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Assessment of Multielement Extractants for Prediction of Available Potassium in Thai Soils

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ABSTRACT

In many countries, the efficiency of Mehlich 3 and ammonium bicarbonate – DTPA (AB-DTPA) has long been elucidated as multielement extractants for simultaneous measurement of nutrient elements including potassium (K) in soils. However, information on their efficiencies for assessing the availability of K in Thai soils is still inadequate. This study was conducted to assess the efficiency of the two multielement extractants in predicting available K in some Thai soils. The relationships between the amounts of K extracted by Mehlich 3 and AB-DTPA with those extracted by NH_4OAc, the conventional extraction method, widely used in soil testing laboratories in Thailand, and those taken up by corn was investigated. The results indicated that the amounts of K extracted by both Mehlich 3 and AB-DTPA were highly correlated to those extracted by NH_4OAc (r = 0.969** and r = 0.894**, respectively) and those absorbed by corn (r = 0.930** and 0.902**, respectively). In addition, coefficient of determination (r^2) for the relationship between amounts of K taken up by corn and extracted by the three extractants were 0.887 (NH_4OAc), 0.866 (Mehlich 3), and 0.813 (AB-DTPA). Therefore, Mehlich 3 and AB-DTPA can be effectively used for determining K availability status in Thai soils. Nevertheless, Mehlich 3 was identified to be better measurement extractant than AB-DTPA.

Key word: Mehlich 3, AB-DTPA, available K, multielement extractant, soil test

INTRODUCTION

In general, neutral ammonium acetate (NH_4OAc) has long been the most widely-accepted extractant for evaluating plant-available soil potassium (K) in most soil testing laboratories in Thailand. However, Mehlich 3 (Mehlich, 1984) and AB-DTPA (Soltanpour and schwab, 1977), the multielement soil extractants, are gaining in popularity because of their ability to extract other nutrient elements apart from K in one extraction (Haby *et al*., 1990). Nevertheless, to adopt either Mehlich 3 or AB-DTPA for assessment of available K in Thai soils, the relationship between amounts of K extracted values by these two methods and the amounts of K taken up by plant should be elucidated. Therefore, this study was conducted i) to compare the amounts of K extracted by two multielement extraction procedures (Mehlich 3 and AB-DTPA) with those extracted by NH_4OAc, and ii) to assess the efficiency of Mehlich 3 and AB-DTPA extraction procedures in predicting available K in eight Thai soils, using corn as the test plant.

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MATERIALS AND METHODS

Soils

Eight surface (0-15 cm) soil series, Chai Badan, Lop Buri, and Buri Rum (Vertisols); Chok Chai, Pak Chong and Tha Mai (Oxisols); Lam Narai (Mollisols) ; Kamphaeng Saen (Alfisols) classified by Soil Survey Staff (2003), collected from cultivated areas in five provinces of Thailand were used in this study. The soil samples were thoroughly mixed, air dried, and ground to pass a 2- mm sieve before analysis.

Laboratory analysis

The soil samples were analyzed for some properties like texture, pH, electrical conductivity (EC), cation exchange capacity (CEC) and organic matter (OM). Each soil sample was also examined for available K by extraction with Mehlich 3, AB-DTPA and ammonium acetate (Table 1). The quantities of extractable K were determined by atomic absorption spectrophotometer (AAS).

Greenhouse experiment

To obtain a quantitative assessment of K status in the eight soil samples used in this study, a greenhouse experiment was conducted. The experimental design was a completely randomized in two factorial treatment arrangement with three replicates. The first factor was soil series (three Vertisols, three Oxisols, one Mollisols, and one Alfisols). The second factor was two fertilizer treatments consisting of 1) the complete treatment, supplementing N P K at the rates of 250 mg N kg^{-1}, 200 mg P_2O_5 kg^{-1} and 150 mg K_2O kg^{-1}, respectively and 2) the –K treatment, supplementing N and P similar to the complete treatment except K. Moreover, to ensure an equilibrated plant nutrition level for supporting corn (*Zea mays* L.) growth, other nutrient elements were added in adequate amounts. Each pot was seeded with one seed of hybrid corn var. Suwan 4452. After 55 days, tasseling stage, the aerial parts of the plant were harvested, cleaned, dried in a forced air oven at 70°C and recorded their dry weight. Plant samples were digested in HNO_3 – H_2SO_4 – $HClO_4$ mixture and analyzed for K by AAS. Total K uptake by corn grown on K-untreated and treated soil was determined.

Verifying efficiency of extractants

The ability of Mehlich 3 and AB-DTPA extractants in measuring soil K was compared with the amounts of K extracted by each method with those extracted by NH_4OAc (conventional test method) and with those taken up by corn (total-K uptake). The linear correlation and regression were used to assess the relationships among them.

Table 1 Summary of methods used for available K extraction.

Extractant	Extractant composition	Soil : extractant	Soil weight (g)	Extractant volume (ml)	Time shaking (min)
Mehlich 3 (Mehlich,1984)	0.2 *M* CH_3COOH, 0.25 *M* NH_4NO_3, 0.015 *M* NH_4F, 0.013 *M* HNO_3 and 0.001 *M* EDTA	1:10	2.5	25	5
AB – DTPA (Soltanpour and Schwab, 1977)	1 *M* NH_4HCO_3 and 0.005 *M* DTPA	1:2	20	40	15
Ammonium acetate (Brown and Warnke, 1988)	1 *M* NH_4OAc pH 7.0	1:10	2	20	5

Significant correlation coefficient (r) and coefficient of determination (r^2) indicated efficiency of extractants.

RESULTS AND DISCUSSION

Soil properties

The eight soil samples used in this study varied in their properties (Table 2). They were loam to clay in texture with pHs ranging from 4.5 – 7.8, low levels of EC, 12-61 cmol(+)$kg^{-1}$of CEC, medium levels of OM, and different levels of K from medium to very high (Land Classification Division and FAO Project Staff, 1973).

The amounts of K extracted by different extractants and their relationships

The amounts of K extracted by NH_4OAc, Mehlich 3, and AB-DTPA extraction methods from soils without K fertilizer supplemented (-K treatment) are shown in Table 3. Generally, the amounts of extracted K increased in the following order: NH_4OAc > Mehlich 3 > AB-DTPA. The ratios of the mean values calculated with respect to that of NH_4OAc were also 1:0.96 and 1:0.57, respectively. Extractable K by both Mehlich 3 and NH_4OAc were rather similar agreeing with results of previous studies by Michaelson *et al.* (1987), Beegle and Oravec (1990), Went (1995), Eckert and Watson (1996), but higher than those removed by AB-DTPA (Elrashidi *et al.*, 2003). Nevertheless, the amounts of K extracted by either Mehlich 3 or AB-DTPA showed high correlation with those extracted by NH_4OAc (Table 4).

In addition, linear regression models were fitted to the data shown in Table 5. The result indicated that the amounts of K extracted by Mehlich 3 and AB-DTPA were highly regressed with those extracted by NH_4OAc. It could be observed that conversion of amounts of K extracted by Mehlich 3 and AB-DTPA to those extracted by NH_4OAc gave accurate results of 94 and 80 %, respectively. The data provided the regression prediction equations that compared K extracted by different soil extractions and that determined the critical K level of one extractant when using another.

Table 2 Selected properties of the soils.

Soil properties	Soil Series							
	Chai Badan	Lop Buri	Lum Narai	Chok Chai	Pak Chong	Kamphaeng Saen	Tha Mai	Buri Rum
Texture[1]	Clay	Clay	Clay	Clay	Clay	Loam	Clay loam	Clay
pH[2]	7.7	7.3	7.8	5.1	6.7	7.3	4.5	7.7
EC[3] (dSm^{-1})	0.13	0.1	0.14	0.02	0.06	0.27	0.02	0.13
CEC[4] (cmol(+)kg^{-1})	61	60	43	20	35	12	25	46
OM[5] (g kg^{-1})	16	23	20	21	30	19	19	20
Avail.K[6] (mg K kg^{-1})	464	299	227	318	129	89	118	387

[1] Hydrometer method
[2] pH meter (soil : water; 1:1)
[3] Electric conductometer
[4] Ammonium acetate saturation method (Sumner and Miller, 1996)
[5] Walkley and Black method (Walkley and Black, 1934)
[6] Ammonium acetate method (Brown and Warnke, 1988)

Table 3 Ranges and means of amounts of K extracted by different extractants.

Extractant	Range	Mean
	mg K kg^{-1}	
NH_4OAc	89 - 464	254
Mehlich 3	67 - 440	244
AB-DTPA	53 - 267	145

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

The relationship between the amounts of extracted K was linearly related to total-K uptake by corn (Table 6 and Figure 1).

The results showed that the amounts of K extracted by NH_4OAc, Mehlich 3, and AB-DTPA were highly correlated with those taken up by corn with *r* value of 0.942**,0.930** and 0.902**, respectively. These are in agreement with those reported by Beegle and Oravec (1990) using NH_4OAc and Mehlich 3.

Moreover, coefficient of determination for the linear regression between the three soil K extraction procedures and total-K uptake were also very high (Table 6). Nevertheless, compared with NH_4OAc, Mehlich 3 gave better accuracy (87%) than AB-DTPA (81 %) in term of their abilities to predict total-K uptake by corn.

CONCLUSIONS

In view of the significant relationships with the conventional test method (NH_4OAc) and with K uptake of corn plant, both Mehlich 3 and AB-DTPA can be effectively used for evaluating available K in soils. However, with careful consideration, Mehlich 3 was found to be better extractant than AB-DTPA.

Further research is needed in order to test the extractants in different soil types in Thailand and to test other nutrient elements especially when ICP is used for quantification.

Table 4 Correlation between K extracted by Mehlich 3 or AB-DTPA and NH_4OAc extraction procedures for eight soils investigated.

Extractant	Correlation coefficient (*r* value)
NH_4OAc vs Mehlich 3	0.969**
NH_4OAc vs AB-DTPA	0.894**

** significant at $p \leq 0.01$

Table 5 Regression equations and coefficient of determination (r^2) for relationships between amounts of K extracted by Mehlich 3 or AB-DTPA, and NH_4OAc extractants (all values are significant at $p \leq 0.01$).

Soil K extractant	Regression model	Coefficient of determination (r^2)
NH_4OAc *vs* Mehlich 3	Y = 0.90X + 34.86	0.938
NH_4OAc *vs* AB-DTPA	Y = 1.35X + 59.12	0.799

Table 6 Total-K uptake by corn grown on eight soil series (means of 3 replicates).

Soil series	Total K uptake (mg K pot^{-1}) 1/
Chai Badan	1,594 a
Lop Buri	1,384 a
Lum Narai	865 b
Chok Chai	1,581 a
Pak Chong	308 c
Kamphaeng Saen	374 c
Tha Mai	334 c
Buri Rum	1,440 a

1/ In a column, values followed by a common letter are not significantly different by Duncan's Multiple Range Test ($p \leq 0.05$).

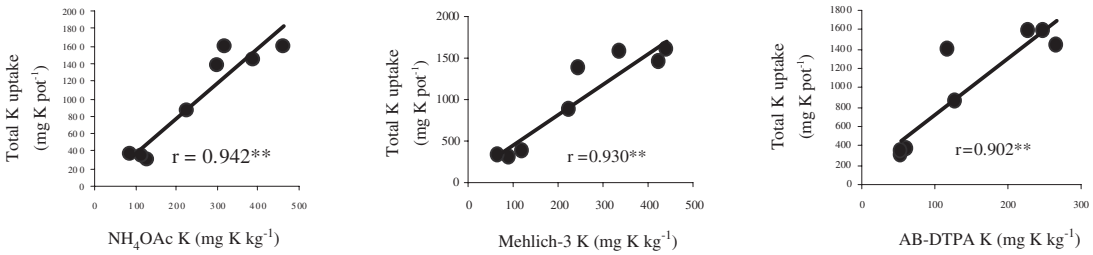

Figure 1 Linear correlation between amounts of K extracted (mg K kg^{-1}) by different extractants and total-K uptake (mg K pot^{-1}) (** = significant at $p \leq 0.01$).

Table 6 Regression equations and coefficient of determination (r^2) for relationships among amounts of K extracted by NH_4OAc, Mehlich 3 and AB-DTPA with total-K uptake by corn (all values are significant at $p \leq 0.01$).

Soil K extractant	Regression model	Coefficient of determination (r^2)
NH_4OAc	Y = 4.01X – 33.98	0.887
Mehlich 3	Y = 3.68X – 88.34	0.866
AB-DTPA	Y = 5.79X + 147.32	0.813

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