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NUTRITIVE VALUE AND THE CONTENT OF MACROELEMENTS IN FODDER AND IN SOIL FROM ORGANIC GRASSLANDS

Summary

Studies were carried out in the years 2006–2007 in organic farms with animal production and over 30% share of permanent grasslands in agricultural lands. Samples of green forage from meadows and pastures, of hay and hay ensilage from meadow sward were analysed for the content of total protein, crude fibre, crude fat, ash and mineral components (N, P, K, Ca, Mg and Na). In the year 2007, soil (0–20 cm layer) richness in these components was also analysed. Mean content of nutritive components in fodder reached the optimum range but the content of total protein and crude fibre was quite variable. Mean content of potassium and magnesium in all types of fodder was satisfactory, that of phosphorus – satisfactory in green fodder from pastures and slightly deficient in other types of fodder. The content of calcium was minimally deficient in hay and that of sodium was small in all types of fodder (only 0.38 g kg^{-1} DM in hay), which resulted in too high K:Na ratio (up to 242 in hay) and K:Mg ratio (ca. 10). Compared with conventional farms, more hay samples from organic farms contained more P, Ca and Mg. Potassium content in hay was comparable and Na content was much smaller in hay from organic farms. Soils of studied grasslands were in general acid or slightly acid of low phosphorus content. Very high potassium content in some soils may indicate too often applied liquid manure. Soil richness in available calcium and magnesium was exceptionally favourable and only in few cases needed supplementation. Improving management methods and periodical analyses of soil and fodder are necessary to increase grassland utilization and fodder quality.
***Key words**: organic farm, hay, hay ensilage, mineral components, nutritive value, green fodder from meadow, green fodder from pasture, soil richness, proportion of components*

WARTOŚĆ POKARMOWA I ZAWARTOŚĆ MAKROELEMENTÓW W PASZACH Z EKOLOGICZNYCH UŻYTKÓW ZIELONYCH ORAZ ZASOBNOŚĆ GLEB W TE SKŁADNIKI

Streszczenie

Badania prowadzono w latach 2006-2007 w ekologicznych gospodarstwach z ponad 30% udziałem trwałych użytków zielonych w strukturze użytków rolnych i prowadzących produkcję zwierzęcą. Analizowano próbki zielonki z łąk i pastwisk, próbki siana oraz kiszonki z runi łąkowej. Oceniano zawartość białka ogólnego, włókna surowego, tłuszczu surowego, popiołu surowego i składników mineralnych N, P, K, Ca, Mg i Na. W 2007 roku określono też zasobność gleb (warstwa 0–20 cm) w te składniki. Średnio zawartość składników pokarmowych w paszach mieściła się w granicach wartości optymalnych, ale zawartości białka ogólnego i włókna surowego były bardzo zróżnicowane. Średnie zawartości potasu i magnezu były zadowalające we wszystkich rodzajach pasz, fosforu zadowalające w zielonce pastwiskowej i nieznacznie niedoborowe w pozostałych paszach, zawartość wapnia minimalnie niedoborowa tylko w sianie, natomiast zawartość sodu mała (zaledwie 0,38 g kg^{-1} s.m. w sianie) we wszystkich rodzajach pasz, co rzutowało na zbyt wysoki stosunek K : Na (nawet 242 w sianie)i K : Mg (ok. 10). W porównaniu z zawartością składników w sianie z gospodarstw konwencjonalnych w sianie z gospodarstw ekologicznych większy był % próbek o większej zawartości P, Ca i Mg, o zbliżonym udziale K i znacznie mniejszej zawartości Na. Gleby badanych użytków były na ogół kwaśne i lekko kwaśne, o niskiej zawartości fosforu; bardzo duża w części gleb zawartość potasu może wskazywać na zbyt częste stosowanie gnojówki. Zasobność w przyswajalne magnez i wapń była wyjątkowo korzystna, tylko w nielicznych przypadkach wymagająca uzupełnienia. W celu poprawy wykorzystania TUZ i jakości ich pasz konieczne jest doskonalenie metod gospodarowania oraz okresowe badanie paszy i zasobności gleb.
***Słowa kluczowe**: gospodarstwo ekologiczne, siano, kiszonka, składniki mineralne, wartość pokarmowa, zielonka łąkowa, zielonka pastwiskowa, zasobność gleb, ilościowe stosunki składników*

1. Introduction

Permanent grasslands (PG) play important role in organic farming. Apart from maintaining grazing animals in good condition, grasslands are the fodder base in organic animal production where feeding herbivore animals is based on maximum utilization of pastures and fresh, dried or ensilaged green fodder constitutes at least 60% of daily feed ration [8, 9]. Other important function of permanent grasslands is to provide the cycling of feed components within the farm [6]. Status of grasslands and the quality of fodder obtained thereof affect animal health and condition and the quality of animal products. A lack of equilibrium between plant and animal production may exhaust plant nutrients in soils. Therefore, it is necessary to periodically control soil richness and pH and, if needed, to apply mineral additives and organic fertilisers in order to maintain soil fertility [3]. Deficit of mineral components in fodder negatively affects growth of the young and productivity of adult animals, particularly those of high milk efficiency [19].

The aim of this study was to assess the content of macroelements and nutritive value of fodder from grasslands in view of its usefulness for animal production in organic farms and to assess soil richness in these elements.

2. Material and methods

2.1. Characteristic of studied farms

Feed studies were carried out in the years 2006-2007 and soil richness studies in the 2007 in 34 organic farms situated in 8 voivodships with animal production based on fodder from permanent grasslands. Farms differed in area – five had an area between 0 and 10 ha, ten – between 10.1 and 20 ha, thirteen - between 20.1 and 50 ha and six had an area above 50 ha [1].

Permanent grasslands (PG) in studied farms occupied 49.0% of agricultural lands (AL) on average. In the year 2007 this share was 2.24 times higher than the country mean and varied from 33.5% in farms from Lubuskie Voivodship to 94.2% in Podkarpackie Voivodship. In most studied farms, soil quality was of the V and IV class, in only few farms grassland soils were of the III and IV class. These were mainly brown soils, muck-mineral and peat-muck soils, black earths, alluvial soils and even podsols.

In terms of agricultural use floristic composition TUZ also can provide information about the utility value of the sward [7]. Pasture sward was composed in 67% of grasses, in 16% of legumes, in 15% of herbs and weeds and in 2% of sedges, rushes and horsetails. Grasses were mainly represented by: *Poa pratensis* L., *Lolium perenne* L., *Lolium multiforum* L., *Festuca rubra* L. s.s., *Festuca pratensis* L., *Dactylis glomerata* L., *Agropyron repens* (L.) Beauv., *Agrostis gigantea* Roth., *Phleum pratense* L.; legumes - by *Trifolium repens* L. and *T. pratense* L. and herbs and weeds – by *Taraxacum officinale* F.H. Wigg., *Achillea millefolium* L. and *Rumex acetosa* L. The yield from meadows was produced in 70% by grasses, in 15% by herbs and weeds, in 4% by legumes and in ca. 8% by sedges. Grasses included: *Poa pratensis* L., *Festuca rubra* L. s.s., *Festuca pratensis* L., *Dactylis glomerata* L., *Phleum pratense* L., *Lolium perenne* L., *Alopecurus pratensis* L., *Deschampsia caespitosa*, *Holcus lanatus* L., herbs and weeds: *Taraxacum officinale* F.H. Wigg., *Ranunculus acer* L., *Leontodon autumnalis* L., *Cirsium arvense* (L.) Scop., *Lythrum salicaria* L., *Rumex acetosa* L., *Plantago lanceolata*, while legumes included: *Trifolium pratense* L., *T. hybridum* L. and *T. repens* L.

In fodder balance for the year 2007, the contribution of bulk fodder from PG varied from 58.8% in farms larger than 50 ha to 83.3% in farms of an area between 20.1 and 50 ha [1]. Green fodder was fed in summer and hay and hay silage from PG – in winter. That is why obtaining fodder of appropriate quality, which determines the size of animal production and farmers' main source of income, is so important [13].

2.2. Methods

Samples of hay (mainly from the first cut), of green fodder from meadows (before the first cut) and pastures (from various regrowth periods) and samples of hay silage from meadow sward were analysed. In total, 164 samples of fodder and (in the year 2007) 102 samples of grassland soils from 0–20 cm layer were analysed.

Analyses for the content of nutritive components (total protein, crude fibre, crude fat and ash) and mineral components (P, K, Ca, Mg, and Na) and chemical analyses of soils for the content of P_2O_5, K_2O, Mg and Ca were made in the Central Laboratory of Chemical Analyses at IUNG-PIB in Puławy. In fodder, total protein based on the content of N, crude fibre was determined gravimetrically, crude fat - with gravimetric method after Soxhlet, ash – gravimetrically after combustion at 580°C. Macroelements were determined after preliminary wet mineralization in a mixture of concentrated acids. Nitrogen and phosphorus was determined with a through-flow colorimetry, potassium and sodium – with the flame emission spectrophotometry and magnesium and calcium – with the atomic absorption spectrophotometry. In soils, nitrogen content was determined after mineralization of soil samples in concentrated H_2SO_4, available phosphorus and potassium – in Egner-Riehm extracts, magnesium – in soil extracts with 0.05 M dm^{-3} $CaCl_2$ and calcium – after extraction with 0.03 M dm^{-3} CH_3 COOH.

3. Results

3.1. Analyses of fodder

Nutritive components. Mean and ranges of the content of nutritive components in fodder are given in table 1. Total protein content was differentiated and ranged: from 63.1 to 195.6 g kg^{-1} DM in hay, from 56.9 to 210.1 g kg^{-1} DM in meadow sward and from 88.1 to 296.8 g kg^{-1} DM in pasture sward. According to Brzóska [2] the minimum protein content in fodder that covers the requirements of highly efficient dairy cows is 150–170 g kg^{-1} DM. Fodder of smaller protein content does not stimulate microbial (mainly bacterial) growth in the rumen sufficiently. Hence, the decreased input of bacterial protein to the small intestine, which negatively affects digestion of crude fibre from green fodder and decreases the digestibility of all nutritive components. The minimum range of protein content was obtained only in pasture sward (mean 157.8 g kg^{-1} DM), in other types of fodder the content of protein was smaller and varied from 110.0 to 130.0 g kg^{-1} DM, on average.

The content of crude fibre, decisive for fodder digestibility, was as a rule negatively correlated with total protein content. Mean contents from the two study years were similar in hay, meadow sward and silage (305.85, 309.55 and 307.3 g kg^{-1} DM, respectively) and slightly smaller in pasture sward (267.1 g kg^{-1} DM). The content of fibre, similarly to protein content, varied largely from 213.7 to 390.4 g kg^{-1} DM in hay and meadow sward and from 172.6 to 364.6 g kg^{-1} DM in pasture sward (tab. 1).

Fat content in both years was highest in the green fodder from pastures with mean content of 39.2 g kg^{-1} DM and range from 24.4 to 49.9 g kg^{-1} DM and the lowest in hay with mean 29.8 g kg^{-1} DM and range 20.8 to 40.0 g kg^{-1} DM. Fat content in hay ensilage (both mean and range) was similar to that in hay. Large variations were noted in the fat content of green fodder from meadows – from 21.3 to 53.3 g kg^{-1} DM with a mean of 32.65 g kg^{-1} DM. Fat content largely depended on the growth phase of plants during harvesting or grazing.

Part of samples, particularly of green fodder, contained much ash (140-150 g kg^{-1} DM) mainly because of their contamination with soil. Also some samples of hay silage were probably contaminated with sand and hence contained over 120 g kg^{-1} DM of ash.

Based on the mean content of nutritive components, the value of analysed feeds may be considered appropriate and their composition close to that given in nutritive norms [17]. Large variations were, however, found in the content of some components, especially of total protein in green fodder from meadows and pastures (tab. 1). The differences

resulted probably from inappropriate (too early or too late) terms of mowing and grazing and from improper technology of harvest and conservation of hay and silage. Delayed mowing, particularly of the first cut, increases crude fibre content in fodder and decreases protein content, digestibility and nutritive value [19].

Table 1. Mean and range of the content of nutritive components in fodders from grasslands in organic farms (years 2006-2007)
Tab. 1. Zawartość średnia i wahania zawartości składników pokarmowych w paszach z TUZ w gospodarstwach ekologicznych (lata 2006–2007)

Type of fodder	Years	Nutritive components, g kg^{-1} DM			
		crude ash	total protein	crude fat	crude fibre
Green fodder from pastures	2006	91.6	163.4	43.5	253.4
	2007	82.8	152.2	34.9	280.8
	mean	**87.2**	**157.8**	**39.2**	**267.1**
	range	57.8–156.6	88.1–296.8	24.4–49.9	172.6–364.6
Green fodder from meadows	2006	75.6	109.6	33.2	305.2
	2007	69.8	124.3	32.1	313.9
	mean	**72.7**	**116.95**	**32.65**	**309.55**
	range	29.3–147.9	56.9–210.1	21.3–53.3	213.7–390.4
Hay	2006	68.4	92.8	27.2	312.9
	2007	77.8	122.2	32.4	298.8
	mean	**73.1**	**107.5**	**29.8**	**305.85**
	range	29.8–109.8	63.1–195.6	20.8–40.0	217.6–374.1
Ensilage	2005	92.3	129.5	24.8	302.6
	2006	72.3	123.1	35.8	312.0
	mean	**82.3**	**126.3**	**30.3**	**307.3**
	range	43.8–123.8	79.3–176.8	21.5–41.7	218.0–361.9

Source: Own work / Źródło: opracowanie własne

Table 2. Mean and range of the content (g kg^{-1} DM) of analysed mineral components in fodders from permanent grasslands in organic farms in the years 2006-2007
Tab. 2. Średnie i wahania zawartości (g kg^{-1} s.m.) badanych składników mineralnych w paszach z TUZ w gospodarstwach ekologicznych w latach 2006–2007

Analysed component	Year	Type of analysed fodder			
		hay	green fodder from meadows	green fodder from pastures	hay ensilage
N	2007 mean	19.6	19.6	24.4	-
	range	12.4–26.3	11.0–26.7	15.6–47.5	
P	2006	2.2	2.4	3.5	2.9
	2007	2.8	2.8	3.3	2.7
	mean	**2.5**	**2.6**	**3.4**	**2.8**
	range	1.3–4.0	1.5–4.2	0.8–6.0	1.6–3.7
K	2006	15.1	16.5	24.8	25.3
	2007	20.6	18.3	22.9	23.1
	mean	**17.9**	**17.4**	**23.9**	**24.2**
	range	6.5–28.9	3.8–34.0	6.3–46.2	10.1–35.2
Ca	2006	6.0	7.6	9.4	5.7
	2007	6.7	7.0	7.6	11.3
	mean	**6.4**	**7.3**	**8.5**	**8.5**
	range	2.7–11.2	3.4–18.2	4.5–16.1	3.6–14.2
Mg	2006	2.1	2.7	3.1	1.8
	2007	2.0	2.3	2.4	2.8
	mean	**2.1**	**2.5**	**2.8**	**2.3**
	range	0.80–3.60	1.20–5.67	1.50–4.99	1.11–3.30
Na	2006	0.44	0.78	0.96	0.29
	2007	0.32	0.73	0.77	not analysed
	mean	**0.38**	**0.76**	**0.87**	not analysed
	range	0.02–1.80	0.05–3.21	0.10–3.47	0.20–0.37*)

*) Ranges in 2006

Source: Own work / Źródło: opracowanie własne

M i n e r a l c o m p o n e n t s . Together with the assessment of nutritive value, the content of mineral components (P, K, Ca, Mg and Na) was determined in fodder. These elements ensure proper physiology of animals and their deficit may negatively affect the growth of the young and productivity of the adults, especially those of high milk efficiency. This is particularly important with fodder from grasslands which is basic and in summer the only feed for ruminants in organic farming [9].

According to Falkowski [4], satisfactory concentrations of elements in fodder from grasslands should amount (in g kg^{-1} DM.):
– P – 3.0 in hay and 3,5 in green fodder from pastures (7.0 and 8.0 g P_2O_5);
– K – 16.6 (20.0 g K_2O);
– Ca – 7.0 (10.0 g CaO);
– Mg – 2.0 in hay and 2.7 in green fodder from pastures (3.3 and 4.5 g MgO);

– Na – 1.0 in hay and 1.5 in green fodder from pastures (1.3 and 2.0 g Na_2O).

The mean content and range of mentioned components in analysed fodders are given in table 2. Threshold minimum content of total protein in fodder acc. to Brzóska [2] is 150-170 g in kg DM, which corresponds to 24.0-27.2 g N/kg DM. The richest in total N among analysed samples was green fodder from pastures (tab. 2). It contained 24.4 g N in kg DM, on average, but some samples showed the concentration of even 47.5 g kg^{-1} DM. Excessive amounts of nitrogen (protein) consumed by animals may result in its excretion in faeces and losses of this component. Such excretion usually takes place in the beginning of grazing when young plants contain much total protein and less structural components in relation to ruminants' demands [10].

Calcium, phosphorus and partly magnesium are the main components of bone tissue and sodium and potassium – the components of fluid body tissues. Mean content of p h o s p h o r u s was satisfactory in the green fodder from pastures (3.4 g kg^{-1} DM) and slightly deficient in other types of fodder: in green fodder from meadows, hay and hay silage (from 2.5 to 2.8 g kg^{-1} DM).

Mean content of p o t a s s i u m was satisfactory in all types of fodder and amounted ca. 24 g in kg DM in green fodder from pastures and in hay silage and over 17 g kg^{-1} DM in green fodder from meadows and in hay. Differences between extreme values were, however, large and amounted from 3.8 to 46.2 g K in kg DM. In 6.6% of fodder samples [1] they were smaller than the threshold value of 8.3 g kg^{-1} DM, when soil is considered impoverished in this element and in further 12.1% of samples they fell in the range of 8.4 to 11,6 g kg^{-1} DM, when soil is very poor in potassium [11]. Depletion of soil potassium or its low content limits yield increments. Therefore, it is necessary to analyse soil richness in potassium and its content in fodder. The excess of potassium inhibits calcium, magnesium and sodium uptake and may disturb cation balance in plant and animal organisms. Potassium content exceeding 30.0 g in kg DM of fodder is considered undesired for animals, especially in pasture feeding.

C a l c i u m content in grassy sward is relatively low (4.0-8.0 g kg^{-1} DM), more calcium contain clovers (9.0–15.0 g kg^{-1} DM) and some herbs (12.0-30.0 g kg^{-1} DM) [5]. The content of 7,0 g Ca kg^{-1} DM is considered satisfactory in fodder from PG [4] and hence its mean content was slightly deficient only in hay (6.4 g kg^{-1} DM) with relatively low variability (from 2.7 to 18.2 g kg^{-1} DM). M a g n e s i u m content was also satisfactory in all types of fodder. It showed low variability among samples and exceeded 2.0 g kg^{-1} DM, which is the optimum value for fodder from PG.

S o d i u m content in all types of analysed fodder was extremely low. In only 27% of samples it exceeded 1.0 g Na per kg DM considered satisfactory for hay. Mean Na content in hay was only 0.38 g kg^{-1} DM, in green fodder from meadows – 0.76 g kg^{-1} DM s.m. and in green fodder from pastures – 0.87 g kg^{-1} DM. There were samples of sodium content equal 0.02 or 0.005 g kg^{-1} DM but in some the content exceeded 3 g kg^{-1} DM.

In general, though mean concentrations of macroelements in fodder were satisfactory (except Na) or slightly deficient, they showed remarkable variation (tab. 3). The latter was especially true for phosphorus and potassium. Usually low potassium contents were accompanied by the low content of other macroelements and characterised fodder from definite farms. This indicates improper fertilisation and the need of increasing soil richness and periodical analyses of soil and fodder, particularly in farms with fodder low in P and K.

Table 3. Comparison of mineral components content in fodders from grasslands in organic farms (years 2006–2007) and in hay from the country-wide study [4]

Tab. 3. Porównanie zawartości składników mineralnych w paszach z użytków zielonych w gospodarstwach ekologicznych (lata 2006–2007) i w sianie z badań krajowych [4]

Analysed component	Data from literature [3]			Results from organic farms			
	hay			hay and green fodder from meadows		green fodder from pastures	
	ranges g kg^{-1} DM	number of samples	% of samples	number of samples	% of samples	number of samples	% of samples
P	<1.3	4 400	8.0	100	1.0	53	1.9
	1.4–2.0		32.7		24.0		9.4
	2.1–2.6		29.8		30.0		11.3
	>2.6		29.5		45.0		77.4
K	<12.5	4 452	22.5	100	29.0	53	7.5
	12.6–16.6		22.2		16.0		20.7
	16.7–24.9		38.6		42.0		30.2
	>24.9		16.7		13.0		41.6
Ca	<5.0	3 950	32.8	100	18.0	53	5.7
	5.1–7.0		31.5		39.0		30.2
	7.1–9.0		17.1		30.0		26.4
	>9.0		18.6		13.0		37.7
Mg	<1.2	3 055	25.4	100	4.0	53	0
	1.3–1.8		24.0		24.0		13.2
	1.9–2.4		23.1		35.0		26.4
	>2.4		27.5		37.0		60.4
Na	<1.5	1 599	61.5	100	89.1	53	84.9
	1.6–2.9		21.9		9.9		13.2
	3.0–5.9		13.2		1.0		1.9
	>5.9		3.4		0		0

Table 4. Quantitative proportions (by weight) of potassium, calcium, magnesium and sodium in fodder from PG in organic farms (in g kg^{-1} DM) in the year 2007

Tab. 4. Ilościowe stosunki (wagowe) potasu, wapnia, magnezu i sodu w paszach z TUZ w gospodarstwach ekologicznych (w g kg^{-1} s.m.) 2007 r.

Components	Value	Type of fodder (number of samples)		
		hay (17)	green fodder from meadows (36)	green fodder from pastures (24)
K : (Ca + Mg)	mean	2.47	2.22	2.55
	range	0.96–4.65	0.64–6.04	1.41–5.12
	optimum			1.9–2.2*
K : Na	mean	242.02	91.53	81.12
	range	12.57–892.70	2.47–574.0	9.77–280.0
	optimum	5 : 1**	5 : 1***	max 10.0*
Ca : P	mean	2.45	2.55	2.44
	range	1.59–4.25	1.11–4.22	1.26–5.53
	optimum			1.8–2.1*
K : Mg	mean	10.49	9.02	10.83
	range	4.00–19.69	1.86–19.43	5.20–20.86

***** Wasilewski [18]; ** Falkowski [4]; *** Falkowski et al. [5]

Table 5. pH and the content of mineral components (in mg/100 g of soil) in soils from permanent grasslands and arable lands of studied organic farms

Tab. 5. Poziom pH oraz zawartość wybranych składników mineralnych (mg w 100 g gleby) w glebach TUZ i gruntów ornych badanych gospodarstw ekologicznych

Component	Value	Type of land (number of samples)		
		meadows (61)	pastures (32)	arable lands (9)
pH in KCl	range	3.99–7.45	4.30–7.48	4.82–7.29
% total N	mean	0.58	0.40	0.12
	range	0.09–3.39	0.10–1.22	0.07–0.24
P_2O_5	mean	9.45	9.81	11.47
	range	<1.0–63.84	<1.0–46.30	4.27–20.12
K_2O	mean	16.17	11.06	10.60
	range	1.81–88.00	1.73–40.35	4.21–21.23
Mg	mean	12.80	11.46	7.83
	range	2.35–29.75	3.05–19.89	4.15–13.33
Ca	mean	568.90	474.47	174.49
	range	74.80–3545.18	86–3266.14	80.09–730.60

Source: Own work / Źródło: opracowanie własne

In both study years green fodder from pastures showed higher content of mineral components. This was partly a result of fertilisation with animal faeces and of grazing plants in younger growth stage, usually richer in macroelements, especially in nitrogen. This type of fodder was also characterised by a high variability of mineral components, which is an evidence of variable soil richness, especially in phosphorus and potassium.

Results obtained in organic farms were compared with the country-wide analyses of hay [4] based on a large representative population of samples from various regions (tab. 3). It appeared that more samples of hay from organic farms showed higher content of P, Ca and Mg and similar K content (tab. 3). However, sodium content in hay and in green fodder from pastures was much lower than in samples representative for hay in Poland. Sodium deficit was found in almost 90% of samples.

Quantitative proportions (by weight). Optimum K : (Ca + Mg) ratio in fodder from pastures is 1.9–2.2, while in analysed samples it was higher on average and amounted 2.55 in green fodder and 2.47 in hay (tab. 4). Giving feed of different proportions may disturb mineral balance in animals and in extreme cases may lead to diseases like hypomagnesemia [19].

Correlation between K and Na in plants is negative; high concentrations of K decrease Na content [5]. Appropriate K:Na ratio should be 5:1, which is hard to achieve in practice. In analysed fodder from organic farms the ratio was also unfavourable and ranged from 81 in green fodder from pastures to over 242 in hay. Optimum value of this index should be 10 at maximum [18] (tab. 5). Falkowski et al. [5] explained observed K:Na ratios of 40:1 by the common excess of potassium accompanied by sodium deficit. In such situation, sodium should be supplemented in animals diet e.g. in a form of salt-licks, which was declared by all cooperating farmers [1].

Calcium and phosphorus should be present in fodder in strict proportions with the optimum ratio between 1.8 and 2.1 (tab. 4). In all analysed types of fodder the ratio was slightly higher. Upper range of the Ca:P ratio was 4.2 in hay and green fodder from meadows.

K:Mg ratio in fodder from permanent grasslands may be an indicator of environmental changes [15]. In all analysed types of fodder the ratio was 10.0 on average, compared with 8.3 adopted as an optimum value in good hay. This is an evidence of a lack of ionic equilibrium in plant uptake and suggests a need of balanced fertilisation of soils with potassium, supplementation in magnesium and limitation of possible magnesium leaching.

3.2. Results of soil analyses

Soil pH is the basic factor affecting the availability of plant nutrients. Unfortunately, ca. 60% of agricultural lands in Poland are acidic and acidification still progresses. Soil acidity (pH_{KCl}) in PG of studied farms varied from 4.0 to 7.5 (tab. 5). Very acid were mainly meadow soils (20% samples of pH below 4.5) compared with soils from pastures (3% samples of that pH). Acid soils (pH_{KCl} up to 5.5) prevailed in meadows (25% soil samples) and pastures (50% of samples) (tab. 6).

Optimum pH_{KCl} of mineral soils under grasslands is 5.0–6.0 and that of organic soils is 4.5–5.0. Inappropriate (below 5.0) pH was found in ca. 34% of analysed soils under meadows and 25% of soils under pastures. Considering the tolerance of grasses (prevailing group of grassland plants) to soil pH, recorded pH was not limiting factor for grasses but it could have hampered the growth of legumes. The greatest requirements for liming was found in 8 out of 34 studied farms where soil pH was about 4.

Table 6. Acidification of soils under grasslands in studied organic farms
Tab. 6. Ocena poziomu zakwaszenia gleb użytków zielonych w badanych gospodarstwach ekologicznych

Reaction*	pH_{KCl} range	Per cent of soil samples under:		
		meadow	pasture	arable land
Very acid	up to 4.5	19.7	3.1	0
Acid	4.6–5.5	24.6	50.0	22.2
Slightly acid	5.6-6.5	21.3	28.1	55.5
Neutral	6.6-7.2	22.9	12.6	22.2
Alkaline	above 7.3	11.5	6.2	0

* Obojski, Strączyński [12]

Mean content of available phosphorus (P_2O_5) in analysed soils was usually low and did not exceed 10 mg per 100 g soil (tab. 5), which can prevent optimum performance of the sword and does not protect the nutritional requirements of animals [16]. In most analysed soils (47% samples from meadows and 37% samples from pastures) the content was very low (<5.0 mg per 100 g of soil) (tab. 7). In several farms the content was extremely high exceeding 60 mg per 100 g of soil from meadows and 40 mg per 100 g of soil from pastures. The latter was probably caused by intensive application of natural fertilisers. Further increasing of P content will not increase the yield markedly but may pose a risk of surface water pollution [14].

Table 7. The content of available phosphorus in soils from studied organic farms in 2007
Tab. 7. Ocena zawartości przyswajalnego fosforu w glebach badanych gospodarstw ekologicznych (2007 r.)

Class of richness*	P_2O_5 content mg per 100 g of soil	Per cent of soil samples under:		
		meadows	pastures	arable lands
Very low	< 5.0	47.5	37.5	11.1
Low	5.1–10.0	24.6	28.1	22.2
Mean	10.1–15.0	13.1	15.6	44.5
High	15.1–20.0	3.3	6.2	11.1
Very high	> 20.1	11.5	12.6	11.1

* Obojski, Strączyński [12]

The content of available potassium (K_2O) was significantly higher in soils from meadows (mean 16.17 mg per 100 g of soil) than from pastures (mean 11.06 mg per 100 g of soil) (tab. 5). According to Moraczewski [11] K content below 15 mg K_2O in 100 g of soil is insufficient. It means that 57% of analysed meadow soils and 72% pasture soils need fertilisation with potassium, preferably in manure or in allowable mineral fertilisers.

The content of available magnesium (Mg) in analysed soils from grasslands was exceptionally favourable. The content was 12 mg per 100 g of soil being significantly higher than in soil samples from arable lands. In only three of the studied farms, grassland soils may be enriched with magnesium for example by applying magnesium-calcium lime [1].

Mean calcium content in analysed soils from grasslands was about 500 mg in 100 g of soil being several times higher than in soils from arable lands. Therefore, grassland soils may be considered very rich in calcium. There were, however, great differences in Ca content among samples and farms. In some farms, especially in Kujawsko-Pomorskie Voivodship, Ca content ranged from 80 to over 3000 mg per 100 g of soil. These soils had weakly alkaline pH and did not require liming [1].

Mean content of total N in samples of soil from meadows was 0.58% and was by 0.18% higher than the content in soil samples from pastures.

4. Conclusions

1. Nutritive value of analysed fodder was similar or slightly better than that given in nutritive norms. Total protein and crude fibre contents showed, however, great variability, which evidenced a lack of matching harvesting or grazing terms with the phase of sward maturity.
2. Mean contents of N, K, Ca and Mg in fodder from grasslands of organic farms were moderate and fell within the range considered optimum. The content of potassium and magnesium was satisfactory in all types of fodder, that of phosphorus was satisfactory in green fodder from pastures and slightly deficient in other types of fodder. Calcium content was slightly deficient and exceptionally great deficits were noted for sodium. Therefore, the unfavourable K:Na ratio was several times higher than the optimum.
3. More samples with higher content of phosphorus, calcium and magnesium, similar share of samples with comparable amounts of potassium and much worse results for sodium were found in fodder from organic farms compared with the country mean values for hay.
4. In all types of fodder, the content of macroelements (especially of phosphorus and potassium) showed a high variability. Samples low in potassium had also lower concentrations of other elements which was typical for some definite farms. In some samples, potassium content was extremely low, which may evidence exhaustion of available potassium from soil or its low content in some types of soil.
5. Green fodder from pastures appeared the richest in all mineral components, hay was the poorest fodder. This can partly be explained by fertilisation with animal faeces and by grazing in the younger growth stage of sward, which contains more macroelements. The content of mineral components underwent a great variability, which may indicate different soil richness, especially in phosphorus and potassium, and improper fertilisation management.
6. Analysed soils of grasslands were acid or slightly acid. The content of available phosphorus was usually low (not

exceeding 10 mg per 100 g of soil) with the exception of few farms where it exceeded 30 mg per 100 g of soil, probably due to application of large amounts of organic fertilisers. Very high content of potassium in some samples may indicate too often application of liquid manure but a half of samples showed K deficits. This points to a need of fertilisation, preferably with manure. Available magnesium and calcium content was satisfactory and only few soils required fertilisation with magnesium lime.

7. To improve fodder utilisation and quality it is necessary to enhance management methods, fertilisation and technology of fodder preparation, especially in basically animal farms of a big share of PG. Moreover, there is a need of periodical analyses of soil richness and fodder quality in farms of extreme (too low or too high) contents of phosphorus and potassium.

8. The K:Mg ratio in fodder from PG is considered an indicator of environmental changes. Its measured value of 10, confronted with the optimum value of 8.3 in hay, suggests a lack of ionic balance in plant uptake and points to a need of balanced soil fertilisation with potassium, of soil enrichment with magnesium and limitation of its possible leaching.

5. References

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