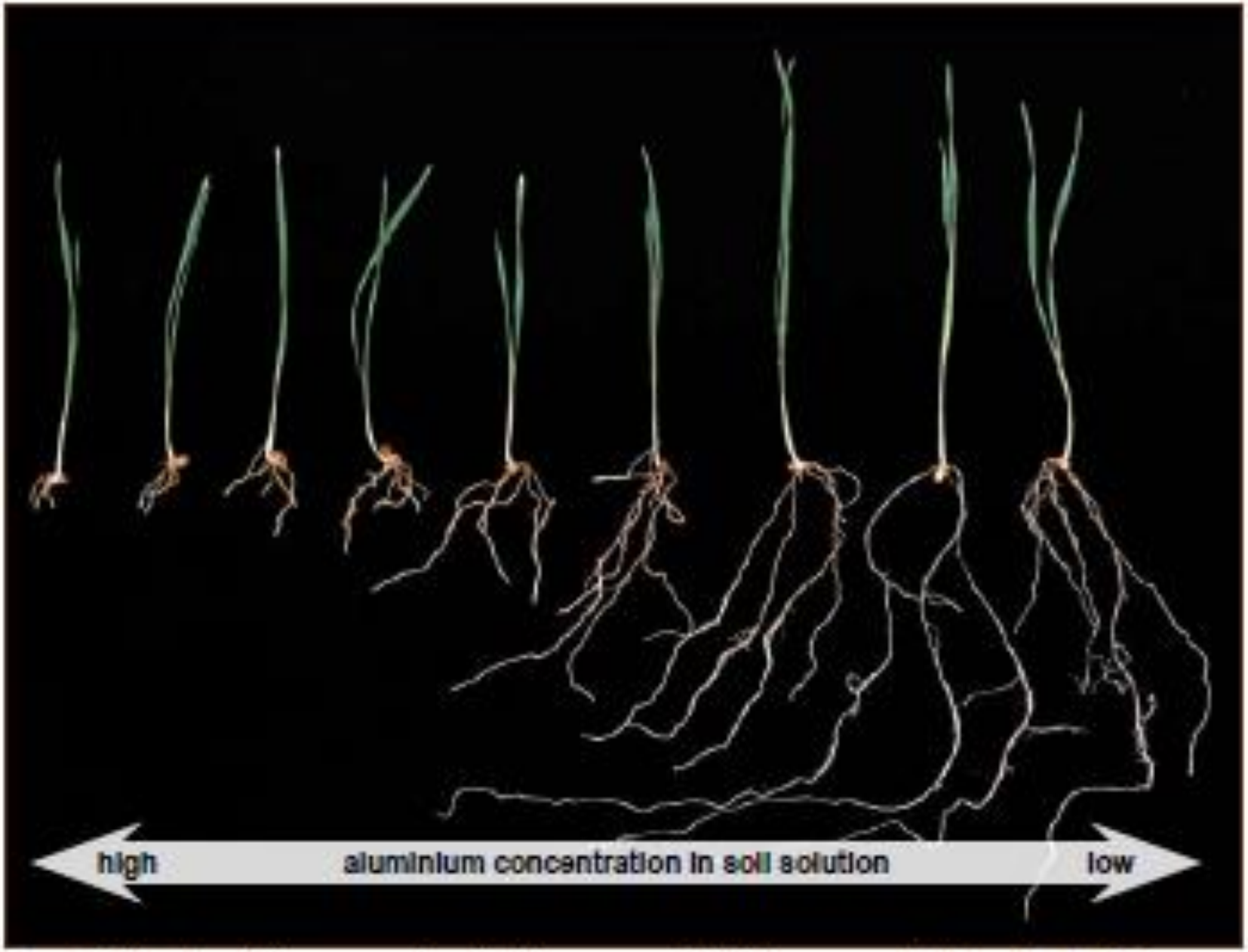


Figure 29 Wheat seedlings grown in soil with a range of aluminium concentrations. Photo: S Carr

http://www.agric.wa.gov.au/objtwr/imported_assets/content/lwe/land/acid/liming/bn_soil_acidity_guide.pdf

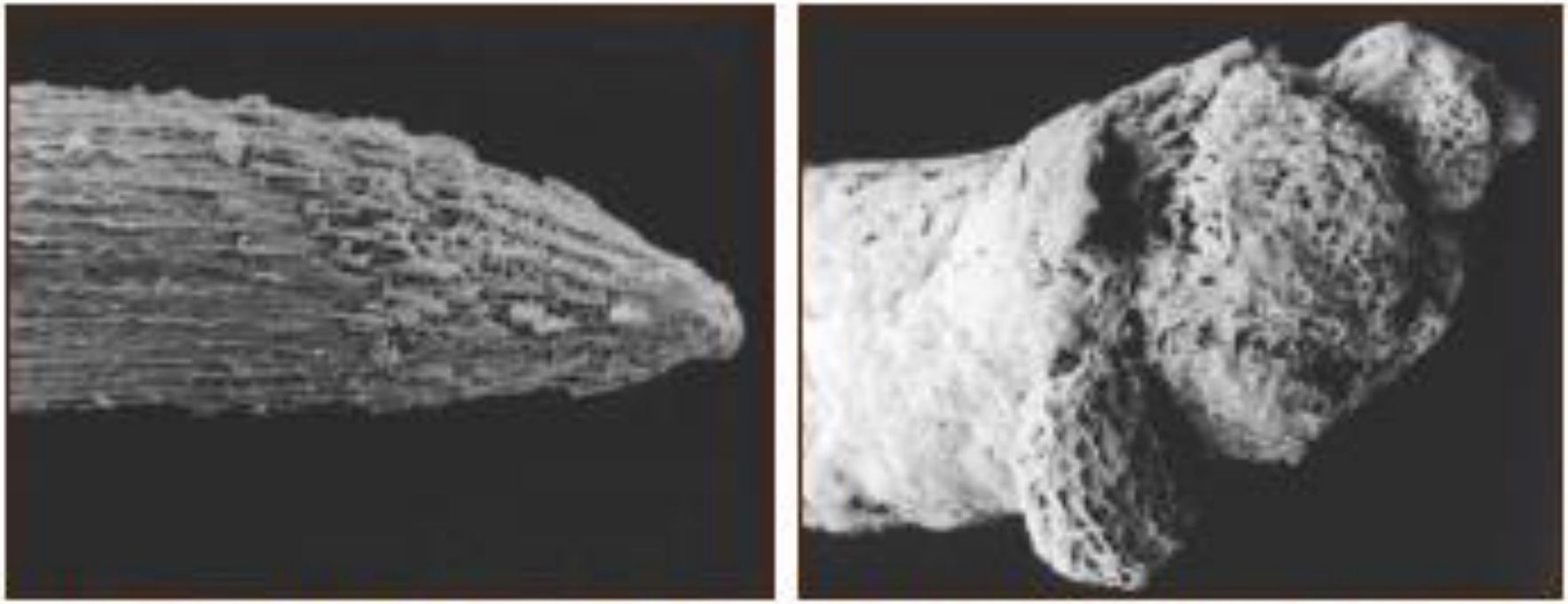


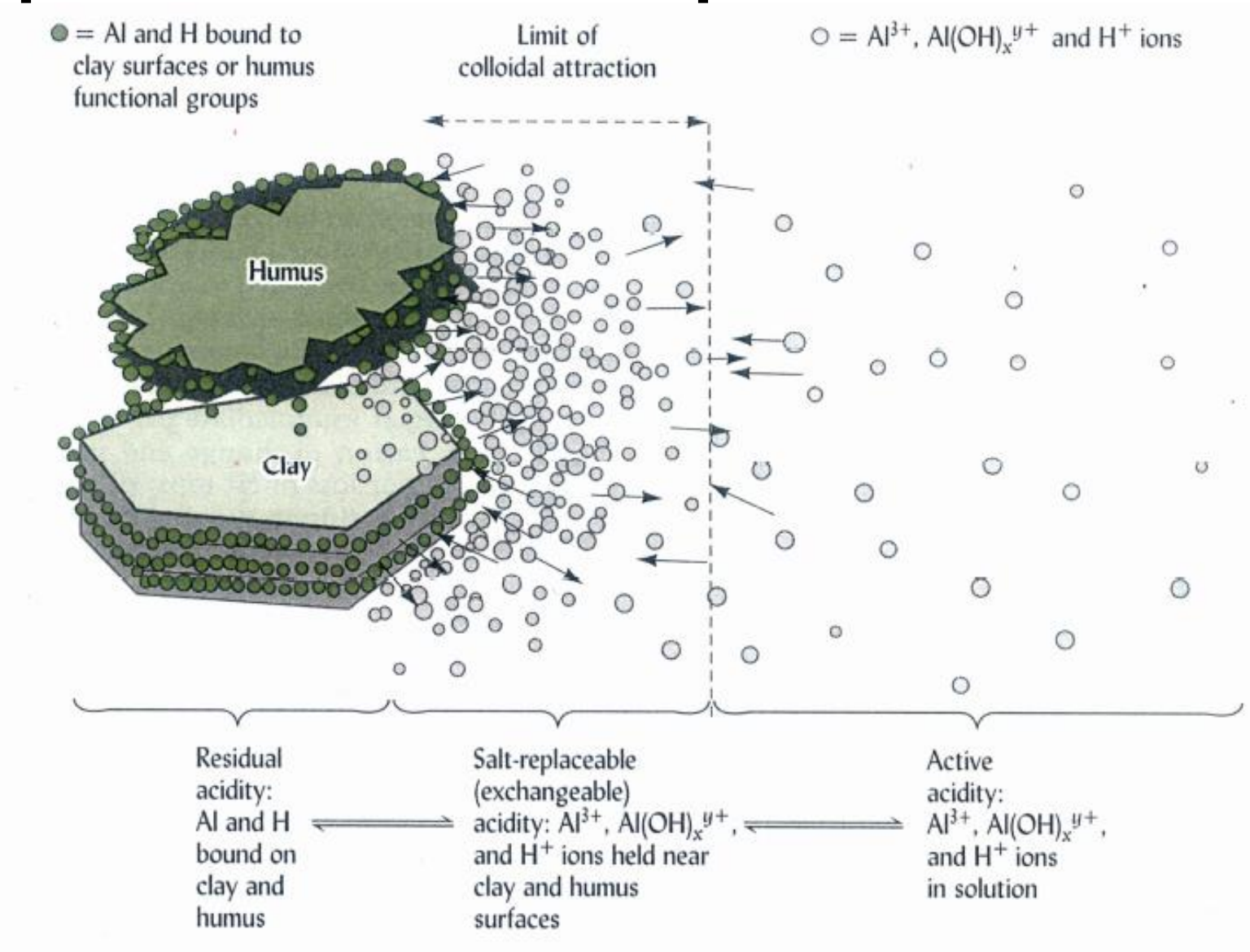
Figure 30 Healthy root tip (left) compared to a root tip affected by aluminium toxicity (right). Photos: CSIRO

http://www.agric.wa.gov.au/objtwr/imported_assets/content/lwe/land/acid/liming/bn_soil_acidity_guide.pdf

Types of soil acidity

- **3. Residual acidity**
  - **H^+ and Al^{3+} ions bound in non-exchangeable forms by organic matter and clays**

Buffer capacity of the soil



(Brady and Weil, 14th ed; figure 9.9)

Overview of most common influences on soil pH

- Root and microbial respiration
- N fertilizers
- Cation and anion uptake by roots

Root and microbial respiration

Vegetative bioremediation of calcareous saline-sodic and sodic soils

This is why one adds lime

$CaCO_3 + H^+ \leftarrow\rightarrow Ca^{2+} + HCO_3^-$

Organic matter

decomposition

$CO_2 + H_2O$

$H_2CO_3 \leftarrow\rightarrow H^+ + HCO_3^-$

Calcareous soils

Non-calcareous soils

Is gypsum ($CaSO_4$) a liming material?

- ***No!***

$$CaSO_4 \leftarrow \rightarrow Ca^{2+} + SO_4^{2-}$$

$$SO_4^{2-} + H_2O \leftarrow \rightarrow H_2SO_4$$

N fertilizers

Uptake NO_3^-

OH^-

Ammonia-N, or -based

$NH_3 + H^+ \leftarrow \rightarrow NH_4^+$

H^+ H^+

Nitrate-N, or -based

Ammonium-N, or -based

Leaching

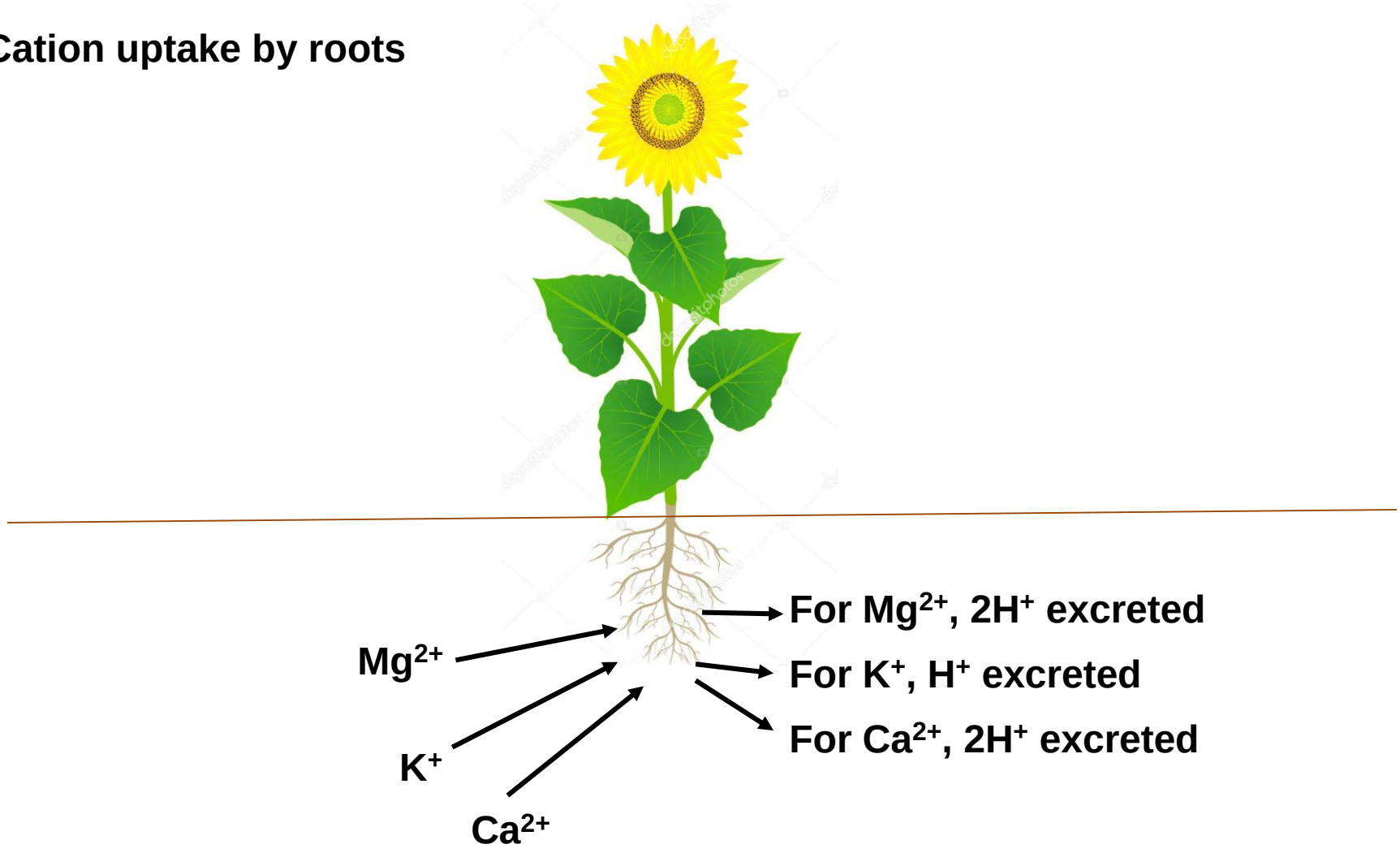
NO_3^- + cation

nitrification

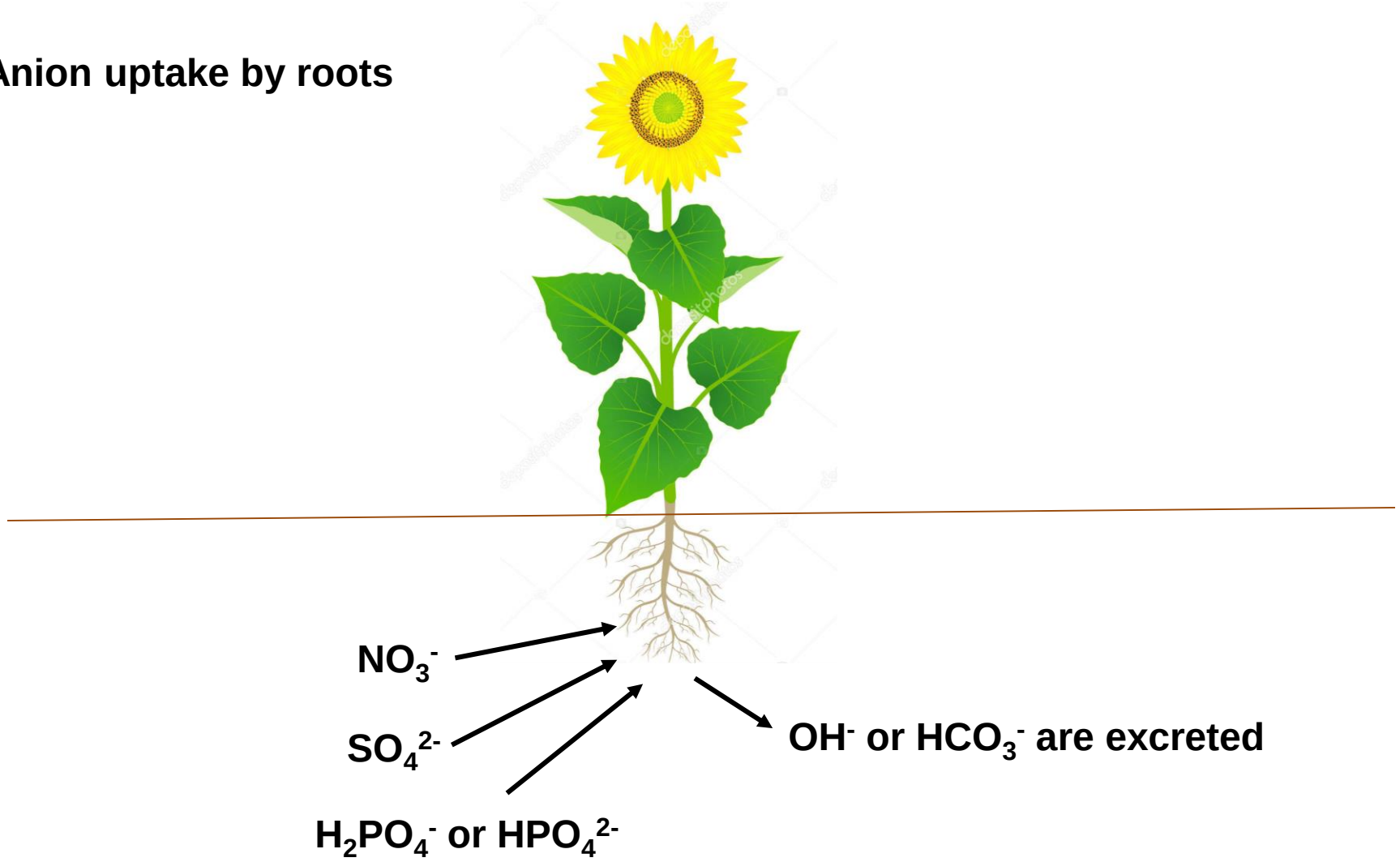
$NH_4^+ + 3/2O_2 \rightarrow NO_2^- + H_2O + 2H^+$

$NO_2^- + 1/2O_2 \rightarrow NO_3^-$

Cation uptake by roots



Anion uptake by roots



Soil acidification occurs when plants take up more cations than anions