

QUICK TEST FOR CATION EXCHANGE CAPACITY IN SOILS

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ABSTRACT

The objective of this study was to develop a quick method for estimating the cation exchange capacity (CEC) of soils, suitable for use in an introductory soil science laboratory, and possibly for routine soil testing. In this method, the soil is reacted with a calcium solution, such as calcium acetate, and the excess removed by filtration. The soil is then suspended in a sodium oxalate solution, and the electrical conductivity (EC) of the suspension determined. For a wide range of topsoils and subsoils from North Dakota, the method was highly correlated ($r^2 = 0.986$) with the standard sodium acetate method. A simplified version of the test has proven to work reliably in an introductory soil science laboratory. Students are generally able to estimate the CEC of soil samples to within 1 or 2 mmol(+)/kg of the result given by the sodium acetate method. The method takes less than 30 minutes to perform, uses no flammable solvents, and the only specialized piece of equipment needed is a conductivity meter.

INTRODUCTION

Cation exchange capacity is an important fundamental property of soils. Soil CEC is generally determined by procedures representing one of three principles. In an index ion procedure, all exchangeable cations are replaced with a single index ion, usually ammonium or sodium. The excess saturating solution is removed, usually with an alcohol, and the index ion removed by another salt, and the index ion determined. In a sum-of-cation method, the ions on the soil cation exchange sites are removed by a salt solution, typically ammonium acetate, and determined individually. The CEC is estimated by summing the charges of all cations removed. In a forced exchange method, the cations on the cation exchange sites are replaced, typically with Ba^{2+} . After removal of the excess Ba^{2+} , another ion is “forced” on the exchange by reaction with a salt solution that precipitates the Ba^{2+} , typically as barium sulfate. A traditional index ion or forced exchange method requires tedious equilibration and centrifugation steps, which renders such procedures impractical for undergraduate teaching or high-volume soil testing. Commercial soil testing labs usually estimate CEC by a sum-of-cation method. This method is often inappropriate for Great Plains soils, as the extracting solution most commonly used, ammonium acetate, liberates significant Ca^{2+} from $CaCO_3$, if the topsoil is calcareous, thus overestimating the CEC of the soil.

Cation exchange capacity is a very important concept, and no method for CEC was found that is suitable for undergraduate teaching purposes. The objective of this study was to develop a method for CEC that would be simple, rapid, suitable for use in teaching, and possibly for routine soil testing. The method developed falls under the “forced exchange” concept, depending on the very low solubility of calcium oxalate.

MATERIALS AND METHODS

A portion of a preliminary study is described, and an example is given of results obtained by students in an introductory soil science laboratory.

Preliminary study

Because of space constraints, only a portion of the first study can be reported here. A range of North Dakota topsoils and subsoils were air dried and crushed to pass a 2 mm sieve. The soil samples included 12 topsoils and 9 subsoils. Textures ranged from loamy sand to clay, and pH values from about 5 to 8. Two of the topsoils, and almost all of the subsoils were calcareous. Five grams of soil were placed in 125 mL Erlenmyer flasks. Fifty mL of 0.05 molar calcium acetate were added, and the contents shaken for 15 minutes. The contents were poured into a specified type of filter paper held by a common laboratory funnel. Additional 15 mL aliquots of the calcium acetate solution were placed into the flask, mixed, and added to the same filter funnel, until all of the soil had been transferred. The excess calcium acetate was allowed to drain, and all filtrates discarded. The filter paper and soil were transferred to a 250 mL wide mouth square bottle, and 50 mL of 0.05 molar sodium oxalate added. The bottles were sealed with rubber stoppers and agitated gently by hand to mix, assuring that all of the soil in the filter paper was completely suspended in the oxalate solution. Vigorous or prolonged shaking was avoided to prevent disintegration of the filter papers. Samples of the suspensions were poured into sample cups, and the EC of the suspensions determined. The analyses were done in triplicate. The CEC of separate samples of the same soils was determined in duplicate by the “Bower” sodium acetate method (Chapman, 1965).

Adaptation for teaching

The above method was further simplified for use by students. Five gram samples of topsoils (air-dried, < 2 mm) were placed directly into filter paper in a funnel. Three 25 mL portions of 0.05 molar calcium acetate were leached through the soil, allowing for five minutes for drainage after each leaching step. After the third leaching step, assuring that all free water had drained through, the filter papers and soil were placed in 250 mL bottles, and 50 mL of 0.05 molar sodium acetate added. The bottles were stoppered, and shaken gently by hand to mix. A portion of the suspensions were transferred to cups, and the EC determined. The method was calibrated for each section by inclusion of loamy sand, loam, and clay loam “standards” of known CEC by the sodium acetate method. The students prepared a graph of CEC vs EC for the three standards, and used the calibration graph to estimate the CEC of their samples. The students did their own samples in duplicate, and the entire section did the standards in triplicate.

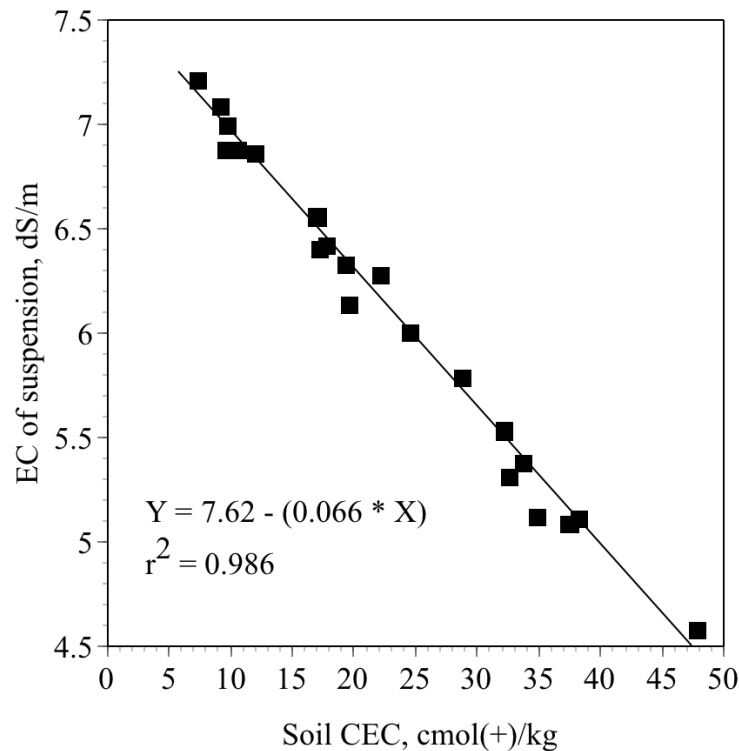
RESULTS

Preliminary study

Results of a portion of the preliminary study are shown in Figure 1. There was a linear relationship between the decline of the EC of the soil:sodium oxalate suspension and the CEC of the soil, with an r^2 value of 0.986. Similar r^2 values were obtained when unbuffered 0.05 molar CaCl_2 was used for the initial equilibration solution (data not shown). Separate studies suggested that the technique does not achieve quantitative replacement of all exchangeable cations with Ca^{2+} . In practice, a quantitative replacement is not necessary. All polyvalent cations common in

soil (Ca^{2+} , Mg^{2+} , Al^{3+}) react with oxalate and precipitate. It is only necessary to react with enough calcium acetate to assure that the monovalent cation content on the cation exchange (K^+ , Na^+) is a minor component, and to bring all of the soil samples to the same initial salinity before adding the oxalate solution.

Figure 1. Relationship between soil cation exchange capacity (CEC) and the electrical conductivity (EC) of a suspension of soil in 0.05 molar sodium oxalate, after reaction with 0.05 molar calcium acetate.



Use for teaching

Typical results obtained by students in a laboratory section of an introductory soil science class are shown in Table 1. The students performed the analysis with three “standard” soils of known CEC (via the sodium acetate method) in triplicate, and also for their assigned soil in duplicate. The students used the data for the standards to generate a calibration graph (Figure 2), and then used the calibration graph to estimate the CEC of their soil (Table 1).

Table 1. Student data from a laboratory section of an introductory soils class.

Soil series	----- Electrical conductivity -----				Est.	NaOAc
	Rep 1	Rep 2	Rep 3	Avg.	CEC†	CEC§
	----- dS/m -----				cmol(+)/kg	
Lefor	7.83	7.77	--	7.80	6	7
Daglun	6.85	6.95	--	6.90	18	17
Noonan	6.63	6.68	--	6.66	21	22
Heimdal	6.34	6.36	--	6.35	25	25
Glyndon	5.95	5.94	--	5.95	31	29
Lindaas	5.84	5.82	--	5.83	33	32
Hamerly	5.31	5.42	--	5.37	38	38
Tonka	4.70	4.70	--	4.70	47	48
Standards						
Loamy sand	7.50	7.53	7.40	7.48*	--	11*
Loam	6.77	6.85	6.75	6.79*	--	18*
Clay loam	5.60	5.82	5.54	5.65*	--	35*

†Estimated from a calibration graph, Figure 2

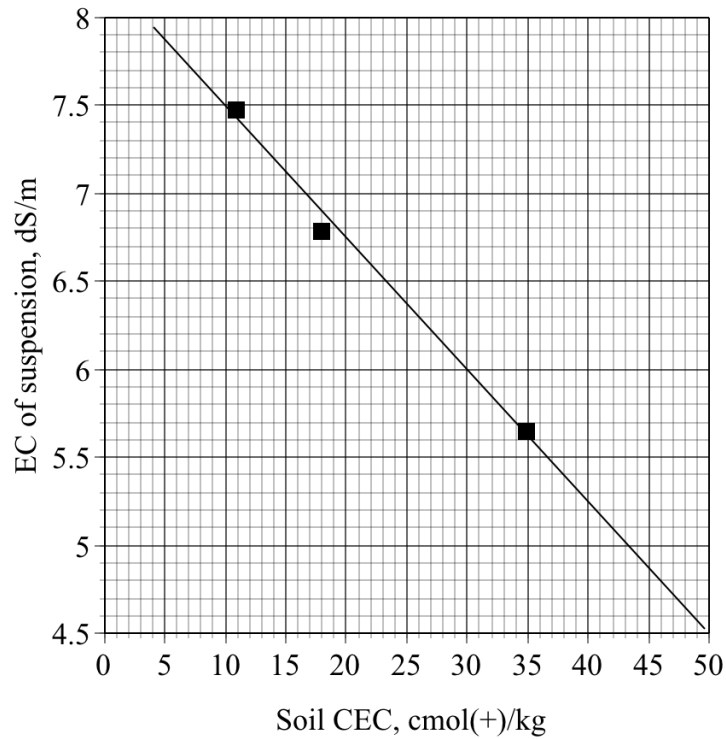
§ CEC by the sodium acetate method, performed separately

*Values used to generate calibration graph, Figure 2

The method has proven to be practical and adequately precise for teaching purposes. Perhaps with a little modification, it would prove useful for routine commercial soil testing as well.

Many grades of filter paper are not suitable for this procedure. Many common brands disintegrate during the reaction step with sodium oxalate, or stick against themselves and do not easily discharge the soil during the oxalate reaction step. We have found that 15 cm Reeve Angel 802 fluted (prefolded) papers to be suitable. Fluted papers discharge the soil readily to the oxalate solution more readily than unfluted papers, and the type of paper did not decompose quickly during the oxalate reaction step.

Figure 2. Calibration graph from student-generated data, used to estimate the CEC of the soils listed in Table 1.



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REFERENCES

Chapman, H.C. 1965. Cation-exchange capacity. In C.A. Black (ed). *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties.* Agronomy Monograph 9, American Society of Agronomy, Madison, WI. pp. 891-901.