

MODULE 1

- **Soil minerals provide the framework of the soil and give physical support for plants.**

Mineral – a naturally occurring homogeneous solid with definite (but not usually fixed) chemical composition & highly ordered atomic arrangement. Create water and air-filled pore spaces, provide physical support for plants, and mineral weathering releases plant nutrients.

Usually derived from igneous or metamorphic rocks. Major soil mineral classes; Halides, Sulfates, and Carbonates. Sulfides. Oxides, Hydroxides, and Oxyhydroxides. Silicates.

- **The minerals are critically important in determining the properties of the soil and the interaction with the soil solution.**

- **Exchange and surface adsorption**
- **Solid phase minerals and precipitates**
- **Organic matter reactions**

- **Soil solids exhibit both permanent structural and pH-dependent charge.**

- **CEC from ca. Zero (e.g. kaolinite) to >150 cmol_c/kg (e.g. vermiculites)**

Two main charge development mechanisms; Isomorphous substitution (Permanent, structural charge, specific to phyllosilicate minerals) and Ionization of edge functional groups (pH-dependent charge)

Phyllosilicate minerals are the main source of permanent charge in soils. Charge arises from isomorphous substitution within mineral structure. Net negative charge. Interact with cations. Development of pH-dependent charge, Ionization of functional groups. Mineral surfaces and organic matter. Organic surfaces, wide range of functional groups, dissociation across wide pH range, responsible for much of CEC in highly weathered soils.

- **Charge results in ion exchange capacity.**

- **Magnitude of pH-dependent charge on phyllosilicate edges is generally low & of limited importance to cation exchange**

Interchange between an ion in solution and another ion of like charge on the solid surface. CEC = quantity of cations a solid material can reversibly adsorb. High CEC = greater ability to store plant nutrients. Due to development of surface charge on :minerals, and organic matter. Characteristics of ion exchange; reversible, instantaneous (controlled by diffusion), stoichiometric, and selective (preference).

CEC composition; selectivity effects dictate distribution between exchange and solution. The weakly held cations are more readily leached from the system, and all exchangeable cations are plant available. The percentage of the CEC satisfied by the various cations is reliant upon many factors including; parent material, depth in profile, weathering, and acidity.

- **Ability of solid phase to reversibly sorb ions from solution is important to nutrient dynamic in soils.**

- **The composition of the soils exchange sites influences soil structure**

Problems caused by too much sodium (Na); Flocculation (clay particles are attracted to each other and form micro-aggregates, and Dispersion (breakdown of microaggregates into individual soil particles)

The thickness of this diffuse layer; the valency of the cations (if the negative charge is balanced by Ca^{2+} , only half as many ions will be required than if the charge was balanced by Na^+), and the concentration of the cations (i.e. ionic strength) (if the ionic strength is high, the cations will be able to 'pack' into the diffuse layer tighter than if there is a low ionic strength).

Surface charge is balanced by; cation excess, and anion deficit.

- **Stability of soils decreases (i.e. increasing repulsion between clay platelets) due to increasing width of DDL:**

- **Increases in monovalent cations**
- **Decreases in ionic strength**

Repulsive forces; electrostatic in nature (repulsion between two similar charged particles) and is long ranged. Attractive forces; London-Van der Waals forces (attractive forces between dipoles and induced dipoles). These forces tend to act over relatively short distances.

Reducing repulsion – counter ion valence; exchangeable sodium percentage (we express Na : divalent cations on the exchange as ESP) and Sodium adsorption ration (we can predict the ESP on the basis of the water's SAR). ESP/SAR relationships vary depending on soil mineralogy. Tendency of soil to disperse with increasing ESP also varies. You need to evaluate the soil that will receive AW, then use.

- **Thus, soil chemistry dictates this component of soil physics.**

MODULE 2

- **Most organic matter originates from plant tissues.**

Soil organic matter is the term used to refer more specifically to the **non-living components** which are heterogeneous mixture composed largely of products resulting from microbial and chemical transformations of organic debris. Higher plants are the greatest contributors to humus formation; structural carbohydrates (cellulose, hemicellulose), non-structural carbohydrates (simple sugars, fructosans), lignin, proteins, tanins, resins, waxes, and pigments.

- **Concentrations of organic matter in soils depend upon both the rate of input (productivity) and the rate of loss (degradation)**
Levels of OM depend upon many factors; parent material (e.g. soil texture), climate (plant growth, rate of degradation), water (waterlogging, drought), soil management practices (inputs, tillage), and harvest and removal of biomass. Five compartments for soil organic matter (half-life); decomposable plant material (0.165), biomass (1.69), resistant plant material (2.31), physically stabilized organic matter (49.5), and chemically stable form of organic matter (1980).
- **Traditional agricultural practices result in substantial decreases in soil organic matter (up to 50-70%)**
- **It is straightforward to measure total OM concentrations, but much of the OM is structurally complex which hinders our ability to understand it and how it functions.**
- **Organic matter is the largest pool of nutrients, and is particularly important for N, P, and S.**
Nutrients not directly available for plant uptake (must be converted to mineral forms). Particularly important as a pool of anionic nutrients (not held on soil's CEC). Pools of SOM; Plant material (high C/N ratio, rapid turnover, and light fraction), Humus (low C/N ratio, slow turnover, and heavy fraction), and Microbial Biomass (small pool, but important, and measurement by fumigation/incubation).
- **Organic matter is in dynamic equilibrium, and human activities can either increase or decrease levels markedly.**
- **The nutrients are not immediately available but must first be mineralised [a balance between energy (C) and nutrient levels (N, P, S)].**
- **Mineralisation/Immobilisation is a microbial-driven process, with factors influencing microbial activity also influencing the breakdown of organic matter and the mineralisation/immobilisation of nutrients.**
Organic matter breakdown may increase the mineral N pool (**mineralization**) or decrease the mineral N pool (**immobilization**). Both processes occur together. Using nitrogen as an example; if $M > I$ there is net mineralization (N increases), if $I > M$ there is net immobilization (N decreases). Dominance of M or I determined by energy (C) and N supply (C/N ratio). Critical values; $C/N = 15-30$ and $N (\%) = 1.2-2.5$. If the decomposing OM contains more N than the micro-organisms required for cell growth, excess N is excreted as NH_4^+ as net **mineralization**: $N > 2.5\%$ and $C/N < 15:1$. If the decomposing OM contains less N than the micro-organisms required for cell growth, NH_4^+ is removed from the soil solution, i.e. net immobilization: $N < 1.2\%$ and $C/N > 30:1$.

M/I rate is influenced by; temperature (40-60 optimum), pH (limiting acidic soils), drying (wetting/drying increases M), water, aeration, soil texture, and presence of plants.

Mineralization is a biological process, therefore conditions which influence microbe growth will influence rate.

- Here, we have focussed on N as an example, but organic matter is an important reservoir of P and S also.

- Soil pH is the **Major Variable** in soils – influences a wide range of other soil properties, including; nutrient availability, biological activity, and toxicant availability.

pH is the negative log of the H⁺ ion activity: $\text{pH} = -\log_{10}(\text{H}^+)$

pH decreases as the salt concentration increases

- Nutrient availability – influenced through a range of processes, including solubility, adsorption, and soil formation processes.

The ideal pH range to ensure the availability of all nutrients is a narrow band from pH 6.0 to pH 7.5.

- It is easily measured, but care must be taken to obtain useful and comparable values.

Most modern pH electrodes are combination electrodes (glass electrode + reference electrode). Measuring pH is not easy, electrode must be maintained, buffers need to be replaced regularly, and even electrodes in poor conditions calibrate. If pH is measure in suspension. The result obtained varies with, the ratio of soil to water, the solution used to make the suspension, and extent of aeration (CO₂ content).

- Plants can tolerate a range of pH values and can also modify the pH value in their rhizosphere.

So, control of pH within broad limits is not critical. Nutrient availability will differ as a function of pH. Plants differ in their pH preference, this preference reflects their capacity to acquire nutrients, often ability to tolerate high/low pH reflects ability to change rhizosphere pH.

Rhizosphere pH can depend on plant nutrition. Rhizosphere pH – plants need to maintain electro-neutrality (cation and anion uptake must balance). Plants are ≈3% N and ≈3% K. Plants with acid preference, typically have problems acquiring Fe in neutral/alkaline soils, tolerant of Al. Plants with alkali preference, typically have capacity to acidify rhizosphere.

- Solubility relationships play a critical role in determining availability of nutrients and toxicants.

Nutrient uptake occurs via soil solution. The concentration of most ions in the soil solution are governed by the solubility of solid phases. Example of solubility relationships; application of fertilizers and amendments, dissolution of soil minerals and release of nutrients, Al toxicity in acidic soils, precipitation of wastes added to soil, and precipitation within cells.

Al toxicity is only problematic in soils with a pH < ~ 5.0 or 5.5. The addition of lime (CaCO₃) to increase pH alleviates Al toxicity. Rock phosphate (hydroxyapatite) contains approximately 9% P, and if sufficiently soluble would represent a useful fertilizer material. The strong pH dependence of the solubility; the phosphate activity decreasing 2.33 units per unit of pH increase, the rock phosphate minerals will only be useful as P fertilizers on acid soils.