

Participation of *Calamagrostis epigejos* (L.) Roth in plant communities of the Bytomka river valley in terms of its biomass use in power industry

Edyta Sierka, Sylwia Kopczyńska

Department of Botany and Nature Protection, Faculty of Biology and Environmental Protection, University of Silesia, Jagiellońska 28, 40-032 Katowice, Poland
E-mail address (corresponding author): edyta.sierka@us.edu.pl

ABSTRACT

The paper presents an attempt of assessing the potential use of *Calamagrostis epigejos* (L.) Roth. as a renewable source of energy raw materials. Abandonment of human management is often followed by a decrease in species richness in semi-natural grasslands, mainly due to the increased dominance of clonal grasses as *Calamagrostis epigejos* which were formerly repressed by management. The biomass resources of this and accompanying species, i.e. from *Solidago* genus and others e.g. *Cirsium rivulare*, *Deschampsia caespitosa*, *Molinia coerulea* and *Filipendula ulmaria*, was evaluated in the green wastelands of the Bytomka River valley (Upper Silesia, Poland). It was found that approx. 1.2 t·ha⁻¹ of dry matter can be obtained from approx. 30% of the average share of *Calamagrostis epigejos* in plant communities of unmowed meadows. This is 10 times less than in the case of *Miscanthus giganteus*, non-native cultivated grass. Increase in *Calamagrostis epigejos* biomass reduces biomass of *Solidago* sp. (-0.522176, $p < 0.05$) and other species (-0.465806, $p < 0.05$). The calorific value of *Calamagrostis epigejos* biomass is approx. 15.91 MJ·kg⁻¹, which is comparable to the calorific value of coal and close to, inter alia, of *Miscanthus sacchariflorus* (19 MJ·kg⁻¹) as an energy crop. Abandonment of human management is often followed by a decrease in species richness in semi-natural grasslands, mainly due to the increased dominance of clonal grasses which were formerly repressed by management. Presented research is preliminary and therefore, it is necessary to investigate the reaction of *Calamagrostis epigejos* to regular mowing and export of biomass on the studied areas.

KEY WORDS: grass, biomass of plants, renewable energy sources, Silesian Upland

1. Introduction

The necessity of implementation of the EU energy and climate policy results in rapid development of alternative energy sources (STRYJECKI, 2011). Energy from solid biomass takes a significant share in the balance of renewable energy in Poland. Combustion of biomass is considered to be beneficial for the environment in comparison to the use of fossil fuels, as the release of carbon dioxide in the combustion process is compensated by its recent absorption by the plants, so called closed cycle of CO₂ (KISIEL ET AL., 2006). However, according to some estimates the production and combustion of biofuels results in worse energy generation and ecological balance than the production and

combustion of fossil fuels and is associated with environmental degradation, among others, by increasing acreage for cultivation, large consumption of fertilizers, exploitation of forests and unsustainable management of plant products (PUDEŁKO, 2010). Particularly valuable group to be used are so called energetic plants, which in addition to low soil and climate requirements are capable of significant increasing their dry matter (DM) during the growing season providing high calorific value.

Native and alien species of grasses, including e. g. *Miscanthus giganteus*, play an important role among these plants. Undoubtedly, the role of grasses deserves the attention only because of the fact that in our climate meadows, where grasses are the most numerous group of plants, are

generally considered as plant formation producing the largest amounts of biomass. Grasses are also the pioneer plants entering spontaneously or due to human activities on the areas restored to nature (MARTYN, 2007). One of the native species, due to its massive occurrence, is *Calamagrostis epigejos*. It is a perennial, wildly growing grass occurring in many habitats, such as grasslands, meadows and forests (SIERKA & CHMURA, 2005). It often numerously occurs in altered habitats, degraded farmlands or waste dumps of coal industry (PATRZĄŁEK ET AL., 2011) and the edges of sand and mineral excavation sites (SIERKA & BABCZYŃSKA-SENDEK, 2013).

The capability of rapid growth of stolons (6-7 mm/day), high seed productivity (about 50 million pieces per 1 hectare) (GORZELAK, 2004) and low habitat requirements make *Calamagrostis epigejos* (L.) Roth a potential pioneer species (PATRZĄŁEK ET AL., 2011). The issue of economic use of bushgrass as energy plant is still poorly recognised subject. So far, HARKOT (2007), MARTYN (2007), ROGALSKI ET AL. (2008), KOZŁOWSKI & SWĘDRZYŃSKI (2010) and PATRZĄŁEK ET AL. (2011) conducted research on the application of *Calamagrostis epigejos* in power industry in Poland. The research results are promising and perhaps they will contribute to the recognition of the bushgrass as a species that can meet the requirements of power industry. However, none of these authors investigated the share of bushgrass in phytocoenoses of wastelands.

Therefore, the aim of this work is to determine the possible use of bushgrass *Calamagrostis epigejos* (L.) Roth as a potential source of biomass for power industry, by providing information on: the percentage of bushgrass in phytocoenoses of the wastelands; accompanying species; bushgrass

biomass and assessment of the suitability of *Calamagrostis epigejos* (L.) Roth for power industry on the basis of existing data and own research.

2. Study area

The study area is located in the Silesian Upland within Bytom Plateau, which is built from Carboniferous and Triassic rocks. It is characterised by small height differences of 15 to 20 m and weak erosion cut (RAPORT O STANIE ŚRODOWISKA, 2000). The average annual precipitation is ranging from 671 to 718 mm (CZAJA, 1999).

Large areas are covered with wet meadows of and fresh meadows. Wet meadows primarily occupy areas of river valleys where the riparian forests were cleared. These meadows are characterized by the presence of a lush herbal layer with *Cirsium rivulare*, *C. oleraceum* and also: solitary growing *Caltha palustris*, *Deschampsia caespitosa*, *Moilinia coerulea* and *Filipendula ulmaria*. According to Zabrze Local Development Plan, a directional development is not provided.

3. Materials and methods

3.1. Characteristic of study plots

The studies were conducted in the Bytomka river valley (Fig. 1), which is channeled and embanked in the studied section and the banks are covered with ruderal vegetation. Research was carried out at three designated plots (Fig. 2), which were selected by the criterion of the occurrence of *Calamagrostis epigejos*.

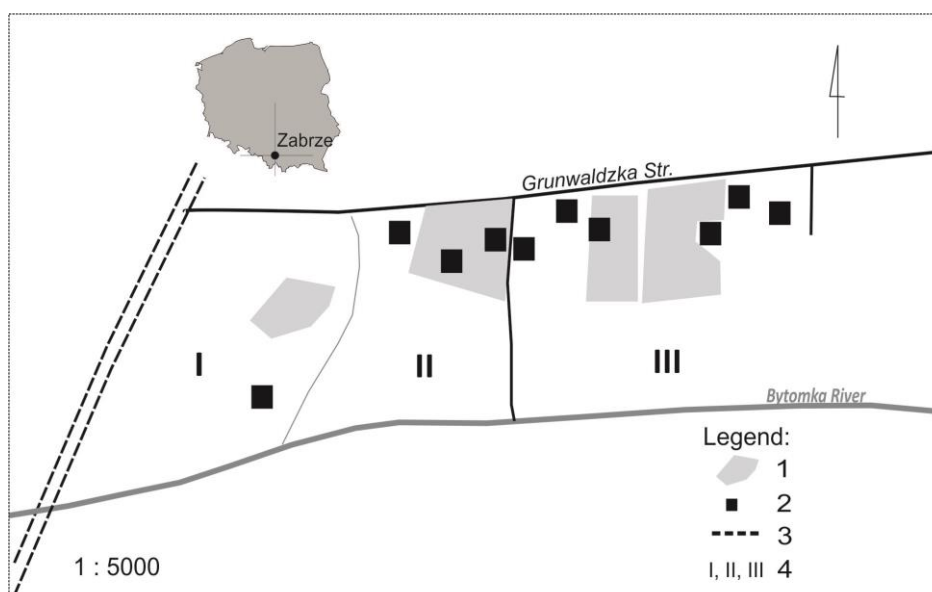


Fig. 1. Location of study area in Zabrze city
1 - area of trees and shrubs; 2 - buildings; 3 - railroad; 4 - study plots



Fig. 2. Areas of research with participation of *Calamagrostis epigejos*: I – 30%, II – 15%, III – 5% (S. Kopczyńska, 2011)

Plot I (N: 50°18'35.4"; E: 18°45'8.8"), located within unmowed meadow and pasture. *Phragmites australis* dominates in lowering of the land-surface in its southern part. Southern boundary of the plot is designated by a railway embankment with clusters of woody species, built by *Populus nigra* L. 'Italica', *Aesculus hippocastanum*, *Salix alba*, *Acer platanoides* and *Sambucus nigra*, while the embankments themselves are covered with *Crataegus monogyna*.

Plot II (N: 50°18'36.7"; E: 18°45'18.83"), covered an area of irregularly mowed meadow, which was covered mainly by grasses such as *Arrhenatherum elatius*, *Phleum pratense*, *Dactylis glomerata*. There are numerous pits located in this area, and there are waste dumps and rubbles next to it. The whole area is covered with low bushes of *Sambucus nigra*.

Plot III (N: 50°18'37.16"; E: 18°45'33.75"), located in the irregularly mowed meadow, burnt in the spring at some spots. The area is dominated by grasses such as couch grass (*Elymus repens*), common bent (*Agrostis capillaris*) and false oat-grass (*Arrhenatherum elatius*).

3.2. Field researches

Field research was conducted from May to October 2011. In total 60 floristic inventories (20 at each of the 3 plots) covering an area of 25 m² were conducted in order to determine the floristic composition of the area where *Calamagrostis epigejos* occurred. Frequency and % share were determined for each species. Due to the fact that *Calamagrostis epigejos* coverage was the highest at the Plot I, 25 biomass samples were collected from this plot for further analyses (0.25 m² each). All plants were cut about 5 cm above the soil level. This was followed by separation and pooling from each sample *Calamagrostis epigejos*, *Solidago* sp., and all other species.

3.3. Laboratory analysis

Each sample was weighed, dried for 5 weeks at 25° C and weighed again. Biomass of the investigated species with the accuracy to 10 milligrams. The names of plant species and

communities were given after MIREK ET AL. (2002). Each plot was provided with: percentage share of *Calamagrostis epigejos* (L.) Roth in each of the 20 floristic inventories, average coverage (%) of *Calamagrostis epigejos* (L.) Roth, *Solidago* sp., and all other species. Furthermore, significance of the relationship between *Calamagrostis epigejos* (L.) Roth biomass and biomass of other species in the studied communities was verified.

4. Results

4.1. Species plants associated *Calamagrostis epigejos* (L.) Roth in the study area of the Bytomka River valley

The number of species recorded on the research plots was similar and was as follows: Plot I - 35, II-34, III-24. Table 1 shows the full list of

recorded species. Average share of *Calamagrostis epigejos* [%] was: Plot I – 33%, II-18%, III- 4%.

4.2. *Calamagrostis epigejos* (L.) Roth biomass

Following three weeks of drying, the average weight of the biomass was 34 grams (fresh biomass 41 g) for *Calamagrostis epigejos* (L.) Roth, 79 grams for *Solidago* sp. (fresh biomass 102 g), and 22 grams for other species (fresh biomass 36 g) (Fig. 3).

Biomass *Calamagrostis epigejos* moisture content was 17.1%; *Solidago* sp. - 22.5%; other species - 39%. A slight but statistically significant correlation (Tab. 2) between the increase in bushgrass biomass and biomass of other species was found. Increase in *Calamagrostis epigejos* biomass results in a reduction of goldenrod's and other accompanying species biomass.

Table 1. Frequency of plant species occurring together with *Calamagrostis epigejos* (without *Calamagrostis epigejos*) (author's research). Bold indicates max. frequency species on the plot

Species		Frequency [%]		
		I	II	III
1	<i>Achillea millefolium</i> L.	40	-	-
2	<i>Aegopodium podagraria</i> L.	25	80	-
3	<i>Agrostis capillaris</i> L.	45	30	85
4	<i>Arctium tomentosum</i> Mill.	-	50	50
5	<i>Arrhenatherum elatius</i> (L.)	75	35	65
6	<i>Artemisia vulgaris</i> L.	40	25	-
7	<i>Calystegia sepium</i> (L.) R. Br.	50	55	75
8	<i>Carex hirta</i> L.	40	25	75
9	<i>Centaurea jacea</i> L.	25	-	-
10	<i>Chenopodium album</i> L.	25	-	-
11	<i>Cirsium arvense</i> (L.) Scop.	85	55	25
12	<i>Convolvulus arvensis</i> L.	25	60	25
13	<i>Crataegus monogyna</i> Jacq.		25	
14	<i>Dactylis glomerata</i> L.	40	25	30
15	<i>Elymus repens</i> (L.) Gould.	55	80	95
16	<i>Equisetum arvense</i> L.	-	50	40
17	<i>Festuca pratensis</i> Huds.	-	50	-
18	<i>Festuca rubra</i> L. S. Str.	-	75	-
19	<i>Galeopsis pubescens</i> Besser.	25	35	25
20	<i>Galium mollugo</i> L. S. Str	80	75	55
21	<i>Heracleum sosnowskyi</i> Manden.	50	-	55
22	<i>Hypericum perforatum</i> L.	25	-	-
23	<i>Linaria vulgaris</i> Mill.	50	-	25
24	<i>Melandrium album</i> (Mill.) Garcke	25	25	-
25	<i>Phleum pratense</i> L.	75	50	80
26	<i>Pimpinella saxifraga</i> L.	60	-	-
27	<i>Plantago lanceolata</i> L.	50	25	-
28	<i>Poa pratensis</i> L. S. Str.	50	30	25
29	<i>Poa trivialis</i> L.	25	25	100
30	<i>Potentilla reptans</i> L.	80	-	50

31	<i>Rumex acetosa</i> L.	50	50	25
32	<i>Rumex acetosa</i> L.	-	35	-
33	<i>Sambucus nigra</i> L.	-	25	-
34	<i>Solidago canadensis</i> L.	35	25	-
35	<i>Solidago gigantea</i> Aiton.	35	25	25
36	<i>Tanacetum vulgare</i> L.	60	-	-
37	<i>Tragopogon pratensis</i> L.	75	25	-
38	<i>Trifolium repens</i> L.	-	-	50
39	<i>Urtica dioica</i> L.	25	55	45
40	<i>Vicia cracca</i> L.	25	50	25
41	<i>Verbascum densiflorum</i> Bertol.	25	-	-
42	<i>Veronica chamaedrys</i> L.	50	-	-
43	<i>Vicia cracca</i> L.	25	-	25
44	<i>Viola tricolor</i> L.	-	25	-
Total number of species		35	34	24

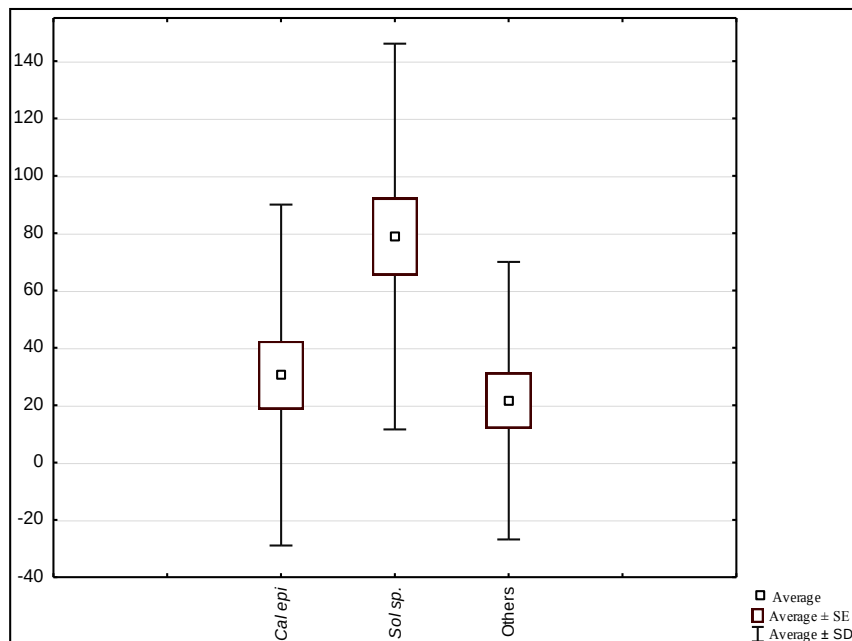


Fig. 3. Average biomass of *Calamagrostis epigejos*, after drying (author's research)

Table 2. Relationships between percentage share of species (author's research)
(*statistically significant results $p < 0,05$)

	Mean	Standard deviation (SD)	<i>Calamagrostis epigejos</i>	<i>Solidago sp.</i>	Other species
<i>Calamagrostis epigejos</i>	40.9272	77.43523	1.000000	-0.522176*	-0.097759
<i>Solidago sp.</i>	102.0400	84.58008	-0.522176*	1.000000	-0.465806*
Other species	36.2980	65.56922	-0.097759	-0.465806*	1.000000

5. Discussion

The studies were carried out to determine the share of bushgrass in meadow communities and its biomass. Results of research shows a negative correlation between the increased involvement of *Calamagrostis epigejos* and a reduction in the number of species meadow and diversity of plant communities e.g. *Cnidion* meadow noted to reduce the number of species by 44% compared to

conventional panels trained in the form of (KRYSZAK ET AL., 2006). In the studies on the occurrence of *Calamagrostis epigejos* conducted at Przemyskie Foothills (BARABASZ-KRASNY, 2011) the number of species in the relevés varied from 20 to 46, which indicated floristic instability of the communities. According to BARABASZ-KRASNY (2011) the dominant plant in the community was *Calamagrostis epigejos* accompanied by, as in the case of the studied area: *Cirsium arvense*,

Equisetum arvense, *Gallium mollugo*, *Stellaria graminea*, *Trifolium medium*, *Urtica dioica*, *Veronica chamaedrys* and *Vicia cracca*. The first and second plots are slightly different in terms of species composition and frequency of the individual species. The largest differences were observed in the third plot, where the occurrence of only 24 species with a significant predominance of couch grass *Elymus repens* (L.) Gould was recorded.

The particular plots differ in the degree of *Calamagrostis epigejos* coverage. The first plot was covered with the highest number of bushgrass patches. Its presence was recorded in all 20 floristic inventories at this plot. The patches of this species covered surfaces located closer to the Bytomka River bed and steep slopes of embankments. Research by KRYSZAK ET AL. (2006) on the occurrence of bushgrass in the grassland communities of river valleys in Wielkopolska showed that *Calamagrostis epigejos* was the most common species in the river valleys, where it inhabited local elevations, steep slopes of edges of valleys and levees. The analysis of the share of bushgrass in each conducted floristic inventory revealed that its coverage ranged between 5 and 80%. FALKOWSKI (1982) described *Calamagrostis epigejos*, as a heliophilous species, which would explain the differences in the degree of coverage at particular plots. The highest coverage occurred in open areas devoid of trees. Small *Calamagrostis epigejos* cover on the second and third plot was probably related to the recent use of this part of the area and its regular burning, the traces of which were clearly visible during the site inspection.

The results of the study show that the average percent coverage with *Calamagrostis epigejos* on the test sites of all three research plots is lower than with other herbaceous species, but higher than the average percent coverage with *Solidago* sp. When assessing the percent coverage of plots, it should be taken into account, that the floristic inventories and evaluation of species coverage were performed in June and July, and as reported by FALKOWSKI (1982) *Calamagrostis epigejos* blooms from June to August. Therefore, it might be expected that in August, after reaching maximum size, its cover might slightly increase.

Calamagrostis epigejos biomass was 1.220016 t·ha⁻¹ of DM. For comparison, dry matter yield of *Salix viminalis* (planted in the amount of 40 000 individuals ha⁻¹, *Miscanthus giganteus*, 15 000 individuals ha⁻¹ and *Sida hermaphrodita*, 20 000 individuals ha⁻¹, collected on an annual basis,

depending on the type of soil was as follows in the first year of research (KUŚ & MATYKA, 2009). For *Salix viminalis*: from 10.1 t·ha⁻¹ on sandy soil to 12.8 t·ha⁻¹ of DM on heavy soil; *Miscanthus giganteus*: from 19. t·ha⁻¹ on heavy soil to 20.7 t·ha⁻¹ of DM on medium soil; *Sida hermaphrodita*: from 20.5 t·ha⁻¹ on sandy soil to 20.8 t·ha⁻¹ of DM on heavy soil.

The yield of *Calamagrostis epigejos* dry matter is from 10 to 20 times lower. However, it has to be emphasised that, *Calamagrostis epigejos* is a wild growing plant, which does not reach 100% of coverage. In addition, bushgrass dry matter samples were collected from a small area and therefore, may not reflect the phenomenon in full.

The largest biomass amount within the investigated area was recorded in samples of two species of goldenrods (*Solidago* sp.), which according to PATRZALEK ET AL. (2011) dominate on meadows that have not been used for many years. It would be reasonable to investigate the possibility of incineration of *Calamagrostis epigejos* together with the addition of *Solidago* sp. Patches of *Calamagrostis epigejos* and *Solidago* sp. in the Bytomka River valley are numerous and either adjacent or overlapping. Carried out correlation showed that, the increase in biomass of one species reduced the biomass of other species.

5.1. *Calamagrostis epigejos* (L.) Roth as a fuel

Research by HARKOT ET AL. (2007) on the grasslands in south-eastern Poland determined combustion heat for *Calamagrostis epigejos* at 18.4 MJ·kg⁻¹. Thus, as reported by the author, combustion heat of investigated species was similar to that of *Salix* spp., for which it varied between 18.6 and 19.6 MJ·kg⁻¹ of dry mass (DM). The same parameter for bushgrass has been assessed by PATRZALEK ET AL. (2011) at 17.19 MJ·kg⁻¹.

The authors present different calorific value of bushgrass, which according to HARKOT ET AL. (2007) was 17.3 MJ·kg⁻¹, whereas PATRZALEK ET AL. (2011) presents the values of about 15.91 MJ·kg⁻¹ in air-dry conditions and 18.58-18.88 MJ·kg⁻¹ in dry, ash-free conditions. HARKOT ET AL. (2007) likens the calorific value of bushgrass to calorific values of species such as *Miscanthus sacchariflorus* (19 MJ·kg⁻¹) and *Spartina pectinata* (16.8 MJ·kg⁻¹).

Another parameter - ash content remaining after combustion of *Calamagrostis epigejos* according to HARKOT ET AL. (2007) is 5.5%. Higher ash content was presented by PATRZALEK ET AL. (2011) amounting to 6.6%. For comparison, ash content from the combustion of common osier is

1.6%, and 4.4% of Amur silver-grass (PATRZAŁEK ET AL., 2011).

Additionally, HARKOT ET AL. (2007) defines also other parameters for bushgrass, such as the total sulfur content, which was 0.16%. It is one of the lowest values, since the sulfur content in grasses ranges from 0.2 to 0.8%. Among species of grasses investigated by HARKOT ET AL. (2007), bushgrass has the lowest chlorine content (0.23%), which is very important in assessing the energy value of its biomass. The chlorine content is an important parameter, since it affects the use of heating systems, accelerating the corrosion of furnaces.

ROGAŁSKI ET AL. (2008) regarded *Calamagrostis epigejos* as a potential source of biofuel showing that 318-459 liters of ethanol can be produced from 1 ha of this species. Moreover, KOZŁOWSKI ET AL. (2010) emphasizes that the chemical composition of *Calamagrostis epigejos* makes this species an interesting source of heating biomass, and to a smaller extent for the production of biogas. The results of his studies show that bushgrass is rich in carbon and is characterised by high calorific value, exceeding even 21 MJ from 1 kg of DM. The author also remarks that the calorific value of grass biomass, and in particular biomass of reed and bushgrass, is similar to the calorific value of coal. Certain limitation for the use of the investigated species as an energy plant, according to KOZŁOWSKI ET AL. (2010), is its relatively small mass above the ground. The mass of stolons located at a depth of 30 cm is five times larger than the mass of stems above the ground.

Taking into account the possibility of harvesting bushgrass as an energetic plant from a given area, the most suitable for this purpose would be the first study plot, where the investigated species occurred with the greatest coverage. In the case of obtaining the investigated species from areas located in the Bytomka River valley, it should also be taken into account that *Calamagrostis epigejos* does not form dense swards. In addition, although the structure of the inflorescence contains a lot of grains, they exhibit very low (12%) germination capability, which indicates their little role in the spread of *Calamagrostis epigejos* (KOZŁOWSKI ET AL., 2010).

It should be pointed out that presented research is only preliminary and is necessary to investigate the impact of regular mowing and biomass export on *Calamagrostis epigejos*.

6. Conclusions

- 1) Share of *Calamagrostis epigejos* (L.) Roth is varied in plant communities, which is influenced by: the latest land use, landform and the presence of tree stands.
- 2) Value of *Calamagrostis epigejos* (L.) Roth biomass is 1.220016 t·ha⁻¹.
- 3) Values of parameters such as combustion heat, calorific value, or the content of chlorine determined for *Calamagrostis epigejos* (L.) Roth by various authors indicate, that interest in this species as a potential energy plant is justified.
- 4) *Calamagrostis epigejos* (L.) Roth can become a potential source of renewable energy, however it is necessary to conduct further research.

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