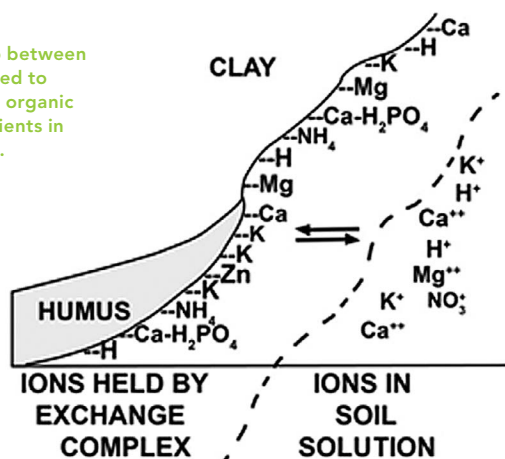# Base Saturation

Base saturation is one of the most important soil properties. Understanding base saturation can help us better understand and manage our soil.

Positively charged soil nutrients are called cations. As shown in Diagram 1, cations spend time on the soil exchange sites, clay and organic matter, or in the soil solution. The ratio between cations on the exchange sites and cations in soil solution is directly affected by the base saturation percentage of each cation. This is why we need to take base saturation into account when calculating fertilizer and amendment applications. The amount of fertilizer and amendments required to correct soil problems can vary greatly depending upon the soil's base saturation.

Diagram 1.
The relationship between nutrients attached to the soil clay and organic matter and nutrients in the soil solution.

How Do You Calculate Base Saturation?

Base saturation is defined as the percentage of the soil exchange sites (CEC) occupied by basic cations, such as potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na). The base saturation percentages are calculated for each cation then added up to determine base saturation. For example, suppose the following soil test ppm values were determined Table 1.

It is assumed the base cations are occupying soil exchanges sites (CEC). If the soil cations are not attached to the exchange sites, the base saturation is over estimated. Base saturation overestimation is most commonly associated with free calcium from limestone and gypsum or excess salts, but can possibly occur with the other three cations.

Amendment and Fertilizer Recommendations

Limestone recommendations

Limestone needs to be applied at a rate to neutralize all of the acidity on the soil exchange sites. It takes 1000 lbs. of limestone for each meq/100g of soil acidity.

Limestone (tons/acre) = 0.5 x (CEC x H%)

This assumes incorporation in the top 6 2/3 inches of soil. This factor needs to be adjusted directly in proportion to the tillage depth.

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Gypsum Recommendations

Soils containing more than 15% exchangeable sodium are prone to poor drainage and salt buildup. Application of a soluble source of calcium, such as gypsum, is recommended to replace the sodium off of the exchange sites and be leached out of the root zone. Gypsum recommendations are 3,440 lbs. per meq/100g of sodium wanting to be replaced per foot of soil.

Gypsum (tons/acre foot) = 1.7 x CEC x (Na% - 5%)

This recommends an amount of gypsum that will replace all but 5% of the sodium in the top foot of soil. Sodium needs to be corrected in the top foot to ensure good root growth in salt-affected soils.

Fertilizer Recommendations

Soil cations become increasingly soluble and available to plants as the exchangeable % increases. The goal is to maintain adequate amounts of nutrients for plant uptake while minimizing nutrient leaching loss. Optimum base saturation percentages recommended are:

Na	K	Mg	Ca
<10%	2-7%	15-20%	65-75%

Fertilizer application rates can be adjusted to reach these optimum saturation levels. This approach works well for soils with low CEC (<10). It does not work well with CEC >40.

For example, let's assume soil test K value of 39 ppm, which calculates out to be 3.3% saturation for a soil with a CEC of 3. Based on these figures, perhaps a maintenance amount of K is all that is needed.

Table 1. Example of Base Saturation Calculation

Element	K	Mg	Ca	Na	Base (Sum)	Acidity (H)	Total
Hypothetical Soil Test (ppm)	75	150	1800	30			
Divide ppm by this factor to calculate meq/100g	390	120	200	230			
meq/100g	0.19	1.25	9.00	0.13	10.57	2.00	12.57
% of CEC	1.5%	9.9%	71.6%	1.0%	84.1%	15.9%	100%

However, a fertilizer recommendation philosophy based on an optimum soil test level of 130 ppm K would classify this soil as being severely deficient.

Which is right? The problem with the critical soil test level approach is that a coarse textured soil will not hold 130 ppm of K. Applying excessive amounts of K to sandy soils could overcorrect a nutrient problem and create a potential nutrient imbalance. The base saturation ratio approach, on the other hand, would balance out the fertility and prevent excessive K leaching.

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Further, heavy texture soils with a CEC of >40 require an excessive amount of K depending on base saturation. The amount K required to obtain a desired K concentration of 2%, 3%, and 5% for CEC ranging from 5 to 60 is shown in Table 2.

Table 2. The effects of CEC and selected optimum K saturation percentage on lbs. of K2O per acre required.

Optimum K % Desired Lbs. of K_2O/Acre			
CEC	3	4	5
5	142	189	237
6	284	378	473
15	426	568	710
20	568	757	946
30	852	1135	1419
40	1135	1514	1892
60	1703	2271	2839

Looking at Table 2, it becomes apparent excessive K is required at high soil CEC values. Some soil analysis experts recommend placing a K "cap" to prevent this excessive K on high CEC soils. Another approach might be to combine the two recommendation philosophies (base saturation and sufficiency level) into one equation such as:

K (critical level) = 110 + 2.5 x CEC

This approach is most popular with K but can also be used for Ca and Mg. Similarly, soils with high CEC will result in excessive amounts of Ca and Mg recommendations. Recommendation equations for Ca and Mg are as follows:

Ca lbs./acre = 400 X CEC (70% - Ca%)/100

Mg lbs./acre = 240 X CEC (18% - Mg%)/100

Conclusion

- Soil cation nutrients become more soluble/available as the base saturation increases.

- Base saturation needs to be taken into account when calculating fertilizer and amendment applications.

- Base saturation is defined as the percentage of the soil exchange sites (CEC) occupied by basic cations, such as potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na).

- Base saturation can be overestimated if there is too much free limestone, gypsum, or salt in the soil.

- Whether or not a base saturation calculation will prove the right approach for your soil depends on soil CEC and the accuracy of CEC estimations. A base saturation calculation can be compared to or combined with a sufficiency level calculation in order to achieve an ideal approach.

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