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CONTENT OF AVAILABLE MAGNESIUM, PHOSPHORUS AND POTASSIUM FORMS IN SOIL EXPOSED TO VARIED CROP ROTATION AND FERTILISATION

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Abstract

Soil richness in available magnesium, phosphorus and potassium forms is one of the key factors of fertility, which ensures the potential of soil for satisfying nutritional requirements of plants. The aim of the present research has been to determine the effect of crop rotation and varied mineral and organic fertilisation on the content of available Mg, K and P forms. Soil was sampled from a long-term experiment, carried out on Luvisol formed from sandy loam (soil valuation class IVa, very good rye complex). The experiment was performed in a 3-factor design, which included two types of crop rotation as well as FYM and nitrogen fertilisation. Basic physicochemical properties of soil were determined. The content of available forms of magnesium was defined with Schachtschabel method and the content of potassium and phosphorus – with Egner-Riehm method (DL). The reaction in the arable-humus horizon of the soils ranged from 4.7 to 6.2. It was found that the Corg to Nt ratio in the arable-humus horizon of soils of all the experiment variants was typical of biologically active soils. The content of available magnesium ranged from 27.8 to 58.3 mg kg^{-1} of soil, while its water-soluble forms varied from 3.5 to 6.8 mg kg^{-1} of soil. The highest content of magnesium, potassium and phosphorus forms available to plants was observed after the application of FYM in the doses of 60 and 80 t ha^{-1} combined with mineral nitrogen fertilisation, in both crop rotation regimes. The content of magnesium and phosphorus forms available to plants was significantly positively correlated with the content of organic carbon. Soil sampled from those plots demonstrated higher classes of the content of that element. The research data proved that the analysed soils showed moderate and high richness in nutrients available to plants. High doses of organic

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and mineral fertilisation, however, did not increase significantly the electrolytic conductivity of the soil solution.

Key words: soil, available nutrients (Mg, K, P), long-term experiment, fertilization.

ZAWARTOŚĆ PRZYSWAJALNYCH FORM MAGNEZU, FOSFORU I POTASU W GLEBIE POD WPŁYWEM ZMIANOWANIA I NAWOŻENIA

Abstrakt

Zasobność gleby w dostępne dla roślin formy magnezu, fosforu i potasu jest jednym z ważniejszych elementów jej żyzności, warunkujących możliwości gleby do zaspokojenia potrzeb pokarmowych roślin. Celem badań było określenie wpływu zmianowania i zróżnicowanego nawożenia mineralno-organicznego na zawartość przyswajalnych form Mg, K i P. Próbki do badań pobrano z wieloletniego doświadczenia statycznego, prowadzonego na glebie płowej wytworzonej z gliny lekkiej (IVa klasa bonitacyjna, kompleks żytni bardzo dobry). Doświadczenie prowadzono w układzie 3-czynnikowym, obejmującym: 2 typy zmianowania; nawożenie obornikiem i nawożenie azotem. Oznaczono podstawowe właściwości fizykochemiczne gleb. Zawartość przyswajalnych form magnezu określono metodą Schachtschabela, a potasu i fosforu metodą Egnera-Riehma (DL). Odczyn w poziomie orno-próchnicznym badanych gleb wahał się od 4,7 do 6,2. Stwierdzono, że stosunek Corg do Nt w poziomie orno-próchnicznym gleb we wszystkich wariantach doświadczenia był typowy dla gleb aktywnych biologicznie. Zawartość magnezu przyswajalnego wynosiła od 27,8 do 58,3 mg kg^{-1} gleby, natomiast jego form wodno-rozpuszczalnych od 3,5 do 6,8 mg kg^{-1} gleby. Najwyższą zawartość przyswajalnych dla roślin form magnezu, potasu i fosforu zaobserwowano po zastosowaniu obornika w dawkach 60 i 80 t ha^{-1} łącznie z nawożeniem azotem mineralnym, w obu rodzajach zmianowania. Zawartość form magnezu i fosforu przyswajalnych dla roślin była istotnie dodatnio skorelowana z zawartością węgla organicznego. Glebę z tych poletek można było zaliczyć do wyższych klas zawartości tego pierwiastka. Na podstawie wyników badań stwierdzono, że analizowane gleby charakteryzowały się średnią i wysoką zasobnością w składniki pokarmowe dla roślin. Wysokie dawki nawożenia organicznego i mineralnego nie wpłynęły w istotny sposób na wzrost przewodnictwa elektrolitycznego roztworu glebowego.

Słowa kluczowe: gleba, składniki pokarmowe (Mg, K, P), doświadczenie wieloletnie, nawożenie.

INTRODUCTION

Intensive agricultural use of soil frequently causes soil degradation. Unbalanced fertilisation, inadequate crop rotation or defective agricultural soil reclamation treatments can trigger unfavourable changes in the soil properties connected with their acidity, inferior sorption capacity, depleted organic matter resources as well as a lower content of nutrients available to plants. The soil richness in magnesium, potassium and phosphorus forms available to plants is a key fertility factor, which ensures the potential for satisfying the nutritional requirements of plants (Askegaard et al. 2005). Numerous research centres perform long-term, multifactor experiments to determine the effect of crop rotation and varied organic and mineral fertilisation on the properties and parameters connected with soil fertility (MERCIK et al. 2000, JASKULSKA, JASKULSKI 2003, MURAWSKA, SPYCHAJ-FABISIAK 2009). The chemical composition of soil solution and the concentration of particular elements determine the uptake of nutrients by plants. As for magnesium and potassium, a considerable share of these metals occurs in a form strongly bound to or incorporated in crystalline forms of minerals. Those are the resources which make up hardly available soil reserve of these elements (BŁASZCZYK 1998). Plants can use some amounts of potassium in the non-exchangeable form, derived from interpackage layers of clay minerals, mostly illites (KOBIERSKI, DĄBKOWSKA-NASKRĘT 2005). The content of nutrients available to plants is affected by the reaction and soil grain size composition (LIPIŃSKI, BEDNAREK 1998; RUTKOWSKA et al. 2006). A considerable share of phosphorus taken up by plants occurs as ions HPO_4^{2-} and $H_2PO_4^-$ in the soil environment of pH 5.0. Alkaline and strongly acid reactions depress the availability of phosphorus to plants. The content of water-soluble forms of Mg, K, P and Ca in arable soils is usually higher than the content of those elements in forest soil solution (SMAL, MISZTAL 1996). Fertilised soils contain relatively more nutrients than non-fertilised ones. By taking up nutrients, crops reduce their content in soil and determine their circulation. Most frequently, it is the circulation of phosphorus and potassium, which usually accumulate in the soil surface layer, that is affected (JOBBAGY, JACKSON 2001, FOTYMA et al. 2005).

The aim of the present research has been to determine the effect of crop rotation and varied mineral-and-organic fertilisation on the content of nutrients available to plants as well as on selected physicochemical properties of soil. The following were determined: the content of magnesium, potassium and phosphorus available to plants and their water-soluble forms, as well as the electrolytic conductivity of soil solution for respective experimental variants.

MATERIAL AND METHODS

The research material was made up of soil sampled from the arable-humus horizon of soils after 22 years of a long-term experiment located at the IUNG Research Station in Grabów near Puławy. The experiment was set up in 1980 on Luvisol: Ap-Eet-Bt-C1-C2 (IUSS Working Group WRB 2007) of the grain size composition of loamy fine sand and fine sandy loam in surface horizons and sandy loam in the parent material. The soils belonged to the very good rye complex, soil valuation class IVa. The content of carbon in organic compounds (C_{org}) in the soil prior to the establishment of the experiment was 7.7 g kg^{-1}.

The field experiment was performed in a 3-factor design:

Factor I: crop rotation A – plants considered as humus-depleting ones (potato, winter wheat, spring barley, corn) and crop rotation B – plants considered as humus-enriching ones (potato, winter wheat + white mustard in intercrop, barley with an undersown mixture of red clover with grasses), factor II: different rates of FYM fertilisation under potato (0, 20, 40, 60, 80 t ha^{-1}); factor III: different rates of mineral nitrogen fertilisation (N0 – no nitrogen; N1 – 170 kg N ha^{-1} in crop rotation A and 275 kg N ha^{-1} in crop rotation B; N2 – 340 kg N ha^{-1} in crop rotation A and 550 kg N ha^{-1} in crop rotation B) per rotation. Throughout the experiment, phosphorus and potassium fertilisers were applied under respective plant species in the following doses: P_2O_5 – potato, spring barley and winter wheat – 60 kg ha^{-1}, corn and a mixture of red clover with grasses – 80 kg ha^{-1}; K_2O – potato: 140 kg ha^{-1}, spring barley: 90 kg ha^{-1}, winter wheat: 100 kg ha^{-1}, corn and a mixture of red clover with grasses: 160 kg ha^{-1}. The experiment was performed in four replications for each treatment.

The following were determined in the soil samples: the grain size composition with the Cassagrande aerometric method, modified by Prószyński; pH – potentiometrically in 1M KCl solution; the content of organic carbon and total nitrogen with a TOCN FORMACS^{TM} analyser provided by *SCALAR*. The content of available phosphorus – P_A and potassium – K_A was determined with Egner-Riehm method (DL), whereas the content of magnesium – Mg_A – with Schachtschabel method. The content of water-soluble (active) cations and the electrolytic conductivity (EC) were defined in distilled water extract in a 1:5 soil to water ratio. The content of elements in the extracts was determined using an atomic absorption spectrometer (Philips PU 9100X). The results were statistically verified with Statistica 8.0 software.

RESULTS AND DISCUSSION

The arable-humus horizon of the analysed soils was found to represent the grain size composition of loamy fine sand and fine sandy loam (Table 1). The experiment was established on soils in which the sand fraction prevailed and the content of clay fraction was relatively low. According to the breakdown into agronomic categories, the soil was classified as light one. The soil reaction was acid and slightly acid and the highest acidity was recorded in the soil samples of crop rotation B. It was found that mineral fertilisation in crop rotation A, without FYM and with FYM in the doses of 20 and 40 t ha^{-1}, resulted in a decrease in the content of Corg in soil. It was not until the higher FYM doses (60 and 80 t ha^{-1}) were applied that the content of organic carbon in soil increased. In crop rotation B, an average 25% increase in the Corg content in soil was identified as compared with its content in soil prior to the experiment (7.7 g kg^{-1}). The content

Table 1

Selected soil properties of long-term field experiment soils

Experimental treatments	pH KCl	C_{org}	Nt	C_{org} /N_t	EC (µS cm^{-1})	Sand	Silt	Clay
		(g kg^{-1})				(%)		
A-0-N0	5.9	6.8	0.6	13.0	330.8	75	20	5
A-0-N1	6.0	6.5	0.6	10.8	342.5	72	23	5
A-0-N2	5.7	6.6	0.6	11.0	333.3	71	25	4
A-20-N0	5.8	6.2	0.6	10.3	333.6	70	24	6
A-20-N1	5.9	6.9	0.6	11.5	350.6	71	25	4
A-20-N2	6.0	6.4	0.6	10.7	343.2	75	23	4
A-40-N0	5.8	7.6	0.7	10.9	342.5	77	18	5
A-40-N1	5.7	7.2	0.7	10.3	412.3	78	18	4
A-40-N2	5.5	7.1	0.7	10.1	357.0	77	19	4
A-60-N0	6.2	8.7	0.7	12.4	428.0	61	34	5
A-60-N1	6.0	8.2	0.7	11.7	439.6	71	22	7
A-60-N2	5.9	7.8	0.7	11.1	419.8	78	16	6
A-80-N0	5.9	7.4	0.7	10.6	343.9	68	25	7
A-80-N1	5.9	7.8	0.7	11.1	522.3	70	25	5
A-80-N2	5.8	8.0	0.7	11.4	554.9	67	26	7
B-0-N0	4.9	8.8	0.8	11.0	386.5	71	23	6
B-0-N1	4.9	8.3	0.8	10.4	337.9	78	16	6
B-0-N2	4.7	9.3	0.9	10.3	352.8	69	23	8
B-20-N0	5.0	9.6	0.9	10.7	354.2	74	21	8
B-20-N1	5.0	9.6	0.9	10.7	361.6	77	15	8
B-20-N2	5.1	9.8	0.9	10.9	465.2	70	24	6
B-40-N0	5.1	9.3	0.9	10.3	347.5	66	26	8
B-40-N1	5.1	9.7	0.9	10.8	413.8	69	25	6
B-40-N2	5.0	9.6	0.9	10.7	395.3	75	20	5
B-60-N0	5.1	9.9	0.9	11.0	318.7	71	24	5
B-60-N1	5.4	10.1	0.9	11.2	329.7	70	24	6
B-60-N2	5.3	9.6	0.9	10.7	347.1	68	25	6
B-80-N0	5.3	10.1	0.9	11.2	397.8	74	22	4
B-80-N1	5.4	10.2	1.0	10.2	491.0	69	25	6
B-80-N2	5.3	10.9	1.0	10.9	390.7	73	22	5

A, B – crop rotation, 0-80 – FYM doses in t ha^{-1}, N0, N1, N2 – nitrogen dose kg ha^{-1},
EC – electrolytic conductivity

of total nitrogen (N_t) in the analysed soils was determined by all the three experimental factors. In crop rotation B, the N_t content in soil was higher than in soil from the crop rotation A plots. The ratio of carbon to nitrogen in the arable-humus horizon of soils in all the experimental variants was typical of biologically active soils.

Soil abundance in magnesium, potassium and phosphorus available to plants is one of the key soil fertility factors. The content of available magnesium forms in the tested soils ranged from 27.8 to 58.3 mg kg^{-1} (Table 2). It was slightly lower than reported in Luvisols by KRAUZE and BOWSZYS (1998). The statistical analysis showed that the FYM fertilisation had a significant effect on the content of available magnesium forms in both crop rotation variants. The content of available magnesium rose by 39.2% (the dose of 80 t ha^{-1}) compared with its content in soil from plots not amended with FYM (Table 3), while the statistical analysis did not demonstrate any significant effect of mineral fertilisation on the content of available magnesium.

The content of potassium available to plants ranged from 52.4 to 234.0 mg kg^{-1} (Table 2). In the samples from crop rotation A plots, its average content was 124.6 mg kg^{-1}, thus being 27.7% higher than recorded in the crop rotation B soil. A significant effect on the content of available potassium in soil was also noted for FYM fertilisation, especially with doses of 60 and 80 t ha^{-1}. The soil from these plots belonged to higher classes of the content of this element. According to ASKEGAARD et al. (2005), the content of available potassium is mostly determined by the grain size composition, mineral composition, soil moisture and the amount of potassium supplied as mineral fertiliser and FYM. Long-term FYM application most considerably increases the content of exchangeable and active potassium and, to a much lesser extent, available potassium (SZYMAŃSKA et al. 2005).

The statistical analysis did not show any significant effect of the crop rotation applied in the field experiment on the content of available phosphorus (Table 2). Its average content in the soil samples from the crop rotation A plots was 76.7, while in the soil sampled from crop rotation B it equalled 78.5 mg kg^{-1}. Likewise, no effect of mineral fertilisation on the content of available phosphorus forms was detected. However, FYM fertilisation was found to have produced a significant effect on the content of this form of phosphorus (Table 3). SIENKIEWICZ et al. (2009) claimed that a combined application of FYM and mineral fertilisers resulted in a significant increase in the content of Mg, P and K available to plants, as compared with the content recorded following the application of mineral fertilisation alone.

The content of water-soluble magnesium (Mg-H_2O), referred to as an active form of this element, ranged from 3.5 to 6.8 mg kg^{-1} (Table 2). The statistical analysis did not show any significant effect of the crop rotation variants on the content of water-soluble magnesium (Table 4). A different effect was reported for FYM fertilisation. The average Mg-H_2O content in the soil sampled from the plots exposed to organic fertilisation tended to

Table 2

Content of available nutrients and their water-soluble forms (mg kg^{-1})

Experimental treatments	Available forms			Content of water-soluble forms			
	Mg_A	K_A	P_A	Mg-H_2O	K-H_2O	Ca-H_2O	Na-H_2O
	(mg kg^{-1})						
A-0-N0	27.8	83.3	68.0	3.6	31.0	10.9	2.7
A-0-N1	28.8	74.9	56.2	4.0	38.1	10.7	2.4
A-0-N2	29.2	60.2	57.4	3.6	32.2	10.1	1.6
A-20-N0	35.2	90.0	58.8	4.4	36.7	11.0	
A-20-N1	35.3	83.2	68.6	4.3	35.8	13.2	4.2
A-20-N2	37.8	98.5	61.4	4.5	34.1	14.4	2.9
A-40-N0	39.4	151.5	73.3	4.4	33.0	11.0	3.3
A-40-N1	42.8	105.0	72.4	5.4	47.3	12.7	2.9
A-40-N2	31.3	82.6	77.7	3.8	34.3	12.0	2.9
A-60-N0	45.5	173.0	97.0	5.3	49.8	14.2	2.9
A-60-N1	51.0	166.1	98.0	5.7	56.3	14.4	5.2
A-60-N2	47.6	172.7	102.4	4.8	54.5	13.0	2.0
A-80-N0	48.5	151.2	89.0	4.3	38.2	15.6	4.7
A-80-N1	49.0	234.1	88.4	6.0	64.0	16.1	2.9
A-80-N2	49.4	142.8	82.1	5.7	47.0	16.5	2.7
B-0-N0	35.5	61.2	77.2	3.9	16.3	5.2	1.0
B-0-N1	31.9	53.4	68.3	4.3	18.0	4.9	1.3
B-0-N2	32.1	67.9	74.5	3.8	15.8	5.1	1.5
B-20-N0	36.7	61.3	70.2	3.5	23.9	6.0	1.2
B-20-N1	36.6	53.3	71.8	5.0	21.4	7.1	1.9
B-20-N2	38.6	52.4	70.9	4.3	20.2	7.8	2.2
B-40-N0	40.8	82.8	80.0	5.0	33.5	8.8	3.4
B-40-N1	42.8	83.1	68.0	4.3	28.5	7.6	2.3
B-40-N2	39.5	68.5	60.3	3.6	22.2	6.1	1.1
B-60-N0	48.3	105.2	86.1	5.7	44.0	13.8	8.5
B-60-N1	48.6	135.1	90.4	6.3	37.7	16.2	3.1
B-60-N2	46.7	98.0	82.5	4.9	35.2	10.5	6.8
B-80-N0	57.3	166.1	96.7	5.3	56.2	13.0	2.0
B-80-N1	58.3	157.7	94.8	6.8	56.2	15.8	2.8
B-80-N2	42.4	106.0	86.0	6.1	48.5	11.3	9.3

A, B – crop rotation, 0-80 – FYM dose in t ha^{-1} FYM, N0, N1, N2 – nitrogen doses kg ha^{-1}

Table 3

Results of the analysis of variance for the content of available magnesium, potassium and phosphorus forms in soil (mg kg^{-1})

Factors		Mg_A		K_A		P_A	
I – crop rotation	A	39.9	LSD n.s.	124.6	LSD 18.57	76.7	LSD n.s.
	B	42.4		90.1		78.5	
II – FYM (t ha^{-1})	0	30.9	LSD 7.17	66.8	LSD 43.99	66.9	LSD 9.36
	20	36.7		73.1		66.9	
	40	39.4		95.5		71.9	
	60	47.9		141.6		92.7	
	80	50.8		159.6		89.5	
III – nitrogen fertiliser (kg N ha^{-1})	N0	41.5	LSD n.s.	112.5	LSD n.s.	79.6	LSD n.s
	N1	42.5		114,5		77.6	
	N2	39.4		94.9		75.5	

A, B – crop rotation, 0-80 – FYM doses in t ha^{-1}, N0, N1, N2 – nitrogen doses kg ha^{-1}

increase when an FYM dose was applied. Analogously, mineral fertilisation has a significant effect on the content of active magnesium in soil. The highest content of the active form of this element was found for the doses of mineral nitrogen variant N1. The content of water-soluble magnesium in the analysed soils was twice as high as the one observed by MURAWSKA and SPYCHAJ-FABISIAK (2009) in soil under long-term field experiment.

Water-soluble potassium in soil was significantly affected by all the three experimental factors. A higher content of the water-soluble potassium form was reported in the soil samples where crop rotation A had been applied, as compared with the soil under crop rotation B, while organic fertilisation showed a similar effect on water-soluble potassium as in the case of the Mg-H_2O content. Similarly, the content of water-soluble potassium in soil tended to rise as the FYM doses increased (Table 4). The statistical analysis showed that mineral fertilisation affected the content of active potassium forms. The highest content of water-soluble potassium in soil was noted for nitrogen dose N1.

The content of water-soluble calcium in soil ranged from 4.9 to 16.5 mg kg^{-1} (Table 2). A significant effect of both crop rotation and organic fertilisation on the content of Ca-H_2O in soil was detected. The average content of active calcium in the soil samples exposed to crop rotation A was 13.0 mg kg^{-1}, being 28.5% higher than in the soil under crop rotation B (Table 4). It was also found that the content of Ca-H_2O in soil increased with the increasing FYM doses, from 7.8 mg kg^{-1} for the dose of 0 t ha^{-1} to 14.7 mg kg^{-1} for the dose of 80 t ha^{-1}. However, no significant effect of any of the experimental factors on the content of water-soluble sodium in the analysed soil samples was confirmed.

Table 4

Results of the analysis of variance for the content of water-soluble cations of Mg^{2+}, K^{+}, Ca^{2+}, Na^{+} in soil (mg kg^{-1})

Factors		$Mg-H_2O$		$K-H_2O$		$Ca-H_2O$		$Na-H_2O$	
I – crop rotation	A	4.6	LSD n.s.	42.1	LSD 3.13	13.0	LSD 0.91	3.1	LSD n.s.
	B	4.8		31.8		9.3		3.2	
II – FYM (t ha^{-1})	0	3.8	LSD 0.85	25.2	LSD 7.43	7.8	LSD 2.14	1.7	LSD n.s.
	20	4.3		28.6		9.9		2.7	
	40	4.4		33.1		9.7		2.6	
	60	5.4		46.2		13.6		4.7	
	80	5.7		51.6		14.7		4.1	
III – nitrogen fertilisation (kg N ha^{-1})	N0	4.5	LSD 0.54	36.2	LSD 4.76	10.9	LSD n.s.	3.3	LSD n.s.
	N1	5.2		40.3		11.8		2.9	
	N2	4.5		34.4		10.6		3.3	

A, B – crop rotation, 0-80 – FYM doses in t ha^{-1}, N0, N1, N2 – nitrogen doses kg ha^{-1}

In biologically active soils, the content of elements available to plants depends mostly on the reaction, grain size composition, amount and quality of humus compounds, oxidation-reduction potential and on the interactions between individual parameters (Bronick, Lal 2005). The soil use is a limiting factor for available magnesium soil resources, although when we compare the analysed arable soils with Luvisols under orchards (Licznar, Licznar 2008) which had similar humus content, grain size composition and pH, the determined differences begin to blur. Rutkowska et al. (2006) report that the ion concentration in soil solution depends on the grain size composition, and especially on the content of silt and clay fractions. Similarly, Holmqvist et al. (2003) claim that the amount of potassium released to soil solution in mineral soil depends on its grain size composition and the intensity of mineral weathering. In the analysed soils, however, no such relationship was noted. The content of organic carbon was significantly positively correlated with the content of magnesium and phosphorus available to plants and with the concentration of water-soluble magnesium (Table 5). Significantly positive correlation was verified between the content of available magnesium and the content of potassium and phosphorus available to plants (r=0.75 and 0.80 for p<0.05). High organic and mineral fertilisation doses applied during the 22 years of the field experiment did not have any significant effect on the electrolytic conductivity of the soil solution. By analogy, Murawska and Spychaj-Fabisiak (2009) did not observe any effect of long-term intensive fertilisation with nitrogen and potassium (32 years of a field experiment) on soil salinity.

Table 5

Significant coefficients of correlation between the investigated parameters (n=35)

Parameters	Mg_A	K_A	P_A	Mg-H_2O	K-H_2O	Ca-H_2O	Na-H_2O
EC	0.54	0.52	0.42	0.49	0.50		
Corg	0.44		0.42	0.39			
Mg_A		0.75	0.80	0.79	0.71	0.61	
K_A			0.75	0.65	0.86	0.78	
P_A				0.68	0.66	0.53	
Mg-H_2O					0.73	0.66	0.40
K-H_2O						0.83	

EC – electrolytic conductivity; confidence level $p<0.05$

CONCLUSIONS

1. FYM fertilisation significantly affected the content of magnesium, potassium and phosphorus forms available to plants. High content of those elements was recorded following the application of 40, 60 and 80 t FYM ha^{-1}.

2. The crop rotation applied had a significant effect on the content of potassium available to plants. More potassium was noted following the humus-depleting crop rotation variant.

3. Significant effect of FYM fertilisation in the doses of 60 and 80 t ha^{-1} and mineral fertilisation in the dose of 170 kg N ha^{-1} on the content of water-soluble forms of magnesium and potassium was detected. The content of active potassium in soil was also significantly affected by crop rotation.

4. The content of magnesium and phosphorus forms available to plants was significantly positively correlated with the organic carbon content. Significantly positive correlation between the content of magnesium and potassium available to plants and the content of their water-soluble forms was confirmed.

5. The correlation results did not imply any significant effect of organic and mineral fertilisation on the electrolytic conductivity of the soil solution.

REFERENCES

Askegaard, M., Hansen, H.C.B., Schjoerring, J.K. 2005. *A cation exchange resin method for measuring long-term potassium release rates from soil*. Plant Soil, 271: 63-74.

Błaszczyk W. H. 1998. *Ilościowe zróżnicowanie form magnezu i potasu w glebach różnie użytkowanych [Quantitative variation of magnesium and potassium forms in differently used soils]*. Rocz. Glebozn., 49(3/4): 73-84. (in Polish)

BRONICK C.J., LAL R. 2005. *Soil structures and management: a review*. Geoderma, 124:3-22.

FOTYMA M., GOSEK S., STRĄCZYK D. 2005. *Zawartość różnych form potasu w glebach województwa lubelskiego [The content and relation of different forms of potassium in the soils of Lublin Region]*. Nawozy i Nawożenie. Fertilizer and Fertilization, 3(24): 124-132. (in Polish)

HOLMQVIST O J., ŘGAARD A.F., ÖBORN I., EDWARDS A.C., MATTSSON L., SVERDRUP H. 2003. *Application of the profile model to estimate potassium release from mineral weathering in Northern European agricultural soils*. Europ. J. Agronomy, 20: 149-163.

IUSS Working Group WRB. 2007. World References Base for Soil Resources 2006. World Soil Resources Reports, No 103, FAO, Rome.

JASKULSKA I., JASKULSKI D. 2003. *Wpływ wieloletniego nawożenia na kształtowanie się właściwości gleby [Effect of long-term fertilization on modification in soil properties]*. Post. Nauk Rol., 4: 21-35. (in Polish)

JOBBÁGY E.G., JACKSON R.B. 2001. *The distribution of soil nutrients with depth: Global patterns and the imprint of plants*. Biogeochemistry, 53: 51-77.

KOBIERSKI M., DĄBKOWSKA-NASKRĘT H. 2005. *Potas w zróżnicowanych typologicznie glebach Równiny Inowrocławskiej [Potassium in different types of soils of Inowrocławska Plain]*. Nawozy i Nawożenie. Fertilizers and Fertilization, 3(24): 171-181. (in Polish)

KRAUZE A., BOWSZYS T. 1998. *Wpływ nawożenia i zmianowania roślin na zasobność gleby płowej w składniki przyswajalne i próchnicę. [Effect of fertilization and crop rotation on available nutrients and humus content in Luvisols]*. Zesz. Probl. Post. Nauk Rol., 460: 291-302. (in Polish)

LICZNAR M., LICZNAR S.E. 2008. *Wpływ sposobów utrzymania gleby w sadzie jabłoniowym na wybrane elementy żyzności [Influence of soil management in an apple-tree orchard on selected soil fertility elements]*. Rocz. Glebozn., 59(1): 141-148. (in Polish)

LIPIŃSKI W., BEDNAREK W. 1998. *Występowanie łatwo rozpuszczalnych form metali w glebach Lubelszczyzny w zależności od odczynu i składu granulometrycznego [Occurrence of readily soluble forms of metals in the soils of Lublin region depending on soil reaction and grain size composition]*. Zesz. Probl., Post. Nauk Rol., 456: 399-404. (in Polish)

MERCIK S., STĘPIEŃ W., ŁABĘTOWICZ J. 2000. *Żyzność gleb w trzech systemach nawożenia: mineralny, organicznym i organiczno-mineralnym w doświadczeniach wieloletnich*. Cz. II. *Właściwości chemiczne gleb [Soil fertility in three fertilization systems: mineral, organic and combined mineral and organic regimes, in long-term experiments]*. Part II. *Chemical properties of soils]*. Biul. Magnezol., 6(4): 607-615. (in Polish)

MURAWSKA B., SPYCHAJ-FABISIAK E. 2009. *Effect of nitrogen and potassium fertilization on the content of ions in the soil solution*. J. Elementol., 14(4): 737-743.

RUTKOWSKA B., SZULC W., ŁABĘTOWICZ J. 2006. *Skład granulometryczny gleby jako czynnik determinujący stężenie jonów w roztworze glebowym [Grain size composition of soil as a factor determining ionic concentration in the soil solution*]. J. Elementol., 11(1): 89-98.

SIENKIEWICZ S., KRZEBIETKE S., WOJNOWSKA T., ŻARCZYŃSKI P., OMILIAN M. 2009. *Effect of long-term differentiated fertilization with farmyard manure and mineral fertilizers on the content of available forms of P, K and Mg in soil*. J. Elementol., 14(4): 770-786.

SMAL H., MISZTAL M. 1996. *Soil solution chemistry in the profiles of forest and arable light textured soils, S.E. Poland*. Appl. Geochem., 11: 81-85.

SZYMAŃSKA M., ŁABĘTOWICZ J., KORC M. 2005. *Zawartość form potasu w glebie w warunkach doświadczenia nawozowego [Estimation of the form of potassium affected by fertilization factors in long-term fertilization experiment]*. Nawozy i Nawożenie. Fertilizer and Fertilization, 3(24): 262-271. (in Polish)