EFFECT OF EXTRACTANT pH ON EXCHANGEABLE CATION DETERMINATION USING AMMONIUM ACETATE AND MEHLICH-3

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ABSTRACT

Neutral pH ammonium acetate is a standard soil test extractant for concentrations of exchangeable bases: calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na), which are used to estimate cation exchange capacity by summation of cations (CEC_sum) and exchangeable sodium percentage (ESP). However, the concentrations of Ca and Mg may be artificially inflated due to dissolution of free carbonates and gypsum. The study objectives were to determine the impacts on CEC_sum and ESP of four exchangeable cation extraction methods [1*N* NH_4OAc at pH 7.0, 7.5, or 8.5 (“AA_7.0”, “AA_7.5”, “AA_8.5”, respectively) or Mehlich-3 at pH 2.5 (“Meh-3”)]. The K, Mg, and Na were generally well correlated across extractants ($r^2 \geq 0.98$). However, the Ca concentrations decreased as extractant pH increased. This was most apparent with high levels of reactive carbonates and most noticeable with Meh-3. Correlations with Meh-3 CEC values were most affected when Meh-3 Ca concentrations exceeded 5000 ppm. The CEC_sum and ESP calculated from AA_7.0 and Meh-3 were not significantly different if Ca concentration values were limited to 5000 ppm).

INTRODUCTION

Exchangeable Ca, Mg, K, and Na can be determined simultaneously from soil samples using a single extractant, typically 1*N* ammonium acetate (NH_4OAc) at pH 7.0 or Mehlich-3 at pH 2.5. Concentrations of Ca, Mg and, especially, K are used in nutrient management decisions, although Ca concentrations are almost always sufficient for crop production. Additionally, the exchangeable base concentrations are used to estimate the soil’s cation exchange capacity (CEC) by the method of summation(CEC_sum). Soil testing laboratories often use the CEC_sum to estimate soil texture used to make nutrient recommendations, as well as in estimating soil sodicity. However, Ca and Mg concentrations may be artificially inflated due to dissolution of free carbonates and/or gypsum, which will inflate the CEC_sum. This overestimates the clay content. This inflation could also reduce the exchangeable sodium percentage (ESP), potentially underestimating the percent of Na and, thus, the potential for sodicity hazard.

MATERIALS AND METHODS

Soil samples from the High Plains region were randomly selected from those submitted to the ServiTech Laboratories in 2011. Samples were not pretreated to remove soluble salts. These were extracted with 1*N* NH4OAc buffered to pH 7.0, 7.5, and 8.5 (“AA_7.0”, “AA_7.5”, “AA_8.5”), and Mehlich 3 (“Meh-3”) buffered to pH 2.5. The Ca, Mg, K, and Na concentrations were measured using Inductively Coupled Plasma-

Optical Emission Spectroscopy (ICP-OES) and used to estimate the CEC_sum and ESP for each extractant. Samples were also analyzed for soil pH, “excess lime” (estimated visually by effervescence), and total carbonate percentage. The AA_7.0 values were compared to the other extractants by linear regression and ANOVA.

RESULTS AND DISCUSSION

The K and Na concentrations were statistically similar for all extractants (Table 1), and the methods were highly correlated with each other ($r^2 > 0.99$; data not shown). The Mg concentrations were statistically similar for the NH_4OAc regardless of pH, but the Meh-3 was significantly higher (Table 1). The NH_4OAc methods were highly correlated with each other ($r^2 > 0.98$; data not shown), but Meh-3 was significantly different than NH_4OAc. The Ca concentrations were inversely proportional as a function of extractant pH (Table 1). The AA_7.5 and AA_8.5 were well correlated with AA_7.0 ($r^2 > 0.96$), but progressively extracted less Ca as concentrations increased (Figs. 1b, 1c, 2b, 2c and Table 1). The Meh-3 increasingly extracted more Ca than AA_7.0 as concentrations increased (Fig. 1a), and was highly correlated at concentrations <4000 ppm Ca ($r^2 > 0.98$, data not shown), but poorly correlated at higher concentrations. The Meh-3 extracted 2 to 8 times as much Ca than AA_7.0 at higher concentrations.

The inflated Ca concentrations from Meh-3 extraction are partially related to soil pH and total carbonate content, but are heavily affected by carbonate reactivity (Fig. 2a). Reactive carbonates tend to have finer particle sizes and more surface area. The acidic Meh-3 reacts with the increased surface area to extract non-exchangeable Ca. This effect with reactive carbonates did not impact Mg concentrations in this population, likely due to a predominance of Ca, rather than Mg, associated carbonates.

Cation concentrations are used to calculate CEC_sum. The calculated Na percentage (ESP) of the CEC_sum is used to identify sodic soils. The CEC_sum values are used to estimate the approximate soil texture for certain nutrient and pesticide applications. The inflated Ca concentrations also inflate the CEC_sum, possibly distorting the texture estimates and ESP values. “Capping” the Meh-3 Ca values at 5000 ppm resulted in CEC_sum values that were well correlated with AA_7.0 values (Fig. 3 and Table 2). The corresponding ESP values using “capped” Meh-3 Ca were also well correlated with AA_7.0 ($r^2 > 0.99$, slope = 0.93).

REFERENCES

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Table 1. Mean cation concentrations in ppm. Values within a column sharing the same letter are not significantly different from one another. (α = 0.10)								
Extractant	**Potassium (K)**		**Sodium (Na)**		**Magnesium, (Mg)**		**Calcium, (Ca)**	
AA_7.0	321	a	100	a	329	a	3127	b
Meh-3	339	a	103	a	395	b	4501	c
AA_7.5	345	a	108	a	347	a	2986	b
AA_8.5	334	a	108	a	329	a	2467	a
LSD	*41*		*27*		*31*		*417*	

Table 2. Mean cation exchanged capacity by summation (CEC_sum) and exchangeable sodium percentage (ESP). Values within a column sharing the same letter are not significantly different from one another. (α = 0.20)				
Extractant	**CEC_sum, meq/100g**		**ESP, Na %**	
Meh-3	27.1	a	2.0	a
Meh-3_{capped}*	21.1	b	2.1	a
AA_7.0	19.6	bc	2.3	ab
AA_7.5	19.1	c	2.6	bc
AA_8.5	16.5	d	2.8	c
LSD	*1.6*		*0.4*	
* Meh-3_{capped} = If Ca ppm > 5000, then Ca ppm = 5000				

Figure 1. Relationships for extracted calcium contents where x = AA_7.0

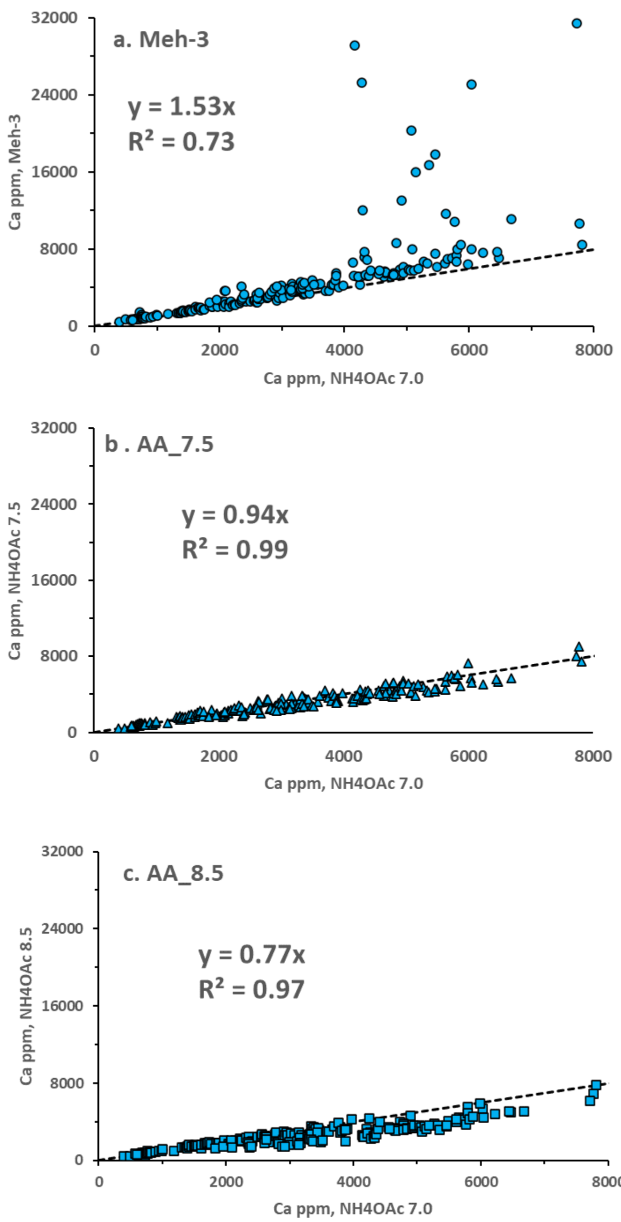

Figure 2. Difference in calcium extracted by soil pH, where: Difference = extractant Ca minus AA-7.0 Ca

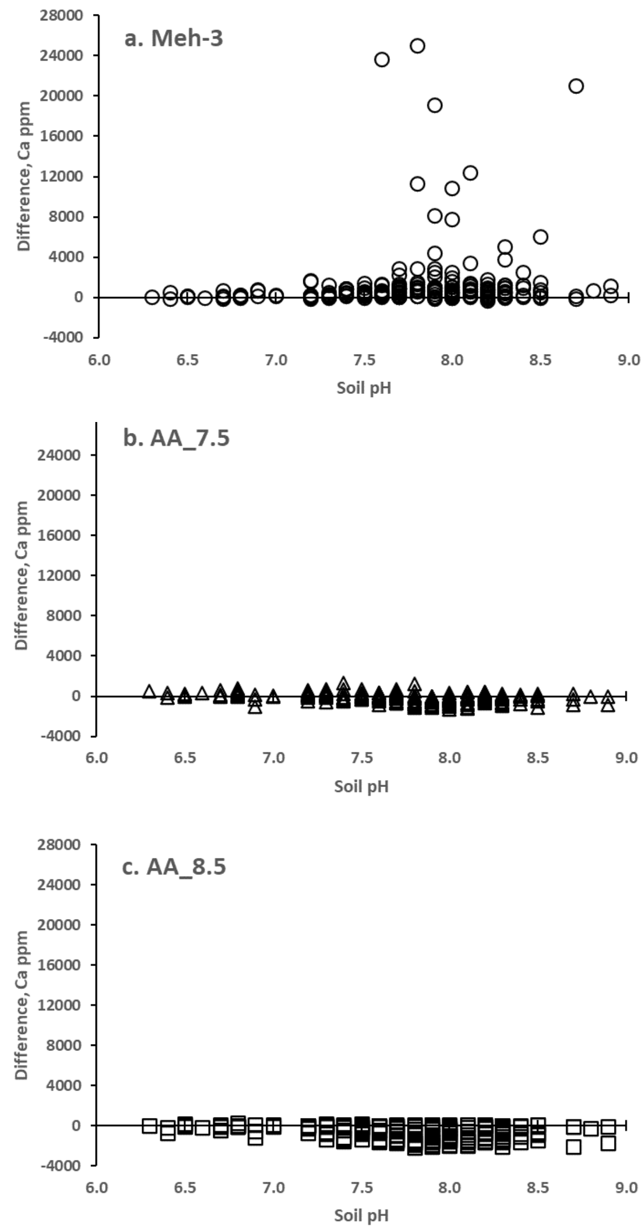

Figure 1. CEC using Mehlich-3 cations, unadjusted Ca vs. "capped" Ca