

# THE RELATIONSHIP BETWEEN EUF-K AND SOIL-K FRACTIONS OF DIFFERENT K SELECTIVITY

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## Abstract

The fraction of K released during EUF 30-35 min, 80°C, 400V (EUF<sub>3</sub>) and various other soil K parameters were compared for 24 soils that range widely in clay mineral composition, clay content and percentage K saturation. When EUF<sub>3</sub> was compared with fractions of soil K containing increasing amounts of non-exchangeable K (=selectively adsorbed K), the R<sup>2</sup> values decreased with increasing quantities of non-exchangeable K. This indicates that EUF<sub>3</sub> is a function of the exchangeable pool of K, although some initially non-exchangeable K is also involved.

## Introduction

The possible use of electro-ultrafiltration (EUF) in determining both the presence and content of K-selective clay minerals in soils has been proposed by Németh (1972; 1979; 1982; 1984). In pure clay systems which contain no 'K-selective' minerals eg kaolinite and montmorillonite, EUF desorption is complete within 25-30 min at 200V and 20°C (Németh, 1972). No further K is released if the temperature and voltage have increased. However, when illite is present K continues to be released if the voltage is raised from 200 to 400V and the temperature raised simultaneously to 80°C (Németh, 1972). Németh and Forster (1976) have also shown that EUF 30-35, 400V is positively correlated with non-exchangeable K.

In studying the effect of field strength on the quantity of K desorbed from soils by EUF, Grimme (1980) has come to the conclusion that only exchangeable K participates in the desorption process and that there is no evidence of release of non-exchangeable K. In other work EUF 30-35 min, 400V, 80°C does not appear to indicate the rate of release of K from the interlayers of clay minerals, but rather the release of K from the interlayers of clay minerals, but rather the release of initially non-exchangeable K which is in close equilibrium with the exchangeable pool (Sinclair, 1980; 1982).

In this communication EUF fractions are compared with other soil K parameters with particular emphasis on the postulate that EUF 30-35 min, 400V is a measure of K selectivity of clay minerals in soils.

## Methods

Twenty four soils with widely varying properties regarding clay content, clay mineral composition and K-saturation were analysed for the following soil-K parameters.

Exchangeable K:	Extraction with 0,5N NH <sub>4</sub> OAc
EUF-K	Three fractions were obtained with: a fully automatic Vogel apparatus viz 0-10 min at 50/200V and 20°C (EUF <sub>1</sub> ); 10-30 min at 200V and 20°C (EUF <sub>2</sub> ) and 30-35 min at 400V and 80°C (EUF <sub>3</sub> ).
HNO <sub>3</sub> -K	Extraction with boiling N HNO <sub>3</sub> (½ hour reaction time) after removal of exchangeable K with 0,5 N NH <sub>4</sub> OAc.
HCl-K	Batch extractions with N HCl at room temperature. Each extraction was equivalent to 2 hours contact time, including one hour shaking in an end-over-end shaker at 60 rpm. Total desorbable K was calculated by extrapolating the cumulative desorption curve, as described by Grimme (1979).
CaCl <sub>2</sub> -K	Batch extractions with 0,025 M CaCl <sub>2</sub> , similar to those described for HCl-K.
XRF-K	K content was determined by means of X-ray fluorescence on Ba-saturated clay samples.

In addition to the above, clay minerals were determined semi-quantitatively by means of X-ray diffraction, cec of the clay fraction and XRF-K.

From the chemical and XRF-K determinations, the following additional soil K fractions were defined for purposes of correlating them with the EUF<sub>3</sub>:

- Fr 1 = difference between 1st HCl-K and CaCl<sub>2</sub>-K fractions  
= easily exchangeable K (contains no non-exchangeable K)
- Fr 2 = difference between first two cumulative HCl-K and CaCl<sub>2</sub>-K fractions  
= mostly exchangeable K plus some non-exchangeable K associated with expanded interlattice K (initially non-exchangeable K)
- Fr 3 difference between total desorbable HCl-K and CaCl<sub>2</sub>-K  
= mostly non-exchangeable K, associated with expanded interlattice K (initially non-exchangeable K)

- Fr 4 = difference between  $\text{HNO}_3$ - and  $\text{HCl}$ -K  
 = non-exchangeable K, associated mostly with expanded and some non-expanded interlayer K. In this calculation  $\text{NH}_4\text{OAc}$ -K was added back to  $\text{HNO}_3$ -K
- Fr 5 = difference between  $\text{HNO}_3$ - and XRF-K  
 = non-exchangeable K originating mostly from non-expanded interlayer K

## Results

Table 1 shows the distribution of K parameters in 4 out of the 24 soils that were investigated. All concentrations are expressed in  $\text{mgK } 100\text{g}^{-1}$  clay in order to eliminate the dilution effect of varying quantities of silt plus sand.

The soils in Table 1 were selected, for illustrative purposes, mainly because of their large differences in content of K selective minerals and percentage K saturation. K selectivity of clay minerals, in the context used in this communication, is associated with the presence of interlattice K (Németh 1972; 1979; 1982; 1984). In Table 1 K selectivity increases from soil No 1 to soil No 4 as is evident from the estimated mica content, and the total K content (XRF) of the clay fraction. Soil No 1 is an oxisol (18% clay) from the Eastern Transvaal highveld, while No 4 is an 'Aueboden' (37% clay) from the Buntehof Experimental Station, Hannover, West Germany. From Table 1 it is evident that  $\text{EUF}_3$  holds no apparent relationship with either the presence or content of K selective minerals. The existence of an  $\text{EUF}_3$  'peak' of  $2,2 \text{ mgK } 100\text{g}^{-1}$  clay in the predominantly kaolinitic soil (soil No 1, Table 1) would suggest the presence of K-selective minerals (Németh 1972; 1979; 1982). When the K saturation of this soil is increased to 5,8% (not shown in Table 1), the  $\text{EUF}_3$  peak is raised from 2,2 to

$5,6 \text{ mgK } 100\text{g}^{-1}$  clay. It is difficult to attribute the existence of such a fairly strong  $\text{EUF}_3$  peak to the presence of only traces of K selective minerals, in this case mica. Soil No 4, which has a very low K saturation but a high content of K selective minerals, released much less K in the  $\text{EUF}_3$  fraction than the predominantly kaolinitic soil (No 2) with a high K saturation. The strength of the  $\text{EUF}_3$  peak consequently seems to be determined more by the percentage K saturation and the exchangeable pool of K than the mineralogical composition/selectivity of clay minerals.

### Correlations between $\text{EUF}_3$ and other soil K parameters

In order to determine which of the soil K fractions described in a previous section contribute most to  $\text{EUF}_3$ , the correlation coefficients of linear regressions between  $\text{EUF}_3$  and each of the other parameters and derived fractions were calculated. A summary of results is presented in Table 2.

TABLE 2:  $R^2$  values of linear regressions between  $\text{EUF}_3$  and other soil K parameters and fractions

(a) Derived fractions				
Fr 1	Fr 2	Fr 3	Fr 4	Fr 5
0,76	0,65	0,56	0,51	0,25 NS
(b) Other K parameters				
$\Sigma\text{CaCl}_2$	$\text{NH}_4\text{OAc}$	$\Sigma\text{HCl}$	$\text{HNO}_3$	XRF
0,84	0,80	0,90	0,57	0,31 NS

TABLE 1: K-parameters of four soils used in the investigation.

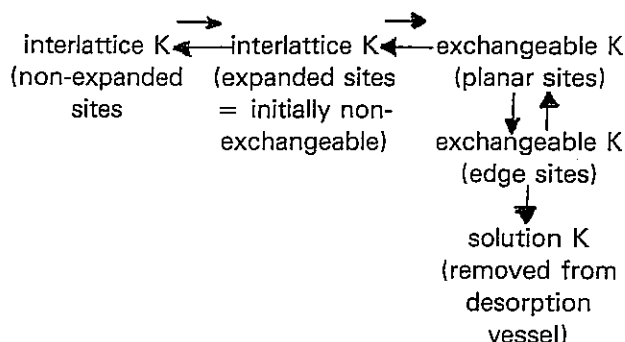
Soil no	mg K $100\text{g}^{-1}$ clay determined by: % K							saturation	Clay minerals (est %)
	XRF	$\text{HNO}_3$	$\Sigma\text{HCl}$	$\Sigma\text{CaCl}_2$	$\text{EUF}_1$	$\text{EUF}_2$	$\text{EUF}_3$		
1	382	29,4	16,1	14,7	3,8	2,7	2,2	2,1	Kt (85) Gb (10) Mi(tr)
2	930	120,8	172,2	134,7	26,7	48,3	30,3	9,3	Kt(70) Mi (15) Oz(10) Is(tr)
3	1635	409,2	239,6	112,5	7,9	23,0	24,8	5,3	St(45) Mi(20) Kt(30) Oz(tr)
4	2307	136,1	56,9	34,0	1,9	4,4	4,6	1,4	Kt(30) Mi(30) Vt(20) St/Ch2:1(20)

Kt = kaolinite, Gb = gibbsite, Mi = mica, Oz = quartz, Is = interstratified minerals, St = smectite, Vt = vermiculite, Ch 2:1 = chloritized 2:1 minerals.

The derived fractions 1 to 5 in Table 2 represent increasing degrees of K selectivity. Fraction 1 corresponds with easily exchangeable K associated with planar adsorption sites while fraction 5 represents non-exchangeable K, associated with non-expanded interlattice — and other mineral bound K. An ample of the distribution of soil K parameters and derived fractions in the correlation study, is illustrated in Figure 1.

In Table 2 K selectivity increases from left to right for K parameters and the derived fractions.  $R^2$  values of linear regressions between  $EU\text{F}_3$  and the derived fractions decrease as K selectivity increases. It is also interesting to note from Table 2 that  $R^2$  values improve when  $EU\text{F}_3$  is correlated with parameters instead of their derived fractions. For example, the  $R^2$  value of  $EU\text{F}_3$  with  $\text{NH}_4\text{OAc-K}$  is considerably better than for fractions 1 and 2, both of which exclude loosely adsorbed K (see also Figure 1). The same applies to  $R^2$  values of linear regression between  $EU\text{F}_3$  and  $\text{EHC}\ell\text{-K}$  (0,90) and fraction 3 (0,56). On the basis of these findings it can be concluded that  $EU\text{F}_3$  is a function of the exchangeable pool plus some non-exchangeable K associated with expanded interlattice sites. However, the contribution of non-exchangeable K to  $EU\text{F}_3$  appears to be considerably smaller than has been reported in earlier work (Németh 1972; 1979; 1982). The question may well be asked in what manner non-exchangeable K contributes to  $EU\text{F}_3$ , if the total amount of K desorbed by  $EU\text{F}_{1+2+3}$  is less than the exchangeable pool. A possible mechanism has been proposed by Grimme (1980). A rapid redistribution of K ions among different bonding sites takes place upon the removal of K ions from the solution phase in

the desorption vessel. In this manner initially non-exchangeable K ions are released and redistributed among planar and edge sites. The mechanism can be explained in the following equation form.



### Conclusions

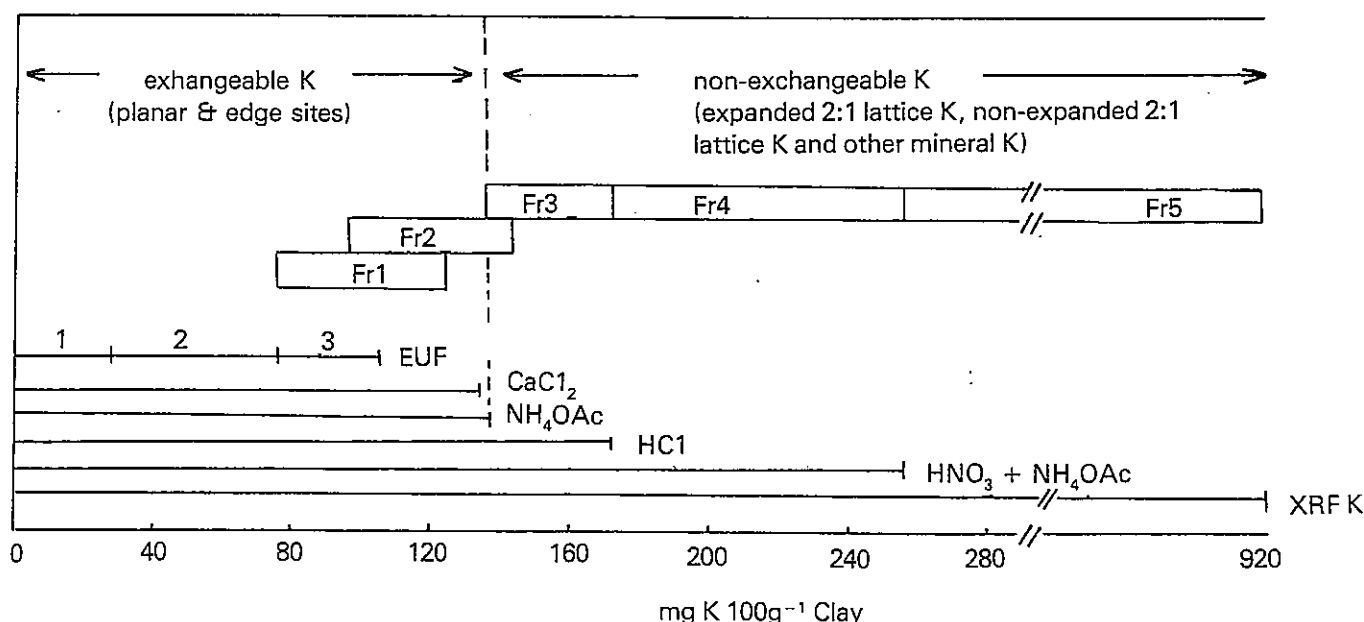
Although  $EU\text{F}_3$  is significantly correlated with initially non-exchangeable K (Fr 3), the  $R^2$  value is not very good. Based on statistical correlations of  $EU\text{F}_3$  with other soil K parameters/fractions, it is concluded that the greatest contribution to  $EU\text{F}_3$  comes from the exchangeable pool, with some non-exchangeable K also involved.

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FIG 1: A schematic diagram of parameters and derived fractions of soil No. 2 (See also Table 1).



## References

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- GRIMME, H. 1979. *Z. Pflanzenernaehr. Bodenk.* 142, 57-68.
- GRIMME, H. 1980 *Z. Pflanzenernaehr. Bodenk.* 143, 1, 98-106.
- GRIMME, H. 1982. *Plant and Soil* 64, 1, 49-54.
- NÉMETH, K. 1972 *Proc. 9th coll. of the Int. Pot. Inst.* 171-180.
- NÉMETH, K. 1979. *Adv. Agron.* 31, 155-187.
- NÉMETH, K. 1982. *Plant and Soil* 64, 1, 7-23.
- NÉMETH, K. 1984. Personal communication.
- NÉMETH, K. & FORSTER, H. 1976. *Die Bodenkultur.* 27, 2, 111-119.
- SINCLAIR, A.H. 1982. *J. Sci. Food Agric.* 31, 532-540.
- SINCLAIR, A.H. 1980. *Plant and Soil* 64, 1, 85-94.