Potash Review

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Subject 28

Experimental and research work **May 1968**
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The use of the isotope method (rubidium 86) in studies on potassium behaviour in soils and its recovery by plants*

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Introduction

A significant portion of the field and pot experiments carried out in Poland shows that potassium fertilization has very low effectiveness, or none at all on soils short of available potassium determined with Egner-Riehm method.

The use of labelled potassium compounds in studies of the problem might make possible the explanation of the behaviour of nutrient in fertilizer-soil-plant systems. The main difficulties are caused by the lack of potassium isotopes with suitable half-life. Radioisotope potassium 42 may be used only in short-term experiments with plants *(2, 3, 8, 18, 30, 52)* and soils *(19, 21, 42, 44)*.

Rubidium 86, being of similar chemical properties as potassium and having a suitable half-life (T½ = 19,5 days), has been choosen by many investigators as a tracer for potassium. Papers on the problem published recently have been reviewed. In physiological researches the radioisotope Rb 86 has been used to study absorption processes, distribution patterns within the plants, ion resorption, etc. *(2, 4, 15, 16, 29, 41, 45, 59, 60, 61, 64, 68, 71)*.

A number of experiments with rubidium 86 (instead of potassium) were carried out in order to study the behaviour of the nutrient in soils-diffusion, sorption and desorption processes, leaching from soil layers *(5, 9, 10, 17, 27, 38, 46, 48, 50, 51, 61)*.

Some studies dealt with the possibilities of using rubidium 86 as a tracer for potassium in studies with soils and plants, as well as the soil-plant system. From a methodical point of view two problems are of importance: 1) the uptake of both elements—potassium and rubidium—by plants, 2) the behaviour of these elements in soils.

The absorption of potassium and rubidium ions by plants, especially their selective uptake and distribution within the plants, was studied by a number of investigators *(7, 8, 12, 13, 14, 20, 31, 35, 36, 37, 52)*. The distribution factor DF-value = Rb/K in the plant: Rb/K in the substrate, was used as a criterion for evaluating the selectivity in the absorption of K and Rb by plants. It was stated by *Michael (37)* and

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Menzel and Heald (36) that in nutrient solutions DF values varied from 1,0 to 0,8. These results indicated the same or quite similar pattern for the uptake of rubidium and potassium by plants. Studies by other authors *(1, 7, 8, 12, 13, 16, 17, 35, 53, 62)*, which were concerned with explanation of absorption processes of ions and their mechanisms, confirmed that both elements—rubidium and potassium—behave similarly.

The problem of the behaviour of the two ions in soils, particularly their sorption and desorption as well as fixation reactions, were studied by numerous investigators *(7, 11, 12, 17, 26, 27, 28, 32, 42, 44, 48, 50, 53, 54, 65, 66, 67, 69)*. Higher differences in non-exchangeable sorption values between two ions Rb and K may significantly influence the results in studies with Rb 86 as a tracer for potassium.

In connection with this problem, the laboratory investigations were carried out in order to determine the sorption capacities for potassium and rubidium in various soils. The pot experiments on soils with different capacities for potassium and rubidium fixation were performed also to establish the applicability of the labelling rubidium 86 instead of potassium in the studies on nutrient uptake in soil-plant system.

Materials and Methods

The capacities of soils for potassium and rubidium absorption were determined radiometrically using radioisotopes K 42 and Rb 86. The wet fixation procedure and N NH_4AcO extractant solution—applied by some authors *(42, 66, 67)*—has been used.

Soil samples (10 g) were equilibrated in a solution containing 10 mg of K labelled with K 42 or Rb 86 as well as in a solution with rubidium (21,8 mg Rb) labelled with Rb 86. After one hour of equilibration, the extractant solution (N $NH_4COO\ CH_3$) was added to the suspension, and after another hour of equilibration the solution was filtrated and the measurements of radioactivity performed. In other series soil samples were equilibrated with potassium and rubidium solutions labelled with radioisotopes but without adding extractant solution, and radioactivity was determined. The results gave the basis for estimations of the values for exchangeable and non-exchangeable sorption capacities of eight soils under investigations.

Three of these soils were applied in pot experiments; two (no. 6 and 8) were of low capacities for potassium and rubidium fixation (15,0 and 16,4%), the third one was with the highest sorption capacity (78,2%). In all these soils the content of available potassium determined with Egner-Riehm method was very low (2,0 to 7,0 mg/100 g of soil).

The first pot experiment was carried out on podzolic loamy sand (no. 6). Two doses of potassium 0,2 and 0,4 g K_2O labelled with rubidium 86 (100 µCi/8 kg of soil) were examined. The scheme of the experiment is given in Table 1. Further greenhouse experiments were carried out on black earth-silty soil (no. 2), and on brown acid loamy soil (no. 8) using small pots containing 1 kg of soil. Three levels of potassium (as shown in Table 2) and three levels of labelling isotopes Rb 86 were examined. The purpose of these tests was also to study to what extent the ratio of Rb/K 86 may influence the results of the uptake of potassium and rubidium ions.

The laboratory examinations of soil capacities for Rb 86 labelling potassium, at the same levels of both elements as the ones used in pot experiments, were performed. The results obtained did not differ significantly from previous laboratory examinations reported in Fig. 1. The data of these tests are not cited because of space limitations.

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Potash Review

Monthly communications by the International Potash Institute, Berne (Switzerland)

28/11

The experimental plant was white mustard. In the first experiment plants were harvested after flowering; in two further-after 21 days of growth.

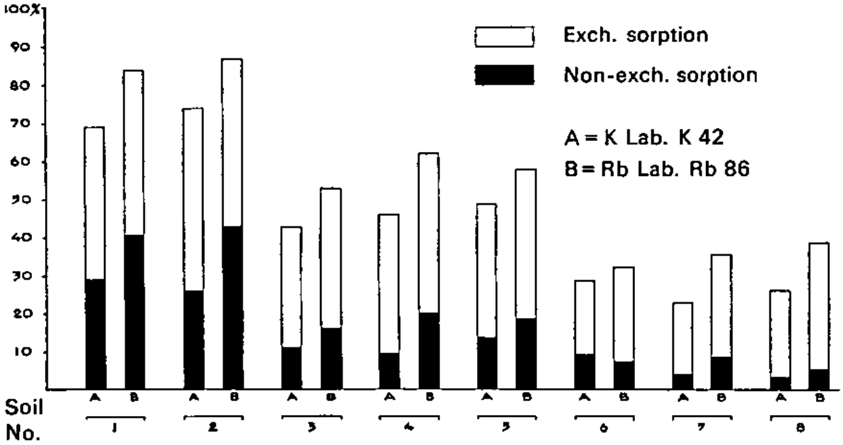
Results and Discussion

The data of laboratory investigations of soil capacities for rubidium and potassium absorption are given in Fig. 1. They show that the capacities differ significantly depending on soil types. The values of non-exchangeable sorption capacities for potassium vary from 3,3% to 29,2% (in percent of total radioactivity) and the ones for rubidium—from 5,3% to 44,1%.

The values for non-exchangeable sorption of rubidium (fixed against extraction with N ammonium acetate) were 1,8–2,8 times higher than for potassium.

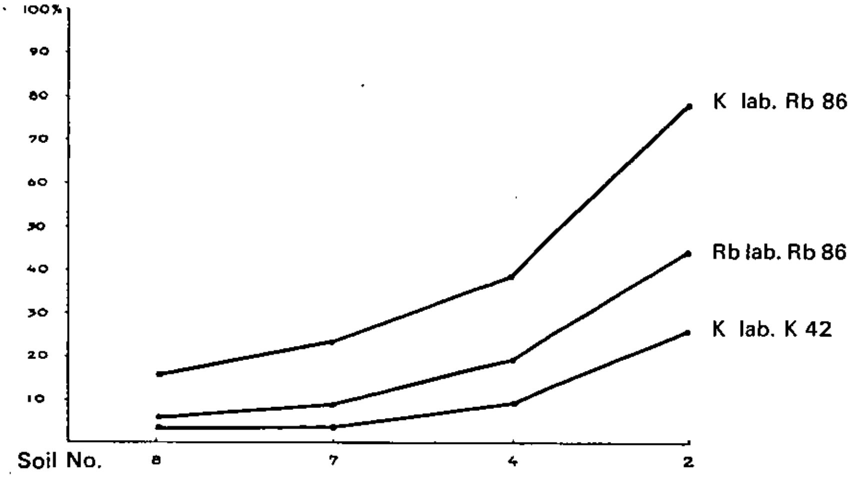
More significant differences occured when sorption capacities of soils were determined using K solution labelled with Rb 86. The highest value was obtained

Figure 1. Sorption capacity of soils determined radiometrically using radioisotopes K 42 and Rb 86, expressed in percent of total radioactivity.



No.	Soil types	Org. matter %	pH KCl	K_2O mg/100 g
1	Black earth-silty soil I	2,86	6,9	4,9
2	Black earth-silty soil II	2,69	6,7	2,7
3	Brown heavy loam	1,49	6,5	2,4
4	Brown leached-silty soil	1,67	7,0	10,9
5	Podzolic sandy loam soil	0,60	6,2	5,4
6	Podzolic loamy sand I	0,87	4,7	2,8
7	Podzolic loamy sand II	0,85	4,9	2,4
8	Brown acid-loamy soil	1,87	5,0	7,0

Figure 2. Capacity for the non-exchangeable sorption of soils depending on the kind of isotopes applied



for black earth (soil no. 2) in which non-exchangeable sorption was 78,2%. Further investigation showed that after extraction of the same soil sample with a fresh portion of N ammonium acetate extractant about 10% of rubidium absorbed was found in solution.

From the data presented in Fig. 2 it may be stated that in spite of great differences in the values of non-exchangeable sorption capacities, both elements, Rb and K, behave similarly in the four soils under investigation.

The results obtained in the first experiment reported in Table 1 include the yields of plants, total potassium content and the uptake of potassium from fertilizer, determined on the basis of radiometric measurements. The data showed that the plant yield increased upon K fertilization with single dose of 25% and double dose of 40%. The potassium fertilization influenced the higher uptake of total potassium, particularly with double dosage (the increase was about 70% of total uptake K_2O).

Potassium recovery from fertilizer established on radiometric measurements was low. The percent of potassium derived from fertilizer in the uptake of total nutrient did not exceed 12,3% with double dosage of K. The total uptake of potassium from fertilizer (at that dosage) was 1,5 times higher than at fertilization with a single dose of K. As may be seen from the Table 1 the recovery of potassium from fertilizer calculated on the basis of these results was at lower potassium rate —18,0%, and higher potassium rate —13,7%. From these results it may be stated that the soil released great amounts of potassium available for plants.

The results of two further experiments are presented in Table 2. In black earth the K fertilization affected plant yields only in some treatments. The little differences which occured are difficult to explanation. In this experiment potassium supply in fertilizer did not influence the potassium uptake by plants. In the experiment on brown acid soil potassium fertilization did not influence the plant yields but increased the potassium content in the plants about 30%.

On the basis of Rb 86 activity measurements of plant materials, the specific activity was determined as well as the total activity found in plant yields.

Potash Review

Monthly communications by the International Potash Institute, Berne (Switzerland)

28/11

Table 1 White mustard yields and potassium content depending on K and P fertilization (using K lab. with Rb 86)

Treatments	Dry matter yield g/pot	Total K_2O content %	Total K_2O content mg/pot	K^x from fertil. %	K^x from fertil. mg/pot	K recov. from fertiliz.
1. K^x without P	6,68	4,10	273,9	8,4	23,0	11,5
2. Without K + P mixed with soil	8,62	3,28	282,7	—	—	—
3. K_1^x + P mixed with soil	10,09	3,20	322,9	11,4	36,8	18,4
4. K_2^x + P mixed with soil	10,80	4,12	445,0	12,2	54,3	13,6
5. K_1^x + P under seeds	11,58	2,98	345,1	10,3	35,5	17,7
6. K_2^x + P under seeds	13,00	3,44	447,2	12,3	55,0	13,8
LSD (5%)	0,70					

The experiment was carried out on sandy loam soil, pH $_{(KCl)}$ = 5,5, low in available nutrients:
2,0 mg K_2O / 100 g of soil; 1,8 mg P_2O_5 / 100 g of soil
K_2O doses: K_1 = 0,2 g / pot = 75 kg pro ha P_2O_5 dose = 40 kg pro ha
K_2 = 0,4 g / pot = 150 kg pro ha

Table 2 Plant yield and potassium content / K_2O / in pot experiments carried out with different levels of K-fertilization and Rb 86 labelling

Potassium	Labelling with Rb 86	Black earth – silty soil: Dry matter yield g/pot	Total potassium (K_2O) content %	Total potassium (K_2O) content mg/pot	Brown acid – loamy soil: Dry matter yield g/pot	Total potassium (K_2O) content %	Total potassium (K_2O) content mg/pot
Without K	Rb^x	3,19	2,28	72,7	2,04	2,40	49,0
	Rb^{xx}	3,12	2,05	64,1	2,23	2,60	57,9
	Rb^{xxx}	3,05	2,25	68,6	2,22	2,45	54,4
K_1	Rb^x	3,36	1,95	65,5	2,33	3,15	73,4
	Rb^{xx}	3,11	2,00	62,2	2,29	3,20	73,3
	Rb^{xxx}	2,97	2,10	62,4	2,02	3,40	68,7
K_2	Rb^x	2,87	2,30	66,0	2,07	3,45	71,3
	Rb^{xx}	2,82	2,15	59,6	2,02	3,70	74,7
	Rb^{xxx}	2,90	2,30	66,7	1,93	3,45	66,6
	LSD	0,23			NSD		

K_1 = 25 mg K_2O/1 kg of soil = 75 kg K_2O/ha Rb^x = 12,5 µCi/1 kg of soil
K_2 = 50 mg K_2O/1 kg of soil = 150 kg K_2O/ha Rb^{xx} = 25,0 µCi/1 kg of soil
Rb^{xxx} = 37,5 µCi/1 kg of soil

The results of specific activity determinations are presented in Fig. 3. They show that the ratio of Rb 86/K found in plants is proportional to the level of rubidium applied and depends on the potassium level. Some greater differences occur in the uptake of rubidium and potassium depending on soil types.

The values for total rubidium uptake by plants are presented in Table 3. Some differences which occur in rubidium content in plants grown in black earth (without K fertilization) and in brown acid loamy soil (with K_1) are difficult to interpret. The other results show that on each potassium level the increasing of the Rb level

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Figure 3. Specific activity of Rb 86/K found in plants depending on soil types and levels of Rb 86 and K fertilization

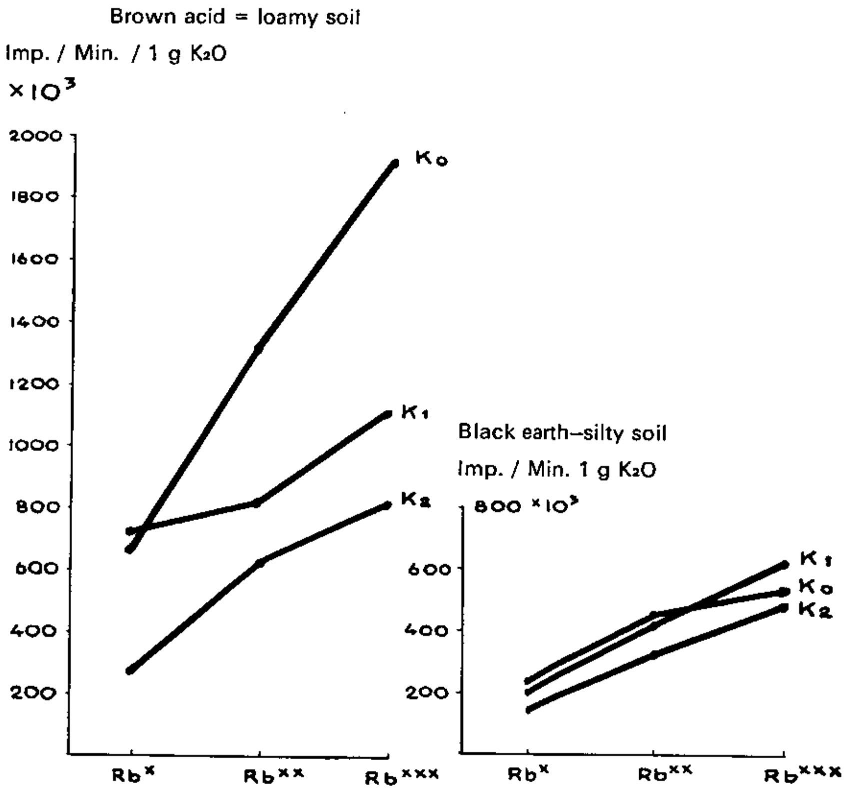

Table 3 The effect of potassium and Rb 86 level on rubidium uptake by plant yields (in % of total activity)

Potassium fertilization (K_2O)	Rb 86 level	Soils Black earth silty soil (no. 2)	Brown acid loamy soil (no. 8)
Without K	Rb^x	5,5	10,8
	Rb^{xx}	4,8	12,5
	Rb^{xxx}	4,0	10,4
K_1 (75 kg/ha)	Rb^x	4,9	15,1
	Rb^{xx}	4,2	10,0
	Rb^{xxx}	4,5	9,3
K_2 (150 kg/ha)	Rb^x	3,7	7,3
	Rb^{xx}	3,6	8,2
	Rb^{xxx}	3,9	6,7

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(used in trace amounts) did not affect the uptake of rubidium by plants. The values obtained are of the same range of magnitude. These results are not in agreement with data reported by *Fried et al. (14)* from experiments in which rubidium was applied in high doses. The increasing of Rb rate from 10 to 160 lb acre significantly influenced its uptake by plants.

The results presented in Fig. 3 and Table 3 indicate that the increase in the potassium level affected the decrease in the uptake of rubidium by plants. Similar results have been obtained by the above mentioned authors *(14)*.

Taking into consideration the significant differences in rubidium recovery by plants growing in two soils the question arises whether the low results obtained on black earth may be due to high soil capacity for rubidium fixation or to various amounts of available soil potassium influencing the isotopic dilution. It may be that both factors are responsible. It is difficult to determine the extent of non-exchangeable sorption of rubidium taking place in soil under experimental conditions with plants. It may be expected that in research with plants non-exchangeable sorption of Rb in soil should be of lower value than in laboratory examinations. The findings by *Broyer (4)* show that in greenhouse experiments, plants were able to use rubidium fixed in soil which was not extractable by chemical methods. Further experiments on the problem are required.

It seems that the results obtained on soils with low capacities for rubidium fixation (such as two other soils applied in pot experiments) do not differ significantly from real values for potassium behaviour, and rubidium 86 may be useful as its tracer. Such an opinion is held by some investigators *(11, 28, 62)*.

The results of pot experiments discussed above show the significant dilution of rubidium with potassium derived from soils. These data suggest that the lack of reaction to potassium fertilization or low level of its recovery may be due to the fact that the amounts of available potassium in soils were sufficient and the nutrient furnished in fertilizer at applied doses had no significance in plant nutrition. It might be possible that in some cases the applied doses of potassium are not sufficient and the influence of K fertilization might appear when potassium rates would be significantly greater.

The final conclusion may be drawn that in further studies on the problem in some conditions (depending on research problem and soil properties) the use of Rb 86 as a tracer for potassium may provide valuable information on nutrient behaviour in soil-plant systems.

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