Soil testing methods for sand-based putting greens

The accuracy of soil test results varies depending on the type of test that is used.

In research at Iowa State University, a set of 24 manufactured sand samples was created for quantifying the accuracy of different analysis techniques for measuring exchangeable cations and cation exchange capacity.
Photo courtesy of R. St. John

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The procedure for measuring exchangeable basic cations involves using an extracting solution that is passed through a soil sample. The extracting solution removes all the exchangeable cations from the cation exchange sites. The collected solution is then taken to a machine, and the exchangeable cation concentrations are measured. Then, it is common to "add up" all of the exchangeable cations and their relative charges to create an estimate of cation exchange capacity (CEC). This summation of exchangeable cations is referred to as the estimated cation exchange capacity (ECEC).

A double-extraction technique more accurately measures a soil's cation exchange capacity by using two processes: a saturating step and an extracting step. The soil sample is saturated several times with a saturating solution that is fairly concentrated with a known index cation (for example, the ammonium ion, NH_4^+) that replaces all of the exchangeable cations in the soil with the index cation. The second solution, the extracting solution, is a concentrated solution of a second cation (for example, the magnesium ion, Mg^{+2}). The sample is washed several times with the extracting solution. The solution is collected from the sample, and the NH_4^+ is measured. Essentially, one NH_4^+ ion will occupy one negatively charged site, and one can relate the number of NH_4^+ ions extracted from the sample to the number of negative charge sites in the soil cation exchange capacity.

However, most soil test reports do not distinguish between estimated cation exchange capacity and measured cation exchange capacity because the difference is usually negligible. However, many soil testing procedures dissolve calcium carbonate ($CaCO_3$), increasing the measured extractable calcium concentration. Because the exchangeable cations are added together to create an estimated cation exchange capacity, this dissolution will also increase the calculated estimate of the cation exchange capacity.

On the high-sand, low-organic matter, calcareous root zones used for construction of some putting greens, the dissolution of calcium carbonate can greatly influence the results. Therefore, the objectives of this research were to determine the effects of calcium carbonate on different soil testing procedures and to make recommendations for soil testing methodology for sand-based putting greens.

Effect of calcium carbonate on different procedures

A set of 24 manufactured sand samples was created for quantifying the effect of calcium carbonate on different analysis techniques for measuring exchangeable cations and cation exchange capacity. Each sand sample was created in the lab using a one-pound bag of silica sand as a base and adding increasing percentages by volume of either a reagent-grade (laboratory-grade) calcium carbonate or a local calcareous sand that had 11% calcium carbonate (Table 1). Subsamples were taken from each of the 24 samples for each analysis. The extraction techniques for exchangeable cations, cation exchange capacity and estimated cation exchange capacity performed in this study are listed in Tables 2 and 3.

Which exchangeable cation tests are best?

The different extractants affected the solubility of calcium carbonate in different magnitudes. The extractable calcium concentrations from sands amended with reagent-grade calcium carbonate were nearly double the calcium concentrations from sands amended with calcareous sand. This difference is to be expected, and it is attributable to particle size and purity. The laboratory-grade calcium carbonate was a finely ground pure powder. The sand, however, had a much larger particle size, and the individual particles of sand-based calcium carbonate probably contained impurities; both these factors will reduce the dissolution rate of calcium carbonate.

Mehlich 3

Mehlich 3 dissolved as much as 400% more lab-grade calcium carbonate than any other procedure. Although Mehlich 3 did not appear to dissolve as much calcium carbonate from silica sands amended with natural calcareous sand as from lab-grade samples, Mehlich 3 should not be used to measure exchangeable cations or estimated cation exchange capacity of calcareous sand samples because the potential for calcium carbonate dissolution is so great.

Ammonium chloride

Compared to the ammonium acetate (NH_4OAc pH 7.0) method and Mehlich 3, the ammonium chloride (NH_4Cl) method (5) reduced extractable calcium concentrations. Because of the labor involved with the post-extraction procedures and its limited effectiveness, it is doubtful that many routine soil testing laboratories will adopt this procedure.

Ammonium acetate

Raising the pH of the industry standard ammonium acetate (NH_4OAc) solution from pH 7.0 to pH 8.1 reduced the calcium concentration of the soil extracts an average of 33%. Raising the pH of the industry standard ammonium acetate pH 7.0 procedure to a pH of 8.1 to limit calcium carbonate dissolution has been recommended for calcareous soils (5) and appears to reduce calcium carbonate dissolution. Based on the results in this paper, measuring exchangeable basic cations of calcareous sand-based samples should be done by ammonium acetate at pH 8.1 because of its reduced calcium carbonate dissolution and its ease of use.

Water-extract procedure

The average nutrient concentration recorded using the water-extract procedure was considerably lower than the extractable cation concentrations. Moreover, the nutrient concentrations from the water-extract procedure did not directly correlate with the extracted nutrient concentrations. Because the water-extraction method only analyzes the soluble and solution phase elements, nutrient concentrations from water-extraction techniques are going to be very small compared to exchangeable nutrient concentrations derived from chemical extractions.

The solution and soluble portions of nutrients in the soil are going to change easily and rapidly throughout the season because of fertilizer, irrigation and rainfall inputs. Using water-extractable nutrients to gauge the nutritional status of sand-based samples can be difficult and misleading. Measuring exchangeable nutrients will offer

Manufactured sand samples

Sample no.	% silica sand	% amendment	Type of amendment	% $CaCO_3$
1	100	0	lab-grade*	0
2	99.5	0.5	lab-grade	0.5
3	99	1	lab-grade	1
4	98	2	lab-grade	2
5	97	3	lab-grade	3
6	96	4	lab-grade	4
7	95	5	lab-grade	5
8	90	10	lab-grade	10
9	85	15	lab-grade	15
10	80	20	lab-grade	20
11	75	25	lab-grade	25
12	70	30	lab-grade	30
13	99.5	0.5	calcareous sand†	0.055
14	99	1	calcareous sand	0.11
15	98	2	calcareous sand	0.22
16	97	3	calcareous sand	0.33
17	96	4	calcareous sand	0.44
18	95	5	calcareous sand	0.55
19	90	10	calcareous sand	1.1
20	85	15	calcareous sand	1.65
21	80	20	calcareous sand	2.2
22	75	25	calcareous sand	2.75
23	70	30	calcareous sand	3.3
24	0	100	calcareous sand	11

*Reagent-grade calcium carbonate (Fisher Scientific C64-500 CAS 471-34-1)
†Local calcareous sand with a calcium carbonate percentage of 11% determined gravimetrically (2).

Table 1. List of "manufactured sand" samples created in the laboratory to measure the effects of calcium carbonate on different soil testing procedures for measuring exchangeable cations, cation exchange capacity and estimated cation exchange capacity. The amendments were either reagent-grade calcium carbonate (lab-grade) or a local calcareous sand and were added by a percent volume basis. The 24 bags of air-dried sand mixed with amendment were subsampled for soil analysis.

Soil testing methods

Method	Reference
0.5 M ammonium acetate pH 7.0 (NH_4OAc pH 7)	5
0.5 M ammonium acetate pH 8.1 (NH_4OAc pH 8.1)	5
0.5 M ammonium chloride pH 7.0 (NH_4Cl)	5
Mehlich 3	1
Water extract	4

Table 2. List of methods used to determine exchangeable cations of 24 samples of amended sand.

Methods for CEC and ECEC

Method	Reference
0.2M $CaCl_2$/0.5M $Mg(NO_3)_2$	6
0.5M NaOAc - 0.1M NaCl/0.5M $Mg(NO_3)_2$	3
ECEC from NH_4OAc pH 7	5
ECEC from NH_4OAc pH 8.1	5
ECEC from NH_4Cl	5
ECEC from Mehlich 3	1

Table 3. List of methods used to determine cation exchange capacity (CEC) and estimated cation exchange capacity (ECEC) of the 24 samples of amended sand. ECEC was determined by summation of exchangeable basic cations.

insight into long-term nutritional status.

Which CEC/ECEC tests are best?

The effect of calcium carbonate dissolution was nearly negligible with a double-extraction cation exchange capacity technique like calcium chloride/magnesium nitrate ($CaCl_2/MgNO_3$) or sodium actetate-sodium chloride/magnesium nitrate [NaOAc-NaCl/$Mg(NO_3)_2$] compared to creating an estimated cation exchange capacity technique that sums together the extractable cations. Therefore, to achieve accurate cation exchange capacity measurements of calcareous sand-based samples, only double-extracting techniques should be used, and estimated cation exchange capacity estimates should be avoided.

With that said, measuring small differences in cation exchange capacity by using different techniques may not provide that much more valuable information to the superintendent. It is more important for the superintendent to know that the sand-based green has a low cation exchange capacity and that care should be taken when developing a fertilization program. However, using more complicated double-extraction techniques for accurately measuring cation exchange capacity may be important when conducting research or trying to compare root-zone media from different locations. Accurate cation exchange capacity measurements taken with double-extraction techniques should also be used when evaluating the statements of products that claim to have the ability to modify the cation exchange capacity of a soil.

What about silica sand greens?

Because silica sand is relatively unaffected by any of the procedures used in the study, pure silica sand samples can potentially be analyzed with any procedure studied in this research. But if the root-zone mix contains any carbonates, the samples should be treated and analyzed as calcareous.

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The research says

➔ **Because sand-based** putting greens have limited nutrient-holding capacity, understanding the nutritional status of the root-zone media is essential to proper turfgrass management. This research evaluated different soil testing techniques for measuring exchangeable basic cations and cation exchange capacity.

➔ **The presence of** calcium carbonate can greatly affect the results of various soil testing techniques.

➔ **Of the methods** examined in this study, the ammonium acetate pH 8.1 method appears to be the best extractant for measuring exchangeable cations from calcareous sand samples, but it still dissolved appreciable quantities of calcium carbonate.

➔ **Calculating an estimated** cation exchange capacity by summation of exchangeable cations measured from any of the procedures evaluated in this research, including ammonium acetate pH 8.1, is not advised for samples from calcareous sands, and a double-extraction technique should be used when extremely accurate tests are needed.