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FORMATION OF EXCHANGEABLE CATION CONTENT IN LOESS SOIL DEPENDING ON THE LAND USE AND MINERAL FERTILIZATION

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A b s t r a c t. Studies of the content of exchangeable cations were carried out in 1986-1993 in Rzeszów Submountain region. The following land uses were considered: forest virgin soil, arable soil - productive field and experimental field. In two fertilization experiments varried NPK+Mg and NPK+Mg+Ca fertilization was applied with plant cultivation in the cropping system (static fertilization field). The experiment was carried out on the clay, very acid grey-brown podzolic soil.

It was found that after 8 years of research the exchangeable Ca, K and Na content was the lowest in the Ah/Eet and Bt horizons of forest soil, but the exchangeable Mg content was the highest.

In the experimental field the highest content of exchangeable Ca was in the Ap and Bt horizon of limed soil, exchangeable Mg in Ap and Bt horizon of limed soil and non-limed one. The content of exchangeable K was very differentiated. The highest content of exchangeable Na was in Ap horizon of limed soil.

K e y w o r d s: exchangeable cation, loess soil, land use.

INTRODUCTION

Up-to-date research indicates that the elements of soil fertility, including the content of exchangeable basic cations, depends on: soil kind [4,12], soil erosion processes [3], and land use [7,12,13,15]. An important role in the formation of exchangeable cation content in soil is played by organic fertilization with: manure [1,8,16], slurry [6,8,14], and straw [16]. Some of the results of that research indicate the greatest content of exchangeable basic cations in soils fertilized with manure [8], smaller in soils fertilized with slurry [8], and the smallest after using mineral fertilizers [6,8,14]. Agrochemical measures also affect the content of basic exchangeable cations.

Liming influences the soil in many ways, including the content of exchangeable cations [7,16,18]]. As a result of the regular use of calcium fertilizers, the content of the exchangeable forms of calcium and magnesium [15,16,18] or calcium and potassium [7] increased in the soil. The content of exchangeable cations in soils is also influenced by mineral fertilization [2,8,11,17] and organic-mineral fertilization [1,14,16]. Several times, fertilizing the soil with mineral fertilizers only and with some manure added [1,14] as a complementary measure, decreased the content of basic cations in the sorption complex. Using mineral fertilizers for many years may be the reason for soil degradation expressed by the unfavourable changes in the sorption complex [1].

Negative effects of mineral fertilization can be prevented by organic-mineral fertilization [1] and liming [1,5,7,18,15]. Liming also slows down the rate of soil degradation caused by acidification due to too high content of sulphur in the soil. In such conditions, there is a decrease in the saturation of the sorption complex with bases caused by the loss of calcium and magnesium [9]. Elution of basic cations from the soil is also one of the main reasons for the loss of calcium, and the amount of leached magnesium exceeds its uptake by the plants. The uptake of potassium exceeds its elution several times [12]. The magnitude of the elution of Ca^{2+}, Mg^{2+}, and K^{+} depends on the soil type and the use the soil is put to. The elution of basic cations is greater in fallow soils than in soils in which plants have been grown in crop rotations. Losses of calcium and potassium are greatest in sand soil, while the smallest loss of calcium was in loess soil [12].

On the basis of many years of research on fertilizers, it was proved that mineral fertilization without organic additions did not cause the appropriate accretion of humus, which means it did not preserve a permanent state of soil fertility [1,8,14].

The aim of this research was to: (i) determine the influence of some of the ways of using loess soil on the content of exchangeable basic cations in the Ah/Eet, Ap, and Bt horizons; (ii) measure the influence of liming and mineral fertilization with NPK Mg in conditions of plant cultivation in crop rotations on the content of exchangeable basic cations in the Ap and Bt horizons of loess soil.

MATERIAL AND METHODS

The research was carried out in the years 1986-1993 in Podgórze Rzeszowskie. Two experiments were included in this research concerning the effect of methods of using loess soil and mineral fertilization on the content of basic cations (Ca^{2+}, Mg^{2+}, K^+, Na^+). On the soil of the grey-brown podzolic type derived from loess, 3 study sites were selected, all used in different ways: in a production field and in an experimental field - arable, and in natural forest soil. Cereal plants had been grown in the production field on the high-production state farm since 1986. NPK mineral fertilization was used in doses that satisfied the nutrition needs of the cultivated winter and spring cereal species. Part of the production field was sectioned off and a fertilizer field was established in it. The agrotechnical measures were intensified in that field, including mineral fertilization and plant cultivation, and introducing 4-year crop rotation. The third way of use included the natural soil under the mixed forest with a majority of deciduous trees. In the permanent fertilizer field, the two-factor field experiment was established using the method of sub-blocks in 4 repetitions. The first variable factor was liming (A_2) carried out every 4 years in the dose calculated on the basis of hydrolytic acidity, and no liming (A_1). The second variable was differentiated mineral NPK fertilization in 13 treatments (B1...B13). Crop rotation was as follows: in years 1986-1989 - potatoes, spring barley, fodder cabbage, winter wheat; in years 1990-1993 - potatoes, spring barley, fodder sunflower, winter wheat.

The basic level of fertilization ($N_1P_1K_1$) for particular plants was from 80-120 kg N ha^{-1}; 60-100 kg P_2O_5 ha^{-1}; and 100-160 kg K_2O ha^{-1}. Potatoes, spring barley, and winter wheat were fertilized with magnesium in the dose of 40 kg MgO ha^{-1}, while fodder cabbage and fodder sunflower were fertilized with 120 kg MgO ha^{-1}. Liming was used in the autumn of 1985 prior to the establishment of the experiment and in 1989 after the first crop rotation, in the dose of 4 t CaO ha^{-1}, according to 1 Hh.

In 1985 the soil was limed with a calcium oxide (60% CaO), and in 1989 - with a calcium carbonate (39.2% CaO). The calcium oxide contained 0.4% MgO, while the carbonate one 9.5% MgO. Differentiated N, P, K, fertilization was applied with a background of constant fertilization with other components. In the other variants, differentiated N,P,K, fertilization was used with increasing doses of other components.

After collecting all the plants from the soil of the production and experimental fields, soil samples were taken from the arable-humus horizon Ap (0-25 cm) and simultaneously in the forest soil from the humus/lessive horizon Ah/Eet (6-30 cm) and from the upper part of the illuviation horizon Bt of the arable soils (26-50 cm) and the forest soil (31-50 cm). The following chemical analyses were carried out in the sampled soil material: pH - potentiometrically in 1 mol dm^{-3} KCl; hydrolytic acidity - with the Kappen's method; C-organic - with the Tiurin's method; N-total - with the Kjeldahl's method; exchangeable basic cations - with the AAS method in the extract of 1 mol dm^{-3} NH_4Cl with pH 8.2. The soil which had the granulometric composition of loamy silt with a very acid reaction contained the following amounts of C-organic: forest soil - 3.04%; production field - 0.66%; experimental field - 0.76%. It also contained the following amounts of N-total: forest soil - 0.23%; production field - 0.09%; experimental field - 0.11%. The content of exchangeable cations in mmol(+) kg^{-1} of the soil was as follows (in the forest soil, production field, experimental field, respectively): Ca^{2+}- 22.0, 32.0, 36.0; Mg^{2+}- 4.3, 0.7, 0.0; K^{+}- 3.7, 4.8, 4.4; Na^{2+}- 1.0, 0.6, 0.1.

For the statistical evaluation of the results of the fertilization experiment, the analysis of variation for triple classification was used. The three factors considered in this research were: liming (A), mineral fertilization (B), and years (C). The interaction of AB, AC, and BC was also determined. Also investigated in the fertilization experiment was the difference between the average content of exchangeable cations in the soil of different fertilization sites and the control measurement (the content of exchangeable cations before establishing the experiment). In order to do that, the Dunnet's half-interval of confidence (LSD_D) was used. The results of the research, which concerned the influence of the ways of loess soil use on the content of exchangeable cations, were verified using the two-factor analysis of variation (way of use, years), and then using the Tukey's half-intervals of confidence in order to determine the statistically significant differences within the investigated factors. Statistic calculations were carried out at the Computer Centre of the University of Agriculture in Lublin.

RESULTS AND DISCUSSION

The uses the soil had been put to had an effect on the differentiation of the content of exchangeable basic cations in it (Tables 1 and 2). Agricultural - arable use of the soil increased the content of the exchangeable forms of calcium, potassium, and sodium in the Ap and Bt horizons, as compared to the forest soil. The content of the exchangeable magnesium in loess soil was different; Ap of the arable soils as related to the content of that form in the Ah/Eet horizon of the forest soil. In the upper part of the Bt horizon of the arable soil of the experimental field, a higher content of magnesium was observed as compared to the forest soil (Table 1). It was probably related to the fertilization with magnesium in the dose of 480 kg Mg ha^{-1} for 8 years, in addition to the NPK fertilization. The magnesium was washed out from the Ap horizon to the Bt horizon in conditions of high acidification of the

Table 1. The exchangeable calcium and magnessium content of loessial soil depending on soil management (mm(+) kg^{-1})

Treatments	Ca-exchangeable		Mg-exchangeable	
	Depth (cm)			
	0-25	26-50	0-25	26-50
Forest[1]				
mean	9.73	3.71	2.97	1.50
range	5.60-20.0	2.000-5.00	2.10-5.40	1.00-1.80
Production field				
mean	13.84	13.61	1.27	1.26
range	11.80-18.0	10.00-16.00	1.00-1.60	1.00-2.00
Experimental field				
mean	18.62	19.22	1.69	1.92
range	15.50-20.0	17.80-22.0	1.40-2.00	1.00-2.30
LSD	4.69**	2.15**	0.78**	0.33**

[1]Depth = 6-30 cm, 31-50 cm; *LSD significant at p=0.05; **LSD significant at p=0.01.

Table 2. The exchangeable potassium and sodium content of loessial soil depending on soil management (mm(+) kg^{-1})

Treatments	K-exchangeable		Na-exchangeable	
	Depth (cm)			
	0-25	26-50	0-25	26-50
Forest[1]				
mean	2.20	1.10	0.10	0.04
range	1.70-3.61	0.91-1.40	0.10-0.20	0.00-0.10
Production field				
mean	6.07	6.32	0.39	0.30
range	5.37-6.70	5.99-6.60	0.20-0.60	0.00-0.50
Experimental field				
mean	8.63	4.75	0.37	0.40
range	5.39-11.00	4.09-5.30	0.20-0.50	0.20-0.60
LSD	1.62**	0.33**	0.14**	0.12**

[1]Depth = 6-30 cm, 31-50 cm; *LSD significant at p=0.05; **LSD significant at p=0.01.

soil. The soil of the production field in conditions of only mineral NPK fertilization and cultivation of cereal plants contained less exchangeable magnesium in the Ap horizon, when compared to the content of that element in the Ah/Eet horizon of the forest soil. Somewhat different was the influence of the agricultural use of the soils derived from sandstone on the content of exchangeable cations since it decreased the content of calcium and magnesium in the Ap horizons when compared to the A horizons of the forest soils. In the Ap horizons of the arable soils, the content of exchangeable potassium and sodium increased. An elution of magnesium and sodium cations into the browning horizon (Bbr) also occurred in those soils [13].

The lower content of exchangeable magnesium in the Ap horizons of the arable soils, in relation to the forest soil, proves the depletion of the magnesium resources, because it is often taken away along with the crops of the cultivated plants. This staggers the proportion in the ion composition of the sorption complex of the loess soil, especially in conditions of its high acidity [5]. The effect of the way in which the soil has been used on the content of basic cations in it was also stated by Kozanecka *et al.* [7]; Ruszkowska *et al.* [12]; Sykut and Ruszkowska [15]. A clearly lower content of exchangeable calcium, magnesium, and potassium cations was also found in fallow soil, as compared to the arable soil [15]. The elution of those elements was also higher from the fallowed soils [12]. The sorption complex of the loess soils contains least sodium, while calcium is in majority. Similar relations are indicated by the research of Skłodowski and Zarzycka [13], Jaworska and Długosz [4], Mazur and Sądej [8], Panak *et al.* [10], and Wiater [16].

The influence of liming (A) and mineral fertilization (B) and the c-ooperation (AB) on the content of exchangeable cations is included in Tables 3-6. Liming positively influenced the content of exchangeable forms of calcium and sodium in the Ap and Bt horizons, magnesium in the Ap horizon, and potassium in the Bt horizon. Similar relations between liming and the content of exchangeable calcium and potassium were stated in the research of Kozanecka *et al.* [7]. Sykut and Ruszkowska [12] also observed an increase in the content of calcium and magnesium in the loess soil as a result of liming and mineral fertilization with NPK. Wiater [16] also reported a growth of exchangeable calcium, magnesium, and potassium in loess soil.

Mineral fertilization (B) increased the content of calcium in the Ap horizon of the sites containing a decreased dose of phosphorus (B7) and potassium (B10) as compared to the control (B1), as well as in the Bt horizon of the site containing an increased dose of nitrogen (B5) compared to sites B7, B9, and B12. Mazur and Sądej [8] gained an increase of exchangeable calcium in the sandy soil under the influence of fertilization and the least amount of that element was found in the soil

Table 3. Influence of liming (A) and mineral fertilization (B) on the exchangeable calcium content in loessial soil (mmol(+) kg^{-1})

Specification	Treatments fertilizer (B)													Mean (A)
	B1 $N_0P_0K_1$	B2 $N_0P_1K_1$	B3 $N_{0.5}P_1K_1$	B4 $N_1P_1K_1$	B5 $N_{1.5}P_1K_1$	B6 $N_1P_0K_1$	B7 $N_1P_{0.5}K_1$	B8 $N_1P_{1.5}K_1$	B9 $N_1P_1K_0$	B10 $N_1P_1K_{0.5}$	B11 $N_1P_1K_{1.5}$	B12 $N_{0.5}P_{0.5}K_{0.5}$	B13 $N_{1.5}P_{1.5}K_{1.5}$	
Depth 0-25 cm														
Liming (A)														
A_1	30.2	31.9	32.9	34.1	29.5	32.7	36.7	30.4	29.6	35.7	31.4	32.2	28.4	32.0
A_2	52.1	60.5	71.8	67.7	73.1	65.5	75.3	61.7	64.2	82.3	68.3	55.4	52.8	65.4
Mean (B)	41.2	46.2	52.3	50.9	51.3	49.1	56.0	46.0	46.9	59.0	49.8	43.8	40.6	
LSD	A-3.3**, B-14.3**, AB-21.8*													
Depth 25-50 cm														
Liming (A)														
A_1	41.9	42.1	51.5	38.6	40.0	36.7	39.2	42.2	41.6	44.9	44.7	35.9	35.6	40.4
A_2	70.0	77.5	61.8	64.6	84.0	65.3	50.1	61.2	53.5	65.3	61.4	56.3	61.8	64.1
Mean (B)	55.9	54.8	56.6	51.6	62.0	51.0	44.7	51.7	47.6	55.1	53.1	46.1	48.7	
LSD	A-3.3**, B-14.4**, AB-21.9**													

x) A_1 - fertilization NPK+ Mg; A_2 - fertilization NPK+Mg+Ca; * significant level p=0.05; ** significant level p=0.01; 0-25 cm = 36.0 mmol(+) kg^{-1} (before establishing the experiment), LSD_D = 17.0; 26-50 cm = 40.0 mmol(+) kg^{-1} (before establishing the experiment), LSD_D = 17.1.

Table 4. Influence of liming (A) and mineral fertilization (B) on the exchangeable magnesium content in loessial soil (mmol(+) kg^{-1})

Specification	Treatments fertilizer (B)													Mean (A)
	B1 N_0P_0K	B2 $N_0P_1K_1$	B3 $N_{0.5}P_1K_1$	B4 $N_1P_1K_1$	B5 $N_{1.5}P_1K_1$	B6 $N_1P_0K_1$	B7 $N_1P_{0.5}K_1$	B8 $N_1P_{1.5}K_1$	B9 $N_1P_1K_0$	B10 $N_1P_1K_{0.5}$	B11 $N_1P_1K_{1.5}$	B12 $N_{0.5}P_{0.5}K_{0.5}$	B13 $N_{1.5}P_{1.5}K_{1.5}$	
Depth 0-25 cm														
Liming (A)														
A_1	6.76	7.60	8.09	7.67	6.76	8.04	8.07	7.37	6.15	5.75	7.41	4.51	5.46	6.90
A_2	6.30	7.00	7.42	6.50	5.91	7.52	8.09	9.66	8.67	8.71	9.56	8.81	6.64	7.68
Mean (B)	6.53	7.30	7.76	7.09	6.34	7.78	8.08	8.52	7.41	7.23	8.49	6.16	6.05	
LSD	A-0.75*, B-n.s., AB-n.s.													
Depth 25-50 cm														
Liming (A)														
A_1	9.37	8.49	10.15	8.07	8.65	8.76	8.88	10.66	7.21	6.37	7.07	4.26	5.46	7.96
A_2	9.84	7.24	7.86	7.17	8.09	9.42	6.90	8.92	5.56	8.57	7.22	7.92	8.05	7.91
Mean (B)	9.61	7.86	9.01	7.62	8.37	9.09	7.89	9.79	6.39	7.47	7.15	6.09	6.76	
LSD	A-n.s., B-3.66*, AB-n.s.													

0-25 cm = 0.0 mmol(+) kg^{-1}(before establishing the experiment), LSD_D = 1.35; 26-50 cm = 3.0 mmol(+) kg^{-1}(before establishing the experiment), LSD_D = 4.70; n.s. - not significant.

Table 5. Influence of liming (A) and mineral fertilization (B) on the exchangeable potassium content in loessial soil (mmol(+) kg^{-1})

Specification	Treatments fertilizer (B)													Mean (A)
	B1 $N_oP_oK_1$	B2 $N_oP_1K_1$	B3 $N_{0.5}P_1K_1$	B4 $N_1P_1K_1$	B5 $N_{1.5}P_1K_1$	B6 $N_1P_oK_1$	B7 $N_1P_{0.5}K_1$	B8 $N_1P_{1.5}K_1$	B9 $N_1P_1K_0$	B10 $N_1P_1K_{o.5}$	B11 $N_1P_1K_{1.5}$	B12 $N_{0.5}P_{0.5}K_{0.5}$	B13 $N_{1.5}P_{1.5}K_{1.5}$	
Depth 0-25 cm														
Liming (A)														
A_1	4.14	5.87	5.26	5.56	4.25	4.91	4.98	5.09	3.34	4.21	5.94	4.74	5.80	4.93
A_2	4.86	4.22	3.92	3.91	4.26	4.35	6.39	4.19	4.07	4.55	5.76	5.80	6.55	4.84
Mean (B)	4.50	5.05	4.60	4.74	4.31	4.63	4.69	4.64	3.71	4.38	5.85	5.27	6.17	
LSD	A-n.s., B-2.31**, AB-2.48*													
Depth 25-50 cm														
Liming (A)														
A_1	2.87	2.69	2.42	2.94	2.12	2.69	2.31	3.30	2.91	2.92	2.62	3.26	2.87	2.77
A_2	3.47	3.01	2.70	2.70	2.52	3.01	3.94	2.91	2.55	2.79	3.81	3.41	4.49	3.58
Mean (B)	3.17	2.85	2.56	2.82	2.32	2.85	3.12	3.11	2.73	2.86	3.22	3.35	3.68	
LSD	A-0.76, B-1.31**, AB-1.41**													

0-25 cm = 4.4 mmol(+) kg^{-1} (before establishing the experiment), LSD_D = 1.96; 26-50 cm = 2.0 mmol(+) kg^{-1} (before establishing the experiment), LSD_D = 1.11.

Table 6. Influence of liming (A) and mineral fertilization (B) on the exchangeable sodium content in loessial soil (mmol(+) kg^{-1})

Specification	Treatments fertilizer (B)													Mean (A)
	B1 N_0P_0K	B2 $N_0P_1K_1$	B3 $N_{0.5}P_1K_1$	B4 $N_1P_1K_1$	B5 $N_{1.5}P_1K_1$	B6 $N_1P_0K_1$	B7 $N_1P_{0.5}K_1$	B8 $N_1P_{1.5}K_1$	B9 $N_1P_1K_0$	B10 $N_1P_1K_{0.5}$	B11 $N_1P_1K_{1.5}$	B12 $N_{0.5}P_{0.5}K_{0.5}$	B13 $N_{1.5}P_{1.5}K_{1.5}$	
Depth 0-25 cm														
Liming (A)														
A_1	0.62	0.59	0.60	0.49	0.51	0.70	0.69	0.34	0.36	0.50	0.31	0.74	0.86	0.56
A_2	1.02	1.24	1.05	1.14	0.87	0.71	0.96	0.87	0.82	0.91	1.04	0.86	0.97	0.96
Mean (B)	0.82	0.91	0.82	0.81	0.69	0.71	0.82	0.61	0.59	0.71	0.67	0.80	0.92	
LSD	A-0.12**, B-n.s., AB-n.s.													
Depth 25-50 cm														
Liming (A)														
A_1	0.66	0.35	0.30	0.16	0.37	0.74	0.74	0.36	0.61	0.60	0.32	0.56	0.65	0.49
A_2	1.17	1.71	1.54	1.45	1.45	1.15	1.05	1.17	0.94	0.75	1.00	0.86	1.15	1.18
Mean (B)	0.92	1.03	0.92	0.81	0.91	0.94	0.89	0.77	0.77	0.67	0.66	0.71	0.90	
LSD	A-0.14*, B-n.s, AB-0.91**													

0-25 cm = 0.1 mmol(+) kg^{-1} (before establishing the experiment), LSD_D = 0.61; 25-50 cm = 0.5 mmol(+) kg^{-1} (before establishing the experiment), LSD_D = 0.71.

fertilized with NPK. Differentiated mineral fertilization (B) did not influence the content of exchangeable magnesium in the Ap horizon of the soil. It only increased the content of that element in the Bt horizon of the site with the increased dose of phosphorus (B8), as compared to the site with the decreased dose of NPK (B12). Increasing content of exchangeable magnesium due to fertilization with NPK was concurrent with the depth [8].

The content of exchangeable potassium grew in the Ap horizon of the site with the increased dose of NPK (B13) compared to the site without potassium (B9) and in the Bt horizon of the same site (B13) in relation to the site with the increased dose of nitrogen (B5). The greatest growth of exchangeable potassium under the influence of fertilization with manure was received by Mazur and Sądej [8]. Also Adamus *et al.* [1] observed a growth in the content of exchangeable potassium as a result of potassium fertilization. Mineral fertilization (B) did not influence the content of exchangeable sodium in the Ap and Bt horizons of the loess soil. The interaction was stated between liming and mineral fertilization (AB) in terms of exchangeable calcium and potassium in the Ap and Bt horizons and sodium in the Bt horizon, which was expressed by the increased content of those elements in particular sites of the limed soil (Tables 3-6). Adamus *et al.* [1] reported a significant decrease in the content of calcium and magnesium ions in the sorption complex of the light soil in the sites fertilized by minerals. Kozanecka *et al.* [7] received a low content of exchangeable magnesium in the A horizon under the influence of fertilization with nitrogen and potassium. Similar tendencies of the content of exchangeable magnesium were observed in the Ap horizon of the loess soil in the sites fertilized with increasing doses of nitrogen (B2-B5) and, to a smaller extent, as the result of fertilization with potassium (B9, B10, B4). Sykut and Ruszkowska [15] stated a decrease in the content of exchangeable forms of calcium, magnesium, and sodium in the loess soil of the sites fertilized with NPK for 20 years. Wiater [16] observed a decrease in the content of exchangeable forms of potassium and sodium due to NPK fertilization comparing to the combined fertilization: straw + NPK; manure + NPK; lime + NPK. The use of increasing doses of nitrogen decreased the saturation of the sorption complex with bases in black earths [10].

After 8 years of research, there was a growth in the content of exchangeable calcium in relation to its state from before the commencement of the research in the Ap horizon of the limed soil (before establishing the experiment - 36.0 mmol(+) kg^{-1}, LSD_D =17.0), and in the Bt horizon (before establishing the experiment - 40.0 mmol(+) kg^{-1}, LSD_D = 17.1) (Table 3). After the same research period, the content of exchangeable magnesium in the Ap horizon increased in all the limed and non-limed soil sites, as compared to its state from before the research (0.0 mmol(+) kg^{-1}, LSD_D =1.35) and in most of the limed (B1, B3, B5, B6, B8, B10, B12, B13) and non-limed (B1-B8) soil sites Bt horizons, comparing to its state from before the research (3.0 mmol(+) kg^{-1}, LSD_D = 4.70) (Table 4). Exchangeable potassium, after 8 years, grew only in sites B7 and B13 in the Ap horizon of the limed soil compared to its state from before the research 4.4 mmol(+) kg^{-1}, LSD_D = 1.96), as well as in a few sites B8 and B12 in the Bt horizon of the non-limed and limed soil (B7, B11, B12) compared to its state from before the research (2.0 mmol(+) kg^{-1}, LSD_D = 1.11) (Table 5). The content of exchangeable sodium, after 8 years, increased in the Ap horizon of all the limed soil sites (0.1 mmol(+) kg^{-1}, LSD_D = 0.61) and in the Bt horizon of some of the sites (B1 - B5) of the limed soil (0.5 mmol(+) kg^{-1}, LSD_D = 0.71). The positive effect of liming and mineral fertilization with NPK Mg on the content of exchangeable cations of calcium and magnesium after 20 years of the experiment on loess soil is also reported by Sykut and Ruszkowska [15].

CONCLUSIONS

1. The way grey-brown podzolic soil derived from loess is used differentiated the content of exchangeable cations in both the arable-humus horizon (Ap) and the upper level of the illuviation horizon (Bt).

2. Arable use of grey-brown podzolic soil derived from loess, increased the content of exchangeable forms of calcium, potassium, and sodium in the Ap and Bt horizons, compared to forest soil. The content of exchangeable magnesium decreased as a result of arable management of the soil in the Ap horizon, and increased in the Bt horizon of the arable soil fertilized with NPK Mg.

3. Liming positively influenced the growth of the content of exchangeable calcium and sodium in the Ap and Bt horizons, exchangeable magnesium in the Ap horizon, and exchangeable potassium in the Bt horizon.

4. Differentiated mineral fertilization with NPK affected to a small extent, the content of exchangeable forms of calcium and potassium in the Ap and Bt horizons, and it had an influence on the content of exchangeable magnesium in the Bt horizon. It did not affect the content of exchangeable sodium in the investigated horizons of the grey-brown podzolic soil derived from loess. However, there was a favourable interaction of liming and mineral fertilization (NPK Mg) in the Ap and Bt horizons of the limed soil in relation to exchangeable calcium and magnesium, and in the Bt horizon in relation to exchangeable sodium.

5. After 8 years of cultivating the plants in crop rotations, the content of the following exchangeable forms increased: calcium in the Ap and Bt horizons of the limed soil; magnesium in the Ap and Bt horizons of the limed and non-limed soil, as a result of fertilization with magnesium; and sodium in the Ap horizon of the limed soil.

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