# Turfgrass and Environmental Research Online

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Rootzones of many putting greens, particularly in the Midwest, are constructed from calcareous sand, sand that contains 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.

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## PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 290 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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# Soil Testing Methods for Sand-based Putting Greens

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## SUMMARY

Sand-based putting greens have limited nutrient holding capacity. Therefore, understanding the nutritional status of the root-zone media is essential to proper turfgrass management. This research is focused on basic cation (calcium, magnesium, potassium, etc.) nutrition of sand-based greens. Specifically, we are looking at different soil testing techniques for measuring exchangeable basic cations and cation exchange capacity (CEC). This study's findings were:

- The presence of $CaCO_3$ can greatly affect the results of various soil testing techniques.
- Of the procedures examined in this research, the $NH_4OAc$ pH 8.1 appears to be the best extractant for measuring exchangeable cations from calcareous sand samples.
- The $NH_4OAc$ pH 8.1 technique had the lowest rates of dissolution of $CaCO_3$, but it still dissolved appreciable quantities of $CaCO_3$. Therefore, calculating an ECEC by summation of exchangeable cations measured from any of the procedures evaluated in this research, including $NH_4OAc$ 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.

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 be able to create an estimation of cation exchange capacity. This summation of exchangeable cations is referred to as the ECEC, or estimated cation exchange capacity.

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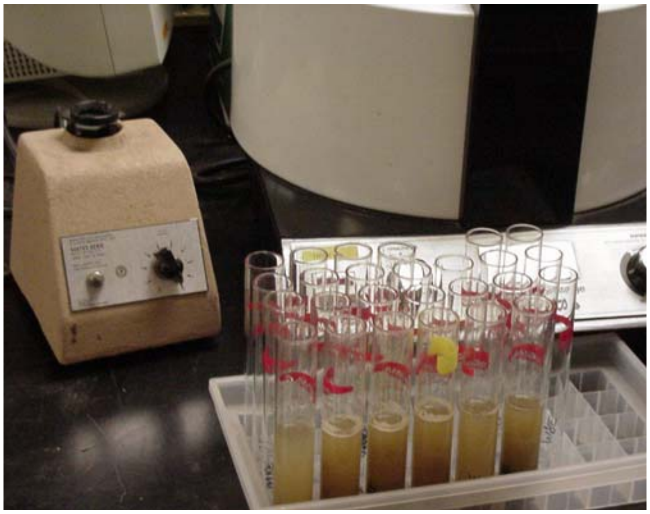
To more accurately measure a soil's CEC, a double extraction technique should be used that utilizes two processes: a saturating step and an extracting step. The soil sample is saturated several times with a saturating solution that is fairly concentrated with a known index cation (e.g. $NH_4^+$) that 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 (e.g. $Mg^{+2}$). 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 on $NH_4^+$ ions extracted from the sample to the number of negative charge sites in the soil, CEC.

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 ($CaCO_3$), which will cause an increase in the measured extractable calcium concentration. Since the exchangeable cations are added togeth-



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.

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| Sample # | % 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 $CaCO_3$ (Fisher Scientific C64-500 CAS 471-34-1)

‡ Local calcareous sand with a $CaCO_3$ percentage of 11% determined gravimetrically (2).

**Table 1.** List of 'manufactured sand' samples created in the laboratory to measure the effects of $CaCO_3$ on different soil testing procedures for measuring exchangeable cations, CEC and ECEC. The amendments were either reagent grade $CaCO_3$ (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 sub-sampled for soil analysis.

er 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 affects of $CaCO_3$ on different soil testing procedures and to make recommendations for soil testing methodology for sand-based putting greens.

## Effect of Calcium Carbonate on Different Procedures

A set of manufactured sand samples was created for quantifying the effect of $CaCO_3$ 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 $CaCO_3$ or a local calcareous sand. The calcareous sand had 11%

| 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 sand mixed with amendment samples

$CaCO_3$. There were 24 one-pound bags of silica sand mixed with either reagent grade $CaCO_3$ 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 $CaCO_3$ in different magnitudes. The extractable Ca concentrations from sands amended with reagent grade $CaCO_3$ were nearly double compared with 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 $CaCO_3$ was a finely ground pure powder; whereas the sand had a much larger particle size and the individual particles of sand-based $CaCO_3$ 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 $CaCO_3$ 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 $CaCO_3$ dissolution.

The $NH_4Cl$ method (5), which utilizes calculations and corrections to estimate the amount of calcium carbonate that was dissolved, reduced extractable Ca concentrations compared to $NH_4OAc$ pH 7.0 and Mehlich 3. But, due to the labor involved with the several post extraction procedures needed and its limited effectiveness, it

|  | Method | Reference |
|---|---|---|
| 1 | 0.2M $CaCl_2$ / 0.5M $Mg(NO_3)_2$ | 6 |
| 2 | 0.5M NaOAc - 0.1M NaCl / 0.5M $Mg(NO_3)_2$ | 3 |
| 3 | ECEC from $NH_4OAc$ pH 7 | 5 |
| 4 | ECEC from $NH_4OAc$ pH 8.1 | 5 |
| 5 | ECEC from $NH_4Cl$ | 5 |
| 6 | ECEC from Mehlich 3 | 1 |

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

is doubtful that many routine soil testing laboratories will adopt this procedure.

Raising the pH of the industry standard ammonium acetate ($NH_4OAc$) 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 $NH_4OAc$ pH 7.0 procedure to a pH of 8.1 to limit $CaCO_3$ dissolution is recommended for calcareous soils (5) and appears to reduce $CaCO_3$ dissolution. Based on the results in this paper, measuring exchangeable basic cations of calcareous sand-based samples should be done by $NH_4OAc$ at pH 8.1, because of its reduced $CaCO_3$ 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 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.

The results of this study indicate calculating an estimated cation exchange capacity of calcareous sand by summation of exchangeable cations measured from any of the procedures evaluated in this research, including $NH_4OAc$ pH 8.1, is not advised for samples from calcareous sand-based rootzones. A double extraction technique should be used when extremely accurate tests are needed.

## Which CEC/ECEC Tests are Best?

The effect of $CaCO_3$ dissolution was nearly negligible when using a double extraction CEC technique like $CaCl_2/MgNO_3$ or NaOAc-$NaCl/Mg(NO_3)_2$ 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.

## 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.

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