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Comparison of Mehlich-3 and DTPA Soil Tests for Analysis of Micronutrients in Kansas Soils

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Summary

Mehlich-3 (M3) was designed as a multi-nutrient soil test procedure and has become common at soil testing labs across the U.S. In Kansas, Mehlich-3 is predominately used as a soil test for phosphorus (P) and potassium (K), but recent studies have also investigated the use of M3 for the extraction of base cations and cation exchange capacity estimation. However, data relating M3 to traditional methods for soil micronutrient extraction remain scarce. The objective of this study was to investigate the relationship between M3 and diethylenetriamine pentaacetate (DTPA) extractable copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) across a wide range of Kansas soils. Strong positive correlations were observed between M3 and DTPA for each metal (Fe, r = .91; Zn, r = .98; Cu, r = .92). Correlations between M3 and DTPA were positive but weak for Mn (r = 0.17). Regression analyses suggest these relationships were not one-to-one and were dependent on soil pH. Results from this study show that conversion of M3 to a "DTPA equivalent" is possible but should take soil pH into consideration, especially for Fe and Mn.

Introduction

The Mehlich-3 soil test procedure has become part of the routine workflow for soil analysis at soil testing labs across the U.S. This procedure allows for the simultaneous measurement of numerous essential plant nutrients from a single extraction and reduces lab operating costs and the cost of soil testing for farmers and homeowners (Rutter et al., 2022). The interpretation of a soil test requires knowledge of its relationship to nutrient uptake by crops, or its correlation to existing soil testing methods. However, data relating M3 extractable micronutrient metals to the conventional soil test (DTPA) for micronutrient metals are scarce for Kansas soils. Previous research conducted in other regions have included the investigation of relationships between these methods (Cancela et al., 2007; Iatrou et al., 2015). Iatrou et al. (2015) found strong correlations between M3 and DTPA for Zn and Cu in Greek soils, but a poor correlation for Mn. Positive correlations between M3 and DTPA extractable Fe were also observed, but the relationship was substantially influenced by soil pH. Similar observations were made by Cancela et al. (2007) in soils collected from the Iberian Peninsula (Spain, Portugal). This study was performed at the Kansas State Research and Extension Soil Testing Laboratory to evaluate the relationship between M3 and DTPA extractable Cu, Fe, Mn, and Zn in Kansas soils.

Procedures

Soil samples were selected randomly from those submitted to the lab by Kansas farmers and homeowners over a six-month period (a total of 308 soil samples for this study), and covered a wide range of pH, organic matter, and micronutrient content (Table 1). Soils were dried in a forced-air oven at 104°F (40°C) and ground to pass a 2-mm sieve using a flail-type soil mill (Custom Laboratory Equipment, MO, U.S.). Samples were stored at 70°F (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 Chapter 9 of the Recommended Soil Testing Procedures for the North Central Region handbook (Whitney, 2015). Briefly, 10 g of soil were extracted with 20 mL of DTPA extracting solution (0.005 M DTPA, 0.01 M triethanolamine (TEA), pH = 7.3) on a reciprocating shaker at 180 rpm for 2 hours. Subsequent extracts were filtered using Ahlstrom 74 filter paper, and the concentrations of Cu, Fe, Mn, and Zn 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 (Skalar Analytical, Netherlands). Buffer pH was determined using the Sikora buffer method. Soil organic matter (SOM) content was determined using the loss on ignition method at 752°F (400°C) and a 4-hour ignition phase.

Results

Correlations between the M3 and DTPA were positive and relatively strong for Zn, Fe, and Cu but weak for Mn (Figure 1). Simple linear regression models between M3 and DTPA indicated that, on average, micronutrient concentrations were higher in M3 extracts than DTPA extracts. However, more complex regression models suggest these relationships were also influenced by soil pH (Table 2; Figure 2). Using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values to compare the models provides further weight toward including soil pH, as AIC and BIC values were minimized when soil pH was included in the model for all four micronutrients (Table 2). This pH dependence complicates the interpretation of micronutrients from the Mehlich-3 soil test, as the soil test indices and crop response calibrations currently available were based on the traditional DTPA soil test.

Conclusion

Relationships between M3 and DTPA extractable micronutrient metals were investigated in soils collected from across Kansas. Mehlich-3 and DTPA micronutrients were positively correlated between the two methods. However, Mehlich-3 extracted substantially higher amounts of Cu, Fe, Mn, and Zn in some soils with a high pH. Regression analysis suggests M3 and DTPA soil tests results do not follow "one-to-one" relationships and appear to be influenced by soil pH. Results from this study show that conversion of M3 extractable to a "DTPA equivalent" is possible, but soil pH should be taken into consideration to improve accuracy, especially for Fe and Mn.

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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	CEC	Cu	Fe	Mn	Zn
		%	meq 100 g^{-1}	------------------------ ppm ------------------------			
Range	4.4 - 8.2	0.8 - 10.0	9.3 - 39	0.3 - 7.3	2.8 - 317	1.8 - 203	0 - 243
Median	6.7	3.0	19.7	1.0	18.4	14.5	1.3

SOM = soil organic matter. CEC = cation exchange capacity. Cu = copper. Fe = iron. Mn = manganese. Zn = zinc. Soils with SOM contents exceeding 10% were removed from the study (n = 2). The reported concentrations of copper, iron, manganese and zinc were determined from DTPA extracts.

Table 2. Comparison of regression models with varying complexity for the relationships between Mehlich-3 (M3), DTPA, and soil pH for zinc (Zn), iron (Fe), copper (Cu), and manganese (Mn)

Element	IVs	Adj. R^2	BIC
DTPA-Zn	M3-Zn	0.90	467
	M3-Zn + Soil pH	0.92	394
	M3-Zn + M3-Zn: Soil pH	*0.95*	*294*
	M3-Zn + Soil pH + M3-Zn: Soil pH	0.95	300
DTPA-Fe	M3-Fe	0.76	1363
	M3-Fe + Soil pH	0.88	1231
	M3-Fe + M3-Fe: Soil pH	*0.90*	*1181*
	M3-Fe + Soil pH + M3-Fe: Soil pH	0.90	1186
DTPA-Cu	M3-Cu	0.72	227
	M3-Cu + Soil pH	*0.86*	*27*
	M3-Cu + M3-Cu: Soil pH	0.84	62
	M3-Cu + Soil pH + M3-Cu: Soil pH	0.86	31
DTPA-Mn	M3-Mn	0.00	2481
	M3-Mn + Soil pH	0.50	2276
	M3-Mn + M3-Mn: Soil pH	*0.65*	*2172*
	M3-Mn + Soil pH + M3-Mn: Soil pH	0.65	2176

Independent variables (IVs) are shown, as well as various statistics such as adjusted coefficient of determination (Adj. R^2) and Bayesian Information Criterion (BIC) for each respective model. Models with the lowest BIC value are indicated in underlined italic font for each element. Soils with extremely high soil test values were omitted prior to fitting regression models to focus on the range of agronomic relevance (e.g., DTPA-Zn > 10 ppm).

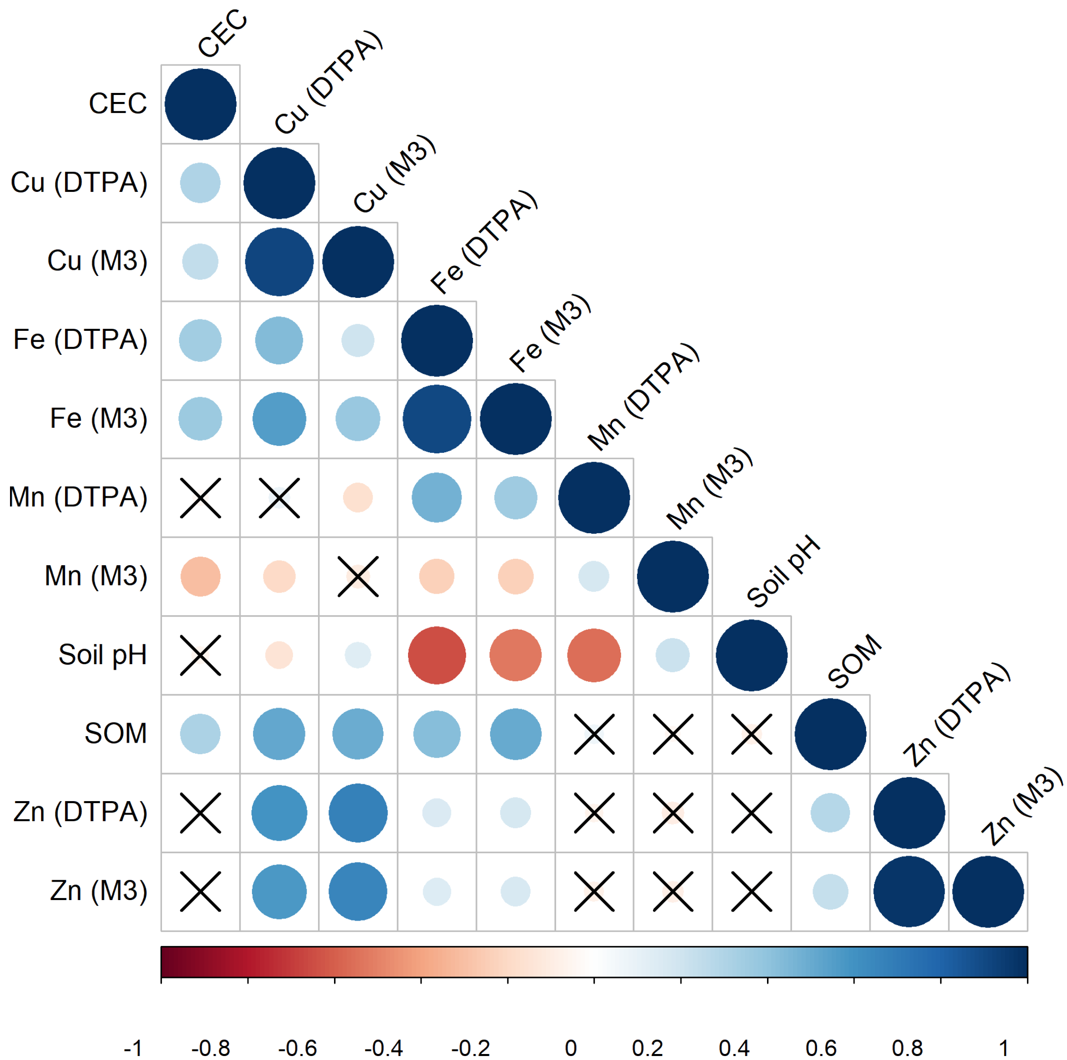

Figure 1. Pearson's correlations between Mehlich-3 (M3) and DTPA extractable copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), soil pH, soil organic matter (SOM), and cation exchange capacity (CEC) measured from 308 soils collected across Kansas. Positive correlations are indicated by blue colors and negative correlations are indicated by red colors. Non-significant correlations are indicated by cross hash marks (*P* > 0.05).

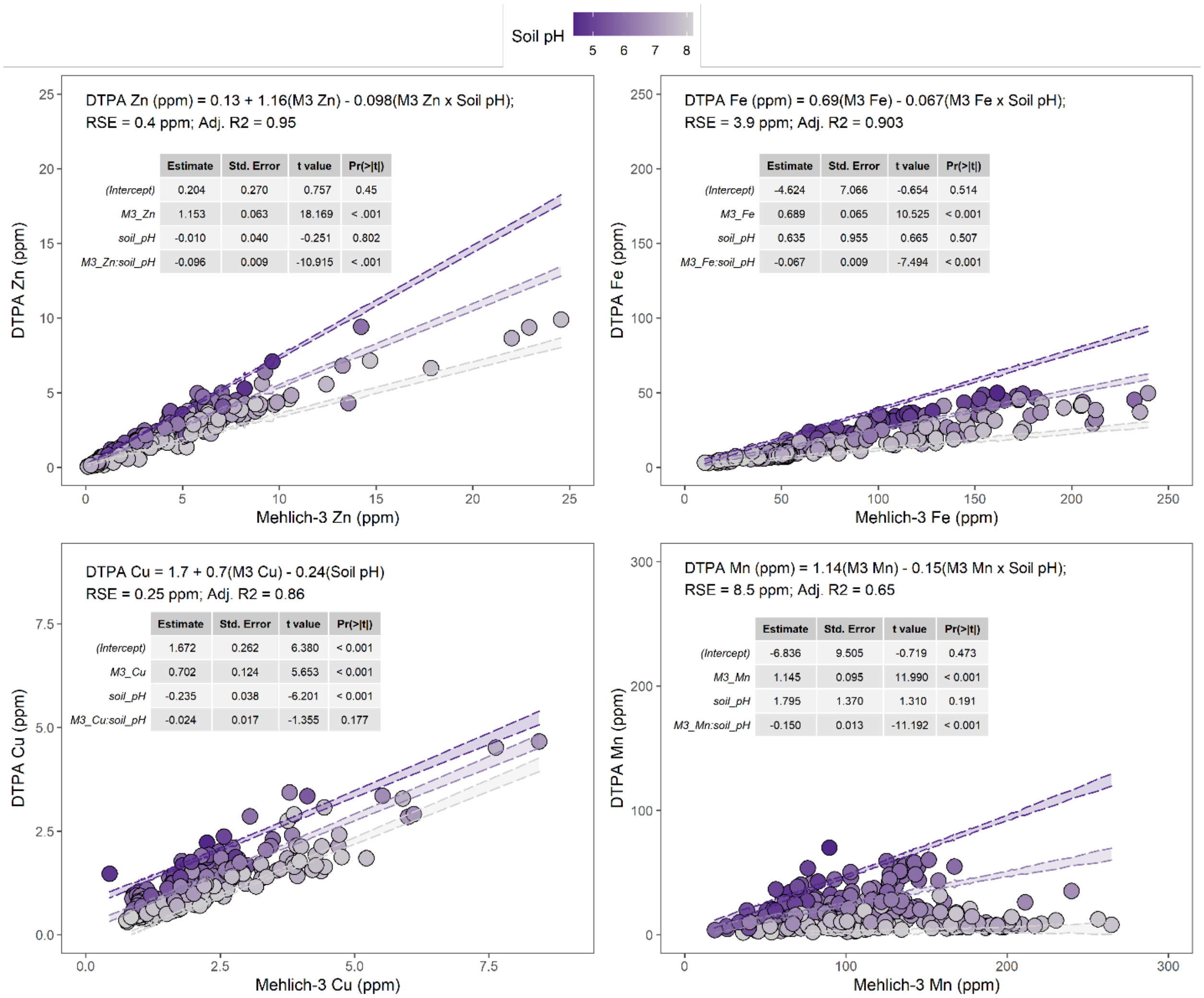

Figure 2. Multiple linear regression models were used to investigate the relationships between Mehlich-3 (M3) and DTPA extractable Zn (top-left), Fe (top-right), Cu (bottom-left), and Mn (bottom-right). The effects of soil pH were also taken into consideration. Model fit estimates are illustrated with the shaded ribbons. The soil pH is indicated by color for both soils (points) and models (ribbons); where lighter shades correspond to higher soil pH and darker shades to lower soil pH. Soils with extremely high soil test values were omitted prior to fitting regression models to place focus on the range of agronomic concern (e.g., DTPA-Zn > 10 ppm).