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CONTENT OF EXCHANGEBALE CATIONS IN GRASSLAND SOIL DEPENDING ON HABITAT CONDITIONS IN THE RADZIEJOWA RANGE

ZAWARTOŚĆ KATIONÓW WYMIENNYCH W GLEBIE UŻYTKÓW ZIELONYCH W ZALEŻNOŚCI OD WARUNKÓW SIEDLISKOWYCH W PASMIE RADZIEJOWEJ

Abstract: The research has aimed to determine the contents and variation of exchangeable cations in the soil of grasslands in the Radziejowa range (The Beskid Sadecki Mountains). The investigations were conducted in the areas with diversified habitat conditions under various type of management. The plant community description considered the altitude above sea level, land slope and aspect, and botanical composition. In the soil taken from the 0.10 cm layer pH was determined in 1 mol $KCl \cdot dm^{-3}$ and exchangeable cations (Ca, Mg, K and Na) by means of extraction with 1 mol $CH_3COONH_4 \cdot dm^{-3}$.

In the experiment the contents of exchangeable calcium forms in soil was conditioned by the altitude above sea level and the slope angle. Similar dependencies were found for the soil reaction. The soil reaction was changing and affected the concentrations of exchangeable cation forms. In soil sorption capacity the dominant alkaline cation was calcium whose concentration in the analyzed soils oscillated from 616 to 7325.79 mg $Ca \cdot kg^{-1}$ soil.

Keywords: exchangeable cations, soil reaction, habitat conditions

Soils constitutes the main link in the natural element cycling, including macro-elements [1]. Changes in chemical composition of soils directly affect the plants and indirectly also influence animals and humans. An important factor shaping soil fertility, is their ability to meet plant nutritional requirements is the amount and bioavailability of nutrients. Exchangeable alkaline cations [2], which are treated as potentially available to plants, play an important role among them [3]. Soil fertility diversification in mountain

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soils depends to a great degree on the altitude and land slope. These properties may be directly reflected in diverse crop yields [4].

The aim of the presented paper is to reveal the variation range for alkaline cation resources in mountain soils in the Radziejowa Range considering the land slope and altitude above sea level.

Material and methods

The research was conducted in the Radziejowa Range (The Beskid Sadecki Mountains) in 2006. 210 samples were collected from grasslands with diversified habitat conditions and various types of management. Each time the altitude above sea level, land slope and slope aspect, and botanical composition were determined, and the plant communities were described. Dominant were acid brown soils (podzolic and typical) [5]. In the soil from the 0–10 cm layer pH was assessed in 1 mol KCl · dm^{-3} and exchangeable cations (Ca, Mg, K and Na) by means of extraction with 1 mol CH_3COONH_4 · dm^{-3}. Vegetation was described with Braun-Blanquet method on 100 m^2 research plots and the share of individual plant species was determined on the basis of an average area cover.

The research material was diversified considering habitat conditions (the altitude above sea level 360–960 m; land slope 0–40 ^{o}; pH 3.59–6.63; the share of grasses in the sward 6–87 %; the share of legumes 0–40 %).

Correlation coefficients, r and determination coefficients, r^2 were computed in order to present relationships between selected habitat properties of the researched soils. The results were presented in a graphic form and as statistical parameters determined using Statistica package No. JGNP0-5B493631AR.

Results and discussion

The reaction of discussed soils was strongly diversified (Table 1). On the basis of mean value of pH assessed in 1 mol KCl · dm^{-3}, the investigated soils may be counted among very acidic and acidic. Mean pH_{KCl} value was 4.28. Usually soil acidification causes worsening of its chemical properties. In the investigated soils pH value depended on the altitude and land slope (Fig. 1). Statistical analysis revealed this dependence on the significance level of $p = 0.01$ but the value of correlation coefficients was small (land slope $r = –0.146$, a.s.l. $r = –0.147$). The lowest pH value were noted from the altitude over 800 m a.s.l. at the land slope over 15 ^{o}. On the other hand at the altitude of 470–800 m a.s.l. at the land slope to 15 ^{o} pH value was the highest.

Backward stepwise multiple regression which analyzed the effect of factors on individual soil cations revealed an influence of soil reaction on the sum of exchangeable cations. It was found that in the soil from the investigated area the content of a half of bivalent cations and a quarter of univalent cations depended on the soil reaction. The higher the soil reaction values, the higher cation content in soil. Such condition was not found for altitude above sea level or the land slope.

Table 1

Statistical parameters of selected factors considered in environmental research

Parameter	pH	Land slope [°]	Exchangeable cation content [mg/kg d.m.]				Sum of base cations [mmol(+) · kg^{-1}]
			Na^+	Mg^{++}	K^+	Ca^{++}	
Arithmetic mean	4.28	17.2	14.79	159.7	79.2	2205	125.7
Standard deviation	0.54	8.22	5.00	104.5	35.9	1235	67.2
Minimum	3.59	0	4.79	33.7	4.6	617	36.4
Maximum	6.53	40	52.23	752.6	249.1	7326	387.7
Lower quartile	3.91	10	12.03	96.8	54.5	1334	82.4
Upper quartile	4.49	20	16.43	189.6	95.1	2634	149.2
CV*	12.6**	47.8	33.8	65.5	45.4	56.0	53.4

* CV – coefficient of variability; ** CV – coefficient of logarithmic values.

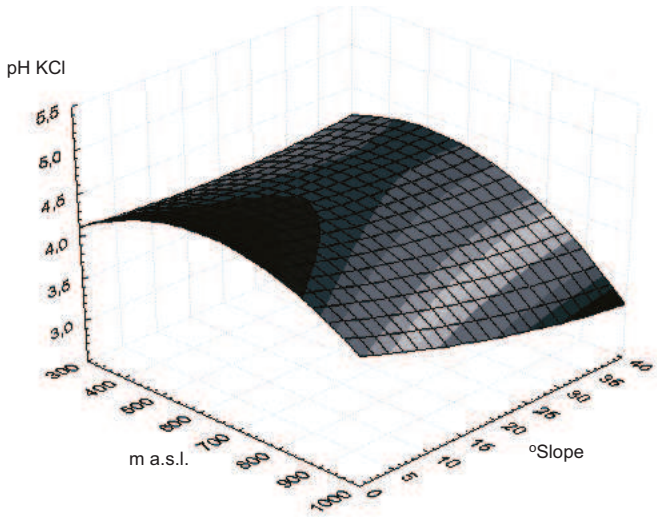

Fig. 1. Values of pH [1 mol KCl · dm^{-3}] in the investigated area depending on the altitude above sea level and land slope

With the slope angle increasing within the 0–25° range, Na^+ concentrations in soil (Fig. 2) decreased with altitude. Above 25° land slope, the content of this element did not change with increasing land altitude. Land slope had a greater effect on exchangeable sodium concentrations in soil than the altitude above sea level. At the land slope above 40° the lowest content of this element was found. Exchangeable sodium concentrations in the analyzed soils was on the level of ca 15 mg Na · kg^{-1} of soil, however its variation was the smallest among the studied cations (Fig. 2, Table 1). Statistical analysis revealed a significant (on < 0.05 level) correlation of sodium exchangeable forms concentrations and land slope, soil reaction and carbon content in soil. This dependence was not found in relation to the altitude above sea level. Values of

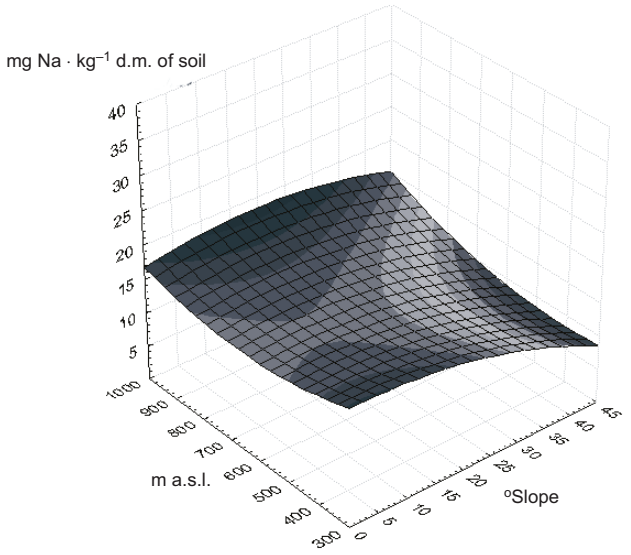

Fig. 2. Sodium concentrations in soil in 1 mol CH_3COONH_4 extract [mg · kg^{-1}] depending on the altitude above sea level and land slope

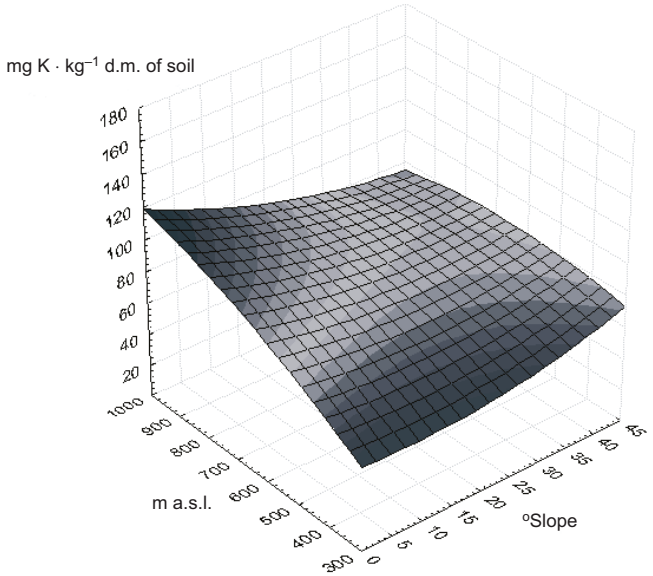

Fig. 3. Potassium concentrations in soil in 1 mol CH_3COONH_4 extract [mg · kg^{-1}] depending on the altitude above sea level and land slope

correlation coefficients of exchangeable sodium content in relation to land slope, pH and carbon content were respectively: –0.17; 0.41 and 0.53.

In the discussed soils land slope was not significantly important for the content of K^+ cations. Exchangeable potassium concentration in the analyzed soils was correlated with the soil reaction, altitude above sea level and carbon content (Fig. 3). Correlation coefficients for these factors were respectively: 0.25; 0.28 and 0.29. Increase in the content of exchangeable potassium content might be caused by this element displacement from more sparingly soluble minerals or compounds in result of stronger soil acidification, which occurred with altitude above sea level. Straczynska [6] pointed to this fact in her studies. The interval of this element exchangeable forms from 4.55 to 249 mg K · kg^{-1} d.m. was considerable but in case of quartiles range it diminished visibly (Table 1). Above 650 m a.s.l. (Fig. 3) a decrease in potassium content was detected along with increasing land slope. The highest concentrations were found on the terrains above the altitude of 800 m a.s.l. and at low land slope (up to 35 ^{o}). Under such conditions, greater moisture and accumulation of floatable particles along with diminishing land slope, soil sorption capacity increases favouring retaining greater contents of exchangeable potassium. According to Wrobel and Stanislawska-Glubiak [7] a higher concentration of K^+ ions in soil sorption complex may lead to dislodgement of bivalent ions from it, indirectly increasing soil acidification.

In the conducted research the contents of exchangeable forms of calcium and magnesium in soil was conditioned by the altitude above sea level and the slope angle (Fig. 4). Calcium was the dominant alkaline cation in sorption capacity, its content in

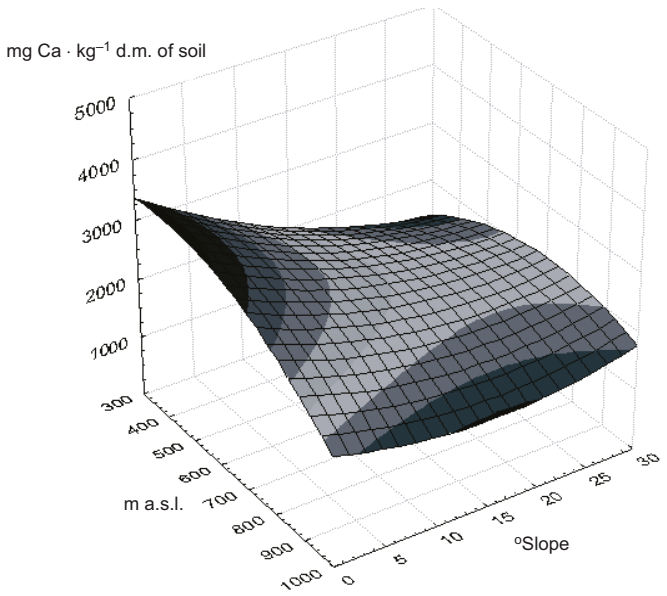

Fig. 4. Calcium concentrations in soil in 1 mol CH_3COONH_4 extract [mg · kg^{-1}] depending on the altitude above sea level and land slope

the analyzed soils ranged from 616 to 7325.79 mg Ca · kg of soil, which corresponds to between 15.41 and 183.14 mmol(+) · kg^{-1}. Kopec [8] confirms the lower values at the application of nitrogen fertilization and liming on the slope angle of 7°, at the altitude of 720 m a.s.l. and NNE slope aspect in the experiment localized 30 km from the discussed experimental site.

According to Filipek and Dechnik [9] the degree of soil saturation with calcium cations depends on the slope aspect. In these authors' opinion soils on northern slopes reach the lowest Ca^{++} contents. Considering mean Ca^{++} content in the analyzed soils, they may be ordered as follows; soils from the: SW, NW, E, N,S, NE and SE slopes (Table 2). However, the differences between mean contents did were not statistically significant. No significant differences were found for Mg^{++}, either (Table 2).

Table 2

Mean concentrations of Mg^{++} and Ca^{++} depending on slope aspect

No.	Aspect	Mean contents of exchangeable cations [mg · kg soil]			
		Ca^{++}	LSD $\alpha < 0.05$	Mg^{++}	LSD $\alpha < 0.05$
1	N	1984	a	139.8	a
2	NE	2021	a	138.1	a
3	E	1899	a	164.7	a
4	SE	1841	a	160.1	a
5	S	2000	a	122.1	a
6	SW	1841	a	135.4	a
7	W	2128	a	166.7	a
8	NW	1890	a	138.2	a

Backward stepwise multiple regression tested the effect of independent factors, such as slope aspect, land slope, soil reaction, altitude a.s.l, insolation and C percent on the concentration of calcium cations in soil. Obtained equation with significant pH factor had the following parameters: r = 0.7094, r^2 = 0.5032, $F_{(3.186)}$ = 62.813, d < 0.0000 Stat. error estim. 883.22.

	BETA	Stat. error	B	Stat. error	t(187)	p level
Intercept			–4014.48	529.70	–7.578	0.000000
pH	0.550	0.057	1270.16	132.87	9.559	0.000000

Exchangeable calcium content in the analyzed soils was diminishing with the altitude (Fig. 4), however is was not confirmed by the statistical analysis. These parameters testify that calcium cation concentration in soil in the investigated area in a half depended on the soil pH. The higher the soil reaction values, the higher exchangeable Ca content in soil.

The variation range for magnesium in the discussed soils (Table 1) was smaller than in case of univalent cations. The multiple regression considering, the same features as

for calcium (at parameters: r = 0.7799, r^2 = 0.6083, $F_{(3.186)}$ = 96.319, p < 0.0000 Stat. error estim. 66.435) it was found that the content of this cation in 40 % depended on soil pH value and in 20 % on carbon concentrations. The higher the values of the analyzed factors, the higher exchangeable magnesium content in soils.

	BETA	Stat. error	B	Stat. error	t(187)	p level
Free intercept			–348.5	38.81	–8.98	0.000000
pH	0.419	0.051	81.9	10.09	8.11	0.000000
% C	0.195	0.051	17.8	4.68	3.80	0.000189

Exchangeable magnesium content in the soils from the investigated area was strongly correlated (r = 0.630) with the soil reaction and organic matter contents (r = 0.50).

Conclusions

The highest values of soil reaction were found at small land slope. Increase in pH value affects the content of exchangeable forms of alkaline cations.

The altitude above sea level and land slope have a lesser influence on the contents of exchangeable cations in soil than the soil reaction.

No effect of direction of slope angle on which the grassland was situated on the contents of exchangeable cations was evidenced.

References

[1] Sammel A. and Niedźwiecki E.: *Zawartość makro- i mikroelementów w glebach murszastych w obrąbie Równiny Odrzańsko-Zalewowej*, Woda – Środowisko – Obszary Wiejskie 2006, **6**(2), 293–304.

[2] Sikorska E. and Lasota J.: *Suma zasadowych kationów wymiennych w ocenie żyzności górskich gleb leśnych*, Probl. Zagosp. Ziem Górskich 2005, **52**, 31–40.

[3] Rehfuess K.E.: *Indikatoren de Fruchtbarkeit von Waldbodenzeitliche Veanderungrn und menschlicher Einfluss. Forstwiss*, Centralbl., Jg. 1999, **118**(2), 88–96.

[4] Dehnik I. and Filipek T.: Influence of post-sewage waters on relation between exchangeable cations in soils. Acta Agrophys 2001, **51**, 29–36.

[5] Maciaszek W.: *Gleby*, [in:] Przyroda Popradzkiego Parku Narodowego, Staszkiewicz J. (ed.), Popradzki Park Krajobrazowy, Nowy Sącz 2000, 47–56.

[6] Strączyńska S.: *Zmiany odczynu i właściwości sorpcyjnych gleby piaszczystej pod wpływem wieloletniego nawożenia mineralnego, organicznego i organiczno-mineralnego*, Zesz. Probl. Post. Nauk Roln. 1998, **456**, 165–168.

[7] Wróbel S., Stanisławska-Glubiak E.: *Skutki 35-letniego mineralnego i organicznego lub organiczno-mineralnego nawożenia gleby lekkiej*, Pamięt. Puław. 1993, **103**, 181–194.

[8] Kopeć M.: *Dynamika plonowania i jakości runi łąki górskiej w okresie trzydziestu lat trwania doświadczenia nawozowego*, Zesz. Nauk. AR 2000, **267**, Rozprawy, 84 pp.

ZAWARTOŚĆ KATIONÓW WYMIENNYCH W GLEBIE UŻYTKÓW ZIELONYCH W ZALEŻNOŚCI OD WARUNKÓW SIEDLISKOWYCH W PASMIE RADZIEJOWEJ

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Abstrakt: W prezentowanych badaniach określono zawartość i zmienność kationów wymiennych w glebie użytków zielonych w paśmie Radziejowej (Beskid Sądecki). Badania prowadzono na terenach o zróżnicowanych warunkach siedliskowych oraz o różnym sposobie gospodarowania. Przy opisie zbiorowiska określano wysokość nad poziom morza, nachylenie oraz ekspozycję i skład botaniczny. W glebie w warstwie 0–10 cm oznaczono pH w 1 mol $KCl \cdot dm^{-3}$ oraz kationy wymienne (Ca, Mg, K i Na), ekstrahując octanem amonu o stężeniu 1 mol $CH_3COONH_4 \cdot dm^{-3}$.

W przeprowadzonych badaniach zawartość wymiennych form wapnia w glebie była uwarunkowana wysokością nad poziom morza oraz nachyleniem stoku. Podobne zależności stwierdzono w przypadku odczyny gleby. Odczyn gleby ulegał zmianie i wpływał na zawartość wymiennych form kationów zasadowych. W pojemności sorpcyjnej dominującym kationem zasadowym był wapń, którego zawartość w analizowanych glebach waha się od 616 do 7325,79 mg $Ca \cdot kg^{-1}$ gleby.

Słowa kluczowe: kationy wymienne, odczyn gleby, warunki siedliskowe