

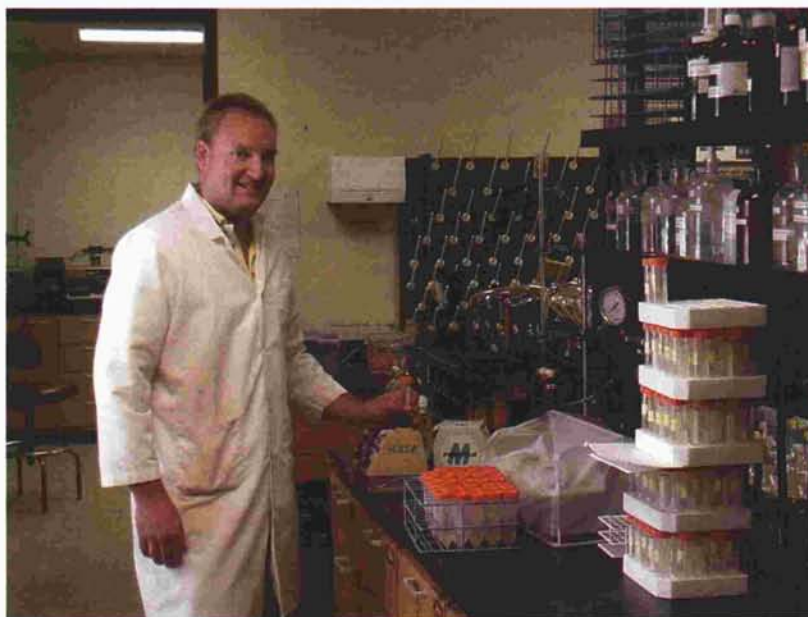
# Soil Testing Methods for Sand-Based Putting Greens

Iowa State University research explores nutrient-holding capacity of putting green rootzones.

BY RODNEY ST. JOHN AND NICK CHRISTIANS

The procedure for measuring exchangeable basic cations involves using an extracting solution that is passed through a soil sample, removing 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 provide an estimation of cation exchange capacity. This summation of exchangeable cations is referred to as the ECEC, or estimated cation exchange capacity.

To more accurately measure a soil's cation exchange capacity, CEC, a double extraction technique should be used that utilizes 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 (e.g.,  $\text{NH}_4^+$ ) 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 another cation (e.g.,  $\text{Mg}^{+2}$ ). The sample is washed several times with the extracting solution. The solution is collected from the sample and the  $\text{NH}_4^+$  is measured. Essentially, one  $\text{NH}_4^+$  ion will occupy one negatively charged site, and one can relate the number of  $\text{NH}_4^+$  ions extracted from the sample to the number of negative charge sites in the soil, the CEC.



Rootzones of many putting greens, particularly in the Midwest, are constructed from calcareous sand, i.e. sands that contain more than 1% free calcium carbonate. However, current soil analysis methods can overestimate calcium and cation exchange capacity (CEC) of calcareous sands. Research conducted at Iowa State University investigated various methods to attain more accurate estimations of CEC of calcareous sand.

However, most soil test reports do not designate this distinction between ECEC and CEC because the difference between the ECEC and measured CEC is usually negligible. But many soil testing procedures dissolve calcium carbonate ( $\text{CaCO}_3$ ), which will cause an increase in the measured extractable calcium concentration. Since the exchangeable cations are added together to create an ECEC, this dissolution will also increase the calculated estimation of the cation exchange capacity.

On the high-sand, low-organic matter, calcareous rootzones 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  $\text{CaCO}_3$  on different soil testing procedures and to make recommendations for soil testing methodology for sand-based putting greens.

## EFFECT OF CALCIUM CARBONATE ON SEVERAL PROCEDURES

A set of manufactured sand samples was created for quantifying the effect of  $\text{CaCO}_3$  on different analysis techniques for measuring exchangeable cations and

CEC. Twenty-four sand samples were created in the lab using a silica sand base and adding increasing percentages by volume of either a laboratory-grade  $\text{CaCO}_3$  or local calcareous sand. The calcareous sand had 11%  $\text{CaCO}_3$ . There were 24 one-pound bags of silica sand mixed with either reagent-grade  $\text{CaCO}_3$  or calcareous sand from which sub-samples were taken for each analysis. The extraction techniques for exchangeable cations, CEC and ECEC, performed in this study are listed in Tables 2 and 3.

### WHICH EXCHANGEABLE CATION TESTS ARE BEST?

The different extractants affected the solubility of  $\text{CaCO}_3$  in different magnitudes. The extractable Ca concentrations

from sands amended with reagent-grade  $\text{CaCO}_3$  were nearly double compared to Ca concentrations from sands amended with calcareous sand. This is to be expected, and it is attributed to particle size and purity. The laboratory-grade  $\text{CaCO}_3$  was a finely ground pure powder, whereas the sand had a much larger particle size, and the individual particles of sand-based  $\text{CaCO}_3$  probably contained impurities, both of which are going to cause a reduced dissolution rate.

Mehlich 3 dissolved a much larger proportion of lab-grade calcium carbonate than any other procedure, as much as 400% more. While Mehlich 3 did not appear to dissolve as much  $\text{CaCO}_3$  from silica sands amended with

natural calcareous sand as from lab-grade samples, Mehlich 3 should not be used to measure exchangeable cations or ECEC of calcareous sand samples, since there is such great potential for  $\text{CaCO}_3$  dissolution.

The  $\text{NH}_4\text{Cl}$  (ammonium chloride) method (5), which utilizes calculations and corrections to estimate the amount of calcium carbonate that was dissolved, reduced extractable Ca concentrations compared to ammonium acetate at pH 7.0 ( $\text{NH}_4\text{OAc}$  pH 7.0) and Mehlich 3. But, due to the labor involved with the several post-extraction procedures needed and its limited effectiveness, it is doubtful that many routine soil testing laboratories will adopt this procedure.

Raising the pH of the industry standard ammonium acetate ( $\text{NH}_4\text{OAc}$ ) solution from pH 7.0 to pH 8.1 reduced the Ca concentration of the soil extracts an average of 33%. Raising the pH of the industry standard  $\text{NH}_4\text{OAc}$  pH 7.0 procedure to a pH of 8.1 to limit  $\text{CaCO}_3$  dissolution is recommended for calcareous soils (5) and appears to reduce  $\text{CaCO}_3$  dissolution. Based on the results in this paper, measuring exchangeable basic cations of calcareous sand-based samples should be done by  $\text{NH}_4\text{OAc}$  at pH 8.1 because of its reduced  $\text{CaCO}_3$  dissolution and its ease of use.

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. Since 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 due to fertilizer, irrigation, and rainfall

**Table 1**

List of "manufactured sand" samples created in the laboratory to measure the effects of  $\text{CaCO}_3$  on different soil testing procedures for measuring exchangeable cations, CEC and ECEC. The amendments were either reagent grade  $\text{CaCO}_3$  (Lab Grade) or a local calcareous sand (Calcareous) and were added by a percent volume basis. The 24 bags of air-dried sand mixed with amendment were sub-sampled for soil analysis.

Sample Number	% Silica Sand	% Amendment	Type of Amendment	% $\text{CaCO}_3$
1	100	0	Lab Grade <sup>1</sup>	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 <sup>2</sup>	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

<sup>1</sup>Reagent-grade calcium carbonate  $\text{CaCO}_3$  (Fisher Scientific C64-500 CAS 471-34-1)

<sup>2</sup>Local calcareous sand with a  $\text{CaCO}_3$  percentage of 11% determined gravimetrically (2)

**Table 2**  
List of methods used to determine exchangeable cations of 24 samples of sand mixed with amendment

Method	Reference
1 0.5M Ammonium Acetate pH 7.0 (NH <sub>4</sub> OAc pH 7.0)	5
2 0.5M Ammonium Acetate pH 8.1 (NH <sub>4</sub> OAc pH 8.1)	5
3 0.5M Ammonium Chloride pH 7.0 (NH <sub>4</sub> Cl)	5
4 Mehlich 3	1
5 Water Extract	4

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

Method	Reference
1 0.2M CaCl <sub>2</sub> / 0.5M Mg(NO <sub>3</sub> ) <sub>2</sub>	6
2 0.5M NaOAc – 0.1M NaCl / 0.5M Mg(NO <sub>3</sub> ) <sub>2</sub>	3
3 ECEC from NH <sub>4</sub> OAc pH 7.0	5
4 ECEC from NH <sub>4</sub> OAc pH 8.1	5
5 ECEC from NH <sub>4</sub> Cl	5
6 ECEC from Mehlich 3	1

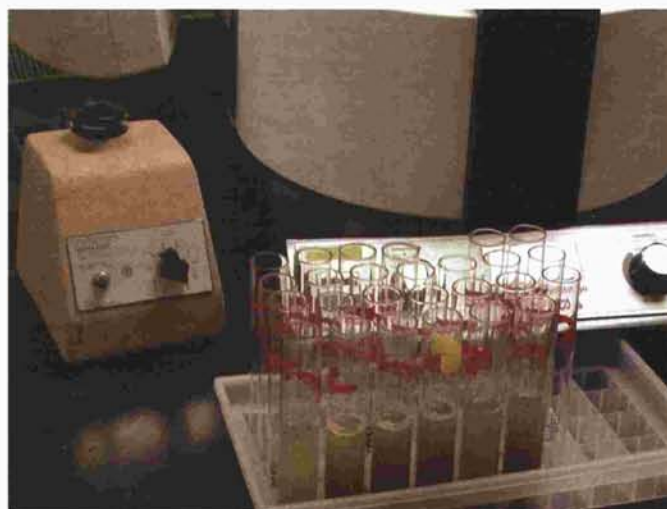
inputs. Using water-extractable nutrients to gauge the nutritional status of sand-based samples can be difficult and misleading. Measuring exchangeable nutrients will offer insight to long-term nutritional status.

### WHICH CEC/ECEC TESTS ARE BEST?

The effect of CaCO<sub>3</sub> dissolution was nearly negligible when using a double-extraction CEC technique like CaCl<sub>2</sub>/MgNO<sub>3</sub> or NaOAc–NaCl/Mg(NO<sub>3</sub>)<sub>2</sub> compared to creating an ECEC technique that sums together the extractable cations. Therefore, to achieve accurate CEC measurements of calcareous sand-based samples, only double extracting techniques should be used, and ECEC estimates should be avoided.

With that being said, measuring small differences in CEC by using different techniques may not provide that much more valuable information to the turfgrass manager. It is more important for the turfgrass manager to know that the sand-based green has a low CEC and that care should be taken when

developing a fertilization program. But using more complicated double-extraction techniques for accurately measuring CEC may be important when conducting research or trying to compare rootzone media from different locations. Lastly, accurate CEC measurements that utilize double-extraction techniques should also be used when evaluating the statements of products that claim to have the ability to modify the CEC of a soil.



Various extractants were used to best quantify cation exchange capacity (CEC) of calcareous sand because current methods tend to overestimate CEC by dissolving some of the free calcium carbonate contained in calcareous sand.

### WHAT ABOUT SILICA SAND GREENS?

Since 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 rootzone mix contains any carbonates, the samples should be treated as calcareous and analyzed as such.

### ACKNOWLEDGEMENTS

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# CONNECTING THE DOTS

A Q&A with DR. RODNEY ST. JOHN regarding testing methods for sand-based putting greens.

**Q: Your research suggests that estimates of cation exchange capacity (CEC), or the ability of rooting media to hold nutrients, can be quite different on calcareous sands depending on the choice of extractant. How much different can these estimates be?**

**A:** Depending on the type of extractant and the sand sample, the difference can be as much as 10 times. We've seen reported CEC change from 10-12 meq/100g when using ammonium acetate and summing the cations to 1-2 meq/100g when using a double-extraction type procedure.

**Q: To your knowledge, what proportion of sand-based putting greens are constructed from calcareous sand? Is this a regional issue?**

**A:** Many greens across the United States are constructed with calcareous sands, most predominately in the Midwest. However, calcareous sands are found in several parts of the country. Most calcareous sands are based on calcium carbonates and are derived from limestone, and some calcareous sands near the coasts are derived from shells. There are simple procedures available at soil testing laboratories that can determine the amount of carbonates present in your sand.

**Q: Can an overestimation of cation exchange capacity lead to serious errors in nutrient management of putting greens built with calcareous sand?**

**A:** Yes, if the CEC is used in making fertility recommendations or management decisions, like those derived from the basic cation saturation ratio theory that involve adding calcium, magnesium, or potassium to correct a cation ratio. The safest approach to managing sand-based greens is to utilize light and frequent fertilizer applications to prevent leaching.

**Q: To your knowledge, are most labs using a double-extraction technique to measure CEC or sandy media?**

**A:** To our knowledge, most labs are not using a double-extraction technique to measure CEC. It is generally a procedure used in research where very accurate results are required. Hopefully, with more research, a procedure can be developed or adopted that is both simple and accurate.

**Q: Do you think that the results of your work will affect how labs measure CEC of sand rootzone mixes?**

**A:** Maybe. At this point, we just want to draw people's attention to the facts that the results from some CEC tests can be misleading if you have a calcareous sand rootzone, and that there are other procedures available that can more accurately measure CEC.

JEFF NUS, PH.D., *manager, Green Section Research.*

Research at Iowa State University tested five soil testing techniques to measure exchangeable basic cations from sand-based rooting media.



*Editor's Note:* A more complete summary of this research may be found on USGA Turfgrass and Environmental Research Online at <http://usgatero.msu.edu/v05/n13.pdf>.

RODNEY ST. JOHN, PH.D., *Assistant Professor/Turfgrass Extension Specialist, Horticulture and Forestry Dept., Kansas State University, Olathe, Kans.;* NICK CHRISTIANS, PH.D., *Professor of Turfgrass Management, Dept. of Horticulture, Iowa State University, Ames, Iowa.*