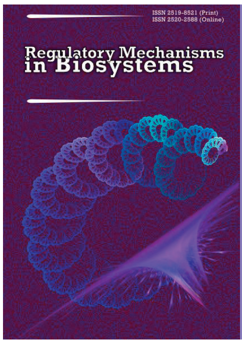

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Prospects of use of *Caltha palustris* in soil plant-microbial eco-electrical biotechnology

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Soil plant-microbial biosystems are a promising sustainable technology, resulting in electricity as final product. Soil microbes convert organic products of plant photosynthesis and transfer electrons through an electron transport chain onto electrodes located in soil. This article presents a study of prospects for the generation of bioelectricity by a soil plant-microbial electro-biotechnological system with *Caltha palustris* L. (Ranunculaceae), a marshy winter-hardy plant that develops early in the spring and is widespread in the moderate climatic zone, in clay-peat medium and with introduction of *Lumbricus terrestris* L. (Lumbricidae). The experiment was carried out in the wetlands of the Ukrainian Polissya and the Carpathian mountains *in situ*, and on the balconies and terraces of buildings to assess the possibilities of using green energy sources located directly in buildings. The electrodes were placed stationary in the soil to measure the values of bioelectric potential and current strength. We monitored the bioelectricity indices in open circle and under load using external resistors, and calculated the current density and power density, normalized to the soil surface covered by plants and electrodes. The revealed high maximal values of the bioelectric potential, 1454.1 mV, and current, 11.2 mA, and high average bioelectricity values in optimal natural conditions in wetlands in situ make *C. palustris* a promising component of soil plant-microbial bio-electrotechnology. We analyzed the influence of temperature and precipitation on the functioning of the soil plant-microbial biosystem. The use of thickets of *C. palustris* in wetlands *in situ*, as a stable source of plant-microbial eco-electricity in the summer, is complicated by the fact that the plant sensitively reacts to long periods of high temperature and periods of drought, which is accompanied by decrease in the level of bioelectric parameters. The cultivation of the marsh plant *C. palustris* as a component of electro-biosystems is possible on terraces and balconies of buildings. The cultivation of *C. palustris* in clay-peat soil with electrode system for production of eco-electricity on shaded balconies and terraces of buildings requires optimal irrigation, lighting, and introduction of *L. terrestris* into the substrate, which increase the bioelectricity values of this biotechnology.

Keywords: plant-microbial bioelectricity; electro-producing microorganisms; renewable energy; green buildings.

Introduction

The essence of soil plant-microbial eco-electric biotechnology is that electro-generating microorganisms produce bioelectricity by utilizing organic matter released into the substrate through the root system of active-photosynthetic plants (De Schamphelaire et al., 2008; Kaku et al., 2008; Strik et al., 2008) or in the process of decay of organic fall foliage (Dai et al., 2015). The technology of obtaining energy from the substrate in which plants and microorganisms develop is completely natural and safe for the environment: it does not contain emissions of toxic and greenhouse gases, which are the product of combustion of traditional non-renewable energy sources. At the same time, plant-microbial electro-biotechnology is potentially more electro-productive than burning biomass or anaerobic digestion of plants of a similar area (Wetser, 2016). This biotechnology does not require the construction of large-scale stations, such as thermal power plants, hydroelectric plants, nuclear power plants or the installation of wind turbines that require large investments and areas. Plant-microbial eco-electric biotechnology uses already existing greenery and does not require the allocation of special areas for itself, as for example, with solar power plants. With this technology, the installation in the soil of electrode systems that collect electricity generated by soil microorganisms is single and low-cost, in comparison with other types of energetics, and interference with the environment is completely non-aggressive.

Currently, eco-electric microbial-plant biotechnology is faced with the problem of low power (Helder et al., 2013; Nitisoravut et al., 2017; Wetser et al., 2017). The methods for maximizing the collection of microbial-plant eco-electricity are the selection of new plants (Helder et al., 2010; Hubenova & Mitov, 2012), the use of new electrode systems (Picot et al., 2011; Chen et al., 2012; Rusyn & Valko, 2019), synthetic nutrient media (Helder et al., 2011; Yadav et al., 2012; Liu et al., 2013), natural media (Rusyn, 2014; Moqsud et al., 2015; Wetser et al., 2017). The objective of this work is to makea contribution to the optimization of electro-biotechnology. The screening of new plants for the optimization of electro-biotechnologies is important, since plant species differ essentially in their root exudation patterns, on which depends the development of electro-generating and associated microorganisms and, consequently, the level of bioelectricity (Hutsch et al., 2012).

The selection of plants for eco-electro-biotechnology was carried out among marshy plants, considering that wetlands are optimal for collecting bioelectricity (Lovley et al., 2011; Helder et al., 2012), and varieties of aquatic plants are the subject of research of bioelectricians throughout the world (Timmers et al., 2012; Lu et al., 2015; Rusyn & Hamkalo, 2018). One of the most important reasons for choosing *C. palustris* for electro-biotechnology is that the marsh marigold is an early developing flowering plant (Schuettpelz & Hoot, 2004), which makes it possible to obtain bioelectricity from the early spring when the earth cover is devoid of vegetation. *C. palustris* is a winter-resistant plant that survives at freezing temperatures up to –35 °C, which is relevant for the application of technology in the moderate climatic zone. The perenniality of *C. palustris* means that the plant actively secretes organic matter through the roots (Lynch & Whipps, 1990; Kuzyakov & Domanski, 2000) and accumulates in the soil a powerful rhizodeposit (Jones et al., 2004; Dennis et al., 2010; Hutsch et al., 2012), which is a substrate for the development of soil electro-generating microorganisms. At the same time, the plant is decorative (Moroziuk & Protopova, 2007), which allows eco-bio-electric technologies with *C. palustris* to perform an aesthetic function. The marsh marigold is widespread throughout the territory of Ukraine and the moderate climatic zone of the Northern and Southern Hemisphere (Schuettpelz & Hoot, 2004), does not require complicated care, which indicates a low budget of eco-electro-biotechnology with *C. palustris* and brings opportunities for the use of vast unused areas of its growth as a source of bioelectricity. That is, the plant has a whole complex of valuable characteristics for application in electro-biotechnology and would become a great biocomponent for them, if plants could provide high bioelectro-productivity.

We studied bioelectro-productivity with *C. palustris* in real climatic conditions, in which biotechnology is used. Research on bioelectricity, mainly, is carried out on constructed marshy systems in laboratory conditions (Lu et al., 2015; Oon et al., 2015; Wetser et al., 2015). Investigation of electro-biotechnologies *in situ* is only at the early stages of development: in rice fields (Kaku et al., 2008; Takanezawa et al., 2010), salines (Timmers et al., 2010) and forest wetland (Dai et al., 2015). The possibility of using the balconies and terrace areas of buildings to produce bioelectricity through their greening with the *C. palustris* is another new idea and provides the hypothesis that we set out to test in this work. Green roofs are building-associated places for electro-biotechnology application (Helder et al., 2013). Balconies and terraces of buildings occupy a large segment of the housing stock. They are the apartment recreation areas of high-rise buildings and mansions, but they could acquire another important value, energy function, for the small local energy needs of the inhabitants of apartments: lighting of balconies and terraces or recharging of mobile phones, if it would be managed to effectively cultivate bioelectro-productive swamp plants on balconies and terraces. And although their area is small, the installation of vertical structures located on top of one another with electro-boxes with plants, solves both the problem of increasing the area of production of bioelectricity and the creation of a decorative green zone.

Most studies on the use of microbial-plant energy are carried out in liquid synthetic media or marsh sediments (Helder et al., 2011; Yadav et al., 2012; Wetser et al., 2015). But microbial-plant bioelectricity can also be obtained in substrates with low conductivity (Wetser et al., 2017; Rusyn & Hamkalo, 2019). We have been studying the possibility of using bioelectro-technologies in natural clay-peat soils. Successful use of clay-peat substrates would significantly reduce the cost of biotechnology and expand the potential of electro-biotechnologies, their location and assortment of plants as bioelectric inducers. Earthworms *L. terrestris* could be the natural bio-booster of bioelectricity production, they are important both for the development of plants and for the functioning of soil microorganisms (Khomyakov, 2009; Edwards et al., 2011; Blouin et al., 2013). Earthworms are active regulators of soil microbiota, promoting the development of some populations of soil microorganisms (Khomyakov, 2009), and quite possibly, electric-generating groups. Based on these data, we have checked the hypothesis about the effect of *L. terrestris* on the yield of microbial-plant energy.

Thus, the objective of the work was to study the prospects for the generation of bioelectricity of 1) the cosmopolitan, early developing and frost-resistant marsh plant *C. palustris*, and of the bioelectroductivity enhancer *L. terrestris* as biocomponents of electro-biotechnology 2) natural clay-peat substrate as a medium and 3) shaded balconies and terraces of buildings, and waterlogged growth sites of *C. palustris in situ* as places of application of electro-biotechnology.

Materials and methods

Installation of electrode systems and conducting experiments. The subject of the study was bioelectricity indices of the soil in which *C. palustris* grows: 1) *in situ* in its wetland-growing places of the Ukrainian Polissya and Carpathians and 2) in pots on terraces and balconies of buildings. In the field, experiments were carried out in a natural location of the growth of marsh marigold in the village Kulchin, Turiysky district of the Volyn Polissya region and at an altitude of 1013 m above sea level in the highland village of Kryvopillia, Verkhovyna district of the Ukrainian Carpathian mountain region. The analyzed soil samples with the *C. palustris* bushes had a different degree of illumination from 800 to 2000 Lux, soil moisture varied 80% to 100%, the soil pH was 6–8, the average air temperature ranged 14 °C in the highlands to 25 °C in Polissya, and the size of the thickets of *C. palustris* was 5 to 70 cm in size.

The electrodes were placed stationary in the soil to measure the values of bioelectric potential and current strength. Plates of galvanized steel of 292 x 30 x 0.8 mm were used as anodes, and graphite plates of 90 x 30 x 15 mm as cathodes, with copper wires connected to them (Rusyn & Medvediev, 2016), the ending of which led to the soil surface. Graphite electrodes were placed at a depth of 15 and 30 cm, galvanized steel electrodes were placed at a depth of 30 cm (Fig. 1) to reach to the area of root extractions.

In order to evaluate the possibility of using *C. palustris* as a biocomponent in electro-biotechnology systems on terraces and balconies of buildings, experiments on the capability and peculiarities of marsh marigold cultivation were carried out under these conditions. Plastic pots with soil substrate, planted plants *C. palustris* and electrodes were placed on terraces and balconies of multi-storeyed buildings shaded by higher-placed terraces and balconies. That is, the yellow marsh marigold was grown in somewhat different conditions than in natural habitats: although at a similar ambient temperature, but with a lower natural light (on average about 300 Lux) through shading of the upper terraces and balconies and in a smaller amount of substrate (in pots, unlike an unlimited amount of soil in situ). Plants were protected from rainwater, watering was carried out regularly.

C. palustris for planting on the terraces and balconies of the buildings was brought from the nursery of plants and directly from the natural growth sites of plants from the marsh areas of the Ukrainian Polissya: villages Kulchyn and Selets of Turiysky district of Volyn region and the villages of Chornyvody of Horodotsky district of Khmelnytsky region. Clumps of *C. palustris*, with average height of 35 cm, were used in the experiment. Plants were planted in pots of 25 cm in diameter and 32 cm in depth with a clay-peat substrate in proportion 1 : 1. In some of the samples, 3 weekly, earthworms *L. terrestris* were added to the soil in a quantity of three individuals per pot. The bottom of the polypropylene pot was covered with a centimeter layer of soil substrate, plant roots and the cathodes and anodes on a certain depth were placed on it, filling them with a substrate to the top of the pot, leaving a free 1 cm of container. The wires from the electrode systems were withdrawn from the depth of the substrate to the soil surface and connected to the multimeter. Containers with plants and electrodes were placed on terraces and balconies of buildings in the city of Lviv. The plants were cared for by watering the substrate as the soil dried. The experiment was conducted during the summer months of 2014.

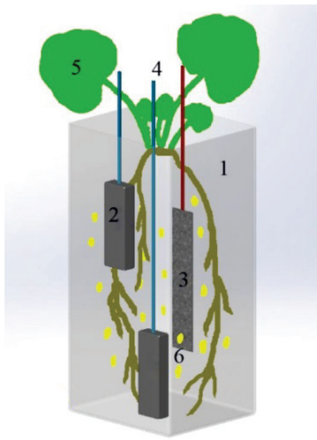

Fig. 1. Scheme of electrode placement in soil *in situ* and on terraces and balconies of buildings: *1* – soil sample with roots of *C. palustris*; *2* – cathode; *3* – anode; *4* – wires connected with electrodes in the depths of the soil and placed on the surface of substrate; *5* – *C. palustris* plants; *6* – colonies of soil electricity-generating microorganisms

Measurements of bioelectricity values were carried out with the application of external resistances and in the open-circuit environment.

Measurements of the bioelectric potential (BEP) in mV and the current (I) in mA were carried out using a digital multimeter whose probes were allocated on wires connected with the cathode and anode. Bioelectricity indicators were recorded daily and average values were calculated. The current power was measured by practically using resistors and also was calculated theoretically through practically measured voltage and resistance. The current density and power density were calculated as described by Rusyn & Hamkalo (2019). Current density and power density were normalized to the experimental area of planting covered by the electrodes. The study of the generation of bioelectricity by samples in conditions of short-term loading was carried out using the external resistances of 10–12 kΩ. Resistors of 10, 50, 250, 500, 1000, 3000, 5000, 12000 Ω were used, and the voltage through the external resistor, connected in the circuit periodically for 15 min, was recorded. The calculation of the average daily rainfall every week was carried out by processing the meteorological data of archive rp5.ua, through the calculation of the total amount of precipitation for a certain period of time. The reported results were presented as the average of all replicate experiments and their standard errors (x ± SE). Significance of difference between average values was established using one-way analysis of variance and F-test for 95% confidence level.

Results

Generation of bioelectricity by soil microorganisms of samples with C. palustris during arid summer months in situ. To determine the possibility of using *C. palustris* in electro-biotechnologies, we studied the bioelectric indicators of the soil in which the plant grows *in situ* in its natural habitats in the wetlands of the Ukrainian Polissya and the Carpathians. The average bioelectric potential of the experimental samples was 1125.4 mV, the maximum and minimum recorded voltage were 1454.1 mV and 1020.2 mV, the average current strength was 9.1 mA, and its maximum and minimum – 11.2 and 3.4 mA, respectively. In order to assess the prospects for obtaining bioelectricity from the natural habitats of *C. palustris*, during the summer, bioelectric potential and current strength displays were recorded. Wetland areas with *C. palustris*, which are not exploited, are a widespread phenomenon in the Ukrainian landscape and could serve as a source of eco-electricity if improved electrode systems that maximize the collection of electrons and protons were installed in them. At the beginning of the summer, *in situ* research samples of developed bushes of *C. palustris* were characterized by high values of both bioelectric potential and current strength (Fig. 2): the average bioelectric potential exceeded 1.1 V, and the average current strength was 9.9 mA.

Prolonged arid weather, which prevailed in July, with absence of rains and high air temperatures, led to drying of plants and loss of leaf mass, accompanied by a decrease in the level of bioelectric parameters: current strength was 45.7–64.4% of the values that were in optimal conditions, and bioelectric potential equaled 59.7% to 77.9%, respectively. In some cases, the drop in values of current strength and bioelectric potential was almost double (Fig. 2). Less than 2 mm of precipitation per day was revealed as critical values that were reflected at the level of bioelectricity parameters.

In early August, under favourable conditions, the plants' growth was restored, young leaves appeared and developed intensively. Along with the restoration of plants, the level of bioelectric potential and current strength began to rise, approaching the initial values of samples of developed bushes under optimal conditions (Fig. 2). However, in mid-August, a new drought led to the re-drying of young plants and the subsequent new reduction of level of bioelectricity. As a result of drought, the average bioelectric potential decreased to 80.3%, and current strength – to 50.4% of the baseline values that were in optimal conditions (Fig. 2). The loss of up to 30.0% of leaf mass had little effect on the generation of BEP and the current strength; the average reduction was 2.2% and 2.8% respectively. However, the drying of the leaves of plants by more than 30.0% was accompanied by decrease in the bioelectric potential (37.0% decrease in average values) and current strength (by 30.1%, Fig. 3).

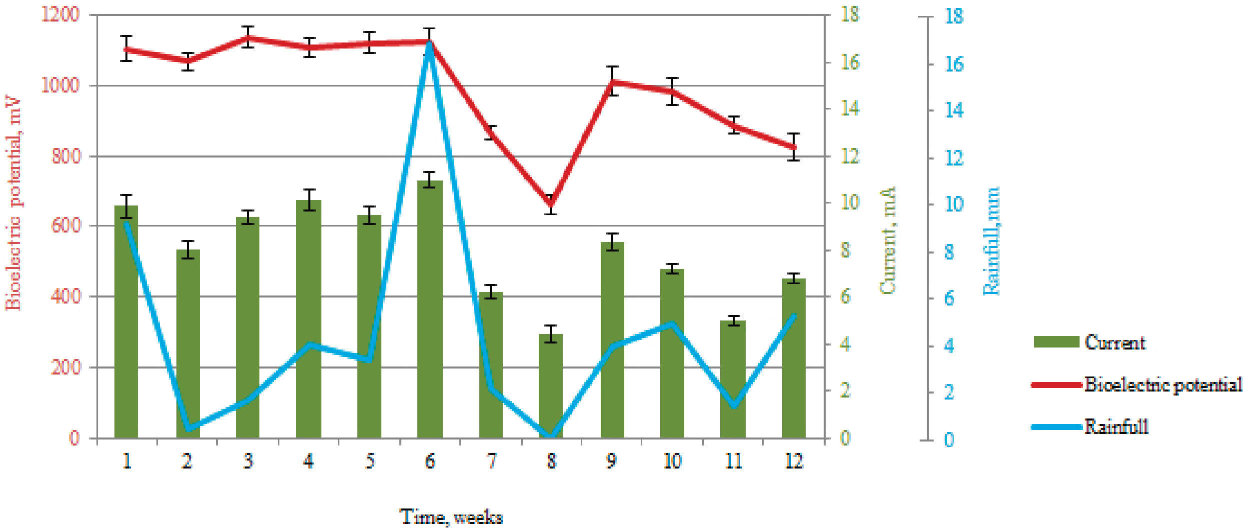

Fig. 2. Dynamics of the bioelectric potential and current of soil samples with *C. palustris in situ* during the summer period 2014: during the long arid and high-temperature period,weeks 7, 8 and 10, 11 in the middle of July and August, bioelectricity level decreased (x ± SE, n = 10)

Bioelectric parameters of soil-microbial samples with C. palustris on terraces and balconies of buildings. With regular watering for most plants, the conditions of the terraces and balconies were favourable and marsh marigold successfully developed. In order to assess the care requirements of the plants, samples were tested in conditions of irregular irrigation. The study showed that plants need a regular supply of moisture of the soil and will dry out if it is not available; in the absence of watering the plants lost leafy mass. To assess the prospects of soil samples with *C. palustris* for generating bioelectricity on terraces and balconies of buildings we carried out polarizing measurements and testing with measurements of open-circuit bioelectric potential and current strength at a load of 10 Ω per month. At short-term loading, the generation of bioelectricity by soil samples was as follows (Fig. 4). The maximum values of power density, normalized to the surface occupied by plants and electrodes were 0.16–0.18 W/m^2 at using external resistances of 200–50 Ω, respectively (Fig. 4). The maximum value of the normalized current density was 1.2 A/m^2 at a load of 50 Ω (Fig. 4). In samples without plants, an open-circle bioelectric potential was of 615.5 mV and a current of 0.9 mA at 10 Ω was determined, which is the result of background activity of soil microorganisms in organic-rich soil substrate (Fig. 5, 6). Average values of the bioelectric potential of samples with *C. palustris* were higher than control, without plants, by almost two times, and slightly higher than *in situ*: 1226.1 mV, on the balconies and teracies of buildings against 1125.4 mV *in situ*. The maximum bioelectric potential indicators on terraces and balconies of buildings were slightly lower than those recorded in natural habitats, 1375.3 mV versus 1454.1 mV *in situ*.

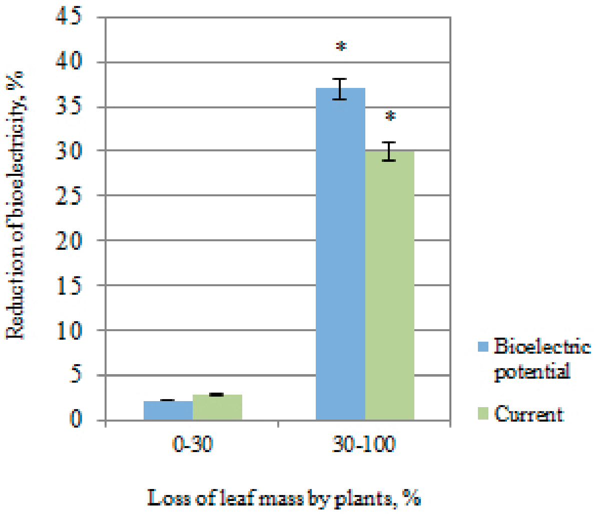

Fig. 3. Decrease of parameters of bioelectricity with loss of leaf mass by plants: loss of more than 30% of the amount of leaves leads to a decrease in the production of bioelectricity of samples (x ± SE, n = 10); * – P < 0.05 between bioelectricity parameters of plants with leaf loss over 30%

It has been found that development of a plant clump is important for obtaining high bioelectric potential and current strength. Samples of soil with intensively developed clumps, with a large number of leaves from 20 to 30, were characterized by higher values of bioelectric potential and current strength than weakly developed clumps with the number of leaves from 10 to 20 (Fig. 5, 6). The average bioelectric potential of mature adult clumps was 1226.1 mV, while the mean bioelectric potential of small-leaf clumps was 1006.5 mV (Fig. 5). The average current strength of well-developed clumps exceeded the average current strength of clumps with a small amount of leaves by 16.1% (P < 0.05, Fig. 6). Obviously, a high level of photosynthetic activity in intensively developed clumps induces more powerful root secretion of organic substances, which are substrates for the development of electricity-generating microorganisms. Another factor that increases the level of bioelectric indicators of soil samples with marsh marigold on balconies is the addition of *L. terrestris* to the soil with plants. The introduction of *L. terrestris* into soil samples with weakly developed clumps of *C. palustris* resulted in an increase in the bioelectric potential of the average of 168.3 mV and in the current strength of 0.6 mA (P < 0.05, Fig. 5, 6). In samples with equally developed plants, in probes with *L. terrestris*, bioelectric potential and current strength were higher. This effect is due, probably, to the hydrophilic products of *L. terrestris*, which create centers of microbiological activity, including, those for electric-generative microorganisms. The introduction of *L. terrestris* approximates the cultivation conditions to natural.

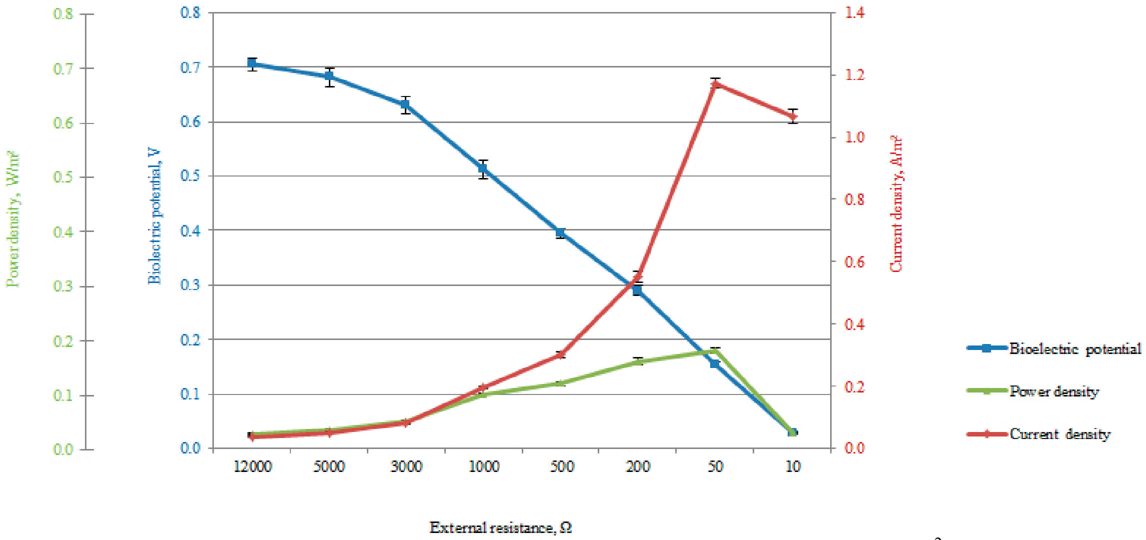

Fig. 4. Bioelectric potential, current density and power density of samples normalized to 1 m^2 surface covered by plants and electrodes under the action of external resistors (x ± SE, n = 20)

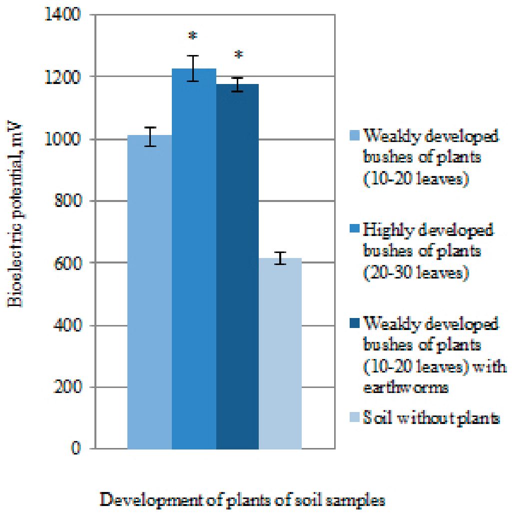

Fig. 5. The average bioelectric potential of soil samples with *C. palustris*, cultivated on terraces and balconies during one month (x ± SE, n = 10); * – P < 0.05 compared to weakly developed samples

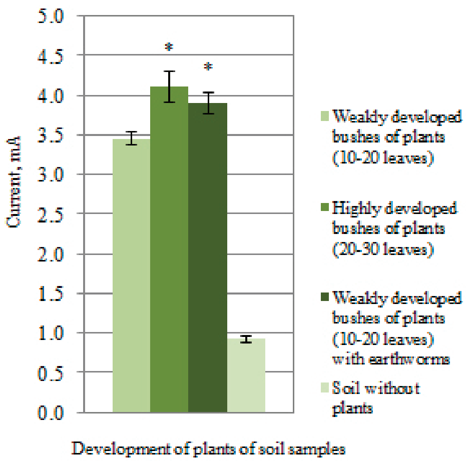

Fig. 6. The average current of soil samples with *C. palustris*, cultivated on shaded terraces and balconies during a month (x ± SE, n = 10); the highest current was observed in samples with the most developed leaf mass and with introduction of *L. terrestris*, * – P < 0.05 compared to weakly developed samples

Discussion

Samples with *C. palustris in situ* in its natural habitats in the wetlands of the Ukrainian Polissya and the Carpathians mountains were characterized by the highest values of bioelectricity parameters among the samples we examined *in situ* (Rusyn, 2014). The high values of the bioelectric potential and the current of biosystems with *C. palustris in situ* make the plant a promising biocomponent in electro-biotechnological systems. Most of the time during the summer, the generation of bioelectricity by soil microorganisms of samples with *C. palustris* did not occur at full capacity due to adverse drought and high-temperature conditions. In dynamics there were a couple of weekly falls of values of bioelectric potential and current strength. The bioelectrical indices of *C. palustris* wetland habitats during the arid July and August declined in the same way as during summer drought in a forested wetland (Dai et al., 2015). Prolonged arid weather and high temperature led to drying of plants. The loss of leaf mass below 30% was accompanied by a decrease in the level of bioelectric values. With return to the optimal level of precipitation, more than 2 mm per day, the plants were restored, bioelectric parameters rose, approaching the initial values. As shown in the paper (Hubenova & Mitov, 2012), the current depends on the physiological stage of the plant and decreases when plants die. Frequent weather abnormalities: prolonged droughts and periods of heat that have become frequent for Ukraine, a moderate climate country, due to global climate change hinder the prospect of the sustainable use of wetlands with *C. palustris* as a source of eco-electricity without resorting to special measures. The natural habitats of *C. palustris* can be effectively exploited as a source of eco-electricity only if periods of drought are short, accompanied by only partial loss of leaf mass, or if the irrigateon systems are installed on them.

C. palustris plants can be successfully cultivated on shaded terraces and balconies of buildings as a component of the electro-biosystem, but they require attentive care, for their full development requires timely irrigation. The ability to use natural clay-peat substate for bioelectricity production allows cheap biotechnology to be obtained, since it does not require specific valuable media. The average current of the samples on the terraces was lower by 2.2 times than the average current of samples *in situ*. Measuring the current strength in high-mountain natural habitats of *C. palustris*, we encountered similar low values of current, which may be due to the lack of optimal growth conditions or the recovery phase of the plant after drought. Perhaps the plants needed more significant lighting for their development. One of the factors that distinguished the conditions on the shaded balconies and terraces of buildings from the conditions of natural habitat was lower lighting. Less intense photosynthesis in low light conditions leads to the fact that all organic matter goes only to the needs of the plant. Under these conditions, there is not a large excess of synthesized organic substances and, accordingly, the secretion of organic substances into the soil is weak, which leads to a significant reduction in the activity of electric-generating microorganisms and a decrease in their production of current strength. As shown by Hubenova & Mitov (2012), the current strength depends on the level of illumination of the samples.

Despite the fact that the level of bioelectricity generated by soil microorganisms in samples with *C. palustris* on shaded terraces and balconies of buildings was lower than in natural habitats, it was still higher than in other plants investigated by us *in situ*. Therefore, if selecting the optimal conditions in outdoor areas of buildings for cultivating *C. palustris*, as one of the most bioelectro-productive plants, and using improved electrode systems (Rusyn & Medvediev, 2018), maximizing the collection of bioelectricity, there is reason to hope for higher bioelectricity performance at the level of their values in natural habitats under optimal conditions. In this first study of the prospects for the generation of bioelectricity induced by *C. palustris* in the clay-peat soil medium *in situ* and on shaded balconies and terraces, the general patterns and trends in the generation of bioelectricity were studied using a cheap and simple mini-electrode system used in similar previous screening experiments. For the purpose of implementing cheap and large-scale experiments, we did not set ourselves the task of using the multiplex high-efficiency multi-electrode systems we developed (Rusyn & Medvediev, 2018) that allow bioelectricity to be collected more efficiently. Adding *L. terrestris* and maintaining the active development of leafy mass *C. palustris* can also increase the level of bioelectricity.

Although we have obtained high bioelectricity values in comparison with other soil-plant samples (Rusyn, 2014), so far the bioelectric potential and current strengths are low for practical application of the biotechnology. However, the estimated possible theoretical maximum of the technology (Strik et al., 2011) and the work of scientists around the world in this direction, including our developments of new electrode systems, give reason to expect that electro-biotechnologies with *C. palustris* have prospects of use for a wide variety of low-energy needs: LED lighting for park areas (Schultz, 2014; Lu et al., 2015) and terraces of buildings, for charging field devices, environmental sensors and field sensors (Tender et al., 2008; Zhang et al., 2011), the support of on-line monitoring systems for natural ecosystems (Dai et al., 2015), the installation of electrified stations of wilderness tourism in natural parks with the ability to charge mobile phones, laptops, camera batteries, electric bicycles, and also for large-scale energy needs, such as a full energy provision for buildings and entire villages (Wetser, 2016).

Conclusion

This work is the starting point for the further development of a highly efficient soil plant-microbial eco-electrobiosystem with *C. palustris*. Soil samples with the plant are characterized by high values of bioelectric parameters. *C. palustris* is an early flowering and winter-resistant plant,which is widely distributed in wetlands in the Ukrainian landscape from early spring, and provides an opportunity to be exploited in biosystems. *C. palustris* plants can be successfully cultivated in natural clay-peat substrate on terraces and balconies of buildings as a component of a electro-biosystem with regular watering and, potentially, receive electricity directly within the building. Exploitation of electro-biosystems with *C. palustris* in wetlands *in situ* is accompanied by a decrease in bioelectric parameters during droughts and periods of high temperature. The sensitivity of bioelectricity generation to the level of soil moisture and the positive reaction to the introduction of *L. terrestris* revealed by us are important for optimizing the cultivation conditions of *C. palustris* for efficient bioelectricity production. The installation of improved electrode systems that will maximize the collection of plant-microbial eco-electricity in the natural habitats of *C. palustris* and terraces and balconies of buildings will allow to use them as a source of bio-electricity in the future. Wetlands that are not exploited and are widespread in the landscape of European and North American countries, and also balconies and terraces of buildings, apart from nature reserve and recreation purposes, will be able to acquire important energetic values.

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