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STATISTICAL ASSESSMENT OF CERTAIN PROPERTIES OF SOIL UNDER PERMANENT GRASSLANDS

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Abstract

Geobotanical studies comprised soil and permanent grasslands in the valley of the Por River. The paper describes an assessment of the content of organic matter, reaction (pH) and availability of P, K and Mg in meadow soils overgrown with plant communities classified within the following syntaxonomic units: associations *Phragmition* and *Magnocaricion*, orders *Molinietalia* and *Arrhenatheretalia*, classes *Scheuchzerio-Caricetea nigrae* and the order *Trifolio fragiferae-Agrostietalia stoloniferae*. The results of chemical analyses were confronted with the limit ordinals after IUNG in Puławy (1990) and submitted to statistical analysis using the system of SAS 9.2 from Enterprise Guide 4.2. The analyzed habitats of permanent grasslands had neutral reaction and were dominated by organic soils. Mineral soils occurred in a small area. Generally, a very high or high availability of assimilable P, a low or very low availability of K and a differentiated content of Mg were found in organic soils. In mineral soils, on the other hand, a very high content of P and Mg and a very low content of K were observed. Comparative analyses of selected properties of the habitats showed very significant diversity. Variability coefficients were generally characterized by high values, which points to considerable differentiation of the analyzed properties of the soils within the distinguished syntaxonomic units. Based on our analysis of the Pearson's correlation coefficients, a number of relations, both positive and negative ones, can be noticed between the properties studied.

Keywords: meadow soils, plant communities, organic matter, pH, P, K, Mg.

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INTRODUCTION

Soil constitutes an important element of an eco-system, which conditions the growth and development of plants. By exploring soils, their natural properties and agricultural suitability, we should be able to shape adequate agricultural and environmental relations (Kopeć 2005, Skłodowski, Bielska 2009, Madejón et al. 2010, Mocek, Drzymała 2010, Paluszek 2011, Pietrzak 2012).

Major factors determining the natural physical, biological and chemical properties of soils are the bedrock and the soil-forming process (Terelak et al. 2008), whereas the most important indicator of the chemical and biological quality of soil is the content of organic matter (Paluszek 2011).

Other important criteria in an assessment of the chemical properties of meadow soil are the content of nutrients and the soil's reaction (Rodrigues et al. 2010, Paluszek 2011, Pietrzak 2012). The natural ability of soil to satisfy plants' nutrient requirements is best expressed by the content of the forms of nutrients assimilable by plants (Mocek, Drzymała 2010, Paluszek 2011). Availability of assimilable forms of mineral elements in soil is largely determined by the level of acidification of the soil (Filipek, Skowrońska 2013).

The purpose of the present paper is to assess the content of organic matter, reaction (pH) and availability of selected macroelements (P, K, Mg) in soils under permanent grasslands overgrown with plant communities classified into definite syntaxonomic units by means of basic statistical methods.

MATERIAL AND METHODS

The geobotanical studies comprised permanent grasslands in the valley of the Por River. The sites were chosen on the basis of an analysis of 519 phytosociological records taken by means of the Braun-Blanquet method (Wyłupek 1999). For easier interpretation of the results, the distinguished phytocoenoses were ordered into superior syntaxonomic units: associations *Phragmition* and *Magnocaricion*, orders *Molinietalia* and *Arrhenatheretalia*, class *Scheuchzerio-Caricetea nigrae* and the order *Trifolio fragiferae-Agrostietalia stoloniferae* (Matuszkiewicz 2012).

An attempt was made to assess the content of selected macroelements in the dry weight, yielding as well as the agricultural suitability of permanent meadow sward by means of basic statistical methods (Wyłupek et al. 2014).

In 2009-2011, soil samples were taken from the depth of 0-15 cm at sites representative of the distinguished syntaxons. The chemical composition of the soil material was analyzed at the *Central Laboratory* of Agroecology of *University of Life Sciences* in *Lublin. The following were determined in the soil material:*

- the content of organic matter – by the loss-on-ignition method at the temperature of 550°C; the results enabled us to divide the examined soil formations into mineral (up to 200 g kg^{-1}) and organic ones (more than 200 g kg^{-1}) (Mocek, Drzymała 2010);
- the reaction – by the potentiometric method;
- the content of assimilable forms of phosphorus, potassium and magnesium, which was established as follows:
- in mineral soils, assimilable P and K were determined by Egner-Riehm method, while Mg was established by Schachtschabel method;
- in organic soils, elements soluble in 0.5 mol dm^{-3} KCl were determined, and then K – by the photoflame method, P – by the calorimetric method, and Mg – on an a*tomic absorption spectroscope.*

The results of the chemical analyses were estimated according to the limit ordinals after IUNG in Puławy (1990) and submitted to statistical analysis using the SAS 9.2 system with Enterprise Guide 4.2.

With the aim of establishing statistically significant differences between the analyzed means from different environments, one-factor analysis of variance Anova was performed. In cases of statistically significant differences, the Tukey's HD tests were conducted to distinguish groups of statistically uniform means at the previously adopted level of significance $p = 0.05$.

Due to the fact that certain properties showed considerable variability, there was a suspicion of deviations from the assumptions of the Anova method on the uniformity of variance between the groups compared. Analyses by the Levene's tests on homogeneity of variance confirmed that supposition, which is why parallel calculations were performed by means of the Welch's Anova method, the latter not requiring an assumption on the homogeneity of variance. Similar values of the test functions F and the corresponding calculated probabilities of both methods confirmed that the analysis of variance is fairly resistant to deviations from the homogeneity of variance. Also, an interrelation between the properties studied was determined by calculating the value of the Pearson's correlation coefficient with the analysis of significance – by *t*-Student tests.

RESULTS AND DISCUSSION

Organic matter is a source of nutrients for plants and a driving force of biochemical processes occurring in a soil eco-system. Moreover, it promotes the protection of a soil environment by inhibiting the development of certain pathogens; besides, it binds heavy metals and pesticides in addition to considerably affecting the physical properties of the soil (Kolář 2009, Paluszek 2011).

The area of permanent grasslands in the valley of the Por River is dominated by organic soils. Mineral soil formations occur in a negligible share. The results of chemical and statistical analyses justify the statement that the mean content of organic matter in the surface layer of the soils under the permanent grasslands was shaped at different levels (Tables 1, 2).

Table 1

Selected statistics of certain properties of the soils of permanent grasslands in the Por River valley

Number of samples -150	One-factor variance analysis Anova			Levene's test		Welch Anova	
Dependent variable	F	Pr. > F	$P = 0.05$	F	Pr. > F	F	Pr. > F
Organic matter	11.97	<.0001	<	6.48	<.0001	14.42	<.0001
pH_{KCL}	2.96	0.0148	<	2.65	0.0261	7.75	0.0002
P	8.86	<.0001	<	3.25	0.0088	13.72	<.0001
K	6.67	<.0001	<	2.59	0.0294	7.39	0.0003
Mg	4.83	0.0005	<	4.41	0.001	4.51	0.0039

Our analysis of the homologous groups revealed that most organic matter accumulated in the soils overgrown with phytoecenoses from the class *cheuchzerio-Caricetea nigrae,* while the least organic matter was in the soils of fresh habitats of the order *Arrhenatheretalia* (Table 2).

On the other hand, while scrutinizing variability coefficients within selected syntaxonomic units, it was noticed that the highest diversity in the content of organic matter was found in soil samples taken from plant patches of the order *Arrhenatheretalia* (Coefficient of Variation = 120.5%), while the lowest one appeared in soil sampled under the class *Scheuchzerio-Caricetea nigrae* (CV = 40.8%) – Table 2.

The Pearson's correlation with the analysis of significance by *t*-Student tests demonstrated that the content of the organic matter in soil was positively correlated with ions of P (r = 0.471*), K (r = 0.467*) and Mg (r = 0.209**) – Table 3. Therefore, it can be assumed that the accumulation of organic matter in the topsoil promotes the availability of assimilable forms of basic nutrients in the soils of the Por River valley.

It is commonly assumed that neutral or weak acidic reaction ensures optimal conditions for the growth and development of plants, favourably affecting the availability of easily assimilable nutrients. Reversely, strong acidification of soils decreases their productivity and fertility (Paluszek 2011, Filipek, Skowrońska 2013).

Plant communities of the distinguished phytosociological units of permanent grasslands in the Por River valley were formed in soil of neutral reaction (IUNG 1990) – Table 2. Comparative analyses pointed to statistically

Table 2

Statistics concerning the content and differentiation of certain properties in the soils of the syntaxonomic units

Syntaxonomic unit	Number of samples (*n*)	Mean	CV (%)	Tukey's grouping
Organic matter (g kg^{-1} D.W.)				
*Phragmition**	9	354,8	87.9	*AB*
*Magnocaricion**	26	311.7	62.4	*AB*
*Molinietalia***	45	234.5	70.2	*ABC*
*Arrhenatheretalia***	49	76.1	120.5	*C*
*Scheuchzerio-Caricetea nigrae****	13	421.3	40.8	*A*
*Trifolio fragiferae-Agrostietalia stoloniferae***	8	217.1	109.7	*BC*
LSD -19.87				
pH_{KCL}				
Phragmition	9	6.68	1.3	*B*
Magnocaricion	26	6.85	4.2	*AB*
Molinietalia	45	6.85	2.7	*AB*
Arrhenatheretalia	49	6.96	2.2	*A*
Scheuchzerio-Caricetea nigrae	13	6.92	2.9	*AB*
Trifolio fragiferae-Agrostietalia stoloniferae	8	6.81	3.1	*AB*
LSD -0.242				
P (mg kg^{-1} soil)				
Phragmition	9	132.2	74.2	*B*
Magnocaricion	26	672.6	116.4	*AB*
Molinietalia	45	594.6	104.4	*AB*
Arrhenatheretalia	49	117.9	149.8	*B*
Scheuchzerio-Caricetea nigrae	13	1150.7	42.3	*A*
Trifolio fragiferae-Agrostietalia stoloniferae	8	444.7	150.9	*B*
LSD -64.34				
K (mg kg^{-1} soil)				
Phragmition	9	216.6	63.9	*AB*
Magnocaricion	26	259.5	48.5	*A*
Molinietalia	45	215.8	67.9	*AB*
Arrhenatheretalia	49	101.0	87.6	*B*
Scheuchzerio-Caricetea nigrae	13	234.9	57.8	*AB*
Trifolio fragiferae-Agrostietalia stoloniferae	8	139.6	70.6	*AB*
LSD -14.84				
Mg (mg kg^{-1} soil)				
Phragmition	9	117.8	31.5	*B*
Magnocaricion	26	187.2	40.2	*B*
Molinietalia	45	390.8	128.4	*AB*
Arrhenatheretalia	49	140.2	105.6	*B*
Scheuchzerio-Caricetea nigrae	13	660.6	97.7	*A*
Trifolio fragiferae-Agrostietalia stoloniferae	8	279.6	157.9	*AB*
LSD -44.31				

* – association, ** – order, *** – class, CV – Coefficient of Variability

Table 3

Pearson's correlation coefficients *r* with the analysis of significance by *t*-Student tests between selected properties of the soils of the Por River valley

Specification	pH_{KCl}	Organic matter	P	K	Mg
pH_{KCl} r =	1,000	-0.290*	0.115	-0.308*	0.122
Calculated probability =	-	0.001	0.207	0.0005	0.178
Organic matter *r* =	-	1.000	0.471*	0.467*	0.209**
P =	-	-	<.0001	<.0001	0.021
P *r* =	-	-	1.000	0.334*	0.415*
P =	-	-	-	0.0002	<.0001
K *r* =	-	-	-	1.000	0.408*
P =	-	-	-	-	<.0001
Mg *r* =	-	-	-	-	1.000
P =	-	-	-	-	-

significant differences between the arithmetic means (Table 1). The Tukey's procedure made it possible to group the means into two homologous groups. Highly significant differences occur between the pH determined in soils of fresh habitats of the order *Arrhenatheretalia* and the reaction determined in plant associations of *Phragmition*. Low variability coefficients (CV < 5%), on the other hand, point to negligible differentiation of the soil pH within the selected syntaxonomic units (Table 2). The reaction of the analyzed soil was poorly correlated (r = -0.290*) with the content of organic matter in the soils of the Por River valley. Besides, a negative value of the Pearson's correlation coefficient between pH and K (r = -0.308*) shows that lower acidification of soil (a higher pH value) favours a decrease in the content of assimilable potassium in the top layer of soil (Table 3).

pH values close to those from the current study have been determined in soils of the Warta River valley overgrown with high-sedge rushes of the association *Magnocaricion* (Kryszak et al. 2010), in soils of the Wieprz River valley, where phytocoenoses from the order *Arrhenatheretalia* (Warda, Stamirowska-Krzaczek 2010) predominated, and in flooded soils of river valleys in Wielkopolska, where plant communities of the order *Trifolio fragiferae-Agrostietalia stoloniferae* were prevalent (Kryszak, Grynia 2005).

The results of our analysis of mineral and organic soils generally indicate a high or very high content of assimilable forms of phosphorus, excluding the organic soils overgrown with phytocoenoses of the association *Phragmition*, where the availability of this macroelement was very low (IUNG 1990). As compared to nitrogen and potassium, phosphorus occurs in small quantities in Polish soils. Data provided by scientific literature suggest that meadow soils are deficient in bio-available forms of phosphorus

(Spychalski et al. 2010, Warda, Stamirowska-Krzaczek 2010, Pietrzak 2012). The content of its assimilable forms depends on the soil's reaction in the presence of other compounds and the soil's biological activity (Potarzycki 2006).

Comparative analyses pointed to significant differences in the content of assimilable forms of phosphorus in the soils studied (Table 1). Using the Tukey's procedure, groups of uniform means were established, implicating that the content of assimilable phosphorus was the highest in organic soils under plant communities of the class *Scheuchzerio-Caricetea nigrae*, and the lowest in soils under phytocoenoses of the association *Phragmition* and the order *Trifolio fragiferae-Agrostietalia stoloniferae*. The content of phosphorus in the other soil samples remained on the average level (Table 2).

On the basis of variability coefficients calculated within selected syntaxonomic units, it was concluded that soils overgrown with plant communities of the order *Trifolio fragiferae-Agrostietalia stoloniferae* showed the highest differentiation in amounts of the assimilable form of phosphorus, while those from the class *Scheuchzerio-Caricetea nigrae* were the least differentiated in this respect.

The content of potassium in meadow soils across Poland is generally very small and does not satisfy the nutrient requirements of meadow and pasture plants (Olszewska 2006, Pietrzak 2012).

The content of phyto-assimilable potassium in organic soils of permanent grasslands of the Por River valley was very low and low, while in mineral soils it was low (IUNG 1990). Similar results concerning bio-availability of potassium in meadow soils were reported elsewhere (Niedźwiecki et al. 2009, Warda, Stamirowska-Krzaczek 2010, Grzegorczyk et al. 2013).

Statistical analyses showed that the soils were characterized by a differentiated mean content of potassium (Table 1). There are highly significant differences between the mean content of potassium marked in organic soils overgrown with the plants of the association *Magnocaricion* and the concentration of the analyzed element in the mineral soil of fresh habitats of the order *Arrhenatheretalia*. The content of assimilable potassium in the soil profile of the other plant communities remains on an average level. Moreover, the calculated values of variability coefficients point to considerable differentiation of the potassium content within particular syntaxonomic units (Table 2).

Results of monitoring meadow soils in Poland indicate that the availability of assimilable magnesium is satisfactory in mineral soils but unsatisfactory in organic soils (Pietrzak 2012).

The content of assimilable magnesium in the surface layer of meadow organic soils in the Por River valley was varied (from very low to average, according to IUNG, 1990). Mineral soils overgrown with associations from the order *Arrhenatheretalia* were characterized by a very high content of the analyzed element (Table 2). Similar observations were made by Grzegorczyk et al. (2013), who studied plant communities in Olsztyn Lake District.

Comparative analyses of the soils included within geobotanical studies showed statistically significant differences in the content of assimilable magnesium (Table 1). The calculated values of the coefficient of variability (CV= 157.9%) prove extremely high differentiation in the content of the examined macroelements in the soils under the distinguished plant communities of the order *Trifolio fragiferae-Agrostietalia stoloniferae* (Table 2).

On the basis of the Pearson's correlation coefficients, relationships can be observed between the assimilable macroelements (P, K, Mg) occurring in the surface layer of the soils of the Por River valley. Positive correlations were found between the content of P and K in the analyzed meadow soils (r = 0.334*), P and Mg (r = 0.415*) and K and Mg (r = 0.408*) – Table 3.

CONCLUSIONS

1. The habitats of permanent grasslands in the valley of the Por River are dominated by organic soils. Mineral soils occurred in a small area overgrown with the plants characteristic of fresh habitats. The depth of groundwater of the river valley varied. All the studied soil samples were characterized by neutral reaction.

2. The analyzed habitats of organic meadow soils of the Por River valley were generally found to have very high or high availability of phosphorus, low or very low availability of potassium and a differentiated content of magnesium. On the other hand, a very high content of available phosphorus and magnesium and a very low availability of potassium were found in mineral soils.

3. Comparative analyses of selected properties of the habitats of the Por River valley pointed to their significant differentiation. Variability coefficients were characterized by a high value (except soil pH), which indicates considerable differentiation of the analyzed properties within the distinguished syntaxonomic units.

4. On the basis of the Pearson's correlation coefficients, it can be conlcuded that an increase in organic matter in soil contributed to the availability of the forms of nutrients (P, K, Mg). Other findings include a positive correlation between the content of P and K, P and Mg, K and Mg and the depth of groundwater and the reaction of the analyzed (pH) meadow soils of the Por River valley.

5. Besides, the reaction (pH) of the analyzed substrate was negatively correlated with the content of organic matter and the availability of potassium in the soils of the Por River valley. An inversely proportional correlation between the depth of groundwater and the content of organic matter in soil or the availability of the basic forms of nutrients (P, K, Mg) was also observed.

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