CLEMSON EXTENSION

SOIL TESTING

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Cation Exchange Capacity and Percent Base Saturation

Among all the information that appears on soil test reports, the cation exchange capacity (CEC) and percent base saturation are the least understood.

Cation Exchange Capacity

Any element with a positive charge is called a cation and, for agricultural purposes, it refers to the basic cations, calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^{+1}) and sodium (Na^{+1}) and the acidic cations, hydrogen (H^{+1}) and aluminum (Al^{+3}). The CEC refers to the total amount of these positively charged elements that a soil can hold. The cations are held on "exchange sites" where one cation can be exchanged for the same type or a different cation. The CEC is expressed in milliequivalents per 100 grams (meq/100g) of soil. The larger this number, the more cations the soil can hold. A clay soil will have a larger CEC than a sandy soil. In the Southeast, where we have highly weathered soils, the dominant clay type is kaolinite, which has very little capacity to hold cations compared to other clays. A typical CEC for a soil in the coastal plains region is about 2.0 meq/100g of soil, and the typical CEC for a soil in the piedmont is about 5.0 meq/100g of soil. The CEC gives an indication of the soil's potential to hold plant nutrients. Increasing the organic matter content of any soil will help to increase the CEC since it also holds cations like the clays. Organic matter has a high CEC, but there is typically small amounts of organic matter in our soils.

Table 1. Sample Soil Test Report Data

CEC (meq/100g)	ACIDITY (meq/100g)	% BASE SATURATION				
		Ca	Mg	K	Na	TOTAL
5.0	1.0	50	20	5	5	80

Percent Base Saturation

Percent base saturation tells what percent of the exchange sites are occupied by the basic cations. If calcium has a base saturation value of 50% and magnesium has a base saturation value of 20% as shown above, then calcium occupies half of the total exchange sites (CEC) and magnesium occupies one-fifth of the total exchange sites (CEC). In this example, where the soil has a CEC of 5 meq/100g, 2.5 meq/100g of the CEC is occupied by calcium and 1 meq/100g of the CEC is occupied by magnesium. If all the exchangeable bases (Ca, Mg, K and Na) total 100%, then there is no exchangeable acidity.

Acidity

The acidity on the soil test report is the amount of the total CEC occupied by the acidic cations (H^{+1} and Al^{+3}). The acidity, like the CEC, is expressed as meq/100g of soil. If the CEC is 5 meq/100g of soil and the acidity is 1 meq/100g of soil (see sample soil test report data in Table 1), then one-fifth of the exchange sites in the soil are occupied by acidic hydrogen and aluminum ions. The remaining 4 meq/100g of soil (or 80% of the CEC) is occupied by the basic cations. The more acidic a soil is and the lower the soil pH value, the closer the acidity number will be to the CEC number.

Sodium

Sodium is included among the bases to indicate whether sodium levels are getting too high. This happens in situations where industrial by-products are applied to the soil or where soils along the coastal region are irrigated with water high in sodium. The acceptable base saturation limit for sodium is 15%.

This is also called the Exchangeable Sodium Percent (ESP). Sodium levels higher than 15% on the exchange site could result in soil dispersion, poor water infiltration, and possible sodium toxicity to plants.

How to Use This Information

So, why bother with the CEC, acidity, and base saturation? Some consultants and farmers prefer to use the base saturation of the plant nutrients instead of the extractable amounts as a guide for maintaining optimum fertility. For Southeastern soils with kaolinitic clays, a base saturation of 45 to 65 percent will be satisfactory for good plant growth. Table 2 gives the approximate base saturation for the soils of a given soil pH:

Table 2. Approximate base saturation for soils.

Soil pH	% Base Saturation
3.9	0
4.5	0
5.3	25
6.2	50
7.1	75
7.5	90
8.0	100

In South Carolina, if fertilizer and lime is applied to raise the base saturation of a kaolinitic soil to 85 percent as commonly done in the Midwest, the resulting pH would be between 7.1 and 7.5. Soil pH values in that range would result in major problems with zinc and manganese deficiency. That is why the Clemson University fertilizer recommendations are determined by the amount of each nutrient extracted from the soil (expressed in pounds per acre) instead of using the percent base saturation as a guide. A favorable base saturation will be obtained if the soil pH is maintained between 5.8 and 6.5. The approach used by Clemson University is also used throughout the Southeast and Mid-Atlantic regions in determining soil fertilizer requirements. The CEC and base saturation is something that many farmers and consultants have asked for to better understand the soil, and so it is now available in response to public demand.

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