Renata JASKULSKA
Instytut Środowiska Rolniczego i Leśnego Polskiej Akademii Nauk, Zakład Chemii Środowiska
ul. Bukowska 19, 60-809 Poznań, Poland
e-mail: renata.jaskulska@isrl.poznan.pl

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SORPTIVE PROPERTIES OF CULTIVATED *LUVISOLS*

Summary

This paper presents results of physicochemical analyses of Luvisols from three cultivated fields located in the area of Agroecological Landscape Park. The study were conducted at four depths. The aim of the research was to compare sorptive properties of Luvisols with reference to selected physicochemical parameters. The sampled soils had the texture of clay sands. The cultivated field (IP) had a neutral pH with low hydrolytic acidity (H_a), whereas cultivated fields IIP and III were acidic with decidedly higher H_a. Sorptive properties of the studied Luvisols varied between cultivated fields and within a given profile. The index of soil saturation with base cations ranged from 33 to 79%. The soil of the cultivated field (IP), which was rich in TOC and had neutral pH, was sorption-saturated. The highest amounts of Ca^{2+}, Mg^{2+} and K^{+} were found in topsoil. Ca^{2+} was dominating alkaline cation.
Key words: *sorptive properties, exchangeable cations, Luvisols, agricultural areas*

SORPCYJNE WŁAŚCIWOŚCI UŻYTKOWANYCH ROLNICZO GLEB PŁOWYCH

Streszczenie

W pracy przedstawiono wyniki analiz fizyczno-chemicznych gleb płowych trzech pól użytkowanych rolniczo, zlokalizowanych na terenie Agroekologicznego Parku Krajobrazowego. Przeprowadzone badania miały na celu porównanie właściwości sorpcyjnych uprawnych gleb płowych na tle wybranych parametrów fizyczno-chemicznych. Badane gleby charakteryzowały się uziarnieniem odpowiadającym piaskom gliniastym. Pole uprawne (IP) wykazało odczyn obojętny o niskiej kwasowości hydrolitycznej (H_h). Natomiast pola uprawne (IIP i IIIP) miały odczyn kwaśny o zdecydowanie wyższej H_h. Właściwości sorpcyjne badanych gleb płowych były zróżnicowane pomiędzy polami uprawnymi i w obrębie danego profilu. Wysycenie gleb zasadami wynosiło od 33 do 79%. Gleby pola uprawnego (IP) zasobne w TOC o odczynie obojętnym były sorpcyjnie nasycone. Udział kationów Ca^{2+}, Mg^{2+} i K^{+} był największy w poziomie orno-próchnicznym. Wśród kationów zasadowych dominował Ca^{2+}.
Słowa kluczowe: *właściwości sorpcyjne, kationy wymienne, gleby płowe, obszary rolnicze*

1. Introduction

Soil sorption capacity is an important issue both from the point of view of agriculture and environmental protection. Soil is the most biologically effective part of the lithosphere and works as a natural barrier in land ecosystems. The soil solid phase has the ability to retain and store ions and particles from the soil solution [11]. This is one of the most important features of any soil and it is a crucial factor regulating leaching of nutrients. Sorption properties of soils determine the effectiveness of fertilisation and affect the nutrition of plants. This is particularly important in intensively used agricultural soils, where agrotechnical measures can modify the rate and direction of changes in chemical and physical properties of soils. It is known that individual soil forms show different sorption capacities [6]. It is worth emphasising that humus, due to its high sorption properties, may limit the phytoextraction of biogens and heavy metals and their introduction to the trophic chain, as well as leaching and migration of these substances to groundwater [17, 24]. Soil, which is a link between animate and inanimate nature, performs many ecological, technical, socio-economic, economic and cultural functions in the environment [4]. As a part of the habitat, it is most resistant to quick pH changes due to its buffer abilities. The sorption properties of soils are determined by their particle size distribution, reaction, and content of mineral and organic colloids [9, 10]. Soil texture and humus content are two of many factors significantly affecting the sorption capacity of soils, which is of particular importance in light soils [3].

The aim of the study was to evaluate the sorption properties of arable Luvisols of the Kościan Plain. This paper describes a continuation research studies.

2. Materials and methods

The study covered the Luvisols of three fields used for agriculture in the Agroecological Landscape Park, in the Wielkopolska Province. The first cultivated field (IP) was located in the village of Rogaczewo Wielkie (52°02'9.5"N 16°49'40.4"E); second field (IIP) in the town of Rąbiń (52º02'57.6"N 16º52'46.2"E), and the third field (IIIP) in Wyskoć (52º04'02.9"N 16º47'23.5"E). The Landscape Park includes the mezoregion of the Kościan Plain and the south-eastern part of the area around Lake Zbęchy which belongs to the Krzywińskie Lake District - part of the macroregion of the Leszczyńskie Lake District [16]. The surface is formed mainly by glacial plains with small denivelations and land slopes. This area lies at an altitude of 78-80 m above sea level [12].

Soil samples for analyses were taken from three profiles marked as IP, IIP and IIIP, from four depths (0-30, 30-60, 60-90 and 90-120 cm) which represented the Luvisols used as arable land. These soils developed on the plateaus of the basal moraine of the Baltic glaciation - Leszno stadial. The moraine clays occurring here underwent processes of diffusion and delamination, forming associations with brown and stagnic Luvisols. These clays have high sand content

and a distribution of loamy sands [18, 22]. Triticale and maize were cultivated alternately on these soils.

All analyses were performed in air-dried soil samples and sieved through a 2-mm diameter sieve. The particle size distribution was determined using Casagrande hydrometer method modified by Prószyński [21]. The TOC content was determined on the TOC-5050A analyser with the SSM-5000A attachment from Shimadzu, Japan; pH was determined potentiometrically in a solution of 1 M KCl [19]; hydrolytic acidity was determined using the Kappen method [19]; and cation exchange capacity was determined according to the $BaCl_2$ method [14, 20]. The analyses of soil samples were made in three replications and the results were averaged.

In order to determine the relationship between the studied features, a correlation analysis was used at the level of $p<0.05$.

3. Results and discussion

The examined soils from cultivated fields IP, IIP and IIIP were classified as Luvisols [22, 23]. They were characterized by high variability of the particle size distribution between the cultivated fields soils within the profile. The smallest differentiation was exhibited by the topsoil (0-30 cm) represented by loamy sands. The analysed soils showed a clear vertical differentiation of the clay fraction content as a result of its leaching, translocation and accumulation in the soil profile. High homogeneity of the topsoil was confirmed by the low content of clay fraction. In deeper levels, the heterogeneity of texture between the soils of cultivated fields was greater, which was particularly evident at depths of 60-120 cm. To a depth of 60 cm, the studied soils (IP, IIP and IIIP) demonstrated the distribution of loamy sand which deeper transitioned into sandy loam [8]. The diverse texture composition and the results of the analyses of the basic physicochemical properties of the studied soils were characteristic for Luvisols [15].

The content of TOC in the topsoil ranged from 4.47 $g \cdot kg^{-1}$ in the IIIP profile to 9.72 $g \cdot kg^{-1}$ in the IP profile and decreased with depth (Table 1).

Table 1. Basic physicochemical properties of cultivated Luvisols

Tab. 1. Podstawowe właściwości fizyczno-chemiczne uprawnych gleb płowych

Name	Depth (cm)	pH_{KCl}	TOC ($g \cdot kg^{-1}$)
IP	0-30	6.78	9.72
	30-60	6.62	8.87
	60-90	6.59	8.48
	90-120	6.53	5.39
IIP	0-30	4.58	7.39
	30-60	4.41	2.16
	60-90	4.39	1.11
	90-120	4.33	0.68
IIIP	0-30	4.32	4.47
	30-60	4.28	2.91
	60-90	4.27	1.59
	90-120	4.23	1.22

Source: own work / Źródło: opracowanie własne

The pH of the studied soils ranged from acidic in soils of cultivated fields IIP (4.33 - 4.58) and IIIP (4.23 - 4.32) to neutral in IP (6.53 - 6.78), (Table 1). A positive correlation was found between soil pH and the TOC content ($r = 0.82$, $p<0.05$), (Table 3).

Sorption properties of soils were clearly differentiated between the analysed cultivated fields and within a given profile (Table 2). The highest values of hydrolytic acidity (H_a) showed soils of cultivated fields (IIP and IIIP), which ranged from 1.25 to 3.26 $cmol_+ \cdot kg^{-1}$ (Table 2). Only the soil of the field IP clearly differed from these values, the content of H^+ ions was low and H_a ranged from 0.79 to 0.94 $cmol_+ \cdot kg^{-1}$. The hydrolytic acidity decreased, and the sum of basic cations, sorption capacity and soil saturation with bases increased deeper into the soil profile. Similar dependencies in arable Luvisols were presented by Jaworska et al. [7], Kobierski et al. [13].

The share of alkaline exchangeable cations in the sorption complex of the studied soils varied and was as follows: IP and IIIP $Ca^{2+}>K^+>Mg^{2+}>Na^+$, and in IIP $Ca^{2+}>Mg^{2+}>K^+>Na^+$. In all analysed soils, calcium was the dominant cation, its content in the soil of the cultivated field IP ranged from 6.02 to 6.28 $cmol_+ \cdot kg^{-1}$. Its value increased with the reaction. In other profiles, no such relationship was observed. Lower values of Ca^{2+} cations were found in the soils of fields IIP and IIIP (1.12-1.32 $cmol_+ \cdot kg^{-1}$), (1.02-1.31 $cmol_+ \cdot kg^{-1}$), respectively. The number of exchangeable Ca^{2+} cations in the studied Luvisols increased with depth (Table 2). Among exchangeable cations, the amount of magnesium was definitely smaller (0.12 - 0.33 $cmol_+ \cdot kg^{-1}$). The share of the remaining cations, i.e. potassium and sodium, varied. Greater amount of potassium was recorded in the topsoil (0-30 cm) of arable fields: IP (0.49 $cmol_+ \cdot kg^{-1}$), IIP 0.19 $cmol_+ \cdot kg^{-1}$), IIIP (0.42 $cmol_+ \cdot kg^{-1}$), (Table 2). The enrichment of this horizon with this element can be associated with long-lasting and intensive farming as well as with mineral fertilization. However, differentiated potassium content in lower levels may indicate inhomogeneous mineral composition of the sorption complex. In mineral soils, the amount of potassium released into the soil solution depends on the granulometric composition and the intensity of the mineral weathering process [1]. The content of Na^+ ions in the studied Luvisols was low and did not show large variations (0.011-0.018 $cmol_+ \cdot kg^{-1}$).

Among the analysed profiles of Luvisols, the highest content of the sum of exchangeable cations (7.97 $cmol_+ \cdot kg^{-1}$) was found in the topsoil of the arable field IP (Table 2). Soil of IP field was sorptionally saturated, and the degree of saturation with bases was high (over 89%), (Table 3). On the other hand, the soil of other cultivated fields showed low sorption capacity and saturation with bases was 35% (IIP) and 34% (IIIP). According to Bache [2] and Ersahin et al. [5], in mineral soils, cation exchange capacity (CEC) depends primarily on the texture and the TOC content.

Statistical analysis of the results indicated significant positive and negative correlations between the TOC content and the pH value and H_a, CEC, TEB,, BS parameters and exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) in the studied soils of three cultivated fields. The content of calcium and magnesium exchangeable cations in the analysed soils was significantly positively correlated with the TOC content, $r = 0.78$, $r = 0.57$, respectively for $p<0.05$. Correlation analysis also showed a statistically significant ($p<0.05$) relationship between pH and values: H_a ($r = -0.73$), CEC ($r = 0.96$), BEC ($r = 0.99$), BS ($r = 0.92$), Ca^{2+} ($r = 0.99$), Mg^{2+} ($r = 0.74$), (Table 3).

Table 2. Sorptive properties of cultivated Luvisol
Tab. 2. Właściwości sorpcyjne uprawnych gleb płowych

Name	Depth	H_a	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	TEB	BS
	(cm)	($cmol_+ \cdot kg^{-1}$)							(%)
IP	0-30	0.86	6.28	0.33	0.49	0.016	7.97	7.11	89.21
	30-60	0.94	6.21	0.31	0.32	0.012	7.79	6.85	87.93
	60-90	0.79	6.02	0.37	0.51	0.015	7.69	6.90	89.73
	90-120	0.81	6.19	0.33	0.48	0.014	7.82	7.01	89.64
IIP	0-30	2.98	1.14	0.29	0.19	0.013	4.61	1.63	35.39
	30-60	2.80	1.12	0.18	0.14	0.011	4.25	1.45	34.13
	60-90	1.25	1.21	0.31	0.21	0.014	2.99	1.74	58.24
	90-120	1.49	1.32	0.29	0.18	0.015	3.29	1.80	54.77
IIIP	0-30	3.26	1.12	0.15	0.42	0.016	4.96	1.70	34.35
	30-60	3.01	1.02	0.12	0.35	0.014	4.51	1.51	33.31
	60-90	1.98	1.31	0.18	0.48	0.018	3.96	1.98	50.10
	90-120	1.78	1.24	0.17	0.32	0.017	3.52	1.74	49.53

H_a – hydrolytic acidity, CEC – cation exchange capacity, TEB – total exchangeable bases, BS – base saturation

Source: own work / Źródło: opracowanie własne

Table 3. Coefficients of correlation between some properties of investigated cultivated Luvisols (n = 12)
Tab. 3. Współczynniki korelacji pomiędzy właściwościami badanych uprawnych gleb płowych (n = 12)

	Clay	TOC	pH_{KCl}	H_a	CEC	TEB	BS	Ca^{2+}
TOC	-0.66*							
pH_{KCl}	-0.32	0.82*						
H_a	-0.27	-0.33	-0.73*					
CEC	-0.45	0.87*	0.96*	-0.54				
BEC	-0.23	0.78*	0.99*	-0.77*	0.95*			
BS	0.01	0.61*	0.92*	-0.93*	0.80*	0.94*		
Ca^{2+}	-0.25	0.78*	0.99*	-0.77*	0.95*	0.99*	0.94*	
Mg^{2+}	-0.03	0.57*	0.74*	-0.79*	0.57*	0.71*	0.80*	0.71*

H_a – hydrolytic acidity, CEC – cation exchange capacity, TEB – total exchangeable bases, BS – base saturation

Source: own work / Źródło: opracowanie własne

There was no significant correlation between TOC and pH and the content of K^+ and Na^+ cations in the sorption complex in the studied soils. Also, there was no influence of the clay fraction on the value of H_a, as well as the correlation between the Na^+ content and saturation of the sorption complex with Ca^{2+} and Mg^{2+} cations (Table 3).

4. Conclusions

1. The sorption properties of the studied Luvisols in cultivated fields varied between IP, IIP and IIIP fields and within a given profile.
2. The studied soils of the three cultivated fields showed that the 0-30 cm level contained higher TOC and Ca^{2+}, Mg^{2+} and K^+ values compared to the remaining lower levels.
3. Soil of cultivated fields IP and IIP showed acidic reaction with high values of hydrolytic acidity (H_a). Based on the analysis of the data, it was found that the soils of these cultivated fields are poorly sorptionally saturated.
4. Out of three studied profiles, the IP field with high TOC content deserves special attention. It showed the best sorption properties in the whole profile. The reaction of the examined cultivated field was close to neutral with low H_a. The content of exchangeable cations allows to include the analysed soil of IP field in sorptionously saturated soils.
5. Correlation analysis showed a significant effect of TOC and soil reaction on the sorption properties of the studied arable soils.
6. The assessment of sorptive and physicochemical properties of Luvisols is a good indicator differentiating the studied soils in agricultural areas.

5. References

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