



Soil minerals play a key role in regulating the supply of important plant nutrients

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Editorial

To complete their life cycle, all plants need 17 elements, and an additional four elements have been described as necessary for some plants. Plants derive the remaining 14 elements from the soil or by fertilizers, manures, and amendments, with the exception of C, H, and O, which plants receive from air and water. Soil minerals that exert major direct and indirect influences on the supply and availability of most nutrient elements constitute the bulk of the soil solid fraction. Dissolution-precipitation and adsorption-desorption are among the key processes involved in the release and fixation of nutrient elements in soils. These processes and how they influence macronutrients and micronutrient will be discussed. In most soil types, except for strongly weathered and sandy soils, primary minerals, including K-feldspars (orthoclase, sanidine, and microcline), micas (muscovite, biotite, and phlogopite), and clay-size micas (illite), are widely distributed. These primary minerals serve as a significant reservoir for K, with over 90% of K in the structure of these minerals in soils. Feldspars also contain large quantities of Ca, Na, and Si, and smaller amounts of Cu and Mn. The most significant source of K in many soils is Micas and Illite, and they also contain Mg, Fe, Ca, Na, Si, and a number of micronutrients. Mg, Fe, Ca, Si, and the rest of micronutrients are essential reservoirs of amphiboles and pyroxenes. Carbonate minerals act as both a source and a sink for Ca and Mg in soils, including those derived from soil parent material and those produced in soil through pedogenic processes.

A number of nutrient elements are released into the soil solution through the physical, chemical, and biological weathering of primary minerals. The weathering rates and pathways of primary minerals, including mineral properties and climatic conditions, are highly variable and rely on several factors. In comparison to primary minerals, low-temperature reactions during the weathering of primary minerals in the aqueous setting on the surface of the Earth typically form secondary minerals in soils. Via adsorption-desorption, dissolution-precipitation and oxidation-reduction reactions, secondary minerals primarily regulate nutrients.

In regulating plant nutrient element availability, adsorption reactions

involving minerals are often more important than the release of nutrient elements through mineral weathering. Permanently charged phyllosilicates (e.g. vermiculite and smectite) provide sites of exchange that hold a number of critical nutrients in their cationic form (cation exchange capacity), such as Ca^{2+} , Mg^{2+} , K^{+} , and Na^{+} ; The nutrients are preserved by complex outer-sphere structure and can be readily consumed by plant roots. On the other side, by forming inner-sphere complexes, variable charge minerals retain some nutrients (P, Zn). The nitrate (NO_3^-) and ammonium (NH_4^+) sources of soil nitrogen are typically taken up by plants. N added by fertilizer and mineralized N from organic matter in soils often ends up in the form of NO_3^- .

The leaching of applied N in the form of NO_3^- ions is a common water quality problem, especially in agricultural regions, due to the limited anion exchange ability of most soils. It is also a major economic inefficiency, as farmers use disproportionate quantities of fertilizer to offset leaching. The exception is heavily weathered soils like oxisols and ultisols. Soils in temperate regions usually have permanent charge minerals (e.g., smectite and vermiculite) with high cation exchange potential and the ability to maintain ammonium (NH_4^+) ions as opposed to highly weathered oxisols and ultisols with variable charge minerals. Indeed, a significant proportion of $\text{NH}_4\text{-N}$ is retained in 2:1 phyllosilicate interlayers and cannot be easily exchanged.

The NH_4 -fixation mechanism is identical to that of K-fixation, shown in Figure 3. The fixation of NH_4^+ ions in soils includes vermiculite, illite, and interstratified minerals with 2:1 layers. The amount of fixed NH_4^+ in the soil varies from 350-3,800 kg $\text{NH}_4\text{-N ha}^{-1}$ in the top 30 cm of soil, with the exception of sandy soils; generally, vermiculite and partly weathered illite have a greater potential in soils to stabilize NH_4^+ than the mineral smectite group (Nieder et al. 2011; Nörmik & Vahtras 1982; Stevenson & Cole 1999). In fixing NH_4^+ ions, the distinct activity and ability of 2:1 phyllosilicates is related to the magnitude and origin of negative charge in these minerals. P is mainly taken up from the soil solution by plants in the form of phosphate ions (HPO_4^{2-} and HPO_4^-). The P concentration in soil water is usually very poor (< 0.01% of total soil P), with organic P being the majority of soil P, Al, Fe and Ca insoluble P compounds, and phosphate adsorbed to Fe and Al oxides and phyllosilicates.

In most soils, phosphate ions from dissolved chemical fertilisers react quickly, resulting in P fixation in the soil. Both adsorption and precipitation processes are involved in these soil reactions. Among the micronutrients, plants in their cationic forms take up Fe, Mn, Cu, Zn, and Ni, while plants in their anionic forms take up B, Mo, and Cl. In most soils, Fe and Mn are always present in large amounts, and adsorption reactions play little role in regulating the availability of plants in the soil. The soil solution mainly regulates oxidation and precipitation reactions.

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