J. Elem. s. 853–864 DOI: 10.5601/jelem.2014.19.3.582

THE CONTENT OF SELECTED MACROELEMENTS IN THE DRY WEIGHT OF PERMANENT GRASSLAND SWARD, GRASS YIELDS AND ITS AGRICULTURAL VALUE

Teresa Wyłupek[1], Wanda Harkot[2], Zbigniew Czarnecki[2]

[1]Department of Plant Biology
[2]Chair of Grassland and Landscape Forming
University of Life Sciences in Lublin

Abstract

Permanent grassland is a valuable source of valuable natural raw material for production of fodders. The fodder value of sward depends on the grass yield volume, agricultural value (UVN), content of minerals, etc.

The present paper discusses the results of a study conducted in 2009-2011, on permanent grassland situated in the valley of the Por River. Samples of the plant material were taken before the first cut from selected, representative areas. They were used to assess, with basic analytical and statistical methods, the yielding, agricultural value (UVN) and chemical composition of hay. The content of P, K, Ca and Mg was determined in the dry weight of the sward by Flame Atomic Absorption Spectroscopy (FAAS), while the total content of N was established by the Kjeldahl's method. For easier interpretation of the results, the classified syntaxons (Matuszkiewicz 2006) were ranked into higher syntaxonomic units.

The present research showed a fairly good content of P, Mg and Ca in the analyzed dry weight of plants, enough to satisfy the nutritional demand of ruminants. However, the total content of N and K in the plant samples was insufficient. The agricultural value (UVN) of the dry weight of plants and the yield volume of the examined phytocenoses were varied, which was statistically verified.

The high value of variability coefficients also testifies to the considerable differentiation of all the analyzed features within particular syntaxonomic units.

Key words: total nitrogen, phosphorus, magnesium, calcium, yielding, agricultural value, meadow sward.

dr inż. Teresa Wyłupek, Department of Plant Biology, University of Life Sciences in Lublin, Szczebrzeska 102, 22-400 Zamość, Poland, e-mail:teresawylupek@op.pl

ZAWARTOŚĆ WYBRANYCH MAKROELEMENTÓW W SUCHEJ MASIE RUNI TRWAŁYCH UŻYTKÓW ZIELONYCH ORAZ ICH PLONOWANIE I WARTOŚĆ ROLNICZA

Abstrakt

Trwałe użytki zielone stanowią cenne źródło naturalnych pełnowartościowych surowców do produkcji pasz. Wartość paszową runi określa się m.in. pod względem zawartości składników mineralnych, wartości rolniczej (LWU) oraz wysokości plonu.

W pracy przedstawiono wyniki badań przeprowadzonych w latach 2009-2011 na trwałych użytkach zielonych w dolinie rzeki Por. Na wytypowanych, reprezentatywnych powierzchniach, przed zbiorem pierwszego pokosu, pobrano próby materiału roślinnego. Stanowiły one materiał do oceny plonowania, wartości rolniczej (LWU) i składu chemicznego siana. W suchej masie runi określono zawartość P, K, Ca, Mg metodą płomieniowej atomowej spektrofotometrii absorpcyjnej (FAAS) oraz ogólną zawartość N metodą Kjeldahla. W celu łatwiejszej interpretacji wyników sklasyfikowane syntaksony (Matuszkiewicz 2006) uszeregowano w nadrzędne jednostki syntaksonomiczne.

Wykazano dość dobrą pod względem potrzeb żywieniowych przeżuwaczy zawartość P, Mg oraz Ca w analizowanej suchej masie roślinnej, jednak ogólna zawartość N i K w badanych próbach roślinnych była niewystarczająca. Wartość rolnicza (LWU) suchej masy roślinnej oraz wysokość plonów badanych fitocenoz kształtowały się na zróżnicowanym poziomie, co potwierdziły analizy statystyczne.

Wysoka wartość współczynników zmienności świadczy również o znacznym zróżnicowaniu wszystkich analizowanych cech w obrębie poszczególnych jednostek syntaksonomicznych.

Słowa kluczowe: azot ogólny, fosfor, potas, magnez, wapń, plonowanie, wartość rolnicza, ruń łąkowa.

INTRODUCTION

The chemical value of fodder obtained from meadows and pastures is determined by the floristic composition of sward (Kozłowski 1996, Trzaskoś 1998, Kiryluk 2005, Sabiniarz, Kozłowski 2009), the developmental stage and parts of plants (Falkowski et al. 2000, Mastalerczuk 2007), patterns of adjacent plant groups, and even by individual species (Wesołowski et al. 2009, Wesołowski et al. 2011).

A significant effect on the level of mineral elements in plants is exerted by environmental factors such as the weather during the plant growing season (Wiśniowska-Kielian, Kasperczyk 1999), plant available elements in the soil (Niedźwiecki et al. 2009), habitat humidity and the groundwater level (Stępień, Pawluczuk 2011).

Numerous studies have shown strong relationships between the occurrence of mineral elements in the meadow soil and herbage and the use of a given habitat (Wiśniowska-Kielian, Kasperczyk 1999, Kasperczyk, Szewczyk 2007, Mastalerczuk 2007, Kolczarek et al. 2008, Baryła et al. 2009).

Grassland productivity is affected by the climatic and soil conditions, the type of a plant community as well as the mineral and organic fertilization

(Kasperczyk, Szewczyk 2007). Significant impact on the agricultural value (UVN) of grassland sward is produced by the quantitative and qualitative differences in the floristic composition during the plant growing season in the successive years of meadow use (Falkowski et al. 1996).

The content of nutrients, especially macroelements like N, P, K, Ca and Mg, affects the biological value of grassland sward, which makes good raw material for hay production (Kulik 2009, Sabiniarz, Kozłowski 2009).

The purpose of the present paper is to assess the content of total nitrogen, phosphorus, potassium, magnesium and calcium in the dry weight of selected grassland sward syntaxonomic units and the agricultural value (UVN) as well as the yield volume.

MATERIAL AND METHODS

In 2009-2011, a study was conducted on permanent grassland in the valley of the Por River (south-eastern Poland). Based on phytosociological records taken by the Braun-Blanquet method, plant communities and associations were distinguished, which were then classified using the syntaxonomic system by Matuszkiewicz (2006). Plant samples (150) were taken, each from an area of 1 m^2, in order to determine the fodder value of the analyzed meadows and pastures before the first cut of hay. They were cut from plant patches characteristic for particular phytocenoses. The samples were dried and then used to estimate the yielding, make botanical and gravimetric analyses and determine the chemical composition of hay.

Botanical and gravimetric analyses were the basis for calculations of the utility value number according to Filipek (1973). In the dry weight of the sward, the content of P, K, C and Mg was determined by Flame Atomic *Absorption* Spectroscopy (FAAS) while the total content of N was assayed by the Kjeldahl's method.

In order to facilitate the interpretation of the results, the distinguished plant communities and associations were ordered into superior syntaxonomic units, namely associations *Phragmition* and *Magnocaricion*, orders *Molinietalia* and *Arrhenatheretalia*, class *Scheuchzerio-Caricetea nigrae* and order *Trifolio fragiferae-Agrostietalia stoloniferae*. For the distinguished taxons, the analyses determined the content of P, K, Ca, Mg and total nitrogen as well as the utility value (V) and size of the yield in the dry weight of the sward.

The results were analyzed statistically using SAS 9.2 Enterprise Guide 4.2. The following methods of statistical analyses were applied: analysis of variance - Anova, the Tukey's HSD test, the Levene's Test for Homogeneity of Variances, the Welch's Anova and the Pearson's correlation coefficients with the analysis of statistical significance by Student's *t*-tests.

RESULTS AND DISCUSSION

Our comparative analysis of the means from different environments of the examined variables was based on a one-factor analysis of variance at the level of significance $\alpha = 0.05$.

Because certain traits presented considerable variability, deviations were suspected from the assumptions derived from Anova regarding the variance homogeneity of the compared groups. That was confirmed by analyses of the Levene's tests on variance homogeneity, which is why parallel calculations were done using the Welch's method to perform Anova, which does not require assuming variance homogeneity (Table 1).

Table 1

The one-factor variance analysis, Levene's tests and Welch's variance analysis of the N, P, K, Ca and Mg, hay yield and the agricultural value between the studied syntaxonomic units

Number of samples - 150	One-factor analysis of variance Anova			Levene's test		Welch's Anova	
Dependent variable	F	Pr.> F	$p = 0.05$	F	Pr.> F	F	Pr.> F
Total N	1.120	0.352	>	3.630	0.004	2.730	0.041
P	1.340	0.252	>	1.070	0.381	1.640	0.189
K	2.090	0.071	>	1.000	0.418	2.940	0.034
Mg	1.480	0.201	>	0.610	0.691	1.470	0.237
Ca	1.050	0.391	>	0.600	0.702	0.740	0.602
UVN	52.30	<.0001	<	2.640	0.027	65.41	<.0001
Hay yield	6.770	<.0001	<	3.050	0.013	12.38	<.0001

Variance analysis is fairly resistant to deviations from variance homogeneity, which was confirmed by the results of both methods (very close to the value of test functions F and the corresponding calculated probabilities).

Although Anova can establish whether groups differ significantly, it cannot state which groups (objects) differ in a statistically significant manner due to the mean values. That is the reason why T-Tukey's tests (HSD) were carried out at the previously adopted level of significance $p = 0.05$ so as to determine homogeneous groups (statistically homogeneous ones). The means followed by the same letter constitute a so-called group of homogenous means, which are the ones that do not significantly differ from each other. The absolute value of the difference of the means from the samples is higher than the so-called least significant difference LSD. Therefore, it can be stated that they are statistically significant (Table 2). The mean total nitrogen concentration in the studied meadow hay ranged from 15.6 g kg^{-1} of to 18.4 g kg^{-1} dry weight (DW). The smallest amount of this element was found in the plant dry weight of the communities from the order *Trifolio fragiferae-Agro-*

Table 2

Descriptive statistics concerning the content and differentiation of the analyzed macroelements, hay yield and agricultural value of the syntaxonomic units

Syntaxonomic unit	Number of samples (*n*)	Means	Variability coefficient Vc (%)	Tukey grouping
Total N (g kg^{-1} DW)				
*Phragmition**	9	15.9	9.6	A
*Magnocaricion**	26	18.4	17.4	A
*Trifolio fragiferae-Agrostietalia stoloniferae***	8	15.6	16.0	A
*Molinietalia caeruleae***	45	18.4	24.6	A
Arrhenatheretalia Pawł.**	49	18.2	19.1	A
*Scheuchzerio-Caricetea nigrae****	13	18.1	12.0	A
				LSD – 0.441
P (g kg^{-1} DW)				
*Phragmition**	9	2.40	27.8	A
*Magnocaricion**	26	2.22	30.6	A
*Trifolio fragiferae-Agrostietalia stoloniferae***	8	2.26	41.8	A
*Molinietalia caeruleae***	45	2.55	46.5	A
*Arrhenatheretalia***	49	2.09	40.6	A
*Scheuchzerio-Caricetea nigrae****	13	2.65	20.8	A
				LSD – 0.113
K (g kg^{-1} DW)				
*Phragmition**	9	18.3	25.4	A
*Magnocaricion**	26	14.8	31.6	AB
*Trifolio fragiferae-Agrostietalia stoloniferae***	8	16.4	18.1	AB
*Molinietalia caeruleae***	45	15.3	25.1	AB
*Arrhenatheretalia***	49	15.1	27.5	AB
*Scheuchzerio-Caricetea nigra****	13	12.0	23.4	B
				LSD - 0.491
Mg (g kg^{-1} DW)				
*Phragmition**	9	2.14	17.0	A
*Magnocaricion**	26	2.13	32.8	A
*Trifolio fragiferae-Agrostietalia stoloniferae***	8	1.91	56.6	A
*Molinietalia caeruleae***	45	2.47	31.9	A
*Arrhenatheretalia***	49	2.53	30.5	A
*Scheuchzerio-Caricetea nigrae****	13	2.45	29.4	A
				LSD – 0.094
Ca (g kg^{-1} DW)				
*Phragmition**	9	9.48	38.5	A
*Magnocaricion**	26	8.12	36.2	A
*Trifolio fragiferae-Agrostietalia stoloniferae***	8	7.60	50.9	A
*Molinietalia caeruleae***	45	8.01	41.8	A
*Arrhenatheretalia***	49	7.70	37.7	A
*Scheuchzerio-Caricetea nigrae****	13	9.83	39.7	A
				LSD – 0.393

Explanations: * – association, ** – order, *** - class

stietalia stoloniferae and the association *Phragmition*. It is assumed that the dry weight of sward should contain about 20 g kg^{-1} of total nitrogen (Falkowski et al. 2000). The concentration of total nitrogen reported herein is below the values considered as optimal ones.

Our comparative analyses demonstrated no statistical differences between the arithmetic means. Quite low variability coefficients also indicate little differences in the total nitrogen concentration within particular syntaxonomic units (Tables 1, 2), except for communities of humid habitats from the order of *Molinietalia caeruleae*, where statistically significant variability was observed (variation coefficient = 24.6%).

The scientific literature finds considerable differences in the content of total nitrogen in plants' dry weight depending on the floristic composition of sward and the conditions within the habitat in which a given plant communities grows (Kozłowski 1996, Baryła, Kulik 2006, Mastalerczuk 2007, Wesołowski et al. 2009, Stępień, Pawluczuk 2011, Wesołowski et al. 2011).

The chemical analyses on the availability of phosphorus in fodders from the examined grassland, from the distinguished syntaxonomic units of the Por River Valley, imply slight deficiency of this element in the plant's dry weight. According to Falkowski et al. (2000), the content of phosphorus in dry hay which is optimum for animals should range from 2.8 to 3.6 g kg^{-1}. Out of all the studied plant samples, the highest concentration of phosphorus was determined for the fodder from sedge-moss peat bogs from the class *Scheuchzerio-Caricetea nigrae* (2.65 g kg^{-1} DW), whereas the lowest one was found for fresh habitats from the order *Arrhenatheretalia* (2.09 g kg^{-1} DW).

The one-factor analysis of variance (Table 1) and Tukey grouping (Table 2) did not show any statistically significant differences in the content of phosphorus in the plant dry weight of the examined syntaxonomic units. On the other hand, the highest statistical variability within the syntaxon was observed in the communities of humid habitats, especially *Molinietalia caeruleae*, while the lowest in *Scheuchzerio-Caricetea nigrae* (Table 3).

Previous studies showed that environmental factors such as soil moisture (Baryła, Kulik 2006) and unstable atmospheric conditions including long droughts (Falkowski et al. 2000), have a considerable effect on phosphorus accumulation in plants. The analyzed plant communities of the Por River Valley were characterized by distinctly different hydrological conditions. However, the results of statistical analyses did not confirm the observations reported elsewehere,

The mean concentration of potassium ranged from 12.0 to 18.3 g kg^{-1} DW. For animal nutrition, the right concentration of this element in hay is 17 g K kg^{-1} DW. (Falkowski et al. 2000). The lowest K concentration was found in the phytocenoses from the class *Scheuchzerio-Caricetea nigrae*, while the highest one was in the associations of *Phragmition*. Comparative analyses confirmed that the potassium content in the other syntaxons did not show any statistically significant differences (Tables 1, 2). In addition, a

Table 3

Descriptive statistics concerning hay yield and agricultural value of the syntaxonomic units

Syntaxonomic unit	Number of samples (*n*)	Means	Variability coefficient Vc (%)	Tukey's grouping
UVN				
*Phragmition**	9	2.90	35.7	CD
*Magnocaricion**	26	1.63	77.3	D
*Trifolio fragiferae-Agrostietalia stoloniferae***	8	5.16	10.1	B
*Molinietalia caeruleae***	45	4.16	41.7	BC
*Arrhenatheretalia***	49	6.83	13.7	A
*Scheuchzerio-Caricetea nigrae****	13	2.98	44.7	CD
				LSD – 1.594
Hay yield (t ha^{-1})				
*Phragmition**	9	3.38	24.2	A
*Magnocaricion**	26	2.47	33.3	AB
*Trifolio fragiferae-Agrostietalia stoloniferae***	8	1.69	66.5	BC
*Molinietalia caeruleae***	45	2.20	42.3	B
*Arrhenatheretalia***	49	2.25	27.9	B
*Scheuchzerio-Caricetea nigrae****	13	1.22	33.8	C
				LSD – 0.962

Key – cf. Table 2

high variability coefficient (Vc =31.6%) was observed, which points to a wide range of variability in the concentration of potassium in plant samples of *Magnocaricion* Koch 1926. Results of studies presented by researchers (Wesołowski et al. 2009, Stępień, Pawluczuk 2011, Wesołowski et al. 2011) on the content of macroelements in rush vegetation confirm considerable differentiation in the content of potassium in sward from excessively humid habitats. It is believed that the potassium content in permanent grassland sward is a species-specific genetic trait (Falkowski et al. 2000).

The magnesium concentration in the dry weight of the analyzed plant samples, in respect of the aforementioned syntaxonomic units of permanent grassland of the Por River Valley ranged from 1.9 to 2.5 g kg^{-1} DW. Falkowski et al. (2000) suggest that from the point of view of animal feeding, the dry weight of plants should contain 2 g of magnesium. Thus, the analyzed hay in most cases meets the requirements set for good quality fodders.

The one-factor analysis of variance Anova did not show any statistically significant differences in the concentration of magnesium in the plant dry weight among the distinguished syntaxonomic units of the Por River Valley. While considering variability coefficients within selected syntaxonomic units, it was observed that the biggest differences appeared in plant patches from the order of *Trifolio fragiferae-Agrostietalia stoloniferae* (Vc = 56.6%), while the smallest ones were typical of *Phragmition* (Vc = 17.0%).

In general, hay produced in Poland contains an insufficient amount of magnesium (Falkowski et al. 2000). Deficiency of this element in hay from excessively humid habitats was shown for example by Wyłupek (2006), Wesołowski et al. (2009), Stępień, Pawluczuk (2011), Wesołowski et al. (2011). On the other hand, Niedźwiecki et al. (2009), who studied the chemical composition of grassland vegetation of Western Pomerania, and Sabiniarz and Kozłowski (2009), who analyzed Czersk grasslands in the aspect of fodders, found out magnesium concentrations in grassland hay close to the optimum.

According to Mastalerczuk (2007), more cuts in a season significantly decrease the amount of magnesium ion in the fodder. Hence, it can be supposed that extensive grassland management dominating in the Por Valley positively affected the content of magnesium in the analyzed plants.

The mean content of Ca in all samples of the analyzed aerial biomass exceeded the optimum value of 7 g kg^{-1} DW (Falkowski et al. 2000). The highest concentration of this element was observed in the dry weight of grassland sward of phytocenoses of the class *Scheuchzerio-Caricetea nigrae* (9.8 g kg^{-1} DW), whereas the lowest one was in the dry weight of samples from plant communities of the order *Trifolio fragiferae-Agrostietalia stoloniferae* (7.6 g kg^{-1} DW). Results of chemical analyses testify to considerable bio-availability of calcium ions to plants. In other regions of Lublin Province, the availability of this element to plants is insufficient (Borowiec, Urban 1992, Urban et al. 2003).

Lack of statistically significant differences in the content of calcium in the plant dry weight between syntaxonomic units can be observed on the basis of grouping the arithmetic means using the *post-hoc* tests. On the other hand, the analysis of variability coefficients within the distinguished syntaxonomic units found out quite remarkable dispersion of results. The broadest spectrum of variability was observed in the dry weight of phytocenoses of the order *Trifolio fragiferae-Agrostietalia stoloniferae* (Vc = 50.9%)**,** while the smallest one appeared in high-sedge rushes *Magnocaricion* (Vc = 36.2%) – Table 2.

In different regions of Poland, the content of Ca in the dry weight of plant communities remains within fairly broad limits. Researchers observe both excess and deficiency of calcium in the plant dry weight referring to the feeding needs of animals (Kozłowski 1996, Trzaskoś 1998, Baryła et al. 2009, Kulik 2009, Sabiniarz, Kozłowski 2009, Wesołowski et al. 2009, Wesołowski et al. 2011).

The statistical analyses find out that the hay of phytocenoses of the Por River Valley was characterized by different agricultural values (UVN). The applied Tukey's procedure made it possible to group the studied syntaxonomic units into four homogenous groups (A, B, C, D). As these group "overlap", it was observed that the highest nutritive value is found for the fodder from plant communities of fresh habitats of the order *Arrhenatheretalia*, slightly lower for hay from the order *Trifolio fragiferae-Agrostietalia stoloniferae*, while the lowest one was for the dry weight of plant samples of plant communities of humid habitats of the association *Magnocaricion*. The dry weight

of plants of the other syntaxonomic units was characterized by an average level of the agricultural value (Table 3).

The grassland was characterized by considerably differentiated yielding, which was confirmed statistically by variance analysis. According to the established homogenous groups, the highest yields of dry weight were from the phytocenoses of the association *Phragmition*, whereas the lowest ones were achieved from the communities of the class *Scheuchzerio-Caricetea nigrae* (Tables 1, 3).

Our analysis of the Pearson's linear correlation coefficient pointed to relationships between certain analyzed features of plant communities from the Por River Valley. Weak ($r < 0.5$) and directly proportional correlations (a positive coefficient of correlation) were found between the content of N total and P ($r = 0.240$), Mg and N total ($r = 0.268$), Mg and P ($r = 0.260$), Mg and Ca ($r = 0.308$). A positive relationship occurs between the hay yield of the 1st cut and its agricultural value (UVN) – Table 4.

Table 4

Pearson's correlation coefficient r with the analysis of significance using t-Student tests p between the selected features

Specification	Total N	P	K	Mg	Ca	UVN	Hay yield
Total N r =	1.000	0.240**	0.067	0.268**	-0.086	-0.014	-0.081
Calculated probability =	-	0.007	0.461	0.003	0.347	0.875	0.375
P r =	-	1.000	-0.092	0.260**	-0.036	-0.076	-0.131
p =	-	-	0.313	0.004	0.693	0.402	0.147
K r =	-	-	1.000	-0.027	0.118	0.032	0.100
p =	-	-	-	0.764	0.192	0.725	0.272
Mg r =	-	-	-	1.000	0.308**	0.115	0.011
p =	-	-	-	-	0.001	0.204	0.907
Ca r =	-	-	-	-	1.000	-0.145	0.038
p =	-	-	-	-	-	0.109	0.680
UVN r =	-	-	-	-	-	1.000	0.188*
p =	-	-	-	-	-	-	0.038
Hay yield r =	-	-	-	-	-	-	1.000
p =	-	-		-		-	

* Significant when ≤0.01,
** Significant when $p \leq 0.05$

CONCLUSIONS

The above results of chemical and statistical studies of the dry weight of permanent grassland of the Por River Valley justify the conclusion that the content of the basic mineral elements in the analyzed plant samples was fairly differentiated.

The dry weight of the examined plant samples was characterized by quite good availability of phosphorus, magnesium and calcium, which ensures adequate nutritional effects. On the other hand, the availability level of total nitrogen and potassium in fodder implied small N deficiency in the dry weight of plants.

Variability coefficients are characterized by a high value, which testifies to considerable differentiation of the availability of phosphorus, potassium, magnesium and calcium in the dry weight of particular plant patches of the analyzed syntaxonomic units. In contras, the content of total nitrogen in the plant dry weight should be considered as moderately stable.

The agricultural value (UVN) of fodder from different plant communities of the Por River Valley and the volume of obtained yields were characterized by considerable statistical variability, inluding differences within particular syntaxons and mutual comparisons of the arithmetic means.

REFERENCES

Baryła R., Kulik M. 2006. *Content of nitrogen and basic mineral components in pasture sward in different years of its utilization.* Ann. UMCS, Sect. E, 61: 157-164. (in Polish)

Baryła R., Sawicka J., Kulik M., Lipińska H. 2009. *Content of components in some grass species irrigated with purified sewage.* J. Elementol., 14(1): 5-12.

Borowiec J., Urban D. 1992. *An initial assessment of the directions of changes in the chemism of the soil and vegetation of the meadows in the Lublin region.* Ann. UMCS, Sect. E, 47: 171-182. (in Polish)

Falkowski M., Kukułka I., Kozłowski S. 1996. *Qualitative sward evaluation of permanent meadows.* Zesz. Probl. Post. Nauk Rol., 442: 41-49. (in Polish)

Falkowski M., Kukułka I., Kozłowski S. 2000. *Chemical properties of meadow plants.* Wyd. UP Poznań, 132. (in Polish)

Filipek J. 1973. *A project of classification of meadow and pasture plants on the basis of the numbers of the utility value.* Post. Nauk Rol., 4(20): 59-68. (in Polish)

Kasperczyk M., Szewczyk W. 2007. *Alterations in meadow grass production for different amounts of precipitation and different types of fertilizer.* Acta Agroph., 90(2): 371-378. (in Polish)

Kiryluk A. 2005. *Species diversity and plant chemism in melioration ditches.* J. Elementol., 10 (2): 333-340. (in Polish)

Kolczarek R., Ciepiela G. A., Jankowska J., Jodełka J. 2008. *Influence of different forms of nitrogen fertilization on the content of macrolements (K, Na) in meadow sward.* Part I. J. Elementol., 13(3): 341-349.

Kozłowski S. 1996. *Sward nutritive values of permanent meadows.* Rocz. AR Poznań, Rol., 47: 29-43. (in Polish)

Kozłowski S., Swędrzyński A. 1996. *Herbal meadows in the context of fodder and landscape*. Zesz. Probl. Post. Nauk Rol., 442: 269-276. (in Polish)

Kulik M. 2009. *Effect of different factors on chemical composition of grass-legumes sward*. J. Elementol., 14(1): 91-100.

Mastalerczuk G. 2007. *Nutrient content in organs of meadow plants in different conditions of management intensity*. Łąkarstwo w Polsce, 9: 131-140. (in Polish)

Matuszkiewicz W. 2006. *A guide for marking plant communities in Poland*. PWN, Warszawa, 540. (in Polish)

Niedźwiecki E., Protasowicki M., Meller E., Malinowski R., Sammel A. 2009. *Content of potassium and magnesium in organic soils and meadow vegetation of Szczecin Pomerania*. J. Elementol., 14(2): 331-340.

Sabiniarz A., Kozłowski S. 2009. *Forage aspects of the Czersk Meadows*. Łąkarstwo w Polsce, 9: 155-163. (in Polish)

Stępień A., Pawluczuk J. 2011. *The effect of different habitat conditions on the content of macro- and microelements in meadow plants on organic soils*. Woda-Środowisko-Obszary Wiejskie, 11, 4(36): 197-208. (in Polish)

Trzaskoś M. 1998. *Differentiation of the botanical composition and fodder value of sward from lowland and submontane herbal meadows*. Zesz. Nauk. AR Kraków, 330, Sesja Nauk., 54: 75-85. (in Polish)

Urban D, Miłosz A.I., Michalska R. 2003. *The content of macroelements in meadow soil and vegetation of selected peat objects of the Polesie National Park*. Ann. UMCS, Sect. E, 58: 167-175. (in Polish)

Wesołowski P., Trzaskoś M., Brysiewicz A. 2011. *Botanical composition and the content of some chemical elements in plants of the litoral zone of Lake Starzyc*. Woda-Środowisko-Obszary Wiejskie, 11, 1(33): 331-345. (in Polish)

Wesołowski P., Trzaskoś M., Konieczny R. 2009. *Floristic composition and the content of macro- and microelements in rush vegetation of the litoral zone of Lake Resko*. Woda-Środowisko -Obszary Wiejskie, 9, 1(25): 171-183. (in Polish)

Wiśniowska-Kielian B., Kasperczyk M. 1999. *Changes in the content of mineral components in plants and soil depending on the method of meadow management*. Zesz. Probl. Post. Nauk Rol., 467: 679-687. (in Polish)

Wyłupek T. 2006. *Economic value of plant communities Huczwa River valley*. Ann. UMCS, Sect. E, 61: 215-223. (in Polish)