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Cation Fertility

Understanding CEC and Base Saturation

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TURF LINE NEWS

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Cation Exchange Capacity (CEC) and Base Saturation are two of the most important concepts in soil agronomy. Understanding how they affect fertility, and applying these principles to your management system, will help you grow better turf.

The Soil Is Like A Magnet

Clay and organic matter particles in the soil have a negative electrical charge. Potassium, magnesium, calcium, hydrogen and sodium - the cations - all have positive electrical charges of varying strength. Much like a magnet, the positively charged cations are attracted to the negatively charged soil particles. Furthermore, the cations have an antagonistic relationship with each other, competing for the same electrical charge sites in the soil.

There are two concepts of cation soil fertility – Sufficient Level of Available Nutrients (SLAN) and Base Saturation. When looking at the fertility of an individual cation, the SLAN philosophy states that it should be available at a certain minimum level, as determined by soil test extraction methods, for optimum availability. The Base Saturation concept of soil nutrition looks at the balance between soil cations as a primary factor in nutrient availability. Both philosophies have merit and should be applied to different fertility and different soil conditions.

It's worth noting that since soil particles attract positively charged ions, they must also repel negatively charged ions (anions). The nitrate (NO3) form of nitrogen, which accounts for well over 90% of the nitrogen consumed by turfgrass, provides a great example. Because nitrate has a single negative charge, it is essentially "free" in the soil solution. This property explains why nitrogen is an extremely difficult nutrient to manage and why it is so prone to leaching losses.

Cation Exchange Capacity (CEC)

As mentioned previously, clay and organic matter particles in the soil have a negative electrical charge. A soil with a high fraction of clay and organic matter has more negative charge sites than a soil with a low fraction of clay and organic matter. Soil testing measures the number of electrical charge sites, which is expressed as the soil's Cation Exchange Capacity (CEC). A high CEC soil has the ability to hold more cations than a low CEC soil. This makes CEC the critical determinant in gauging the ability for a soil to store and release cations.

The correlation between CEC and stored nutrient levels has a direct effect affect on fertilizer practices. A low CEC soil, such as a sand-based green, often cannot hold enough of an individual cation to maintain a sufficient level of fertility. In order to avoid nutrient leaching, these soils require small amounts of fertilizer applied on a frequent basis – the spoon feeding approach. Conversely, soils with a high CEC, such as playing fields or fairways, can maintain and supply a larger amount of these positively charged nutrients. As a result, high CEC soils require fewer total plant food nutrients and less frequent fertilizer applications.

Optimum Cation Nutrient Range (ppm) Based on CEC*				
CEC	**5**	**10**	**15**	**20**
Potassium	91-120	121-160	151-200	181-240
Magnesium	60-119	120-239	180-359	240-479
Calcium	600-1199	1200-2399	1800-3599	2400-4799
* based on ammonium acetate extraction method				

The inability of low CEC soils to build and retain cation levels has led to the concept of a cation fertilization "cap". We've all heard stories of Golf Course Superintendents frustrated by an inability to build cation levels (usually potassium) beyond a certain point in their sand-based greens. Since these low CEC soils cannot build potassium (or other cations) to a sufficient level, offsetting high nutrient applications are pointless. In such circumstances consider a potassium (K2O) cap of 5-7 pounds per 1000 and a magnesium (Mg) cap of 20-25 pounds per acre.

Base Saturation

Base saturation is one of the most important concepts in soil nutrition. It is defined as the percentage of soil exchange sites (CEC) occupied by each of the cations - potassium, magnesium, calcium, hydrogen and sodium. As the percentage of soil exchange sites occupied by a cation increases, it becomes increasingly soluble and increasingly plant available. Conversely, as the percentage of soil exchange sites occupied by a cation decreases, it becomes increasingly insoluble and less plant available. Research in this area of soil science has determined the optimum percentage of exchange sites that each cation should occupy in order to maximize collective nutrient availability and overall soil health. The Base Saturation concept of nutrient balance is normally expressed in percentage terms, but is sometimes described as an ideal set of ratios between cations (such as a Ca:Mg ratio).

Optimum Base Saturation				
Hydrogen	**Potassium**	**Magnesium**	**Calcium**	**Sodium**
0-5%	2-7%	15-20%	65-75%	0-5%

What are the implications of a Base Saturation imbalance? In answering this question, it's important to keep in mind that an excess of one cation results in a deficiency of another. For instance, excess calcium (common in high pH, calcareous soils) limits the availability of potassium and magnesium simply because there is correspondingly less room on soil exchange sites for these nutrients. The Base Saturation of sodium is of particular concern because as sodium Base Saturation rises above five percent, the soil loses its structure, water infiltration rates decline and turf health suffers. A strongly acid soil is actually the result of a Base Saturation imbalance, with hydrogen occupying soil exchange sites at the expense of calcium. In short, Base Saturation gives you the "big picture" of overall soil health and fertility.

A Practical Approach to Soil Fertility

As we discussed previously, low CEC soils often cannot supply cations at a level considered sufficient for turfgrass growth – but this does not necessarily mean that your turf will experience a nutrient deficiency. When assessing the fertility of your low CEC soils, Base Saturation likely provides a more accurate assessment of cation availability than does the traditional SLAN approach. In other words, don't get overly focused on extracted parts per million of the cations in your low CEC soils. Instead, try to maintain target base saturation levels, which maximizes nutrient availability, through frequent and light fertilizer applications.

When looking at the fertility of your fairways or other high CEC soils, focus primarily on extracted nutrient levels – the SLAN approach. Manipulating base saturation through amendment and fertilizer applications on a high CEC soil usually requires massive application rates, making the Base Saturation approach both impractical and cost prohibitive. In the case of high CEC soils, use Base Saturation as a tool to identify problems with soil health, such as increasing sodium levels or declining soil pH.

Finally, soil test frequently with a reputable laboratory. And always have them include a measurement of CEC, Base Saturation as well as extracted nutrient levels.

Sources: MDS Harris Labs (various publications)

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