Soil acidity

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pH

= −log (H^+)

riba Home page

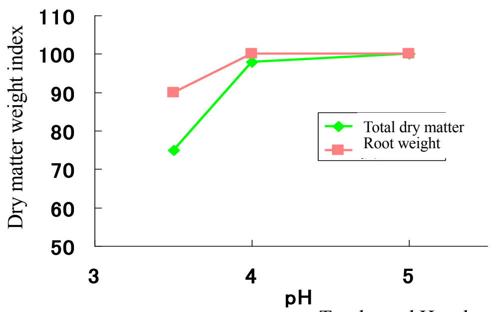
pH and crop growth (vegetables and root crops)

Low pH tolerance	Crops
strong (4.0~5.0)	Potato, taro
A little strong (4.5~6.0)	Sweet potato, white radish, turnip, green bean, carrot, cucumber, parsley
A little weak (5.5~6.5)	Tomato, egg plant, cabbage, cauliflower, broccoli, celery, green peas, melon
weak (6.0~7.0)	Spinach, Onion, leek, burdock, asparagus, red pepper, lettus

pH and crop growth (grains and pasture crops)

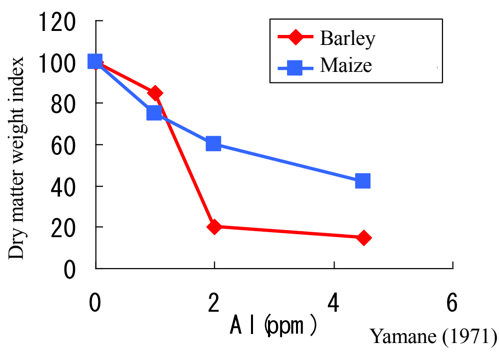
Low pH tolerance	Crops
strong (4.0~5.0)	Rice, tea, tobacco
A little strong (4.5~6.0)	Wheat, timothy
A little weak (5.5~6.5)	Adzuki bean, clover, milk vetch
weak (6.0~7.0)	Sugar beet, barley, rye

Growth medium pH and the dry matter production of crops: average of 49 crops.



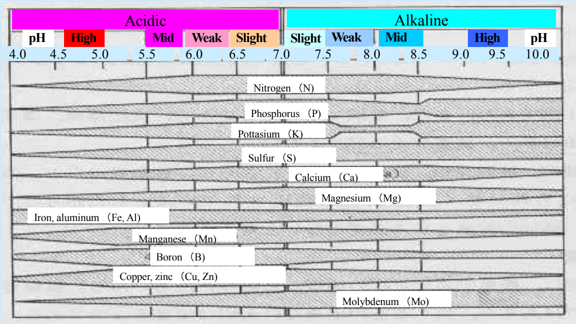
Tanaka and Hayakawa (1974)

Al toxicity in hydroponic culture



Yamane (1971)

Soil pH and the availability of nutrients



Soil acidity and the growth of crops (1)

A) Damage by hydrogen ion.

B) Damage by active aluminum.

C) Deficiency in calcium and magnesium

D) Deficiency in phosphate.

Binding of phosphate and aluminum.

Soil acidity and the growth of crops (2)

E) Leaching and deficiency of boron.

Decrease in solubility of molybdenum and its deficiency.

→Legumes frequently suffer from molybdenum deficiency.

F) Excess in manganese.

As manganese become more soluble in acidic condition.

Soil acidity and the growth of crops (3)

G) Repression of organic matter decomposition.

By ameliorating the soil acidity, mineralization of organic nitrogen and organic phosphorus increase.。

H) Change in microbial flora.

Fungi prefer acidic condition, while bacteria and actinomycete prefer alkaline condition.

Soil acidity and the growth of crops (4)

I) Repression of nitrogen fixation.

Optimum pH 6.5～7.5

J) Repression of nitrification.

By liming, the activity of nitrification increases remarkably.

Improvement of soil acidity (1)

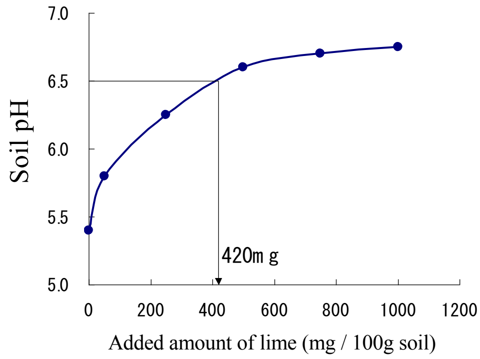
- **Calcium carbonate ($CaCO_3$)**

  Apply 3 times of exchangeable acidity (y_1).

  Buffer curve method.
- **Gypsum ($CaSO_4$)**

  In the sublayer, Al^{3+} is replaced by Ca^{2+}.

  High solubility of gypsum helps the reaction.



Determine the lime requirement by buffer curve method.

Calculation of lime requirement (example)

Goal pH 6.5 → $CaCO_3$ 420 mg / 100g soil

= 4.2g / kg = 4.2 kg / t

Amount of soil in 1 ha, to the depth 15 cm.

= 100m ×100m × 0.15m = 1500 m^3

≒1500 Mg = 1500 t （Bulk density = 1 ）

Lime requirement / 1 ha is

4.2 × 1500 = 6300 kg

Improvement of soil acidity (2)

- Apply phosphates in large amounts, because phosphate is hardly soluble in acidic soil.
- Apply organic matter, to increase the buffer capacity to pH change of the soil.

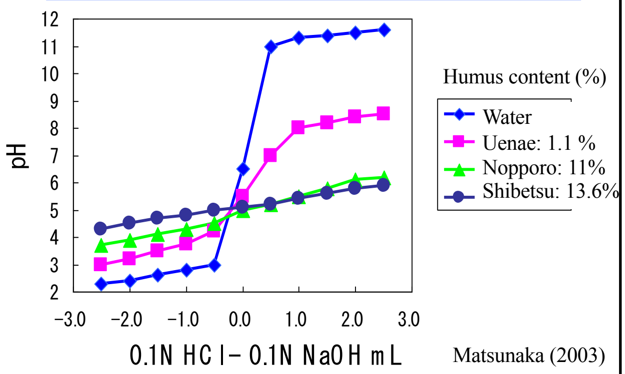
If the soil is made too alkaline,

Nutrient deficiency occurs.

For example,

Phosphate, calcium, magnesium, boron, iron, manganese, and zinc.

Buffer curves in various soils and water



Matsunaka (2003)

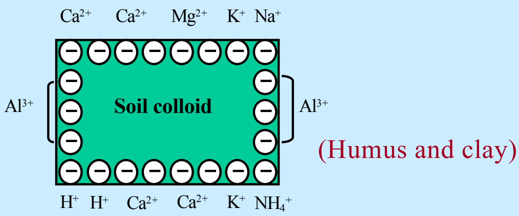
Features of 3 types of soils

soil	classification	feature
Uenae	Immature volcanic fallout soil	Coarse particles
Nopporo	Gray terrace soil	Clay rich
Shibetsu	Humic andosoil	Humus rich

Mechanisms of soil acidification

- **CO_2 in rain water.**
- **Aluminum in acidic soil.**
- **Fertilizer application.**
- **Acid rain.**
- **Acid sulfate soil.**

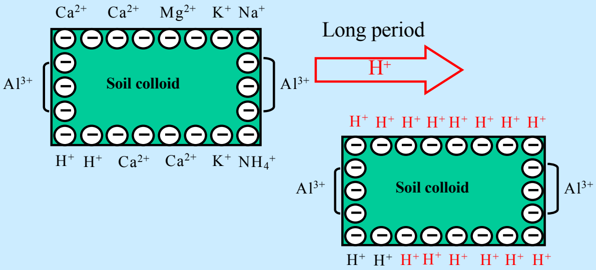
Cation holding by soil colloids



Exchanging power of different cations:
$H^+ > Al^{3+} > Ca^{2+} > Mg^{2+} > K^+ > Na^+$

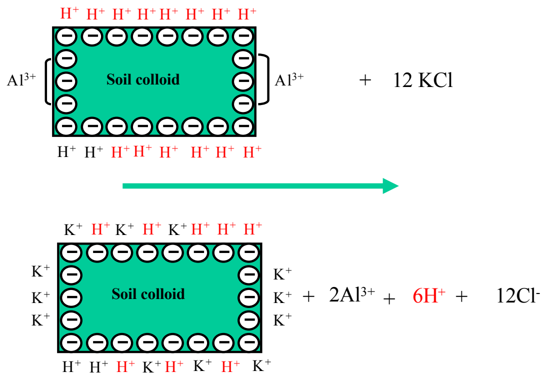
Soil acidification by rain water

$$CO_2 + H_2O \rightarrow H^+ + HCO_3^-$$

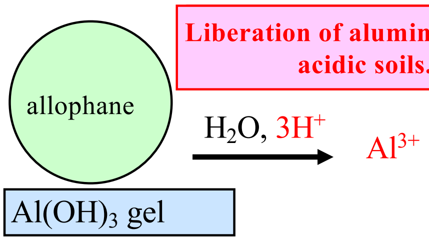


Ca^{2+}, Mg^{2+}, K^+, Na^+ are leached.

Liberation of Al^{3+} and H^+ with KCl.



Liberation of aluminum ion in acidic soils.

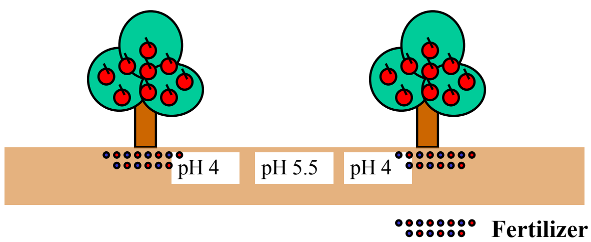


$$Al^{3+} + H_2O = Al(OH)^{2+} + H^+$$

log K = - 4.97 （as strong as acetic acid）

log K of acetic acid = - 4.76 (25°C)

Acidification by fertilizer application



$(NH_4)_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

NH_4^+ is absorbed by crops, and

H^+ is supplied from soil colloids, root exudates, and

Physiologically acidic fertilizers

- Ammonium sulfate $(NH_4)_2SO_4$
- Ammonium cloride NH_4Cl
- Potassium sulfate K_2SO_4
- Potassium cloride KCl

NH_4^+ and K^+ are absorbed, but SO_4^{2-} and Cl^- remain in soil, unabsorbed.

Physiologically neutral fertilizers

- Urea $(NH_2)_2CO$
- Ammonium nitrate NH_4NO_3
- Ammonium phosphate $(NH_4)_2HPO_4$
- **Same for compost.**

All the constituents are absorbed or decomposed.

Acid rain

- $SO_2 + H_2O \rightarrow H_2SO_3$
- $H_2SO_3 + (1/2)\,O_2 \rightarrow 2H^+ + SO_4^{2-}$
- N_2O, NO, NO_2
  $+ m\,H_2O + (n/2)\,O_2 \rightarrow H^+ + NO_3^-$

Acid sulfate soil

- Iron sulfide (pyrite) is accumulated stably under anaerobic condition in the lake and sea sediments.
- When pyrite is oxidized in air after the reclamation, sulfuric acid is formed.
- $FeS_2 + nO_2 + H_2O \rightarrow FeSO_4 + H_2SO_4$
- Frequent problems in reclaimed paddy soils, upland field dressed with soils, and reclaimed wetland soils.

Damage by soil acidity : fixation of phosphate

- $Al^{3+} + PO_4^{3-}$
  $\rightarrow AlPO_4 \sim Al(OH)_2H_2PO_4$
  variscite, (hardly soluble)
- $Fe^{3+} + PO_4^{3-}$
  $\rightarrow FePO_4 \sim Fe(OH)_2H_2PO_4$
  strengite, (hardly soluble)

Exchangeable bases

- Mineral nutrients in the forms of cations in soils.
- Actually, Ca^{2+}, Mg^{2+}, K^+, Na^+
- It is important that they exist in available form for crops in soil.
- Balance between these cations is important.
- K, Mg should be decreased if they are in excess.

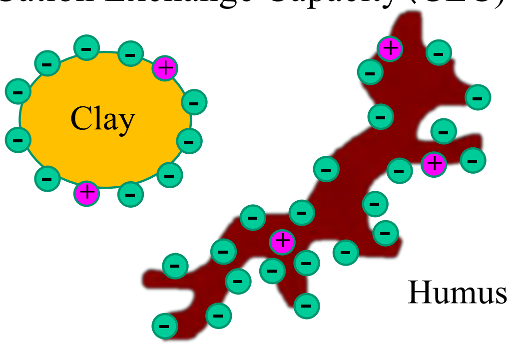
Exchangeable bases
(Ca^{2+}, Mg^{2+}, K^{+}, Na^{+})

- Extracted with1M ammonium acetate from soil.
- Determined by the atomic absorption photometer or flame photometer.
- Essential cations existing in available forms in soil.

Exchangeable bases
(Ca^{2+}, Mg^{2+}, K^{+}, Na^{+})

- By soil acidification, Ca^{2+} and Mg^{2+} decrease.
- K^{+} reflects the applied amount of potassium fertilizers.
- Na^{+} is high in alkaline soil or in salinized soils. However, not so high in Japan.

Cation Exchange Capacity（CEC)



Cation Exchange Capacity（CEC)

- Ability of soils to hold cations electrostatically.
- It is due to the negative charges of clay minerals and humus in soil.
- Soil is first saturated with pH7 1M ammonium sulfate, then ammonium ion is eluted out with 1 M KCl. Eluted ammonium is determined by distillation and titration, or by colorimetry (indophenol method).

Soils with high CEC.

- Soils rich in humus.
- Soils rich in clay.

To increase CEC,

- Apply organic matter (compost) continuously.
- Dress soils rich in clay.

Standard values for CEC

- Used as fundamental data for planning the methods of soil improvement and fertilizer management.
- Immature sand dune soil: 3-10 $cmol_c$/kg
- Gray lowland soil, light colored ando soils: 15-25 $cmol_c$/kg
- Humic ando soils: 20-30 $cmol_c$/kg