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CONTENT OF POTASSIUM AND MAGNESIUM IN ORGANIC SOILS AND MEADOW VEGETATION OF SZCZECIN POMERANIA

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Abstract

The studies included the major organic meadow soils of Szczecin Pomerania, left fallow or sporadically used extensively. The following determinations were made: the content of plant available magnesium and potassium (using HCl at the concentration of 0.5 mol·dm^{-3}), their total forms (soluble in the mixture of concentrated acids HNO_3 + $HClO_4$) as well as the content of potassium and magnesium in the meadow-pasture sward from the area under study. The results are presented in Table 1. The investigated peat-muck, gyttia-muck, mineral-muck and muckous soils, in the surface layer 0-30 cm deep (which was primarily the muck layer) mostly contained the amounts of potassium and magnesium typical of organic soils when soluble in the mixture of concentrated acids HNO_3+$HClO_4$ but low and frequently very low amounts of potassium soluble in 0.5 mol·dm^{-3} HCl from (0.04 to 0.51g·kg^{-1}). The content of this form of potassium depended on the degree of peat siltation. Low resources of available potassium were caused by the deficiency of this element in the meadow pasture sward since only in the sward of the Gryfinski Polder in Miedzyodrze and the sward from gyttia-muck soils near Miedwie Lake the optimum amounts were detected (above 15.0 g·kg^{-1} dry matter). In comparison with these results, the content of magnesium, soluble in 0.5 mol·dm^{-3} HCl in these soils was more favourable to plants (generally above 0.40 g·kg^{-1}), which is considered high according to the Institute of Soil Science and Plant Cultivation (IUNG 1990). In meadow sward, magnesium content mostly exceeded 2.0 g·kg $^{-1}$ dry matter so either approached or reached the optimum value for fodder. Despite this, the calculated K:Mg ionic ratios confirm an unfavourable fodder value.

Key words: organic soils, soil content of potassium and magnesium, sward content of potassium and magnesium.

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ZAWARTOŚĆ POTASU I MAGNEZU W GLEBACH ORGANICZNYCH I ROŚLINNOŚCI ŁĄKOWEJ POMORZA SZCZECIŃSKIEGO

Abstrakt

Badaniami objęto ważniejsze obszary organicznych gleb łąkowych Pomorza Szczecińskiego, które znajdują się w stanie odłogowania lub są tylko sporadycznie ekstensywnie użytkowane. Określono w nich zawartość dostępnego roślinom magnezu i potasu (stosując HCl o stężeniu 0,5 mol•dm^{-3}) oraz formy ogólne (rozpuszczalne w mieszaninie stężonych kwasów HNO_3+$HClO_4$) tych pierwiastków. Ustalono także zawartość potasu i magnezu w runi łąkowo-pastwiskowej porastającej badany teren.

Badane gleby torfowo-murszowe, mułowo-murszowe, gytiowo-murszowe, mineralno-murszowe i murszaste w powierzchniowej 0-30 cm warstwie (stanowiącej przeważnie poziom murszowy tych gleb) na ogół zawierały typowe dla gleb organicznych wartości potasu i magnezu rozpuszczalnego w mieszaninie stężonych kwasów HNO_3+$HClO_4$. Wykazywały natomiast niskie, a często nawet bardzo niskie ilości potasu rozpuszczalnego w HCl o stężeniu 0,5 mol·dm^{-3} (od 0,04 do 0,51 g·kg^{-1}). Przy czym na zawartość tej formy potasu duży wpływ wywierał stopień zamulenia torfu. Stan niskiej zasobności gleb w dostępny roślinom potas wywołał niedobór tego pierwiastka w runi łąkowo-pastwiskowej, bowiem tylko w runi Polderu Gryfińskiego w obrębie Międzyodrza oraz ruń na glebach gytiowo-murszowych w pobliżu jeziora Miedwie wykazano jego optymalną ilość (powyżej 15,0 g·kg^{-1}s.m.). Na tym tle badane gleby odznaczały się korzystną dla roślin zawartością magnezu rozpuszczalnego w HCl o stężeniu 0,5 mol·dm^{-3} (z reguły powyżej 0,40 g·kg^{-1}), co jest zasobnością wysoką. W runi łąkowej zawartość magnezu na ogół przekroczyła 2,0 g·kg^{-1} s.m., czyli zbliżyła się lub osiągała wartość optymalną dla pasz. Pomimo to wyliczone proporcje jonowe K:Mg potwierdzają niekorzystną wartość paszy.

Słowa kluczowe: gleby organiczne, potas i magnez w glebach, potas i magnez w runi łąkowej.

INTRODUCTION

According to the CENTRAL STATISTICAL OFFICE, in 2007 permanent meadows and pastures covered about 3.3 mln ha in Poland, nearly 10.5% of the country's total area. However, in recent years the pastures have been shrinking. In comparison with 1980, 3.2-fold less land is under pastures now, which may be attributed to the reduction in cattle stock from 12.6 mln in 1980 to 5.6 mln in 2006. Apparently, this must have happened over the area formerly occupied by state farms, including the region of Szczecin Pomerania, where permanent meadows and pastures make up 14% of agricultural acreage.

In Szczecin Pomerania, permanent grassland (over 80% of total area) occurs predominantly on organic soils (peat-muck, mud-muck, gyttia-muck, mineral-muck and muckous soils). They used to be the source of fodder for cattle breeding on state farms. As a result of intensive grassland management, especially NPK fertilization, up to 3 hay cuts were harvested. As early as 1990 a reverse trend appeared and many meadows and pastures of Szczecin Pomerania were left fallow.

The present study focuses on chemical properties of fallowed or sporadically extensively used soils under permanent grassland and chemical content of their vegetation cover.

This paper is the synthesis of study results on the content of magnesium and potassium in the above elements of natural habitat.

MATERIAL AND METHODS

Since 1995, the Department of Soil Science of Szczecin Agricultural University has been investigating chemical properties of organic soils under permanent grassland. So far the studies have included the largest meadow complexes of Szczecin Pomerania which have been left idle or sporadically extensively grazed with cattle or horses. The studies were conducted in the Ina valley (Wapnica-Suchanówko), the Odra valley (Marwice-Gryfino), Międzyodrze (mainly in its southern part with the Widuchowski Polder, southern part of the Gryfiński Polder and Pucka Isle), Miedwie Lake and the meadows along the Baltic Sea coast with halophytic vegetation (objects: the Dziwna valley near Jarzębowo, Chrząszczewska Isle, the Rega valley near Włodarka). The study objects are presented in Figure 1. Usually, both the topsoil and the peat thickness were examined. Over 1000 soil samples and 260 samples of pasture vegetation were analysed. The sward samples were collected at the end of June and the beginning of July, and mineralised in a 1:1mixture of concentrated HNO_3 + $HClO_4$.

In order to determine the content of available forms of magnesium and potassium, a solution of HCl at the concentration 0.5 $mol \cdot dm^{-3}$ was used according to the recommendation of the Institute of Soil Science and Plant Cultivation in Puławy (IUNG, 1990). Approximate total values of these elements were obtained by soil mineralisation in a mixture of concentrated acids HNO_3+$HClO_4$. Potassium forms were determined using flame spectrophotometry and magnesium content – by atomic absorption spectrophotometry.

General characterisation of study area

This research was conducted on organic meadow soils of Szczecin Pomerania developed from lowmoor peat of varying siltation, especially in the upper part of soil profile, classified as peat-muck soils according to the Classification of Polish Soils (1989), Fibric Histosols according to WRB classification 1998 and, near Miedwie Lake, shallow organic-carbonate soils on lacustrine chalk, included in gyttia-muck soils (according to WRB 1998 – Saprihistic Gleysols).

Kochanowska and Rygielski (1994) point out that these soils constitute vast meadow complexes, measuring 200-4,000 ha, and that 40% of their area

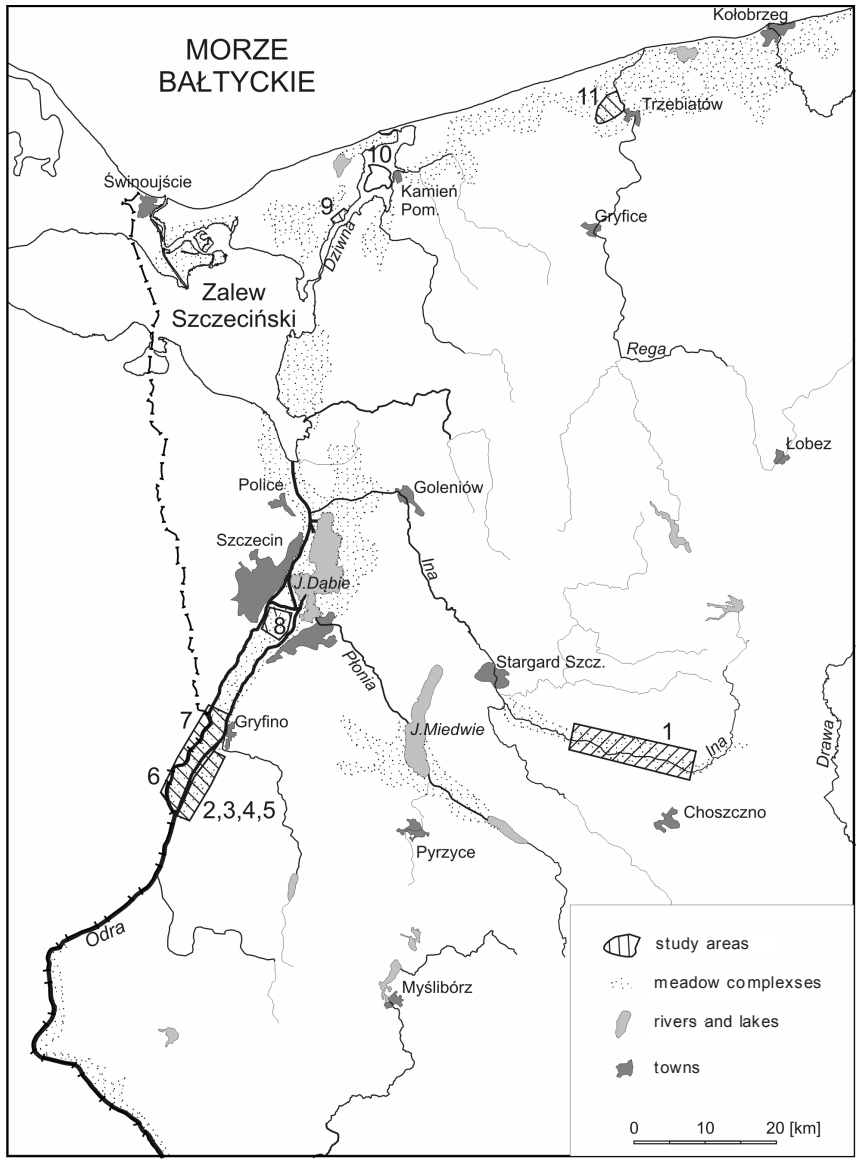

Fig. 1. Distribution of studied areas (1-10: study objects according to Table 1)

exists due to the polder drainage system. Siltation processes are typical of valley organic soils but in the case of the Odra valley and the Miedzyodrze region, a great role in their intensification is played by river regulation works and a parallel construction of the waterway Świnoujście-Szczecin. These works provided considerable amounts of material from the deepened

water bodies, which were spread on the adjacent lower areas to enhance their fertility (BOROWIEC, KWARTA 1959).

In the years 1960-1980 the valley meadows in the Province of Szczecin were drained (occasionally by pumping stations) and reclaimed (frequently using all cultivation practices), which intensified the development of animal farms and dry goods production. That period has been documented in many publications, for example RYGIELSKI (1992). During the intensive management of meadows and pastures owned by state farms, doses of mineral fertilisation were as follows: N – above 180, K_2O – 80-140, P_2O_5 – 40-80 $kg \cdot ha^{-1}$, plus sporadic applications of magnesium .

As a result of the economic transformations of the 1990s, most of these meadows and pastures ceased to be utilized and fertilized, which led to the abundant appearance of common reed rushes, scrub and then woodland. Only the EU subsidies for agriculturally used land encouraged grassland owners to cut them once or utilize as pasture or arable land.

This paper presents the content of potassium and magnesium only in the surface layer (0-30 cm), being the muck horizon or its upper part, and its vegetation cover. Muck horizon develops from peat transformation in natural processes occurring during drainage of organic soils. These processes bring about the gradual disappearance of primarily fibrous or spongy peat structure in the direction of tiny aggregates contributing to humus formation and immobilization of essential plant nutrients.

According to OKRUSZKO and SAPEK (1991), the muck formation process results in the increase in the total content of chemical elements such as potassium, phosphorus and iron. Therefore, the level of muck formation affects the development of grass communities and soil agricultural value. Transformations in the soils developed from lowmoor peat, taking into consideration biological and chemical changes, coupled with the changes in the soil composition, with the emphasis on the role of mud formation process have been discussed in detail by OKRUSZKO (1993) and OKRUSZKO and ILNICKI (2003).

After meadow soils had ceased to be utilized, their topsoil (0-30 cm) was found to have a high organic matter content (20- 85%) and varying reaction (pH_{KCl} 4.1-6.5). The only exception was the alkaline soil (pH_{KCl} 7.3-7.8) in the carbonate-muck horizon.

RESULTS AND DISCUSSION

In the surface layer (0-30 cm), mostly muck or mud-muck, the mean values for the content of potassium soluble in 0.5 $mol \cdot dm^{-3}$ HCl varied from extremely low to low according to the IUNG standards (1990) and SAPEK and SAPEK (1997). In was only in the Odra valley that this value exceeded

0.50 $g \cdot kg^{-1}$ dry matter, which indicates medium availability. The analysis of variations in the content of this element proves that the resources of available potassium in the examined soils are unfavourable. The highest content (0.19-0.51 $g \cdot kg^{-1}$ dry matter on average) was observed in the strongly silted muck layer, which occurs predominantly in the valley of the Lower Odra, especially in Międzyodrze and at Marwice, where the highest content of potassium soluble in the mixture of concentrated HNO_3+$HClO_4$ (Table 1) was also found, ranging on average from 0.60 to 4.71 $g \cdot kg^{-1}$ dry matter. The smallest amounts were obtained from the degraded, strongly dried out soils in the vicinity of the power plant Dolna Odra (mean 0.60 $g \cdot kg^{-1}$ dry matter). The content of this form of potassium drastically fell below the 0-30 cm layer with weakened siltation in lowmoor peat (NIEDZWIECKI 2000). Such regularity did not occur in the silted peat deposit in Międzyodrze. In the mud or gyttia-muck layers (organic-carbonate soil on lacustrine chalk; MELLER 2006) the content of potassium soluble in the mixture of HNO_3+ + $HClO_4$ was within the range 0.33-0.55 $g \cdot kg^{-1}$ dry matter (mean 0.46 $g \cdot kg^{-1}$) and was decreasing with depth to 0.11-0.25 $g \cdot kg^{-1}$ dry matter (mean 0.16 g $g \cdot kg^{-1}$ dry matter). Before World War II attention had been paid during the Odra regulation works to the need of fertilizing meadow soils with potassium, as it can be seen from WAGNER'S papers (1921), suggesting that hay of good nutritive value should contain 1.7% of potassium, and the data presented by HONCZARENKO (1961) concerning pre-war grassland fertilization per 1ha in Szczecin region: pure N to 36.7 kg, P_2O_5 29-32 kg and K_2O 38-50 kg. On the basis of German and his own studies, conducted in the years 1955-1961 he stated that there is high profitability of potassium fertilization on peat soils of Szczecin province. NIEDZWIIECKI (2000) and NIEDZWIECKI et. al. (2006) also noticed low resources of available potassium in organic soils of Szczecin Pomerania. Similar evaluation of organic soils in other lowland regions of Poland is given by PIAŚCIK and ŁACHACZ (2001) and BRANDYK et.al. (2001), who described the content of potassium as extremely poor.

Low resources of available potassium in organic soils result from the discontinuation of K fertilization, which is confirmed by OKRUSZKO and SAPEK (1991) and SIGUA et. al. (2006) in their studies on marshlands with a high organic matter content. These authors emphasize that peat soils with a low content of mineral clay have low potassium holding capacity due to weak bonds in the sorption complex and easy potassium ion dislodgement by other cations, mainly calcium and magnesium.

At the same time, there was hardly any interest in magnesium content in these soils as the cited literature shows, probably due to the belief that NPK fertilization covers all the needs of grassland vegetation.

The values of magnesium, soluble in HCl at the concentration 0.5 $mol \cdot dm^{-3}$ (available forms), are favourable since, as a rule, they exceed 0.40 $g \cdot kg^{-1}$, which means that according to IUNG (1990) there is either high or very high content of this element in the examined soils. The mead-

Table 1

Content of potassium and magnesium in surface layer (0-30 cm) of organic, peat-muck, peat-mud-muck soils and their vegetation cover ($g \cdot kg^{-1}$)

Study object		K soluble in 0.5 $mol \cdot dm^{-3}$ HCl		K in concentrated HNO_3+$HClO_4$		Mg soluble in 0.5 $mol \cdot dm^{-3}$ HCl		Mg in concentrated HNO_3+$HClO_4$		Mean content in sward dry matter		
		min-max	$\bar{x}$	min-max	$\bar{x}$	min-max	$\bar{x}$	min-max	$\bar{x}$	K	Mg	K:Mg
1	Ina valley	0.04-0.07	0.05	1.16-1.51	1.33	0.29-0.53	0.43	1.92-2.06	1.99	4.0	2.7	0.46
2	Odra valley (at Dolna Odra Power Plant) – dried area	0.06-0.34	0.16	0.18-1.75	0.60	0.24-1.33	0.64	0.34-4.36	1.46	7.8	4.3	0.56
3	Odra valley near ash dumping ground	0.08-0.42	0.19	0.63-6.17	1.91	0.36-1.41	0.78	1.39-5.38	2.83	12.6	3.4	1.14
4	Odra valley – Krajnik	0.04-0.23	0.13	0.38-1.84	1.41	0.67-0.90	0.80	1.26-2.84	2.32	6.5	3.8	0.53
5	Odra valley – Marwice	0.41-0.56	0.51	3.57-5.37	4.71	0.88-1.14	0.99	2.33-2.92	2.65	13.8	2.2	1.94
6	Międzyodrze – Widuchowski Polder	0.09-0.42	0.20	1.99-4.75	3.09	0.81-1.08	0.92	1.99-5.35	3.53	7.3	2.6	0.87
7	Międzyodrze – Gryfiński Polder	0.08-1.05	0.38	0.82-6.50	3.66	0.72-1.15	0.92	1.56-6.70	3.99	17.9	1.6	3.46
8	Międzyodrze – Pucka island	0.01-0.31	0.19	0.25-2.08	1.38	0.44-1.01	0.67	0.62-3.08	1.78	9.3	4.7	0.61
9	Pre-Baltic area – Dziwna valley (Jarzębowo)	0.05-0.38	0.19	1.39-5.10	2.91	0.45-2.30	1.24	1.84-5.24	3.45	15.3	1.3	3.64
10	Pre-Baltic area – Chrząszczewska island	0.02-0.06	0.04	0.74-5.01	2.90	0.41-0.61	0.57	0.96-5.35	3.30	12.3	2.8	1.36
11	Rega valley – Włodarka	0.04-0.15	0.08	0.92-3.16	1.92	0.31-0.65	0.57	1.73-3.13	2.36	12.0	2.3	1.61

ow soils in the valley of the Dziwna (Jarzębowo), the Odra, and Międzyodrze, appeared to be the richest in the forms of available magnesium (over 0.80 $g \cdot kg^{-1}$). The content of magnesium soluble in the mixture of concentrated acids was several times higher (Table 1). The amounts of both forms of magnesium were growing with the growing thickness of peat deposit. In the gyttia-muck soils near Miedwie Lake, in the muck layer, the total amount of this element ranged from 2.30 to 6.96 $g \cdot kg^{-1}$ dry matter (mean 4.26 $g \cdot kg^{-1}$ dry matter) and in calcareous gyttia (at the depth 30-50 cm) increased to 7.05 $g \cdot kg^{-1}$ dry matter on average. Nutrient uptake by sward depends on many factors such as the kind and level of fertilization (Falkowski et.al. 2000, Grabowski et.al. 2006), floristic composition of meadow and pasture communities. However, in agricultural practice the mineral composition of grassland fodder from sward is given without taking into account its floristic composition. In the opinion of Oswit and Sapek (1982) the content of potassium and magnesium in the grasses of Polish meadows is as follows: K – 14.1, Mg – 1.6 $g \cdot kg^{-1}$ dry matter. Good quality fodder according to the recommendations of Czuba and Murzyński (1989) Falkowski et. al. (2000) should contain 17-20 g K and 3.0g $Mg \cdot kg^{-1}$ dry matter. Minimum content of potassium, essential to animals, should amount to 10 $g \cdot kg^{-1}$ dry matter, and magnesium – 2.0 $g \cdot kg^{-1}$ dry matter. In Nowak's opinion (1983) maximum potassium content should not exceed 20.0-25.0 $g \cdot kg^{-1}$.

Mean values of potassium content reveal the deficiency of this element since only the sward from the Gryfiński Polder, in Międzyodrze, contained the optimum amount, which was reported by Nied•wiecki et. al. (2008), whereas the minimum amounts (minimum indispensable for fodder) were recorded in 5 study objects and in the remaining ones they were assessed as low. A relatively favourable potassium content (15.0-17.5 $g \cdot kg^{-1}$) was found in the analysed vegetation cover from gyttia-muck soils.

Compared to these results, the magnesium content in meadows and pastures under study is much better, with the dominant values above 2.0 $g \cdot kg^{-1}$ dry matter (Table 1) and only two objects scoring below that value. It should be noted that the magnesium deficiency in sward is accompanied by the greatest potassium accumulation. Content of magnesium in pasture grass from gyttia-muck soils ranged from 1.5 to 3.1 g kg dry matter.

Our results concerning the content of potassium and magnesium are to a great extent consistent with Nowak's studies (1983), in which he determined hay mineral resources during grassland intensive fertilization. His data show that in the vicinity of Szczecin only a few hay samples contained excessive amounts of potassium whereas hay from Szczecin Province had a more advantageous content of magnesium in comparison with low magnesium resources in the whole country

The calculated K:Mg ionic ratios confirm unfavourable value of fodder from the examined grassland objects. The optimum K:Mg ratio in fodder equals 6:1 and should not be lower than 2-6:1.

CONCLUSIONS

1. Fallow or extensively used organic soils of Szczecin Pomerania were generally found to have a low content of available potassium and medium to high magnesium content in their 0-30 cm layer.

2. Grassland sward from the investigated objects was deficient in potassium but had a more favourable amount of magnesium. Calculated ionic proportions of K:Mg confirm its unfavourable fodder value.

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