

Evaluation of AB-DTPA Extractant for the Estimation of Plant Available Macro and Micro Nutrients in Acidic and Neutral Soils

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ABSTRACT

*Use of multi nutrient extractants to assess available nutrients in soils is economically advantageous in routine soil testing. Even though AB-DTPA extractant has been proved to be successful for alkaline soils, its potential as a multi nutrient extractant for acidic soils has not been documented. This study examined the suitability of AB-DTPA extractant to determine plant available P, K, Na, Ca, Mg, Fe, Mn, Cu and Zn in acidic and neutral soils of Sri Lanka. Thirty one soils were collected from different locations, including alfisols, ultisols, entisols, and inceptisols. Available nutrient status of soils was analyzed by conventional methods as well as by AB-DTPA method. Conventional methods tested were; Olsen and Bray-1 methods for available P, neutral ammonium acetate extraction for exchangeable Ca, Na, K and Mg, and DTPA extraction for available Fe, Mn, Cu and Zn. Contents of nutrients in plants and plant uptake of nutrients were determined by conducting a pot experiment, using Guinea grass (*Panicum maximum*) as the indicator plant. Relationships between the amount of nutrients extracted by AB-DTPA method with those of conventional methods, and with plant nutrient concentration and uptake were analyzed using simple linear regression, for each nutrient separately. The amount of P, K, Na, Ca, Mg, Fe, Mn, Cu and Zn extracted with AB-DTPA method showed highly significant correlation ($p < 0.001$) with those extracted by conventional methods. The correlation between AB-DTPA extractable nutrient levels and plant uptake was highly significant for P ($r = 0.85^{***}$), K ($r = 0.83^{***}$), Na ($r = 0.86^{***}$), Mn ($r = 0.75^{***}$), Zn ($r = 0.74^{***}$) and Cu ($r = 0.75^{***}$). Comparatively weak, but a significant correlation was observed between AB-DTPA extractable Fe with plant uptake of Fe ($r = 0.48^*$). However, Ca and Mg extracted by both AB-DTPA and ammonium acetate methods did not show a significant correlation with plant uptake, probably due to the relatively high level of Ca and Mg in the tested soils. It could be concluded that AB-DTPA method can be recommended as a suitable extraction for routine soil analysis for acidic and neutral soils of Sri Lanka.*

Key Words: Available nutrients, multi nutrient extractants, soil analysis

Introduction

A soil test provides an index of the plant available nutrients in soils. This, in turn, is used to provide the amount of supplemental nutrients needed. In addition, it helps to monitor the quantity of available nutrients

present over time, which is useful in fertilizer management practices. Most biological methods of assessing nutrient status are laborious and time consuming, and are not suitable for the determination of soil nutrient status on routine basis. Therefore, much attention has been given for the use of

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chemical methods to assess plant nutrient status. In routine laboratory analysis, use of multi nutrient extractants is more economical, because a range of nutrients can be simultaneously determined.

Soltanpour and Schuwab (1977) introduced AB-DTPA extraction method (1M NH_4HCO_3 , 0.005M DTPA, pH 7.6) as a new soil test for simultaneous extraction of NO_3^- , P, K, Zn, Cu, Fe and Mn from alkaline soils of Colorado State. Ammonium in this solution acts as a displacing agent for cations adsorbed onto clay minerals, and therefore is used for the extraction of exchangeable cations. Bicarbonate ion is used for the extraction of soil phosphorus while DTPA is used to extract micro nutrients.

When practical aspects of soil tests are considered, multi nutrient extractants are useful in the sense of time, cost of analysis and material for routine analysis. When using the AB-DTPA extractant for 50 soil samples, an estimated 6 hours can be saved due to the reduction in time spent on weighing, shaking, filtering and utensil washing (Soltanpour and Schuwab, 1977).

In a preliminary study using Sri Lankan soils (Madurapperuma and Kumaragamage, 1995), significant correlations were obtained between P extracted by AB-DTPA, Olsen and Bray 1 methods, and exchangeable cations extracted by AB-DTPA and standard ammonium acetate methods. However, the effectiveness of AB-DTPA extractant in assessing plant available nutrients is not documented for acidic soils, even though it has been proven successful for neutral and alkaline soils (Soltanpour and Schuwab, 1977). This study examined the suitability of AB-DTPA extractant in determining available P, K, Na, Ca, Mg, Zn, Cu, Fe and Mn in acidic and neutral soils of Sri Lanka.

Materials and Methods

Soil samples were collected from different locations of Sri Lanka (Fig. 1), including different soil types, namely Reddish Brown Earth (Rhodustalfs), Non Calcic Brown Earth (Haplustalfs), Reddish Brown Latosolic (Rhodudults), Immature Brown Loams (Ustropepts), Red Yellow Podsolc (Tropudults), Alluvial soils (Tropofluents), Red Yellow Latasols (Eustrustox) and Regosols (Quartzpsamments). Soils of the Ap horizon were collected from a depth varying from 1-15 cm. All samples were air dried, ground and passed through a 2 mm sieve for pot experiments and for laboratory analysis.

Soil samples were analyzed for pH (Mclean, 1982), organic matter content (Dalal, 1979; Amato, 1983), texture (Bouycous, 1926) and cation exchange capacity (Chapman, 1965). Most soils were acidic or neutral in reaction with pH values less than 7.0. Only three soils exhibited pH values greater than 7.0 (Table 1).

A pot experiment (3 kg soil per pot) was conducted using Guinea grass (*Panicum maximum* L.) as the indicator plant. Soil moisture was maintained approximately at 70% field capacity throughout the experiment. Pots were arranged in a CRD design with three replicates. To obtain proper plant growth N was added at a rate of 0.262 g per pot (373 N kg/ha) in the form of $(\text{NH}_4)_2\text{SO}_4$. Because the amount of fertilizer added to a pot is minute, application was done by dissolving the fertilizer in de-ionized water. After application of N fertilizers, pots were kept at the green house for one week, maintaining the moisture status at 70% field capacity level. Five uniform rootstocks of *Panicum maximum* cuttings were planted in each pot. Pots were watered using de-ionized water twice a day throughout the experimental period. Two weeks after planting the weakest plant was removed and four plants per pot were left.

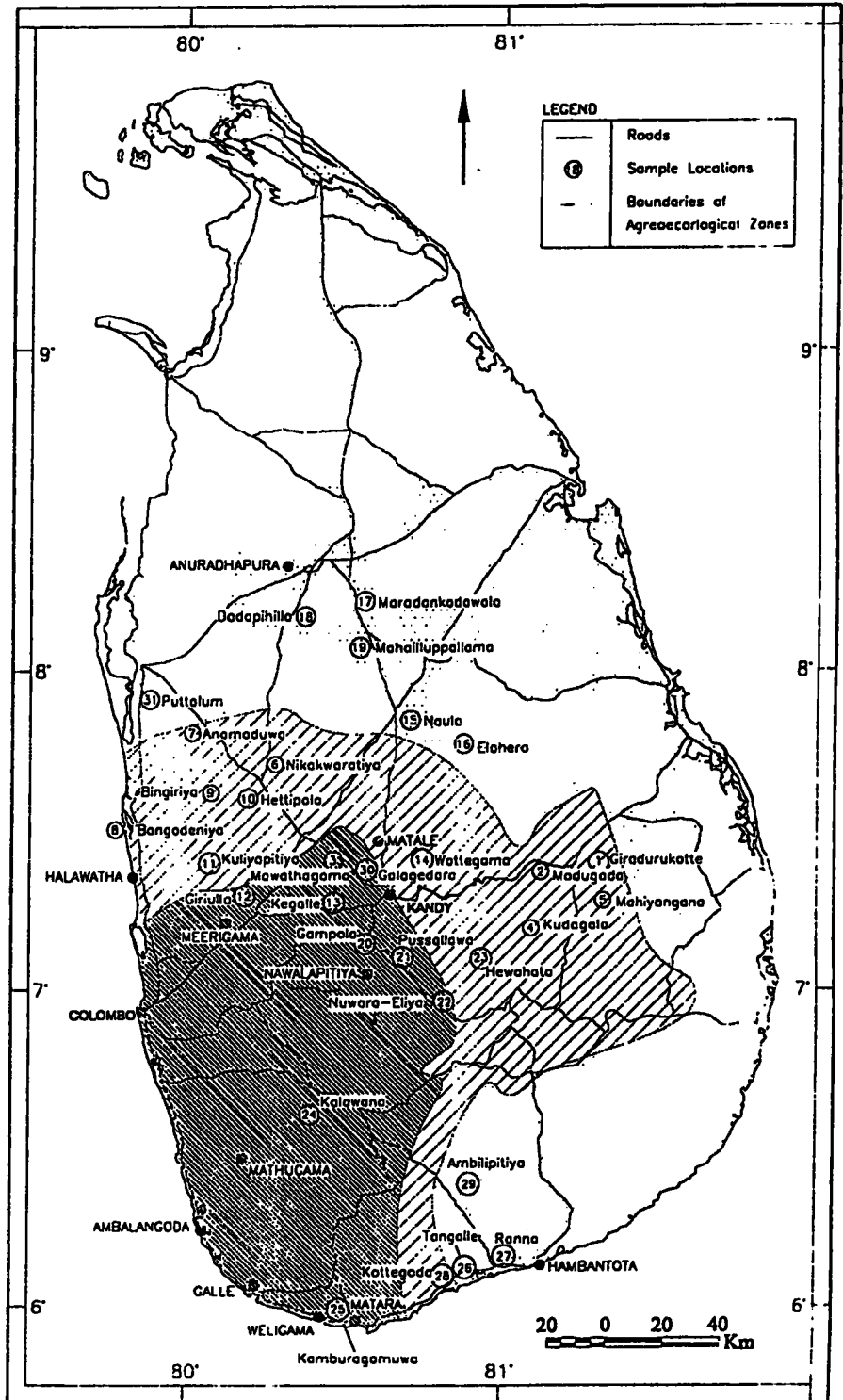


Fig. 1. Locations of the sampling sites

Table 1. Important chemical and physical properties of soils used in the pot experiment.

Location	pH	CEC cmol(+)/kg	OM (%)	Soil texture		
				Sand%	Silt%	Clay%
Girandurukotte	5.7	4.4	2.8	68.2	15.6	16.2
Madugoga	5.7	18.1	9.3	75.5	11.6	12.9
Mawathagama	5.6	6.1	1.5	48.7	29.7	21.6
Kudagala	6.5	15.9	3.2	70.6	12.1	17.3
Mahiyangana	6.3	12.2	2.3	80.1	10.5	9.4
Nikawaratiya	6.4	9.8	1.3	81.1	10.1	8.8
Anamaduwa	6.1	16.6	2.4	80.3	10.4	9.3
Bangadeniya	7.6	11.1	2.0	79.1	11.3	9.6
Bingiriya	6.7	7.1	1.0	48.9	32.4	18.6
Hettipola	6.5	9.5	2.6	76.7	8.3	15.0
Kuliyapitiya	6.2	5.0	1.1	72.5	15.6	11.9
Giriulla	5.5	23.9	5.1	68.2	15.7	16.1
Kegalle	4.8	17.7	2.8	46.6	13.1	40.1
Wattegama	5.8	19.4	5.2	45.3	11.8	42.9
Naula	6.2	15.1	3.3	42.6	22.9	34.5
Elahera	6.3	23.2	3.0	6.4	68.0	25.6
Maradankadawala	5.6	15.9	2.3	60.1	18.5	21.4
Dadapihilla	6.8	27.8	3.2	79.5	12.6	7.9
Maha Illuppallama	7.2	18.5	3.0	26.3	17.0	56.7
Gampola	5.2	25.6	3.8	41.4	41.5	17.1
Pussallawa	5.2	22.9	4.1	84.7	4.4	10.9
Nuwara Eliya	3.8	49.3	10.1	36.1	28.7	34.2
Hewahata	5.2	7.9	1.8	84.1	9.5	6.4
Kalawana	4.5	17.8	2.8	79.1	12.7	8.2
Kamburugamuwa	7.2	22.1	4.6	55.2	35.6	9.2
Tangalle	5.1	4.7	1.7	93.1	2.1	4.8
Ranna	6.5	22.9	2.9	36.8	13.6	49.6
Kottegoda	6.2	17.0	1.9	65.1	10.3	24.6
Ambilipitiya	6.7	19.7	2.8	67.2	6.2	26.6
Galagedara	6.9	20.9	3.5	77.3	8.4	14.3
Puttalum	6.5	24.5	0.2	89.1	4.1	6.8

pH = 1 : 2.5 soil: H₂O ; CEC = Cation Exchange Capacity; OM=organic matter

Harvesting was done at one-month interval on five occasions. Vegetative parts of each plant were cut about 4 cm above the soil surface. Each pot was treated with (NH₄)₂SO₄ after each harvest, at the same rate as the initial application. Plant samples were washed thoroughly, oven dried, ground and analysed for nutrients according to the method of Chapman and Pratt (1961).

Soil samples taken prior to treatment application were used for chemical analysis. Available P content was determined by extracting soils with 0.5M NaHCO₃ (Olsen *et al.*, 1954) and 0.03 M NH₄F + 0.025 M HCl solution (Bray and Kurtz, 1945). Concentration of P in the extract was determined by molybdenum blue method (Murphy and Riley, 1962) using a UV / visible spectrophotometer.

To determine the exchangeable Ca, Mg, K and Na, soil samples were extracted with neutral 1M ammonium acetate (Schollenberger and Simon, 1945). DTPA extracting solution (0.005 M DTPA, 0.01 M CaCl₂, 0.1M Triethanolamine) adjusted to a pH of 7.3 was used to extract cationic micro nutrients in soils (Lindsay and Norvell, 1978). Filtrates were analyzed for Ca, Mg, K, Na, Zn, Cu, Fe, and Mn using a Shimadzu AA-670 Atomic Absorption Spectrophotometer.

AB-DTPA solution was prepared by dissolving 1.97 g of DTPA in 800-ml distilled water to which 2 ml of 1:1 NH₄OH was added. To the above solution, 79.06 g NH₄HCO₃ was added and stirred gently until complete dissolution. The pH in the solution was adjusted to 7.6 (Soltanpour and Schuwab, 1977). Fresh solutions were prepared daily for analysis since ammonium bicarbonate is not stable for more than 24 hours. Ten g of soil was weighed into 250-ml polyethylene bottle, to which one tablespoonful of "C-Black" (free of P and other cations) and 20 ml of AB-DTPA extractant were added, shaken for 30 min and centrifuged. The solution was analyzed for P using the Murphy and Riley (1962) method. Exchangeable cations and micro nutrients were analyzed using the Atomic Absorption Spectrometer (Shimadzu AA-670).

For each nutrient analyzed, simple linear regression analysis was carried out separately, to discern the relationships between the amount extracted by AB-DTPA method with that of conventional methods, as well as with plant nutrient concentration and plant uptake.

Results and Discussion

Phosphorus

Highly significant correlations were obtained between AB-DTPA extractable P and Bray-1 P ($r = 0.90^{***}$) and AB-DTPA

extractable P and Olsen P ($r = 0.71^{***}$). Soltanpour and Schuwab (1977) have reported similar results for neutral and alkaline soils.

All three methods of P extraction (Olsen, Bray-1, and AB-DTPA) showed highly significant correlation with plant P concentration and plant uptake (Table 2). In evaluating P availability no significant difference was observed between Bray-1, Olsen and AB-DTPA methods. However, when numerical values of the correlation coefficients were considered, Bray-1 gave the highest value compared with the other two methods. AB-DTPA extractable P showed a better correlation with plant P concentration than Olsen extractable P, indicating that the effectiveness of AB-DTPA method in evaluating phosphorus status of soils is equal or even better than the Olsen method. Critical level of AB-DTPA P calculated based on the established critical level of Olsen P and the regression equation between AB-DTPA and Olsen P (Fig. 2), was 1.16 mg kg⁻¹.

Table 2. Relationships between P extracted by different methods with P concentration in plants and P uptake

Method	Correlation coefficients (r)	
	P concentration	P uptake
Bray-1 P	0.827 ^{***}	0.856 ^{***}
Olsen P	0.751 ^{***}	0.745 ^{***}
AB-DTPA P	0.793 ^{***}	0.849 ^{***}

^{***}Highly significant at $p=0.001$

Exchangeable cations

Highly significant correlations (Fig. 3) were observed between AB-DTPA extractable and ammonium acetate extractable values of K ($r = 0.99^{***}$), Na ($r = 0.96^{***}$) and Mg ($r = 0.92^{***}$). The correlation between AB-DTPA extractable and ammonium acetate extractable Ca was less, but still significant ($r = 0.72^{***}$).

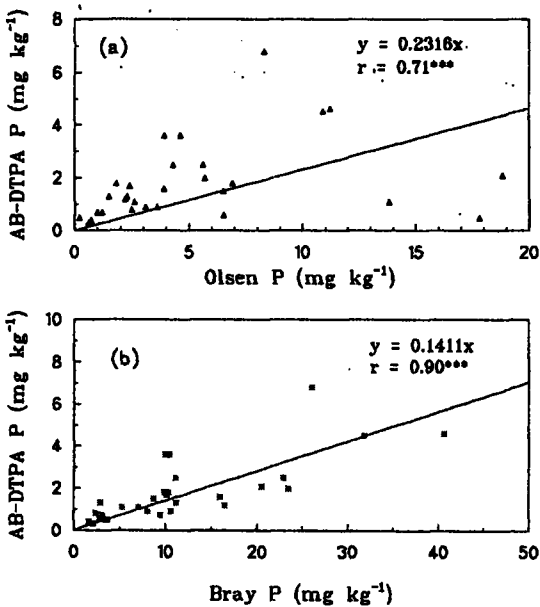


Fig. 2. Relationship between P extracted by conventional methods and AB-DTPA method (a) Olsen P (b) Bray P

Extractable K and Na measured by 1 M ammonium acetate and AB-DTPA methods showed significant correlations with plant concentrations and plant uptake of K and Na, respectively (Table 3). However, extractable Mg and Ca evaluated by AB-DTPA and 1M

Table 3. Relationships between Na, K, Ca and Mg extracted by different methods with plant concentrations and plant uptake

Element	Correlation coefficients (r)			
	Plant concentration		Plant uptake	
	AB-DTPA	AA	AB-DTPA	AA
Na	0.808***	0.815***	0.857***	0.820***
K	0.857***	0.812***	0.808***	0.812***
Ca	0.165 ^{ns}	0.364 ^{ns}	0.214 ^{ns}	0.364 ^{ns}
Mg	0.393 ^{ns}	0.068 ^{ns}	0.134 ^{ns}	0.066 ^{ns}

*** Highly significant at p = 0.001

^{ns} Not significant

AA- 1M ammonium acetate method

ammonium acetate methods did not show good relationships with plant Mg or Ca concentrations, or plant uptake of Mg and Ca, probably due to the high level of Ca and Mg in tested soils.

Critical levels for AB-DTPA method were calculated based on the established critical levels for ammonium acetate method (Landon, 1984) and the regression equations between AB-DTPA and ammonium acetate extractable nutrients (Fig. 3). The calculated critical levels for K, Ca and Mg were 57.3, 15.6 and 30.2 mg/kg, respectively.

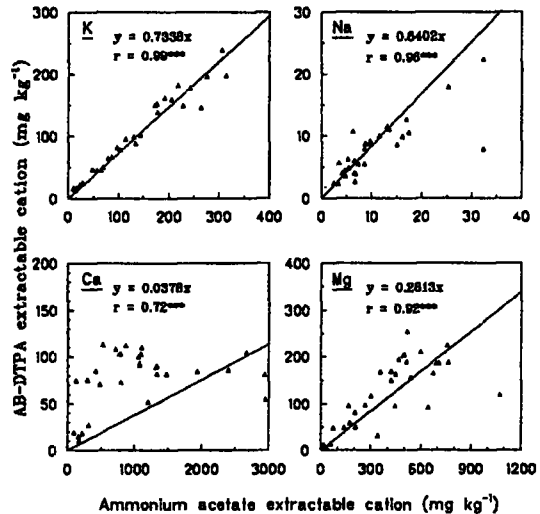


Fig. 3. Relationship between K, Na and Mg extracted by ammonium acetate method and AB-DTPA method

Micro nutrients

Highly significant correlations were observed between AB-DTPA extractable and DTPA extractable Zn ($r = 0.82^{***}$) Cu ($r = 0.91^{***}$), Fe ($r = 0.73^{***}$) and Mn ($r = 0.78^{***}$). Plant concentration and plant uptake data showed significant correlation with AB-DTPA extractable Zn, Cu, Fe and Mn (Table 4). However, DTPA extractable Fe and Mn did not show a significant relationship with plant

uptake indicating that AB-DTPA method is better than the conventional DTPA extraction in assessing available Fe and Mn.

Table 4: Relationships between Zn, Cu, Fe and Mn extracted by different methods with plant concentrations and plant uptake

Element	Correlation coefficients (r)			
	Plant concentration		Plant uptake	
	AB-DTPA	AA	AB-DTPA	AA
Zn	0.895 ^{***}	0.703 ^{***}	0.736 ^{***}	0.467 [*]
Cu	0.851 ^{***}	0.748 ^{***}	0.748 ^{***}	0.540 [*]
Fe	0.706 ^{***}	0.547 [*]	0.478 [*]	0.283 ^{ns}
Mn	0.809 ^{***}	0.589 [*]	0.752 ^{***}	0.566 [*]

^{***} Highly significant at p = 0.001

^{*} Significant at p = 0.05

^{ns} Not significant

Conclusions

Based on the results of this experiment AB-DTPA method can be introduced as a multi nutrient extraction method in routine laboratory analysis for available P, Na, K, Zn, Cu, Fe and Mn. AB-DTPA method seems to be equally effective or better than Olsen method in extracting soil available P, whereas in extracting micro nutrients such as Fe, Mn, Cu and Zn, it proved to be better than DTPA extractant for the soils tested. AB-DTPA and 1M ammonium acetate methods showed similar effectiveness in extracting exchangeable Na and K. Use of AB-DTPA method in routine analytical work will reduce the time and cost of analysis, since it requires only a single extraction to analyze many nutrients. Calculated critical levels for P, K, Ca and Mg were 1.16, 57.3, 15.6 and 30.2 mg/kg, respectively. To use this method for fertilizer recommendation, critical levels should be validated, preferably under field conditions.

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