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NATURE AND FODDER VALUE, YIELDING AND CALORIFIC VALUE OF RUSHES OF GREAT MANNA GRASS *GLYCERIETUM MAXIMAE* HUECK 1831 FROM EXTENSIVELY MANAGED MEADOWS

Summary

Studies concerning nature and fodder value, yielding and calorific value of the community Glycerietum maximae Hueck 1831 from extensively managed meadows were conducted in the years 2012-2015 in the Noteć valley varying in moisture content and trophic conditions. The analyses were made on a total of 28 relevés of the association, prepared according to the Braun-Blanquet method [1]. Recorded data included the taxonomic affiliation, botanical composition of the association, percentage shares of individual species in the community as well as the current habitat conditions based on Ellenberg's indicator values [3]: F, R and N, while moisture content conditions were determined according to Oświt [20]. Mean values of EIVs and Oświt's indexes showed a significant effect of moisture content, soil reaction and nitrogen content on trophic conditions, species composition of flora, yield and economic value as well as species diversity. These indicators indicate their applicability in the evaluation of directions in the transformation of rush flora. In their typical form the rushes are strongly dominated by one species Glyceria maxima, (S= IV and D =6485.0). This community due to strong inundation, late cutting, lack of fertilisation or cultivation has poor swards (FVS=2.2) of low fodder value and moderate nature value. However, thanks to huge yielding potential and relatively high fibre content it is one of the most promising energy crops, which is confirmed by the calculated lower heating value of 17.1 MJ·kg^{-1} DM and higher heating value of 18.1 MJ·kg^{-1}s.m.
***Key words**: biomass, chemical composition, higher heating value, energy value, production of energy and heat, energy source*

WALORY PRZYRODNICZO-UŻYTKOWE, PLONOWANIE I WARTOŚĆ ENERGETYCZNA SZUWARU MANNOWEGO *GLYCERIETUM MAXIMAE* HUECK 1831 Z ŁĄK UŻYTKOWANYCH EKSTENSYWNIE

Streszczenie

Badania dotyczące walorów przyrodniczych, użytkowych, plonowania i wartości energetycznej zbiorowiska Glycerietum maximae Hueck 1831 z łąk ekstensywnie użytkowanych przeprowadzono w latach 2012-2015 w dolinie Noteci o zróżnicowanych warunkach wilgotnościowych i troficznych. W badaniach wykorzystano i przeanalizowano 28 zdjęć fitosocjologicznych wykonanych metodą Brauna-Blanqueta [1]. Określono systematykę, skład botaniczny zespołu, procentowy udział gatunków w zbiorowisku oraz aktualny stan warunków siedliskowych na podstawie wartości liczb wskaźnikowych Ellenberga [3]: F, R i N, a także identyfikację warunków wilgotnościowych metodą Oświta [20]. Średnie wartości wskaźników Ellenberga i Oświta, wykazały istotny wpływ wilgotności, odczynu gleby i zawartości azotu w glebie na warunki troficzne, skład gatunkowy flory, plon i wartość gospodarczą oraz różnorodność gatunkową. Wskaźniki te wskazują na możliwości ich zastosowania w ocenie kierunkowości przemian flory szuwaru. W typowej formie szuwar zdominowany jest przez jeden gatunek Glyceria maxima, (S= IV i D =6485,0). Zbiorowisko ze względu na silne podtopienia, późne koszenie, brak nawożenia i pielęgnacji ma ruń ubogą (Lwu = 2,2) o małej wartości użytkowej i umiarkowanych walorach przyrodniczych. Ze względu jednak na ogromny potencjał plonotwórczy oraz stosunkowo wysoką zawartość włókna, należy do najbardziej perspektywicznych roślin energetycznych. Potwierdza to wyliczono wartość energetyczna w MJ·kg^{-1} s.m., która wynosi 17,1 i ciepło spalania – 18,1 MJ·kg^{-1}s.m.
***Słowa kluczowe**: biomasa, skład chemiczny, ciepło spalania, wartość energetyczna, produkcja energii i ciepła, źródła energii*

1. Introduction

Phytocenoses with great manna grass (*Glycerietum maximae* Hueck 1831) are some of the most common Phragmition rushes found at variable water levels. It results from field observations that *Glycerietum maximae* is frequently formed in shallow oxbow lakes, along drainage ditches and in slow flowing watercourses within river valleys [8]. In the typical form these rushes are dominated by one showy, 1.5m tall species - *Glyceria maxima*, accounting for as much as over 90% mass of the entire yield of dense swards. Other plant species forming this community include plants representing mainly the classes of *Lemnetea, Potametea, Phragmitetea, Bidentetea tetrahit* and *Alnetea*

glutinosae [14, 21]. Great manna grass is relatively frequently found in the Noteć and Warta river valleys [2, 21] in phytocenoses of 20-500 m^2, occasionally up to 1000 m^2, in locations when the ground is silty due to drying of cyclic river inundation deposits. It is also found at shores of water bodies or banks of watercourses with very slow water flow. As a rule it is found in wide, swampy river valleys of organic character [8]. It grows on fertile soils, mostly frequently with peaty substrates, covered with water for a greater part of the year (up to 30-40 cm land surface), while in the summer water may retreat even below ground surface. The soils have typical properties, characteristic of soils of Poland with similar genesis [14]. They have high organic matter contents, advantageous soil reaction and satisfactory nitrogen content. Their water permeability may be considered optimal and retention potential as good. At sustainable management natural processes of evolution – degradation may progress at a natural rate. They constitute very good substrate for the development of valuable plant communities. Phytocenoses with great manna grass are sensitive to fluctuations in the water levels and retreat when the water table is considerably lowered [2, 6, 13].

Rushes of great manna grass *Glycerietum maximae* Hueck 1931, thanks to their huge yielding potential and relatively high fibre content, are considered to be some of the most promising energy crops. When cut early, before flowering, the plant provides good ensiling material, while it is less typically used as green forage or hay due to the hazard of cyanogenic glycosides or liver fluke larvae [19]. This grass shows water purification capacity, similarly as reed.

At present communities of Phragmition and sedge rushes, due to changes in management systems as well as changes in hydrological and soil conditions or their complete exclusion from agricultural use, are exposed to degeneration processes, consisting first of all in floristic depletion.

The aim of this study was to assess floristic diversity, nature value, yielding and calorific value of biomass with the predominance of great manna grass as material which may be used as energy crops.

2. Methods of the study

Geobotanical analyses of the community *Glycerietum maximae* were conducted in the vegetation period of 2009-2013 in the Noteć Leniwa and Bystra river valleys, at the Białośliwie-Radolinek course, while in the years 2014-2016 in the Nowe Dwory, Marianowo-Lubcz Wielki river courses. A total of 42 relevés were prepared according to Braun-Blanquet [1], with areas depending on the community structure and phytocenosis homogeneity, ranging from 10 to 400 m^2, located at 28 sites of the river valley. The plant community was subject to floristic and phytosociological analyses and classified applying the syntaxonomic system according to Matuszkiewicz [17]. The species nomenclature was adopted according to Mirek et al. [18]. Within the community the taxonomic affiliation, botanical composition of the association, the percentage shares of species in the community, the distribution of the degrees of constancy in the association and the current habitat conditions based on Ellenberg's indicator values [3]: F, R and N, as well as moisture contents determined according to Oświt [20] were recorded. Nature value of identified communities was evaluated on the basis of the number of species and the Shannon-Wiener diversity index (H'). Fodder value was estimated based on the yield of dry matter and fodder value score (FVS) according to Filipek [4].

Ash content, moisture content as well as higher and lower heating values were determined using a calorimeter at the Institute of Chemical Wood Technology, the Poznań University of Life Sciences. Higher heating value was determined according to the PN-81/G-04513 standard in a ZKL-4 calorimeter, dedicated to HHV measurements of solid fuels. Values were calculated using the formula:

$$Q^a_s = [C(D_t-k)-c]/ m \text{ [kJ/kg]}$$

where:
C – heat capacity of a calorimeter of 12 783.69 [J/^{o}C],
D_t – total temperature increment for the main period [^{o}C],
k – adjustment for heat exchange with the medium [^{o}C],
c – total adjustment for additional heat effects [J],
m – fuel weight.

In order to provide a more comprehensive characteristic of the analysed material its calorific value was also calculated, i.e. higher heating value reduced by the heat of vaporization of water released from fuel during its combustion. These values were calculated from the formula:

$$Q^a_i = Q^a_s - 24.42(W^a - 8.94H^a) \text{ [kJ/kg]},$$

where:
Q^a_s – mean higher heating value of solid fuel in analytical state [J/g],
24.42 – heat of water vaporization at 25^{o}C corresponding to 1% water in fuel [J/g],
W^a – moisture content in analytical sample of fuel [%],
8.94 – conversion factor of hydrogen content to water.

3. Analytical results and their discussion

3.1. Floristic analyses

A total of 21 plant species were recorded in the community phytocenoses, mainly from the class *Phragmitetea* along with scarce representatives from the classes *Lemnetea*, *Bindentea tripartiti* and *Molinio-Arrhenatheretea* (Table 1), which shows that it is a relatively poor community. This regularity has been confirmed by many researchers in their studies [2, 8, 11, 21]. The highest percentage share in the sward was recorded for grasses at 81.1%, with a marked predominance of great manna grass (*Glyceria maxima*) at 72.3%. Sedges as well as herbs and weeds, among which species from the families *Asteraceae*, *Polygonaceae*, *Rubiaceae* and *Ranunculaceae* predominate, have 10.8% and 18.6% shares in the sward, while Fabaceae (Leguminoceae) were not reported.

In the analysed phytocenoses characteristic species were identified, with 14 belonging to the class *Phragmitetea*, 4 species - to the class *Molinio-Arrhenatheretea*, 2 species to the class *Lemnetea* and 1 species to the class *Bindentea tripartiti*. The occurrence of species from the class *Molinio-Arrhenatheretea*, i.e. semi-natural and anthropogenic meadow and pasture communities, may indicate changes in habitat moisture contents in the vegetation season, which promote colonisation by species requiring less moist habitats.

The diversification of phytocenoses in the community with *Glycaria maxima* results from a large number of factors. One of the most important measures of floristic diversity in phytocenoses is provided by the Shannon-Wiener index. In a scale proposed by Jurko [12] it takes the mean

value H' = 2.1 (Table 2). Native species predominate in the community, including over 25.6% of spontaneophytes.

Table 1. Floristic diversity of the association *Glycerietum maximae*
Tab. 1. Różnorodność florystyczna zespołu Glycerietum maximae

Family / Syntaxon	Percentage share in association	Degree of constancy (S)	Systematic value (D	Characteristic species for class
Poaceae				
- Glyceria maxima	72.3	V	6485.0	Ch. *Phragmitetea*
- Phalaris arundinacea	4.9	II	62.8	Ch. *Phragmitetea*
- Phragmites australis	2.8	II	18.2	Ch. *Phragmitetea*
- Glyceria fluitans	0.7	I	4.9	Ch. *Phragmitetea*
- Agrostis stolonifera	0.4	I	0.7	Ch. *Molinio-Arrhenatheretea*
Total	81.1			
Sedges				
- Carex gracilis,	5.9	II	124.8	Ch. *Phragmitetea*
- Carex acutiformis	4.7	II	24.2	Ch. *Phragmitetea*
- Carex riparia	0.2	II	5.6	Ch. *Phragmitetea*
Total	10.8			
Herbs and weeds				
- Rorippa amphibia	5.5	III	87.2	Ch. *Phragmitetea*
- Rumex hydrolapathum	4.5	III	47.6	Ch. *Phragmitetea*
- Oenanthe aquatica	3.2	III	29.6	Ch. *Phragmitetea*
- Lemna minor	3.4	III	22.6	Ch. *Lemnetea*
- Mentha aquatica	3.2	III	15.0	Ch. *Phragmitetea*
- Sium latifolium	1.8	II	9.2	Ch. *Phragmitetea*
- Iris pseudoacorus	1.8	II	7.6	Ch. *Phragmitetea*
- Myosotis palustris	0.8	II	5.0	Ch. *Molinio-Arrhenatheretea*
- Lysimachia vulgaris	0.8	I	2.6	Ch. *Molinio-Arrhenatheretea*
- Lysimachia trisulca	0.5	I	2.0	Ch. *Lemnetea*
- Bidens frondosa	0.5	I	0.8	Ch. *Bindentea tripartiti*
- Symphytum officinalis	0.5	I	0.8	Ch. *Molinio-Arrhenatheretea*
- Galium palustre	0.3	I	0.6	Ch. *Phragmitetea*
Total:	18.6			

Source: own study / Źródło: opracowanie własne

Another measure indicating nature value is connected with the mean value of the nature value index, which in our case is (2.9). This indicates moderate nature value of the community.

Table 2. Expansiveness of species in sedge rush association *Glycerietum maximae*
Tab. 2. Waloryzacja przyrodnicza szuwaru mannowego Glycerietum maximae

Parameter	*Glycerietum maximae*
H' diversity index	2.1
Mean nature value index	2.9
Nature value	moderate nature value
Evaluation category	IV

*H'– Wiener floristic diversity index

Source: own study / Źródło: opracowanie własne

3.2. Habitat analysis

Habitat conditions are a major factor determining functions and the floristic composition of a community [5, 7, 8, 13, 14]. For this reason in order to determine the effect of habitat conditions on the great manna grass community it was decided in this study to determine these conditions using the indicator method.

Calculated mean values of soil moisture content index according to Oświt [20] and Ellenberg [3] indicate that it is a community on moist or even very wet soils (Table 3). Soil reaction was weakly acid, while nitrogen content was high. Similar results were reported by Grzelak et al. [6] and Trzaskoś et al. [23].

Table 3. Habitat conditions for *Glycerietum maximae* according to Ellenberg [3] and Oświt [20]
Tab. 3. Ocena warunków siedliskowych Glycerietum maximae według Ellenberga [3] i Oświta [20]

Plant associations	Mean values of Ellenberg's indicators					
	Value of indicator	Moisture content F	Value of indicator	Soil reaction R	Value of indicator	Soil nitrogen content N
Mean value of Ellenberg's indicator	9.2 (8.8-9.6)	very wet	6.4 (5.9-6.8)	weakly acidic	7.6 (6.4-8.7)	high
Mean values of Oświt's index	8.4 (7.9-8.9)	swampy	5.4 4.7-6.1)	weakly acidic	6.4 (5.9-6.8)	high

Source: own study according to [3, 20] / Źródło: opracowanie własne według [3, 20]

3.3. Economic and fodder value

The great manna grass community has swards of a poor and mediocre value, mainly due to the small area, species composition and strong inundation. Yields of hay from the first cut in individual years are on average 5 t·ha^{-1}. This is a community of plants of low fodder value, at various degradation stages and swards of low value at FVS = 2.2 (Table 4). In this community sedges predominate along with herbs and weeds, whose shares increase gradually as a result of lack of fertilisation or management. Their joint share frequently exceeds 90.0%. Due to such a high percentage share of the above-mentioned group of plants it is a phytocenosis of low economic value, which disqualifies it from fodder use. In terms of its overall agricultural value this community has to be considered to be of low value. Thus the primary reason for its preservation is connected with the nature value related with the protection of plant communities and natural habitats [15].

3.4. Calorific value

The most important temperature and physical parameters of biomass include its lower and higher heating values. These parameters depend primarily on the chemical composition and moisture content of the material. In this study these values are very high (Table 5) and comparable to those reported by Harkot et al. [10] and much higher than those obtained by Rogalski et al. [22]. Such advantageous results are a consequence of the high bulk density resulting from biomass pelleting, which was confirmed in their studies by Grzybek et al. [9] and Łabiak et al. [16].

4. Conclusions

1. The formation, phytosociological diversification, floristic diversity, nature value and yielding of the community dominated by great manna grass are significantly affected by moisture content, water circulation and oxygenation as well as type of use.
2. A total of 21 plant species were recorded in the community phytocenoses, with the highest percentage share of grasses in the sward at 81.1%, with the marked dominance of great manna grass (*Glyceria maxima*) amounting to 72.3%.
3. The biological diversity index H' is 2.1, while the mean fodder value score is 2.9 and value class is IV, which indicates moderate nature value of this community.
4. Calculated mean values of the soil moisture content indexes according to Oświt and Ellenberg indicate that the community is located on very wet and swampy soils with a weakly acid reaction and high nitrogen content.
5. The lower and higher heating values are very high and are connected with high bulk density resulting from biomass pelleting.

Table 4. Yielding and utilisation value number (UVN-index) of communities *Glycerietum maximae*
Tab. 4. Plonowanie i wartość użytkowa (Lwu) zbiorowiska Glycerietum maximae

Site	Yield of hay of 1st cut t·ha^{-1}			Mean usefulness value number (UVN)	Value of sward
	2014	2015	2016		
Białośliwie	5.4	4.7	4.8	4.2 (3.6-4.8)	*mediocre*
Radolin	4.9	4.8	4.7	4.3 (3.7-4.9)	*poor*
Radolinek	4.9	4.7	4.7	4.3 (3.6-5.0)	*poor*
Herbutowo	5.2	5.1	4.9	4.4 (3.7-5.1)	*poor*
Marianowo	5.3	5.0	5.0	4.2 (3.6-4.7)	*mediocre*
Średnia	5.1	4.9	4.8	4.3 (3.6-4.9)	

* FVS – fodder value score index according to [4] *Source: own study / Źródło: opracowanie własne*

Table 5. Characteristics of calorific value of *Glycerietum maximae*
Tab. 5. Charakterystyka wartości energetycznej Glycerietum maximae

Measurement	Calorific value of yield (MJ·kg^{-1}s.m. – DM)	Higher heating value (MJ·kg^{-1}s.m. – DM)	Ash (g·kg^{-1} s.m. – DM)	Moisture content (%)
I	17.1	18.2	62	9.9
II	16.9	17.6	66	9.8
III	17.3	18.2	65	9.9
IV	17.4	17.9	69	9.2
V	17.0	18.4	68	9.4
Mean	17.1	18.1	86	9.6

Source: own study / Źródło: opracowanie własne

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