

Soil Testing Procedures for Calcareous Soils

Well-established soil testing methods on soils containing calcium carbonate or gypsum often underestimate fertilizer and soil amendment requirements.

BY BRIAN WHITLARK

Imagine a scenario where you have been consistently collecting soil data for tees, fairways, and greens for more than five years, using one lab and one procedure. Does this sound familiar to you? If it does, great! Regular soil testing is an invaluable tool for developing and fine-tuning fertilizer and soil amendment programs. Receiving accurate and consistent values from the laboratory, coupled with personal observations, allows for intelligent decision-making in the field. But what if you were to discover that the data for all those years was wrong? Would you change to a more accurate procedure? If you grow turf on calcareous soils (those containing calcium carbonate) or gypsum, it is possible, and even likely, that you should consider changing soil testing procedures. However, in the absence of free carbonates or gypsum, a change in soil testing methods is unneeded. The objective of this article is to alert golf course superintendents who manage turf on calcareous or gypsiferous soils (containing gypsum in excess of 2%) that nutrient data obtained from the most commonly used and accepted soil testing extractants may result in misguided fertilizer and soil amendment programs.

WHAT IS A SOIL TESTING EXTRACTANT?

Nationwide, soil laboratories that test golf tees, fairways, and putting greens use a variety of soil extractants to determine plant-available nutrients in the soil. You may wonder what exactly a soil testing extractant is. An extractant is a solution of water and various chemicals that, when mixed with soil, extract or remove nutrients from the soil that are: 1) contained in the soil solution, 2) easily dissolved in water, and 3) held on soil exchange sites and available for plant use. Once

Soil Testing Extractant	Solution pH	Notes
Mehlich 1	1.5	Should not be used to determine cations on calcareous or gypsiferous soils
Mehlich 3	2.5	Should not be used to determine cations on calcareous or gypsiferous soils
Modified Morgan	4.8	Should not be used to determine cations on calcareous or gypsiferous soils
Saturated Paste	7.0	Yields nutrients in the soil solution
1:5 soil-water extraction	7.0	Values must be corrected to correlate with saturated paste
Ammonium Acetate	7.0	Most commonly used extraction method, but should not be used on calcareous or gypsiferous soils
Ammonium Chloride	5.5	Not commonly used due to extra steps that account for the dissolution of calcium carbonate
Elevated pH Ammonium Acetate	>8.0	Most accurate extraction currently used for soils containing calcite or gypsum

shaken with the soil, the extractant is filtered and analyzed for soil nutrient content. It is important to understand the nutrients removed from the soil represent those nutrients immediately available and those that are slowly available for turf use. An entirely different test provides total nutrients in the soil — those that are available and those that are unavailable or “structurally bound” in the soil. A third test is the water-based extraction (saturated paste test), which measures only what is in the soil-water solution or immediately soluble at the time of testing and grossly underestimates the nutrient supplying power of the soil. These three extracting methods are often confused.

IS THERE A PROBLEM WITH THE EXTRACTANT THAT I AM CURRENTLY USING?

The answer may be yes, especially if you are growing turf on a calcareous or gypsiferous soil. Unfortunately, a “universal” soil testing extractant is not currently available, hence a wide variety of solutions are used, including acid extractants such as Mehlich I, Mehlich 3, and the Modified Morgan, a neutral pH ammonium acetate extractant (pH 7.0), and the elevated pH ammonium acetate solution (>pH 8.0) (Table 1). The problem is this: when testing a soil that contains calcium carbonate, magnesium carbonate, or gypsum, the acid and neutral pH extractants overestimate calcium (Ca)



When acid is placed on a soil containing appreciable calcium carbonate, the soil fizzes in the form of carbon dioxide gas bubbles.

and to a lesser extent magnesium (Mg). For example, when the pH-neutral ammonium acetate extractant is used on a calcareous soil, it may overestimate Ca by as much as 60% (3). In another example, the pH 7.0 ammonium acetate procedure may yield up to 40% more calcium than is actually available for plant use and exchange for sodium (Na) in the soil (2). Overestimating Ca levels in the soil not only affects Ca, but will cause inaccurate estimates of CEC, base saturation levels, and cation ratios, and will underestimate the exchangeable sodium percentage (ESP).

HOW WILL THE WRONG EXTRACTANT AFFECT THE SOIL CATION EXCHANGE CAPACITY?

Overestimating Ca and Mg will result in erroneously high estimated CEC values (ECEC). You may be curious what "estimated CEC" means. Soil testing laboratories often calculate the CEC by summing the four basic cations: Ca, Mg, K, and Na. Such a calculation assumes the cations occupy 100% of the soil exchange sites. In alkaline soils, this assumption

is quite accurate and results in a value similar to the actual CEC. The actual CEC is measured via a complex, time-consuming procedure and is typically only performed upon request. Testing a calcareous soil with a neutral or acid extractant will overestimate Ca and Mg, and when the cations are summed, the estimated CEC is much higher than the actual CEC. It is important to note that such an error does not occur in the absence of Ca or Mg carbonates or gypsum. Largely dependent on the calcium carbonate levels in the soil, the ECEC may be overestimated by a substantial margin. The more the calcium carbonate, the greater the difference will be.

It is important to know whether the soil has a high or low CEC when determining fertilizer frequency and rates. A low-CEC soil will require more frequent, light fertilizer applications to sustain healthy turf and to avoid unnecessary nutrient losses due to over-application and subsequent leaching. The CEC is also commonly used to determine gypsum, sulfur, and lime requirements and to calculate amendments to remediate sodium affected (sodic) soils.

HOW WILL THE WRONG EXTRACTANT AFFECT MY FERTILIZER PROGRAM?

When testing a calcareous soil, acid and neutral extractants will overestimate ECEC, exchangeable Ca, and related base saturation percentage and cation ratios. Although research does not support the use of cation ratios and percentages as a basis to develop fertilizer programs, those turf managers who still use this method will find the data they have been using is incorrect if their soils contain calcium carbonate and the soil testing extractant is acidic or has a neutral pH.

HOW WILL THE WRONG EXTRACTANT AFFECT MY SODIUM REDUCTION PROGRAM?

Mike Rothenberg, a soil consultant for Brookside Laboratories, encourages turf managers in the Southwest to use the elevated pH ammonium acetate extractant. Mr. Rothenberg stresses the importance of testing the soil to confirm the presence of calcite prior to recommending a change in soil testing procedure. Over the last few years, Mr. Rothenberg noticed that when superintendents changed to the correct extractant, they were always surprised to see the Ca levels decreased and the sodium percentage increased. Many realize they need to modify their Na reduction program to address the correct values. Let's take a look at a few examples where turf managers in Arizona have realized the benefits of accurate soil test data.



Different soil testing methods are used to determine the total nutrients in the soil, the available nutrients, and those in the soil solution. These three extracting methods are often confused.

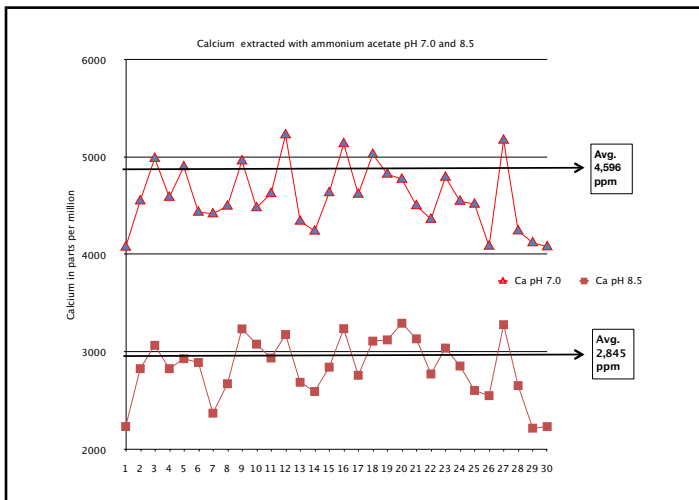


Figure 1. Calcium values extracted with ammonium acetate at pH 7.0 (red line) and pH 8.5 (green line) from 30 soil samples collected from a calcareous soil fairway in Goodyear, Ariz.

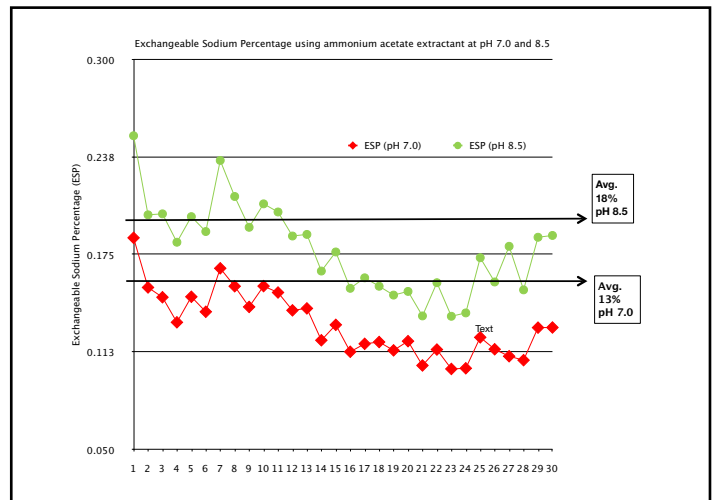


Figure 2. Exchangeable sodium percentage computed using exchangeable cation values from 30 different soil samples collected from a calcareous soil fairway in Goodyear, Ariz., with ammonium acetate at pH 7.0 (red line) and at pH 8.5 (green line).

GOODYEAR, ARIZ., GOLF COURSE FAIRWAY

In a study completed in 2008 (3), 30 soil samples were collected from a calcareous soil fairway in Goodyear, Ariz. The soils were analyzed with ammonium acetate at pH 7.0 and at pH 8.5. Averaged over the 30 soils, the extractant with the neutral pH overestimated Ca by 1,800 ppm (3,600 lbs/acre) (Figure 1), and Mg by 120 ppm (240 lbs/acre). Moreover, the average Na percentage (ESP) was calculated at 13% with the neutral extractant and more than 18% for the elevated pH solution (Figure 2). These soils are classified as sodic, or sodium affected soils, but are categorized incorrectly when using the wrong extractant. How does this affect the gypsum requirement in this example? Based on the pH 7.0 solution, the gypsum requirement averages 3,000 lbs/acre to reduce the ESP to 8%, but increases to nearly 4,500 lbs/acre when using the correct extractant. This scenario is not uncommon in the Southwest, where native soils and sand rootzones are often calcareous and Na is high from irrigation inputs.

SUN LAKES, ARIZ., GOLF COURSE FAIRWAY

In a second example, a superintendent in Sun Lakes, Ariz., struggled with turf on his 12th fairway for several years. In

fact, the turf was so thin, the members were not allowed to drive on the fairway. Soil testing using the Mehlich 3 extractant revealed Ca levels equaled about 7,400 ppm, Na levels at 1,700 ppm, and an ESP of 14%. Recommendations called for an annual gypsum program at about 3,100 lbs/acre, in addition to frequent aeration. However, once the correct soil testing procedure was used, the data revealed that Na levels remained unchanged, but Ca decreased to only 4,900 ppm and consequently, the ESP increased to 21%. As a result, gypsum applications were increased to 6,700 lbs/acre/year and the superintendent employed a more aggressive aeration and leaching strategy. After one year, Ca levels soared to nearly 10,000 ppm (as measured with the correct extraction), Na dropped to about 1,000 ppm, and the ESP decreased from 21% to only 7.9%. More importantly, members can now enjoy the turf conditions on this fairway all year long.

WHY NOT USE THE WATER-BASED METHOD INSTEAD?

The water-based extractant, also known as the saturated paste test, offers a snapshot in time of the nutrients in the soil-water solution and those that are immediately soluble. A saturated paste is made by mixing the soil with enough water to completely fill the

pore space, yet not so much that any water rests on top of the soil. The soil-water paste is poured into a funnel lined with filter paper and placed over a vacuum to suck the soil solution from the mixture. The filtered solution is analyzed for nutrient content.

The saturated paste test shows the nutrients immediately available during one irrigation event, but keep in mind that the values will be different during the next irrigation cycle or rainfall event. The water-based test does not include the nutrients held on soil exchange sites or those that are moderately soluble, which are available for plant use. Unfortunately, some labs still report that the nutrients extracted with solutions such as ammonium acetate are not available for plant use. As a result, some turf managers will use the saturated paste test to determine fertilizer requirements, but such an approach will lead to unnecessary nutrient applications.

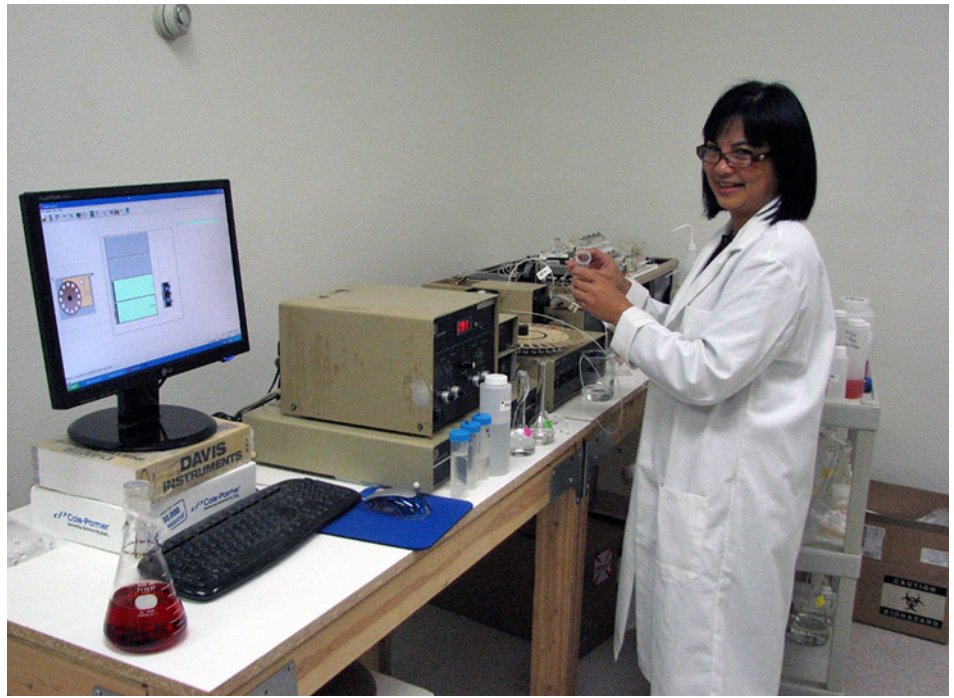
Nutrient levels found in saturated paste tests will be considerably lower than other extraction methods and should not be used to base fertilizer programs. Calcium and potassium are good examples of nutrients that are sometimes applied as a result of low values reported on a water-based extraction. It is not uncommon for Ca and K levels from a water-based test to register only 4-5% of those found on

other extractions. For example, a recently collected soil test from a golf course green in Arizona revealed Ca and K values of 3,000 and 230 ppm, respectively, with an ammonium acetate extraction (pH 8.5). The water-based extraction yielded only 67 ppm Ca and 11 ppm K. Tissue tests confirmed both Ca and K were sufficient in the plant, even though nutrient levels in solution were low, as was expected. If the water-based test was the only method used, one might fertilize heavily with Ca and K. It is known that excessive Ca additions typically reduce tissue K and Mg, and conversely, over-applying K often results in reduced plant tissue Ca and Mg levels.

The water-based extraction should be used to determine total soluble salts, soil pH, and the Sodium Adsorption Ratio (SAR). Keep in mind that the SAR is a useful tool to predict the Na hazard of the soil, but should not be confused with the percent Na that is often reported on saturated paste tests.

I GROW TURF ON AN ALKALINE, CALCAREOUS SOIL: WHICH LAB SHOULD I CHOOSE?

Research is needed to develop new extractants that are suitable for a



Using the wrong extracting solution on soils that contain calcite or gypsum can underestimate fertilizer and soil amendment requirements.

wide variety of soil types, but as of right now, the only commercially available extractant suitable for alkaline, calcareous soils is the elevated pH ammonium acetate extractant. Early in this article the question was raised whether you would change to a more accurate soil testing method. If you have made it this far, you likely

answered “yes,” and you may consider contacting one of the following laboratories that offer the elevated pH ammonium acetate procedure:

Kuo Testing Labs, Inc.
Othello, WA
<http://kuotesting.com>

MotZZ Laboratory, Inc.
Tempe, AZ
<http://www.motzzlaboratory.com>

Brookside Laboratories, Inc.
New Knoxville, OH
<http://www.blinc.com>

Best-Test Analytical Services
Moses Lake, WA
<http://www.besttestlabs.com>

Soiltest Farm Consultants, Inc.
Elevated pH extraction available upon request
Moses Lake, WA
<http://www.soiltestlab.com>

Note:
The list of laboratories offered here is not inclusive, and you might want to contact the laboratory you are currently working with regard to the elevated pH ammonium acetate method.



A “universal” extracting solution is not currently available, so turf managers must choose the right extractant for the soil type at their courses.



In the desert southwest, where irrigation water often contains high sodium levels, it is imperative that agronomic programs are based on accurate soil data.

WHY CAN'T WE FIND A SUITABLE EXTRACTANT FOR ALL SOILS?

Research is ongoing to find a soil testing extractant suitable for a wide variety of soil types with diverse pH, CEC, and calcium carbonate levels. One such extractant that shows potential is a dilute solution of strontium chloride (SrCl_2). Dr. Micah Woods' research compared SrCl_2 to commonly used extractants to determine if the SrCl_2 method may be used to measure the basic cations and ECEC (4). His research revealed the SrCl_2 method works very well regardless of calcium carbonate content and soil pH; however, it is generally limited to soils with fairly low CEC values (< 6 meq/100g soil). Dr. Ketterings and other scientists at Cornell University are currently studying the ability of the SrCl_2 extraction to accurately assess soil cations on higher CEC soils.

In another study, Dr. Bob Miller and Brian Whitlark sent 18 soils to five different laboratories across the United States. The soils were analyzed using

six different soil testing extractants. The SrCl_2 method and a new potential extractant called silver-thiourea were evaluated, in addition to the commonly used extracting solutions. The soils were divided into groups that contain a range of CEC values (0-5, 5-10, 10-20, 20-30 and >30 meq/100g soil). The soils represented a diverse cross section of soil texture (clay content 5-60%, sand content 11-91%) and calcium levels (21-9760 ppm). The data from this evaluation may be available about the time this article is published.

Ideally, labs may one day use a single extractant to easily and efficiently assess soil nutrients regardless of soil pH, CEC and calcium carbonate content. If and when such a solution is available, it will simplify soil testing interpretations — a welcome notion in the complex world of soil testing.

REFERENCES

1. Normandin, V., Kotuby-Amacher, J., and Miller, R. O. 1998. Modifications of the ammonium acetate extractant for the determination of exchangeable

cations in calcareous soils. *Commun. Soil Sci. Plant Anal.* 29:1785-1791.

2. St. John, R. A., and Christians, N. E. 2010. [Special approaches are needed when testing calcareous sands.](#) Online. *Applied Turfgrass Science* doi:10.1094/ATS-2010-0831-01-RS.

3. Whitlark, B., and Umeda, K. 2008. Unpublished Data.

4. Woods, M.S. 2006. [Nonacid Cation Bioavailability in Sand Rootzones.](#) PhD dissertation. Cornell University.

5. Woods, M. S., Ketterings, Q. M., and Rossi, F. S. 2005. [Measuring the Effects of Potassium Application on Calcium Magnesium Availability in a Calcareous Sand.](#) *International Turfgrass Society Research Journal*. Volume 10.

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