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Comparison of Mehlich-3 and Ammonium Acetate Extractable Calcium and Magnesium in Kansas Soils

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Summary
The use of the Mehlich-3 (M3) soil test procedure to assess the plant availability of numerous macro and micronutrients has become common at soil testing labs across the US. Mehlich-3 is used for soil tests for phosphorus (P) and potassium (K) in Kansas; however, data for other base cations for existing methods are scarce for Kansas soils. The objective of this study was to investigate the relationship between M3 and ammonium acetate (AA) extractable calcium (Ca) and magnesium (Mg). Regression analyses indicate a near 1:1 linear relationship between M3-Mg and AA-Mg across a wide range of soil pH and soil organic matter (SOM) contents. The relationship between M3-Ca and AA-Ca was relatively constant for acidic to neutral pH soils. However, M3 extracted substantially more Ca in higher pH soils. Regression analysis indicates that M3-Ca and AA-Ca diverge exponentially at a soil pH of 7.3 and higher. Given the current interpretation of AA-Ca as a measure of exchangeable Ca, these results suggest that M3 may extract Ca from non-exchangeable soil-Ca pools in soils with above neutral pH levels. Based on these results, M3 should not be used to assess the plant availability of soil-Ca or estimate cation exchange capacity (CEC) in soils with a pH above 7.3, as the values are likely to be overestimated.

Introduction
The Mehlich-3 soil test procedure has become part of the routine soil analysis workflow at soil testing labs across the US. This procedure allows for the simultaneous measurement of numerous essential plant nutrients from a single extraction, which reduces lab operating costs and the cost of soil testing for farmers and homeowners. However, the interpretation of these measurements requires knowledge of their relationship to nutrient uptake by plants, as well as correlation to existing soil testing methods. The interpretation of M3 extractable calcium (Ca) has been questioned, as the solubility of soil-Ca is strongly influenced by pH and the M3 extracting solution is both acidic and strongly buffered. Data relating M3 extractable Ca to conventional soil tests (ammonium acetate) for Ca are scarce, particularly for high pH soils in Kansas (Liesch et al. 2011 and 2012). A study was performed at the Kansas State University Soil Testing Laboratory to evaluate the relationship between M3 and AA extractable Ca from Kansas soils.

Procedures

Soil samples were selected randomly from those submitted to the lab by Kansas farmers and homeowners over a six-month period during the 2020 calendar year (a total of 308 soil samples for this study). They covered a wide range of pH, organic matter, Ca, and Mg contents (Table 1). These samples were dried in a forced-air oven at 104°F and ground to pass a 2-mm sieve using a flail-type grinder. Samples were dried, ground, and stored at 21°C until analysis. A summary of general soil characteristics can be found in Table 1.

The extraction procedures employed during this study are described in the Recommended Soil Testing Procedures for the North Central Region handbook (Denning et al., 2011). The concentrations of Ca and Mg were measured using inductively coupled plasma atomic emission spectroscopy (ICP-AES). Soil pH was measured from 1:1 soil-water suspensions using a dual probe robotic pH meter equipped with glass electrodes. Buffer pH was determined using the Sikora buffer method. Soil organic matter (SOM) content was determined using the loss on ignition method.

Results and Discussion

The concentrations measured from M3 and AA extracts were positively correlated for both Ca (r = 0.88) and Mg (r = 0.98). On average, M3 extracted approximately 12.65% more Ca than AA, and 10.2% more Mg than the AA extraction. Linear models fit the Mg soil test data well, with a nearly 1:1 linear relationship between M3- and AA-Mg (Figure 1). However, linear models fits the Ca soil test data poorly. The trends in the Ca data showed the M3 extraction procedure clearly extracts more Ca than AA in higher pH soils (Figure 1). Nonlinear regression models were used to further explore this effect. The difference between M3 and AA extractable Ca (Ca) was calculated for each soil sample. The resultant model fit the data reasonably well and suggests a soil pH breakpoint of approximately 7.3 (Figure 2). This indicates that the difference between M3-Ca and AA-Ca is relatively constant below a pH of approximately 7.3. However, as the soil pH of the sample increases to 7.3 and higher, the difference between M3 and AA extractable Ca grows exponentially. Large and variable differences between M3 and AA extractable Ca are problematic in that they prevent the use of a simple equation or conversion factor to approximate from one to the other. These results also indicate that M3 can extract appreciable amounts of Ca from non-exchangeable pools of soil-Ca, especially in higher pH calcareous soils.

Neutral ammonium acetate is the recommended extraction procedure for Ca in Kansas and the North Central US region (Denning et al., 2011), and is commonly interpreted as being "exchangeable" soil-Ca (Ciesielski et al., 1997). These exchangeable Ca values may be used to assess the plant availability of soil-Ca, and to estimate cation exchange capacity (CEC) of the soil. While Kansas soils are naturally high in Ca and deficiencies are rare, the nonlinear relationship between M3-Ca and AA-Ca makes converting one to another quite difficult, and necessitates the development of separate calibration curves for M3 in order to evaluate the likelihood of any potential crop response to Ca. Furthermore, the results of this study suggest that replacing traditional Ca measurements with M3 Ca would likely result in overestimation of exchangeable Ca and CEC calculations. The CEC by summation is used by farmers and consultants to adjust fertility and pest management practices, and the use of M3 as a soil test for Ca may result in inaccurate fertilizer, herbicide, and pesticide application rates, especially in calcareous soils.

References

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Table 1. General soil information and summary statistics for soil samples (n = 308) included in the study

Statistic	Soil pH	SOM	Calcium	Magnesium	CEC
		%	ppm	ppm	meq 100 g^{-1}
Range	4.4 - 8.2	0.8 - 10	165 - 6430	31 - 1417	9.3 - 39
Median	6.7	3.0	2518	291	19.7

SOM = soil organic matter. CEC = cation exchange capacity.

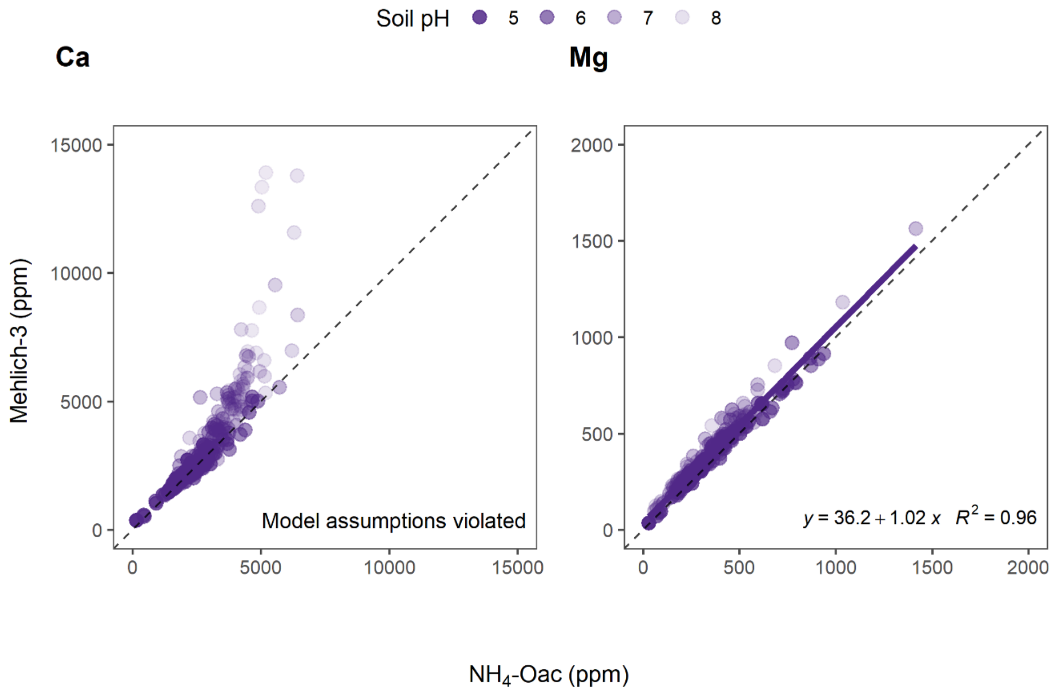

Figure 1. Mehlich-3 and ammonium acetate (AA) extractable calcium (Ca) and magnesium (Mg) from 308 soil samples from across Kansas. Regression analysis indicated a nearly 1:1 linear relationship between Mehlich-3 and AA extractable Mg. However, a linear regression was appropriate for the Ca data. Soil pH information is also displayed, where lighter shades indicate higher soil pH values. The 1:1 ratio is indicated by a dashed line for visual reference.

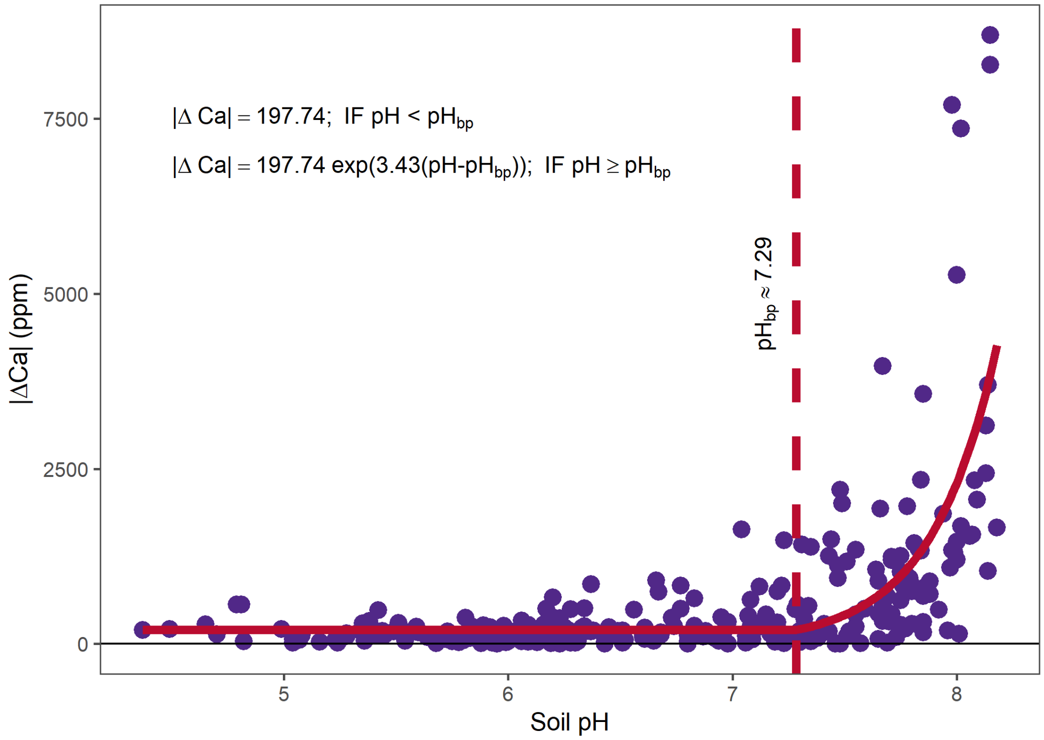

Figure 2. The difference between Mehlich-3 and ammonium acetate (AA) extractable calcium (Ca) versus soil pH using nonlinear regression. Results indicate that the difference between M3-Ca and AA-Ca (Ca) increases exponentially at approximately 7.29 soil pH. The Ca values were calculated by subtracting AA-Ca from M3-Ca.