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WETLAND MEADOWS OF *CAREX ACUTIFORMIS* AS A SOURCE OF BIOELECTRICITY

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Abstract. The article presents the assessment of bioelectroproductivity of wetland sedge ecosystems of *Carex acutiformis* in situ. It was found that it is possible to obtain a bioelectric potential at the level of 864.2–1114.8 mV, depending on external conditions using a pair of electrodes graphite/zinc-galvanized steel and graphite/aluminum. The increase in soil moisture had a positive effect on bioelectric potential parameters. Widespread in Polissya biotopes of sedge have prospects as sources of green plant-microbial energy.

Keywords: bioelectricity; renewable energy; plant; rhizospheric microorganism; ecosystem.

1. Introduction

Swamps and wet meadows are characterized as a highly promising source of bioelectricity, which is produced during the development of wetland plant-microbial associations (de Schamphelaire et al., 2010; Liu, 2013; Lu et al., 2015; Wetse et al., 2015). By using electrode systems installed in the rhizosphere, it is possible to collect the generated bioelectricity, which is an environmentally friendly and renewable energy source (Strik et al., 2008). The analysis of wetlands is important in terms of their large share in the land fund, especially for the Rivne and Volyn regions, where they occupy 8.3 and 10.3 % of the total area of the region, respectively, and cover 160.5 thousand hectares (Ivchenko, 2009; Bodnar, 2016). The meadow vegetation type is the second most represented in the vegetation cover of Ukraine and occupies about 9 million hectares (Balashov, Solomakha, 2005). Meadow ecosystems, which are formed under conditions of sufficient moisture in the floodplains of the Polissya and Forest-Steppe rivers, are often represented by sedge thickets of different species (Balashov, Solomakha, 2005). As a study object, we selected a population of sedge acutiformes, which occupies a large area near the lake Hlynske, Manevychi district of Volyn region, a swampy valley of 3–5 km wide along the Veselukha River, which stretches for 69 km and along the reclamation canal (Marynych et al., 1989). Sedge thickets occupy a vast area that is not used, they are concentrated in the immediate neighbourhood of the surrounding villages and could serve as an important source of green electricity.

There are only a few experiments to obtain bioelectricity in situ. Most experiments are performed with model laboratory wetland systems. In situ bioelectricity production is mainly studied in wetland rice field ecosystems in Japan and Indonesia (Kaku et al., 2008; Takanezawa et al., 2010; Kouzuma et al., 2013; Ueoka et al., 2016; Sudirjo et al., 2019), floodplain ecosystems in South Carolina, USA (Dai et al., 2015) and wetland salt marshes in the Netherlands (Wetser et al., 2017). Therefore, the study of the bioelectric potential of wetlands in the climatic conditions of Western Ukraine is of considerable interest. Taking into account the above facts, the aim of the study was to assess the prospects of sedge biotopes in situ as an alternative source of renewable energy.

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2. Materials and Methods

The object of the research was the populations of Carex acutiformis Ehrh., 1789 of wetland meadows along the reclamation canal of Veselukha and the lake Hlynske, Manevychi district of Volyn region (Fig. 1). The subject of the research was the dynamic and environmentally dependent fluctuations of the bioelectric potential of plant-microbial associations of the sedge population. To register the bioelectric potential, we used a developed monoelectrode system of two types: graphite/zinc-galvanized steel and graphite/aluminum (Rusyn, Medvediev, 2016). Electrode systems were placed stationary in the soil at a depth of 0.3 m in the thickness of the substrate, where the bulk of the root system of field plants is concentrated, in the zone of association of plant roots and rhizosphere microorganisms, where electrons and protons are released (Eshel, Beeckman, 2013). Bioelectric potential parameters were recorded using a digital multimeter. The reported results were presented as the average of all replicate experiments and their standard errors (x ± SE). Statistical evaluation of the significance of the difference between average values was established using one-way analysis of variance and F-test for 95 % of certainty level.

Fig. 1. Populations of *Carex acutiformis* wetland meadows along the reclamation canal of Veselukha, Manevychi district, Volyn region

3. Results and Discussion

The average bioelectric potential of sedge populations ranged from 864.2 to 1114.8 mV during 12 weeks of observations (Fig. 2). Bioelectricity parameters varied depending on a set of environmental factors such as temperature, lighting and humidity. The set of meteorological factors has a great influence on the electrical productivity of the biotope because the generation of bioelectricity depends on the activity of plant photosynthesis (Strik et al., 2008). Organic compounds formed by plants in the process of photosynthesis serve as a source of carbon in the rhizosphere for electro-active microorganisms. Favourable conditions of sunlight, temperature and humidity for photosynthesis of plants simultaneously increase the production of bioelectricity. The obtained data correlate with the recorded parameters of bioelectricity presented in other studies (Rusyn, Hamkalo, 2019; Tou et al., 2019).

The increase in substrate humidity had a positive effect on the obtained parameters of bioelectricity of sedge populations (Fig. 3). Thus, with an increase in humidity from 70 % to 85 %, the average bioelectric potential increased by 40.1 mV – 106.3 mV. Under conditions of high soil moisture, its electrical conductivity increases, charged particles are more actively cleaved and migrate, and photosynthesis and removal of photosynthetates are more active. Humidity activates the development of rhizosphere microorganisms involved in the generation of bioelectricity.

The difference between the bioelectric potential of *Carex acutiformis* biotopes in the morning and in the evening was not significant (Fig. 4). The average difference between the maximum and minimum values was up to 30.1 mV in most habitats and in some habitats up to 80.5 mV. In some cases, there is a tendency to reduce the bioelectric potential during the day. The higher yield of bioelectricity during the light period of the day, compared with the dark period of the day was also recorded in researchs (Chiranjeevi et al., 2012). Obviously, light-dependent phases of phototysynthesis can play an important role here. In the dark phase of photosynthesis an active accumulation of organic compounds take place and phothosynthetates are used and excreted by plants during the day. The level of accumulation of organic compounds required for the development of electroactive microorganisms is dependent on weather conditions, resulting in fluctuations in bioelectrical parameters.

To select the optimal materials as electrodes, the bioelectric potential of the same microbial-plant associations of sedge populations was analyzed using two-electrode systems: graphite/aluminum and graphite/zinc-galvanized steel under natural conditions. The bioelectric potential recorded by graphite/zinc-galvanized steel electrode systems slightly exceeded the values obtained by graphite/aluminum electrodes (Fig. 5).

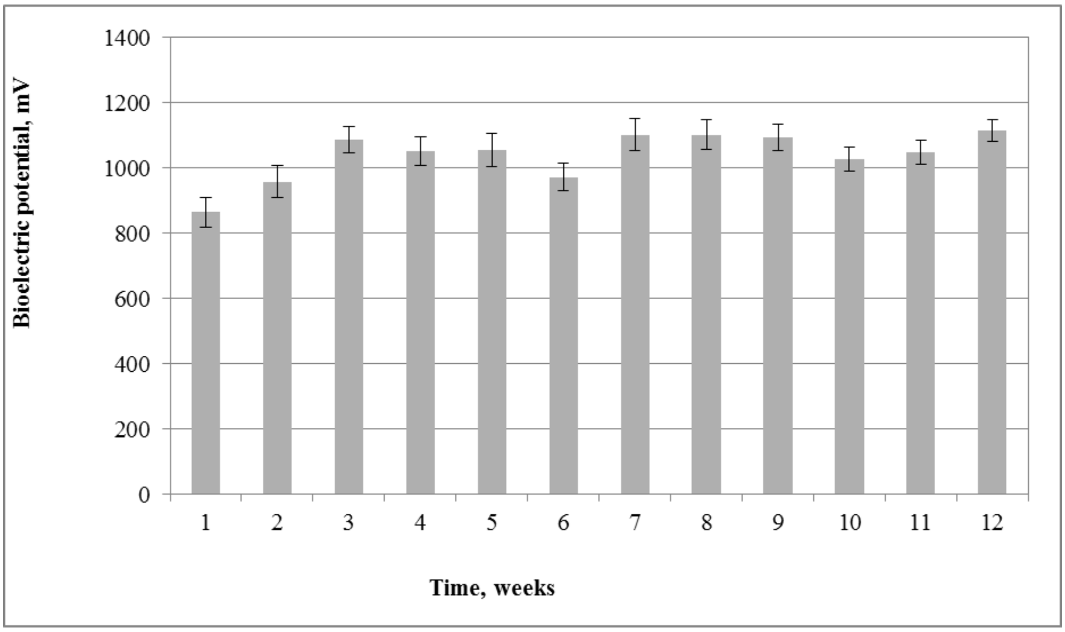

Fig. 2. Average bioelectric potential of *Carex acutiformis* populations during 12 weeks (x ± SE, n = 10)

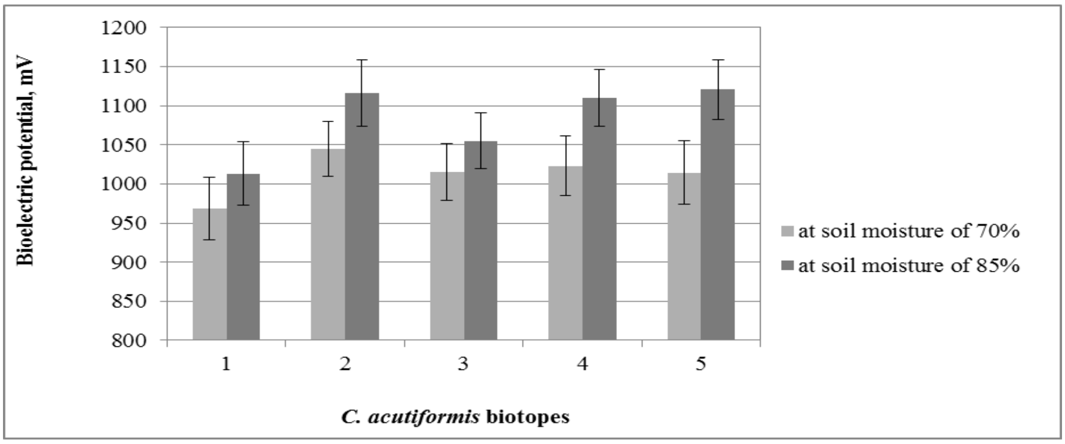

Fig. 3. Bioelectric potential of *Carex acutiformis* biotopes with increasing soil moisture from 70 % to 85 % on the 20th and 25th day of the experiment (x ± SE, n = 10)

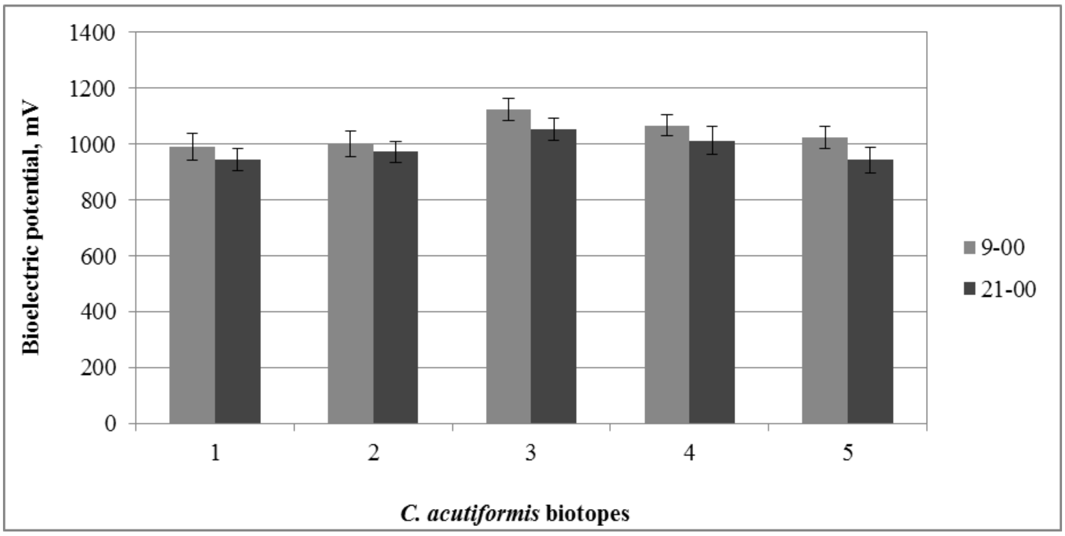

Fig. 4. Diurnal fluctuations of the bioelectric potential of *Carex acutiformis* populations during the 25th – 30th days of the experiment (x ± SE, n = 10)

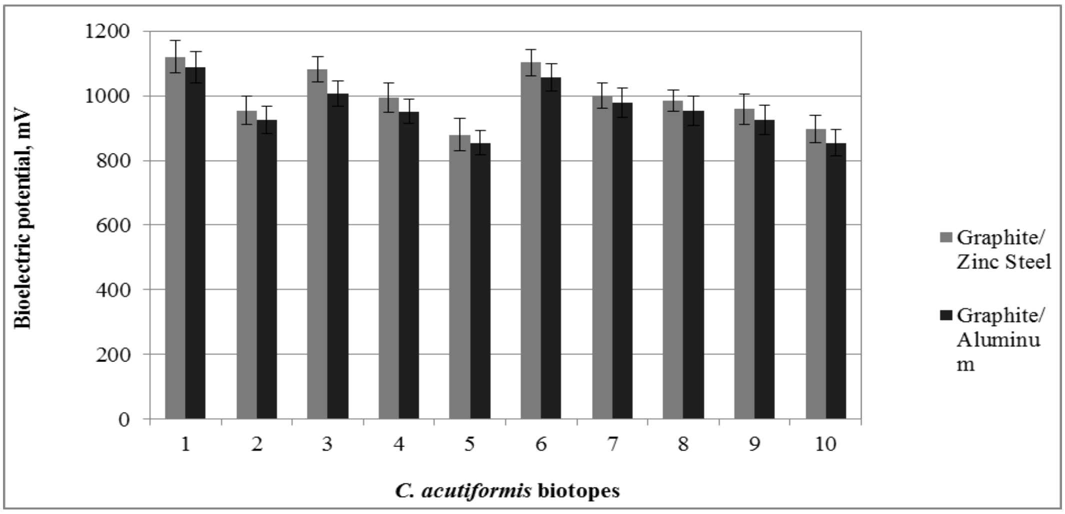

Fig. 5. Bioelectric potential of *Carex acutiformis* biotopes obtained by different electrode systems (x ± SE, n = 10)

Two metals, aluminum and zinc-galvanized steel have corrosion resistance, but aluminum is characterized by a slightly higher cost compared to galvanized steel (Ndjebayi, 2017). Due to the higher values of bioelectric potential and the budget of the pair of graphite/zinc-galvanized steel electrodes, it can be recommended for collecting bioelectricity in wetland meadows.

4. Conclusions

Wetland meadows of sedge *Carex acutiformis* are characterized by a high level of bioelectroproductivity at the level of 864.2–1114.8 mV depending on external conditions. Soil moisture has a positive effect on the bioelectric potential of plant-microbial associations of sedge. Populations of Carex acutiformis, widely represented in the floodplains of the Polissya River, have prospects as a source of renewable energy.

References

Balashov, L. S., & Solomakha, V. A. (2005). Klasyfikatsiia ekosystem zaplavnykh luk Ukrainy [Ecosystem`s classification of flood-plain meadow of Ukraine]. *Ukrainskyi fitotsenolohichnyi zbirnyk,1*(23),108–114.

Bodnar, V. O. (2016, April 1). *Zahalna kharakterystyka lisiv ta lisovoho hospodarstva Ukrainy* [*General characteristics of Ukraine forests*]. Public report of the State Agency of Forest Resources of Ukraine.. Retrieved from http://dklg.kmu.gov.ua/forest/control/uk/publish/article?art_id=62921

Chiranjeevi, P., Mohanakrishna, G., & Mohan, S. V. (2012). Rhizosphere mediated electrogenesis with the function of anode placement for harnessing bioenergy through CO_2 sequestration. *Bioresoure Technology, 124*, 364–370. doi: https://doi.org/doi: 10.1016/j.biortech.2012.08.020

Dai, J., Wang, J.-J., Chow, A. T., & Conner, W. H. (2015). Electrical energy production from forest detritus in a forested wetland using microbial fuel cells. *Global Change Biology Bioenergy*, *7*, 244–252. doi: https://doi.org/10.1111/gcbb.12117

de Schamphelaire, L., Cabezas, A., Marzorati, M., Friedrich, M. W., Boon, N., & Verstraete, W. (2010). Microbial community analysis of anodes from sediment microbial fuel cells powered by rhizodeposits of living rice plants. *Applied & Environmental Microbiology*, *76*, 2002–2008. doi: https://doi.org/10.1128/AEM.02432-09

Eshel, A., & Beeckman, T. (2013). *Plant Roots: The Hidden Half*. Boca Raton: CRC Press.

Ivchenko, A. S. (2009). Bolotnyie massivyi Ukrainyi [Marshlands of Ukraine]. *Svitohliad*, *4*, 42–47.

Kaku, N., Yonezawa, N., Kodama, Y., & Watanabe, K. (2008). Plant/microbe cooperation for electricity generation in a rice paddy field. *Applied Microbiology & Biotechnology*, *79*(1), 43–49. doi: https://doi.org/10.1007/s00253-008-1410-9

Kouzuma, A., Kasai, T., Nakagawa, G., Yamamuro, A., Abe, T., & Watanabe, K. (2013). Comparative metagenomics of anode-associated microbiomes developed in rice paddy-field microbial fuel cells. *PLoS One*, *8*(11), Article e77443. doi: https://doi.org/10.1371/journal.pone.0077443

Liu, S., Song, H., Li, X., & Yang, F. (2013). Power generation enhancement by utilizing plant photosynthate in microbial fuel cell coupled constructed wetland system. *International Journal of Photoenergy*, Article ID 172010, 1–10. doi: https://doi.org/10.1155/2013/172010

Lu, L., Xing, D., & Ren, Z. J. (2015). Microbial community structure accompanied with electricity production in a constructed wetland plant microbial fuel cell. *Bioresource Technology*, *195*, 115–121. doi: https://doi.org/10.1016/j.biortech.2015.05.098

Marynych, O. M., Babychev, F. S., Bieliaiev, V. I., Dorohuntsov, S. I. (Eds.) (1989-1993). *Heohrafichna entsyklopediia Ukrainy* [Geographical encyclopedia of Ukraine]. (Vol. 1–3). Kyiv: Ukrainska Radianska Entsyklopediia im. M. P. Bazhana [in Ukrainian].

Ndjebayi, J. N. (2017). *Aluminum Production Costs: A Comparative Case Study of Production Strategy*. Walden University. Minneapolis.

Rusyn, I. B., & Medvediev, O. V. (2016). *U.A. Patent No 112093*. Ukrainskyi instytut intelektualnoi vlasnosti (Ukrpatent).

Rusyn, I. B., & Hamkalo, Kh. R. (2019). Bioelectricity production in an indoor plant-microbial biotechnological system with *Alisma plantago-aquatica*. *Acta Biologica Szegediensis*, *62*(2), 170–179. doi: https://doi.org/10.14232/abs.2018.2.170-179.

Strik, D. P. B. T. B., Hamelers, H. V. M., Snel, J. F. H., & Buisman, C. J. (2008). Green electricity production with living plants and bacteria in a fuel cell. *International Journal of Energy Research*, *32*(9), 870–876. doi: https://doi.org/10.1002/er.1397

Sudirjo, E., de Jager, P., Buisman, C. J. N., & Strik, D. P. B. T. B. (2019). Performance and Long Distance Data Acquisition via LoRa Technology of a Tubular Plant Microbial Fuel Cell Located in a Paddy Field in West Kalimantan. *Indonesia Sensors*, *19*, 4647, 1–18. doi: https://doi.org/10.3390/s19214647

Takanezawa, K., Nishio, K., Kato, S., Hashimoto, K., & Watanabe, K. (2010). Factors affecting electric output from rice-paddy microbial fuel cells. *Bioscience, Biotechnology & Biochemistry*, *74*, 1271–1273. doi: https://doi.org/10.1271/bbb.90852

Tou, I., Azri, Y. M., Sadi, M. H., Lounici, H., & Kebbouche-Gana, S. (2019). *Chlorophytum* microbial fuel cell characterization. *International Journal of Green Energy*, *16*(12), 1–13. doi: https://doi.org/10.1080/15435075.2019.1650049

Ueoka, N., Sese, N., Sue, M., Kouzuma, A., & Watanabe, K. (2016). Sizes of Anode and Cathode Affect Electricity Generation in Rice Paddy-Field Microbial Fuel Cells. *Journal of Sustainable Bioenergy Systems*, *06*(01), 10–15. doi: https://doi.org/10.4236/jsbs.2016.61002

Wetser, K., Liu, J., Buisman, C. J. N., & Strik, D. P. B. T. B. (2015). Plant microbial fuel cell applied in wetlands: Spatial, temporal and potential electricity generation of *Spartina anglica* salt marshes and *Phragmites australis* peat soils. *Biomass & Bioenergy*, *83*, 543–550. doi: https://doi.org/10.1016/j.biombioe.2015.11.006

Wetser, K., Dieleman, K., Buisman, C., & Strik, D. P. B. T. B. (2017). Electricity from wetlands: Tubular plant microbial fuels with silicone gas-diffusion biocathodes. *Applied Energy*, *185*, 642–649. doi: 10.1016/j.apenergy.2016.10.122