Grow YOUR SOIL

Soil Science Spotlight

If we understand a soil, we can improve it

Base Saturation

Q: When you test your soil and the lab report lists "base saturation" results, what are they and how are they useful in understanding and improving your soil?

A: Base saturations are the proportions of the available calcium, magnesium, and potassium (as well as hydrogen, sodium and aluminum) held in your soil. They are reported as percentages, so they tell you the proportion of each nutrient compared the total amount of cations (positively charged nutrients) held in your soil. For example, if you have a soil that has a calcium base saturation of 70%, you know that 70% of the cations held by the soil are calcium; the rest are a mix of magnesium, potassium, sodium and other cations like hydrogen, zinc, copper, manganese, iron or aluminum. Base saturations do not tell you anything about the total *amount* of each cation; that is usually given elsewhere in the lab results.

Q: Are there ideal base saturation percentages for the major cations (calcium, magnesium and potassium) that farmers should strive to achieve in order to maximize their yields?

A: No, although some would still disagree. In the 1930s and 40s, Dr. Firman E. Bear suggested that crops do best in soils that have base saturations of 65% calcium, 10% magnesium, 5% potassium and 20% hydrogen. This idea was further developed by Dr. William Albrecht, then by Dr. E. R. Graham, and later by Dr. E. O. McLean into an "ideal range" that varied depending on the author, but tended toward base saturations of approximately 60-85% calcium, 10-20% magnesium, and 2-5% potassium.

However, for more than 35 years, extensive and scientifically rigorous testing has shown that achieving these "ideal" base saturation percentages is not critical for optimizing yields, and that the expense and resources required for the additional fertilizers is generally not justified. This modern research makes it clear that *having all necessary nutrients in sufficient quantities in the soil – rather than their ideal ratios – is what is critical for crops to thrive*.

Q: So why do we still do the tests?

A: Because knowing a soil's base saturation percentages can still be useful in some circumstances. Regarding calcium and magnesium, research shows that crops perform to their maximum potential with a variety of calcium to magnesium ratios, but that high calcium saturation levels can be one indicator of a calcareous soil, and can interfere with the availability of phosphorus, iron and zinc. Similarly, high magnesium saturation levels can interfere with a plant's uptake of potassium and vice versa, although this still is unlikely to significantly impact yields if all nutrients are available in sufficient amounts. Regarding sodium, the less sodium the better – crops don't need it and it can be very detrimental to soil structure and health. However, determining whether a soil contains harmful amounts of sodium – and what amount (if any) needs to be leached from the soil to prevent crop damage – is generally based on the soil's sodium saturation *percentage* and not the *total* amount of sodium in the soil. This is because sodium, a positively charged ion, can be held by the soil's negatively charged clay and organic matter that determine the soil's ability to hold cations: its *cation exchange capacity* (CEC). If the soil has a very high CEC, it can hold onto more sodium before it becomes harmful to plants, whereas if it as a low CEC, even small amounts of sodium can be detrimental to your crops.

Q: What if your soil test results do not list base saturations?

A: To calculate base saturations yourself, you divide the amount of each cation by the total CEC. Simple enough, right? The only tricky part is making sure the total CEC and the amount of each cation are using the same *units*.

The unit used to express CEC is generally milliequivalents[1] per 100 grams (meq/100g) or centimole per kilogram (cmol/kg), which are equivalent. However*,* the unit often used to express the amount of a cation is *parts per million* (ppm) and not cmol/kg. So, to correctly calculate base saturation of a cation in your soil, you need to convert ppm to cmol/kg before you can divide the number by the CEC (which is in cmol/kg).

How do you do this conversion from ppm to cmol/kg? cmol/kg is different than ppm in that it takes into account the *charge* and *atomic mass* of each cation (they're listed in the chart below). To convert each cation from ppm to cmol/kg, use the following formula:

ppm of cation / ((atomic mass of cation x 10)/charge of cation)

Calcium: Divide the ppm of calcium in your soil sample by 200 to convert to get cmol/kg of calcium.

Magnesium: Divide ppm of magnesium by 120 to get cmol/kg of magnesium.

Potassium: Divide ppm of potassium by 390 to get cmol/kg of potassium.

Sodium: Divide ppm of sodium by 230 to get cmol/kg of sodium.

Cation	Charge	Atomic Weight
Calcium (Ca)	+2	40.078
Magnesium (Mg)	+2	24.305
Potassium (K)	+1	39.098

[1] meq or milliequivalents is one thousandth of a chemical equivalent. It is calculated by multiplying the milligrams per liter by the valence of the chemical and dividing by the molecular weight of the substance.

Sodium (Na)	+1	22.990

As an exercise, if the soil test report says you have 4300 ppm of calcium in your soil sample, with a CEC of 24 cmol/kg, what percentage of calcium is in the soil (base saturation)?

1. First convert 4300 ppm to cmol/kg: 4300/200 = 21.5 cmol/kg.
2. Next, divide 21.5 cmol/kg of calcium by the soil's CEC, which is 24 cmol/kg
3. Result: a base saturation for calcium of almost 90%.

This is a soil dominated by calcium! While excess calcium is not inherently toxic to plants, it can in extreme cases reduce the uptake of other cations, particularly those needed in small amounts like iron, zinc and manganese. That degree of calcium saturation also suggests that you may be working with a calcareous soil (though not always). Check out the Soil Science Spotlight on calcareous soil to learn more.