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Electro-ultrafiltration (EUF) Technique in Relation to Conventional Methods of Soil Testing for the Determination of Available P, Ca, Mg and NO_3-N in some Tropical Soils

[1]Ezekiel A. Akinrinde, [1]Gabriel O. Obigbesan and [2]Thomas Gaiser
[1]Department of Agronomy, University of Ibadan, Ibadan, Nigeria
[2]Institute of Soil Science and Land Evaluation, University of Hohenheim, D-70593 Stuttgart, Germany

Abstract: This study investigated the usefulness of the Electro-ultrafiltration (EUF) technique of soil analysis as alternative to the conventionally accepted methods for the determination of available P, Ca, Mg and NO_3-N. In achieving this goal, twenty-seven soil samples of various ecological zones and parent materials were subjected to conventional and EUF analyses. Nutrient release was further characterized by exhaustive cropping in pots and the techniques were subsequently related to each other and to sorghum (*Sorghum bicolor* var. LS 187) growth and nutrient uptake. The relationships between Ca and Mg quantities extracted by the techniques were close and significant unlike for N and P. The largest proportion of the nutrients desorbed by EUF was from the soil organic fraction while those of the conventional methods were from the inorganic fraction. Using the quadratic regression model and employing the best relationship with sorghum growth and nutrient uptake, the EUF nutrient data were tentatively ranked into low, medium and high levels: NO_3 -$N_{(30-35\ min)}$ -< 0.014, 0.014-0.021, >0.021 mg kg^{-1} soil; $P_{(30-35min)}$ -<0.070, 0.070-0.075, >0.075 mg kg^{-1} soil; $Ca_{(0-35min)}$ -<120.0, 120.0-219.0, >219.0 mg kg^{-1} soil and Mg $_{(0-10\ min)}$ -<10.75, 10.75-18.25 >18.25 mg kg^{-1} soil. The EUF was more useful in studying the availability of the nutrients in the experimental soils as its estimated nutrient values on un-cropped soils and soils sampled after successive sorghum cuts correlated better with crop response than the case with the conventional methods.

Key words: Electro-ultrafiltration (EUF) technique, conventional soil test methods, available nutrients, EUF nutrient data ranking

INTRODUCTION

Over the years, many soil analytical procedures have been employed to assess the fertility status of soils. The chemical extractants include pure or carbonated water, organic or inorganic solutions of weak and strong acids, neutral salt solutions and various buffer solutions. There has been no general agreement about the most suitable extractant(s) for isolation of the various forms of specific nutrient elements. The resulting analytical values are, however, highly empirical. According to Akinrinde and Obigbesan (2005), procedures that have less empirical foundations involve the specification of the factors (intensity, quantity and rate/dynamics), which must be considered in defining nutrient availability in soils. The conventional use of such parameters will involve investigating the adsorption characteristics for specific soils, which can be quite cumbersome for a large number of samples and are rarely employed in routine analysis. They can also diverge widely in different soils according to the soil properties (Simonis and Nemeth, 1985; Memon, 1991; Indiati, 2002; Akinrinde and Obigbesan, 2005).

The Electro-ultrafiltration (EUF) technique of soil analysis is gaining recognition by soil chemists in many countries. It has been introduced for routine soil analysis in West Germany, Austria, Hungary, China and Yugoslavia (Nemeth, 1979, 1982, 1985; Olfs *et al*., 2005). Several reports (Obigbesan and Mengel, 1981a, b; Akinrinde *et al*., 1983; Xiaolin and Keming, 1986; Akinrinde and Obigbesan, 1999) have indicated that the method provides a means of assessing the nutrient availability in soils more comprehensively and could be adopted as a tool for widespread application (Appel *et al*., 1996; Imas *et al*., 2002; Simonis and Setatou, 1996). The amount of nutrients desorbed by EUF after 10 min (EUF_{0-10}) represents the intensity factor, EUF_{0-35} is the quantity factor while EUF_{30-35} is the buffer capacity and EUF_{5-10}/EUF_{30-35} is the fixation capacity of the soil (Xiaolin and Keming, 1986; Akinrinde and Obigbesan, 2005).

The present study aimed at comparing the relative efficiency of the EUF technique with other soil analytical procedures for determining available P, Ca, Mg and NO_3-N in twenty-seven soils collected from various locations in

Corresponding Author: Ezekiel A. Akinrinde, Department of Agronomy, University of Ibadan, Ibadan, Nigeria
Tel: 00234-2- 8033937476

Nigeria. The efficiencies were defined by relationships between soil test methods and nutrient uptake or dry matter yield of guinea corn grown in pots. The importance of the EUF procedure as an alternative to the conventionally accepted methods in the country is discussed.

MATERIALS AND METHODS

Soils: The soils used in this study represent typical soils on which major crops (maize, cowpea, cassava and Irish potato) are grown in the Western, Eastern and Middle belt of Nigeria. Their classification and geographical locations have been described (Akinrinde and Obigbesan, 1999). Composite topsoil samples (0-15 cm) were air-dried, crushed and passed through a 2 mm sieve. Sub-samples were also passed through a 1 mm sieve for analysis by the EUF technique.

Greenhouse studies: Five hundred grams of each of the soil samples were exhaustively cropped in triplicate pots using guinea corn (*Sorghum bicolor* var. LS 187) in the greenhouse of the Agronomy Department, University of Ibadan (UI), Nigeria between January and February 1998. One hundred seeds were sown in each pot but thinned to 50 plants per pot after germination. The plants were watered to keep the soil at 60% field capacity. At four weekly intervals, the above ground portions were cut and soil samples taken were analyzed.

Analytical procedure: The physical and chemical properties of the experimental soils, as determined by International Institute of Tropical Agriculture (IITA) methods described by Juo (1981) have been given (Akinrinde and Obigbesan, 1999). Solutions of 1N KCl and 0.01M $CaCl_2$ were similarly used in order to stabilize the pH readings in saline or calcareous soils. Exchangeable acidity was extracted with 1N KCl and determined by titration while exchangeable K, Ca and Na were determined by flame photometry after extraction with neutral 1N NH_4OAc and Mg was determined by atomic absorption. Effective CEC was taken as sum of exchangeable bases and total acidity. The kjeldahl analytical procedure was used for determining the total amounts of nitrogen. It involves initial digestion with concentrated sulphuric acid and later auto-analyzing the digest to determine the concentration of nitrogen in the samples. Total elemental analysis was done by hydro-fluoric and perchloric acid ($HF-HClO_4$) digestion (Pratt, 1965). The amounts of P, Ca and Mg extractable by deionised-H_2O, IN NH_4OAc, Bray-1, 0.01M $CaCl_2$ and 0.13N HCl were also determined using 1:10 soil: solution ratio and shaking for 30 min. Phosphate sorption characteristics of the soils were investigated using the method described by Akinrinde and Obigbesan (2005).

The NH_4-N, NO_3.N, P, Ca and Mg were also extracted using the EUF apparatus (Model 724 produced by "FIRMA VOGEL" in Giessen, donated by the Alexander von Humboldt foundation, Germany) in seven (7) fractional parts (i.e., 5 min desorption time intervals with stepwise increase in voltage after 5 and 30 min to 200 and 400 V, respectively from an initial of 50 V). Thus, the first aliquots (0-5 min) were extracted at 50 volts; the next five aliquots (5-30 min) were extracted at 200 volts and the final 5 min aliquots (30-35 min) at 400 volts. Ammonium-N and NO_3-N in the extracts were determined with an auto-analyzer while P was determined using the blue color method of Murphy and Riley (1962) and the absorbance measured on spectronic-20 equipment. The emission spectrophotometer was used for Ca while the atomic absorption spectrophotometer was used for Mg. The cumulative quantities of the nutrients desorbed after 10, 30 and 35 min were subsequently calculated.

The harvested sorghum tops were oven dried at 100°C, weighed and milled into a fine powder, which was wet digested with a mixture of HNO_3 and $HClO_4$ and the nutrient content in the extracts determined.

RESULTS AND DISCUSSION

The correlation coefficients relating the EUF and conventional techniques are given in Tables 1-6. The r-values were extremely low and insignificant in the case of nitrogen (Table 1). The poor correlation is attributable to the fact that the EUF procedure extracts a very minute fraction of the total-N contents of the soils as a result of concomitant clay deposition on the anode filter to reduce permeability as reported by Nemeth (1982, 1985). Nevertheless, this could not be used to invalidate the new (EUF) technique since analytical values are generally highly empirical and their usefulness is determined by their ability to closely simulate the absorption of the nutrient elements by plants' roots (Mengel and Uhlenbecker, 1993; Akinrinde and Obigbesan, 1999).

Table 1: Correlation coefficients relating % Total-N (Kjehldal method) to EUF-N measurements

EUF-N measurement	EUF-desoprtion time (min)	Correlation coefficients (r)
NO_3N	10	-0.1291ns
	30	-0.0074ns
	35	-0.0025ns
NH_4N	10	-0.0429ns
	30	-0.1178ns
	35	-0.1708ns
N	10	-0.0428ns
	30	-0.1179ns
	35	-0.1713ns

ns = r not significant at 5%, n = 23

Table 2: Correlation-matrix relating P extracted by conventional and EUF techniques

	EUF-I	EUF-Q	EUF-PBC^P	EUF-FC^P	Bray-P-1 NH_4OAc -P	H_2O-P	HCl-P	$CaCl_2P$	Total P	PBC^P	Langmuir P-adsorption capacity
EUF-I	-										
EUF-Q	0.8675**	-									
EUF-PBC^P	0.8432**	0.9828**	-								
EUF-FC^P	-0.0086	-0.1956	-0.2118	-							
Bray-P-1	0.1794	0.2290	0.3055	0.2264	-						
NH_4OAc-P	-0.1721	-0.2277	-0.2893	0.1751	-0.2556	-					
H_2O-P	0.0967	-0.0249	0.0425	-0.0715	0.3112	-0.1294	-				
HCl-P	0.2644	0.4306*	0.5093**	-0.2185	0.7565**	-0.1010	0.2384	-			
$CaCl_2P$	0.0125	-0.0737	-0.0563	0.1611	0.3641	-0.0042	0.0590	0.0204			
Total P	0.0286	0.0663	0.0107	-0.0392	0.2814	-0.1003	0.0241	0.1190	0.0880	-	
PBC^P	0.0216	-0.0951	-0.0901	-0.6310**	-0.2356	-0.2160	-0.0304	-0.0282	-0.0717	-0.3849	-
Langmuir P-adsorption Capacity	-0.0631	-0.0664	-0.0347	-0.3478	0.1907	-0.1980	-0.1725	0.1202	-0.1165	0.0493	0.5816**

N = 25, **Significant at 1%, *Significant at 5%

Table 3: P-Sorption parameters in relation to soil pH, % organic matter, % clay, exchangeable Fe and acidity

Soil Properties	Langmuir P-sorption capacity	P-sorption capacity at 0.2 ppm	2.0 ppm	Adsorption maxima	Conventional P-buffering capacity	EUF estimated P-fixation capacity
pH (H_2O)	0.4309ns	0.7492**	-0.7145**	-0.4045ns	0.6090*	-0.127ns
pH (KCl)	0.1421ns	-0.6143	-0.5869*	-0.1349ns	0.7096**	-0.5294*
pH ($CaCl_2$)	0.1439ns	-0.6363*	-0.6674**	-0.2225ns	0.6261*	-0.5115ns
% O.M.	0.0855ns	0.1481ns	0.1056ns	-0.1778ns	0.4197ns	0.5203*
% Clay	-0.5494ns	0.6979**	0.8163**	0.6972**	0.6711**	-0.1931ns
Exchangeable Fe	0.9899ns	-0.7923**	-0.3826ns	-0.3400ns	-0.5199*	0.5311*
Exchangeable acidity (Al + H)	-0.3699ns	-0.7967ns	0.6331*	0.1448ns	-0.6402*	0.4595ns

n = 15, ** Significant at 1%, * Significant at 5%, ns = Not significant

Table 4: Bray P-l and EUF-P in relation to P-remaining in equilibrium solution at various P-addition levels

Soil P-measurements	P-remaining in equilibrium solution P-added (mg kg^{-1} soil) 50	100	300
Bray-P-1	-0.459ns	0.1074ns	0.5446*
EUF-P 5	0.3819ns	0.3678ns	0.5866*
EUF-P10	0.2175ns	0.1665ns	0.5014ns
EUF-P15	0.3564ns	0.3120ns	0.5297*
EUF-P20	0.2596ns	0.2085ns	0.5338*
EUF-P25	0.3662ns	0.3380ns	0.5402*
EUF-P30	0.4710ns	0.4315ns	0.4159ns
EUF-P35	0.4277ns	0.3730ns	0.4082ns

n = 15, * Significant at 5%, ns = not significant

The EUF-technique was also at variance with the conventional methods regarding P-extraction. Significant correlations were obtained only when EUF estimated quantity and buffering factors were related to 0.13N HCl extracted-P (Table 2). This is probably due to variance in the type and quantity of soil P-fraction extracted by them. Thus, the P-fixation capacity estimated via the EUF correlated significantly with percent organic matter while the conventional P-sorption parameters did not but instead correlated with percent clay (Table 3). With the exception of P Sorption Capacity (PSC) at 2.0 ppm and adsorption maxima, all the P-sorption parameters also correlated with exchangeable Fe. Both PSC and EUF-estimated P-fixation capacity factor were inversely but significantly related to soil pH while conventional P-buffering capacity had a direct, significant relationship with it and an inverse one with exchangeable acidity. The relationship between the conventional P-buffering capacity and EUF estimated P-fixation capacity was, however, significant (Table 2) indicating that both techniques are equally good in estimating P-sorption by the soils. Thus, both Bray P-1 and EUF-P at certain desorption times were related to the amounts of P-remaining in equilibrium solution in a similar way (Table 4).

The EUF-Ca and-Mg values at 10, 30 and 35 min desorption times were also related to the conventionally accepted NH_4OAc-Ca or NH_4OAc-Mg and the deionised-H_2O, Bray-1, HCl, $CaCl_2$-extractable Ca or Mg values (Table 5 and 6). Good correlations were obtained between the EUF-Ca and the conventionally extracted Ca values except for Bray-1-Ca Vs EUF-Ca at all three desorption times and EUF Ca at 10 min Vs 1N NH_4OAc-Ca, or HCl-Ca or Total-Ca. As regards Mg, only HCl, $CaCl_2$ and Total-Mg values were not significantly correlated with the EUF-Mg values at the various desorption times. In almost all cases, the correlations involving the 1N NH_4OAc, Deionised-H_2O or Bray-1-extractable Mg values and EUF-Mg results were significant at 1% confidence limit. Thus, the EUF-technique is confirmed as a useful extraction procedure.

Table 5: Correlation Matrix relating Ca extracted by conventional and EUF techniques

	1N NH_4OAC-Ca	Deionised; H_2O	Bray-1-Ca	Hcl-Ca Total Ca	EUF Ca10	Ca30	Ca35
1N. NH4OAC-Ca	-						
Deionised H_2O Ca	-0.0636	-					
Bray-1-Ca	0.1360	0.1907	-				
HCl-Ca	0.7062	0.1503	-0.0606	-			
Total-Ca	0.3927	0.3918	-0.1107	0.4243*	-		
EUF							
Ca10	0.2609	0.6060**	0.2919	0.0930	0.3230	-	
Ca30	0.6074**	0.6345**	0.0874	0.4265*	0.5228*	0.8021**	-
Ca35	0.7142**	0.6371**	0.0849	0.5208	0.5241	0.7148**	0.9805

n = 23, **Significant at 1 %, *Significant at 5%

Table 6: Correlation Matrix relating Mg extracted by conventional and EUF techniques

	1N NH_4OAC-Mg	Deionised H_2O	Bray-1-Mg	HCl-Mg	$CaCl_2$-Mg	Total-Mg	EUF Mg10	Mg30	Mg35
1N. NH_4OAC-Mg	-								
Deionised H_2O Mg	0.3148	-							
Bray-1-Mg	0.5894**	0.2292	-						
HCl-Mg	0.6222**	-0.1262	0.5495**	-					
$CaCl_2$-Mg	0.3361	0.1667	-0.0706	0.1781	-				
Total-Mg	-0.4672*	-0.2156	-0.1824	-0.3768	-0.0494	-			
EUF									
Mg10	0.4371*	0.5698**	0.5271**	0.1843	-0.2089	-0.2550	-		
Mg30	0.5371**	0.5792**	0.6127	0.2945	0.0475	-0.3135	0.8792**		
Mg35	0.5757**	0.5744**	0.6217**	0.3403	0.0920	-0.3348	0.8485**		0.9951**

n = 23, ** Significant at 1 %, * Significant at 5%

Table 7: Growth and nutrient content and uptake of sorghum plants cut at weekly intervals

Growth parameter		No. of cuts/weeks after planting 1	2	3	4
Fresh straw	Mean	3.66	1.97	1.01	0.56
(g pot^{-1})	Range	2.63-5.05	1.10-4.33	0.63-1.43	0.28-0.97
	SD	0.51	0.34	0.18	0.17
	CV (%)	13.9	17.24	18.13	30.20
	SE ±	0.29	0.20	0.11	0.10
Dry straw	Mean	0.53	0.33	0.24	0.21
(g pot^{-1})	Range	0.40-0.65	0.25-0.46	0.15-0.32	0.16-0.27
	SD	0.06	0.04	0.03	0.05
	CV (%)	10.99	12.67	14.47	21.26
	SE ±	0.03	0.02	0.02	0.03
%P	Mean	0.23	0.84	0.31	0.21
	Range	0.16-0.32	0.60-1.20	0.20-0.50	0.11-0.34
	SD	0.05	0.15	0.07	0.06
	CV (%)	23.82	17.96	23.68	30.44
	SE ±	0.03	0.09	0.04	0.04
P-uptake	Mean	1.19	2.71	0.72	0.43
(mg pot^{-1})	Range	0.93-1.77	1.94-3.93	0.44-107	0.21-0.70
	SD	0.31	0.54	0.16	0.14
	CV (%)	26.33	19.95	22.59	32.86
	SE ±	0.18	0.31	0.09	0.08
%Ca	Mean	0.18	0.28	0.17	0.08
	Range	0.08-0.53	0.15-0.56	0.09-0.55	0.05-0.13
	SD	0.15	0.15	0.14	0.03
	CV (%)	79.60	54.61	82.12	33.02
	SE ±	0.08	0.09	0.08	0.01
Ca uptake	Mean	0.99	0.94	0.42	0.17
(mg pot^{-1})	Range	0.40-2.38	0.39-1.97	0.19-1.64	0.09-0.28
	SD	0.69	0.54	0.41	0.09
	CV (%)	69.85	57.74	97.47	51.39
	SE ±	0.40	0.31	0.24	0.05
%Mg	Mean	0.14	0.21	0.14	0.06

Table 7: Continued

Growth parameter		No. of cuts/weeks after planting 1	2	3	4
	Range	0.08-0.36	0.15-0.29	0.08-0.23	0.03-0.10
	SD	0.04	0.05	0.04	0.02
	CV (%)	24.50	22.41	28.93	39.34
	SE ±	0.02	0.03	0.02	0.01
Mg-uptake	Mean	0.78	0.67	0.33	0.13
(mg pot^{-1})	Range	0.32-2.02	0.37-1.08	0.17-0.76	0.05-0.21
	SD	0.21	0.16	0.13	0.07
	CV (%)	26.34	23.69	37.64	52.45
	SE ±	0.12	0.09	0.07	0.04

Table 8: Cumulative fresh and dry yields of guinea corn (*Sorghum bicolor* Var. LS 87) at successive cutting times

Soil location	Cumulative fresh forage^{+} (g pot^{-1}) 2	3	4	Cumulative dry forage^{+} (g pot^{-1}) 2	3	4
Ilesha	5.68 a-d^{++}	7.03a-c	7.70ab	0.97a	1.28a	1.49ab
Akure	6.72a	8.12a	8.77a	0.99a	1.29a	1.54a
Ilora	6.20ab	7.28ab	7.72ab	0.95ab	1.23ab	1.47a-c
Ikenne	6.07a-c	6.69b-d	6.97b-c	1.02a	1.17a-c	1.37a-f
Ilorin	4.73d-g	5.47d-g	5.90d-f	0.77d-f	0.98e-g	1.19c-h
Agparo	4.33e-g	5.08fg	5.53ef	0.75d-f	0.95e-g	1.16gb
Abak	3.92g	4.68g	5.23f	0.72ef	0.92fg	1.14gh
Jos I	5.63a-d	6.82a-c	7.27a-d	0.97a	1.24ab	1.43a-c
Jos II	5.65a-d	7.00a-c	7.57a-c	0.90a-d	1.20a-c	1.42a-d
Umudike	4.68d-g	5.43d-g	5.88d-f	0.78c-f	0.99e-g	1.22d-h
Texagri	5.40b-e	6.27b-f	6.83b-e	0.87a-e	1.09b-c	1.33b-g
Ijaiye	6.15ab	7.27ab	7.77ab	0.95ab	1.20a-c	1.44a-c
Ajibode I	4.57d-g	5.23e-g	5.60ef	0.78c-f	0.99d-g	1.18f-h
Ajibode II	5.53a-c	6.57b-e	7.28a-d	0.88a-e	1.08b-f	1.29b-g
Ajibode III	4.50d-g	5.25e-g	5.65ef	0.78c-f	0.99e-g	1.17f-h
Ajibode IV	4.87e-g	5.83c-g	6.20c-f	0.80b-f	1.05c-f	1.21e-h
Barthroad	6.10a-c	7.20a-c	7.83ab	0.94a-c	1.17a-c	1.39a-c
Rockefellar	3.87g	4.68g	5.22f	0.64f	0.86g	1.08g
Enugu	6.53ab	7.60ab	8.10ab	0.99a	1.24ab	1.44a-c
Oyo I	4.50d-g	5.45d-g	6.18c-f	0.85a-e	1.08b-f	1.27c-h
Oyo II	4.12fg	5.22e-g	5.97d-f	0.75d-f	0.96e-g	1.17f-h
Iwo	6.38ab	7.65ab	8.53a	0.98a	1.19a-c	1.43a-c
Alabata	5.28b-f	6.72b-d	7.68ab	0.87a-e	1.15a-d	1.42a-d
Overall mean	5.2788	6.2841	6.8431	0.8640	1.1010	1.3148
Range	3.87-6.72	4.68-8.12	5.22-8.77	0.64-1.02	0.86-1.29	1.08-1.54
S.E	0.3799	0.4170	0.4548	0.0493	0.0504	0.0627
C.V (%)	12.4673	11.4940	11.5127	9.8979	7.9443	8.2614
LSD (5%)	0.6581	0.7223	0.7878	0.0855	0.0874	0.1086

$^{+}$Mean of replicates, $^{++}$Means in each vertical column followed by the same letter are not significantly different at 5% level (DMRT)

Table 9: Regression equations and correlation coefficients relating EUF-nutrient fractions (X) to response parameters (Y) of Guinea corn (*Sorghum bicolor* var. LS 187)

Response parameter (y)	Nutrient element	Desorption period (min.)	Regression equation	r
Nutrient Content	Ca	1-35	$Y = 0.604 - 0.0025X + 00002X^2$	0.6132**
	Mg	1-10	$Y = 0.577 - 0.0111X + 0.009X^2$	0.5621**
Nutrient Uptake	Ca	1-35	$Y = 4.37 + 0.0075X + 0.0004X^2$	0.659**
	Mg	1-10	$Y = 1.931 - 0.0589X + 0.004X^2$	0.7470**
Forage Yield	NO_3N	31-35	$Y = 4.16 - 306.0X + 7501 - 0.0X^2$	-0.5747**
	P	31-35	$Y = -3.96 + 167.0X - 1301.0X^2$	-0.5514**

n = 23, *Significant at 5% confidence limit, **No significant at 1% confidence limit

The growth and nutrient content and uptake of sorghum plants cut at weekly intervals are presented in Table 7. Further details are provided with respect to variations among soils in Table 8. In all cases, the mean values are for three replicates. It is evident from the data that forage yields; the contents of the various nutrients elements in plants tissue and the respective total amounts removed per pot varied widely among the soils at each of the cutting times. The trend is such that the dry matter accumulation decreased from the first cut (overall mean of

Table 10: Calibration of EUF-nutrient data for sorghum yield in the greenhouse

Plant nutrient	EUF desorption period	EUF nutrient rating	EUF nutrient values	Corresponding yield (% of maximum)
NO_3N	31-35	Low	<0.014	<81.25
		Medium	0.014-0.021	81.25-87.5
		High	>0.021	>87.5
		Optimum	0.020	67.97
P	31-35	Low	<0.070	<83.33
		Medium	0.070-0.075	83.33-89.58
		High	>0.075	>89.58
		Optimum	0.064	91.08
Ca	1-35	Low	<120.0	<50.0
		Medium	120.0-219.0	50.0-63.0
		High	219.0	>63.0
		Optimum	93.75	45.2
Mg	1-10	Low	<10.75	<60.0
		Medium	10.75-18.25	60.0-71.67
		High	>18.25	>71.67
		Optimum	7.36	57.13

0.53 g pot^{-1} and a range of 0.4-0.65 g pot^{-1} to the final (4th) cut (overall mean of 0.21 g pot^{-1} and a range of 0.16-0.27 g pot^{-1}) while nutrient contents and uptake by the plant reached their various peaks at the second cut before decreasing to the minimum values at the final cut. Thus, the overall mean P content was 0.23% (a range of 0.16-0.32%) at the first cut, reached a peak of 0.84 % (a range of 0.60-1.20%) before declining to 0.21% (a range of 0.11-0.34%). In the final analysis, Akure and Rockefeller location soils gave the highest and lowest yields per pot, respectively, after the 4 weeks of growth (Table 8). The considerable variation in the amounts of available soil nutrients and abilities of the soils to release them for the growth of the crop is indicated by the respective coefficients of variation (Table 7). The highest values of 79.6 and 69.9% were in respect of Ca-contents and uptake, both of which decreased with successive cuts, indicating improved solubility and uptake of the element within the growing period.

In order to allow for the rating of the EUF nutrient data for the growth of the crop, the extractable nutrient values after specific desoprtion periods were related to the response parameters after four cuts, using a quadratic regression model (Table 9). This made the categorization of the various EUF-nutrient data into low, medium, high and optimum levels possible (Table 10). It is evident from the evaluations that during the last 5 min desorption period (buffering factor), EUF-NO_3N values of less than 0.014, 0.014- 0.021 and above 0.021 mg kg^{-1} soil are indicative of low, medium and high NO_3-N status, respectively (Table 10). Mathematical differentiation of the regression equation was employed to give an optimum value of 0.020 mg kg^{-1} soil. During the same desorption period, EUF-P values of less than 0.070, 0.070-0.075, above 0.075 and 0.064 mg kg^{-1} soil imply low, medium, high and optimum P-status, respectively. The respective EUF-Ca_{35} values are <120.0, 120.0-219.0, above 219.0 and 93.75 mg kg^{-1} soil. Magnesium extracted values of less than 10.75, 10.75-18.25, above 18. 25 and 7.36 mg kg^{-1} soil after 10 min of EUF extraction are similarly indicative of the same categories of soil nutrient status. The relatively low soil nutrient critical values obtained in this report compared with corresponding ones for soils from other countries (West Germany, Austria, Hungary, China and Yugoslavia) where the EUF technique has been introduced for routine soil analysis is most probably due to inherently low fertility status of the soils which have probably received less fertilizer dressings. The comparatively lower level of organic matter from which the largest proportions of the nutrient extracted from the soils were desorbed further evidences this. The 1:1 lattice clay type dominant in the soils also contributed to the low effective CEC and hence the low nutrient retention capability and higher depletion rates by means other than plant removal in the face of continuous land use.

CONCLUSIONS

The EUF and conventional techniques may be poorly correlated as they extract nutrients from different soil nutrient pools. The EUF proved to be more useful in studying the availability of nutrients in soils as it determines the rate of nutrient release whereas the conventional soil-testing methods extract only nutrient quantities. Furthermore, as the yield of sorghum plants declined, the amount of each of the nutrients desorbed by the EUF also diminished considerably. As such, the values of extracted nutrients obtained by its use on un-cropped soils and soils sampled after successive cuts correlated better with crop response. Being a simultaneous extractant of nutrients, it should help in the detection of sub-optimally available nutrients that may affect the availability of others.

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REFERENCES

Akinrinde, E.A., G.O. Obigbesan and J.E. Okeke, 1983. Electro-ultrafiltration extractable K in relation to crop yields in Tropical soils. In: Proc. of the 6th Intl. Sci. Conf. on problems of an optimum nutrient supply to tropical crops., Inst. Trop. Agric. Karl Marx Univ., Leipzig. 6th-12 June, pp: 337-348.

Akinrinde, E.A. and G.O. Obigbesan, 1999. Quantity-Intensity parameters of potassium in relation to uptake by guinea-corn in representative soils of the ecological zones of Nigeria. Commun. Soil Sc. Plant Analysis, 30: 2695-2710.

Akinrinde, E.A. and G.O. Obigbesan, 2005. Phosphorus adsorption in selected alfisols, oxisols and ultisols. Eur. J. Sci. Res., 3, 3, pp: 41-54.

Appel, T., B. Scheider and H. Kosegarten, 1996. Extractability of labeled microbial biomass N by electro-ultrafiltration and $CaCl_2$ extraction. Biol. Fertil. Soils, 23: 314-320.

Imas, P., S.K. Bansal, R.C.Srinivasa and N.S. Pasricha, 2002. Changes in Electro-ultrafiltration Fractions of K in Major Benchmark Soil Series of India Under Long-term Cropping. Proc. Symposia of the 17th. World Congress of Soil Science. Symposium 16, Paper No. 277, II: 641.

Indiati, R., I. Trujillo and F. Gutierrez, 2002. Characterization of P Adsorption Properties of Some Agricultural Volcanic Soils from Canary Islands, Spain. Trop. Agric. (Trinidad), 79: 254-259.

Juo, A.S.R. (Ed.), 1981. Selected methods for soil and plant analysis. Manual series No. 1. International Institute of Tropical agriculture (IITA), Ibadan, Nigeria.

Murphy, J. and J.P. Riley, 1962. Anal. Chem. Acta., 27: 31-36.

Memon, K.S., H.K. Puno and R.L. Fox, 1991. Phosphate sorption approach for determining phosphorus requirements of wheat in calcareous soils. Fert. Res. 28: 67-72.

Mengel, K. and K. Uhlenbecker, 1993. Determination of available interlayer potassium and its uptake by ryegrass. Soil Sci. Soc. Ann. J., 57: 761-766.

Nemeth, K., 1979. The availability of nutrients in the soil as determined by Electro-Ultrafiltration. Advances in Agron., 31: 155-188.

Nemeth, K., 1982. Application of Electro-ultrafiltration (EUF) in agricultural production. Plant and Soil, 64: 5-6.

Nemeth, K., 1985. Recent advances in EUF research (1980-1983). Plant Soil, 83: 1-19.

Obigbesan, G.O. and K. Mengel, 1981a. Use of electro-Ultrafiltration method of investigating the behaviour of phosphate fertilizers in tropical soils. Fert. Res., 2: 169-176.

Obigbesan, G.O. and K. Mengel, 1981b. Relationship between EUF extractable phosphates, P-uptake and P-buffer capacity of selected tropical soils. Nig. J. Soil Sci., 1: 1-12.

Olfs, H., K. Blankenau, F. Brentrup, J. Jasper, A. Link and J. Lammel, 2005. Soil-and plant-based nitrogen-fertilizer recommendations in arable farming. J. Plant Nutr. Soil Sci., 168: 414-431.

Pratt, P.H., 1965. Potassium. In: Black, C.A. (Eds.-in-chief) Methods of soil analysis. Agron. 9: Am. Soc. Agron., pp: 1022-1030.

Phillips, I.R. and M. Greenway, 1998. Changes in water soluble and exchangeable ions, cation exchange capacity and phosphorus max in soils under alternating water logged and drying conditions. Commun. Soil Sci. Plant Anal., 29: 1-2, 51-65.

Simonis, A.D. and K. Nemeth, 1985. Comparative study on EUF and other methods of soil analysis for the determination of available potassium in soils from Northern Greece. Plant and soil, 83: 93 - 106.

Simonis, A.D. and H.B. Setatou, 1996. Determination of available P in soils from northern Greece by the Electro-ultra Filtration (EUF) and other methods of soil analysis. Commun. Soil Sci. Plant Anal., 27: 695-711.

Xiaolin, Lir and Keming Peng, 1986. Potassium supplying power of several soils in Biejing District. Transactions of the XIII. Congress of the Intl. Soc. of Soil Sci. Held at Hamburg. 13-20 Aug., Extended Information Summaries. Band ISSS-AISS-IBG, 111: 840-841.