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SORPTION COMPLEX OF SELECTED SOILS OF THE DRAWSKIE LAKELAND*

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Abstract

Magnesium, calcium, potassium and sodium occur in soil in various forms but for plant nutrition their exchangeable forms are the most important. Cations bonded in soil colloids constitute a specific reservoir of nutrients.

The aim of this research was to determine sorption properties and to evaluate the distribution of exchangeable cations in the profiles of soils of the Drawskie Lakeland. Samples were taken from 6 soil profiles formed from glacial till of the Baltic glaciation in the vicinity of Z³ocieniec and Czaplinek. In general, the sampled soils had the grain-size composition of loams. The reaction of most soil samples was acid. Exchangeable cations were extracted with the $BaCl_2$ solution according to PN-ISO 11260. The cation exchange capacity (CEC) ranged from 52.6 to 216.6 mmol(+) kg^{-1} of soil. The soils, despite acid reaction, were sorption-saturated. Alkaline cations were dominated by calcium, whose highest share in the sorption capacity was identified in the horizons of the parent material of all the examined soils. The lowest amounts of exchangeable calcium and magnesium were found in horizons Ap and Eet. The horizons rich in clay fraction contained higher contents of Ca^{2+} and Mg^{2+}, which was confirmed by significantly positive correlation. The acid reaction did not affect significantly either the content of exchangeable cations or their distribution in the soil profiles. The highest content of K^+ in arable-humus horizons of some of the soils can be related to potassium fertilisation and the weathering of minerals containing that metal. The highest content of magnesium and calcium cations in horizons Bg and the parent material of Gleysols point to the possibility of some overlapping of the top-down gleyic process features with *lessivage* features.

Key words: Luvisols and Gleysols, glacial till, exchangeable cations.

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KOMPLEKS SORPCYJNY WYBRANYCH GLEB POJEZIERZA DRAWSKIEGO

Abstrakt

Magnez, wapñ, potas i sód wystêpuj¹ w glebie w ró¿nych formach, z których najwa¿niejsze w aspekcie od¿ywiania roœlin s¹ ich formy wymienne. Zasorbowane w koloidach glebowych kationy stanowi¹ swoisty rezerwuar sk³adników pokarmowych.

Celem badañ by³o okreœlenie w³aœciwoœci sorpcyjnych oraz ocena rozmieszczenia kationów wymiennych w profilach gleb Pojezierza Drawskiego. Próbki do badañ pobrano z 6 profili gleb wytworzonych z gliny zwa³owej zlodowacenia ba³tyckiego z okolic Z³ocieñca i Czaplinka. Badane gleby charakteryzowa³y siê na ogó³ uziarnieniem glin. Wiêkszoœæ próbek glebowych mia³a odczyn kwaœny. Kationy wymienne ekstrahowano roztworem $BaCl_2$ zgodnie z norm¹ PN-ISO 11260. Pojemnoœæ wymienna (CEC) wynosi³a od 52,6 do 216,6 mmol(+) kg^{-1} gleby. Badane gleby pomimo kwaœnego odczynu by³y sorpcyjnie nasycone. Wœród kationów zasadowych dominowa³ wapñ, którego najwy¿szy udzia³ w pojemnoœci sorpcyjnej stwierdzono w poziomach ska³y macierzystej wszystkich badanych gleb. Najmniej wymiennego wapnia i magnezu stwierdzono w poziomach Ap i Eet. Poziomy zasobne w i³ koloidalny zawiera³y wiecej Ca^{2+} i Mg^{2+}, co potwierdzi³a istotnie dodatnia korelacja. Kwaœny odczyn nie wp³yn¹³ w istotny sposób na zawartoœæ kationów wymiennych oraz ich rozmieszczenie w profilach gleb. Najwy¿sz¹ zawartoœæ K^+ w poziomach orno-próchnicznych kilku gleb mo¿na wi¹zaæ z nawo¿eniem potasem oraz wietrzeniem minera³ów zawieraj¹cych ten metal. Najwy¿sze zawartoœci kationów magnezu i wapnia w poziomach Bg oraz stropie ska³y macierzystej gleb opadowo-glejowych wskazuj¹ na mo¿liwoœæ nak³adania siê cech procesu odgórnego oglejenia na cechy procesu *lessivage*.

S³owa kluczowe: gleby p³owe i opadowo-glejowe, glina zwa³owa, kationy wymienne.

INTRODUCTION

The chemical composition of soil is mostly determined by the origin and the mineral composition of parent material, the effect of which on soil properties decreases along with its development. As a result of the effect of different soil-formation processes in genetically-homogenous parent material, soils representing different soil types can be formed (Targulian, Krasilnikov 2005). In arable soils, the differentiation of their physicochemical properties is strengthened by agrotechnical treatments (Paterson, Richter 1986). The soil sorption properties connected with the ionic exchange between the soil solution and the sorption complex determine the plant uptake of nutrients or their leaching deep into the soil profile (Hartmann et al. 1998). In soils poor in nutrients, the highest content of nutrients available to plants is usually observed in arable-humus horizons (Jobbágy, Jackson 2001). The mineral soil sorption capacity depends on the grain size composition, the type of minerals, the humus content and on the fertilisation level (Askegaard et al. 2005, Ersahin et al. 2006). The type of the fertilisation applied considerably affects the quantitative and qualitative composition of exchangeable cations in arable soils. In many cases, high nitrogen fertilisation doses result in a decrease in the saturation of the sorption complex with cations

Ca^{+2}, Mg^{+2}, Na^{+} (Panak et al. 1996). A decisive effect on the content of cations bonded in soil colloids is also attributed to oxydo-reducing conditions of soils. The dynamics of aerobic conditions transformations to the total anaerobiosis of the soil environment depends on the amount of precipitation and the infiltration process. The intensity of that process is also affected by the grain size composition, reaction and the content of organic matter, especially visible in Gleysols, which, beside Luvisols, have been covered by the present research. In Gleysols profiles, stagnating water generally covers the eluvial horizon and illuvial horizons, determining their reducing conditions, thus changing the availability of many nutrients, and the oxygen anaerobic states can trigger permanent changes in the chemical composition of the crops (Stêpniewski, Przywara 1992).

The aim of the present research was to evaluate the sorption complex of Luvisols and Gleysols formed from glacial till of the Baltic glaciation.

MATERIAL AND METHODS

The soil was sampled from 6 soil profiles formed from glacial till in the vicinity of Z³ocieniec and Czaplinek in the Drawskie Lakeland (Figure 1). Profiles PD1, PD2, PD5 represented Luvisols, while PD3, PD4 and PD6 were qualified as Gleysols. All the analyses were performed in air-dry samples passed through a sieve with the mesh 2.0 mm in diameter. The grain size composition was determined with the Cassagrande erometric method modified by Prószyñski; the exchangeable acidity – potentiometrically in the solution of 1 M KCl; the content of organic carbon – with Tiurin method: the hydrolytic acidity with Kappen method. Exchangeable cations were extracted with barium chloride solution, (ISO 11260), and their content was determined with an atomic absorption spectrometer (Philips PU 9100X). The results were statistically verified, using Statistica 8.0 software.

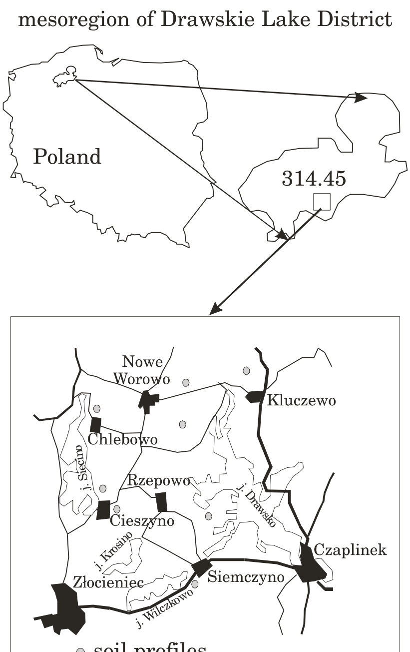

Fig. 1. A map showing the analyzed area and location of the soil profiles

RESULTS AND DISCUSSION

The Luvisols and Gleysols demonstrated the grain size composition of loams (PTG 2009), except for the parent material horizon (IIC) of soil PD5, which showed the grain-size-composition of medium sand (Table 1). A detailed analysis demonstrated very fine sandy loam and sandy loam in arable-humus horizons (Ap) as well as sandy clay loam and clay loam in the enrichment horizons. Total organic carbon (TOC) ranged from 8.2 to 11.9 g kg^{-1} in Ap horizons. As for the reaction, in most samples it was acidic. The pH values determined in 1 M KCl ranged from 3.8 to 5.3. The samples from the parent material formation of soil PD1 and the sample from horizon C of soil PD6 were neutral and alkaline in their reaction (Table 1). The alkaline reaction in those horizons was caused by the presence of calcium carbonate, whose content ranged from 7.5 to 9.5%. The hydrolytic acidity (Hh) ranged from 2.0 to 57.5 mmol(+) kg^{-1} (Table 2). The highest Hh values were observed in the arable-humus horizon, and in soil PD6 – in Bg horizon. The values of cation exchange capacity (CEC) of the soils ranged from 52.6 to 216.6 mmol(+) kg^{-1} of soil. The content of exchangeable magnesium cations ranged from 1.2 to 23.0 mmol(+) kg^{-1}. A slightly higher content of Mg^{2+} was identified in the soils formed from glacial till of the Krajeñskie Lakeland mesoregion (KOBIERSKI, PYTLARZ 2006). The parent material of those soils, however, showed a higher content of the clay fraction than the parent material of soils of the Drawskie Lakeland.

The examined soils, despite the acid reaction, must be considered as sorption-saturated ones. It was only in horizon Ap of soil PD3 that the degree of saturation of the sorption complex with alkaline cations (V) was below 50%. The highest share of alkaline cations was identified in the parent material horizons of all the soils. The base saturation was dominated by Ca^{2+}, the content of which was significantly positively correlated with the cation exchange capacity (Table 3). The highest share of calcium cations in CEC was observed in illuvial horizons and the roof of the parent material. The ratio of cations Ca^{+2}/Mg^{+2} was narrowing with the soil depth, which could have been due to its partial leaching and magnesium uptake by plants when exposed to insufficient magnesium fertilisation. In soils PD1, PD2, PD6, the arable-humus horizons were richest in exchangeable potassium, which must be related to potassium fertilisation and the process of mineral weathering. The lowest content of exchangeable potassium was found in the horizons rich in the clay fraction, which is significantly confirmed by the negative correlation between those parameters (Table 3). The amounts of potassium released to the soil solution as a result of the weathering of minerals and K^{+} desorption depend on the content of exchangeable potassium and the type of clay minerals, mostly illites (KOBIERSKI et al. 2005). The content of exchangeable sodium varied across the soils researched and

Table 1

Selected properties and texture of the analyzed soils

Profile No	Horizon	Depth (cm)	PH KCl	TOC (g kg^{-1})	Particle size fractions			Texture classa	
					sand	silt	clay	PTG*	USDA**
					(%)				
PD1	Ap	0-25	4.6	8.6	63	20	17	gl	SL
	Btg1	25-50	4.8	2.7	56	23	21	gpi	SCL
	Btg2	50-80	5.0	1.5	50	25	25	gpi	SCL
	Bt	80-95	5.0	0.7	57	21	22	gpi	SCL
	B/C	95-120	5.0	0.3	61	19	20	gl	SL
	Cca1	120-180	7.3	-	62	19	19	gl	SL
	Cca2	180-200	7.4	-	62	20	18	gl	SL
PD2	Ap	0-30	50	10.9	64	22	14	gl	SL
	AE	30-46	5.1	4.7	66	22	12	gp	FSL
	Eet	46-74	4.9	2.8	69	19	12	gp	FSL
	Eetg	74-125	4.5	1.3	68	21	11	gp	FSL
	Bt	125-180	4.4	0.6	32	37	31	gi	CL
	C	180-200	5.1	-	60	23	17	gl	SL
PD5	Ap	0-28	4.9	9.0	62	24	14	gl	SL
	Bt	28-72	5.1	3.4	55	24	21	gpi	SCL
	BC	72-90	5.3	1.4	70	14	16	gp	FSL
	C	90-120	4.9	0.5	57	24	19	gl	SL
	IIC	120-180	4.9	-	95	3	2	pl	S
PD3	Ap	0-25	4.0	11.9	61	23	16	gl	SL
	Gg	25-57	4.0	3.6	57	25	18	gl	SL
	Bg	57-115	4.1	1.4	55	26	19	gl	SL
	Cg	115-180	4.1	0.4	62	23	15	gl	SL
	C	190-200	4.2	-	59	23	18	gl	SL
PD4	Ap	0-28	4.4	10.1	69	23	8	gp	FSL
	Gg1	28-50	4.4	4.7	67	25	8	gp	FSL
	Gg2	50-83	4.3	1.1	65	24	11	gp	FSL
	Gg3	83-114	4.0	0.4	69	26	5	gp	FSL
	Bg	114-170	3.8	-	55	27	18	gl	SL
	C	170-200	5.2	-	58	26	16	gl	SL
PD6	Ap	0-26	4.5	8.2	70	26	4	gp	FSL
	Gg1	26-55	4.3	1.7	56	24	20	gl	SL
	Gg2	55-81	4.1	1.2	64	19	17	gl	SL
	Bg	81-120	3.7	0.5	55	23	22	gpi	SCL
	Cg	120-180	3.9	-	57	24	19	gl	SL
	C	180-200	7.0	-	61	23	16	gl	SL

TOC – total organic carbon; sand: 2.0-0.05 mm; silt: 0.05-0.002 mm; clay: <0.002 mm;
The texture classes are based on PTG 2008 and USDA classification.
*PTG: pl – sand; gp – sandy loam; gl – sandy loam; gpi – sandy clay loam; gi – clay loam
**USDA: S – sand; FSL – fine sandy loam; SL – sandy loam; SCL – sandy clay loam; CL – clay loam

Table 2

Content of exchangeable cations and sorptive capacity parameters

Profile No	Horizon	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Hh	S	CEC	V
		(mmol kg^{-1})							(%)
PD1	Ap	59.6	3.4	12.3	2.9	34.5	78.2	112.7	69.4
	Btg1	71.6	4.1	3.3	2.8	18.0	81.8	99.8	82.0
	Btg2	84.9	7.5	3.6	2.6	16.0	98.6	114.6	86.0
	Bt	82.4	7.2	2.5	2.0	11.5	94.1	105.6	89.1
	B/C	73.7	6.9	2.3	2.2	11.0	85.1	96.1	88.6
	Cca1	88.5	3.4	2.2	1.6	2.0	95.7	97.7	98.0
	Cca2	85.9	4.4	2.1	1.8	2.5	94.2	96.7	97.4
PD2	Ap	54.8	3.3	16.7	2.5	33.5	77.3	110.8	69.8
	AE	45.9	1.8	2.1	2.1	24.0	51.9	75.9	68.4
	Eet	44.7	1.7	3.5	2.3	26.5	52.2	78.7	66.3
	Eetg	37.1	1.7	5.5	2.2	25.5	46.5	72.0	64.6
	Bt	108.8	15.7	11.6	5.1	30.0	14.2	171.2	82.5
	C	85.5	8.6	14.1	4.3	15.0	112.5	127.5	88.2
PD5	Ap	96.2	14.2	22.8	10.4	28.0	143.6	171.6	83.7
	Bt	133.9	18.4	16.2	15.7	15.0	184.2	199.2	92.5
	BC	111.0	11.8	17.5	10.6	13.0	150.9	163.9	92.1
	C	126.3	20.7	24.7	13.0	17.0	184.7	201.7	91.6
	IIC	24.1	1.2	9.2	11.1	7.0	45.6	52.6	86.7
PD3	Ap	34.5	4.7	1.6	2.0	44.0	42.8	86.8	49.3
	Gg	40.8	7.1	2.6	5.0	38.5	55.5	94.0	59.0
	Bg	45.9	13.5	2.2	4.0	28.5	65.6	94.1	69.7
	Cg	98.0	23.0	9.5	7.7	24.5	138.2	162.7	84.9
	C	98.2	21.4	17.5	12.3	22.0	149.4	171.4	87.2
PD4	Ap	69.9	4.9	12.8	10.9	42.0	98.5	140.5	70.1
	Gg1	61.9	1.6	11.5	9.6	34.0	84.6	118.6	71.3
	Gg2	66.4	3.6	14.6	9.6	22.5	94.2	116.7	80.7
	Gg3	46.7	6.8	27.7	12.1	28.0	93.3	121.3	76.9
	Bg	12.,3	20.4	18.3	11.1	30.5	174.1	204.6	85.1
	C	148.1	14.2	26.5	15.8	12.0	204.6	216.6	94.5
PD6	Ap	80.2	2.0	29.2	13.4	40.5	124.8	165.3	75.5
	Gg1	98.3	7.9	16.5	14.3	26.5	137.0	163.5	83.8
	Gg2	93.4	10.5	12.3	14.5	33.0	130.7	163.7	79.8
	Bg	63.2	10.6	2.5	1.1	57.5	77.4	134.9	57.4
	Cg	107.5	4.7	2.1	1.4	27.5	115.7	143.2	80.8
	C	78,3	8.3	2.5	0.9	4.0	90.0	94.0	95.7

S – base saturation; CEC – cation-exchange capacity; V=S/CEC · 100

Table 3

Correlation coefficients between the investigated parameters (n = 35)

Parameters	Mg^{2+}	Ca^{2+}	K^+	Na^+	S	CEC
Clay	0.44	0.46	-0.34			
Mg^{2+}		0.64	0.36	0.44	0.76	0.75
Ca^{2+}			0.39	0.42	0.87	0.81
K^+				0.81	0.67	0.70
Na^+					0.68	0.70

S – base sturation; CEC – cation-exchange capacity; confidence level $p<0.05$

ranged from 0.9 to 15.8 mmol(+) kg^{-1}, and the share of Na^+ in CEC ranged from 1.0 to 21.1%. The share of magnesium cations in the cation exchange capacity ranged from 1.2 to 14.9%. A similar share of Mg^{2+} in CEC (from 5.3 to 10.6%) was recorded in Luvisols and Cambisols formed from glacial till of the Inowroc³awska Plain (Kobierski et al. 2005).

Analysing the exchangeable magnesium distribution in the profiles of the soils, it was found that their content varied in respective genetic horizons. The highest content of that cation was noted in the sorption complex of the horizons richest in the clay fraction. The statistical analysis of the results demonstrated a significantly positive correlation between the content of exchangeable magnesium and the content of the clay fraction (Table 3). A similar relationship was reported by B£aszczyk (1998) who found that exchangeable Mg resources in soils formed from glacial tills increased with the increasing amount of clay fraction. The lowest share of magnesium cations in CEC, whose mean content of Mg^{2+} was 1.7 mmol(+) kg^{-1}, was identified in the sorption complex of eluvial horizons (Eet) of soils PD2. Arable-humus horizons of soils demonstrated a lower variation in the content of that cation, and its average content was 5.4 mmol(+) kg^{-1}, thus being similar to the average content of Mg^{2+} in gleyic horizons (6.2 mmol(+) kg^{-1}). The highest content of exchangeable magnesium was reported in illuvial horizons of soils PD1, PD2, PD4, PD6, for which the values of the Mg^{2+} distribution index across the profiles were the highest (1.0-1.8). The values of the distribution index calculated from the ratio of the content of cations in the solum genetic horizon to its mean content in the parent material also confirm the pedogenic nature of Ca^{2+} accumulation in the profiles of Luvisols. Magnesium is very easily leached from genetic horizons within the solum. Exchangeable cations triggered as a result of chemical weathering of minerals reach the soil solution, from which they are taken up by plants, can be bonded by soil colloids or leached deep down the soil profile. In the examined Gleysols of the mesoregion, the highest content of exchangeable magnesium cations in the deepest genetic horizons of solum and the roof of the parent material was identified. A similar relationship was recorded for calcium cations. These findings can suggest some overlapping of the features of the surface gleyic process involving precipitation waters with *lessivage* features, characteristic for Luvisols. The distribution of nutrients in the soil profile depends considerably on the grain size composition and the physicochemical properties of soil, especially pH, an increase of which results in a clear increase in the content of easily-soluble magnesium (LIPIŃSKI, BEDNAREK 1998). The present results, however, did not coincide with a significant effect of the reaction on the content of exchangeable magnesium in the profiles of the investigated soils. The nature and the durability of organic-mineral bonds of the sorption complex depend on the existing acidic-alkaline equilibrium of soil. The properties determine the form of occurrence of elements and their leaching down the soil profile, which concerns mostly soils under intensive agricultural use, in which agrotechnical treatments affect the rate and the direction of changes in physicochemical properties (SK£ODOWSKI, ZARZYCKA 1995).

CONCLUSIONS

1. In the Luvisols of the Drawskie Lakeland, the lowest amount of exchangeable calcium

and magnesium was observed in arable-humus and eluvial horizons. The highest content of Ca^{2+} and Mg^{2+}, both in the profiles of Luvisols and Gleysols, was identified in the deepest genetic horizons of the solum and in the roof of the parent material, which points to the possibility of overlapping of the features of the surface gleyic process with the *lessivage* features. The exchangeable potassium and sodium distribution in the profiles of the analysed soils varied.

2. Horizons rich in the clay fraction contained a significantly higher content of Ca^{2+} and Mg^{2+} and a significantly lower content of K^{+}, which is confirmed by the results of the analysis of correlation.

3. The acidic reaction did not affect significantly either the content of exchangeable cations or their distribution in soil profiles.

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