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CONTENT OF MACROELEMENTS IN MEADOW SWARD ALONG ROAD NO. 957*

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Abstract. The aim of the research was to determine the content of selected macroelements (N, P, K, S, Ca, Mg) in meadow plant samples collected from places located at a distance of 5 m and 200 m from regional road no. 957 on the area which runs through Zawoja, and to evaluate the fodder value of this sward. Content of nitrogen and of phosphorus, potassium, calcium and magnesium in the sward collected 5 m from the road was slightly higher than in the sward that was collected 200 m from the road. Sulfur content was higher (by 7%) in the samples collected farther from the road edge. In terms of fodder requirements of herbivores, it needs to be stated that the mean nitrogen, phosphorus, potassium, sulfur and magnesium content in the sward was too low, at both distances. The mean value of the Ca:P, Ca:Mg, K:Mg, and K:Ca ratios took slightly higher than optimal values (at both distances from the road). The value of the ionic ratio K:(Ca+Mg) was 1.5, which was below the bottom value for good quality fodders. The N:S weight ratio took the correct value.

Key words: meadow plants, fodder value, macroelements, traffic pollutants

INTRODUCTION

Sward of grasslands located near traffic routes is often directly grazed by animals or intended for production of hay, hay silages or silages. The fodder aspect of permanent meadows is their most important function, although their uses other than for fodder, i.e. in shaping and protection of the environment as well as their landscape functions are becoming more and more important [Falkowski 1996, Fleury et al. 2015, Monteiro et al. 2011, Sabiniarz and Kozłowski 2009].

Sward chemical composition, apart from other parameters, decides on the quality of obtained fodder [Grygierzec 2012]. Plants are a source of nutrients (e.g.: N, P, K, S, Ca, Mg) for animals. In order to obtain high quality fodder it is important not only to maintain proper contents of individual elements, but also to maintain proper ratios between these contents (e.g.: Ca:P, Ca:Mg, K:Mg, K:Ca, N:S, K:(Ca+Mg), P:Zn, Ca:Cu, Ca:Mn, Ca:Zn) [Antonkiewicz 2007]. It controls element availability for animals, and in consequence influences the state of their health. The value of the ratio of potassium ion content to the sum of contents of calcium and magnesium is very important. If this value is greater than 2.2, grass tetany may appear. Abnormal muscular work leads to convulsions, stiffening of extremities, and problems with movement [Radkowska 2012]. In extreme cases, this metabolic disease may lead to animal deaths.

The aim of the research was to determine the content of selected macroelements (N, P, K, S, Ca, Mg) in meadow plant samples collected from places located along road no. 957 on the area which runs through Zawoja, and to evaluate the fodder value of this sward.

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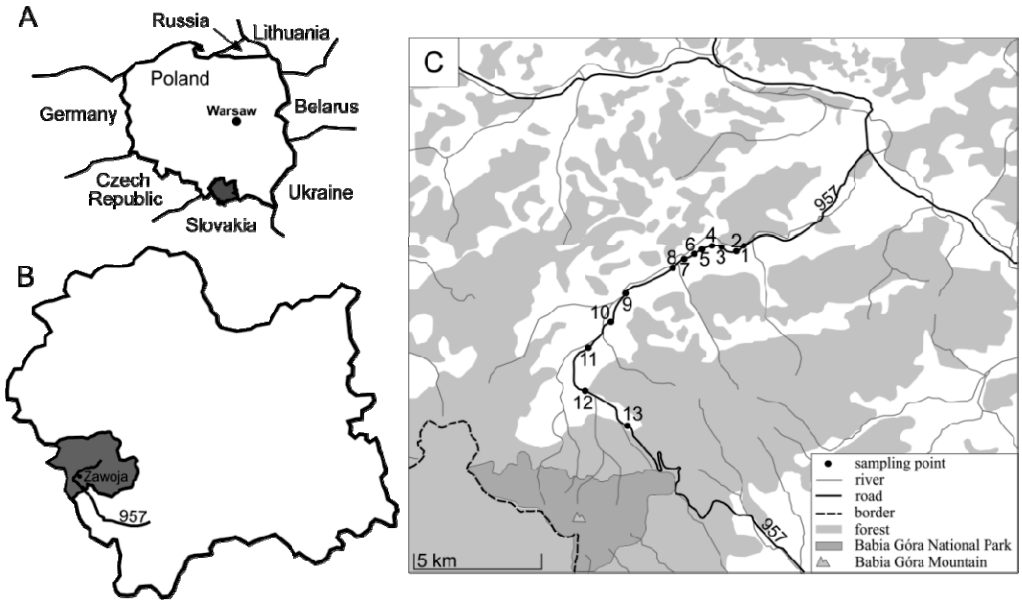
MATERIAL AND METHODS

The research material consisted of meadow sward samples collected from points located along road no. 957 at the section passing through Zawoja (the Malopolska Region), from places at a distance of 5 and 200 m from the road edge (Fig. 1). The samples were collected from 13 points, from areas covered with grasses. The precise characteristics of the research area, the intensity of car traffic as well as basic physico-chemical properties of soils from the points where the plant material was collected are presented in an earlier publication [Filipek-Mazur et al. 2013].



A – Poland with marked Małopolska region
B – Małopolska region with marked Suski district, road no. 957 and Zawoja
C – sampling points along road no. 957

Fig. 1. Location of the sampling points

The plant samples were dried at 70°C in a hot air dryer, and then milled. Nitrogen content in the plant material was determined by Kjeldahl distillation method on the Kjeltec 2300 Analyzer Unit (FOSS), after reducing nitrate nitrogen to ammonia nitrogen (using zinc and iron dust, mixed at 9:1 (m/m) ratio) [Ostrowska et al. 1991]. The content of potassium, calcium and magnesium was determined with atomic spectrometry on SOLAAR M6 Mk2, Thermo Electron Corporation apparatus, and the content of phosphorus and sulphur was determined with inductively coupled plasma atomic emission spectrometry on JY 238 Ultrace apparatus, according to the methodology provided by Ostrowska et al. [1991]. Content of phosphorus, potassium, calcium and magnesium was determined after dry mineralization of the samples at 450°C for 8 hours

and digestion of the residue in nitric acid. In order to determine sulfur content, the plant material was evaporated with concentrated nitric acid, then with magnesium nitrate solution, and then incinerated in a muffle furnace (2 hours at 300°C, and then 3 hours at 450°C). The residue was diluted in nitric acid solution.

Statistical elaboration of the results was conducted using Statistica 10.0 software. Values of arithmetic mean and standard deviation were computed, as were coefficients of simple correlation between selected soil and plant properties.

RESULTS AND DISCUSSION

Content of elements in meadow sward depends on biological properties of individual species [Falkowski et al. 1990, Wolański et al. 2015, Yoshihara et al. 2013] and on habitat conditions [Kotlarz et al. 2010, Trąba and Wyłupek 1998]. Compared with papilionaceous plants, grasses are generally poorer in Ca, Mg and Cu, and richer in Mn [Falkowski et al. 1990]. Presence of herbs in fodder increases the content of P, K and Mg [Wolański et al. 2015].

Content of six macroelements in the studied meadow sward is presented in table 1 and in figure 2. The mean nitrogen content in plants located 5 m from the road edge was slightly higher (19.0 $g \cdot kg^{-1}$ d.m.) than in plants located 200 m from the road edge (18.5 $g \cdot kg^{-1}$ d.m.). It was a 3% increase. Using a conversion factor of 6.25 it was calculated that total protein content was, respectively, 118.8 and 115.6 $g \cdot kg^{-1}$d.m. At both distances, the mean nitrogen content was low. Antonkiewicz [2007, based on different sources] gives a range of 15–30 g $N \cdot kg^{-1}$ d.m. as optimal for grassland fodder, whereas Zarzycki and Kopeć [2015 after Wasilewski 1997] state that optimal nitrogen content in fodder for cattle should not be lower than 24 $g \cdot kg^{-1}$ d.m.

Table 1. Content of macroelements in plants ($g \cdot kg^{-1}$ DM)

Distance from the road (m)	Parameter	N	P	K	S	Ca	Mg
5 (n = 13)	Mean	19.0	2.23	10.89	1.50	5.32	1.59
	Minimum	13.8	1.53	5.85	1.33	2.38	0.87
	Maximum	23.8	3.46	18.31	1.89	7.75	2.14
	SD	2.7	0.52	3.43	0.17	1.64	0.40
200 (n = 13)	Mean	18.5	2.13	9.81	1.60	4.36	1.31
	Minimum	14.0	1.49	4.96	1.17	2.93	0.94
	Maximum	30.4	3.07	22.69	2.28	5.79	1.83
	SD	4.2	0.48	4.99	0.30	0.93	0.31
Optimal value Antonkiewicz [2007] based on different sources		15–30	2.6–3.5	17–20	2.0–3.0	4.5–9.0	3.0

SD – standard deviation

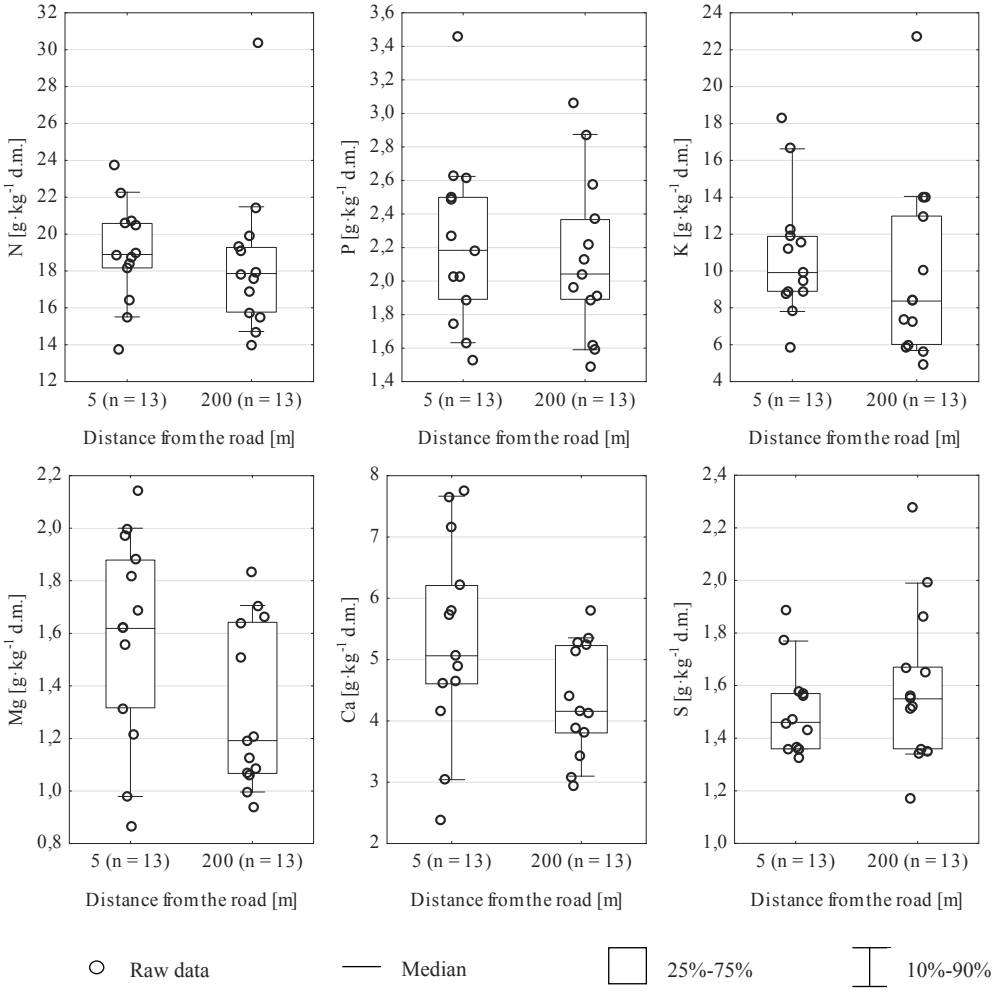


Fig. 2. Content of macroelements in plants (raw data)

Obtained values were comparable to the ones presented by Grygierzec [2012], higher than values obtained by Zarzycki and Kopeć [2015] and lower than the ones obtained in research conducted by Sabiniarz and Kozłowski [2009] and Gaweł and Nędzi [2015]. Protein content in meadow sward which was similar to the one found by the authors of this research was obtained by Zarzycki et al. [2005], who analyzed the chemical composition of meadow sward of the Pieninski National Park. The small amount of protein in hay may indicate that the harvest took place in delayed plant developmental stage [Jamróz et al. 2001].

Similarly to nitrogen content, the content of phosphorus, potassium, calcium and magnesium in the sward collected 5 m from the road was slightly higher than in the sward that was collected 200 m from the road. The mean content was, respectively: 2.23 and 2.13 g P·kg^{-1} d.m.,

10.89 and 9.81 g K·kg^{-1} d.m., 5.32 and 4.36 g Ca·kg^{-1} d.m., and 1.59 and 1.31 g Mg·kg^{-1} d.m. The increase in content of the elements near the road was 22% in the case of calcium, 21% with respect to magnesium, 11% for potassium, and 5% for phosphorus. According to Antonkiewicz [2007, based on different sources], the optimal content of macroelements in grassland fodder is: 2.6–3.5 g P (the most commonly recommended value is 3.0 g), 17–20 g K, 4.5–9.0 g Ca (the most commonly recommended value is 7.0 g), and 3.0 g Mg·kg^{-1} d.m. In authors' own research, the mean content of P, K and Mg in the sward was too low, at both distances from the road edge. The content of elements was usually lower than values obtained by Gaweł and Nędzi [2015] and higher than values published by Kotlarz et al. [2010]. Zarzycki and Kopeć [2015] obtained similar content of calcium and magnesium and lower content of phosphorus.

Sulfur content in meadow sward decides on the quality of protein, including the content of exogenous amino acids that contain this element. Sulfur content in the studied sward was slightly higher (by 7%) in the samples collected farther from the road edge, and it amounted to 1.60 g S·kg^{-1} d.m. This content was lower than the mean content for grasses in Poland (2.10 g S·kg^{-1} d.m.), as reported by Motowicka-Terelak and Terelak [2000], and lower than the optimum content of sulfur in grassland fodder (2.0–3.0 g S·kg^{-1} d.m.) [Antonkiewicz 2007, based on different sources]. Results concerning sulfur content in the sward which were obtained in the authors' own research are compliant with research results obtained by Kopeć and Gondek [2004], where the mean sulfur content in Czarny Potok was 1.77 g S·kg^{-1} d.m.

Fodder value of sward depends not only on the absolute content of elements (macroelements and microelements) but also on ratios of content of these elements. The value of the ratios of the macroelement content in the meadow sward is presented in table 2 and in figure 3. The optimal

Table 2. Ratios of content of macroelements in plants

Distance from the road (m)	Parameter	Ca:P	Ca:Mg	K:Mg	K:Ca	N:S	K:(Ca+Mg)
5 (n = 13)	Mean	2.5	3.3	7.3	2.3	12,6	1.5
	Minimum	1.4	2.4	3.6	1.1	10,4	0.8
	Maximum	4.7	4.2	14.1	5.0	14,4	3.0
	SD	1.0	0.5	3.1	1.1	1,2	0.7
200 (n = 13)	Mean	2.1	3.4	7.7	2.3	11,6	1.5
	Minimum	1.1	1.9	3.9	1.2	8,5	0.8
	Maximum	3.1	5.3	14.9	4.3	14,3	2.9
	SD	0.6	0.9	3.6	1.0	1,8	0.7
Optimal value Antonkiewicz [2007] based on different sources		2	2–3	6	2	12–15	1.6–2.2

SD – standard deviation

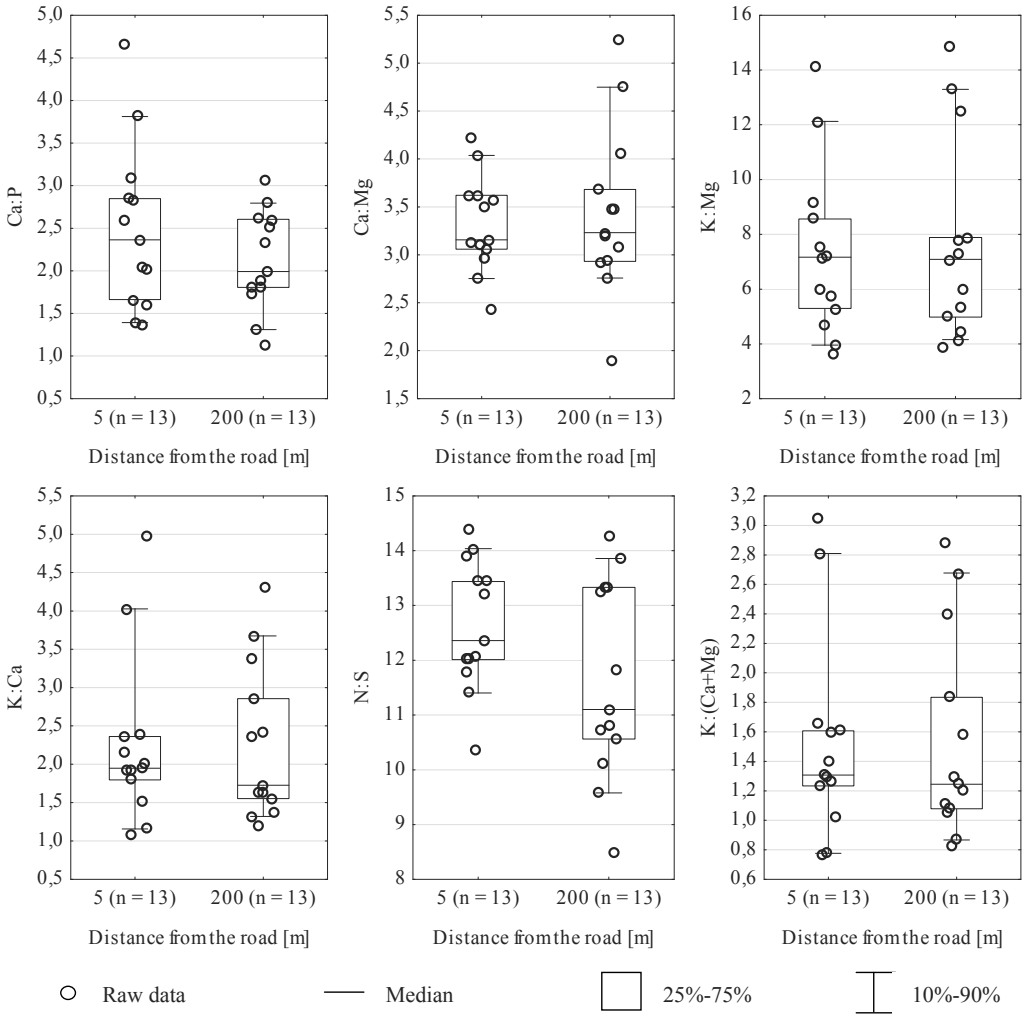


Fig. 3. Ratios of content of macroelements in the plants (raw data)

Ca:P weight ratio value in fodder should be within the range from 0.5 to 2.0, whereas the optimal Ca:Mg weight ratio value should be between 2.0 and 3.0 [Filipek 1999]. In terms of element requirements of animals, the recommended value of the Ca:P weight ratio should be between 1.7 and 2.6 (many authors state that the optimal value of the Ca:P ratio amounts to 2, because this is the ratio in which calcium and potassium occur in the human skeleton) [Antonkiewicz 2007, based on different sources]. The value of the ionic ratio K:(Ca+Mg) is an important qualitative indicator of grassland fodder. Values between 1.6 and 2.2 are considered to be optimal [Antonkiewicz 2007, after Czuba and Mazur 1996]. Data presented in Table 2 indicate that the mean

Table 3. Ratios of content of macroelements to microelements in plants

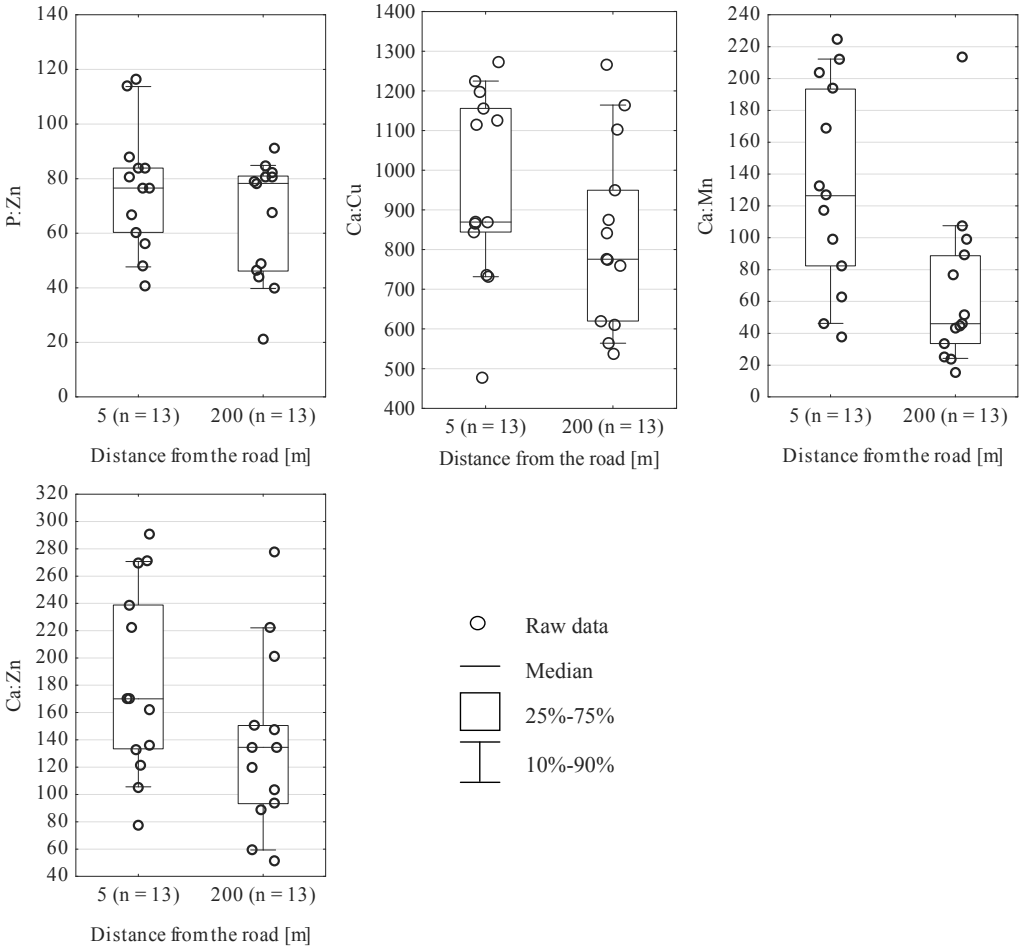
Distance from the road (m)	Parameter	P:Zn	Ca:Cu	Ca:Mn	Ca:Zn
5 (n = 13)	Mean	76	961	131	182
	Minimum	41	478	38	77
	Maximum	116	1273	224	292
	SD	23	239	65	70
200 (n = 13)	Mean	65	834	67	137
	Minimum	21	537	15	52
	Maximum	91	1266	213	278
	SD	22	233	53	65
Optimal value Antonkiewicz [2007] based on different sources		140–400	300–500	100–200	100–200

SD – standard deviation
Source of data about microelement content in plants: Filipek-Mazur et. al [2013]

value of the Ca:P, Ca:Mg, K:Mg, and K:Ca ratios took slightly higher than optimal values (at both distances from the road). Independently from the distance from the road edge, the value of the ionic ratio K:(Ca+Mg) was 1.5, which was below the bottom value for good quality fodders. The N:S weight ratio took the correct value. The results of authors' own research did not differ considerably from the results obtained by Kotlarz et al. [2010]. Barszczewski and Ducka [2012] obtained high values of K:(Ca+Mg) and K:Mg ratios in intensively fertilized plants.

Table 3 and figure 4 show values of ratios of the macroelement to microelement content in the studied meadow sward. Results concerning the content of microelements in the analyzed plants are presented in an earlier publication – it was stated that copper content was deficient and zinc content was optimal [Filipek-Mazur et al. 2013]. Values provided in this paper indicate that the mean value of the P:Zn ratio was too low, and of the Ca:Cu ratio too high, at both distances from the road. The value of the Ca:Zn ratio was optimal, and the value of the Ca:Mn ratio depended on the distance from the road – close to the road it was optimal, and farther away it was too low. Trąba and Wolański [2003] obtained much higher values of Ca:Cu and Ca:Zn ratios in sward with participation of some papilionaceous plants. Mountain meadow sward was characterized by very low values of Ca:Mn and Ca:Zn ratios [Antonkiewicz 2007, after Kopeć and Gondek 2000].

Using numerical data from an earlier publication [Filipek-Mazur et al. 2013] and numerical data presented in this study, the values of correlation coefficients between soil acidity (the number of hydrogen ions calculated on the basis of the pH_{KCl} value) and element content in the



Source of data about microelement content in plants: Filipek-Mazur et al. [2013]

Fig. 4. Ratios of content of macroelements to microelements in the plants (raw data)

sward, and the ratios between them were calculated (Table 4). Calcium content in the plants was significantly negatively correlated with the number of hydrogen ions in soil. A negative correlation was also found between the number of hydrogen ions and the value of the ratios: P:Zn, Ca:Cu, Ca:Mn and Ca:Zn.

Table 4. Correlation coefficients between soil acidity and element content in the sward, and the ratios between elements

	N	P	K	S	Ca	Mg
$[H^+]$	0,082	-0,100	-0,339	0,138	-0,418*	-0,216
	Ca:P	Ca:Mg	K:Mg	K:Ca	N:S	K:(Ca+Mg)
$[H^+]$	-0,281	-0,286	-0,229	-0,126	-0,026	-0,169
	P:Zn	Ca:Cu	Ca:Mn	Ca:Zn		
$[H^+]$	-0,549**	-0,429*	-0,653***	-0,606**		

* significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$
Source of data about soil acidity: Filipek-Mazur et. al [2013]

CONCLUSIONS

1. Content of nitrogen, phosphorus, potassium, calcium, and magnesium in the sward collected 5 m from the road was slightly higher than in the sward that was collected 200 m from the road. These relations were reversed for sulfur.
2. In terms of fodder requirements of animals, the mean nitrogen, phosphorus, potassium, sulfur and magnesium content in the sward was too low, at both distances from the road edge.
3. The mean value of the Ca:P, Ca:Mg, K:Mg, and K:Ca ratios was slightly higher than optimal values (at both distances from the road). The value of the K:(Ca+Mg) ionic ratio was 1.5, which was below the bottom value for good quality fodders. The N:S weight ratio took the correct value.
4. The value of the P:Zn ratio was too low, Ca:Cu was too high, Ca:Zn optimal, and the value of the Ca:Mn ratio was optimal close to the road, but farther away it was too low.
5. Calcium content in the plants was significantly negatively correlated with the value of soil hydrolytic acidity. A negative correlation was found between the value of soil hydrolytic acidity and the value of the P:Zn, Ca:Cu, Ca:Mn, and Ca:Zn ratios.

REFERENCES

Antonkiewicz J. 2007. Evaluation of mineral composition of fodder from meadow and pasture sward. [In:] Evaluation of the chemical composition of plants. Wiśniowska-Kielian B., Lipiński W. (red.). Oddział Krakowski Polskiego Towarzystwa Inżynierii Ekologicznej, Krajowa Stacja Chemiczno-Rolnicza, Kraków-Warszawa-Wrocław, 23–30 (In Polish).

Barszczewski J., Ducka M. 2012. Management of potassium and quality changes of sward from irrigated meadow during the long-term study. J. Res. Appl. Agric. Eng. 57(3): 6–9 (In Polish).

Falkowski M., Kukułka I., Kozłowski S. 1990. Właściwości chemiczne roślin łąkowych. AR Poznań: pp. 111.

Falkowski M., Kukułka I., Kozłowski S. 1996. Qualitative evaluation of permanent meadow sward. Zesz. Probl. Post. Nauk Rol. 442: 41–49 (In Polish).
Filipek T. 1999. Podstawy i skutki chemizacji agroekosystemów. Wyd. AR w Lublinie: pp. 242.
Filipek-Mazur B., Tabak M., Gorczyca O. 2013. Trace element content in meadow sward and soil along road No. 957 passing through Zawoja village. Ecol Chem. Eng. A. 20(6): 631–641.
Fleury P., Seres C., Dobremez L., Nettier B., Pauthenet Y. 2015. "Flowering Meadows", a result-oriented agri-environmental measure: technical and value changes in favour of biodiversity. Land Use Policy 46: 103–114.
Gaweł E., Nędzi M. 2015. Impact of cutting leavings on the botanical composition and mineral elements content in legume-grass sward in organic regime. Fragm. Agron. 32(1): 17–27 (In Polish).
Grygierzec B. 2012. The content of basic nutrients and fibre fractions in hay from extensively used *Alopecuretum pratensis* and *Holcetum lanati* communities. Łąkarstwo w Polsce/Grassl. Sci. Poland 15: 53–65 (In Polish).
Jamróz D., Podkówka W., Chachułowa J. (Ed.) 2001. Żywienie zwierząt i paszoznawstwo. Paszoznawstwo. T. 3. Wyd. PWN Warszawa, pp. 430.
Kopeć M., Gondek K. 2004. The effect of long-term diversified fertilization on sulphur contents in soil and sward of a mountain meadow. Nawozy i Nawożenie/Fert. Fertiliz. 1: 62–74 (In Polish).
Kotlarz A., Stankiewicz S., Biel W. 2010. Botanic and chemic composition of hay from semi-natural meadow and its nutritive value for horses. Acta Sci. Pol., Zootechnica 9(4): 119–128 (In Polish).
Monteiro A.T., Fava F., Hiltbrunner E., Della Marianna G., Bocchi S. 2011. Assessment of land cover changes and spatial drivers behind loss of permanent meadows in the lowlands of Italian Alps. Landscape and Urban Planning 100: 287–294.
Motowicka-Terelak T., Terelak H. 2000. Sulphur in soils and plants of Poland. Folia Univ. Agric. Stetin. 204, Agricultura 81: 7–16 (In Polish).
Ostrowska A., Gawliński S., Szczubiałka Z. 1991. Metody analizy i oceny właściwości gleb i roślin. IOŚ Warszawa: pp. 333.
Radkowska I. 2012. Effect of pasture management system on welfare of dairy cows. Wiad. Zootechniczne 50(1): 3–10 (In Polish).
Sabiniarz A., Kozłowski S. 2009. Forage aspects of Czersk Meadows. Łąkarstwo w Polsce/Grassl. Sci. Poland 12: 155–163 (In Polish).
Trąba Cz., Wolański P. 2003. Some aspects of fodder value of papilionaceous plants occuring in sward of seminatural meadows and pastures. Biul. IHAR 225: 73–79 (In Polish).
Trąba Cz., Wyłupek T. 1998. Chemical composition of soil and meadow sward of *Arrhenatheretum elatioris* association with a considerable share of papilionaceous plants. Biul. Nauk. 1: 395–401 (In Polish).
Wolański P., Trąba Cz., Rogut K. 2015. Occurrence and fodder value of herbs and meadow sward in the Dynowskie Foothills. Woda Środ. Obszary Wiejskie/Water Environ. Rural Area 15(3): 127–144 (In Polish).
Yoshihara Y., Mizuno H., Ogura S., Sasaki T., Sato S. 2013. Increasing the number of plant species in a pasture improves the mineral balance of grazing beef cattle. Anim. Feed Sci. Technol. 179: 138–143.
Zarzycki J., Gałka A., Góra-Drożdż E. 2005. Fodder value of the Pieniny National Park meadows sward used in the view of nature protection. Acta Sci. Pol., Agricultura 4(2): 119–132 (In Polish).
Zarzycki J., Kopeć M. 2015. Assessment of the influence of extensive management on the macronutrient content in the mountain grasslands sward. Fragm. Agron. 32(4): 89–96 (In Polish).

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ZAWARTOŚĆ MAKROSKŁADNIKÓW W RUNI ŁĄKOWEJ WZDŁUŻ DROGI NR 957

Synopsis. Celem badań było oznaczenie zawartości wybranych makroelementów (N, P, K, S, Ca, Mg) w próbkach roślinności łąkowej pobranej z miejsc znajdujących się w odległości 5 m i 200 m od drogi wojewódzkiej nr 957, na terenie przebiegającym przez Zawoję, oraz ocena wartości paszowej tej runi. Zawartość azotu oraz fosforu, potasu, wapnia i magnezu była nieznacznie większa w runi pobranej w odległości 5 m od drogi, w porównaniu do runi oddalonej o 200 m. Zawartość siarki była natomiast większa (o 7%) w próbkach pobranych w dalszej odległości od skraju jezdni. Z punktu widzenia wymagań paszowych zwierząt trawożernych należy stwierdzić, że średnia zawartość azotu, fosforu, potasu, siarki i magnezu w runi była zbyt mała, w obu odległościach. Średnia wartość stosunków Ca:P, Ca:Mg, K:Mg i K:Ca przyjmowała wartości nieznacznie większe od optymalnych (w obu odległościach od drogi). Wartość stosunku jonowego K:(Ca+Mg) wynosiła 1,5, a więc była poniżej dolnej wartości podawanej dla pasz dobrej jakości. Prawidłową wartość przyjmował stosunek wagowy N:S.

Słowa kluczowe: rośliny łąkowe, wartość paszowa, makroskładniki pokarmowe, zanieczyszczenia komunikacyjne

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