Effects of long-term K fertilization and liming on the extractable and exchangeable K contents of a Haplic Phaeosem soil

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SUMMARY

Effects of regular K fertilization and liming on the easily extractable K content of a Haplic phaeosem soil determined in 0.01 M $CaCl_2$ and AL (traditional method in Hungary) were examined in the B1740 type of the National Uniformed Long-Term Fertilization Experiments at Karcag.

Close correlation (r=0.95) was found between the 0.01 M $CaCl_2$ and ammonium lactate - acetic acid (AL) extractable K contents of soils.

K fertilization increased the amount of 0.01 M $CaCl_2$ and AL extractable K significantly. Liming had different effects on the amounts of K extracted by these two methods. Liming increased the amount of AL-K and decreased the amount of $CaCl_2$-K. $CaCl_2$ extractable K was in close correlation with the relative amount of exchangeable K content of the soil (K%) and the agronomic K balance. The results of regression analysis confirmed that the $CaCl_2$-K characterized K% and the AL-K related to the absolute amount of exchangeable K.

On the basis of the presented results it can be stated that the 0.01 M $CaCl_2$ is able to detect not just the increase of easily extractable K caused by fertilization and liming but the changing of the rate of the relative amount of exchangeable K.

INTRODUCTION

The environmentally conscious and site-specific nutrient management is an important objective of the advanced agriculture. Therefore we have to know the easily available nutrient content of soils. The traditional extractant of Hungary is the ammonium lactate acetic acid (AL) (Egnér et al., 1960).

Houba et al. (1990) suggested to use the 0.01 M $CaCl_2$ extractant to determine the easily available amounts of macro and some micro-nutrients. The research project on this topic is started in several European countries (Baier & Baierova, 1997; Fotyma et al., 1996; 1998), and also in Hungary at the Department of Agricultural Chemistry, Agricultural University of Debrecen (Loch, 2006; Loch et al., 1995; Jászberényi et al., 1994; Houba et al., 1991).

Advantages of this method were summarized by Houba et al. (1991) and Loch (2006) as follows:
- dilute salt solution has moderate solving and ion exchanging effects,
- Ca content of the extractant is similar to the Ca concentration of soil solutions,
- the extracted solution can be filtered easily,
- several nutrients are well measurable (N, P, K and certain microelements),
- easily soluble and oxidizable organic N, P and S forms are also measurable in the extraction.

The 0.01 M $CaCl_2$ extractant is also suitable for characterizing K-supply of soils. Loch et al. (1997) found medium or close (r = 0.7-0.8) correlation between AL and $CaCl_2$ extractable K in 633 samples. The relationship depended on the carbonate content of soils.

According to our previous researches it can be stated that the K content extracted by AL depended on the texture and pH values of soils, while the $CaCl_2$-K didn't change as an effect of soil parameters (Bertáné et al., 2009).

Jászberényi et al. (1994) found significant close (r = 0.914) correlation between the $CaCl_2$-K and the agronomic K balance (fertilizer K- K uptake of plants) in a Hungarian long-term fertilization experiment.

Zsigrai et al. (2008) studied the effects of long-term fertilization and liming on the AL-K content of the soil in the National Uniformed Long-Term Fertilization Experiments at Karcag. They found that liming decreased the average amount of AL-K.

The aims of the presented research were to examine the effects of regular K fertilization and liming on the amounts of $CaCl_2$-K, AL-K and extractable K and to study the relations among AL-K, $CaCl_2$-K and extractable K.

MATERIALS AND METHODS

The B17 variant of the National Uniformed Long-Term Fertilization Experiments was established in autumn of 1967 by uniform directives at the trial site of the Karcag Research Institute. The arrangement of the small-plot field experiment is split-plot with four replications. The sequence in the crop rotation was the same in all of the ten completed cycles: winter wheat–maize–maize–winter wheat. The fertilization treatments are summarized in

Table 1. As the data show, the number of treatments is altogether twenty: combinations of 3 nitrogen-, 3 phosphorus-, and 2 potassium doses, completed by the control treatment and by a $N_4P_3K_2$ treatment with increased doses.

Table 1.

Fertilizer doses applied in the B17 experiment ($kg \cdot ha^{-1}$) (Karcag, 1971–2007)

Treatments	Cycle 2–5			Cycle 6–10		
	N	P	K	N	P	K*
$N_0P_0K_0$	–	–	–	–	–	–
$N_1P_0K_0$	50	–	–	100	–	–
$N_1P_1K_0$	50	21.8	–	100	26.2	–
$N_1P_2K_0$	50	43.6	–	100	52.3	–
$N_2P_0K_0$	100	–	–	150	–	–
$N_2P_1K_0$	100	21.8	–	150	26.2	–
$N_2P_2K_0$	100	43.6	–	150	52.3	–
$N_3P_0K_0$	150	–	–	200	–	–
$N_3P_1K_0$	150	21.8	–	200	26.2	–
$N_3P_2K_0$	150	43.6	–	200	52.3	–
$N_1P_0K_1$	50	–	83	100	–	83/166
$N_1P_1K_1$	50	21.8	83	100	26.2	83/166
$N_1P_2K_1$	50	43.6	83	100	52.3	83/166
$N_2P_0K_1$	100	–	83	150	–	83/166
$N_2P_1K_1$	100	21.8	83	150	26.2	83/166
$N_2P_2K_1$	100	43.6	83	150	52.3	83/166
$N_3P_0K_1$	150	–	83	200	–	83/166
$N_3P_1K_1$	150	21.8	83	200	26.2	83/166
$N_3P_2K_1$	150	43.6	83	200	52.3	83/166
$N_4P_3K_2$	200	65.4	83	250	78.5	83/207

* Remark: 83 $kg \cdot ha^{-1}$ for winter wheat; 166 and 207 $kg \cdot ha^{-1}$ for maize

After the harvest of winter wheat grown in the 20th and 32nd years of the experiment 14.5 and 11.05 t ha^{-1} of lime was used on the plots of replications I and III, respectively.

The soil of the experimental site is a Luvic Phaeosem with loamy clay texture, solonetzic in the deeper layers. The parent material is infusion loess. The topsoil is slightly acidic; below 40 cm the soil is calcareous. The soil is moderately supplied with N, poorly with P and moderately with K.

Soil samples were taken in 2007 from 20 points of each plot, from the 0–20 cm soil layer after the harvest of winter wheat. We measured the 0.01 mol dm^{-3} $CaCl_2$ solution (0.01 M $CaCl_2$) extractable K content of soil (Houba et al., 1990) with a flame emission spectrophotometer at the laboratory of the Department of Agricultural Chemistry and Soil Science. The samples were also analysed in the Central Laboratory of the Karcag Research Institute in accordance with the Hungarian standard (MSZ 08 0205-215) to determine the AL-K_2O values and the exchangeable K, Ca, Mg and Na contents of the soil samples.

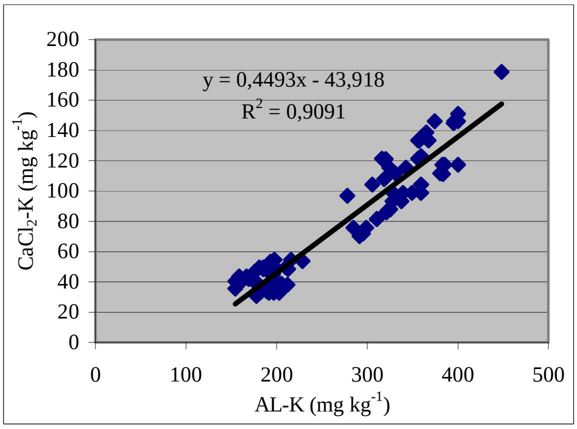
All statistical analyses (regression analyses, variance analyses) were performed with SPSS (version 13). Significant differences were examined by One Way Anova and LSD post hoc tests.

RESULTS AND DESCUSSION

During our research work the relationship between AL and 0.01 M $CaCl_2$ extractable K content of the soil samples were studied (*Figure1*).

Close correlation (R^2=0.91; r=0.95) was found between amounts of AL-K and $CaCl_2$-K. According to our previous researches soil texture is the most important factor modifying the closeness of the correlation between AL-K and $CaCl_2$-K, because AL-K depends on this parameter significantly. Presumably AL is capable to exchange a part of bounded K, which is not available for plants so it characterizes K-reserves as well. The reason of the close relation between extracted K contents on the studied soil samples are that the important soil properties (texture, pH, carbonate content, humus content) are the same in all samples (samples originated from the same soil type, with different fertilization rates) in one hand, and the dominant clay mineral in clay fraction is illite which means that K-fixation is not typical in this soil in the other hand.

Figure 1.: **Relationship between the amounts of AL-K and $CaCl_2$-K**



We studied the effects of liming and long-term K fertilization on the AL and 0.01 M $CaCl_2$ extractable K, exchangeable K (mg ekv $100g^{-1}$) contents and K% (K $(Ca+Mg+K+Na)^{-1}$ (mg ekv $100g^{-1}$)) of the soil (*Table 2*). The treatments had significant effect on the amounts of extractable and exchangeable K. K fertilization increased the amounts of all studied parameter significantly. Liming without K fertilization increased the amounts of AL-K and exchangeable K significantly comparing to the K_0 treatment, but it didn't cause significant differences in case of application of K_1 fertilizer rate. The $CaCl_2$-K content of the soil and the K% decreased significantly as an effect of liming. We can explain this observation with the increase of exchangeable Ca content of the soil, which causes changes of the ratio of exchangeable bases.

It can be stated that while AL-K characterizes exchangeable K content of soils, changes of K% are reflected in the $CaCl_2$-K.

Table 2.

The effect of liming and long-term K fertilization on the AL and 0.01 M $CaCl_2$ extractable K content of the soil, exchangeable K and K%

Treatment	AL-K (mg kg^{-1})	SD*	$CaCl_2$-K (mg kg^{-1})	SD*	Exchangeable K (mg ekv $100g^{-1}$)	SD*	K %**	SD*
K_0	182.1	a	45.8	a	0.52	a	2.34	a
K_0 with liming	197.4	b	37.0	b	0.59	b	2.00	b
K_1	355.7	c	129.4	c	1.11	c	5.24	c
K_1 with liming	339.2	c	94.8	d	1.01	c	3.60	d
Total	268.6		76.8		0.81		3.30	

*Significant difference: Means designated by the same letter were not significantly different at P = 5% level.
**K $(Ca+Mg+K+Na)^{-1}$ (mg ekv $100g^{-1}$)

Relationships between exchangeable K, K% and K content of soil extracted by AL and 0.01 M $CaCl_2$ were studied with regression analysis (*Figure 2*, *Figure 3*). We found significant, close correlations between the soil parameters:
- exchangeable K – AL-K (R^2=0.87; r=0.93)
- exchangeable K – $CaCl_2$-K (R^2=0.81; r=0.9)
- K% – AL-K (R^2=0.74; r=0.86)
- K% – $CaCl_2$-K (R^2=0.88; r=0.94)

It means that the amounts of K extracted by these two methods depend on the amount of exchangeable K and on its ratio compared to the amount of exchangeable bases. The results of regression analysis confirmed that the $CaCl_2$-K characterized the relative amount of exchangeable K and the AL-K was related to the absolute amount of exchangeable K.

Figure 2.: **Relationships between exchangeable K and K content of soil extracted by AL and 0.01 M $CaCl_2$**

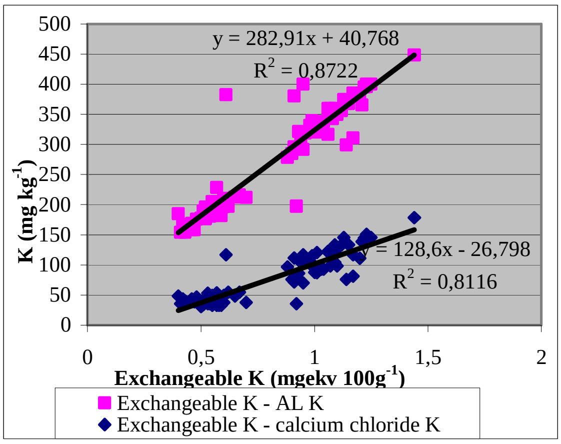
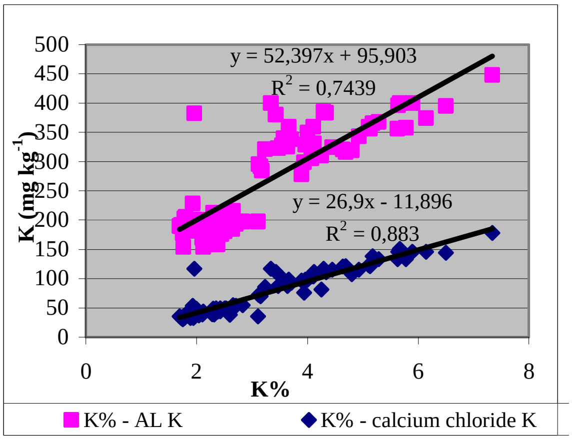
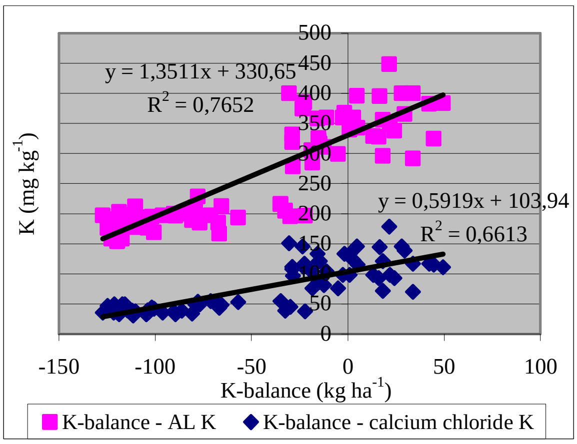


Figure 3.: **Relationships between K% and K content of soil extracted by AL and 0.01 M $CaCl_2$**



We studied the relationship between the agronomic K-balance (fertilizer K – K uptake of plants) and the K content of soil extracted by AL and 0.01 M $CaCl_2$ (*Figure 4*). Significant close correlations (R^2=0.77, r=0.88; R^2=0.66, r=0.81) were found between these parameters. It is in accordance with the earlier results of long term experiments. It means that these two extractants are able to detect the K deficit and surplus of soils and to characterize the K-supply of soils.

Figure 4.: **Relationships between K-balance and K content of soil extracted by AL and 0.01 M $CaCl_2$**



CONCLUSIONS

The results of regression analyses confirmed that there was close correlation (r=0.95) between the amounts of AL-K and $CaCl_2$-K in the same soil type. This result is in accordance with our previous researches.

There were significant close correlations between 0.01 M $CaCl_2$ and AL extractable K, exchangeable K and agronomic K balance. It can be concluded that both method could describe the K-supply, but the application of $CaCl_2$-K is suitable for characterization of the relative amount of K as well, which defines the solubility conditions.

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