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Comparison between DTPA Extracting Methods for Available Zinc with Multinutrient Extractants in Vertisols and Inceptisols

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate relationships between some universal soil extractants and legacy methods.
Place and Duration of Study: The study was carried out at IISS, Bhopal.
Methodology: Samples were analyzed by different methods being related; e.g. GLOSOLAN/international method or rapid methods/universal extractant and legacy methods. Measured data was obtained under the best achievable laboratory quality control conditions, for

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maximal transfer function reliability with the lowest RMSE (Root Mean Square Error). Out of the 60 samples in each category, a representative set (80% of the samples) was used (e.g. by linear regression analysis) for the development of the transfer function and the rest 20% of the samples were retained for validation of transfer functions. Residuals (differences) between measured and estimated soil property values were calculated. The correlation and RMSE (Root Mean Square Error) were calculated for the validation data set.

Results: The Zinc extractable DTPA and Mehlich-3 had a regression coefficient of R^2= 0.92. while the extracted with AB DTPA had the regression coefficient of R^2= 0.72 with DTPA, with extraction in the order of Mehlich3> AB DTPA> DTPA. Hence, Mehlich-3 and AB-DTPA both extractants can replace DTPA extractants for the determination of available micronutrients in soils in Vertisols.

Conclusion: In conclusion, different regression equations are developed between the various methods of analysis that must be used to compare the results obtained from different extraction methods.

Keywords: Universal extractants; zinc; DTPA; mehlich-3.

1. INTRODUCTION

The phrase "universal soil extractant" has been used to describe a reagent that can be used to extract well over one category of elements and/or ions from soil, the concentration of which can be used to determine the soil's fertility or toxicity levels. The use of universal extractants in soil testing procedures has several benefits, including raising the dependability of the tests, improving their accuracy and precision, and speeding up routine soil analysis. Over the past few years, several procedures have been created and released for quick soil tests to detect the amounts of various components in soil. Multi-nutrient extractants present a workable solution to these problems since they allow for the simultaneous extraction of multiple nutrients. The nutrients can be estimated using a multielement analyzer such as the inductively coupled plasma emission spectrometer or atomic absorption spectrophotometer. The invention of extracting solutions containing chelating agents, primarily DTPA and EDTA, represents one of the most significant developments in micronutrient soil testing. In addition to macronutrients, the Mehlich-3 extractant was created as an all-purpose (many nutrients) extractant for routine analyses of micronutrients (Cu, Fe, Mn, Zn, etc.) for a variety of soils over acidic, neutral, and high pH soils. High correlation coefficients between Zn values obtained by TEA-DTPA and AB-DTPA were discovered. Therefore, it is crucial to assist laboratories in selecting the best approach and to encourage the switch to more environmentally friendly ones. To do so, the following information is to be taken care of per SOP (standard operating procedures): (i) health risk (related to the use of chemicals and the overall implementation of the procedure by staff); (ii) Environmental risk (related to waste disposal); (iii) Level of technology required to perform the analysis and (iv) Average duration of the test. The aim of the study was to harmonize methods, data and information to (1) provide reliable and comparable information between countries and projects; (2) allow the generation of new harmonized soil data sets; and (3) support evidence-based decision-making for sustainable soil management.

2. METHODOLOGY

Extractable micronutrients i.e., zinc, and copper were determined using Atomic Absorption Spectrophotometer (AAS) [1]. The multi-nutrient extractant ammonium bicarbonate-DTPA (AB-DTPA) has been shown to be able to extract all the nutrients—available P, K, and micronutrients simultaneously in alkaline soils. For the chelation of micronutrients, DTPA is employed, whereas bicarbonate is used to remove phosphorus, ammonium for the extraction of potassium, HCO_3 is for the extraction of P, DTPA for chelation of Ca, Mg, and micronutrients: Zn, and Cu. The solution's pH was adjusted to 7.6 [2]. Since ammonium bicarbonate is not stable for longer than 24 hours, fresh solutions were made every day for analysis.

Mehlich extracting Solution (0.2 M acetic acid + 0.25 M NH_4NO_3 + 0.015 M NH_4F + 0.013 M nitric acid + 0.001 M ethylene diamine tetra acetic acid) by shaking 2 g of soil with 20 mL of the extractant for 5 min at 1:10 soil/solution ratio soil extracts were filtered through Whatman No. 2 filter paper [3]; and the concentration of P was read on. The filtrates were analyzed by ICP at 327.393 nm for Cu, and 206.200 nm for Zn.

Data was interpreted in MS EXCEL software using the DATA ANALYSIS tool and OPSTAT. Descriptive statistics and measures of central tendencies were carried out for micronutrient data with different extractants and ratios. Variability in soil parameters (variants) was analyzed using the coefficient of variation (CV).To find out whether the mean difference between two sets of observations is zero, the paired t-test statistical approach was used. This approach offers a number of reports for concluding the variance between two population means from a paired sample. At a significance level of 0.05, 0.01 and 0.001 the null hypothesis is assumed to be zero in this situation and the degree of significance was compared with the p-value for the two tail values.

3. RESULTS AND DISCUSSION

3.1 DTPA as Soil Micronutrient (Zinc) Extractant as comPared with AB-DTPA and Mehlich-3 in Vertisols

Tables 1, for Vertisols provide a summary of the mean values, errors, and range for zinc with various extractants. According to Table 1 and Figs. 1 and 2; DTPA extractable Zn had a range of 0.112-1.772 mg/kg with a mean value of 0.922mg/kg and had a correlation (r= 0.84***) with Mehlich-3 extractable Zinc in a range of 1.67-4.17 mg/kg with a mean value of 3.18mg/kg and AB-DTPA extractable Zn in a range of 0.22-2.04 mg/kg with a mean value of 1.16 mg/kg and had a correlation (r= 0.96***). In comparison to all other extractants for Vertisol, DTPA and Mehlich-3 had the regression coefficient (R^2= 0.92) and DTPA and AB-DTPA had the regression coefficient (R^2= 0.72), with extraction in the order of Mehlich-3>AB DTPA> DTPA. RMSE and MAE are given in Table 2.

3.2 DTPA as Soil Micronutrient (Zinc) Extractant as Compared with AB-DTPA and Mehlich-3 in Inceptisols

Table 2 provides a summary of the mean values, errors, and ranges in Inceptisols soil for Zinc in various extractants. According to Table 2 and Figs. 3, 4; DTPA extractable Zn had a range of 0.07-1.96 mg/kg with a mean value of 0.92 mg/kg and had a strong correlation (r= 0.89***) with Mehlich-3 extractable Zn in a range of 0.13-2.14 mg/kg with a mean value of 1.07 mg/kg. AB-DTPA extractable Zn was in a range of 0.04-1.79 mg/kg with a mean value of 1.07 mg/kg and had a strong correlation (r= 0.91***). In comparison to all other extractants for Inceptisols DTPA and Mehlich-3 had the regression coefficient (R^2=0.82). DTPA and AB-DTPA had the coefficient of determination (R^2=0.79), with extraction in the order of Mehlich-3 >AB DTPA> DTPA.

.Table 1. Range of Concentrations and Means for available Zinc by DTPA, AB-DTPA and Mehlich-3 in Vertisols

	Extractant	Soil: Solution Ratio	Min	Max	Mean	Median	Std. Error	SD
Zn	DTPA	1:2	0.11	1.77	0.92	0.79	0.05	0.41
	AB DTPA	1:2	0.22	2.04	1.16	1.04	0.05	0.42
	Mehlich-3	1:10	1.67	4.17	3.18	3.12	0.06	0.52

Table 2. Range of Concentrations and Means for available Zn by DTPA, AB-DTPA and Mehlich-3 in Inceptisols

	Extractant	Soil to Solution Ratio	Min.	Max.	Mean	Median	Std. Error	Std. Deviation
Zn	DTPA	1:2	0.07	1.96	0.92	0.79	0.05	0.42
	AB DTPA	1:2	0.04	1.79	0.82	0.77	0.05	0.39
	M3	1:10	0.13	2.14	1.07	0.99	0.05	0.41

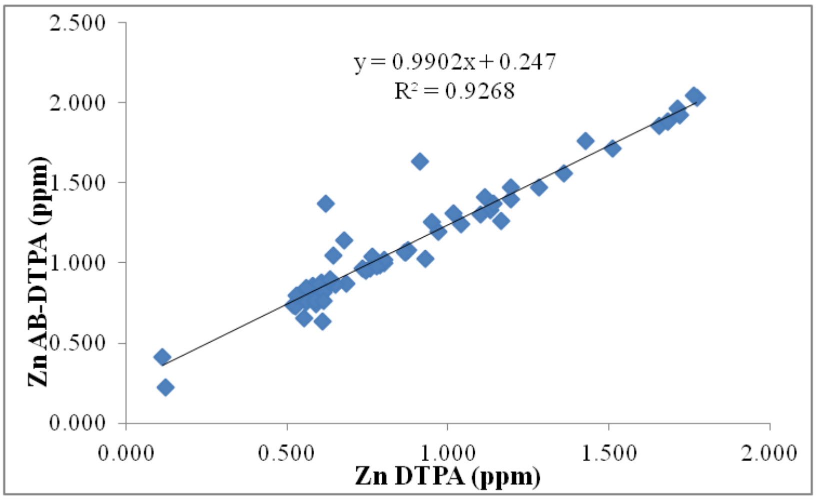

Fig. 1. Relationship between DTPA and AB-DTPA method of available Zn in Vertisols

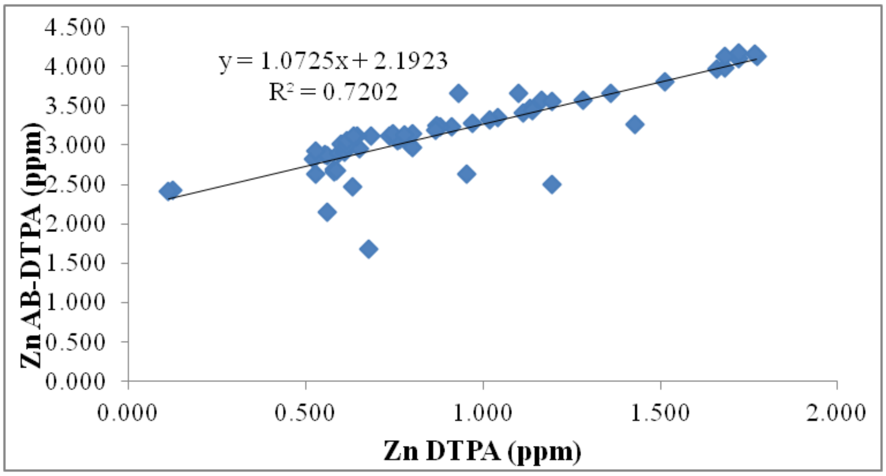

Fig. 2. Relationship between DTPA and AB-DTPA method of available Zn in Vertisols

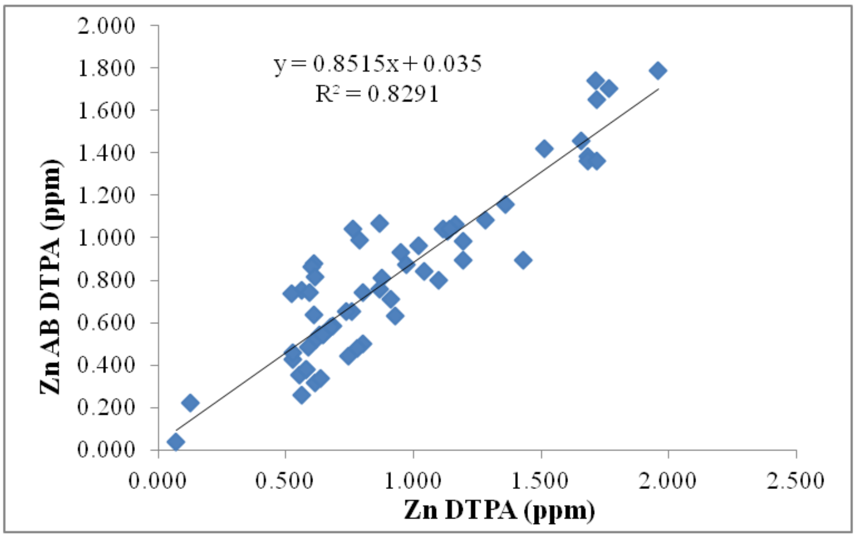

Fig. 3. Relationship between DTPA and AB-DTPA method of available Zn in Inceptisols soil

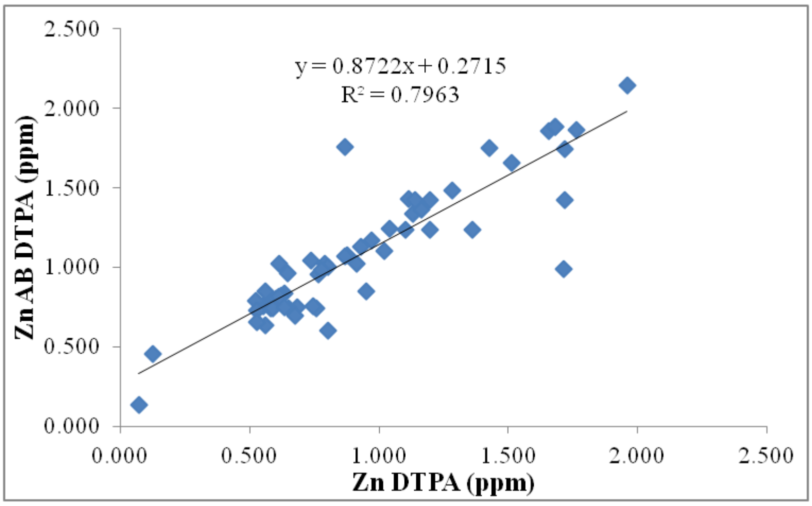

Fig. 4. Relationship between DTPA and AB-DTPA method of available Zn in Inceptisols soil

Table 3. Coefficient of determination (R^2), Root Mean Square Error and Mean Absolute Error of DTPA as extractant compared with AB-DTPA and Mehlich-3 method for Zinc in both Vertisols and Inceptisols

Vertisols		**R^2**	**RMSE**	**MAE**
Zn DTPA	Zn AB-DTPA	0.926	0.176	0.132
	Zn Mehlich-3	0.720	0.152	0.096
Inceptisols				
Zn DTPA	Zn AB-DTPA	0.829	0.136	0.111
	Zn Mehlich-3	0.796	2.190	2.180

Table 4. Correlation coefficients (r) of micronutrient concentrations (Zinc) extracted by DTPA, Mehlich-3 and AB-DTPA in Vertisol and Inceptisol soils

DTPA	**Mehlich-3**	**AB DTPA**
Vertisol	0.84***	0.96***
Inceptisol	0.89***	0.91***

3.3 DTPA as Soil Micronutrient (Zinc) Extractant as Compared with AB-DTPA and Mehlich-3 in Vertisols

According to Table 1 and Figs. 1 and 2; DTPA extractable Zn showed highly significant results with a correlation (r= 0.84***, p<0.001and 0.05) with Mehlich-3 which indicates that M3 can extract Zn from the soil more than DTPA. AB-DTPA extractable Zn also showed highly significant results with a correlation (r= 0.96***, p<0.001and 0.05). In comparison to all other extractants for Vertisols, DTPA and Mehlich-3 had the regression coefficient (R^2= 0.92). DTPA and AB-DTPA had the regression coefficient (R^2= 0.72), with extraction in the order of M3>AB DTPA> DTPA. Hence, M3 and AB-DTPA both extractants can replace DTPA extractants for the determination of available micronutrients in the soils of the studied areas.

The presence of acid and EDTA in Mehlich-3 may have contributed to Mehlich-3 higher Zn extraction capability compared to DTPA and AB-DTPA extractants. Moreover, metals such as Fe, Mn, Cu, and Zn are extracted by H^+, and NH_4^+ ions in M3 extractant. Similar results were reported by authors (Walworth et al. 1992; Volcasek and Friedericks, 1994) Elrashidi et al. [4] Maftoun et al. [5,6] for Vertisols.

3.4 DTPA as Soil Micronutrient (Zinc) Extractant as Compared with AB-DTPA and Mehlich-3 in Inceptisols

According to Tables 3 and 4 and Figs. 3 and 4 DTPA extractable Zn and Mehlich-3 extractable

Zn showed significant results with the regression coefficient (R^2=0.79) with correlation (r= 0.89* at P<0.001 and 0.05) and DTPA extractable Zn and AB-DTPA extractable Zn showed non-significant results with the regression coefficient (R^2=0.82) in Inceptisols soils with extraction in the order of M3>AB DTPA> DTPA. Similar results were reported by authors [4,7,8,9].

4. CONCLUSION

The choice of extraction method for zinc analysis in soil depends on the soil properties, pH conditions, and the specific objectives of the study. DTPA and AB-DTPA are commonly used for acidic to neutral soils, while Mehlich-3 is suitable for a broader pH range. The selection of the appropriate method should consider the specific characteristics of the soil under investigation to obtain accurate and meaningful results for zinc availability assessment. Thus, DTPA and Mehlich-3 cannot be recommended as general test procedures for extraction of the studied micronutrients from natural soil samples having various chemical and physical properties unless field calibrations are collected for these soils.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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