

POTASSIUM FIXATION IN HEAVY SOILS OF EAST CROATIA

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Introduction

Plant availability of soil K is controlled by dynamic interactions among its different pools. Misunderstanding of this dynamics leads to mismanagement of soil fertility (Wang et al. 2004). Bioavailability of potassium is strongly affected by present alkaline earth ions Ca and Mg (Aeppli, 1971) and fixation of potassium into interlayer zones of some clay minerals (Duthion, 1968). Soil fixation ability strongly affects the efficiency of fertilization. Therefore, while determining the dosage of potassium, one must take into consideration soil texture. AL method is most frequently used in Croatia for evaluating available potassium in soil (Riehm, 1959). According to some research conducted on the soils with high potassium fixation ability, especially Croatian gley soils (Vukadinović et al. 1988a) and semigley in Slavonia (Vukadinović et al. 1988b), this method overestimates the value of bio available potassium. Most soil K tests focus on measurements of K intensity, using mol dm^{-3} neutral ammonium acetate (NH_4OAc) or similar extractions, to characterise solution and exchangeable K (Mehlich, 1984; McLean and Watson, 1985). The aim of this paper is the evaluation of the east Croatian heavy soil ability to fixate potassium while increasing fertilizing dosages ($450\text{--}4500 \text{ kg ha}^{-1} \text{ K}_2\text{O}$).

Material and methods

The research has been conducted on 6 hydromorphic and gleysoils in eastern Croatia, chosen in accordance with pedological map of Croatia (Bogunović 1996). After probing and determining the type of the soil, the average samples were taken (25 separate samples in the radius of 25 m) in which physical and chemical characteristics were determined, as well as the ability of potassium fixation. Fertilization with $450\text{--}4500 \text{ kg ha}^{-1} \text{ K}_2\text{O}$ was simulated in lab-conditions, in a way that 50 g of soil was treated with 50 ml of solution (0, 10, 25, 50, 75 and $100 \text{ mg K}_2\text{O } 100\text{g}^{-1}$ of soil). After 30 minutes of shaking and 24 hours of standing, the samples were shaken for 2 hours in 75 ml of NH_4OAc (1.67 mol dm^{-3} , $\text{pH}=7$, ratio soil:solution = 1:2.5) and centrifuged at 1000G for 10 minutes. The solution was then transferred through filter paper into 200 ml volumetric flask, which were filled with NH_4OAc (mol dm^{-3} , $\text{pH}=7$). After that, 125 ml of NH_4OAc was added to soil sample in 6 turns, shaken, centrifuged and transferred into flasks. The concentration of potassium in eluates was measured with the AAS (Perkin Elmer, AAnalyst 200) in air-acetylen flame. Fixation of potassium was measured according to the formula:

$$K_f = K_a - K_e + K_o,$$

in which K_f is fixated K_2O in $\text{mg } 100\text{g}^{-1}$ of soil; K_a is K_2O added as fertilizer in $\text{mg } 100\text{g}^{-1}$; K_e is K_2O determined in the eluate and K_o is K_2O in the sample which was not fertilized.

Results and discussion

The researched hydromorphic soils of eastern Croatia (Table 1) are, according to their texture class, silty clay and silt loam (Škorić, 1991). Reaction of the soil is from slightly acid to slightly alkaline, level of supply with humus from poor to reach, and with potassium from medium to good (Vukadinović and Bertić, 1989).

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Table 1. General characteristics and K-status of the soil before fertilization

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Soil	Locality	Properties of surface soil layer (0-30 cm)					K ₂ O mg 100g ⁻¹		
		pH		%		TC*			
		H ₂ O	KCl	Humus	Clay		A	B	C
S ₁	Vodjinci	8.20	6.81	1.70	28.3	scl	17.5	9.69	23.67
S ₂	Ivankovo	6.18	4.53	1.61	29.4	scl	13.6	7.86	18.32
S ₃	Svilaj	8.08	6.71	3.10	37.2	scl	28.3	11.04	29.35
S ₄	D. Bebrina	6.36	5.09	4.37	25.3	sl	11.1	5.45	12.87
S ₅	Ruscica	8.25	7.03	1.36	11.6	sl	11.9	7.76	14.60
S ₆	Kaniza	8.05	6.78	2.39	28.6	scl	13.0	5.49	12.92

*TC= textural class: s = silt, c = clay, l = loam

A = AL-method B = first NH₄OAc elution C = sum of six NH₄OAc eluations

Table 2. Potassium status and fixation

Soil	Locality	Fertilization (mg K ₂ O kg ⁻¹) levels						K ₂ O mg kg ⁻¹ KD* (a level)
		<i>a</i> 0	<i>b</i> 100	<i>c</i> 250	<i>d</i> 500	<i>e</i> 750	<i>f</i> 1000	
		Potassium status in NH ₄ -Acetate eluate (mg K l ⁻¹)						
S ₁	Vodjinci	20.1	28.9	41.5	67.6	91.7	117.7	
S ₂	Ivankovo	16.3	19.7	27.7	44.0	67.6	91.8	
S ₃	Svilaj	22.9	29.3	35.5	51.0	67.9	86.5	
S ₄	D. Bebrina	11.3	11.9	12.2	18.7	15.3	18.7	
S ₅	Ruscica	16.1	25.5	40.4	69.6	99.3	136.9	
S ₆	Kaniza	11.4	12.5	13.4	18.4	32.4	44.1	
	Mean	16.35	21.30	28.45	44.88	62.37	82.62	
		Potassium fixation (% of added K by fertilization)						
		a) the first elution by NH ₄ -Acetate solution						
S ₁	Vodjinci		57.6	58.7	53.9	54.0	53.0	9.69
S ₂	Ivankovo		83.6	78.0	73.3	67.0	63.6	7.86
S ₃	Svilaj		69.2	75.7	72.9	71.1	69.3	11.04
S ₄	D. Bebrina		97.1	98.3	92.9	97.4	96.4	5.45
S ₅	Ruscica		54.7	53.1	48.4	46.5	41.8	7.76
S ₆	Kaniza		94.7	96.1	93.3	86.5	84.2	5.49
	Mean		76.15	76.65	72.45	70.42	68.05	7.88
		Potassium fixation (% of added K by fertilization)						
		b) total after six eluations by NH ₄ -Acetate solution						
S ₁	Vodjinci		34.5	37.0	32.7	28.5	27.5	23.67
S ₂	Ivankovo		56.1	58.6	55.3	46.7	43.3	18.32
S ₃	Svilaj		51.8	62.4	57.2	52.3	54.6	29.35
S ₄	D. Bebrina		96.6	97.9	90.8	93.9	91.2	12.87
S ₅	Ruscica		21.9	24.6	24.7	23.8	21.3	14.60
S ₆	Kaniza		81.7	90.0	83.5	72.4	71.0	12.92
	Mean		57.10	61.75	57.37	52.93	51.48	18.62

According to the AL method, the soil that is best supplied with potassium is soil S3, which is the richest in clay (37.2%), and it kept the highest concentration of potassium in B and C eluat. Silt loam (S4) has the highest supply of humus and shows the lowest level of all three kinds of potassium. The results of the first evaluation in NH₄OAc (B) shows that the supply with potassium of all sites is very low, below 10 mg 100g⁻¹ (except S3), and these values are close to

AL-results only after 6th eluation in NH_4OAc (C). On four other sites the results of these extractions are almost identical, minor difference can be found at site S2, and the greatest difference can be found at site S1 ($17.5 \text{ mg } 100\text{g}^{-1} \text{ AL-K}_2\text{O}$ and $23.67 \text{ mg } 100\text{g}^{-1}$ in the sum of the 6 eluates). The results are showing that the AL method is exhibiting far higher values of potassium availability from single NH_4OAc extraction that indicates the difficulty of choosing the method for extraction for a certain soil. Even more so, in production of corn and soybeans symptoms of potassium deficit are often found in these soils (Kovačević and Vukadinović, 1992), although, according to the AL method, they are well supplied with this element.

The examined soils were significantly different in their capacity of potassium fixation (Table 2). The highest potassium fixation displayed site S4 (92-98% of added potassium), then S6 (84-96%), then S2 (63-83%). The lowest fixation was on site S5 with almost less then half of the above mentioned values. The highest fixation was on the sites with the highest content of clay and humus, lower pH values, and the lowest concentration of plant available potassium (Table 1). The exception is site S3, which in spite of the highest supply of clay and humus didn't have the highest fixation, which is probably connected to the highest concentration of the plant available potassium (AL K_2O and NH_4OAc K_2O). Especially strong fixation had the site S4, which kept the level of fixated potassium on 90-98% even after 6 extraction in NH_4OAc .

Table 3. Potassium fixation and desorption at varied K-fertilization

	Locality	K fixation ($\text{kg K}_2\text{O ha}^{-1}$)				
		b 450 $\text{kg K}_2\text{O ha}^{-1}$	c 1125 $\text{kg K}_2\text{O ha}^{-1}$	d 2250 $\text{kg K}_2\text{O ha}^{-1}$	e 3375 $\text{kg K}_2\text{O ha}^{-1}$	f 4500 $\text{kg K}_2\text{O ha}^{-1}$
S ₁	Vodjinci	259.2	660.4	1212.7	1822.5	2385.0
S ₂	Ivankovo	376.2	877.5	1649.2	2261.2	2862.0
S ₃	Svilaj	311.4	851.6	1640.2	2399.6	3118.5
S ₄	D. Bebrina	436.9	1105.8	2090.2	3287.2	4338.0
S ₅	Ruscica	246.1	597.4	1089.0	1569.4	1881.0
S ₆	Kaniza	426.1	1081.1	2099.2	2919.4	3789.0
	Mean x_1	342.65	862.30	1630.1	2376.67	3062.25
S ₁	Vodjinci	155.2	416.2	735.7	961.9	1237.5
S ₂	Ivankovo	252.4	659.2	1244.5	1576.1	1948.5
S ₃	Svilaj	233.1	702.0	1287.0	1765.1	2457.0
S ₄	D. Bebrina	434.7	1101.4	2043.0	3169.1	4104.0
S ₅	Ruscica	98.5	276.7	555.7	803.2	958.5
S ₆	Kaniza	367.6	1012.5	1878.7	2443.5	3195.0
	Mean x_2	256.92	694.6	1290.8	1786.4	2316.6
x_1-x_2	K-desorption $\text{kg K}_2\text{O ha}^{-1}$	85.73	167.7	1290.8	1786.4	2316.6

After being fertilized with potassium, soil fixated approximately 70% of added potassium (the results of the first eluation, Table 2), fixing 342 kg at the lowest dosage of $450 \text{ kg K}_2\text{O}$ (b), which left in the soil approximately 100 kg of available potassium. At the highest dosage (f), soil fixed approximately 3062 kg, and about 1400 kg left available (Table 3). Separately looking, two soils can be singled out (S4 and S6) as particularly problematic because they fixated almost entire amount of added potassium, even at the highest dosage. Therefore, soil S4 fixed 4338 kg out of 4500 kg, and soil S6 fixed 3789 kg out of the same dosage. During the analyses of these two soils before fertilization, more then 25% of clay and the lowest concentration of available potassium (AL K_2O and NH_4OAc K_2O) were found. Soils S2 and S3 also showed high level of potassium

Fertilizing simulation of heavy soils in eastern Croatia with medium or very high dosages of potassium ($450\text{--}4500 \text{ kg ha}^{-1}$), deducted in lab-conditions, showed that AL method of potassium extraction gives relatively high values of available potassium (two times higher than extraction in NH_4OAc (mol dm^{-3} , $\text{pH}=7$)).

Also, highest relative amount of potassium is fixated at lower fertilizing dosages (approximately 76%), the increase in fertilization increases absolute, but reduces relative fixation.

Some heavy soils have high ability of fixation (above 70-90%) and very low desorption, and require special attention when establishing dosages for fertilization and ameliorative fertilization with potassium.

Results obtained by soil analyses show connection between high fixation of potassium added by fertilization and higher amount of clay in the soil as well as lower level of available potassium before fertilization.

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