

Interpreting soil test results

This information is obsolete. Refer to MLSN Guideline methods for current methods: https://www.paceturf.org/journal/minimum_level_for_sustainable_nutrition

Bottom line: Healthy, high quality turfgrass can flourish when grown on soils with a wide spectrum of nutritional and physical properties. In other words, there is no one “ideal” soil for turf growth. This is nice for the turf, but it makes things difficult for turf managers. If there is no ideal soil, then how do you determine your soil nutrition goals? How do you know when you have too much or too little of a nutrient, and how can you predict the interactions among shifting levels of nutrients in the soil? The answers to these questions lie in being able to take a multi-faceted approach towards evaluation of your soils. We favor looking at soil nutrient reports by integrating at least three perspectives: the SLAN (sufficiency level of available nutrients) approach, the BCSR (basic cation saturation ratio) approach, and perhaps most importantly, your own observations linking the abstract test data to good performing (or poor performing) turf at your specific site. We suggest that full-scale soil tests, including assessment of soil nitrogen and soil EC levels be conducted at least twice a year, and that nutrient deficits be corrected using the formulae presented on page 4 of this *Insights*. Know which test procedures are used at your lab so that you can interpret the results correctly, and can make any mathematical conversions that are necessary to obtain the most accurate nutrient measurements.

Get yourself a big cup of full-strength coffee and have a seat. We are about to enter the extremely important, but also extremely dry topic of soil testing. In this *PACE Insights*, we will step through the key nutrients that are quantified in soil tests, the methods of analysis that are used to extract and measure them, and some pointers on interpretation of the results. A set of guidelines for key soil macronutrients, micronutrients and other important soil measurements is provided in Tables 1 - 3 of the attached **PACE Reference** (9:9).

Extracting the truth?

Most nutrients in the soil are not readily available to plants because they are present either in insoluble mineral compounds or are tightly bound to soil particles or complex organic matter. Only a fraction of each nutrient present in the soil is truly available to the plant (this is known as the **plant available nutrient, or PAN** fraction). The remainder is physically there in the soil, but the plant cannot take advantage of it.

It stands to reason then, that if a soil test is to reflect the true condition of the soil as far as the plant is concerned, the analytical procedures used must quantify the plant available fraction – the fraction of each nutrient that the plant “sees” and can make use of. A soil test that reported the entire quantity of a nutrient present in the soil – whether available to the plant or not -- would erroneously lead you to believe that there are gobs upon gobs of nutrients floating around in the soil, and that fertilization is rarely, if ever, needed.

How then do soil labs get it right? That is, how do they separate the PAN fraction of each nutrient from the fractions that the plant cannot use? They do this by choosing the right **chemical extractant** – a liquid material that strips nutrients from the soil – so that plant available nutrients are selectively removed from the soil for analysis, while the materials that are not available to the plant are cleverly left behind.

Extractants are selected based on the nutrient in question, and depending on the nature of the soil. For example, in the case of soluble salts, which are discussed below, scientists use the simplest of all extractants – water – to harvest plant available nutrients.

In the case of other nutrients, which are more tightly bound to the soil, the choice of extractant gets more complex and can range from acids, to bicarbonates, to salt solutions.

Salts and water-based extractions

Monitoring soluble soil salts (examples are sodium chloride, calcium sulfate or magnesium sulfate) has become increasingly important as more golf courses deal with poor quality reclaimed water and/or poor quality well water.

As you might guess from their name, the water soluble salts are most easily separated from the soil using (you guessed it!) water. The saturated paste extraction (SPE) procedure, a water-based extraction method, was developed by the U.S. Salinity Laboratory in 1954 to determine the **Electrical Conductivity (EC_e)** and **Sodium Adsorption Ratio (SAR)** of soil. Although other methods are used by some labs to quantify these two soil characteristics, the saturated paste method is generally regarded as the most accurate. The SPE method is also sometimes used to measure concentrations of the micronutrient **boron**, although other methods, including the Mehlich III (see below) are equally accurate.

Electrical Conductivity (EC). When EC measurements are based on the SPE extraction method, the EC is sometimes represented as **EC_e**. Results are usually reported in units of dS/m (decisiemens/meter) or mmhos/cm (millimhos/centimeter). To estimate **total soluble salts (TSS)**, the EC_e is multiplied by 640 to give you a TSS value in ppm (parts per million) or mg/kg (milligrams per kilogram).

Sodium Adsorption Ration (SAR) is a measure of sodium permeability hazard -- the potential for the soil to have structural deterioration due to excess sodium. The soil solution concentrations of Na, Ca, and Mg in meq/L that are used in the SAR formula are based on the SPE extraction procedure. SAR levels above 12 are considered adverse for soil and plant health. Ideally, we like to see SAR levels at 3 or below.

What to do if your lab doesn't use SPE

Rather than the SPE, some labs use alternate methods known as **dilute water extract** procedures to quantify soluble salts. These tests are frequently named by the extent of the dilution used. For example, a 2:1 water:soil method uses more than twice as much water as the SPE method. If your soil report does not specify which extraction procedures were used to measure soluble salts, you should call the lab and ask. If dilute methods were used, you also need to know if the lab has modified the numbers to correlate with a true ECe (as determined with the saturated paste extraction), or if they are reporting the actual numbers that result from the dilute analysis, in which case you will need to pull out your calculator to determine the "true" ECe. This is important information to get hold of, since, depending on the method used, you can get wildly different EC values that can be very misleading if they are not properly converted. For example, an EC value of 3.0 dS/m obtained using a 2:1 dilute extraction method would need to be converted, based on the formula below, to obtain the "true" ECe of 6.8.

$$ECe = 2.1 \times (2:1 \text{ dilution EC value}) + 0.5$$

$$ECe = (2.1 \times 3.0) + 0.5 = 6.8$$

When the SPE doesn't apply

Although water-based extracts are the best way to go when you need accurate determinations of electrical conductivity and sodium absorption ratio values, these tests are not useful for measurement of soil **macronutrients** (nutrients that are used in relatively large quantity by the plant such as nitrogen, calcium, magnesium, phosphorous and potassium) or **micronutrients** (nutrients that are used in smaller quantities by the plant such as copper, iron, manganese and zinc). The water extraction method on which SPE is based isn't strong enough to shake these nutrients loose from the soil. For this reason, more powerful extraction systems (with names such as Olson, Bray, Mehlich and Morgan) based on acids, salt solutions or bicarbonates are used. A wide variety have been developed -- some for specific nutrients and others based on regional preferences. With so many different tests floating around, interpretation of soil tests can become very confusing.

Recently, there has been a movement toward developing a single "**universal extractant**" that could be used to analyze all major macro- and

micronutrients. In addition to lowered cost, the primary benefit of this approach lies in its name -- that is, its universality. Rather than futilely trying to compare results from different labs, all of which are using different extraction methods, a universal extractant would allow us to compare and communicate about results much more effectively. **Mehlich III**, an extraction system that relies on a combination of several dilute acids plus fluorine, has become widely used as the "universal extractant" of choice since it often correlates to other extractants that have been widely used for many years. The guideline values for macro- and micronutrients shown in Tables 1 and 2 were determined using the Mehlich III extraction.

The art and science of reading a soil test

On a typical soil test, the quantities of each macro- and micronutrient are often reported in two different ways.

Using the **SLAN (sufficiency level of available nutrients)** approach, the amount of each nutrient is shown in terms of **parts per million (ppm)** or **pounds per acre**. Each nutrient may also be classified according to its concentration in the soil as "very low", "low", "moderate", "high" or "very high". The sufficiency data shown in the top portion of Table 3 uses the SLAN approach for representing soil nutrient data.

The **sufficiency ranges** that are typically used to interpret data that is reported in ppm or lb/A are:

Low range denotes that there is a high probability (80-100 %) of getting a response from application of that nutrient.

Medium range implies that there is approximately a 50 % chance of getting a plant response from application of the nutrient.

High range denotes that there is little or no crop response expected from applying the particular nutrient.

Very high range suggests that further application of the particular nutrient may cause a nutrient imbalance, toxicity or reduced growth in some cases.

Using the **BCSR (basic cation saturation ratio)** approach (sometimes also known as "the balance approach"), some of the same nutrients listed in terms of ppm or lb/A (calcium, magnesium, potassium, hydrogen and sodium) are also listed in terms of the **percent** that each contributes to the **cation exchange capacity, or CEC** of a soil. These nutrient percentages will frequently appear under a section entitled "Base Saturation Percent" on your soil report. Some reports will also list the **ratios** of these percentages to one another.

Why interpret nutrient composition in two different ways? For very much the same reasons that you might seek a second medical opinion, or listen to two different news commentators, or appreciate the

appearance of a painting when viewed from several different angles. In other words, the soil is an incredibly complex system that cannot always be accurately described with just one method. When different ways of looking at the same soil are combined, we can frequently obtain a broader and more robust picture of what is happening in the soil than any single method can provide.

More on the SLAN, or sufficiency approach

This approach towards interpreting soil test data relies on the concept that the lower the concentration of each nutrient in the soil, the greater the positive response when that nutrient is applied as a fertilizer. Conversely, if the soil is classified as having a “high” concentration of a nutrient, you should expect little or no plant response when the nutrient is applied as a fertilizer. Guidelines for soil nutrients based on the SLAN approach are shown at the top of Table 3. The values shown fall roughly into the “high” sufficiency range, where addition of fertilizer or amendments will have little or no positive effect.

The SLAN approach is a straightforward and extremely useful tool for evaluating soils. The major pitfall with this approach is that it studies each nutrient in isolation, and ignores what happens when they interact with one another. This is where the BCSR approach can help round things out.

More on the balance (BCSR) approach

This approach is based on the concept that optimal plant growth occurs when there is an optimal balance of cations (positively charged nutrients such as calcium, magnesium and potassium) in the soil. The desired percentage levels of these nutrients are shown in Table 1 and the lower portion of Table 3.

BCSR further relies on the concept that soil is capable of adsorbing, or holding on to a fixed number of cations (positively charged ions). The most important of these cations are calcium, magnesium, potassium, sodium and hydrogen. Fine textured soils and soils that are high in organic matter are able to hold onto large quantities of these nutrients, while very sandy soils have trouble holding onto any of these cationic nutrients at all. The measurement that is used to talk about this characteristic of the soil is the **cation exchange capacity (CEC)**; as you might expect, soils that are either fine textured or are high in organic matter have high CECs, while sandy soils have low CECs. The CEC is also sometimes called the **total exchange capacity [TEC]** or **base exchange capacity**.

By utilizing percentages to quantify soil nutrients, it is easier to understand how the amounts and types of each nutrient interact with one another. For example, if levels of magnesium exceed 20%, it will cause a decrease in another important nutrient such as calcium, by literally knocking it off of the cation exchange. Decisions on when and how much to

fertilize are therefore made with the goal of maintaining the balances listed above.

While the balance method gives us a different and very useful way of looking at the soil, its major flaw is that it does not directly indicate the quantity of a nutrient – only its percentage. This can lead to some erroneous decisions, particularly in soils with low cation exchange capacity (sandy soils with CEC values of less than 4 meq/100g). In an example that is commonly encountered in the coastal southeast, a very sandy soil with a CEC of 3 meq/100g using Melich III extraction may meet the BSCR guideline of 68% calcium. However, because there are so few cations in the soil altogether, 68% of the CEC is equivalent to only 408 ppm calcium, below the desired sufficiency value (750 ppm) listed in Table 3. **For this reason, nutrient percentages as reported using the balance method must always be looked at in conjunction with the absolute concentrations of nutrients reported with the SLAN method. Your goal is to satisfy both sets of guidelines if possible.**

Another watch-out with the balance method lies in the way that different labs determine the cation exchange capacity of the soil. Since the CEC is the basis for calculating the percentages of each nutrient, inaccuracies in the CEC will result in inaccurate fertilizer recommendations. In most cases, the ammonium acetate extraction method buffered at pH 7.0 for determining CEC is the most accurate. However, there are special situations where this method will give rise to erroneous CEC numbers:

- When the soil is acid (pH less than 7.0). To correct this, CECs for acid soils should be determined using an unbuffered extractant.
- When soils are saline (EC > 4.0 dS/m), the high levels of cations in the soil are extracted and contribute to a high, but erroneous, CEC value.
- Similarly, when soils are calcareous (with high levels of calcium carbonate or lime precipitated in a form that is unavailable to the plant), calcium will be extracted by the ammonium acetate and will contribute to an inflated CEC value.

These special situations require changes in the soil evaluation procedure that are specific to your site. Before proceeding further with soil testing, you should consult with an agronomist about the best approach for your specific situation.

What about nitrogen?

A standard soil test rarely includes an assessment of soil nitrogen levels. We think that this is a major omission, partly because soils that are low in nitrogen will result in poor quality turf. But perhaps equally, if not more, important is the surprisingly common problem of excessive, toxic levels of nitrogen, which can cause serious and long-lasting damage to turfgrass of all types. It may cost a bit more, but it is well worth the money to request that your testing lab

include analyses of nitrate and ammonium (reported in parts per million). From these values, you can calculate total plant available nitrogen (nitrate plus ammonium) and nitrate to ammonium ratios (nitrate divided by ammonium values), and then compare them against the guideline values shown in Table 1.

What about “quick and dirty” tests?

We are big advocates of quick, on-site monitoring tests and for this reason we have developed procedures such as the use of TDS-4 meter for measuring soil EC (see PACE Reference 9:3) and the use of Hach water test strips (PACE Insights 9:5) for monitoring soil nitrate levels. While these procedures are very useful as rapid diagnostic tools, the values obtained are quite rough, and much less comprehensive than the information you get from a standard soil test. Ideally, you should run full-scale soil tests twice a year (in spring and fall) to get a broad-based and integrated look at your soils. The function of your on-site monitoring tests is then to tweak and adjust your soils in the periods in between your spring and fall soil tests.

Integrating the information

So your soil report has just arrived in the mail, and, armed with all of the information above, you look forward to being an enlightened, brilliant and wise turf manager. The only problem is, where do you start?

The best place to start is with the SLAN, or sufficiency values that usually appear towards the top of your report. Compare these values against the desired sufficiency values shown in the top portion of Table 3. Are there deficiencies in any of your nutrients, and if so, what do you need to do to correct them? Use the formulae in Section A below to calculate the rates of fertilizer that need to be applied to correct any deficits.

Now, take a look at the base saturation percentage numbers, and compare them to the desired guidelines provided in the bottom portion of Table 1. Are calcium, magnesium and potassium present in the right balance (approximately 68% to 12% to 4% respectively?) If not, will any fertilizers that you will be adding as a result of correcting sufficiency levels (see above) help to correct this? Consult the formulae in Section B below to determine whether additional fertilizer or amendment applications are required, and in what quantities.

Finally, you need to weigh these conclusions against the ultimate indicator – your own historical records and observations. What is the nutrient composition of soils from areas that have good turf performance? Bad turf performance? If you consistently keep track of soil test results vs. turf quality ratings, then you should, over time, be able to identify a set of nutritional guidelines that are at least as valuable as those in Tables 1 – 3. These personal, site-specific guidelines are a powerful tool that should be included in your final decision about the need, or lack thereof,

for application of amendments. (Labeling soils as either “good” or “poor” when you send them into the lab can help you, and the lab, to keep track of this type of information more easily).

Congratulations! You have now plowed your way through some fairly complex concepts and calculations dealing with the major soil nutrients, and you are on your way towards building a soil system that will sustain healthier, and higher quality turf.

Correcting Deficits

A. Sufficiency values (SLAN)

$$\text{Desired ppm (see Table 3) – Reported ppm} \\ = \text{Deficit ppm}$$

(if you come up with a negative number, you have more than enough of the nutrient)

- To convert ppm to pounds per acre (lb/A), multiply ppm by 2
- To convert lb/A to lb/1000 sq ft, divide lb/A by 43.56

Example: Your soil report shows that calcium is present in your sandy soil at 350 ppm using the Melich III extraction. To calculate the deficit:

$$750 \text{ ppm} - 350 \text{ ppm} = 400 \text{ ppm deficit for calcium}$$

$$400 \text{ ppm} \times 2 = 800 \text{ lb/A calcium required to correct deficit}$$

$$800 \text{ lb/A} \div 43.56 = 18.4 \text{ lb calcium/1000 sq ft to correct deficit}$$

NOTE: To correct nutrient deficits, amendments should be added in small amounts throughout the year, rather than in a single large application.

B. Base saturation percentage (BSCR or balance)

1. determine the desired percentages of calcium, magnesium and potassium in terms of ppm. This equation requires the use of equivalent weights (EWs) for each of these nutrients which are 20, 12 and 39, respectively.

$$\text{Desired ppm} =$$

$$\text{CEC} \times (\text{desired percentage}/100) \times 10 \times \text{EW}$$

We have simplified this equation for calcium, magnesium and potassium below:

$$\text{Desired ppm calcium} = \text{CEC} \times 0.68 \times 200$$

$$\text{Desired ppm magnesium} = \text{CEC} \times 0.12 \times 120$$

$$\text{Desired ppm potassium} = \text{CEC} \times 0.04 \times 390$$

2. determine the extent of the deficit and calculate the amount of nutrient needed as illustrated in section A above.