Mieczysław GRZELAK[1], Eliza GAWEŁ[2], Piotr GAJEWSKI[3], Zbigniew KACZMAREK[3], Leszek MAJCHRZAK[4]
[1] Poznań University of Life Sciences, Department of Grassland and Natural Landscape, Poznań, Poland
[2] Institute of Soil Science and Plant Cultivation - State Research Institute, Puławy, Poland
[3] Poznań University of Life Sciences, Department of Soil Science and Land Protection
[4] Poznań University of Life Sciences, Department of Agronomy

Received: 2019-07-22 ; Accepted: 2019-07-30

FLORISTIC DIVERSITY, YIELDING AND CALORIFIC VALUE OF PLANT COMMUNITIES WITH DOMINANT NATIVE GRASS SPECIES

Summary

Studies on floristic diversity, yielding and calorific value of biomass of communities with a dominance of 10 native grass species were conducted in the years 2013-2018 over an area of 180 ha in the Noteć River valley in the Trzcianka–Wieleń–Krzyż Wielkopolski stretch. The species composition, the percentage shares of the dominant species and the other plant groups were investigated in these plant communities. Moreover, habitat conditions, yielding and fodder value were determined. The calorific value, heat of combustion, ash content and moisture content in a dry biomass were recorded. Results indicate that the investigated communities differ in terms of habitat conditions, floristic composition, as well as yielding and fodder value of the sward. Moreover, harvested plant biomass characterised by high calorific value and heat of combustion as well as low ash content, thus facilitating pellet production for energy generation.
Keywords: *calorific value, biomass, grass communities, heat of combustion*

RÓŻNORODNOŚĆ FLORYSTYCZNA, PLONOWANIE I WARTOŚĆ ENERGETYCZNA ZBIOROWISK Z DOMINACJĄ RODZIMYCH GATUNKÓW TRAW

Streszczenie

Badania nad różnorodnością florystyczną, plonowaniem oraz wartością energetyczną biomasy zbiorowisk z dominacją 10 gatunków rodzimych traw, przeprowadzono w latach 2013-2018 w dolinie Noteci, na odcinku Trzcianka–Wieleń–Krzyż Wlkp., na obszarze o powierzchni 180 ha. Określono skład botaniczny zbiorowisk, procentowy udział dominanta oraz pozostałych grup roślinnych. Ponadto określono warunki siedliskowe, plonowanie oraz wartość użytkową. Zbadano wartość energetyczną, ciepło spalania, zawartość popiołu i wilgotność w suchej masie. Otrzymane wyniki wskazują, że badane zbiorowiska różnią się uwarunkowaniami siedliskowymi składem florystycznym, a także pod względem plonowania i wartości użytkowej runi. Ponadto, zebraną masę roślinną cechuje wysoka wartość energetyczna i ciepło spalania oraz niska zawartość popiołu, co umożliwia produkcję z niej peletu dla celów energetycznych.
Słowa kluczowe: *wartość energetyczna, biomasa, zbiorowiska trawiaste, ciepło spalania*

1. Introduction

River valleys show high variability in their habitat conditions, particularly moisture contents, which results in the formation of many habitats of diverse floristic composition [5, 11]. They include both habitats of moderate moisture levels, periodically water-logged and even marshy habitats. Grasses dominate there and due to their common distribution, diversity and multiple functions they constitute the most important plant group. Their nature value and the calculated valuation class reflect soil conditions, resulting from the habitat mosaic, manifested in soil diversification in terms of its fertility and moisture content, as well as vegetation cover and productivity [5, 7, 11]. Among the many habitat factors a major role is played by water, as it influences not only their yielding, but also fodder value and nature value [12]. It is essential to gain data on yielding of grass biomass, as it ensures rhythmical and systematic supplies of huge amounts of this raw material for the production of pellets, provided as a result of photosynthesis [6]. Biomass obtained from permanent grassland is characterised by high annual growth and considerable heating value. It is a product of photosynthesis, thus it is a renewable fuel and as such it is considered to be environmentally friendly, since levels of harmful elements (primarily sulphur) in biomass are low and the amount of carbon dioxide released in the combustion process is offset by its absorption by growing plants [10]. Due to their mosaic character grassland ecosystems are typically characterised by rich flora and fauna. Grasses and tall herbs are main components of economically valuable plant communities in river valleys. They play an advantageous role in fodder production, environmental and landscape protection, while also being havens of biodiversity [8, 11]. Thanks to abundance of herbs such extensively managed, semi-natural fresh and moist meadows and moor grass meadows are particularly scenic [5]. However, in order to preserve their landscape value they require agricultural management measures, particularly mowing at least once a year and removal of the crop from the meadows so as not to hinder regrowth in the next year. The most important factors reducing the floristic composition of meadows and pastures include deterioration of natural soil fertility resulting from a lack or limited fertilization, NPK fertilization at proportions inadequate to soil nutrient contents and requirements of plants, regular over drying of habitats and errors in their management, as well as negligence of their regular use [1].

The aim of this study was to analyse the floristic composition, yielding, fodder value and calorific value of plant communities with a dominance of 10 native grass species.

2. Material and Methods

Natural and semi-natural plant communities with predominance of grasses were analysed in the years 2013 - 2018 in meadows located in the Noteć river valley in the communes of Trzcianka, Wieleń and Krzyż Wielkopolski in the Czarnków–Trzcianka county, the Wielkopolskie province. These communities differed in terms of their phytosociological attributes and typological characteristics. A total of 82 relevés in 28 locations within the valley were prepared according to Braun-Blanquet [2], with areas ranging from 10 to 400 m^2 depending on the plant community structure and homogeneity of the phytocenosis. Plant communities were subjected to floristic and phytosociological analyses and classified applying the syntaxonomic system according to Matuszkiewicz [13]. Species nomenclature was adopted after Mirek et al. [14]. For each community the systematics, floristic composition of the associations, percentage shares of species in the community were established. Material for laboratory analyses was collected from 10 natural and semi-natural communities of 1 m^2 in area in three replications. It was decided to select for analyses the phytocenoses with a marked *dominance of a species* characteristic of a given community: *Phragmitetes australis, Phalaris arundinacea, Glyceria maxima, Festuca arundinacea, Calamagrostis epigejos, Dactylis glomerata, Bromus inermis, Arrhenatherum elatius, Alopecurus pratensis* and *Deschampsia caespitosa*. Based on the collected plant samples yielding was assessed (d.m. in $t \cdot ha^{-1}$) and fodder value score (FVS) was calculated according to the classification proposed by Filipek [3]

Laboratory analyses of bulk samples to determine the calorific value of grasses were conducted at the Institute of Chemical Wood Technology, the Poznań University of Life Sciences. The chemical composition was analysed according to the PN-92/P-50092 standard, with moisture content determined by the over drying method and referred to dry weight of the raw material. Crude ash was determined applying the gravimetric method by combustion in a Linn Elektro Therm muffle furnace (6h, 550°C) and heat of combustion was determined using a ZKL-4 calorimeter (the PN-81/G-04513 standard).

The respective values were calculated according to the formula:

$$Q_s^a = \frac{C(D_t - k) - c}{m} \quad \left[\frac{\mathrm{J}}{\mathrm{kg}}\right],$$

where:

C - heat capacity of a calorimeter of 12 783.69 $\left[\frac{\mathrm{J}}{^{\mathrm{o}}\mathrm{C}}\right]$,

D_t - total increase in temperature of the main period [°C],

k - correction for heat exchange with the environment [°C],

c - sum of corrections for additional thermal effects [J],

m - mass of fuel.

3. Results and Discussion

The authors of this paper are fully aware that determination of floristic diversity of plant communities based on samples with a marked dominance of one species from selected phytocenoses is not equivalent to the thorough identification of the specific community as a whole. However, determination of the percentage dominance of a species in the community and the percentage shares of individual species indicates the yielding potential influencing the calorific value of the community.

The investigated communities comprised phytocenoses of grass beds, flooded areas, with high and variable groundwater tables (Table 1). They included phytocenoses of tall rushes in standing or slow flowing waters with the dominance of common reed with a 96.4% percentage share in the community (Table 1), as well as phytocenoses of Phragmition reed beds with variable water levels and dominance of great manna grass (88.6%) and a slight share of other grass, sedge and weed species. In terms of uses for energy generation a particularly valuable species is reed canary grass (87.8%), found in the Noteć valley over large areas, which may be as vast as several hectares, in flooded areas, frequently permanently excessively waterlogged [5, 7]. Analyses were also conducted on communities of flood meadows on organic soils, intensively cultivated and managed, with the dominant meadow foxtail (66.9%), although the shares of other grass species were relatively high (19.1%), including legumes, herbs and weeds (Table 1). On wet, partly marshy meadows a community with 69.8% tufted hairgrass is frequently found. In turn, in the community of lowland hay meadows on fresh mineral soils phytocenoses with the dominant false oat-grass (79.5%) were selected. For experimental purposes in phytocenoses of the community found on moderately moist and dry mineral soils it was decided to select phytocenoses with the dominance of cock's foot (67.4%), one of the most common grasses in Poland, while in relatively less fertile, degraded habitats it was tall fescue (78.4%). From areas of sandy, less fertile soils wood small-reed (86.6%) and awnless brome (74.2%), also called marginal grass, were sampled for analyses.

Analysed phytocenoses differ considerably in terms of yielding and fodder value of their swards. This results from habitat conditions (Table 2), primarily the groundwater table [4]. The best yielding and fodder value are found for phytocenoses of grass beds in flooded areas, with a high and variable groundwater table, with the dominance of *Phalaris arundinacea* and *Alopecurus pratensis*, as well as communities of fertile, moderately moist meadows, with dominant *Arrhenatherum elatius* and *Dactylis glomerata*, which was confirmed by a study by Murawski et al. [15]. The community with the dominance of *Phragmites australis*, found in a strongly moist habitat, with a high and variable groundwater table is distinguished by the highest mean yielding (11.4 t ha^{-1} d.m.), but a low fodder value score (FVS = 2.1). It is mainly for this reason as well as the presence of grasses with a limited nutritional value this community is of low economic importance. This is also the case with the community with the dominance of *Deschampsia caespitosa* and *Calamagrostis epigejos.* Moreover, late mowing, a lack of fertilisation and cultivation make it useless in terms of fodder value. Communities of limited fodder use as a rule are of considerable nature value, thus they need to be protected both as plant communities and habitats.

Among the group of communities from less fertile, degraded and sandy soils the community with the dominance of *Festuca arundinacea* and *Bromus inermis* are distinguished by good yielding and fodder value (Table 2)

Table 1. Floristic diversity of identified communities
Tab. 1. Różnorodność florystyczna wyróżnionych zbiorowisk

Plant community	% dominant	% proportion of other species			
		Other grass species	Leguminous	Sedges	Herbs and weeds
Grass beds from flooded areas, with high and variable groundwater tables					
Phragmites australis	96.4	-	-	-	3.6
Phalaris arundinacea	87.8	4.7	-	5.1	2.4
Glyceria maxima	88.6	3.9	-	4.2	3.3
Alopecurus pratensis	66.9	19.1	6.7	0.7	6.6
Communities in a wet, partly marshy area					
Deschampsia caespitosa	69.8	11.8	1.7	-	16.7
Communities of fertile, moderately moist meadows					
Arrhenatherum elatius	79.5	6.7	3.9	2.1	8.5
Dactylis glomerata	67.4	15.6	4.9	0.8	11.3
Communities of relatively infertile, degraded and sandy soils					
Festuca arundinacea	78.4	9.6	1.9	-	10.1
Calamagrostis epigejos	86.6	2.6	-	4.2	6.4
Bromus inermis	74.2	12.8	1.4	-	11.6

Source: own study / Źródło: opracowanie własne

Table 2. Yielding ($t \cdot ha^{-1}$) and fodder value score (FVS) of different grass species
Tab. 2. Plonowanie ($t \cdot ha^{-1}$) i wartość użytkowa (Lwu) różnych gatunków traw

Species	Habitat	Mean yield (t ha^{-1} d.m.)	Fodder value	
			FVS	Value
Grass beds from flooded areas, with high and variable groundwater tables				
Phragmites australis	strongly moist	11.4	2.1	**poor**
Phalaris arundinacea	very moist	7.6	6.1	good
Glyceria maxima	very moist	9.6	4.8	mediocre
Alopecurus pratensis	moist	7.2	6.2	good
Communities in a wet, partly marshy area				
Deschampsia caespitosa	fresh	-	2.9	poor
Communities of fertile, moderately moist meadows				
Arrhenatherum elatius	fresh	8.4	7.7	good
Dactylis glomerata	partly fresh	7.8	6.4	good
Communities of relatively infertile, degraded and sandy soils				
Festuca arundinacea	partly fresh	5.6	7.1	good
Calamagrostis epigejos		4.9	3.1	poor
Bromus inermis	partly fresh	4.2	7.3	good

Source: own study / Źródło: opracowanie własne

This study focused on a comparison of the calorific value, heat of combustion, ash content and water content. These characteristics turned out to vary between the individual grass species (Table 3). Moisture content is a highly significant parameter affecting the use of biomass for energy purposes and the amount of generated energy, while it also results in an increased emission of pollutants in flue gases. Expressed in terms of the percentage content in the analysed material as a rule biomass has an excessive high moisture content to constitute an independent fuel. In the investigated communities moisture content (in %) ranged from 6.4% (*Bromus inermis* and *Calamagrostis epigejos*) to 8.9% (*Glyceria maxima*) and 7.9% (*Phragmites australis*).

Ash content fell within the range of 6.5-7.2 $g \cdot kg^{-1}$ d.m. These relatively small amounts of ash generated during combustion show that it does not contain harmful substances, while it also does not lead to the accumulation of the deposit disturbing the inflow of ash to the furnace and thus resulting in incomplete combustion of fuel. Such an ash content predisposes it for use as mineral fertiliser.

However, the most important thermal and physical parameters of biomass include heat of combustion, also referred to as lower heating value, and the calorific value of grasses expressed in $MJ \cdot kg^{-1}$ (megajouls per kilogram). This is dependent on the chemical composition and moisture content, which has a negative effect on heating value and thus also calorific value [15]. Biomass with a moisture content of 50-60% may provide 6-8 $MJ \cdot kg^{-1}$ energy, biomass dried to 10-20% moisture content supplies 15-17 $MJ \cdot kg^{-1}$, while completely dry biomass generates as much as 19 $MJ \cdot kg^{-1}$ [16]. In another study by these authors [6] these values were very high and comparable to the data reported by Harkot et al. [9], Rogalski et al. [17] as well as the results of this study (Table 3). Such advantageous results are a consequence of high bulk density provided by biomass pelleting. Heat of combustion ranged from 17.1 $MJ \cdot kg^{-1}$ d.m. in tall fescue to 19.5 $MJ \cdot kg^{-1}$ d.m. in large yellow-sedge. Groups homogeneous in terms of their division were similar to the groups of calorific values for individual species. The calorific value in individual grass species varied greatly, ranging from 15.6 $MJ \cdot kg^{-1}$ d.m. for *Bromus inermis* to 18.4 $MJ \cdot kg^{-1}$ d.m. obtained from *Phalaris arundinacea*.

Table 3. Calorific value of selected grass species
Tab. 3. Wartość energetyczna wybranych gatunków traw

Species	Moisture content (%)	Ash ($g \cdot kg^{-1}$ d.m.)	Heat of combustion (MJ kg^{-1} d.m.)	Calorific value of yield (MJ ha^{-1} d.m.)
Grass beds from flooded areas, with high and variable groundwater tables				
Phragmites australis	7.9	6.8	17.8	17.1
Phalaris arundinacea	7.6	6.9	19.2	18.4
Glyceria maxima	8.9	6.5	17.9	17.1
Alopecurus pratensis	7.5	7.1	17.8	17.3
Communities in a wet, partly marshy area				
Deschampsia caespitosa	7.8	6.6	16.9	16.1
Communities of fertile, moderately moist meadows				
Arrhenatherum elatius	6.8	7.1	16.8	15.7
Dactylis glomerata	7.5	6.8	17.0	16.2
Communities of relatively infertile, degraded and sandy soils				
Festuca arundinacea	7.6	7.0	17.2	16.7
Calamagrostis epigejos	6.4	7.2	18.1	16.9
Bromus inermis	6.4	6.9	16.8	15.6

Source: own study / Źródło: opracowanie własne

4. Conclusions

- The establishment, floristic diversity, yielding and calorific value of communities with the dominance of grasses are significantly influenced by the moisture content of the habitat, resulting from the mosaic character of the area and land use.
- Grasses, frequently growing under extreme habitat conditions, may constitute an exceptionally productive source of biomass.
- Individual plant communities with the dominance of grasses differed in terms of their calorific value, heat of combustion, moisture content and ash content.

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Acknowledgement:
Research funded under grants to maintain research potential of Department of Grassland and Natural Landscape Sciences 508.108.00 „Multi-functionality of grassland and grass communities in agriculture, environmental protection and natural landscape".

Publikacja przygotowana na XXI Konferencję ROL-EKO w Poznaniu w dniu 10.10.2019 r.