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EFFECT OF THE RELEASE RATE OF AVAILABLE POTASSIUM FROM THE RESERVE FORMS ON THE ESTIMATED POTASSIUM FERTILISATION REQUIREMENTS

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A b s t r a c t. In the pot experiments conducted on the four mountain meadow soils with high reserves of soil potassium, a possible supply of this element for ryegrass supply was examined, when potassium was excluded or its dose was limited in the fertiliser.

Differences in potassium removal with yield during exhaustive cultivation were difficult to justify using both static and dynamic indicators of plant supply with potassium. Thus, dynamics of potassium transformations in the soil corresponding to the uptake amount, was assessed through the speed with which reserve potassium was passing into the solution using oxalic acid, and by the share of potassium from unexchangeable forms in the removal of this element removal with ryegrass yield.

K e y w o r d s: pot experiments, meadow soils, potassium uptake, activating unexchangeable potassium.

INTRODUCTION

Numerous studies have revealed that the amount of potassium released from unexchangeable forms should be considered when determining fertiliser doses [1,3,5,11,15,16]. A possibility of using a reserve potassium form by plants depends on the level to which the soil sorption complex was depleted from exchangeable potassium [10]. Thus, it may be concluded that with a considerable content of reserve potassium in the amount taken up by plants, it is not possible to obtain high yield.

The present investigation attempted at determining the value of the negative balance in the fertilisation of mountain meadow soils.

MATERIAL AND METHODS

The soils used in the pot experiment were collected from the humus level (Ah) of the mountain meadow soils developed from the Carpathian flysch. They differed in a number of physical and chemical properties, and contained high levels of total potassium, as illustrated in Table 1.

Table 1. Some soil properties before the experiments

Soil property	Jaworki I	Jaworki II	Grodziec Śląski	Czarny Potok
% of soil fractions (in mm):				
1.0-0.1	5	23	40	51
0.1-0.05	6	7	3	4
0.05-0.02	19	15	16	10
0.02-0.006	25	17	13	14
0.006-0.002	24	18	9	9
<0.002	19	20	19	12
pH_{H_2O}	4.93	6.55	7.20	4.82
pH_{KCl}	4.38	6.32	6.55	4.12
Exch. ions in mg/100 g of soil:				
Ca	162	368	375	47
Mg	12.1	9.2	15.8	3.9
K	28.2	17.4	47.8	8.3
Na	9.1	12.3	13.5	2.3
Corg (%)	2.92	2.44	2.45	1.92
N total (%)	0.34	0.276	0.265	0.164
C/N	8.6	8.8	9.2	11.7
K total (%)	1.93	2.25	2.03	1.82

Pot experiments were conducted according to the experimental scheme presented in Table 2.

Nitrogen fertilisation was applied as 0.25 g NH_4NO_3; N_1 per pot with 5 kg of air dry soil. Phosphorus doses were 0.25 g P and 0.5 g P per pot was applied as Ca $(H_2PO_4)_2$. In the series treated with potassium, 0.25 and 0.5 g K per pot was used as KCl, for magnesium treatment, 0.16 g Mg was applied as $MgSO_4$. Italian ryegrass, Kroto cv. was the test plant. Three cuts were harvested each year.

In the soil samples collected prior to the experiment, initial soil granulometric composition was assayed using commonly used methods, together with such parameters as: pH, cation exchange capacity (CEC), organic C content and total nitrogen.

X-ray radiography was carried out in the TUR M-62 X-ray diffractometer using the SDH method and filtered radiation Co Kα. Colloidal fractions were subjected to spectroscopic examination in infrared. The examined preparations were

Table 2. Potassium uptake during a 3-year experiment

Fertilizer object	Experiment I	Experiment II	Experiment III	Experiment IV
O-without fertiliser	1987	1298	1522	616
N_1	2252	2216	2989	595
N_1P_1	2678	1872	3046	550
N_2P_2	2638	1959	4270	509
N_3P_1	2538	1901	4971	520
N_3P_2	2334	1783	4815	520
N_4P_2	2044	1288	5265	568
N_4P_2Mg	1968	1579	5242	539
$N_3P_2K_1$	3618	3096	5440	1853
$N_4P_2K_2$	4780	4171	6265	3090
$N_4P_2K_2Mg$	4872	4259	6345	3308

in the shape of tablets with KBr. The registered adsorption spectra ranged between 400-1800 and 2800-3800 cm^{-1}.

The rate of potassium release was estimated using oxalic acid, after leaching of exchangeable potassium from the soil with $CaCl_2$ and drying the soil by means of anhydrous ethanol. After additional drying of the samples at 60 ^oC, 0.02 mol/dm^{-3} oxalic acid was added over a period of 1 to 270 hours.

RESULTS AND DISCUSSION

Omission of potassium in the fertiliser dose affected yielding in various ways and, as a consequence, it also affected potassium removal with yield. During the whole more than three-year long investigation period, total potassium removal with the yield of Italian ryegrass ranged between 595 mg K_2O per pot in the experiment IV on the soil from Czarny Potok and 5265 mg K_2O per pot in the experiment III on soil from Grodziec Śląski.

The soils used in the experiments I, II and III contained similar amounts of fine silt and clay particles and colloidal clay. Their organic carbon content ranged between 2.44-2.92%. They showed high abundance in the available potassium before the experiment. However, the individual soils revealed quite different abilities to supply Italian ryegrass with potassium. It became especially evident when total potassium uptake by the successive Italian ryegrass cuts was determined and calculated as the mean values of all the fertiliser series without potassium in the dose (Fig. 1).

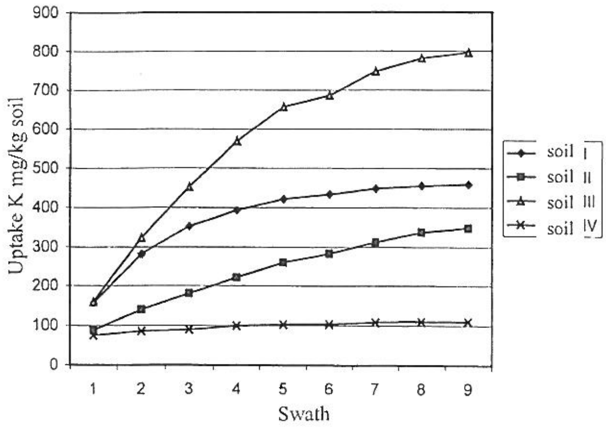

Fig. 1. Accumulated potassium uptake by plants from soil over three-year experimental period.

In the experiment I, on the soil from Jaworki potassium uptake in the first experimental year constituted 77% of the total uptake, in the experiment III - 56% and in the experiment II, only 52%.

Differentiated potassium removal with the ryegrass yield resulted from different possibilities for the reserve potassium release to its available forms observed in individual soils. On the basis of changes in the exchangeable potassium content before the experiment and after its completion, a percentage of potassium from unexchangeable forms in the amount removed with yield, was calculated. Data presented in Table 3 show that the plants in the experiment IV utilised the reserve forms of potassium the least, whereas the plants in the experiment II on the soil from Jaworki, used it to the highest degree (over 73%). It should be also mentioned that in the experiments where the potassium share in the uptake from the unexchangeable forms was the lowest (experiments I and IV), recession of yield was both the highest and observed the earliest [7].

The speed with which the reserve potassium passed into the form available to plants and the rate of fertiliser potassium fixation in different soils may be explained

Table 3. Share of potassium from unexchangeable forms absorbed by ryegrass

Fertilizer object	Experiment I	Experiment II	Experiment III	Experiment IV
O-without fertiliser	45	69	45	50
N_1	51	80	49	48
N_1P_1	58	77	46	43
N_2P_2	58	78	58	38
N_3P_1	55	78	61	38
N_3P_2	51	73	61	35
N_4P_2	39	58	62	37
N_4P_2Mg	36	68	63	34
$N_3P_2K_1$	55	69	58	55
$N_4P_2K_2$	55	64	55	57
$N_4P_2K_2Mg$	56	66	57	60

by the composition of the soil clayey particles [2,4,8,9,12]. In order to estimate diversification of minerals in the studied soils, X-ray radiography was carried out using a X-ray diffractometer to examine the soils and colloidal fraction isolated from them. Spectroscopic examinations in infrared were also conducted for the colloidal fraction in the initial soils (I-IV) and after the completion of the experiments (IA-IVA)(Figs 2 and 3). Both electrograms and spectra of the examined samples show a lot of similarity, which proves their analogous mineral composition. It concerns particularly the soil samples from the experiments I, II and IV, where clayey minerals were represented mainly by illites (reflexes 14.6, 7.13, 4.78, 3.56 A). Illites and mixed packet minerals were the main components in the sample III.

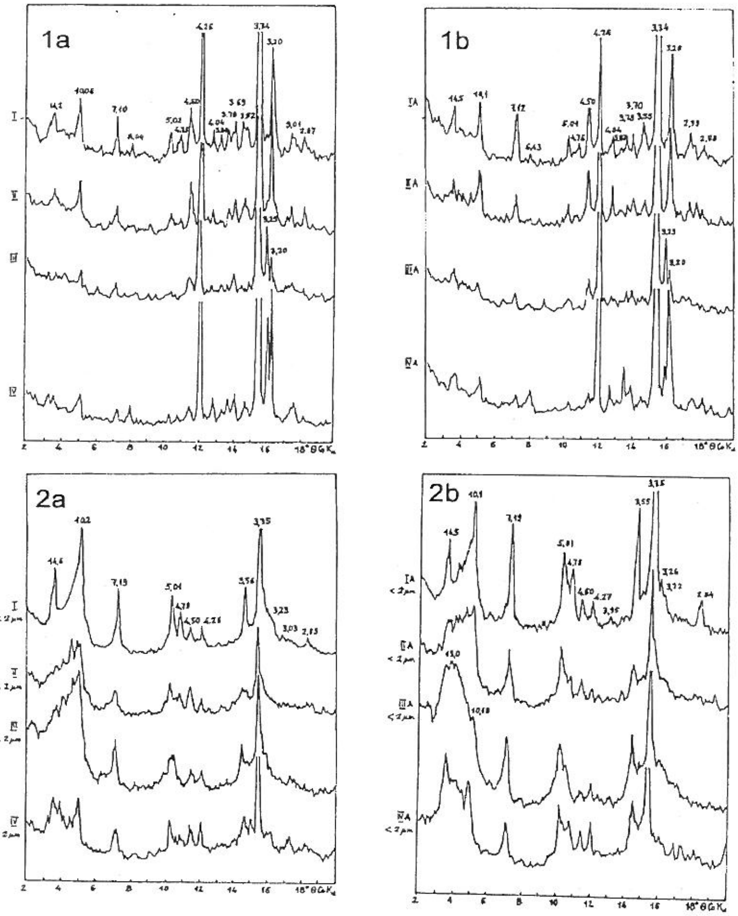

Fig. 2. X-ray electrograms: 1 - soil; 2 - colloidal fractions; a - prior to the experiment outset; b - after the experiment completion.

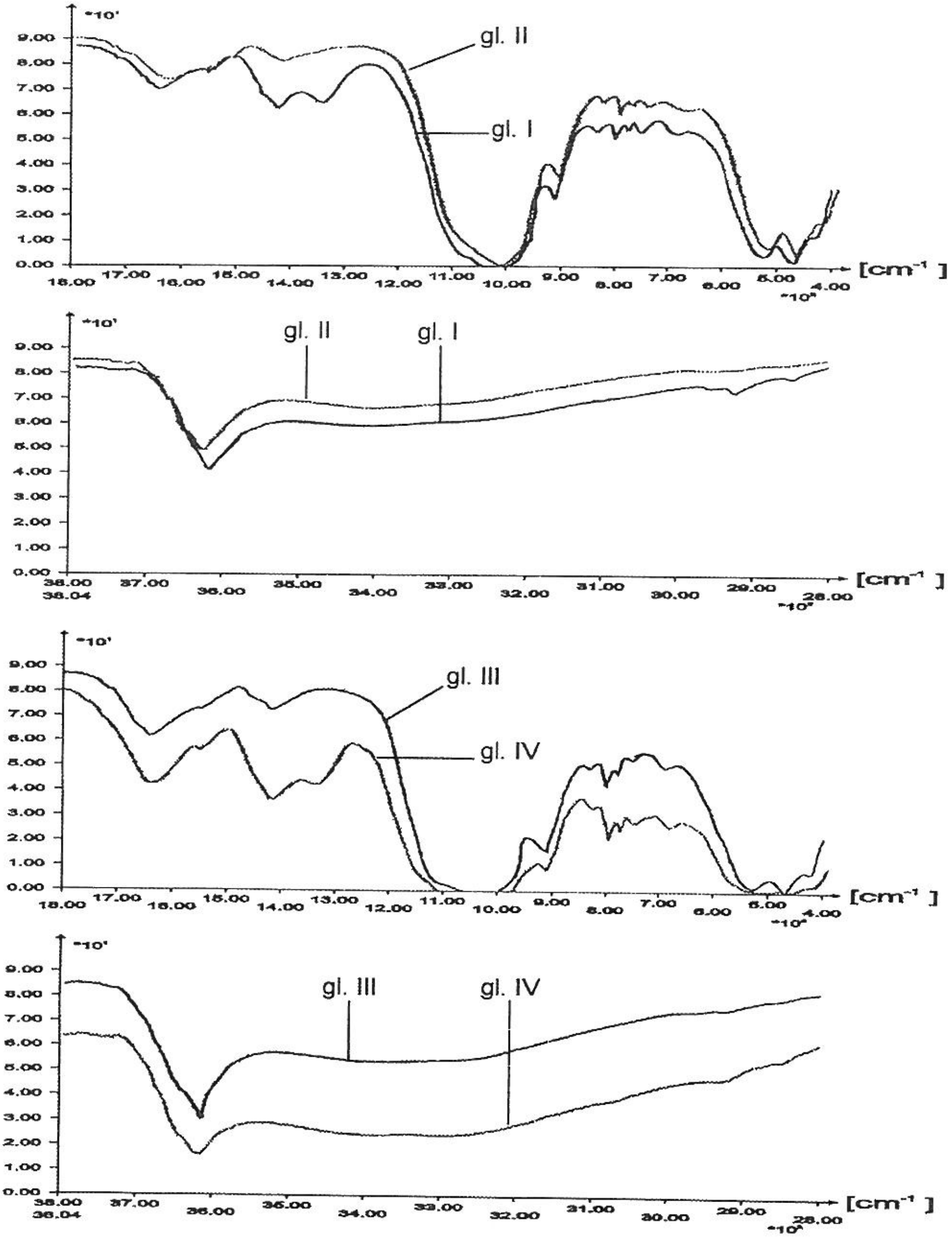

Fig. 3a. Absorption spectra in the infrared of colloidal fraction in soils before the experiments.
gl. = soil

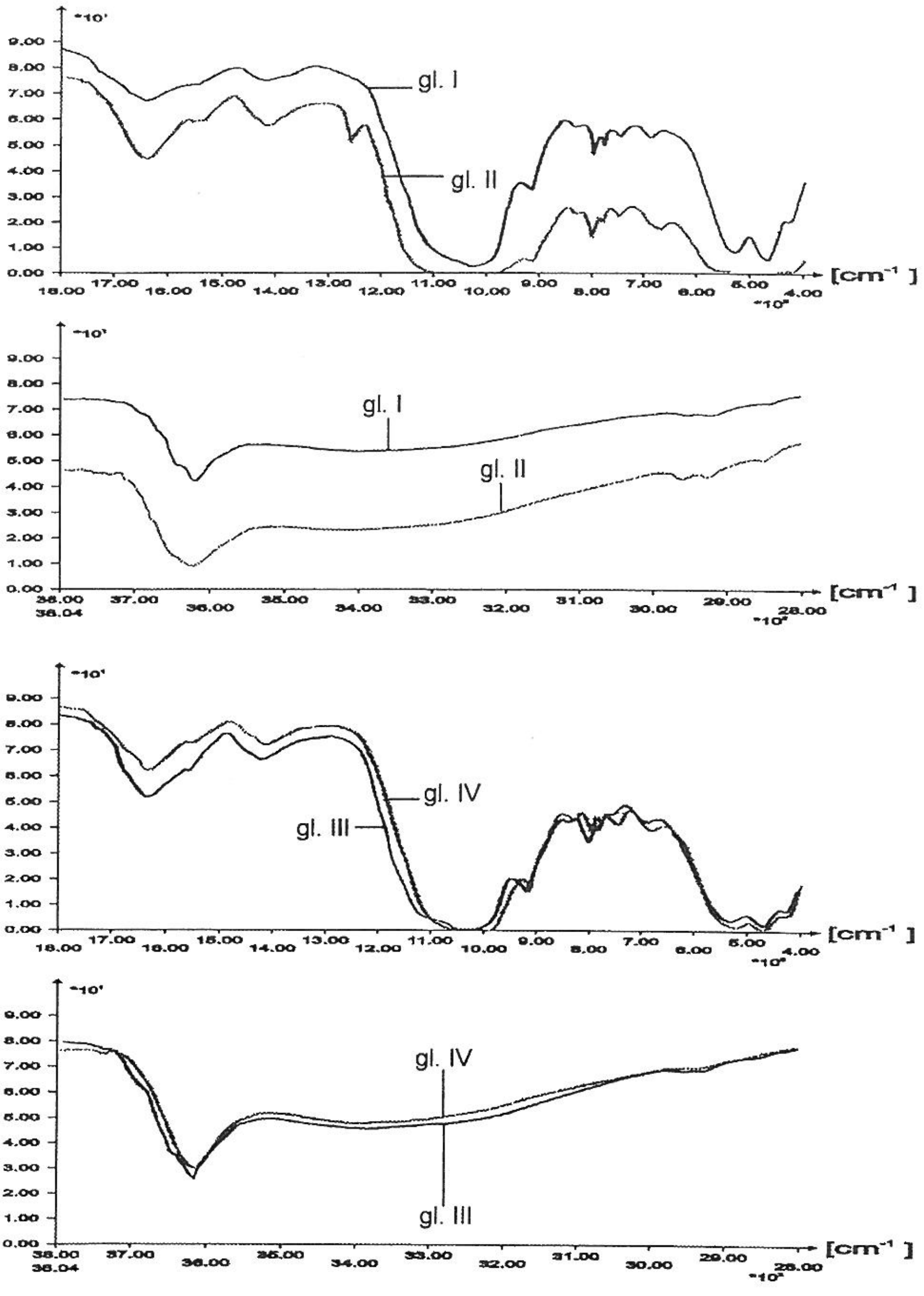

Fig. 3b. Absorption spectra in the infrared of colloidal fraction in soils after the experiment completion.
gl. = soil.

Spectra comparison after three-year period of ryegrass cultivation without potassium treatment allow us to draw a conclusion on the decreasing share of minerals in the illite structure as a result of potassium removal from their structure (Fig. 3b). Soil samples from the experiments I, II and IV contained the minerals like quartz, plagioclases and mixed packet minerals with prevailing illite packages, chlorite and some amount of calcite. The soil from the experiment III contained quartz, potassium feldspar mixed packet mineral illite (montmorillonite with prevailing illite) and some crumbs of calcite. The contents of the two potassium bearing minerals in the soil from the experiment III might be the result of considerably better possibilities of plant supply with potassium than in the other soils.

The present investigations did not allow to form any explanation for such better possibilities of plant supply with potassium in the soil of the experiment II than in the soil from the experiment I. As shown in earlier work [6], these soils revealed a very similar content of total, reserve, mobile and active potassium. Thus, an estimation of the rate of reserve potassium release to the forms available for plants was carried out in the samples before the experiments and after completion of the series with potassium free fertiliser doses with the highest negative balance of this element. The amount of 0.02 m/dm^3 oxalic acid was used as an extractor. According to some researchers [13,14,17], it releases the amount of potassium which is very well correlated with the amount of reserve potassium determined in 1 M HNO_3 using the Reitemeires method. Figure 4 shows trends illustrating the relation accepted after Song [14] and Yong-Guan [17] as an equation:

$$\mathrm{Inn}\,(K_o\text{-}K_t) = a \cdot bt$$

where K_o - 1/3 of total K; K_t - amount of potassium released in t time.

The results confirm differences in the potassium uptake by ryegrass obtained in earlier experiments. In the soil from the experiment II in Jaworki, oxalic acid brought much more potassium into the solution than in the soil from the experiment I despite slightly lower content of exchangeable potassium in this soil than at the beginning of the experiments. It confirms the results obtained in some earlier pot experiments concerning better possibilities of soils from the experiments II and III to supply plants with potassium over a longer experimental period. The results concerning the speed of potassium activation conducted in the soils after 3-year extensive cultivation of ryegrass, which exhausted the soils of the available potassium reserves revealed that only in the soil from the experiment III, there are still considerable possibilities for potassium activation.

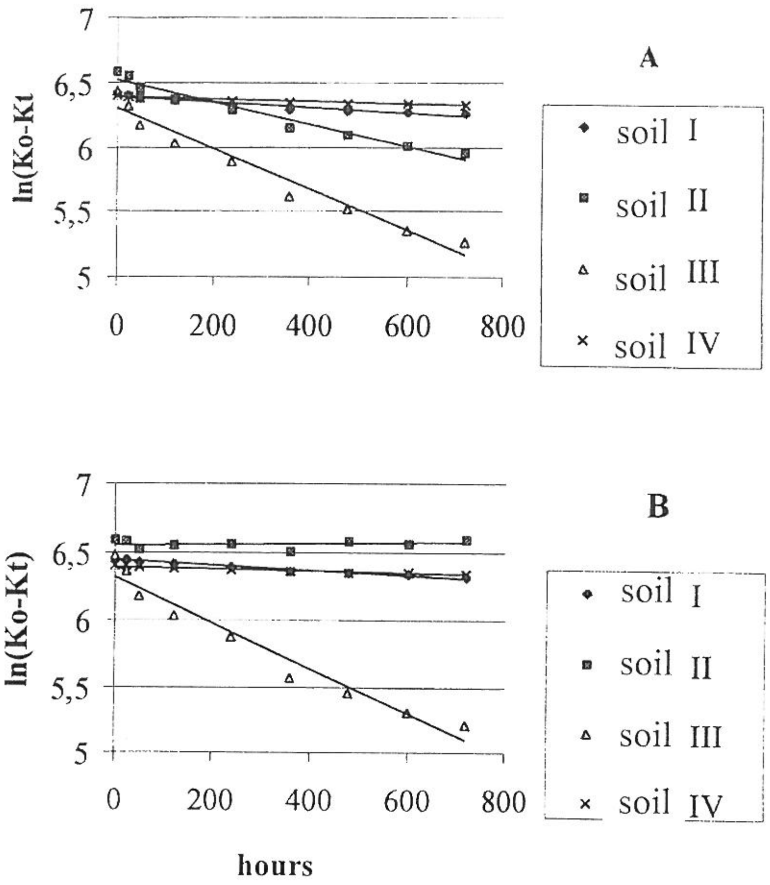

Fig. 4. Rate of available potassium release from reserve forms: A - soils before the experiment; B - soils after the exhaustive ryegrass cultivation.

CONCLUSIONS

1. When potassium was omitted from the fertiliser dose, its uptake by ryegrass was highly differentiated in the individual experiments, even in the soils which contained similar quantities of colloidal clay and revealed high abundance in available potassium.

2. The share of potassium originating from its reserve forms in the amount removed with yield ranged from 36% in the soil from the experiment IV to 73% in the soil from the experiment II.

3. The quantity of potassium brought into the solution from the reserve forms using 0.02 mol/dm^{-3} oxalic acid was the same as the amount absorbed from these forms by ryegrass in pot experiments.

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