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Does the genetic variability of *Phragmites australis* (Cav.) Trin. ex Steud determine the spatial distribution of the species?

by

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Abstract

This paper is an attempt to answer the question whether common reed specimens growing in a particular habitat are genetically related. We have tried to identify groups of plants homogeneous in terms of habitat requirements and genetic similarity. Our objective was also to answer the question whether habitat conditions can affect the morphological characteristics of plants. Plants and bottom sediments were collected from 40 sites in central Poland, which differ in soil moisture and the degree of urbanization. Our research and analysis confirm the hypothesis to a certain extent. During the study, we identified three groups of plants homogeneous in terms of habitat and genetic factors (CVA model), which constitute 20% of all examined plants. In our opinion, further research is required on a larger population of *P. australis* in a larger area. The research revealed that plants growing in moist and wet areas were characterized by higher content of chlorophyll in leaves, longer stems as well as thicker and wider laminae. The common reed plants preferred anthropogenic substrates, which did not contain many nutrients, but were abundant in calcium. Our study confirmed the high tolerance of *P. australis* to soil salinity.

Key words: *Phragmites australis*, genetic variability, morphological features, soil and bottom sediment chemical content

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Introduction

The common reed is a well-known, common and usually dominant species in numerous aquatic and wet ecosystems. It is also a taxon whose representatives live in considerably different habitats. The common reed is capable of adapting to unfavorable habitat conditions. Various ecotypes of the species are characterized by genetic differences, which have enabled the development of mechanisms of resistance to drought, salinity or low temperatures (Chen et al. 2006; Čurn et al. 2007; Liu et al. 2012; Rocha et al. 2014). Both the morphology and growth characteristics of the common reed (*Phragmites australis* (Cav.) Trin. ex Steud) have been studied many times and have provided a great deal of information published in scientific papers (Antonielli et al. 2002; Dykyjová, Hradecká 1976; Engloner 2004; Engloner 2009). The authors of the studies on common reed plants compiled a detailed list of morphological features that should be investigated (Dykyjová et al. 1973). They also presented results proving the negative correlation between the density and the length of shoots (Björk 1967) and the positive correlation between the shoot base diameter and the shoot height as well as between the shoot height and the number of internodes (Ksenofontova 1988; Ostendorp 1991). However, Coops et al. (1996) did not observe a correlation between the common reed shoot base diameter and the shoot length. The most intensive growth of the plant was observed between April and May. After that period, the growth rate gradually decreased until October (Hardej, Ozimek 2002).

The vascular system of plants is responsible for the transport of water as well as dissolved mineral salts, carbohydrates and other nutrients (Chen et al. 2006). So far, researchers have investigated a wide range of characteristics of the vascular structure in plants, e.g. changes in the cell wall architecture, the ionic composition, protein expression and changes in the phloem/wood ratio. According to researchers, all these characteristics contribute to the development of plants' resistance to stress induced by environmental factors (Child et al. 2003; Equiza, Tognetti 2002; Zwieniecki et al. 2003). Experiments have shown that salinity affects tissue lignification patterns, peroxidase activity and changes in cell wall composition (Wang et al. 1997). Kawashima et al. (2005) observed that plants develop adequate enzymatic properties and gene expression patters in response to environmental changes.

Cell walls have a significant impact on the growth, development and response of plants to environmental factors. They are also responsible for interactions with pathogens and provide signaling molecules that are necessary for self-recognition (Brownlee 2002; Kączkowski 2003). Differences in the cell wall structure can be the basis for research on plant growth regulation and adaptation to changing environmental conditions (Enstone et al. 2003; Sabba, Lulai 2002). Available studies have shown that modifications of cell wall polymers (lignins, suberins), pectins and proteins in plants growing under stress conditions may result in the formation of barriers to water, gases and pathogens (Hartmann et al. 2002; Hose et al. 2001).

Apart from the common reed morphology and growth characteristics, the influence of environmental factors on the growth of these plants was also researched. Detailed studies on the effect of nutrient availability and soil fertility (Engloner 2009; Hardej, Ozimek 2002; Romero et al. 1999), as well as organic matter decomposition (Van der Putten et al. 1997) and salinity (Lissner et al. 1999) were carried out.

Studies to date have shown that different reed ecotypes growing in different habitats exhibit some regular variability in morphological, physiological and genetic traits in response to salinity and drought (Zhu et al. 2003). So far, the genetic variability of reed clones has been researched using allozyme and molecular marker polymorphism (Clevering, Lissner 1999). The authors of the studies published so far observed the occurrence of large numbers of common reed clones, which could be caused by environmental and genetic factors. Studies have shown that the development of resistance to variable climate, humidity and salinity in *P. australis* plants is of the genetic nature (Clevering, Lissner 1999).

The main objective of our study was to assess the relationships between the morphology of aerial parts of *P. australis* plants, the chemical composition of soil or bottom sediments and genetic variability represented by selected markers. We have also tried to identify groups of plants homogeneous in terms of habitat requirements and genetic similarity. Our objective was also to answer the question whether habitat conditions can affect the morphological characteristics of plants and the content of chlorophyll in leaves.

Materials and methods

Sampling sites and plant specimens

The research was conducted in three areas (Fig. 1), which differ in population density, the degree of urbanization, terrain, soil use as well as the size and density of waterbodies.

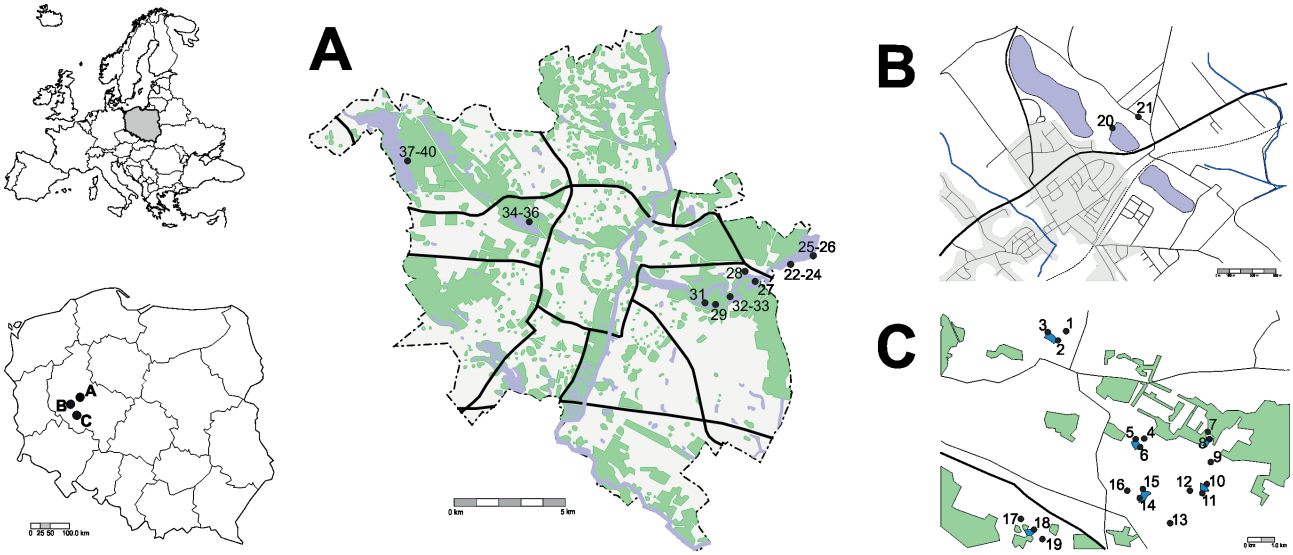

Figure 1

Location of field research sites (A – the city of Poznań, B – Lake Bochenek in the village of Dębienko, C – General Dezydery Chłapowski Landscape Park)

The first area (A) comprised the city agglomeration of Poznań. The area of Poznań is about 261.3 km^2. About 48% of the city area is occupied by public green space, forests and farmlands. The geological structure of the city is mostly composed of glacial till, fluvial sand and gravel as well as loam, silt, sand and marl (Lis, Pasieczna 2005). The research was conducted on plants collected from the littoral zone of six waterbodies: Lake Swarzędz, Pond Antoninek, Pond Browarny, Pond Olszak, Lake Rusalka and Lake Strzeszyńskie. Samples were numbered 22–40. Sample No. 30 was excluded from the analysis as it was destroyed.

The second and smallest research area was located on the shoreline of Lake Bochenek in the village of Dębienko, near the town of Stęszew (B). Only two samples were collected from the site. They were numbered 20 and 21. Lake Bochenek is located next to the busy trunk road No. 5. It was included in the research due to its interesting location.

The third area (C) was represented by rural areas and open landscape belonging to General Dezydery Chłapowski Landscape Park. The region is characterized by large areas of arable lands and meadows, medium soil quality and low afforestation rate. Common reed samples were collected from small waterbodies located in fields or forests and they were numbered 1–19.

Measurement of chlorophyll content

Five leaves were collected from each plant. A fragment of the lamina was cut along the midrib. Four samples weighing 0.5 g were prepared in this way. They were flooded with dimethyl sulfoxide (DMSO) and left in darkness at room temperature for one hour. Next, they were incubated at a temperature of 65°C (water bath) for 30 minutes. After cooling, 5 ml of distilled water was added. Next, the content of chlorophyll *a* and *b* was measured by a Beckman DU70 spectrophotometer operating at adequate wavelengths. The extract absorbance for chlorophyll *a* was measured at a wavelength of 663 nm, whereas for chlorophyll *b* – at a wavelength of 645 nm. The content of chlorophyll *a* and *b* was calculated according to the following formulae (Arnon 1949):

$$\text{Chlorophyll } a = (12.7 \times A663 - 2.7 \times A645) \times V \times (1000\ W)^{-1} \quad (1)$$

$$\text{Chlorophyll } b = (22.9 \times A645 - 4.7 \times A663) \times V \times (1000\ W)^{-1} \quad (2)$$

where:

A – absorbance at a specific wavelength,
V – total extract volume (cm^3),
W – sample weight (g).

The amounts of individual pigments were expressed as μg g^{-1}.

Measurement of chemical content

Soil samples were collected by a soil probe at a depth of 20–25 cm, 1 m away from the nearest plant. During each sampling event, the soil was probed 20 times. This resulted in 1 kg of an averaged soil

sample. The sample was transported to a laboratory, where the soil was placed in Petri dishes and dried for 48 h until air-dry weight. Next, it was placed in a dryer and dried at a temperature of 105°C for 96 h. After that, the soil aggregates were broken in a mortar and sieved through a sieve of d = 0.49 mm. This procedure provided homogenous material for analysis. The samples were carefully mixed, and 15 g of soil was collected from each sample and flooded with 150 cm^3 of 0.03 M acetic acid. Next, nitrate nitrogen and phosphates were measured calorimetrically, K and Mg – by the AAS method, Ca and Na – by atomic emission spectroscopy. In addition, pH and electrolytic conductivity were measured in an aqueous soil suspension. The results were converted into the content of g NaCl kg^{-1} of soil (Komosa, Roszyk 2006).

DNA extractions

The material for molecular analysis was collected from 39 plants. The genomic DNA was isolated from all collected samples with a method using CTAB, where the mycelium was macerated in liquid nitrogen (Doyle, Doyle 1987). Relatedness among the isolates of *P. australis* was estimated using scorable DNA bands amplified from different URP markers (URP-PCR). The resulting DNA was amplified with three URP primers (URP 38F, URP 17R, URP 2) (Mann et al. 2014). The volume of the reaction mixture was 25 µl. It consisted of 12.5 µl 2 × PCR Master Mix (A&A Biotechnology), 30 ng of the primer, 10 ng of the DNA and deionized water. The PCR was conducted in a Biometra thermocycler under the following conditions: initial denaturation at 94°C for 4 min, followed by 35 cycles at 94°C for 1 min, at 55°C for 1 min and at 72°C for 2 min, and final prolongation at 72°C for 7 min. The amplification product was separated by electrophoresis in 3.0% agarose gel (2% NuSieve agarose, Cambrex, BioScience, Wokingham, UK + 1% standard agarose) stained with ethidium bromide (0.5 mg ml^{-1}). The DNA Mass Ladder (Invitrogen catalogue No. 10068-013) and the Dramix DNA Marker (A&A Biotechnology) were used as DNA size markers. The amplifications of all isolates obtained with the three URP primers were used to construct a binary matrix by scoring the presence and absence of fragments as 1 and 0, respectively. The matrix was used to calculate the genetic distance applying the formula developed by Nei & Li (1979) and the latter was analyzed using PAST with Jaccard's coefficient of similarity and the DGGEstart 1.0 beta software. A phylogenetic tree was created using UPGMA and Bootstrap with 1000 repetitions. All amplifications were repeated at least twice for each isolate in separate experiments.

Statistical analysis

Statistical analyses and models were based on discriminant analysis. The analyses provided information which variables may affect the growth and development of *Phragmites australis* under different habitat conditions. The model was based on canonical variate analysis (CVA), which is a canonical variant of Fisher's linear discriminant analysis (LDA). The discriminant analysis was used for comparison of the effect of different variables on morphological parameters of *P. australis*. The following variables were included in the analysis: location (urban, rural and open landscape areas), soil moisture (dry, moist and wet areas), morphological and chemical variables ($N\text{-}NO_3$, P, K, Mg, Ca, Na, NaCl, pH) and chlorophyll *a* and *b*. All of the above variables were tested on 39 samples collected (omitting sample number 30) in 4 replicates (156 reps in total). Progressive stepwise analysis was used to determine which variables had the greatest effect on the growth of *P. australis* depending on the changing habitat conditions. For each variable, an F test was performed before its inclusion in the model to check whether the unexplained variance is smaller than the explained variance. If the value of F is greater than or equal to 2, the variable is statistically significant. The *p* value was calculated. The statistical significance threshold was set at 0.05 – all variables above this threshold were removed from the model. Moreover, the percentage of explanation (% Expl.) was calculated for each variable, which additionally describes which of the tested variables had the greatest impact on the distribution of all 40 samples (excluding sample 30). The Monte Carlo permutation test was conducted for each variable individually and for the entire model to determine the significance limit. The Canoco for Windows and Microsoft Excel programs were used for all comparisons, calculations and graphic elements. The following tools of the Canoco for Windows kit were used: Canoco for Windows 4,5, CanoDraw for Windows and WCanoIMP (Šmilauer, Lepš 2003).

Results

Twenty seven samples gave positive products. Primer URP 2 did not discriminate between the isolates. The two other primers discriminated between the DNA of the isolates. This resulted in 15 polymorphisms in total. There were 3–7 polymorphic markers per primer. The largest number of polymorphic markers resulted from the reaction with primer URP 17R. On average, one primer

generated six polymorphic bands. Samples 7, 8, 9, 19, 21 and 1; 4, 5 and 11; and 14 and 17 generated identical band patterns in all the primers. One representative was selected from each group and subjected to phylogenetic analysis, which revealed genetic variability. Samples 32, 28, 26 and 20 became isolated into a separate system (Fig. 2).

The research showed that the highest chlorophyll concentration in *P. australis* leaves was observed in plant tissues collected in urban areas (Table 1). Specimens from urban areas were taller and had larger laminae.

The comparison in Table 2 shows that the concentrations of all analyzed elements contained in the soil collected in urban areas were lower compared to samples collected in rural areas and open landscape. Only the Ca concentration was higher in the soil from urban areas. The higher concentrations of nutrients in soil samples collected in rural areas and open landscape may have been caused by intensive mineral and organic fertilization. When comparing the results in Table 2 with the data on morphological parameters of *P. australis*, it can be concluded that common reed plants prefer habitats with calcium-rich soil and slightly alkaline pH. The species may be resistant to deficits or low concentrations of the main nutrients, i.e. $N\text{-}NO_3$ and K.

The research has shown that plants collected from dry areas were smaller. They were shorter, the diameters of their shoots were smaller, and their laminae were shorter and narrower. As evidenced by the standard deviation values, specimens collected from dry areas were characterized by the narrowest amplitude of variation in all morphological parameters (Table 3). The highest chlorophyll content was found in leaves of specimens growing on soils with the highest moisture content.

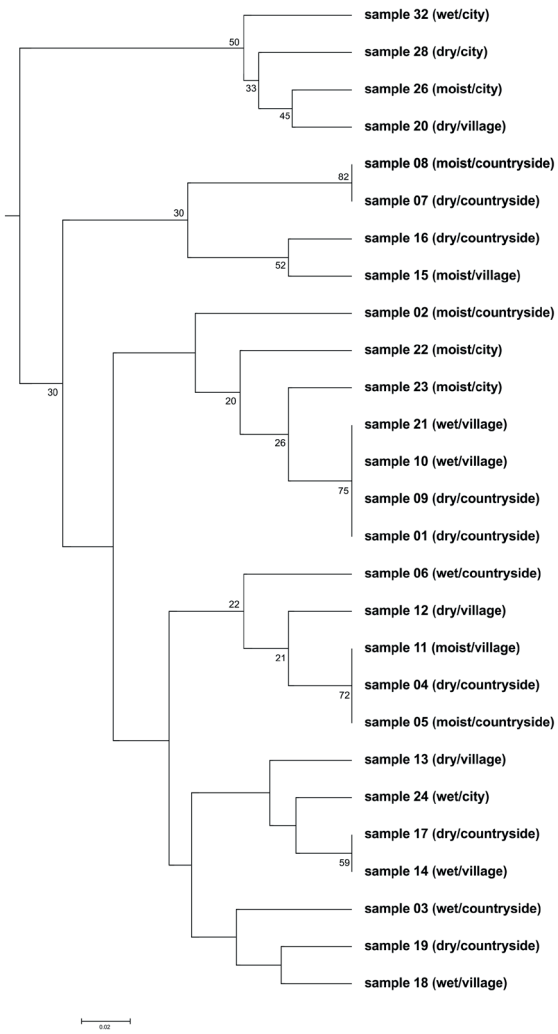

Figure 2

Phylogenetic tree based on UPGMA and Bootstrap

Table 1

Morphological parameters and chlorophyll content in *P. australis* collected from different locations (chl – chlorophyll)

		chl *a*	chl *b*	total chl	height	stem ø	leaf length	leaf width
city	min.	0.604	0.440	1.153	110.0	0.4	33.0	2.2
	max	2.076	1.280	3.360	260.0	1.2	62.0	4.4
	mean	1.151	0.823	1.976	180.8	0.7	47.6	3.2
	SD	0.295	0.209	0.450	45.2	0.2	7.3	0.7
village	min.	0.668	0.432	1.142	115.0	0.5	30.0	2.4
	max	1.298	0.953	2.057	270.0	1.0	53.0	4.0
	mean	0.989	0.634	1.625	177.2	0.8	42.9	3.2
	SD	0.157	0.120	0.209	49.6	0.2	8.5	0.5
open landscape	min.	0.527	0.275	0.803	110.0	0.4	26.5	1.8
	max	1.578	1.065	2.645	210.0	1.0	53.0	3.9
	mean	1.030	0.594	1.626	161.6	0.6	41.9	3.1
	SD	0.234	0.198	0.411	30.7	0.2	8.2	0.6

Table 2

Chemical parameters of sediments and soil collected from different locations

		N-NO_3	P	K	Mg	Ca	Na	NaCl	pH
city	min.	1.35	12.60	6.40	50.10	2424.4	42.5	0.22	6.90
	max	13.60	109.40	196.90	287.60	6125.3	239.7	2.40	8.00
	mean	5.79	56.39	51.86	148.93	4920.3	187.6	0.85	7.67
	SD	3.09	26.62	47.37	66.32	999.8	57.6	0.62	0.28
village	min.	3.65	23.10	22.30	187.20	1709.8	54.9	0.28	7.30
	max	13.10	126.50	489.00	442.80	6479.2	2351.0	2.30	8.20
	mean	7.55	65.34	200.36	277.43	4623.7	226.0	1.01	7.63
	SD	2.46	37.35	174.43	76.07	1595.9	372.1	0.58	0.26
open landscape	min.	1.45	23.70	14.70	42.20	357.1	21.2	0.19	6.40
	max	19.50	103.90	482.40	314.50	5925.2	218.7	0.83	8.10
	mean	8.01	51.74	157.28	178.68	2663.0	95.0	0.49	7.46
	SD	4.97	27.74	128.58	72.16	1983.0	70.2	0.19	0.48

Table 3

Morphological parameters and chlorophyll content in *P. australis* according to soil moisture (chl – chlorophyll)

		chl *a*	chl *b*	total chl	height	stem ø	leaf length	leaf width
dry	min.	0.527	0.275	0.803	110.0	0.4	26.5	2.1
	max	1.578	1.095	2.665	210.0	0.8	53.0	3.9
	mean	1.068	0.673	1.742	149.6	0.6	43.0	3.1
	SD	0.249	0.220	0.436	30.3	0.1	6.9	0.5
moist	min.	0.663	0.407	1.153	110.0	0.4	27.5	1.8
	max	1.673	1.130	2.634	270.0	1.1	56.0	4.4
	mean	1.049	0.668	1.718	181.3	0.7	44.2	3.1
	SD	0.245	0.201	0.397	48.4	0.2	8.0	0.7
wet	min.	0.668	0.432	1.142	150.0	0.5	30.0	2.3
	max	2.076	1.280	3.360	250.0	1.2	62.0	4.3
	mean	1.115	0.797	1.914	197.5	0.9	47.5	3.4
	SD	0.284	0.202	0.435	35.0	0.2	9.4	0.7

The content of Ca, Na and NaCl in the soil of wet areas, where the largest specimens were found, was higher compared to the soil at other sites. The soil pH at all the sites was similar. The lowest content of potassium was found in wet soils (Table 4).

The model in Fig. 3 shows the relationships between the morphological parameters of reed plants, chemical parameters of soil, the sites where samples were collected and *P. australis* specimens. The research has shown that larger specimens occur on soils with higher Ca content and soils more contaminated with NaCl compared to other sites (Table 5). The CVA model shows that *P. australis* plants growing on wet soils were much taller and had wider leaves. We can assume that wetlands in urban areas with moderately NaCl-contaminated soils are optimal habitats for *P. australis* plants.

The comparison of the data in the CVA model (Fig. 3) and the results of molecular analysis led to the identification of three groups (G1, G2 and G3) of specimens with homogenous genetic codes and habitat requirements. Group 1 consisted of two specimens only – 14 and 24. They preferred a wet habitat located in the urban area, with a higher content of NaCl in soil (Tables 2 and 4). Groups G2 and G3 consisted of specimens preferring rather dry habitats located in rural or open landscape areas, where soils have a high N-NO_3 content.

Discussion

The research on the growth and development of common reed revealed differences in the morphological structure of plants growing in waters of different depths. However, the results of experiments were often contradictory (Engloner 2004). Some studies have shown that there was no correlation between the height of shoots, the shoot base diameter and the depth of water in which the plants grew

Table 4

Chemical parameters of sediments and soil according to soil moisture

		N-NO_3	P	K	Mg	Ca	Na	NaCl	pH
dry	min.	1.45	24.10	14.70	42.20	357.10	21.20	0.19	6.40
	max	13.60	126.50	489.00	314.50	6125.30	239.70	0.94	8.10
	mean	6.30	65.83	137.64	170.10	3342.92	116.66	0.44	7.56
	SD	3.23	31.78	123.64	69.95	2036.71	77.12	0.18	0.44
moist	min.	3.20	12.60	6.40	50.10	1512.70	42.50	0.22	7.20
	max	19.50	96.20	489.00	364.00	6015.80	236.90	2.40	8.20
	mean	8.03	46.27	145.07	205.77	4470.23	168.39	0.79	7.68
	SD	4.26	26.98	162.71	85.02	1387.42	68.29	0.56	0.27
wet	min.	1.35	18.10	8.10	70.50	837.40	41.20	0.42	6.90
	max	13.50	109.40	297.00	442.80	6479.20	2351.00	2.30	8.00
	mean	6.46	56.77	68.22	191.74	4862.42	231.88	1.18	7.57
	SD	3.74	27.35	81.34	102.94	1446.20	319.44	0.58	0.30

(Coops, Van der Velde 1996; Paucã-Comãnescu et al. 1999; Squires, Van der Valk 1992). Dinka (1986) showed statistically significant differences in the stem height between reeds collected in July at depths of 20–50 cm and those collected at depths of 120–150 cm. However, most of these differences became statistically insignificant at the end of the growing season. White & Ganf (2002) found a positive correlation between the shoot length and the depth of standing water ranging from 5 to 65 cm. They also found a negative correlation at sites with variable water level. As evidenced by our study, there is a correlation between the morphological parameters of common reed plants (the height of plants, the width of the lamina) and their ecosystems. Our study has shown the statistically significant correlation between the height of plants and wet or moist soils in urbanized areas. This means that the height of plants depends on the type of their habitat. However, there are no studies on the impact of habitat conditions (urban, industrial or agricultural areas) on morphological parameters and plant growth.

Wilson et al. (2017) studied the effect of Fe and Mg fertilization and their combinations on the growth of *P. australis* subsp. *americanus*. A significant effect of Fe fertilizers on the growth of plants and chlorophyll content in their leaves was found. The same effect was not found in the case of Mg fertilization. Referring these results to those presented in our work, we can

Table 5

Correction coefficients for the CVA model in Fig. 3

Parameters	*p*-value	F-value	% EXPL.
Mg	**0.001**	**7.215**	**23.45**
NaCl	**0.001**	**7.186**	**18.89**
plant height	**0.003**	**6.452**	**14.25**
Ca	**0.005**	**5.874**	**13.13**
chlorophyll *b*	**0.014**	**5.112**	**10.24**
N-NO_3	**0.027**	**4.896**	**9.45**
leaf width	**0.048**	**2.894**	**4.78**
pH	0.059	2.184	2.11
P	0.087	1.541	0.97
K	0.091	1.414	0.95
Na	0.129	1.084	0.83
leaf length	0.156	0.098	0.52
chlorophyll *a*	0.259	0.079	0.31
stem diameter	0.385	0.027	0.12

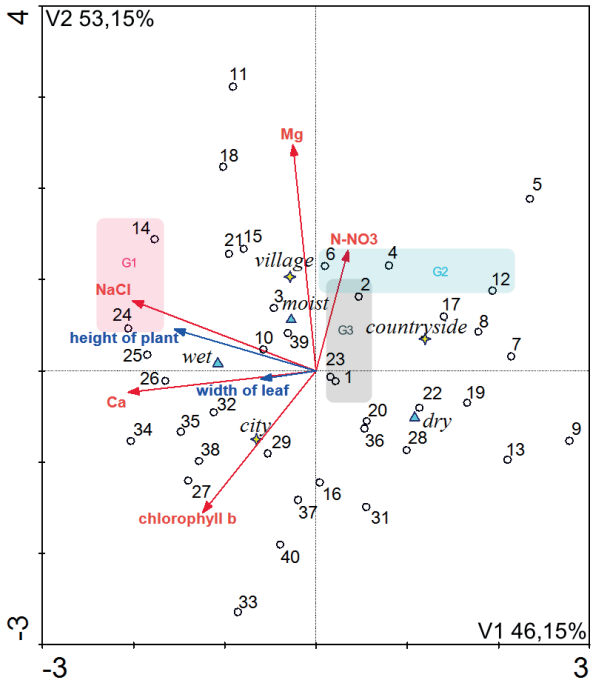

Figure 3

CVA model (n = 156). Relationships between the morphological parameters of reed plants, biochemical parameters, sampling sites and *P. australis* specimens

conclude that analogously we did not find a significant impact of Mg on the growth of *P. australis* (CVA model) – the angle of inclination between Mg and plant height. Many authors provide information on the content of minerals in soil in relation to the degree of urbanization. Šorša et al. (2018) and Lollar (2005) strongly indicate the alkaline reaction and higher content of Ca and Mg in soils with a high degree of urbanization (soils of urban and industrial areas) compared to agricultural soils. The above correlation is also confirmed by our research, which was presented in the CVA model.

Salinity is a well-known stress factor for *P. australis* plants as it reduces their growth rate (Rocha et al. 2014). According to available data, there are considerable fluctuations in the tolerance of reeds to salinity. Different tolerance limits in various ecotypes may depend on plants' adaptive capacity or genetic factors (Brix 1999; Gorai et al. 2007; Rocha et al. 2014). Our research conducted in central Poland confirmed the resistance of *P. australis* to salinity. Furthermore, the research showed that specimens growing soils with higher NaCl content were larger (the height of plants, the width of the lamina).

Many researchers reported that reed populations growing in wet and moist areas were characterized by lesser genetic variability than those growing in dry areas (Güsewell, Klötzli 2000; Koppitz 1999; Zeidler et al. 1994). Our study confirmed high genetic variability in different ecosystems and resulted in the identification of genetically similar plants growing both in wet and dry areas. There are two hypotheses accounting for the differences in genetic variability between the locations: 1) the superiority of vegetative reproduction in locations where a population may develop from one or a few rhizomes, or 2) high genetic variability at the initial stage of the population development decreases over time due to natural selection and competition (Čurn et al. 2007; Neuhaus et al. 1993). There were four common reed ecotypes found in research conducted in China: swamp reed (SR), low-salt meadow reed (LSMR), high-salt meadow reed (HSMR) and dune reed (DR). The research proved that the ecotypes retained changes in their morphological, physiological and genetic features, which they developed in response to drought and salinity (Chen et al. 2006). According to the Chinese scientists, the genes involved in photosynthesis may increase the photosynthetic capacity of leaves exposed to water stress but this is not directly related to the adaptive capacity of plants exposed to water deficit (Wang et al. 1998). Our study confirmed that there was a significantly higher content of chlorophyll *b* in the leaves of plants collected in urban areas with water deficit caused by high salinity levels compared to the leaves of plants collected in open landscape rural ecosystems.

Our research and analysis confirm the hypothesis to a certain extent. During the study, we identified three groups of plants homogeneous in terms of habitat and genetic factors (CVA model), which constitute 20% of all examined plants. In our opinion, further research is required on a larger population of *P. australis* in a wider area.

Conclusions

- The research resulted in the identification of three groups of specimens with similar habitat preferences and the homogenous genetic code. They accounted for 20% of all plants under analysis.
- Specimens growing on moist and wet soils in urban areas were characterized by higher values of morphological parameters and higher content of chlorophyll b in leaves.
- The common reed plants preferred slightly alkaline soils with high Ca content. The species was resistant to $N\text{-}NO_3$, P and K deficit.
- The species was tolerant to various soil salinity levels.

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