Unit 2: Soil acidity and liming

Krishna Poudel

Senior Agriculture Instructor

Department of Plant Science

Shree Triveni Secondary School

Province 1, Nepal

Contact: +9779847016830

Krishna Poudel (researchgate.net)
E-mail: poudelkrishna051@gmail.com

Soil Acidity:

* Soil acidity is **a condition in which the soil pH is lower than a neutral pH (less than 7)**.
* **Soil pH** is a measure of the hydrogen (H+) ion concentration expressed as the negative common logarithm of H+ concentration.

  i.e. Soil pH = -log (H^+)

* When soil becomes too acidic it can: **decrease the availability of essential nutrients**, increase the impact of toxic elements, decrease plant production and water use.
* The main cause of soil acidification is inefficient use of nitrogen, followed by the export of alkalinity in produce. Ammonium based fertilizers are major contributors to soil acidification.

* Soil acidity is common in all regions of moderate to heavy rainfall (e.g. eastern Terai of Nepal) where precipitation is sufficient to leach appreciable amt. of exchangeable non-acid cations) like Na^+, K^+, Mg^{2+}, Ca^{2+}.
* As basic cations are removed, soil tends to become acidic in reaction.
* Predominant acid causing cations are H^+, Al^{3+} .

Causes of soil acidity

1. Characteristics of parent materials

- Soils formed from the rocks having acidic ions are acidic eg Granite/Quartz
- Soils formed from rocks having basic ions are basic eg. Basalt
- Clay minerals such as Kaolinite, montmorillonite, Fe and Al are acidic in nature

2. Accumulation of OM & their decomposition

- OM contains numerous acid functional groups from which H^+ ions can dissociate.
- During decomposition, many (in)organic acids are released.
- Slow & persistent action of weak inorganic acids especially of carbonic acid on mineral constituent of soil is responsible for the removal of base forming cations like Ca^{2+}, Mg^{2+}, etc. by dissolution & leaching.

3. High rainfall & low evaporation

- Basic cations are more soluble than acidic cations
- Under high precipitation, basic cations (Ca^{2+}, Mg^{2+}, K^{+} , Na^{+}) leach out but the acid cations such as Al^{3+} & H^{+} tends to retain in the soil surface.
- So surface soil becomes acidic & consequently the sub - surface soil is basic.

4. Acid rain

- Rain with pH value <5 is termed an acid rain.
- The acid rain has pH of about 4-4.5 but sometime as low as 2.
- When raindrops falls through unpolluted air, water reacts with CO2 & forms weak acids H_2CO_3 which dissociates & release H^+
- In polluted air with N & S gases coming from industrial combustion, forest fires, volcanic eruptions, N & S reacts with water forming HNO_3 & H_2SO_4 .
- These strong acids dissociates in soil and release H^+, N_2, N_2O, H_2O HNO_3

$$SO_2 + \tfrac{1}{2} O_2 + H_2O \longrightarrow H_2SO_4 \rightleftarrows SO_4^{2-} + 2H$$

$$CO_2 + H_2O \longrightarrow H_2CO_3 \rightleftarrows HCO_3^- + H^+$$

$$N_2, N_2O + H_2O \longrightarrow HNO_3$$

6. Plant residues

- **Root respiration/OM decomposition** by MOs produce **CO_2**.
- **CO_2 & H_2O reacts** to form **H_2CO_3**; H^+ dissociates
- Because H_2CO_3 is a **weak acid**, its contribution to H^+ ions is **negligible** when the pH **is much below 5.0.**
- This **decomposition of OM is very common in forest soils**.

$$CO_2 + H_2O \longrightarrow H_2CO_3 \rightleftarrows HCO_3^- + H^+.$$

7. Oxidation of nitrogen (nitrification) & sulfur

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + \mathbf{2H^+} + H_2O$$

- Firstly, breakdown of plant residues also involves **oxidation of organic-SH groups** to yield H_2SO_4.
- Secondly, reduced sulfur (such as FeS4) also release **H+**

8. Plant uptake of basic cations

- Plants uptake more of certain cations (e.g. K^+, NH^{4+} & Ca^{2+}).
- For every +ve charge taken in on a cation, a root maintain charge balance either by taking up anion or by exuding cations.
- When they take up far more of cations (Ca, Mg, NH_4, K) than they do of anions (SO_4^{2-}, NO_3^-) (for eg Legumes), plant usually exude H^+ ions into the soil sol to maintain charge balance & contribute to acidification.
- When plant root maintain charge balance by up taking the same quantity of opposite charged ions, it does not change soil P.

9. H^+ ions (Root exudates)

- Some H^+ ions excreted by plants are exchanged for nutritive cations such as Ca^{2+}, process known as contact cation exchange.

10. Crop removal of basic cations

- Some dicot plants such as legumes absorb basic cations thus indirectly causing soil to be acidic.
- Eg. Yield of 13 ton/ha alfa-alfa removes 45 kg Ca and 9 kg Mg

Liming material and their uses

* Liming materials are found in 3 major forms :

i. Oxide form: eg. CaO (unslaked, burned, quick lime)

ii. Carbonate form: eg.Calcite ($CaCO_3$), dolomite $CaMg(CO3)_2$

iii. Hydroxide form: eg. $Ca(OH)_2$ (slaked, hydrated lime)

Oxide form: eg. CaO

* Commercial oxide of lime is normally referred to as unslaked (no water molecule) lime, or burned lime or quick lime.
* It is the white powder & more expensive than other limes.
* It is produced by heating calcite (CaCO3) or dolomite in oven or furnace, in which the following reaction takes place :

$$\underset{\text{(Calcite)}}{CaCO_3} + \text{heat} \longrightarrow CaO + CO_2\uparrow$$

$$\underset{\text{(Dolomite)}}{Ca.Mg(CO_3)_2} + \text{heat} \longrightarrow CaO + MgO + 2CO_2\uparrow$$

* It has caustic properties; reacts much rapidly with soil.
* Thorough/well mixing with soil is necessary otherwise there will be caking problem (difficult to handle).
* It is much more effective among all liming materials, NV is 178% as compare to pure $CaCO_3$

ii. Carbonate forms eg Calcite & dolomite

- The 2 important minerals included in **limestone** are **Calcite ($CaCO_3$)** & **Dolomite ($Ca.Mg.(CO_3)_2$)**;.
- When there is little or no-dolomite, it is referred to as **calcite**. As the Mg increases, it is referred to as **dolomitic limestone.**
- Dolomite has **NV 75 to 99%** while the representative crushed limestone is about **94%.**

Ii. Hydroxide form

- Hydroxide form of lime is commonly referred as **hydrated lime** or **slaked lime**, since adding water to burned lime produces it.

$$CaO + MgO + 2H_2O \longrightarrow Ca(OH)_2 + Mg(OH)_2$$

- $Ca(OH)_2$ has **NV 135%.**

Describe how liming materials increase soil pH

- Limestone contain $CaCO_3$ & $MgCO_3$
- The limestone **dissolves in water** to form **carbonic acid &** calcium hydroxide: $CaCO_3 + H_2O \leftrightarrow H_2CO_3 + Ca(OH)_2$
- Carbonic acid is u**nstable** and converts to carbon dioxide (CO2) and water; the CO_2 gas escapes: $H_2CO_3 \leftrightarrow CO_2 + H_2O$
- Calcium hydroxide dissociates: $Ca(OH)_2 \leftrightarrow Ca^{2+} + 2OH^-$
- The Ca^{2+} replaces $2H^+$ from the soil, increasing the soil BS
- The **hydroxide anion (OH^-)** reacts with the soil **acid cation (H^+)**, forming water: $OH^- + H^+ \leftrightarrow \mathbf{H_2O}$

Factors affecting the liming

1. Amount:

- Crops differ in sensitivity to soil and added lime in soil.
- Amount of lime to be applied depends on inherent properties of soil i.e. texture, clay type and OM content.
- In a coarse textured with low OM soil, the lime requirement will be less than for a fine textured, high OM soils.

2. Timing:

- Liming reacts slowly with soil acidity.
- Lime may not have adequate time to react with soil if applied just before seeding.
- Due to its gradual effect, lime should be spread about 6-12 Months ahead of crop that has the highest pH and Ca requirement.
- For rotations that include leguminous crops, lime should be applied 3-6 months before the seeding time.

3. Frequency:

* The lime requirement depends on soil texture, N source and rate, crop removal, precipitation patterns and lime rate.

* On sandy soils, frequent light applications are preferable whereas on fine textured soils, large amounts may e applied less frequently.

* For humid regions, where the forces of acidification proceed excessively, application to arable soils is not done once but must be repeated every 3-5 years.

Soil salinity

- The condition of soil where there will be the higher concentration of dissolved/soluble salts(ions) that is sufficient to interfere the growth of most plants is known as soil salinity.

- Salts present are typically dominated by carbonate (HCO_3^-/CO_3^-), sulfate (SO_4^{2-}) & chloride (Cl^-) of Ca, Mg, Na, K

- In general, NaCl is the most abundant.

- The salinity is measure primarily by measuring the Total Dissolved Solids (TDS) and Electrical Conductivity (EC).

THANK YOU