Haim Time

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CATION-EXCHANGE CAPACITY

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The origin of cation exchange in soils derives from the activities of the soil microbe community and the sustained decomposition and recycling of the soil organic matter. In this process, organically linked elements are released in their inorganic form, a transformation called mineralization. Among the numerous positive electrostatically charged elements released in this way are calcium Ca^{2+}, magnesium Mg^{2+}, sodium Na^{1+}, and potassium K^{1+}, which are referred to as the base cations. Since humus and clays are rich in negative surface anionic electrostatic charges, they attract and retain the positive solution ions. Herein lies the significance of the cation exchange capacity (CEC), becoming a measure of nutrient retention. Molecules not favored by nature with a positive charge, such as nitrate NO_3^{1-}, are swept out with ground water movement and lost to plant availability.

Formally defined, cation-exchange capacity (CEC) is the total number of cations a soil can hold at a given pH– or its total negative charge. The higher the CEC, the higher the negative charge and thus the greater the soil fertility (more cations that can be held). Organic materials in soil increase CEC through an increase in available negative charges, although they are sensitive to soil acidity, which can cause the release of ions to the soil solution.

Base saturation, the fraction of exchangeable base cations expressed as a percentage, is related to CEC. Higher amounts of exchangeable base cations allow the soil to neutralize acidity more quickly, and as a result, create a soil that can resist acidification longer. Conversely, CEC is also dependent on soil pH. This is mainly due to the lyotropic series, which describes the relative strength of various cations' absorption: $Al^{3+} > H^{1+} > Ca^{2+} > Mg^{2+} > K^{1+} = NH_4 > Na^{1+}$. As soil acidity increases, the pH decreases, more H+ ions are attached to the soil colloids while pushing other cations from them back into the soil solution and the CEC decreases. Inversely, when soils become more basic, the pH rises, available cations in solution decrease because there are fewer H+ ions to push cations into the soil solution and the CEC increases.

The CEC of a soil is determined by laboratory analysis and in most soil reports is expressed as milliequivalents (meq) of charge (number of charges) per 100 grams of soil. Common soil nutrients can be expressed in pounds per acre of available nutrient (equivalent to 1 meq/100 g): Calcium 400 lb./acre, Magnesium, 240 lb./acre, Potassium, 780 lb./acre and Ammonium 360 lb./acre.

Similar to the CEC, Anion Exchange Capacity (AEC) is a measure of the positive charges in soils affecting the number of negative charges that a soil can absorb. The few important anions in agriculture according to the anionic lyotropic series are phosphate PO_4^{3-}>sulfate SO_4^{2-}>Cl^->NO_3^-. As opposed to CEC, AEC will generally increase when pH falls and decrease when pH rises.

In summary, the higher the CEC, the higher the soil fertility, nutrient retention capacity, pH stability and groundwater protection from cation contamination.

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