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SALT DISTRIBUTION IN COMMON REED BIOMASS AT INCREASED SALINITY

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ABSTRACT

This article describes salt distribution (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) in halophytic plants, common reed *(Phragmites australis)* taken from four locations in Ostrava - Důl Lazy, Karvinský potok, Heřmanický rybník, Nový rybník. The research aimed to find out where salts, but also other elements acting as contaminants in the environment are stored, how they are distributed, what physiognomic changes they cause in the plant, and to what extent common reed can face the stress conditions of salinity in the phytoremediation process.

The experiment took place under controllable conditions in the phytotron - temperature 25 °C, light regime 12 hours day/12 hours night, air humidity 60 %, light intensity 150 $\mu mol.m^{-2}.s^{-1}$. Bunches of reeds were subjected to gradual salinization with 1% to 5% Darkov salt solutions. Biomass samples were analyzed by instrumental neutron activation analysis (NAA) and atomic absorption spectrometry (AAS) methods.

Based on the results of measurements conducted using the AAS and NAA methods, it can be concluded that the dominant element in the reed beds at all four specified sites of interest is potassium. It is bioaccumulated in the aboveground part of the plant. The highest concentration of potassium was found in the aboveground part of the reeds from the Karvinský potok site; the lowest was observed in the aboveground part of the reeds from the Nový rybník site.

The growth analysis was not conducted according to the methodology, but another interesting finding is that reed beds from the Nový rybník site exhibited the best tolerance to salt stress and the gradual process of salinization with 1% to 5% solutions of Darkov salt.

Keywords: AAS; Common reed; NAA; Phytoremediation; Salinity; Salt distribution; Salt stress.

1 INTRODUCTION

Salinity is a global environmental issue nowadays, especially in arid and semiarid climates as well as coastal areas, which are induced by precipitation of soluble salt in soils and water systems. It is likely due to natural and anthropogenic activities. High soluble salts in water and soil hinder plant growth, which directly affects crop productivity and leads to land degradation. In non-agricultural lands, it affects urban landscapes through subsidence, corrosion, and groundwater quality deterioration. Moreover, it induces negative impacts on human health to a large extent [1].

A growing human population needs more and more to feed itself. Since quite a large part of the land surface is of desert or semi-desert in character and the water usable for irrigation is mainly salty, plants acclimatized to conditions of high salinity will in the future be an irreplaceable source not only of food but also of fodder, biofuels, textile fibres, etc. [2].

Halophytes are flowering plants native to saline habitats. These habitats contain high salt, heavy metals, and other toxic anthropogenic agents. To complete their life cycle in such harsh conditions, halophytes have evolved different strategies like the development of succulence, compartmentalization of toxic ions, synthesis of osmolytes, increase in activity of antioxidants, and synthesis of compatible solutes. Halophytes have significant applied interests in various agricultural and non-agricultural purposes besides for maintenance of ecological balance. Important bioactive metabolites can be derived from halophytic plant species for commercial value. In addition, halophytes can be utilized as alternative plants as they could be cultivated for food, fodder/forage, fuel, and medicinal crops on saline lands with the help of salty water irrigation. Apart from tolerance, halophytes can be utilized for environmental cleanup. Many halophytes are hyperaccumulators of different heavy metals and salts [3].

Plants have developed complex defences to resist salt stress that rely on a variety of mechanisms, such as osmolyte biosynthesis, alterations in ion homeostasis, intracellular compartmentalization of toxic ions, and ROS scavenging systems. Induction of these pathways through brief exposure to low levels of salt stress, a process called salt acclimation, can improve plants´ resistance to salinity. However, tolerance to soil salinity levels varies between plant species, and plants can be characterized as halophytes or glycophytes. Halophytes are salt-resistant or salt-tolerant and can complete their life cycles in soil containing more than 200 mM NaCl, while glycophytes cannot. Generally, halophytes follow three mechanisms of salt tolerance: reduction of the Na^+ influx, compartmentalization, and excretion of sodium ions. Pseudo-halophytes intercept ions in roots and minimize transport to the shoot parts of the plant to protect the main metabolic tissues. Euhalophytes can dilute salt within their succulent leaves or stems and thus have high salt tolerance. Recretohalophytes can actively excrete absorbed salt to the outside via a typical salt excretory structure in the epidermis [4].

Phragmites australis (common reed) is one of the most extensively distributed species of emergent plant worldwide. The adaptive features of this plant show its competitive character [5].

Phragmites australis (common reed) is one of the most distributed macrophytes in aquatic ecosystems, and numerous studies showed its capacity for trace element bioaccumulation. *P. australis* (Cav.) Trin. ex Steud., known as common reed, is a large perennial grass living in lakes and rivers or brackish wetlands such as marshes, across temperate and tropical regions all over the world. It belongs to the Poaceae family and is the most common species of the *Phragmites* genus. This species prefers eutrophic and stagnating waters and tolerates a moderate salinity. It is a rhizomatous hemicryptophyte/geophyte and forms wide stands known as reed beds that provide microhabitats for many birds and mammals [6].

Phytoremediation is the use of plants for remedying water and soil pollution. The treatment of heavy metals in contaminated lands or water reservoirs has attracted most of the research attention as it seems to be a promising technology to mitigate pollution without excavation of the contaminants for mechanical disposal [7].

The method based on the absorption of the contaminant by the roots of the plant with subsequent accumulation in the above-ground part of the plant is called phytoaccumulation (phytoextraction). A necessary prerequisite for the functioning of the method is the hyperaccumulation property of the plant species towards the remedied contaminant [8].

Another method of phytoremediation is rhizofiltration, which is applied during contaminant removal from surface, sewage or depleted groundwater using the root system of plants. It's running out to precipitate the contaminant on the root system or to absorb it directly in the roots [8].

Atomic absorption spectrometry (AAS) is one of the most commonly used techniques for analytical purposes. It has been widely used in research laboratories and also in the food, environmental, pharmaceutical, petroleum, and in other industrial sectors. It can be employed by three different atomization processes, which are: flame atomic absorption spectrometry (FAAS), electrothermal atomization atomic absorption spectrometry (ETAAS), and chemical vapor generation atomic absorption spectrometry (CVG-AAS). However, the choice of the ideal technique is determined by the analyte's chemical nature and its content in the sample, as well as the sample's chemical composition and its physical state [9].

Neutron activation analysis (NAA) is a method of elemental analysis utilizing the properties of the atomic nucleus. Instrumental NAA is remarkably free of systematic errors when practiced with care and excellent results can be easily obtained. The radioactive isotopes are potentially useful for NAA, and assay of their decay radiations occurs after the neutron irradiation. Neutron capture cross-section values for most isotopes are near their maxima for thermal neutrons. Some elements with large cross-sections are present at low enough concentrations in most soil samples so that the thin target assumption is valid. The limited availability of neutron sources is the major deterrent to the more widespread use of NAA. Research nuclear reactors at university and government facilities are most commonly used for irradiations. Multichannel analysers are needed for pulse height analysis and for recording the gamma-ray spectrum. Other required modules include an amplifier and a high-voltage source for the detector [10].

This study describes the salt distribution mechanism of common reed (*Phragmites australis*).

2 MATERIAL AND METHODS

2.1 Characteristics of places of interest

2.1.1 Důl Lazy

GPS: 49°49'46.56" N, 18°26'40.56" E

Area of interest of the experiment – Důl Lazy is located in the southwestern part of the Ostrava-Karviná coal mine. The mining field of this mine is located in the cadastres of the cities of Orlová and Karviná, while the surface area is located in the Orlová local part of Lazy [11].

2.1.2 Karvinský potok

GPS: 49°51'6.682" N, 18°29'46.033"E

It was and still is the most damaged watercourse ever due to mining influences. It originally flowed into the river Stonávka. For the purposes of drainage of the mined area and removal of pumped mine waters, the stream was diverted with its mouth into the river Olše. Karvinský potok is currently almost entirely an artificial water feature, and it is no longer possible to determine its proven source or place of origin. The Karvinský potok is part of the Kozinec reservoir [12].

2.1.3 Heřmanický rybník

GPS: 49.8716783 N, 18.3266433E

The location is situated in the territory of Ostrava, Bohumín, and Rychvald. It is a system of five ponds (Heřmanický, Záblatský, Lesník, Figura, and Nový Stav) with extensive reed beds and adjacent wetland meadows. Due to its extraordinary natural scientific importance, exceeding the level of the Moravian-Silesian Region, the territory was included among the so-called European significant localities.

To this day, the territory is affected by deep coal mining, which, since the 1960s of the 20th century, has manifested itself on the surface in the subsidence of the terrain. The Heřmanický rybník itself served since 1972 as a dosing tank for salty mine waters that accompanied the coal deposits around Ostrava. In addition to mine waters, small amounts of surface technological waters from the mine area were also pumped into the Heřmanický rybník and drained from adjacent heaps [13].

2.1.4 Nový rybník

GPS: 49.8018133 N, 18.2023181E

The new pond dominates the Rezávka nature reserve with an area of 84,05 ha in terms of water areas. This is a floodplain area located in the city of Ostrava, south of the Svinov district and west of the Zábřeh district in the Ostrava district [14].

2.2 Collection of plant material

For this study, reeds were collected in early April 2019 from three diverse locations in the Ostrava region with varying degrees of salinity (Důl Lazy, Karvinský potok, Heřmanický rybník). Nový rybník was chosen as the reference site for sampling from a non-saline area. The common reed has natural conditions here.

The reed roots were dug up with a spade. It was necessary to select high-quality plants with a sufficiently developed root system, including rhizomes. Smaller plants are very fragile, and it is advisable to cultivate them in clumps for mutual support. Once removed, the plants were immediately planted in prepared plastic pots measuring 20 × 24 cm in diameter. The flowerpots were properly labeled with the location and date of collection.

Důl Lazy

12 reeds were collected at the wastewater inlet to the WWTP (wastewater treatment plant). Sludge sediment was used as substrate.

Karvinský potok

Karvinský potok was chosen as the second area of interest. The banks of the stream are overgrown with tall reeds, 12 of which were taken for our experiment. These reeds, like the reeds growing at the Důl Lazy, are exposed to salt stress. The sediment of the Karvinský potok was taken as a substrate, in which reeds grow naturally in this area.

Heřmanický rybník

The third area of interest, Heřmanický rybník, has the character of a wetland with extensive stands of reeds (*Phragmites sp.*) and cattails (*Typha sp.*). For our experiment 12 reeds were taken again. The sediment of the Heřmanický rybník was taken as a substrate, in which reeds grow naturally in this area.

Nový rybník

The last, fourth area of interest was Nový rybník, which is part of PR Rezávka. A large part of the territory is overgrown with communities of reeds and sedges, which, unlike the previous locations, are not exposed to salt stress, and have suitable natural conditions. 12 reeds were also taken from this area for our experiment. The sediment of Nový rybník was taken as substrate, in which reeds grow naturally in this area.

2.3 Plant adaptation to phytotron conditions

A total of 48 bunches of reeds from four different habitats were planted in 12 classic plastic pots Ø 22 × 24 cm (3 pots from each habitat). As a substrate sediment was taken from the respective locality, in which the plants were further grown, for the duration of the experiment.

The prepared reed samples were placed in a Wiss Gallenkamp type phytotron and adapted to the new environment for 3 months at a temperature of 25 °C, a light regime of 12 hours day / 12 hours night, air humidity 60 %, light intensity 150 $\mu mol.m^{-2}.s^{-1}$). During the entire period of adaptation, the plants were watered 3 times a week with a 1% solution of Darkov salt, the amount of watering was 200 ml.

During the study, pots with reed bunches were placed on three non-draining plastic trays measuring 90 × 40 × 10 cm. Three properly marked flowerpots from the respective locality were placed on each plot (1st row – Nový rybník, 2nd row – Heřmanický rybník, 3rd row – Karvinský potok, 4th row – Důl Lazy) (Figure 1).

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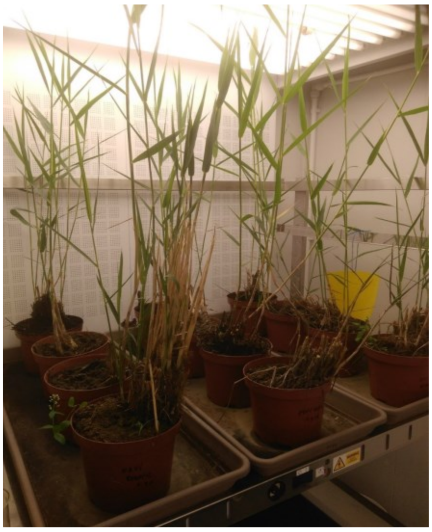

Figure 1. *Common reed samples taken from different habitats and placed in controllable phytotron conditions (temperature 25 °C, light mode 12 hours day / 12 hours night,air humidity 60 %, light intensity 150 µmol.m^{-2}.s^{-1}) (photo: J. Kočířová, 2019)*

2.4 Implementation of the experiment

As the effect of salt stress on common reed was monitored as part of this experiment, the plants were watered 3 times a week with a salt solution of 250 ml. During the entire experiment, the concentration of the salt solution was gradually increased from 1% to 5%. Salt solutions were prepared from Darkov salt:

- 1% solution
- 2% solution
- 5% solution

The sampling of biomass for the determination of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} in leaves, stems and roots was carried out once, on the day of sampling from individual locations. Another sampling for a one-time biomass analysis was carried out 3 months after the adaptation of the plant in the phytotron. Further during the gradual salinization with prepared Darkov salt solutions.

Composition of Darkov salt: strongly mineralized (with total mineralization above 20 g/l) chloride-sodium iodine hypotonic water (minimum iodide content) with trace concentrations of barium and strontium [15].

2.5 Determination of biomass analyses

2.5.1 Neutron activation analysis (NAA)

For determination by the NAA method, the collected reed samples were dried at room temperature (20 - 25 °C). After that, a dried sample weighing 1 g was weighed, sealed in a polyethylene bag and sent to the United Institute of Nuclear Research (SÚJV), where the sample was further processed in a chemical laboratory.

2 × 0,3 g were weighed from the sample. With the help of a compression piston, these two samples were pressed into sampling tablets. One was then wrapped in polyethylene foil, which was intended for the analysis of isotopes with a short half-life (SLI), and the other in aluminium foil for the analysis of isotopes with a long half-life (LLI) [16].

The research pulse reactor IBR2M was used for sample analysis. The reactor was put into operation in 1984 with an average power of 2 MW [16].

2.5.2 Atomic absorption spectrometry (AAS)

For determination by the ASS method, the collected reed samples were first dried in an oven at a temperature of 65 °C for 2 hours. Then the dry matter was homogenized in a mixing vessel and weighed 0,3 g. Biomass mineralization was carried out using a microwave unit for high-pressure decomposition of the company Milestone. The procedure was according to the manual for the device [17].

The prepared samples were analysed for the content of selected elements (calcium, magnesium, sodium, potassium) using a Varian AA 280 FS atomic spectrometer. The analysis was performed according to the attached manual: "Flame atomic absorption spectrometers - Analytical methods" [18].

3 RESULTS

The values of Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} were measured by the AAS method in the leaves, stems, and roots of plants collected at the beginning of April 2019 (Table 1) in the locations of interest Důl Lazy, Karvinský potok, Heřmanický rybník, Nový rybník and in samples of leaves.

The experiment itself started in July 2019 and lasted until April 2020. The plants were gradually salted with 1% to 5% solutions of Darkov salt. The measured values of Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} were monitored by the NAA method in the leaves and stems of plants at the above locations. The values of selected indicators were monitored for 10 months (Table 2).

3.1 Evaluation of selected cations in biomass by the AAS method

The stated results indicate the number of monitored indicators (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) in the biomass of leaves, stems and roots of reeds taken for one-time analysis before the start of the experiment on 1 April 2019 at selected locations of interest (Důl Lazy, Karvinský potok, Heřmanický rybník, Nový rybník) (Table 1).

Table 1. *The concentration of ions Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} in the biomass of leaves, stems, and roots of reeds collected in the locations of interest on 1 April 2019*

CONCENTRATION (mg/g)	KARVINSKÝ POTOK			DŮL LAZY			HEŘMANICKÝ RYBNÍK			NOVÝ RYBNÍK		
	LEAF	STEM	ROOT	LEAF	STEM	ROOT	LEAF	STEM	ROOT	LEAF	STEM	ROOT
Ca^{2+}	12.70	4.05	1.11	12.30	3.88	0.995	11.50	3.39	0.193	5.67	0.752	0.071
Mg^{2+}	10.40	5.43	13.90	8.81	4.89	7.350	8.69	4.68	6.820	8.61	3.420	1.140
Na^{+}	22.10	32.70	10.20	3.23	9.79	8.330	2.52	6.52	6.210	1.98	4.530	4.130
K^{+}	142.00	179.00	73.70	138.00	148.00	64.40	114.00	132.00	59.700	107.00	102.000	35.700

Selected parameters (Ca^{2+}, Mg^{2+}, Na^{+},K^{+}) of common reed plants from the most saline locality Karvinský potok and from the Nový rybník locality, where common reed plants grow in a natural environment and are not exposed to salt stress, were evaluated (Figure 2).

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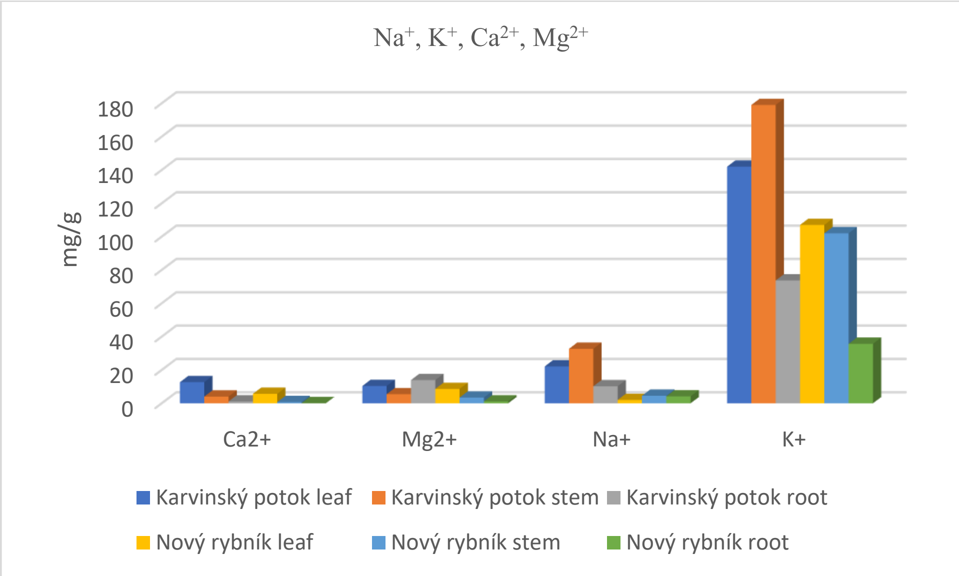

Figure 2. *The concentration of Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} ions in the biomass of leaves, stems, and roots of reeds taken from the sites of interest Karvinský potok and Nový rybník on 1 April 1 2019*

A low concentration of Ca^{2+} ions was measured in the roots of plants from both the saline sites Karvinský potok and Důl Lazy. The concentration in the roots of plants from the Karvinský potok was measured at 1.11 mg/g and in the roots of plants taken at the Důl Lazy 0.995 mg/g. It was 0.193 mg/g in the roots of plants taken from the Heřmanický rybník, and a very low concentration of 0.071 mg/g was measured in the roots of plants taken from the Nový rybník (Table 1).

The most Ca^{2+} ions, 12.7 mg/g, were found in reed leaves of plants taken from the most saline locality, Karvinský potok, and an almost comparable concentration was measured in leaves of plants taken at the Důl Lazy, 12.3 mg/g, in leaves of plants taken from the Heřmanický rybník a concentration of 11.5 mg/g was measured, the lowest concentration of 5.67 mg/g was found in the leaves of plants taken from Nový rybník (Table 1).

In plant stems, the concentration of Ca^{2+} ions was significantly lower than in plant leaves. The highest concentration of 4.05 mg/g was again detected in the stems of plants taken from the most saline location Karvinský potok, almost comparable concentrations were measured in the stems of plants taken at the Důl Lazy 3.88 mg/g and at Heřmanický rybník 3.39 mg/g. The lowest concentration of 0.752 mg/g was found in the stems of plants taken from Nový rybník (Table 1).

The difference in the concentration of Ca^{2+} ions in plants taken from the most saline locality Karvinský potok and plants from the least saline locality Nový rybník is 7.03 mg/g in the leaves, 3.30 mg/g in the stems, and 1.04 mg/g in the roots (table 1).

The concentration of Mg^{2+} ions in the leaves of plants collected in the localities of interest does not differ significantly. The most Mg^{2+} was stored in the leaves of plants taken from the Karvinský potok, 10.4 mg/kg. At other locations, the measured concentration of Mg^{2+} in the leaves of the plants sampled is almost the same: 8.81 mg/g, Heřmanický rybník 8.69 mg/g and Nový rybník 8.61 mg/g in the plants taken from the Důl Lazy (Table 1).

The concentration of Mg^{2+} ions is the highest in the plants taken from the Karvinský potok, 5.43 mg/g, at the Důl Lazy, 4.89 mg/g. A lower concentration of 4.68 mg/kg was measured in the plants taken from the Heřmanický rybník, a significantly lower concentration compared to the previous locations was measured at 3.42 mg/g in the plants taken from the Nový rybník (Table 1).

The concentration of Mg^{2+} ions in the roots of plants is the highest in plants taken from the Karvinský potok, 13.9 mg/g. Lower concentrations were found in the roots of plants taken at the Důl Lazy, 7.35 mg/g

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and Heřmanický rybník, 6.82 mg/g. A significantly lower concentration of 1.14 mg/g was measured in the plants taken from Nový rybník (Table 1).

The difference in the concentration of Mg^{2+} ions in plants taken from the most saline locality Karvinský potok and plants from the least saline locality Nový rybník is 1.79 mg/g in leaves, 2.01 mg/kg in stems, and 12.76 mg/g in roots (Table 1).

The concentration of K^+ in the leaves of the plants at the two saline locations differs minimally. A concentration of 142 mg/g was found in the leaves of the plants taken from the Karvinský potok, and 138 mg/g at the Důl Lazy. The concentration of K^+ in the leaves of the plants taken from the Heřmanický rybník was measured to be 114 mg/g, and 107 mg/g in the leaves of the plants taken from the Nový rybník (Table 1).

The most K^+ was stored in plant stems at the three monitored locations. The concentration of K^+ was found to be 179 mg/g in the plants taken from Karvinský potok, 148 mg/g at the Důl Lazy, 132 mg/g in the Heřmanický rybník, and the lowest concentration of 102 mg/g was found in the plants taken from the Nový rybník. At the same time, the K^+ concentration in plant stems is 5 mg/g lower than in plant leaves in this locality (Table 1).

The least amount of K^+ was deposited in the roots of plants at all monitored locations. A concentration of 73.7 mg/g was measured in the plants taken from the Karvinský potok, 64.4 mg/g at the Důl Lazy, 59.7 mg/g at the Heřmanický rybník, and the lowest concentration was 35.7 mg/g in the plants taken from the Nový rybník (Table 1).

The difference in the concentrations of K^+ ions in plants taken from the most saline locality Karvinský potok and plants from the least saline locality Nový rybník is 35 mg/g in the leaves, 77 mg/g in the stems, and 38 mg/g in the roots (table 1).

The most Na^+, 22.1 mg/g, was deposited in the leaves of plants taken in the most saline locality, Karvinský potok. At other locations, the concentration of Na^+ in the leaves of plants is significantly lower - at the Důl Lazy, 3.23 mg/g, Heřmanický rybník, 2.52 mg/g, and 1.98 mg/g in the leaves of plants taken from the Nový rybník locality (Table 1).

The same was the case with plant stems, the most Na^+ 32.7 mg/g was stored in plant stems from the most saline location Karvinský potok, 9.72 mg/g in plant stems from the Důl Lazy, 6.52 mg/g in plant stems from Heřmanický rybník and at least 4.53 mg/g in plant stems from the Nový rybník location (Table 1).

A significantly lower concentration of Na^+ was deposited in the roots of plants from the most saline locality Karvinský potok, 10.2 mg/g, in the roots of plants taken from the Důl Lazy site 8.33 mg/g, 6.21 mg/g in the roots of plants taken from locality Heřmanický rybník and at least 4.13 mg/g in the roots of plants taken from the locality Nový rybník (Table 1).

From this, it can be concluded that the samples from the Důl Lazy, Heřmanický rybník, and Nový rybník sites deposited sodium in the stems and roots of plants, at least in the leaves of plants. Here the concentrations of Na^+ in the stems and roots of the plants of the individual locations are almost balanced: Heřmanický rybník - 6.52 mg/g in the stems of the plants, 6.21 mg/g in the roots of the plants. Nový rybník - 4.53 mg/g in plant stems, 4.13 mg/g in plant roots (table 1).

The situation is different for the plants from the most saline locality Karvinský potok, the most sodium was deposited in the leaves and stems of the plants, the least in the roots of the plants.

The maximum concentrations of Na^+ in plant leaves were found in plants from the most saline locality Karvinský potok (22.1 mg/g), the minimum concentrations were found in plants from the non-saline location Nový rybník (1.98 mg/g).

The maximum concentrations of Na^+ in plant stems were found in plants from the most saline locality Karvinský potok (32.7 mg/g), the minimum concentrations were found in plants from the non-saline location Nový rybník (4.53 mg/g).

The maximum concentrations of Na^+ in plant roots were found in plants from the most saline locality Karvinský potok (10.2 mg/g), the minimum concentrations were found in plants from the non-saline location Nový rybník (4.13 mg/g).

The maximum concentration of K^+ in plant leaves was found in plants from the most saline locality Karvinský potok (142 mg/g), the minimum concentrations were found in plants from the non-saline location Nový rybník (107 mg/g).

The maximum concentrations of K^+ in plant stems were found in plants from the most saline locality Karvinský potok (179 mg/g), the minimum concentrations were found in plants from the non-saline location Nový rybník (102 mg/g).

The maximum concentrations of K^+ in plant roots were found in plants from the most saline locality Karvinský potok (73,7 mg/g), the minimum concentrations were found in plants from the unsalinated Nový rybník locality (35.7 mg/g).

In the plants from the Karvinský potok locality, the concentration of Na^+ in all parts of the plant was found to be higher than in the plants from the Nový rybník locality: in the leaves by 201.2 mg/g, in the stems by 28.17 mg/g, in roots by 6.07 mg/g (Figure 3).

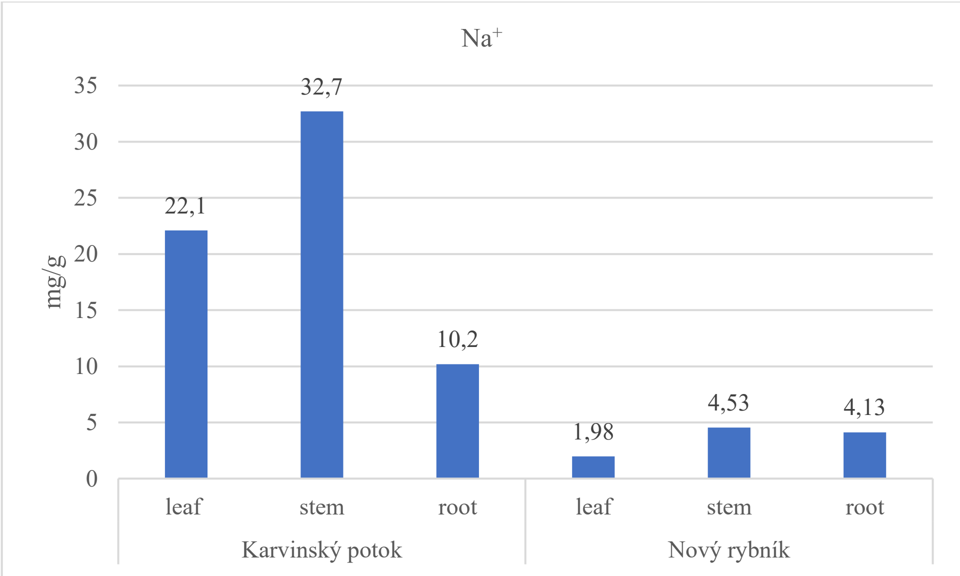

Figure 3. *The difference in Na^+ concentration in plants - Karvinský potok and Nový rybník localities*

In the plants from the Karvinský potok locality, the concentration of K^+ in all parts of the plant was found to be higher than in the plants from the Nový rybník locality: in the leaves by 35 mg/g, in the stems by 77 mg/g, in roots by 38 mg/g (Figure 4).

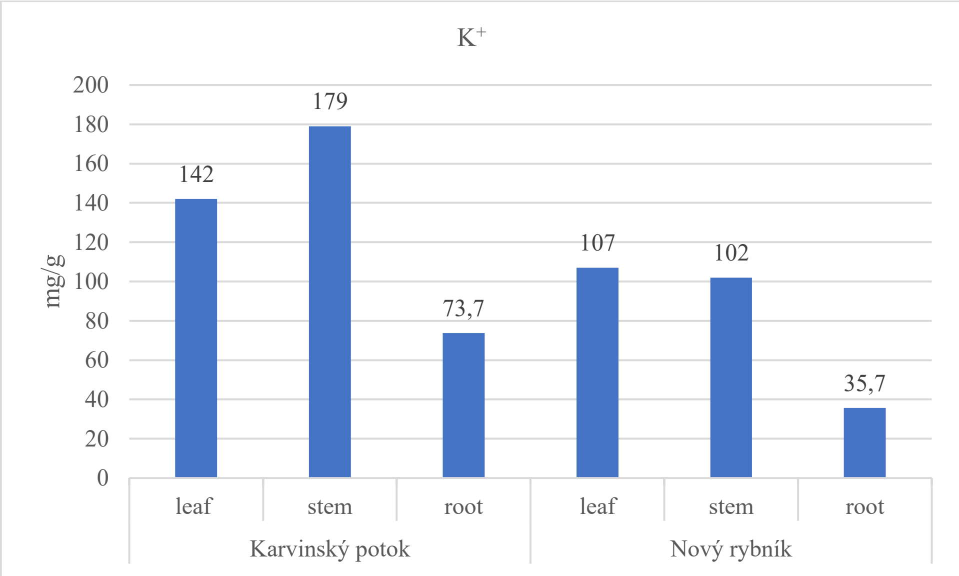

Figure 4. *The difference in K^+ concentration in plants - Karvinský potok and Nový rybník localities*

The highest concentrations of all analysed elements (Ca^{2+}, Mg^{2+}, Na^+, K^+) in leaves, stems and roots were found in plants from the most saline site Karvinský Potok, while the lowest concentrations were found in all parts of plants from the non-saline site Nový rybník (Table 1).

It can therefore be concluded that potassium was the dominant element in reeds from all locations (Karvinský potok: leaf 142 mg/g, stem 179 mg/g, roots 73.7 mg/g; Důl Lazy: leaf 138 mg/g, stem 148 mg/g, roots 64.4 mg/g; Heřmanický rybník: leaf 114mg/g, stem 6.52 mg/g, roots 59.7 mg/g; Nový rybník: leaf 107 mg/g, stem 102 mg/g, roots 35.7 mg/g) (Table1).

The maximum concentrations of Ca^{2+} in plant leaves were found in plants from the most saline locality Karvinský potok (12.7 mg/g), and the minimum concentrations were found in plants from the non-saline location Nový rybník (5.67 mg/g). The maximum concentrations of Ca^{2+} in plant stems were found in plants from the most saline locality Karvinský potok (4.05 mg/g), the minimum concentrations were found in plants from the unsalinated Nový rybník locality (0.752 mg/g). The maximum concentrations of Ca^{2+} in plant roots were found in plants from the most saline locality Karvinský potok (1.11 mg/g), and the minimum concentrations were found in plants from the unsalinated Nový rybník locality (0.071 mg/g) (Table 1, Figure 2).

The maximum concentrations of Mg^{2+} in plant leaves were found in plants from the most saline locality Karvinský potok (10.7 mg/g), and the minimum concentrations were found in plants from the unsalinated Nový rybník locality (8.61 mg/g). The maximum concentrations of Mg^{2+} in plant stems were found in plants from the most saline location Karvinský potok (5.43 mg/g), the minimum concentrations were then found in plants from the non-saline location Nový rybník (3.42 mg/g). The maximum concentrations of Mg^{2+} in plant roots were found in plants from the most saline locality Karvinský potok (13.9 mg/g), and the minimum concentrations were found in plants from the unsalinated Nový rybník locality (1.14 mg/g) (Table 1, Figure 2).

The maximum concentrations of Na^+ in plant leaves were found in plants from the most saline locality Karvinský potok (22.1 mg/g), and the minimum concentrations were found in plants from the non-saline location Nový rybník (1.98 mg/g). The maximum concentrations of Na^+ in plant stems were found in plants from the most saline locality Karvinský potok (32.7 mg/g), the minimum concentrations were then found in plants from the non-saline location Nový rybník (4.53 mg/g). The maximum concentrations of Na^+ in plant roots were found in plants from the most saline locality Karvinský potok (10.2 mg/g), and the minimum concentrations were found in plants from the non-saline location Nový rybník (4.13 mg/g) (Table1, Figure 2).

The maximum concentration of K^+ in plant leaves was found in plants from the most saline locality Karvinský potok (142 mg/g), and the minimum concentrations were found in plants from the non-saline location Nový rybník

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(107 mg/g). The maximum concentrations of K^+ in plant stems were found in plants from the most saline locality Karvinský potok (179 mg/g), the minimum concentrations were then found in plants from the non-saline location Nový rybník (102 mg/g). The maximum concentrations of K^+ in plant roots were found in plants from the most saline locality Karvinský potok (73.7 mg/g), and the minimum concentrations were found in plants from the unsalinated Nový rybník locality (35.7 mg/g) (Table 1, Figure 2).

3.1.1 Statistical evaluation

Due to the very small samples, non-parametric tests were used to determine the difference in sodium and potassium content. For the locations Karvinský potok and Nový rybník it was the Mann-Whitney U test. It compares the mean values of two independent samples. For plant parts, it was the Kruskal-Wallis test. It compares the mean values of more than two independent samples. All tests are performed at the 5% significance level (Table 2, Table 3).

The p-values are all greater than the chosen significance level. We were unable to demonstrate the effect of location or part of the plant on sodium and potassium content. Which may be due to the very small number of measurements.

Table 2. *Comparison of the content of Na^+ and K^+ using the Mann-Whitney U test in the biomass of leaves, stems, and roots of common reed collected on April 1, 2019 in the localities of interest Karvinský potok and Nový rybník*

LOCATION	MANN-WHITNEY U TEST	
TRACKED ELEMENT	**THE VALUE OF THE TEST CRITERION Z**	**p-VALUE**
Na^+ mg/g	1.746	0.081
K^+ mg/g	0.436	0.663

Table 3. *Comparison of the content of Na^+ and K^+ using the Kruskal-Wallis test in the biomass of leaves, stems, and roots of common reed collected on April 1, 2019 in the localities of interest Karvinský potok and Nový rybník*

PART OF PLANT	KRUSKAL-WALLIS TEST	
TRACKED ELEMENT	**THE VALUE OF THE TEST CRITERION H**	**p-VALUE**
Na^+ mg/g	0.286	0.867
K^+ mg/g	3.429	0.180

3.2 Evaluation of selected cations in biomass by the NAA method

The stated results indicate the number of monitored indicators (Ca^{2+}, Mg^{2+}, Na^+, K^+) in the biomass of leaves and stems of plants from the locations of interest (Karvinský potok, důl Lazy, Heřmanický rybník, Nový rybník) of common reed, taken during the experiment itself in the period of July 2019 - April 2020. The plants had the same growth conditions in the phytotron environment and were gradually salted with 1% to 5% Darkov salt solutions.

Table 4. *Concentration of Na, Mg, K, Ca in biomass by the NAA method. Collection in phytotron 3.10.2019. Watered for 6 months (from the beginning of the adaption in the phytotron on 1/4/2019) on with a 1% solution of Darkov salt.*

CONCENTRATION (µg/g)	KARVINSKÝ POTOK		DŮL LAZY		HEŘMANICKÝ RYBNÍK		NOVÝ RYBNÍK	
	LEAF	STEM	LEAF	STEM	LEAF	STEM	LEAF	STEM
Ca^{2+}	8 100	720	6 200	570	4 900	1 030	4 400	560
Mg^{2+}	910	710	1 840	950	1 490	760	1 040	480
Na^{+}	16 700	9 500		7 500	7 400	7 200	12 100	6 300
K^{+}	11 800	16 800		6 300	14 800	10 600	8 500	6 100

Concentration of Na, Mg, K, Ca in biomass by the NAA method. Collection in the phytotron 3. 10. 2019. Watered for 6 months (from the beginning of adaptation 1. 4. 2019) with a 1% Darkov salt solution (Table 4).

Selected parameters (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) of common reeds from the most saline locality Karvinský potok and from the Nový rybník locality, where common reed-like plants grow in a natural environment and are not exposed to salt stress, were again evaluated (Figure 5).

The difference in the sodium concentrations of the two remaining locations is 300 µg/g. A concentration of 7 500 µg/g was measured at the Důl Lazy, and a concentration of 7 200 µg/g was measured in the reeds from the Heřmanický rybník. These two sites represent the less saline sites in this study (table 4).

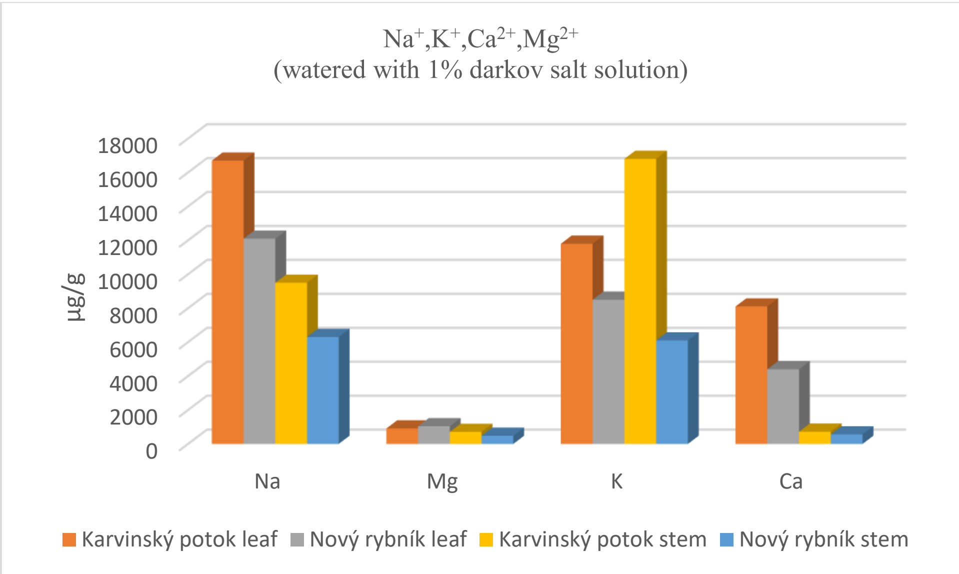

Figure 5. *Concentration of Na, Mg, K, Ca in biomass by the NAA method. Collection in phytotron 3.10.2019. Watered for 6 months (from the beginning of the adaption in the phytotron on 1/4/2019) on with a 1% solution of Darkov salt.*

The maximum concentration of Ca^{2+} in the leaves of plants watered with a 1% solution of Darkov salt was found in plants from the most saline location Karvinský potok (8 100 µg/g), the minimum concentrations were found in plants from the most saline location Nový rybník (4 400 µg/g). The maximum concentrations of Ca^{2+} in plant stems were found in plants from the most saline locality Karvinský potok (720 µg/g), the minimum concentrations were found in plants from the unsalinated Nový rybník locality (560 µg/g) (Table 4, Figure 5).

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The maximum concentration of Mg^{2+} in the leaves of plants watered with a 1% solution of Darkov salt was found in plants from the most saline location Karvinský potok (910 µg/g), the minimum concentrations were found in plants from the most saline location Nový rybník (1 040 µg/g). The maximum concentrations of Mg^{2+} in plant stems were found in plants from the most saline locality Karvinský potok (710 µg/g), the minimum concentrations were found in plants from the unsalinated Nový rybník locality (480 µg/g) (Table 4, Figure 5).

The maximum concentration of Na^{+} in the leaves of plants watered with a 1% solution of Darkov salt was found in plants from the most saline location Karvinský potok (16 700 µg/g), the minimum concentrations were found in plants from the most saline location Nový rybník (12 100 µg/g). The maximum concentrations of Na^{+} in plant stems were found in plants from the most saline locality Karvinský potok (9 500 µg/g), the minimum concentrations were found in plants from the unsalinated Nový rybník locality (6 300 µg/g) (Tble 4, Figure 5).

The maximum concentration of K^{+} in the leaves of plants watered with a 1% solution of Darkov salt was found in plants from the most saline location Karvinský potok (11 800 µg/g), the minimum concentrations were found in plants from the most saline location Nový rybník (8 500 µg/g). The maximum concentrations of K^{+} in plant stems were found in plants from the most saline locality Karvinský potok (16 800 µg/g), the minimum concentrations were found in plants from the unsalinated Nový rybník locality (6 100 µg/g) (Table 4, Figure 5).

In the plants from the Karvinský potok locality, the concentration of Na^{+} in all parts of the plant was found to be higher than in the plants from the Nový rybník locality: in the leaves by 4 600 µg/g, in the stems by 3 200 µg/g (Figure 6).

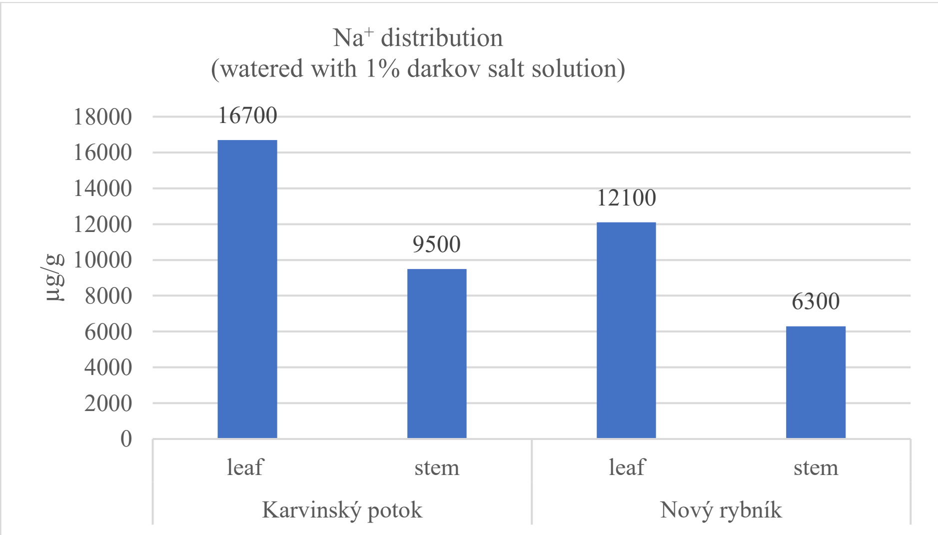

Figure 6. *The difference in Na^{+} concentration in plants - Karvinský potok and Nový rybník localities (washed with 1% Darkov salt solution)*

In the plants from the Karvinský potok locality, the concentration of K^{+} in all parts of the plant was found to be higher than in the plants from the Nový rybník locality: in the leaves by 3 300 µg/g, in the stems by 6 100 µg/g (Figure 7).

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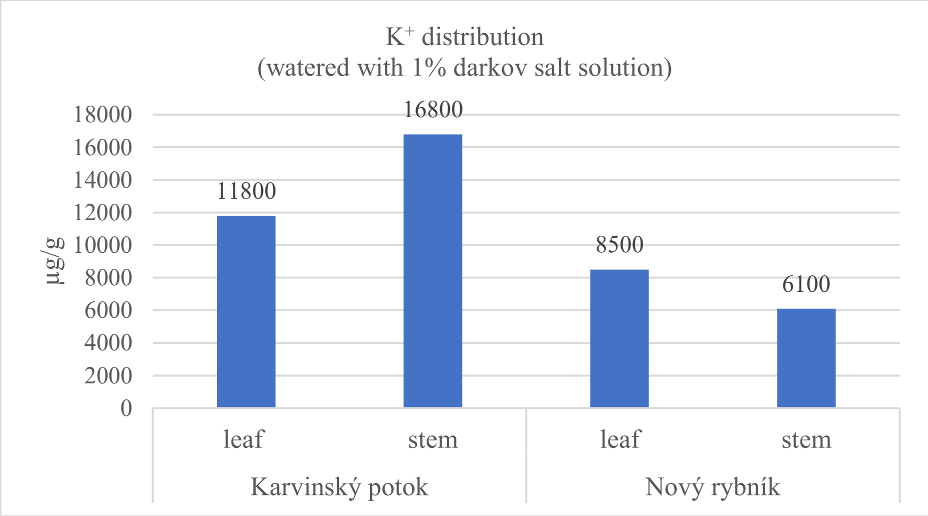

Figure 7. *The difference in K^+ concentration in plants - Karvinský potok and Nový rybník localities (washed with 1% Darkov salt solution)*

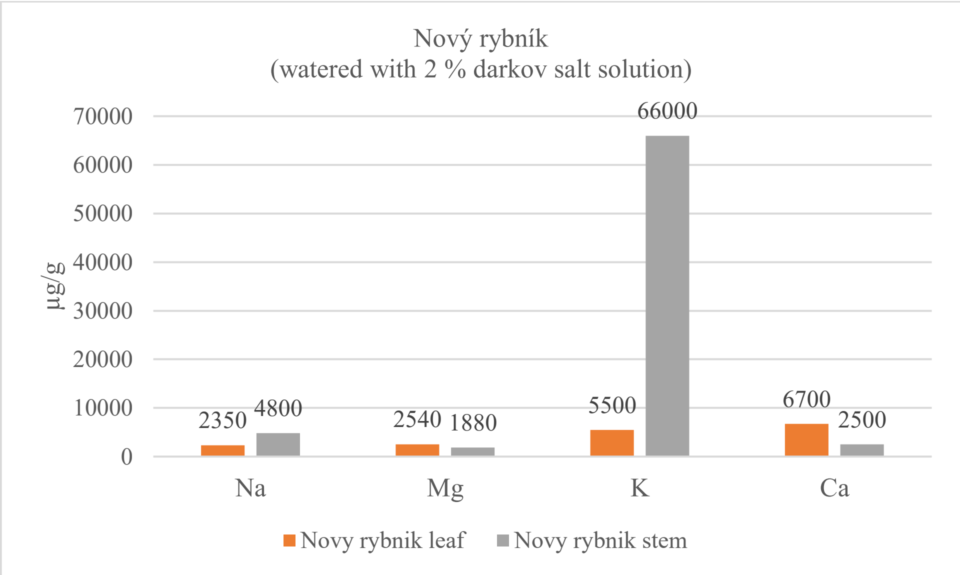

Figure 8. *Concentration of Na, Mg, K, Ca in biomass by the NAA method. Collection in phytotron 2. 3. 2020. Watered for 1 month (from 3/2/2020) with a 2% solution of Darkov salt*

Figure 8 shows the measured concentrations in reeds taken from Nový rybník when watered with a 2% solution of Darkov salt and treated. A high concentration of potassium of 66 000 µg/g was detected in plant stems. The smallest concentration of 1 880 µg/g was found in plant stems for calcium.

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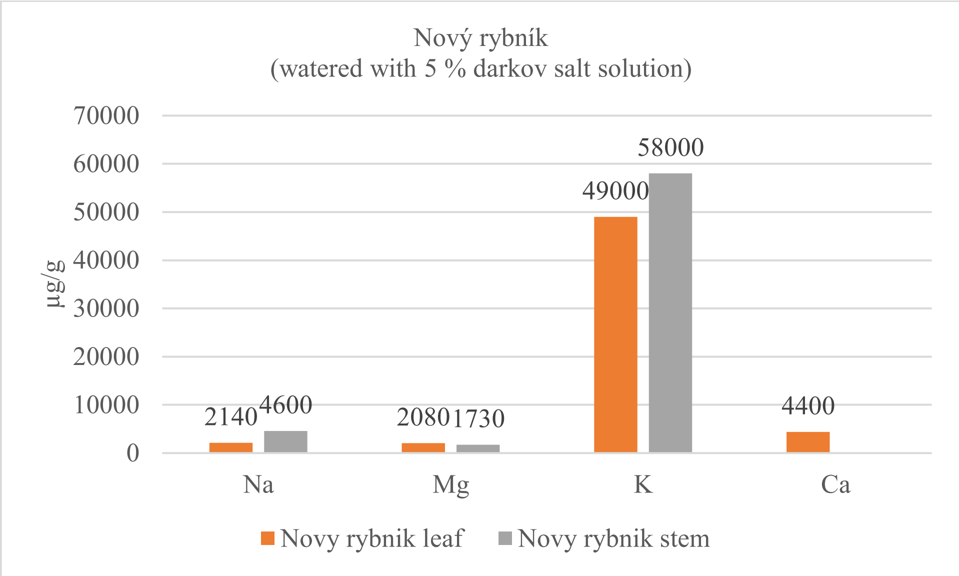

Figure 9. *Concentration of Na, Mg, K, Ca in biomass by the NAA method. sampling in the phytotron 1. 4. 2020. Watered for 1 month (from 2/3/2020) with a 5% solution of Darkov salt*

Figure 9 shows the measured concentrations in reeds taken from Nový rybník when watering with a 5% solution of Darkov salt. A high concentration of potassium 58 000 µg/g was found in the stems. The smallest concentration of magnesium 1 730 µg/g was found in plant stems.

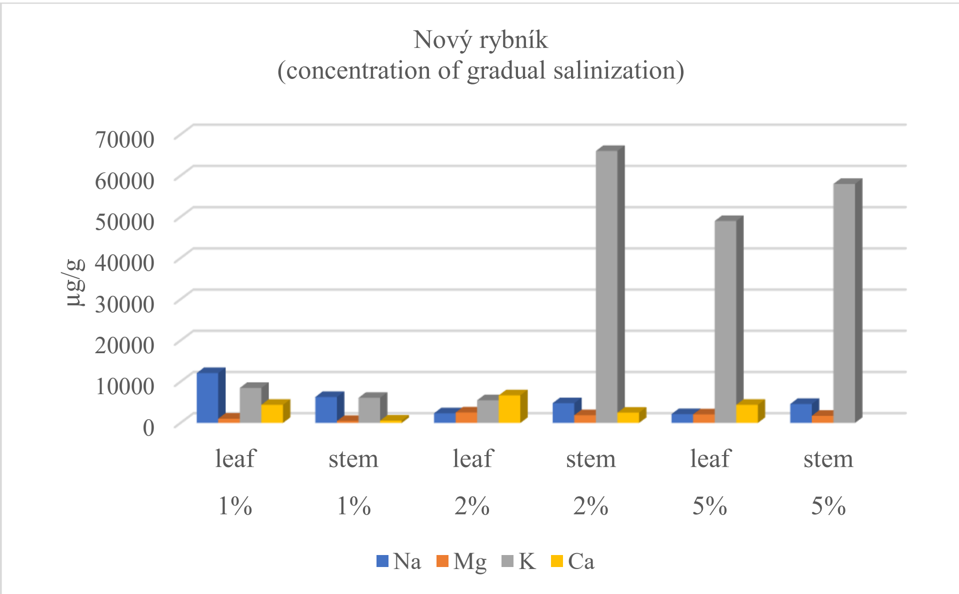

Figure 10. *Concentration of gradual salinization of reeds from the Nový rybník locality*

Figure 10 shows the concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} in reeds from the Nový rybník locality, during gradual salinization with 1 - 5% Darkov salt solutions.

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The concentration of potassium increased in the leaves from the initial 8 500 µg/g when reeds were watered with a 1% Darkov salt solution to a final 49 000 µg/g when the plants were watered with a 5% Darkov salt solution. The increase in concentration in plant leaves was 40 500 µg/g. In plant stems, the concentration increased from the initial 6 100 µg/g to the final 58 000, i.e., by 51 900 µg/g (Figure 9).

The sodium concentration in the leaves decreased from an initial 12 100 µg/g when the canes were watered with a 1% solution of Darkov salt to a final 2 140 µg/g when the plants were watered with a 5% solution of Darkov salt. The reduction in concentration in plant leaves was 9 960 ug/g. In plant stems, the concentration decreased from the initial 6 300 µg/g to the final 4 600, i.e., by 1 700 µg/g (Figure 10).

After evaluating all the results, it can be seen that the reeds taken from the unsalted Nový rybník locality best tolerated gradual salinization.

3.2.1 Statistical evaluation

Due to very small samples, the non-parametric Mann-Whitney U test was used to determine the difference in sodium and potassium content. It compares the mean values of two independent samples (two localities Karvinský potok and Nový rybník, two parts of the plant, leaves and stems) (Table 5, Table 6).

Again, the p-values are all higher than the chosen significance level. It was not possible to prove the influence of the locality or part of the plant on sodium and potassium content.

Table 5. *Comparison of Na^+ and K^+ concentrations in plants - locations Karvinský potok and Nový rybník (washed with 1% Darkov salt solution) using the Man-Whitney U test*

LOCATION	MANN-WHITNEY U TEST	
TRACKED ELEMENT	THE VALUE OF THE TEST CRITERION Z	p-VALUE
Na^+ µg/g	-0.387	0.699
K^+ µg/g	-1.162	0.245

Table 6. *Comparison of Na^+ and K^+ concentrations in the biomass of leaves and stems of common reed - Karvinský potok and Nový rybník localities (washed with 1% solution of Darkov salt) using the Man- Whitney U test*

PART OF PLANT	Mann-Whitney U test	
TRACKED ELEMENT	THE VALUE OF THE TEST CRITERION Z	p-VALUE
Na^+ µg/g	1.162	0.245
K^+ µg/g	-0.387	0.699

4 DISCUSSION

For the implementation of the experiment, plants were taken at the beginning of April 2019 from four locations of interest in Důl Lazy, Karvinský potok, Heřemanický rybník, and Nový rybník. At the same time, leaves, trunks, and roots of plants were taken from these locations of interest for analysis of Ca^{2+}, Mg^{2+}, Na^+, K^+ using the AAS method on the day of reed collection.

According to the results of analyses conducted using the AAS method, it can be inferred that potassium was the dominant element in the reed beds sampled from all four monitored sites. It is bioaccumulated in the aboveground part of the plants.

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The concentrations of potassium in various parts of the reed beds were determined using the AAS method and returned the following results (Table 7):

Table 7. *Concentration of ions K^+ in the biomass of leaves, stems and roots of reeds collected in locations of interest on April 1, 2019*

CONCENTRATION (mg/g)	**KARVINSKÝ POTOK**			**DÚL LAZY**			**HEŘMANICKÝ RYBNÍK**			**NOVÝ RYBNÍK**		
	LEAF	**STEM**	**ROOT**	**LEAF**	**STEM**	**ROOT**	**LEAF**	**STEM**	**ROOT**	**LEAF**	**STEM**	**ROOT**
K^+	142.00	179.00	73.70	138.00	148.00	64.40	114.00	132.00	59.70	107.00	102.00	35.70

The highest concentration of potassium was found in the stems of reeds collected at the Karvinský potok (179 mg/g), Důl Lazy (148 mg/g), and Heřmanický rybník sites (132 mg/g). In reeds collected at the Nový rybník site, the highest potassium concentration was found in the leaves of the plants (107 mg/g) (Table 7).

The highest concentrations of potassium in the aboveground parts of the plants were found in the reed beds sampled at the Karvinský potok site. The lowest concentrations of potassium in the aboveground parts of the plants were found in the reed beds sampled at the Nový rybník site (Table 7).

The experiment began in July 2019 and ended in April 2020. The plants were gradually salted with 1% to 5% solutions of dark salt. The measured values of Ca^{2+}, Mg^{2+}, Na^+, and K^+ were monitored by the NAA method in the leaves and stems of plants at the above locations. The values of selected indicators were monitored for 10 months.

Potassium was once again the dominant element in bioaccumulation in all experiments conducted using NAA analysis. It is also bioaccumulated in the aboveground part of the plant.

Using the NAA method, the following concentrations were measured in individual parts of the plant (Table 8):

Table 8. *Concentration of K^+ in biomass using the NAA method. Collection in phytotron October 3, 2019. Watered for 6 months (from the beginning of adaption in the phytotron on April 1, 2019) with a 1% solution of Darkov salt*

CONCENTRATION (µg/g)	**KARVINSKÝ POTOK**		**DŮL LAZY**		**RYBNÍK**		**NOVÝ RYBNÍK**	
	LEAF	**STEM**	**LEAF**	**STEM**	**LEAF**	**STEM**	**LEAF**	**STEM**
K^+	11 800	16 800		6 300	14 800	10 600	8 500	6 100

The highest concentration of potassium was found in the stems of reeds collected at the Karvinský potok site (16 800 mµ/g). For reeds collected at the Heřmanický rybník (14 800 µg/g) and Nový rybník (8 500 µg/g) sites, the highest potassium concentration was found in the leaves of the plants (Table 8).

The highest concentrations of potassium in the aboveground parts of the plants were again found in the reeds collected at the Karvinský potok site. The lowest concentrations of potassium in the aboveground parts of the plants were found in the reeds collected at the Nový rybník site (Table 8).

The above results measured by the NAA method indicate to what extent common reeds were able to face the stress factors of gradual salinization under controllable conditions. Due to growing in pots, it was not possible to take the roots of the plants for analysis. The assumption was that the roots would grow through the holes in the bottom of the pots, which unfortunately did not happen. The roots remained intertwined in the substrate. This method makes it possible to analyze a total of 31 elements in biomass. The following were selected: Na, K, Ca and Mg.

Furthermore, after evaluating all of them by the NAA method, it is evident from the results that the reeds taken from the locality with natural conditions from the non-saline location of Nový rybník best tolerated gradual salinization and resistance to salt stress, which were able to better adapt to gradual salinization (1% - 5% Darkov salt solutions). These reeds were not exposed to long-term salt stress in their natural environment, so they tolerated the salinization process better.

Salt stress is usually the result of a long-term effect of a high concentration of ions, when the accumulation of salts takes place gradually and the plant can initially cope with the stress better. The value of the concentration inside the plant and cells becomes critical (which happened in the case of reeds taken in saline locations, especially the Karvinský potok and the Důl Lazy, when the plants began to wither during further gradual salinization). The first signs of damage appear later (days to weeks) on old leaves subject to premature senescence due to the toxic concentration of salt ions. With increased leaf death, flowers may not even form due to a lack of energy from photosynthesis [19].

Regarding potassium as the dominant element in all reeds from the monitored locations, Richter (2004) states that the level of potassium is relatively high in the cells and that potassium is usually leached out in stressful conditions. Thus, it can be concluded that potassium plays an important role in plant resistance to biotic and abiotic stress, including diseases, pests, drought, salinity, cold and frost, and waterlogging [20] [21].

A review focusing on the emerging role of K in defense against a range of biotic and abiotic stresses, including disease, pests, drought, salinity, cold and freezing, and waterlogging, is described by Wang et al. (2013) in his study. K availability and its effects on plant growth, anatomy, morphology and plant metabolism are discussed. Physiological and molecular mechanisms of K function in plant stress resistance are summarized here [21].

The salinity tolerance of *Phragmites australis* was discussed in their study by Lissner and Schierup (1997). The field salinity tolerance of *Phragmites australis* was evaluated by investigating 27 natural reed habitats along the eastern and western coasts of Jutland, Denmark. Die-back took place in the lower fringe of stands, before the onset of flowering, at sites where soil water salinities were higher than 15‰ within the rooting depth. In greenhouse experiments, juvenile plants produced from seeds and rhizome-grown plants, grown over a range of salinity levels, displayed different levels of salt tolerance. Both types of plants showed low mortality at salinity levels of 15‰ and lower. A total of 75% of the rhizome-grown plants survived 22.5‰ salinity in the rooting medium, whereas only 12% of the juvenile plants survived this salinity level. All plants grown at salinity levels of 35‰ and 50‰ died [22].

The ability of different *Phragmites australi*s clones, which differ in their morphology and therefore their ability to cope with environmental stress, is described in their study by Achenbach et al. (2013) [23]. They analyzed the responses of 15 *P. australis* clones with distinct ploidy levels (PLs) (4n, 6n, 8n, 10n, 12n) and geographic origins (Romania, Russia, Japan, Czech Republic, Australia) to step-wise increased salinity (8, 16, 24, 32, 40, 56 and 72 ppt). Shoot elongation rate, photosynthesis and plant part-specific ion accumulation were studied in order to assess if traits associated with salinity tolerance can be related to the genetic background and the geographic origin of the clones. Salt stress affected all clones, but at different rates. They conclude that the salinity tolerance of distinct P. australis clones varies widely and can be partially attributed to their longitudinal geographic origin, but not to PL.

Brodská (2018) describes salt stress in common reed grown as hydroponics in her diploma thesis. Phytoremediation abilities and salt stress were monitored and confirmed for common reed grown in an inert material called expanded clay and watered with a nutrient and salt solution (in hydroponics). Changes in growth and viability as well as the results of measurements and analyzes were compared in two types of hydroponics. The first reeds were taken from the saline environment of the Důl Lazy and from the Rojek pond in Ostrava Svinov, an area free of salt and a natural environment for reeds [24].

Accumulation of Na^+ at high concentrations in the cytoplasm results in deleterious effects on cell metabolism, e.g., on photosynthetic activity in plants. It is involved in electrical neutralization of inorganic and organic anions and macromolecules, pH homeostasis, control of membrane electrical potential, and the regulation of cell osmotic pressure. Through the latter function in plants, it plays a role in turgor-driven cell and organ movements. It is also involved in the activation of enzymes, protein synthesis, cell metabolism, and photosynthesis. Thus, plant growth requires large quantities of K^+ ions that are taken up by roots from the soil solution, and then distributed throughout the plant. The availability of K^+ ions in the soil solution, slowly released by soil particles and clays, is often limiting for optimal growth in most natural ecosystems. In contrast, due to natural salinity or irrigation with poor quality water, detrimental Na^+ concentrations, toxic for all crop species, are present in many soils (Nieves-Cordone et al., 2016) [25].

The roles of potassium K^+ and Na^+ in plant nutrition suggest that K^+ is the only monovalent cation which is essential for most higher plants and is involved in three important functions, i.e., enzyme activation, charge balance and osmoregulation [26].

Sodium is absorbed by plants very quickly. It is fully equal to or even surpasses potassium in the rate of uptake. Increasing the sodium content in the nutrient medium leads to an increase in Na concentration in the plant. This reduces the intake of K, Ca, Mg in plants [27].

Increasing the sodium content in the nutrient medium leads to an increase in Na concentration in the plant. This reduces the intake of K, Ca, Mg in plants. Potassium is a monovalent cation that the plant receives actively at lower concentrations (up to 0,5 mM) or passively at higher concentrations. The intake of potassium is significantly influenced by interactions of an antagonistic nature. Increasing concentration of K reduces intake of Mg^{2+}, Ca^{2+}, NH_4^+, Zn^{2+}, Mn^{2+} and stimulates intake of NO_3^-, $H_2PO_4^-$, Cl^-, SO_4^{2-}. Of the cations, the intake of NH_4^+ is the least affected due to the size of the hydrated radius for both ions. A number of external conditions (air access, soil temperature, lighting intensity) also have a positive effect on K intake. In the plant, potassium is very mobile and is transported both basipetally and acropetally. A characteristic feature for K^+ is its high ability to penetrate cell membranes. K^+ of the cytoplasm, where 100-200 mM potassium is found, is important for cell metabolism. It is found in vacuoles as KNO_3, KCl or K-malate, its content varies from 10 to 200 mM or up to 500 mM in stomatal cells and fulfils an osmotic function here. The level of potassium is relatively high in cells, and K^+ is usually washed out in stressful situations for plants (low temperatures, drought, etc.) [27].

Potassium is the main cation that controls the osmotic potential of plant cells and balances the fluxes of other ions. Thus, it participates in various vital movements (e.g. closing of the stomata). In addition, it is an activator of the whole series in energy metabolism and proteosynthesis. Therefore, without potassium, plants cannot exist thrive (unlike sodium) [28].

The role of potassium in abiotic stress is described by Pandey, Mahiwal (2020), which emphasizes the important role of K^+ in abiotic and biotic stresses [29].

During long-term exposure to salinity, plants experience ionic stress, which can lead to premature senescence of adult leaves, and thus a reduction in the photosynthetic area available to support continued. High concentrations of Na^+ in the soil solution may depress nutrient-ion activities and produce extreme ratios of Na^+, Ca^{2+} or Na^+, K^+ [30].

Potassium uptake is vital for plant growth but in saline soils sodium competes with potassium for uptake across the plasma membrane of plant cells. This can result in high Na^+: K^+ ratios that reduce plant growth and eventually become toxic. Our understanding of the molecular basis underlying the interaction between essential potassium and toxic sodium was limited until the recent cloning and electrophysiological characterization of several genes encoding different types of molecules that are involved in K^+ and Na^+ transport. These molecules, and their regulation, are important in determining the K^+: Na^+ homeostasis of plants in saline soils, although it is not yet known which is most critical in determining the K^+: Na^+ ratios in whole plants [31].

Potassium (K^+) is an essential macronutrient in plants and a lack of K^+ significantly reduces the potential for plant growth and development. By contrast, sodium (Na^+), while beneficial to some extent, at high concentrations it disturbs and inhibits various physiological processes and plant growth. Due to their chemical similarities, some functions of K^+ can be undertaken by Na^+ but K^+ homeostasis is severely affected by salt stress, on the other hand. Recent advances have highlighted the fascinating regulatory mechanisms of K^+ and Na^+ transport and signalling in plants. Overview of K^+ and Na^+ transport mechanisms from soil to shoot and to cellular compartments; the mechanisms by which plants perceive and respond to the availability of K^+ and Na^+ and the components involved in the maintenance of K^+/Na^+ homeostasis in plants exposed to salt stress are described in his study Adams and Shin (2014) [32].

5 CONSLUSION

This paper aimed to verify the distribution of salts in the halophytic plants *Phragmites australis*.

After evaluating all the results for common reed (*Phragmites australis*), it can be seen that gradual salinization and resistance to salt stress were best tolerated by reeds taken from the site with natural conditions from the non-saline site Nový rybník, which was able to better adapt to gradual salinization (1% - 5% Darkov salt solutions). These reeds were not exposed to long-term salt stress in their natural environment.

Based on the results of measurements conducted using the AAS and NAA methods, it can be concluded that the dominant element in the reed beds exposed to salt stress at all four specified sites of interest is potassium. This element is bioaccumulated in the aboveground part of the plant.

Halophytes will play increasingly important roles as models for understanding plant salt tolerance, as genetic resources contributing towards the goal of improvement of salt tolerance in some crops, for re-vegetation of saline lands, and as 'niche crops' in their own right for landscapes with saline soils [33].

Today, we know of several other plants tolerant to salt stress. Halophytic plants, due to their considerable resilience to various adverse conditions such as drought and toxic environments, and thanks to mechanisms regulating ion entry into plants, are potential candidates for use in phytoremediation. Although most plant species accumulate the majority of absorbed heavy metals in their roots, partial translocation into above-ground parts has been demonstrated in many, which must be considered when choosing phytoremediation technology. Saline soil may even increase the translocation factor [2].

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