Soil Cation Exchange Capacity (CEC)

AGRONOMY

The CEC of soil directly affects the amount of fertilizer and the frequency with which fertilizer should be applied. Based on soil type, the percentage of organic matter in the soil, and the relative strength of positively and negatively charged nutrients in the soil, one can devise a sound soil treatment plan that accomplishes the most with the least.

The Soil is Like a Magnet

Imagine that your soil is a giant magnet for soil nutrients. Clay and organic matter in the soil have a negative charge. So naturally it attracts positively charged nutrients and repels negatively charged nutrients. This explains why cations, the positively charged nutrients, find an easy home in the soil while anions, negatively charged nutrients, are repelled and easily leached out of the soil.

Cations & Anions

Cations include everything from hydrogen, with a +1 positive charge, to aluminum, with a +3 positive charge. Anions include phosphate, nitrate, and other essential elements that hold a -1 or -2 charge. Table 1 shows the most common cations and anions along with their chemical formula and charge.

Table 1. Cation and Anions in the Soil

Cations	Formula	Anions	Formula
Hydrogen (acid)	H+	**Phosphate**	H_2PO_4-
Ammonium	NH_4+	**Nitrate**	NO_3-
Sodium	Na+	**Chloride**	Cl-
Potassium	K+	**Sulfate**	SO_4--
Calcium	Ca+ +	**Boron**	H_3BO_3-
Magnesium	Mg+ +	**Bicarbonate**	HCO_3-
Copper	Cu+ +		
Iron	Fe+ + +		
Aluminum	Al+ + +		

Competition among Cations

Just because a cation has a positive charge doesn't mean it can't be leached out of the soil. More strongly charged cations can be used to knock out others. For example, aluminum has three positive charges and would very easily displace sodium. This explains why gypsum ($CaSO_4$) is so effective in correcting a sodium rich soil. The sodium (one positive charge) is pushed out by the calcium (two positive charges).

Table 2. Typical Cation Exchange Capacities of Soils and Soil Components

The CEC of soil is expressed as charges per 100 grams of soil (meq/100g).

Material	CEC (meg/100g)
Clay Types	
Kaolinite	3-15
Illite	15-40
Montmorillonite	80-100
Organic Matter	200-400
Soil texture	
Sand	1-5
Fine Sandy loam	5-10
Loam	5-15
Clay Loam	15-30
Clay	>30

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Effect of pH on Soil CEC

In addition to clay and organic matter, pH also has an effect on CEC. And, of these three factors, usually only pH can be changed. Soil pH changes the CEC because the soil has exchange sites that become active as the pH increases. Soil CEC could be expected to increase up to 50 percent if the pH was changed from 4.0 to 6.5 and nearly double if the pH increased from 4.0 to 8.0.

Estimating CEC

Soil texture can be used to estimate CEC. A general rule of thumb is that organic matter % x 2 plus clay % x 0.5 equals CEC. For example, a soil with a three percent organic matter and 20% clay would be expected to have a CEC of 16 (3% OM x 2 + 20% Clay x 0.5).

Asking Your Laboratory for an Estimate of CEC

You can ask your soil testing laboratory to estimate CEC. But there are some factors you should consider when reading their report. Soil testing laboratories tend to overestimate CEC if the soil contains free limestone, gypsum, or excess salts.

Short of an actual test for CEC (which can prove expensive), laboratories will estimate CEC by measuring the amount of H, Ca, Mg, K, and Na in the soil. These estimates, however, assume that all of these cations are attached to the exchange sites. When alkaline or salty soils are tested, extra Ca and Na are measured that is not attached to the exchange sites. This causes an overestimation of CEC for alkaline soils--anywhere from five to eight meq/100g all the way up to 15 meq/100g for severely salt affected soils.

On neutral and acid soils, however, you can receive a very good estimation using the above methodology.

Using CEC to Plan Fertilization

As we mentioned above, the CEC of your soil can be used to plan how much fertilizer to use and how often to apply it. Soils with very low CECs, such as sands, require small quantities of fertilizer on a frequent basis. Excess fertilizer cannot be held by the soil because of the small CEC. Therefore, you should be careful not to over apply and aim to frequently replenish what your crop uses.

On the other hand, heavy textured soil can go for longer periods of time without fertilizer because of the larger reserves stored on the soil CEC. When heavy textured soils are deficient, however, it takes considerable more fertilizer to correct the deficiency. That's why recommendations are always higher for soils with high CEC.

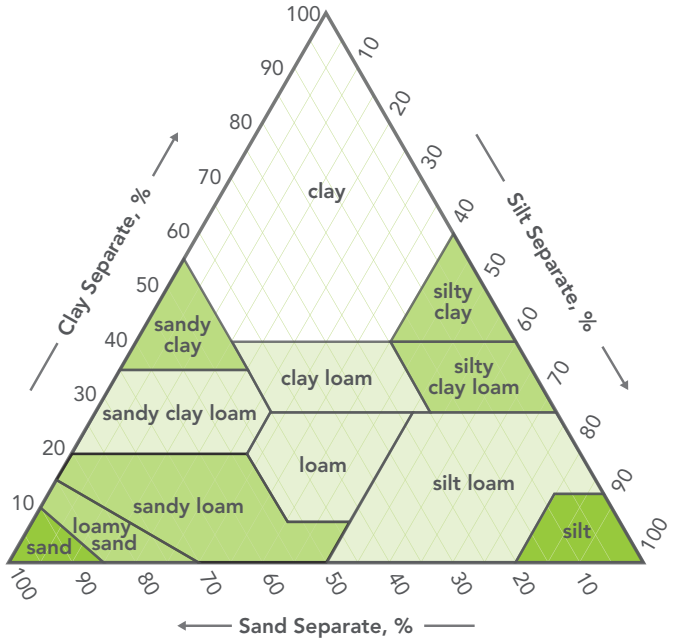
Summary

Your soil works like a giant magnet, attracting cations and repelling anions – positively and negatively charged nutrients. Knowledge of this process can be used to develop appropriate soil treatment and fertilization plans for your specific type of soil.

You can estimate your soil's CEC using a basic formula based on your soil type and percentage of organic matter. You can also ask your laboratory for an estimate of CEC based on cation readings, but these estimates are more accurate for neutral or acid soils than they are for alkaline soils.

You can increase your soil's CEC by increasing its pH level. Soils with low CEC need more frequent but smaller applications of fertilizer. Soils with high CEC can go for longer periods of time before needing fertilizer but need larger quantities to refill their exchange sites.

Figure 1. Soil Textural Triangle



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