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Evaluation of Mehlich 3 and Ammonium Bicarbonate-DTPA Extractants for Prediction of Available Zinc in Calcareous Soils in Central Thailand

Natta Takrattanasaran[1], Jongruk Chanchareonsook[1]*, Suthep Thongpae[1] and Ed Sarobol[2]

ABSTRACT

This study was conducted in order to evaluate the efficiency of Mehlich 3 and ammonium bicarbonate-DTPA (AB-DTPA) extractants for predicting available zinc (Zn) in calcareous soils in the central part of Thailand. The relationships between the amounts of Zn extracted by Mehlich 3 and AB-DTPA with those extracted by DTPA (the conventional extraction method widely used in soil testing laboratories in Thailand) and those taken up by corn were elucidated. The results showed that the amount of Zn extracted by both Mehlich 3 and AB-DTPA was significantly correlated with that extracted by DTPA (r = 0.951** and r = 0.950**, respectively) and that absorbed by corn (r = 0.954** and r = 0.925**, respectively). Moreover, the coefficient of determination (r^2) for the relationship between amounts of Zn taken up by corn and extracted by the three extractants was 0.845 (DTPA), 0.855 (AB-DTPA) and 0.910 (Mehlich 3). Accordingly, Mehlich 3 and AB-DTPA could be used effectively for estimating Zn availability in calcareous soils in central Thailand. However, Mehlich 3 was superior to AB-DTPA.

Keywords: Mehlich 3, AB-DTPA, available Zn, soil test, multinutrient extractant

INTRODUCTION

In Thailand, most soil testing laboratories use DTPA extractant (Lindsay and Norvell, 1978) for estimating available zinc in the soil, whereas several soil testing laboratories in other countries use Mehlich 3 (Mehlich, 1984) and ammonium bicarbonate-DTPA (AB-DTPA) (Soltanpour and Schwab, 1977), as multinutrient extractants for assessing available zinc in soils (Martens and Lindsay, 1990; Elrashidi *et al*., 2003; Brennen *et al*., 2008). Mehlich 3 and AB-DTPA extracants are attractive to soil testing laboratories, since these extractants simultaneously extract several nutrients (macro and micronutrients) including zinc (Martens and Lindsay, 1990; Beegle and Oravec, 1990). Using a single extracting solution for extraction of multiple elements reduces the cost of labor and reagents. The objective of the current research was to evaluate the efficiency of Mehlich 3 and AB-DTPA extractants for predicting available zinc in calcareous soils in the central part of Thailand. In addition, DTPA extractant was used for comparison.

1 Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.
2 Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.
* Corresponding author, e-mail: agrjoc@ku.ac.th

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MATERIALS AND METHODS

Soils used

Seven surface (0-15 cm) soil samples (three Mollisols and four Vertisols) were collected from cultivated areas composed of calcareous soils in the central part of Thailand. The soil samples were thoroughly mixed, air dried and ground to pass through a 2-mm sieve.

Laboratory analysis

The soil samples were analyzed for some properties. Soil texture was determined by the pipette method (Gee and Bauder, 1986), pH by glass electrode using a soil water ratio of 1:1 (Thomas, 1996), electrical conductivity (EC) by an electric conductometer (Rhoades, 1996), cation exchange capacity (CEC) by the ammonium acetate saturation method (Sumner and Miller, 1996), organic matter (OM) by the Walkley and Black method (Walkley and Black, 1934) and calcium carbonate ($CaCO_3$) by a titration method (Loeppert and Suarez, 1996).

Each soil sample was also analyzed for available Zn by extraction with Mehlich 3 (Mehlich, 1984), AB-DTPA (Soltanpour and Schwab, 1977) and DTPA (Lindsay and Norvell, 1978) (Table 1). The concentration of Zn in the extracts was determined by atomic absorption spectrophotometer.

Greenhouse experiment

A greenhouse experiment was conducted to obtain a quantitative assessment of the Zn status in the seven soil samples used in the study. The experimental layout used a completely randomized design arranged in two factorial treatments with three replications. The first factor was the seven calcareous soil samples (three Mollisols and four Vertisols). The second factor was two fertilizer treatments, consisting of +Zn (Zn application at the rate of 4 mg kg^{-1} soil, as $ZnSO_4.7H_2O$) and –Zn (without Zn application) treatments. Every pot received a standard nutrient dose of 200 mg N kg^{-1} soil (as urea), 200 mg P_2O_5 kg^{-1} soil (as KH_2PO_4) and 150 mg K_2O kg^{-1} soil (as KCl and KH_2PO_4). In addition, other nutrient elements were added in amounts considered to be adequate. Five seeds of

Table 1 Detail of methods used for extraction of available Zn.

Extractant	Extractant composition	Soil : Extractant	Soil weight (g)	Extractant volume (mL)	Time shakening (min)
DTPA (Lindsay and Norvell, 1978)	0.005 *M* DTPA 0.0 1 *M* $CaCl_2$ 0.1 *M* TEA	1 : 2	25	50	120
AB-DTPA (Soltanpour and Schwab, 1977)	1 *M* NH_4HCO_3 0.005 *M* DTPA	1 : 2	10	20	15
Mehlich 3 (Mehlich, 1984)	0.2 CH_3COOH,0.25 *M* NH_4NO_3, 0.015 *M* NH_4F, 0.013 *M* HNO_3, 0.001 *M* EDTA	1 : 10	2.5	25	5

corn (*Zea mays* L., var. Suwan 4452) were planted in each pot, watered with deionized water and then thinned to one seedling at 7 d after planting. The plants were thoroughly irrigated with deionized water at field capacity. After 55 d, in the tasselling stage, the aerial parts of the plant were harvested, dried in a forced-air oven at 65°C and the dry weight recorded. Plant samples were ground and digested with a triacid mixture (HNO_3-H_2SO_4-$HClO_4$) and the amount of Zn was determined in the digestates by atomic absorption spectrophotometer. Total Zn uptake was determined for the corn grown in soil that was treated with Zn and in soil that was untreated with Zn.

Verifying efficiency of extractants

The ability of Mehlich 3 and AB-DTPA extractants in measuring soil Zn was evaluated based on the amounts of Zn extracted by each method compared with those extracted by DTPA (the conventional test method) and with those taken up by corn (-Zn treatment). Linear correlation and regression analysis were used to evaluate the relationships. The correlation coefficient (r) and coefficient of determination (r^2) were used to appraise the efficiency of the extractants.

RESULTS AND DISCUSSION

Soil properties

Some physical and chemical properties of the investigated soils samples are shown in Table 2. The soils were clayey in texture with pH ranging from 6.9 to 8.1, low levels of EC and high level of CEC (Land Classification Division and FAO Project Staff, 1973). The amount of OM ranged from 16.8 to 38.3 g kg^{-1} and the $CaCO_3$ content ranged from 12 to 550 g kg^{-1}.

The amounts of Zn extracted by different extractants and their relationships

The amounts of Zn extracted by the DTPA, Mehlich 3, and AB-DTPA extraction methods from soils without Zn fertilizer supplement (-Zn treatment) are shown in Table 3. A large variation in the amount of Zn extracted by the three extractants was observed. In general, the amounts of extracted Zn followed the order:

Table 2 Classification and physical and chemical properties of soils used.

soil			Texture	pH	EC	CEC	OM	$CaCO_3$
No.	Series	Classification		(soil water ratio of 1 : 1)	(dS m^{-1})	($cmol_c$ kg^{-1})	(g kg^{-1})	(g kg^{-1})
1	Tahkli	Entic Haplustolls	Clay	7.80	0.15	54	32.9	540
2	Takhli	Entic Haplustolls	Clay	8.10	0.10	52	32.9	550
3	Lop Buri	Typic Haplusterts	Clay	8.00	0.11	60	31.6	410
4	Lop Buri	Typic Haplusterts	Clay	8.00	0.13	59	38.3	400
5	Lum Narai	Vertic Haplustolls	Clay	8.10	0.11	65	16.8	45
6	Chai Badan	Leptic Haplusterts	Clay	7.80	0.13	56	20.2	38
7	Ban Mi	Ustic Endoaquerts	Clay	6.90	0.20	39	35.7	12

Table 3 Ranges and means of amount of Zn extracted by different extractants.

Extractant	Range	Mean
	——mg Zn kg^{-1}——	
DTPA	0.31-1.31	0.64
AB-DTPA	0.49-1.89	1.06
Mehlich3	0.82-2.62	1.64

Mehlich 3 > AB-DTPA > DTPA. The result revealed that DTPA removed lower amounts of Zn than Mehlich 3 and AB-DTPA. This finding agrees with that reported by Walworth *et al*. (1992), Volcasek and Friedericks (1994), Elrashidi *et al*. (2003) and Maftoun *et al*. (2003). In the present study, the mean of amounts of Zn extracted by Mehlich 3 was 2.6 times and 1.5 times greater than those extracted by DTPA and AB-DTPA, respectively. The greater Zn extraction capacity of Mehlich 3 than either the DTPA or AB-DTPA extractants might have been due to the presence of acid and EDTA in Mehlich 3.

The amounts of Zn extracted by Mehlich 3 and AB-DTPA were highly significantly correlated with that extracted by DTPA (Table 4). Similar results were observed by Schmisek *et al*. (1998), Elrashidi *et al*. (2003) and Maftoun *et al*. (2003).

The regression equations and coefficients of determination (r^2) for the relationships between amount of Zn extracted by Mehlich 3 or AB-DTPA and DTPA extractants are presented in Table 5. The results showed that there was a strong relationship between the amount of Zn extracted by Mehlich 3 or AB-DTPA and that extracted by DTPA. The conversion of amounts of Zn extracted by Mehlich 3 or AB-DTPA to those extracted by DTPA gave accurate results of 91% and 90%, respectively. The results provided regression prediction equations that compared Zn extracted by different soil extraction methods and that determined the critical Zn levels of one extractant when using another.

Relationship between amounts of Zn taken up by corn and extracted by extractants

The relationship between total Zn uptake (Table 6) by corn and the amounts of Zn extracted by DTPA, AB-DTPA and Mehlich 3 extractants are presented in Figure 1. The results showed that the amounts of Zn extracted by DTPA, AB-DTPA and Mehlich 3 were significantly *($p \leq 0.01$)* correlated with total Zn uptake with an *r* value of 0.919, 0.925 and 0.954, respectively. Similar results were observed by Soltanpour and Schwab (1977), Halvin and Soltanpour (1984), Abreu *et al*. (2002) and Maftoun *et al*. (2003).

The coefficient of determination (r^2) values for the linear regression between Zn uptake by corn and the amount of Zn extracted by DTPA, AB-DTPA and Mehlich 3 were 0.845, 0.855 and 0.910, respectively (Table 7). This indicated that Mehlich 3 was more accurate than AB-DTPA and DTPA in terms of ability to predict total Zn uptake by corn.

Table 4 Correlation between Zn extracted by Mehlich3 or AB-DTPA and DTPA extraction procedures for seven soils investigated.

Extractant	Correlation coefficient (*r* value)
Mehlich3 *vs* DTPA	0.951**
AB-DTPA *vs* DTPA	0.950**

** = significant at $p \leq 0.01$

Table 5 Regression equations and coefficient of determination (r^2) for relationships between amounts of Zn extracted by Mehlich3 or AB-DTPA and DTPA extractants (all values are significant at $p \leq 0.01$).

Soil Zn extractant	Regression model	Coefficient of determination (r^2)
Mehlich3 *vs* DTPA	Y = 0.539X – 0.239	0.905
AB-DTPA *vs* DTPA	Y = 0.652X – 0.049	0.902

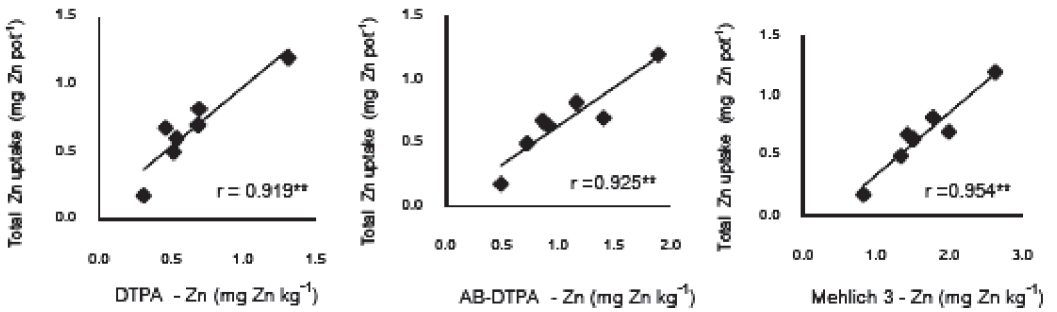

Figure 1 Linear correlation between amounts of Zn extracted (mg Zn kg^{-1}) by different extractants and total - Zn uptake (mg Zn pot^{-1}) (** = significant at $p \leq 0.01$).

Table 6 Total Zn uptake by corn grown on seven soil samples.

Soil samples	Total Zn uptake (mg Zn pot^{-1})[1/]
1 (Takhli)	0.64b
2 (Takhli)	0.68b
3 (Lop Buri)	0.70b
4 (Lop Buri)	0.82b
5 (Lum Narai)	0.18c
6 (Chai Badan)	0.50bc
7 (Ban Mi)	1.20a

[1/] Column values followed by a common letter are not significantly different by Duncan's multiple range test ($p \leq 0.01$).

Table 7 Regression equations and coefficient of determination (r^2) for relationships among amounts of Zn extracted by DTPA, AB-DTPA and Mehlich3 with total Zn uptake by corn (all values are significant at $p \leq 0.01$).

Soil Zn extractant	Regression model	Coefficient of determination (r^2)
DTPA	Y = 0.956X – 0.002	0.845
AB-DTPA	Y = 1.401X + 0.116	0.855
Mehlich3	Y = 1.751x + 0.455	0.910

CONCLUSIONS

The results from this study indicated that Mehlich 3 and AB-DTPA extractants could be effectively used for predicting available Zn in calcareous soils in central Thailand. However, Mehlich 3 was superior to AB-DTPA.

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