Dynamics of Available Potassium Fractions of Soils in a Pot Experiment

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Introduction

The availability and movement of plant nutrients to roots is mainly controlled by the concentration of the given nutrient. In the case of potassium, it depends on the equilibrium of K amounts existing between potassium in the soil solution and the easily, slowly or non-exchangeable forms in the soil. The availability of nutrients is mainly affected by the extent of roots, soil moisture, the clay and humus content of the soil, soil pH and others factors (VAN DIEST 1978; MENGEL, 1982). Even with the knowledge of these soil properties, it is rather complicated to calculate the precise potassium requirement of crops throughout the whole vegetation period.

On the other hand, there are considerable differences in the potassium supplying capacity of soils, thus the effectiveness of potassium fertilization also varies. For the study of potassium availability, supplying capacity and its dynamics in soils, several laboratory, chemical and biological methodologies (e. g. pot experiments) are known (QUÉMENER, 1979; GRIMME & NÉMETH, 1979; SÁRDI & DEBRECZENI, 1992; etc.). Among these, the electro-ultrafiltration (EUF) procedure allows the assessment of nutrient desorption in an electric field (NÉMETH, 1976).

In Hungary soils differ significantly in clay content and quality of clay minerals. A nation-wide survey of the clay mineral composition of soils has been carried out by STEFANOVITS & DOMBOVÁRI (1994) with the aim of improving K fertilization recommendations.

The National Long-term Fertilization Trials in Hungary (NLFT) have been continued at 9 experimental sites on representative soil types to study the effects of increasing fertilizer rates on soil nutrient status as well as on soil properties. Two crop rotations were introduced in the trials. The potassium supplying capacity of soils was also studied in pot experiments (biological testing). Results of these experiments are reported by SÁRDI & DEBRECZENI (1998).

Materials and Methods

A pot experiment was carried out under greenhouse conditions with perennial ryegrass to study the dynamics in plant available soil K. Soil samples were taken from the upper 0-20 cm layer at the 9 experimental sites of the National Long-term Fertilization Trials, from experiment II (winter wheat – maize biculture rotation) in the last year of the fourth rotation.

The treatments selected for this study were:

1. Unfertilized control (code No. 000)
2. N_5P_3 (250 N and 150 P_2O_5 kg/ha/year – treatment code No. 530)
3. $N_5P_3K_1$ (250 N, 150 P_2O_5 and 100 K_2O kg/ha/year – treatment code No. 531)
4. $N_5P_3K_2$ (250 N, 150 P_2O_5 and 200 K_2O kg/ha/year – treatment code No. 532)

(In the text these treatments were simply labelled 000, NP, NPK_1 and NPK_2.)

The main characteristics of the experimental soils are given in Table 1.

Table 1

The main characteristics of the experimental soils

Sampling site	Soil type*	Clay, %	pH (KCl)	Humus, %
1. Bicsérd (BI)	Luvic Phaeosem	33	5.6	1.9
2. Iregszemcse (IR)	Calcaric Phaeosem	22	7.4	2.4
3. Hajdúböszörmény (HB)	Luvic Phaeosem	35	6.1	3.5
4. Karcag (KA)	Luvic Chernozem	37	4.7	2.7
5. Keszthely (KE)	Eutric Cambisol	24	6.3	1.7
6. Kompolt (KO)	Haplic Phaeosem	41	3.9	2.6
7. Mosonmagyaróvár (MO)	Calcaric Fluvisol	12	7.4	1.7
8. Nagyhörcsök (NH)	Calcaric Phaeosem	23	7.2	2.7
9. Putnok (PU)	Ochric Phaeosem	28	4.6	2.0

* Soil types according to the FAO Soil Classification System

The exchangeable potassium content of soils was determined from the ammonium lactate extract (according to Egner et al. (1960); soil:extractant ratio = 1:20, 2 hours shaking). The potassium content of samples was determined by flame photometry. The potassium supplying capacity of soils was studied by the electro-ultrafiltration (EUF) methodology at 20 °C temperature for 5 minutes and 50 V voltage, then in 10–15–20–25–30 minute time intervals at 200 V and for another 5 minutes at 400 V voltage and 80 °C temperature. Clay mineral composition of soils was determined by the X-ray diffraction method.

Results and Discussion

The exchangeable potassium content of the experimental soils in the ammonium lactate extract (K_2O mg/kg soil) are summarized in Table 2.

Amounts of potassium determined in the *AL-extract* in the soil samples of NLFT plots after 16 years of fertilization responded to the levels of K supply. On the other hand, exchangeable K levels without fertilization varied related to the clay content and quality of clay minerals in the experimental soils (Table 2).

Table 2

AL-extractable potassium contents (AL-K_2O mg/kg) of soils (*a*) and amounts of potassium calculated for a unit clay content (*b*) (mg K_2O/g clay)

Site	Code No. of treatments							
	000		530		531		532	
	a	b	a	b	a	b	a	b
BI	174	(0.53)	167	(0.51)	251	(0.76)	364	(1.10)
HB	165	(0.47)	123	(0.35)	195	(0.56)	183	(0.52)
IR	156	(0.71)	185	(0.84)	215	(0.98)	359	(1.63)
KA	170	(0.46)	180	(0.49)	259	(0.70)	485	(1.31)
KE	164	(0.68)	170	(0.71)	263	(1.09)	336	(1.40)
KO	166	(0.40)	187	(0.46)	264	(0.64)	304	(0.74)
MO	215	(1.79)	197	(1.64)	193	(1.61)	207	(1.73)
NH	137	(0.60)	151	(0.66)	209	(0.91)	282	(1.23)
PU	217	(0.77)	175	(0.62)	296	(1.06)	318	(1.14)

As the result of increasing K rates (i. e. in the NPK_2 plots), the AL-extractable K content had become more than twice as high as the initial K level at 5 sites during the 16 years of fertilization.

It is worth noting that the K supplying capacity of the MO Calcaric fluvisol – having the lowest clay content among the experimental soils – was unexpectedly high. Soil moisture conditions are favourable at this site (the River Lajta has a beneficial influence) as well as clay mineral composition with the dominantly high illite content (see Table 3), which facilitates the release of K ions to the soil solution.

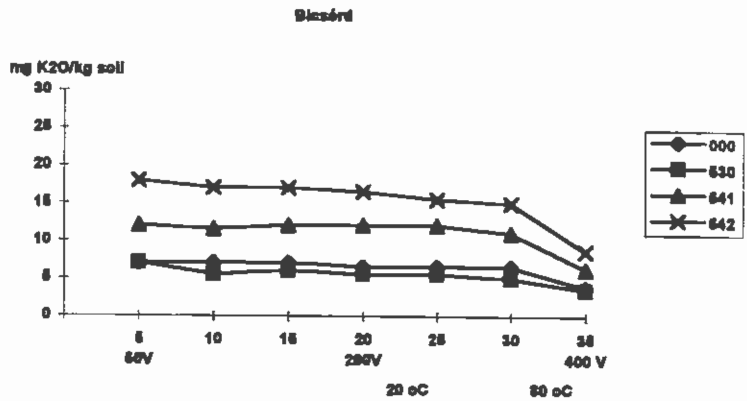
Another soil to be mentioned is the HB Luvic phaeosem, showing the lowest potassium level in the NPK_2 treatment. The possible explanation for this may be that this soil has a high clay content and an unusually high K fixation capacity (smectite content is 47% out of clay).

Changes in K levels in the other soils responded to K fertilizer rates.

In the EUF extracts, potassium fractions obtained for the different time intervals, temperatures and voltages are summarized in Figure 1. Based on these values it was possible to model the K supplying capacity and its dynamics in soils as well as its equilibrium depending on time.

Quantitative parameters of clay minerals – based on the research of STEFANOVITS & DOMBOVÁRI (1994) – are shown in Table 3.

Amounts of K fractions obtained by EUF may serve as more detailed information on the K supplying characteristics of soils in the long-term scale (re-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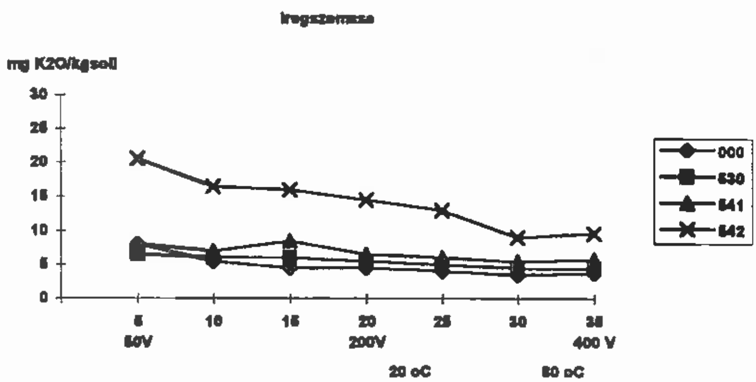
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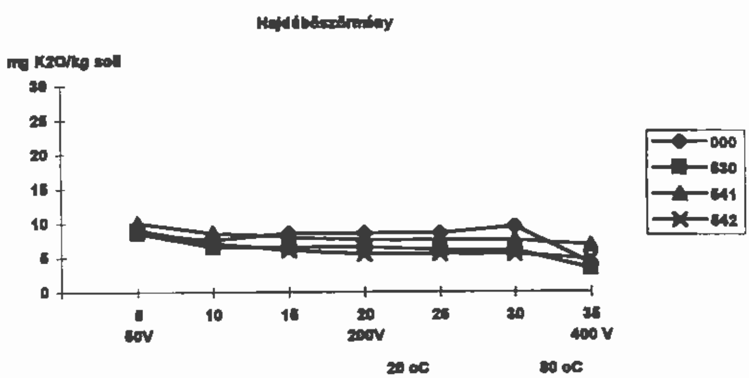
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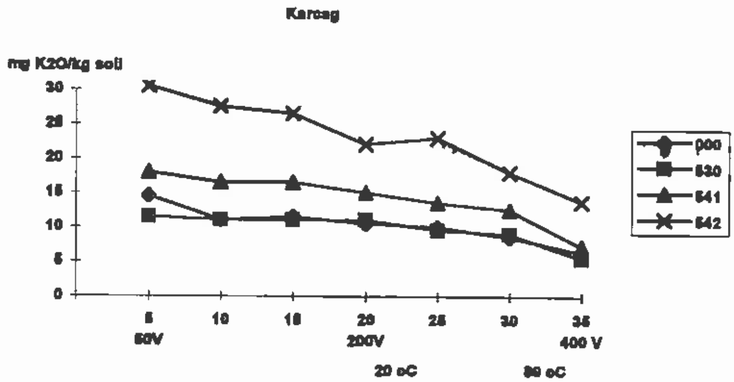
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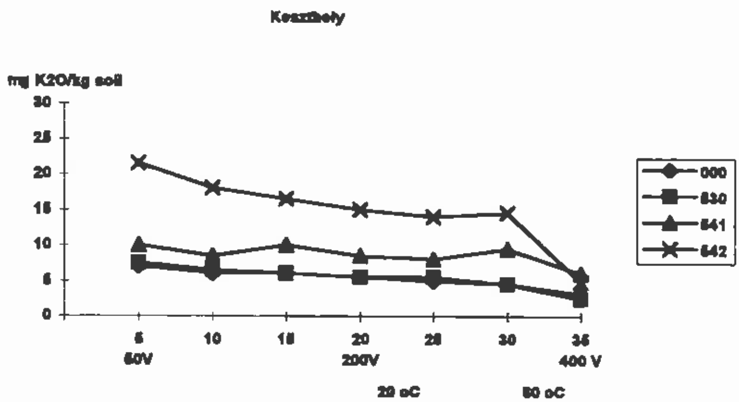
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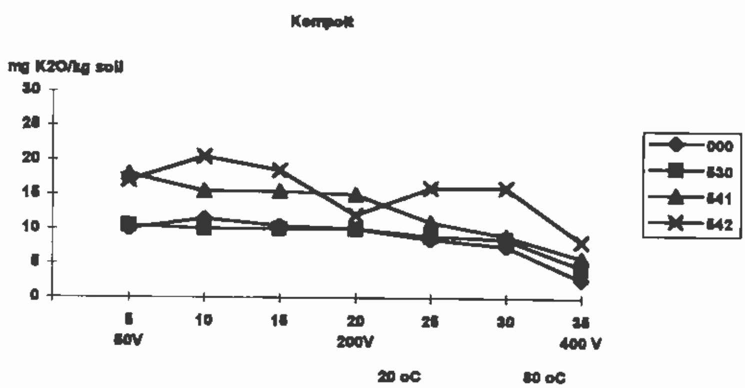
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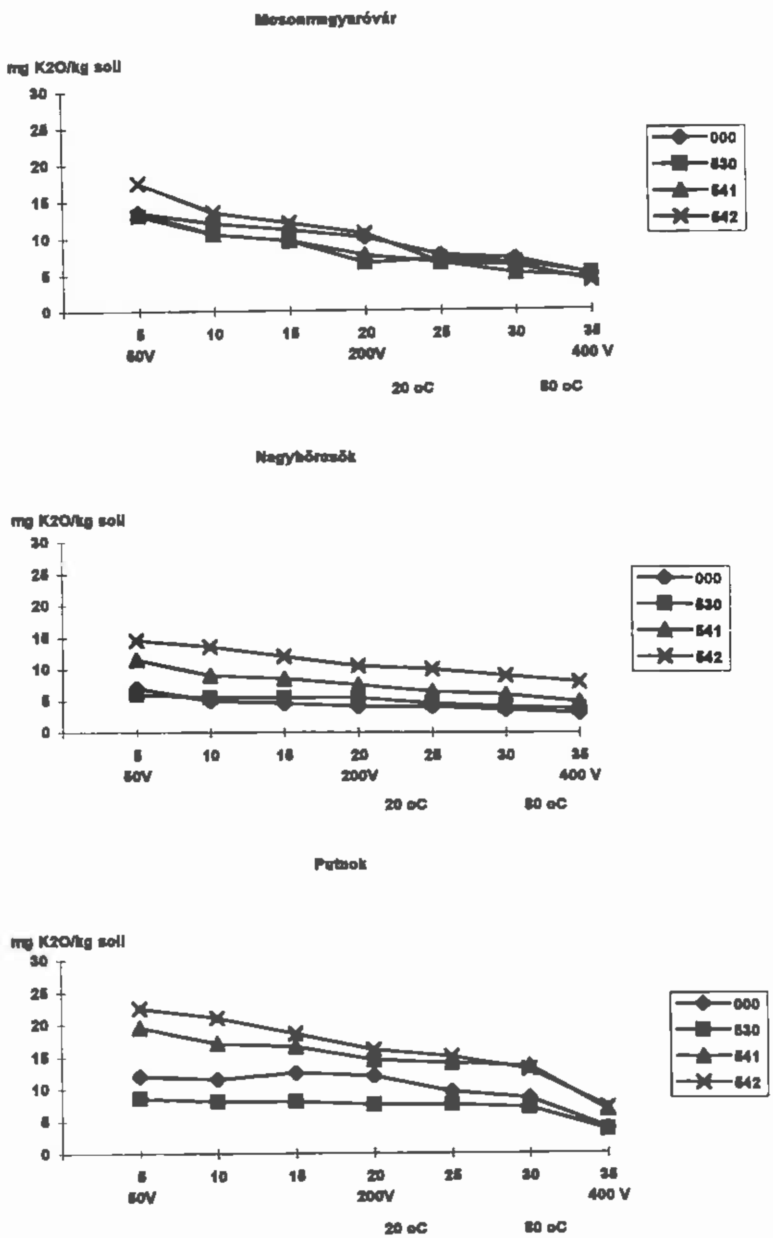

Figure 1
EUF-K_2O fractions in the experimental soils (mg K_2O/kg soil)

sults are summarized in Figure 1). It was established that K desorption obtained in the first 5 minutes was high for most soils. In the successive fractions, amounts of K ions decreased to a greater extent.

Amounts of potassium determined in the EUF fractions showed the tendencies of changes in the K levels (i. e. with or without K fertilization). Highest rates of K supply were observed for acidic soils (KA, KO and PU, respectively). Results were related to clay content and amounts of dominant clay minerals (Table 3).

Table 3

Clay mineral composition of the 0-30 cm soil layer at the experimental sites (STEFANOVITS & DOMBOVÁRI, 1994)

Soils	Illite	Kaolinite	Chlorite	Smectite	Vermiculite	Illite-smectite	Illite-chlorite	Illite-vermiculite
BI	45	-	19	17	66	10	3	-
HB	29	-	7	47	6	5	3	3
IR	50	-	30	8	-	10	2	-
KA	56	-	17	7	3	11	5	1
KE	59	10	13	6	-	9	3	-
KO	27	20	-	37	-	10	6	-
MO	48	-	28	16	-	7	-	-
NA	no data							
PU	33	14	-	27	-	24	-	2

Different levels of potassium supply were obtained for the different soil types. In the chernozem soils, such as IR, BI and NH soils, some similarities could be observed in the curves of EUF fractions.

By contrast, in the MO and HB soils, relatively slight differences were observed between treatment effects in the amounts of potassium, which were independent of K fertilization. Lowest quantities of removed potassium were recognized at 400 V and 80 °C as compared to the values obtained for other soils.

Further useful information can be obtained when findings in nutrient supplying capacities of soils are compared to quantities and proportions of clay minerals.

Summary

Pot experiments were carried out with perennial ryegrass grown in soils from several plots of the National Long-term Fertilization Trials in Hungary (four selected treatments). Dynamics in plant available soil potassium were studied by determining K uptake of perennial ryegrass and amounts of available K forms (determined both in AL extract and by EUF).

From the results of the experiment, it was concluded that studying the equilibrium of potassium forms and its dynamics by the EUF procedure allowed a good assessment of soil K status and supplying characteristics of the different soil types. However, further investigations are needed for some experimental sites (such as MO and HB soils), for the better understanding of the relationships between long-term K fertilization and soil K status.

Acknowledgement

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