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Laboratory Date: \_\_\_\_\_

# FOR 2505 - Soil Quality Report 2016

**Objectives** of this report:

**Principles** behind methods used to determine soil base cation content and cation exch. capacity:

**Personal Lab Results: (show calculations with units)**

Soil Sample: Site \_\_\_\_\_ Horizon \_\_\_\_\_

Potassium –  $K^+$  (cmol / kg) =

Calcium –  $Ca^{2+}$  (cmol / kg) =

Magnesium –  $Mg^{2+}$  (cmol / kg) =

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Cation Exch. Capacity - CEC (cmol / kg) =

Base Saturation - BS (%) =

Rank the sites according to **total exchangeable bases (eq/ha)** in the rooting zones. Suggest likely reasons for the rankings.

TOTAL BASES  
(eq/ha)

Likely reason(s) for the base content and ranking?

**MOST**

1

2

3

4

5

6

**LEAST**

7

Discuss the site data (compiled data spreadsheet) with respect to base cation contents and base saturation %; site class assessment (TU – treatment unit); soil parent material(s), and coarse fragment content / type. Do the **qualitative** and **quantitative** assessments support each other? Any surprises among the various sites visited?

What would be an “ideal” soil for Yellow Birch? For Eastern White Pine? Would the soil conditions for both be the same? Explain.



Soil bases exist in solution, on the exchange sites, and as part of the soil minerals. In the lab, which of these did you determine, and why is this important?

Ion exchange is an important process in nutrient uptake by tree / plant rooting systems. Explain how the uptake of base cations affects soil pH.

Which soil would have a higher base saturation: a soil derived from basalt, or a soil derived from pink granite?

Soil pH increases or decreases with increasing base saturation? Explain.

Normally, base cation content tends to be higher under deciduous forest cover than coniferous forest. Explain.

If a 75 cm deep soil has a calcium ( $\text{Ca}^{2+}$ ) content of 8.5 meq/100g, then how much calcium is there in kg/ha? Assume that the soil has a bulk density (Db) of 1.08 g/cm<sup>3</sup>.

Draw and label a single, **THREE DIMENSIONAL** (yes...3D!) landscape profile diagram that identifies: 1. the topographical soil landscape positions of the visited field sites; and 2. the total base cation contents **BY SOIL LAYER** (shade layers darker according to increasing content). Cross-hatch soil horizons that are included in the "rooting zone". Indicate soil parent materials, vegetation types (forest cover), and the underlying bedrock type(s). If possible, include the estimated watertable position.

## Some background information on CEC & Base Saturation...

The cation exchange capacity (CEC) is a value given on a soil analysis report to indicate its capacity to hold cation nutrients. The CEC, however, is not something that is easily adjusted. It is a value that indicates a condition or possibly a restriction that must be considered when working with that particular soil. Unfortunately CEC is not a packaged product. The two main colloidal particles in the soil are clay and humus and neither are practical to apply in large quantities.

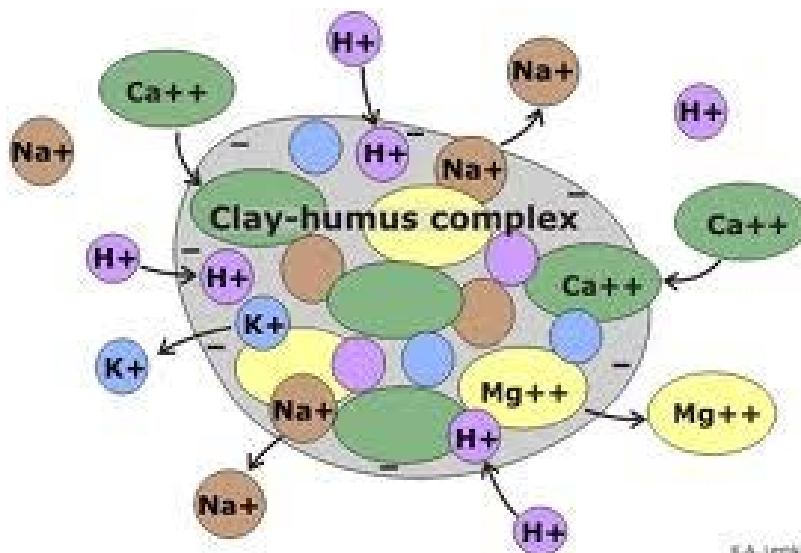
The CEC of the soil is determined by the amount of clay and/or humus that is present. These two colloidal substances are essentially the cation warehouse or reservoir of the soil and are very important because they improve the nutrient and water holding capacity of the soil. Sandy soils with very little organic matter (OM) have a low CEC, but heavy clay soils with high levels of OM would have a much greater capacity to hold cations.

The disadvantages of a low CEC obviously include the limited availability of mineral nutrients to the plant and the soil's inefficient ability to hold applied nutrients. Plants can exhaust a fair amount of energy (that might otherwise have been used for growth, flowering, seed production or root development) scrounging the soil for mineral nutrients. Soluble mineral salts (e.g. Potassium sulfate) applied in large doses to soil with a low CEC cannot be held efficiently because the cation warehouse or reservoir is too small.

### CATION EXCHANGE

Water also has a strong attraction to colloidal particles. All functions that are dependent on soil moisture are also limited in soils with low CEC. Organisms such as plants and microorganisms that depend upon each other's biological functions for survival are inhibited by the lack of water. Where there is little water in the soil, there is oftentimes an abundance of air which can limit the accumulation of organic matter (by accelerating decomposition) and further perpetuate the low level of soil colloids.

High levels of clay with low levels of OM would have an opposite effect (i.e. a deficiency of air), causing problems associated with anaerobic conditions. The CEC in such a soil may be very high, but the lack of atmosphere in the soil would limit the amount and type of organisms living and/or growing in the area, causing dramatic changes to that immediate environment. If a soil has a very low CEC, adjustments can and should be made but not solely because of the CEC. A soil with a very low CEC has little or no clay or humus content. Its description may be closer to sand and/or gravel than to soil. It cannot hold very much water or cation nutrients and plants cannot grow well. The reason for the necessary adjustment is not for the need of a higher CEC but because the soil needs conditioning. A result of this treatment is higher CEC.



Base saturation is the amount of positively charged ions, excluding hydrogen and aluminum ions, that are absorbed on the surface of soil particles and is measured and reported as a percentage. Base saturation is positively related to soil pH because a high base saturation value would indicate that the exchange sites on a soil particle are dominated by non-acidic ions.

### **What Is Base Saturation?**

Base saturation refers to the proportion of the cation exchange sites in the soil that are occupied by the various cations (hydrogen, calcium, magnesium, potassium). The surfaces of soil minerals and organic matter have negative charges that attract and hold the positively charged cations. Cations with one positive charge (hydrogen, potassium, sodium) will occupy one negatively charged site. Cations with two positive charges (calcium, magnesium) will occupy two sites.

Base saturation does not have any relation to fertilizer recommendations for the negatively charged nutrient ions, such as phosphate, nitrate and sulfate.

To determine the base saturation, you must first know the cation exchange capacity (CEC), which is a measure of the amount of negative charge in the soil. To determine this precisely, the soil is saturated with an unusual cation such as barium, to displace all of the other ions. The amount of barium sticking to the soil is then determined.

### **How Is It Used?**

Fertilizer recommendations using base saturation are aimed at "balancing" the cations in the soil to meet a particular range of base saturation percentages for each cation. This approach goes back to the work during the 1940's of Dr. F. Bear of New Jersey. He found that an acid, infertile coastal plain soil, which had been limed and fertilized for optimum crop production, had a base saturation percentage of 5% hydrogen, 3% potassium, 15% magnesium and 70% calcium.

### **What Are The Limitations of Base Saturation?**

There are three key limitations to using base saturation percentages for fertilizer recommendations. The first is that the proportion of cations in the soil is not easily changed, particularly in soils with high cation exchange capacity. It takes huge additions of calcium or magnesium to raise the contents of either.

The second limitation is the lack of evidence of any change in crop yield or quality in response to a particular percent base saturation. The usual justification for using base saturation is anecdotal evidence that soils at particular base saturations grew good crops. In trials where direct comparisons were made between treatments intended to produce different base saturation percentages, there were no significant differences between treatments as long as the soil pH was adequate, and there was adequate supply of each nutrient.

The third, and possibly the greatest practical limitation, is that a normal soil test does not actually measure the cation exchange capacity. The lab adds up the amount of calcium, magnesium and potassium extracted from the soil sample, and adds a factor for hydrogen ions based on the buffer pH. The approach provides approximately the same answer as a direct determination of cation exchange capacity in acid soils, but errors appear in alkaline soils. Most alkaline soils contain calcium and magnesium carbonate compounds, which dissolve in the extracting solution. The net result is a much higher measured amount of calcium and magnesium, and apparently larger cation exchange capacity. If you are trying to raise the potassium level to 3% of the CEC, you would be adding fertilizer to balance the amount of undissolved limestone in the soil.

### **Is % Base Saturation Useful At All?**

There are some situations where the percent base saturation provides useful information. Where the amount of magnesium in the soil is very high (equal to or greater than the amount of calcium), for example, there can be serious problems with soil structural stability. It is also a good check on the lab, since any sudden changes in % base saturation from previous samples likely indicates a problem in the lab or with the sampling.

# For 2505 - Calculations For Soil Quality Lab

Equation #1 - Dilution Factor  $DF = \frac{\text{Vol. of test solution}}{\text{Vol. of Aliquot}}$

\* Note: The unit "meq/100g" has been replaced by "cmol/kg" although they are equivalent, where  $1 \text{ meq}/100\text{g} = 1 \text{ cmol}/\text{kg}$ .

Convert the "ppm" readings from AAS analysis (for K, Ca, Mg) into the concentration per soil sample extracted...

Equation #2 - Calculate K, Ca, Mg (cmol/kg)

$$\text{cmol/kg (element)} = \frac{(\text{ppm} \times DF \times \text{Vol. Extract Sol'n})}{(\text{Eq. wt. element} \times \frac{\text{mass soil extracted}}{\text{extracted}} \times 10)}$$

\* Chemical used...

Ammonium Acetate  
NH<sub>4</sub>OAc

\* Extracted  $\approx$  3.0g soil  
using 30ml of  
NH<sub>4</sub>OAc

Equation #3 - Calculate K, Ca, Mg Exch. Cations (eq/ha)

$$\text{Exch. Cation (eq/ha)} = \frac{\text{Exch. Cation (cmol/kg)}}{(\text{cmol/kg})} \times \frac{\text{Bulk Density (Db)}}{(\text{Db})} \times \frac{\text{Soil Horizon Depth (cm)}}{(\text{Depth (cm)})} \times 1000$$

Equation #4 - Calculate K, Ca, Mg Exch. Cations (kg/ha)

$$\text{Exch. Cation (kg/ha)} = \frac{\text{Exch. Cation (eq/ha)} \times \text{Cation Eq. Wt}}{1000 \text{ g/kg}}$$

Calculating Cation Exchange Capacity + Base Saturation

Equation #5 - Calculate CEC (cmol/kg) from OM + Clay %

$$\text{CEC (cmol/kg)} = 2 \times \text{OM \%} + 0.5 \times \text{Clay \%}$$

Equation #6 - Calculate CEC (eq/ha) from CEC (cmol/kg)

$$\text{CEC (eq/ha)} = \frac{\text{CEC (cmol/kg)} \times \text{Db (g/cm}^3\text{)} \times \text{Soil Depth (cm)} \times 1000}{(\text{cmol/kg}) \quad (\text{g/cm}^3) \quad (\text{cm})}$$

Equation #7 - Calculating Soil Base Saturation %

$$\text{BS (\%)} = \left[ \frac{\text{Sum of Exch. K, Ca, Mg (eq/ha)}}{\text{CEC (eq/ha)}} \right] \times 100$$

Equivalent Weight  
of The Elements

Potassium (K) = 39

Calcium (Ca<sup>2+</sup>) = 20

Magnesium (Mg<sup>2+</sup>) = 12



# EXAMPLE DIAGRAM – EDAPHIC GRID ZONATION

Describe the soil type, forest cover, and landscape / landform for each delineated section

