LECTURE 2 **Soil pH and Buffer pH**

Soil pH This is a measure of the soil acidity or alkalinity and is sometimes called the soil "water" pH. This is because it is a measure of the pH of the soil solution, which is considered the active pH that affects plant growth. Soil pH is the foundation of essentially all soil chemistry and nutrient reaction and should be the first consideration when evaluating a soil test. The total range of the pH scale is from 0 to 14. Values below the mid-point (pH 7.0) are acidic and those above pH 7.0 are alkaline. A soil pH of 7.0 is considered to be neutral. Most plants perform best in a soil that is slightly acid to neutral (pH 6.0 to 7.0). Some plants like blueberries require the soil to be more acid (pH 4.5 to 5.5), and others, like alfalfa will tolerate a slightly alkaline soil (pH 7.0-7.5).

The soil pH scale is logarithmic, meaning that each whole number is a factor of 10 larger or smaller than the ones next to it. For example if a soil has a pH of 6.5 and this pH is lowered to pH 5.5, the acid content of that soil is increased 10-fold. If the pH is lowered further to pH 4.5, the acid content becomes 100 times greater than at pH 6.5. The logarithmic nature of the pH scale means that small changes in a soil pH can have large effects on nutrient availability and plant growth.

Buffer pH (BpH) This is a value that is generated in the laboratory, it is not an existing feature of the soil. Laboratories perform this test in order to develop lime recommendations, and it actually has no other practical value.

In basic terms, the BpH is the resulting sample pH after the laboratory has added a liming material. In this test, the laboratory adds a chemical mixture called a buffering solution. This solution functions like extremely fast-acting lime. Each soil sample receives the same amount of buffering solution; therefore the resulting pH is different for each sample. To determine a lime recommendation, the laboratory looks at the difference between the original soil pH and the ending pH after the buffering solution has reacted with the soil. If the difference between the two pH measurements is large, it means that the soil pH is easily changed, and a low rate of lime will suffice. If the soil pH changes only a little after the buffering solution has reacted, it means that the soil pH is difficult to change and a larger lime addition is needed to reach the desired pH for the crop.

The reasons that a soil may require differing amounts of lime to change the soil pH relates to the soil CEC and the "reserve" acidity that is contained by the soil. Soil acidity is controlled by the amount of hydrogen (H^+) and aluminum (Al^{+++}) that is either contained in, or generated by the soil and soil components. Soils with a high CEC have a greater capacity to contain or generate these sources of acidity. Therefore, at a given soil pH, a soil with a higher CEC (thus a lower buffer pH) will normally require more lime to reach a given target pH than a soil with a lower CEC.

Soil Colloids

During physical and chemical weathering processes in which rocks, minerals, and organic matter decompose to form soil, some extremely small particles are formed. Colloidal-sized particles are so minuscule that they do not settle out when in suspension. These particles generally possess a negative charge, which allows them to attract positively charged ions known as cations. Much like a magnet, in which opposite poles attract one another, soil colloids attract and retain many plant nutrients in an exchangeable form. This ability, known as cation exchange capacity, enables a soil to attract and retain positively charged nutrients (cations) such as potassium (K+), ammonium (NH4+), hydrogen (H+), calcium (Ca++), and magnesium (Mg++). Also, because similar charges repel one another, some of the soluble negatively charged ions (anions), such as nitrate (NO3-) and sulfate (SO4=), are not bonded to soil colloids and are more easily leached than their positively charged counterparts.

Organic colloids contribute a relatively large number of negative charges per unit weight compared with the various types of clay colloids. The magnitude of the soil's electrical charge contributed by colloids is an important component of a soil's ability to retain cationic nutrients in a form available to plants.

Cation Exchange Capacity

The ability of a soil to retain cations (positively charged ions) in a form that is available to plants is known as cation exchange capacity (CEC). A soil's CEC depends on the amount and kind(s) of colloid(s) present. Although type of clay is important, in general, the more clay or organic matter present, the higher the CEC.

The CEC of a soil might be compared to the size of a fuel tank on a gasoline engine. The larger the fuel tank, the longer the engine can operate and the more work it can do before a refill is necessary. For soils, the larger the CEC, the more nutrients the soil can supply. Although CEC is only one component of soil fertility, all other factors being equal, the higher the CEC, the higher the potential yield of that soil before nutrients must be replenished with fertilizers or manures.

When a soil is tested for CEC, the results are expressed in milliequivalents per 100 grams (meq/100 g) of air-dried soil. For practical purposes, the relative numerical size of the CEC is more important than trying to understand the technical meaning of the units. In general, soils in the southern United States, where physical and chemical weathering have been more intense, have lower CEC's (1-3 meq/100 g) than soils in the northern United States, where higher CEC's are common (15-25 meq/100 g) because weathering has not been as intense. Soils in warmer climates also tend to have lower organic matter levels, and thus lower CEC's than their northern counterparts.

Soils high in clay content, and especially those high in organic matter, tend to have higher CEC's than those low in clay and organic matter. The CEC of soils in Maryland generally ranges from 1-2 meq/100 g for coarse-textured Coastal Plain soils to as high as 12-15 meq/100 g for certain Piedmont and Mountain soils. The CEC of most medium-textured soils of the Piedmont region ranges about 8-12 meq/100 g.

There are many practical differences between soils having widely different CEC's. It has already been mentioned that the inherent fertility (exchangeable nutrient content) of soils varies in direct relationship to the magnitude of the CEC. Another important CEC-related property is soil buffering capacity, that is, the resistance of a soil to changes in pH. The higher the CEC, the more resistance soil has to changes in pH. The CEC and buffering capacity are directly related to the amount of liming material required to produce a desired change in pH. Higher CEC soils require more lime than those with low CEC's to achieve the same pH change.

If CEC is analogous to the fuel tank on an engine, soil pH is analogous to the fuel gauge. The gauges on both a large and a small tank might read three fourths full; but, obviously, the larger tank will contain more fuel than the smaller tank. If a soil test indicates that two soils, one with a low CEC and the other with a high CEC, have the same low pH, indicating that they both need lime, the one with the higher CEC will require more liming material to bring about the desired pH change than will the one with the lower CEC. The reason for this difference is that there will be more exchangeable acidity (hydrogen and aluminum) to neutralize in the high CEC soil than in the lower CEC soil. Thus, a soil high in clay or organic matter will require more liming material to reduce soil acidity (and raise the pH) than a low organic matter sandy soil will.