ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Agricultura 18(4) 2019, 181–187
www.agricultura.acta.utp.edu.pl pISSN 1644-0625 eISSN 2300-8504 DOI: 10.37660/aspagr.2019.18.4.4

ORIGINAL PAPER

Received: 22.11.2019
Received in revised form: 17.01.2020
Accepted: 18.01.2020

DIVERSITY OF FLORISTIC, HABITAT AND ENERGY VALUE OF SELECTED SPECIES OF GENUS *Carex* L.

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ABSTRACT

Background. Sedges play an important role in various types of ecosystems due to, inter alia, participation in their biomass not only as living components of phytocenoses, but also as important components in the organic sediments of various types of peatbogs. Moreover, sedge meadows perform many positive functions in the natural environment including being a place for the existence and breeding of many animal species, especially avifauna. They also have aesthetic and landscape significance. The aim of this study was to characterize the floristic, habitat and energy diversity of rush communities of the class *Phragmitetea* against the background of some ecological factors determined by the laboratory and phyto-indication methods.
Material and methods. Materials for the study were collected from natural sites from the Wielkopolska region, mainly the Noteć Bystra valley and the inter-embankment zone of the Warta river, around Raków and Trzebiszewo, during the growing periods of 2013, 2015 and 2016. The study concerned five rush communities: *Caricetum appropinquatae, Caricetum distichae, Caricetum ripariae, Caricetum rostratae* and *Caricetum vesicariae.* These are naturally valuable phytocenoses with a natural or semi-natural character that are found in very moist marshy habitats, the coastal zones of rivers, ox-bow lakes, drainage ditches and even overgrown water holes.
Results. The specified associations occurred on slightly acidic or acidic soils, often devoid of oxygen, with high levels of groundwater that were rich in nitrogen. Structural carbohydrate content was: cellulose 36.5%–42.3%, lignin 19.2%–23.6%, and holocellulose 60.8%–65.5%. The amount of extractive substances ranged from 5.2%–6.4%.
Conclusion. The energy value of the studied communities is very high, which is confirmed by a heat of combustion ranging from 17.6 to 18.1 (MJ·kg^{-1} DM) and a calorific value ranging from 16.6 to 17.3 MJ·kg^{-1} DM.

Key words: biomass, *Carex* community, energy value

INTRODUCTION

Sedges (*Carex* L.) are, next to grasses, a group of herbaceous plants frequently found in meadow and pasture communities and they are widespread, both in Poland and almost throughout the entire globe. This genus includes more than 2,000 species (Egorova, 1999), sometimes occurring on a large scale and growing amongst many different plant communities in flooded, wet and dry areas. As a genus, they show a wide amplitude of habitat requirements. They are also an important component of many plant communities.

Many researchers, including meadow cultivation specialists, believe that sedges in sward reduce the yield and economic value of the sward. However, recent studies have shown that in many cases sedges

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are valuable in terms of their nutrient content (Grzelak *et al*., 2014; 2015; 2016; Alberski *et al*., 2015; Koopman, 2015; Murawski *et al*., 2015). Sedges play an important role in various types of ecosystems due, inter alia, to participation in their biomass and not only as living components of phytocenoses, but also as important components of organic sediments in various types of peatbogs. Moreover, sedge meadows perform many positive functions in the natural environment as they are a place of existence and breeding for many animal species, especially avifauna, while they also have aesthetic and landscape significance.

Meadows and pastures that are not cultivated and that have been unused for a number of years undergo degradation and lose value (Ducka and Barszczewski, 2012). To prevent the rapid degradation of sedge meadows and help preserve their natural, protective and landscape value the biomass produced from them can be used as an energy raw material (Terlikowski, 2012).

Some *Carex* species meet many of the requirements for energy raw materials and in the climate conditions of Central Europe one of the most desirable moves would be to use the biomass from straw, grasses and sedges for energy purposes (Harkot *et al*., 2007). They are a very valuable, renewable raw material for pellet and briquette production, which are used as an energy raw material (Roth *et al*., 2005). The use of biomass for energy purposes can bring a number of benefits that are associated with reducing greenhouse gas emissions, increasing employment in rural areas, and improving the efficiency of agricultural production on family farms (Harkot *et al*., 2007). It turns out that the use of the biomass of some *Carex* species can be an alternative to the non-renewable energy sources currently used, the extraction and processing of which is a main source of environmental pollution (Nawrocki, 2006).

The aim of this study was to characterize the floristic, habitat and energy diversity of rush communities of the class *Phragmitetea* against the background of some ecological factors determined by the laboratory and phyto-indication methods.

MATERIAL AND METHODS

Materials for the study were collected from natural sites from the Wielkopolska region, mainly the Noteć Bystra valley and the inter-embankment zone of the Warta river, around Raków and Trzebiszewo, during the growing periods of 2013, 2015 and 2016. Systematics, botanical composition of the associations and the percentage of species were determined in this community. Only patches with a clear dominance of the species characteristic of a community were selected for the study. Yield (DM in $Mg \cdot ha^{-1}$) was assessed from the collected plant samples. The current state of habitat conditions was assessed based on Ellenberg's indicator values (1992) F – moisture, R – reaction and N – nitrogen content in the soil (Pietrzak, 2015).

Whole above-ground parts of plants – leaves, stems and inflorescences – were dried for chemical analyses and ground up after drying. Laboratory tests of the collected samples were carried out at the UP Institute of Wood Chemical Technology in Poznań. The results shown are the mean of three measurements and were calculated in relation to the dry matter of the raw material. Chemical composition analyses of the raw material were carried out according to PN-92/P-50092 for plant material and the following were determined:

– moisture by the dry-weight method; two sample of shredded plant material (2 × 3.5 g) were dried in a dryer at a temperature of 105^0C for 3 hours then quenched in a desiccator for half an hour and then weighed again. Based on the weight difference before and after drying, taking into account the weight of the dish, the percentage of water content in the plant material was determined.
– cellulose content by the Seifert method using a mixture of acetylacetone and dioxane (Browing, 1967);
– lignin content by the Tappi method using concentrated sulfuric acid (Stephen *et al*., 1992);
– holocellulose content using sodium chlorite (Rabemanolontsoa and Saka, 2012);
– the amount of substances soluble in organic solvents by the Soxhlet method (Prosiński, 1984).

The heat of combustion was determined according to PN-81/G-04513 in a ZKL-4 calorimeter, which is designed to measure the heat of combustion (Q^a_s) of solid fuels. A test portion of 1 g of the raw material was burned completely in an atmosphere of oxygen under a pressure of 3 MPa.

For more complete characteristics of the analysed raw material its calorific value was also calculated, i.e. the heat of combustion reduced by the heat of evaporation of the water separated from the fuel during its combustion.

RESULTS AND DISCUSSION

Specified *Carex* communities are represented by the following syntaxonomic units:

Cl. *Phragmitetea* R. Tx. et Prsg 1942,
O. *Phragmitetalia* Koch 1926,
All. *Magnocaricion* Koch 1926.

Medium-high tufted and creeping sedge communities:

Ass. *Caricetum appropinquatae* (Koch, 1926) Soó 1928,
Ass. *Caricetum rostratae* Rübel, 1912.

Communities of high sedges (up to 1.5 m) with thick, non-turfed runners:

Ass. *Caricetum ripariae* Soó, 1928.

Sedge meadows communities, partly anthropogenic:

Ass. *Caricetum distichae* (Nowiński, 1928) Jonas 1933,
Ass. *Caricetum vesicariae* Br.-Bl. et Denis, 1926.

The taxonomy of the *Carex* communities listed above relates to valuable natural or semi-natural associations. They occur in floodplains, most often permanently flooded, typical of the valleys of large rivers. Often these are areas not used for agriculture because they are permanently flooded and are described by, among others, Borysiak (1994); Mosek (1995); Brzeg and Wojterska (1996). The level of water retention is very high, changing throughout the year, especially in the patches of communities from the alliance *Phragmition*. These are usually eutrophic habitats.

The sward value of the discussed communities is small, defined as mediocre (Table 1), and floristic analysis in the studied associations showed the percentage dominance of *Carex* species (Table 1). The percentage of *Carex* and *Cyperaceae* ranged from 56.8% in the community dominated by *Carex distichae* to as much as 82.6% in the community dominated by *Carex vesicariae*. Herbs and weeds are a group of plants that were found in all communities, but the largest percentage shares were recorded with *Carex distichae* (34.8%) and *Carex appropinquatae* (32.1%). Grasses usually occurred in small percentages with the exception of with *C. ripariae*, where the percentage in the sward was 18.4%. Herbs and weeds are groups of plants that were found in all associations, while for papilionaceous plants in sward only small percentages were recorded (Table 1).

Table 1. Floristic diversity of utility groups in distinguished communities

Species	Value of sward	Proportion in sward, %			
		Carex/Cyperaceae	Fabaceae	Grasses	Herbs and weeds
C. appropinquata	poor	65.5	–	2.4	32.1
C. disticha	poor	56.8	1.8	6.6	34.8
C. ripariae	poor	62.6	2.4	18.4	16.6
C. rostratae	poor	78.8	–	4.8	16.4
C. vesicariae	poor	82.6	–	5.5	11.9

The highest dry mass yields of the studied plant associations were recorded in *C. rostratae* communities (Table 2). *Phragmitetum australis* gives yields of 8.2–14.8 Mg·ha^{-1}, it is cut relatively rarely and has poor sward value (Murawski *et. al*., 2015). The calculated value of the moisture index (F) for the communities ranged from 8.2 to 9.0, which indicates that these are wet and even very wet locations, often without oxygen. The habitat reaction of the sedge communities *C. rostratae* and *C.vesicariae* was slightly acidic while it was neutral for communities with the dominance of *C. disticha, C. ripariae* and *C. appropinquata,* which illustrates an ability to adapt to environmental conditions.

Table 2. Assessment of habitat conditions according to Ellenberg

Species	Yield DM Mg·ha^{-1}	Means of Ellenberg's indices		
		Moisture F	Soil reaction R	Soil nitrogen content N
C. appropinquata	4.6	8.8	6.9	4.2
C. disticha	4.9	8.2	7.1	5.3
C. ripariae	5.2	8.9	7.0	4.4
C. rostratae	6.2	9.0	5.9	4.7
C. vesicariae	4.7	9.0	5.8	4.8

Explanations: index according to Ellenberg
F – moisture content index
R – soil reaction index
N – soil nitrogen content index

Extractive substances are a very diverse group of compounds in chemical terms, whose common characteristic is the ability to undergo the extraction process with inert organic substances and water. This group of compounds includes essential oils, resins, fatty acids, fats, waxes, phytosterols, tannins, phenolic substances such as dyes and glycosides. Their content in the sward varied from 5.2% (*C. vesicariae*) to 6.2% (*C. appropinquata*) (Table 3).

The content of the basic building component, cellulose, in the aboveground parts of the studied sedge species was within the range from 36.5% to 42.3%. The highest content was found in the raw material from *C. vesicariae*, and the lowest from *C. appropinquata* (Table 3).

When analyzing the content of lignin in the studied material, slight variations in its content were found between species. *C. appropinquata* and *C. disticha* were characterized by the highest content of lignin – 23.6%.

Similarly to the analysis of the basic building components of plant materials, the content of holocellulose in the studied species showed variations in its content. *C. disticha* contained the highest amounts – 66.5% of holocellulose, while *C. rostratae* the lowest – 60.8%. (Table 3). Cellulose together with hemicelluloses acts as skeletal components and their fibrous structure provides cells with considerable mechanical strength.

Plant material for energy purposes must meet certain heat requirements. The most important thermo-physical biomass parameters are calorific value and heat of combustion, also called the lower calorific value. These parameters depend primarily on the chemical composition and moisture content of the material. In the present author's study, these values are very high (Table 4) and comparable with the results of other studies (Harkot *et al*., 2007; Grzelak *et al*., 2010).

The heat of combustion determined by the calorimetric method was very high and ranged from

17.6 to 18.1 $MJ·kg^{-1}$ DM. At the same time, the calorific value ranged from 16.6 to 17.3 $MJ·kg^{-1}$ DM. This amount is comparable to brown coal and other grass species (Grzelak *et al*., 2014).

The calorific value of a fuel depends on its moisture and ash content (Patel and Gami, 2012). In this case that means that the higher the moisture and ash content of the fuel the lower is its calorific value. It is assumed that the average ash content in solid non-wood biofuels is between 4 and 7% (Prade *et al*., 2012). This study group of sedges did not exceed these typical values for plant raw materials.

The plant material for energy purposes must meet certain heat requirements. When assessing the quality of the raw material the crucial factor most often taken into account is moisture content. This content was not very diverse and ranged from 8.8% to 9.6%.

Table 3. Chemical composition of above ground parts of the studied sedges, % DM

Species	Contents, %			
	Extractive substances	Cellulose	Lignin	Holocellulose
C. appropinquata	6.4	36.5	23.6	65.0
C. disticha	5.4	39.3	23.6	66.5
C. ripariae	5.7	40.4	19.2	61.7
C. rostratae	5.4	40.1	20.1	60.8
C. vesicariae	5.2	42.3	22.6	63.8

Table 4. Basic parameters of *Carex* pellets, $MJ·kg^{-1}$ DM

Parameter	*Carex* species				
	C. appropinquata	*C. disticha*	*C.ripariae*	*C. rostratae*	*C. vesicariae*
Calorific value	17.3	16.9	16.6	16.6	16.8
Heat of combustion	18.1	17.6	17.7	17.9	18.1
Moisture (%)	9.2	9.4	9.1	8.8	9.6
Ash (%)	6.8	6.8	6.6	6.9	6.8

CONCLUSIONS

The formation of rush communities, their floristic diversity, and, consequently, their natural and agricultural value are determined primarily by the moisture level of the habitats and their trophism. The studied communities occur in moist and even extremely moist habitats (F = 8.2–9.0), slightly acidic (R = 6.9–7.1), often lacking oxygen and with a moderate nitrogen content (N = 4.2–5.3). The energy value of the studied communities was very high, which was confirmed by a heat of combustion ranging from 17.6 to 18.1 ($MJ·kg^{-1}$ DM) and a calorific value ranging from 16.6 to 17.3 ($MJ·kg^{-1}$ DM). Structural carbohydrate content was cellulose 36.5–42.3%, lignin 19.2–23.6%, and holocellulose 60.8–65.5%. The amount of extractive substances ranged from 5.2–6.4%.

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RÓŻNORODNOŚĆ FLORYSTYCZNA, SIEDLISKOWA I ENERGETYCZNA WYBRANYCH GATUNKÓW Z RODZAJU *Carex* L.

Streszczenie

Badania dotyczyły pięciu zbiorowisk szuwarowych: *Caricetum appropinquatae*, *Caricetum distichae*, *Caricetum ripariae*, *Caricetum rostratae i Caricetum vesicariae.* Są to fitocenozy przyrodniczo cenne, o naturalnym lub półnaturalnym charakterze, spotykane w siedliskach silnie uwilgotnionych, zabagnianych, w strefie brzegowej rzek, starorzeczach, rowach melioracyjnych, a nawet zarastających oczkach wodnych. Wyróżnione zespoły występują na glebach o odczynie lekko kwaśnym lub kwaśnym, często pozbawione tlenu, o wysokim poziomie wód gruntowych zasobnych w azot. Materiały do badań zostały pobrane z naturalnych stanowisk z Wielkopolski, głównie z doliny Noteci Bystrej i strefy międzywala rzeki Warty wokół Rakowa, Trzebiszewa w okresach wegetacyjnych 2013, 2015 i 2016. Strukturalna zawartość węglowodanów wynosiła: celulozy 36,5–42,3%, ligniny 19,2–23,6% i holocelulozy 60,8–65%. Zawartość substancji ekstrakcyjnych wahała się od 5,2 do 6,4%. Wartość energetyczna biomasy zbiorowisk z dominacją turzyc jest bardzo wysoka, o czym świadczy ciepło spalania wynoszące od 17,6 do 18,1 $MJ \cdot kg^{-1}$ s.m. i wartość opałowa od 16,6 do 17,3 $MJ \cdot kg^{-1}$ s.m.

Słowa kluczowe: biomasa, wartość energetyczna, zbiorowiska turzycowe