

ECOLOGICAL CHARACTERISTICS OF *POLYGONUM POLYSTACHYUM* POPULATION IN NORTH-WESTERN POLAND (WEST POMERANIA: NIEPOŁCKO)

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Key words: *Polygonum polystachyum*, *Polygonaceae*, inter-individual attributes, population biology, West Pomerania.

Abstract

This paper presents the results of the study conducted on the *Polygonum polystachyum* population located in a manor park in Niepołcko (West Pomerania). This species in Poland has been recorded only in 11 localities so far, most of which are situated in the south of the country. The aim of the investigation was to identify the current status and edaphic conditions of the *P. polystachyum* population, as well as to recognize its selected inter-individual and group attributes. Number of specimens, their density per 1 m², and mean crowding was determined. Also the population's type of spatial structure was identified through observation and by calculation of the dispersion coefficient. On the basis of the conducted research it was found that the investigated population numbers 609 specimens and it currently occupies the area of 38 m². It has clustered spatial distribution type (dispersion coefficient > 1) and is characterized with high value of mean shoot density, which amounts to 27.8 spec./1 m² (max. 38 spec./1 m²). On the basis of the investigation of biometric attributes of 50 randomly selected specimens, it was found that shoots of *P. polystachyum* achieve the height from 163 to 222 cm, and width from 6.0 mm (lower height specimens) to 19.5 mm (taller specimens). Mean length of the examined bottom and top leaves is respectively 25.4 and 24.1 cm, while their mean width achieves 7.5 and 7.2 cm. The number of the inflorescence primary branches has the highest value of the coefficient of variation (V = 75.5%), whereas the height of the specimens has the lowest one (V = 7.4%). Conducted correlation analysis revealed that there is a statistically significant positive correlation between the width of *P. polystachyum* shoots and the length of the leaves from the top of the stem ($r_s = 0.949367$). On the basis of the conducted chemical analysis of the soil from the *P. polystachyum* habitat, the substrate was classified as alkaline soil (pH = 7.1), with low total nitrogen content (0.26%), as well as low organic carbon content (2.8%).

CHARAKTERYSTYKA EKOLOGICZNA POPULACJI *POLYGONUM POLYSTACHYUM* W PÓŁNOCNO-ZACHODNIEJ POLSCE (POMORZE ZACHODNIE: NIEPOŁCKO)

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Abstrakt

Dotychczas w Polsce *Polygonum polystachyum* stwierdzono tylko na 11 stanowiskach, występujących w większości w południowej części kraju. Badania miały na celu rozpoznanie stanu i warunków edaficznych populacji *P. polystachyum* odnotowanej w parku podworskim w Niepołcku (Pomorze Zachodnie) oraz przedstawienie jej wybranych właściwości osobniczych, jak i grupowych. Określono liczbę osobników i ich zagęszczenie na 1 m², średnie zatłoczenie, rozpoznano także typ struktury przestrzennej populacji na podstawie obserwacji oraz obliczonego współczynnika dyspersji. Stwierdzono, że populacja liczy 609 osobników i aktualnie zajmuje powierzchnię 38 m². Cechuje ją skupiskowy typ rozmieszczenia przestrzennego (Wsp. dysp.>1) i wysoka wartość średniego zagęszczenia pędów, która wynosi 27,8 osobn./1 m² (maks. 38 osobn./1 m²). Na podstawie zbadanych cech biometrycznych losowo wybranych 50 osobników stwierdzono, iż pędy *P. polystachyum* osiągają wysokość od 163 do 222 cm i grubość od 6,0 mm (u niższych osobników) do 19,5 mm (u wyższych). Średnia długość zbadanych dolnych i górnych liści wynosi odpowiednio 25,4 i 24,1 cm, zaś ich średnia szerokość to 7,5 i 7,2 cm. Najwyższym współczynnikiem zmienności (V= 75,5%), charakteryzuje się liczba gałązek kwiatostanowych, najniższym zaś wysokość badanych osobników (V=7,4%). W przeprowadzonej analizie korelacji stwierdzono istnienie statystycznie istotnej dodatniej korelacji między grubością pędów osobników *P. polystachyum*, a długością liści z górnej części pędu ($r_s=0,949367$). Osobniki *P. polystachyum* występowały na glebach o odczynie obojętnym (pH = 7,1) o niskiej zawartości zarówno azotu ogólnego (0,26%) oraz węgla organicznego (2,8%).

Introduction

The genus *Polygonum* L. (*Polygonaceae* Juss.) in Poland is represented by 21 species, which mostly occur in grassland and ruderal habitats (RUTKOWSKI 2008). The majority of them are the common species with a wide range of ecological amplitude. However, within this genus, there are some species that are very rare in the flora of Poland. One of them is the Himalayan knotweed *Polygonum polystachyum* Wall. ex Meissner [= *Aconogon polystachyum* (Wall. ex Meissner) Haraldson, *Persicaria polystachya* (Wall. ex Meisn.) Gross, *P. wallichii* Greuter & Burdet, and *Reynoutria polystachya* (Wall. ex Meisn.) Moldenke]. To date, only 11 localities of this taxa have been recorded in Poland. Currently, only 10 of them have remained, 9 of which are situated in the south of the country: in Głuchołazy (Silesia) CF-31 – the first locality recorded in Poland (SCHUBE 1927), in Walim BE-94, Mąkolno BF-27, Budniki

BE-80, Górki Wielkie DF-91, Wielkie Drogi DF-78, Zawoja DG-17 (BARTOSZEK et al. 2006), near Duszniki-Zdrój BF-24 (SMOCZYK 2005), and in Potoczek village BF-54 (www.odkrywanie.bystrzyca.pl/20091011/relacja/20091011_rdest.html).

Polygonum polystachyum is a species easy to identify and it is different from the remaining invasive knotweeds recorded in Poland: *Reynoutria japonica* Houtt., *Reynoutria sachalinensis* (F. Schmidt) Nakai, and the hybrid between them – *Reynoutria x bohémica* Chrtek et Chrtková (Regulation of the Minister of the Environment 2011). Among them, *Polygonum polystachyum* is being distinguished by its lanceolate leaves with long-pointed tips, as well as by inflorescence panicles gathered atop the stem (TOKARSKA-GUZIŁ et al. 2009).

Polygonum polystachyum, unlike the taxa of *Reynoutria* genus, originates from the Central Asia. Its native range covers the Himalayas, whereas its colonized range includes central and north-west Europe, e.g.: Switzerland, Austria, Belgium, France, and Denmark (WEBB & CHATER 1964, RECHINGER 1957).

In Poland, *Polygonum polystachyum* currently has a status of an established neophyte. It was introduced to Poland in 1927 (TOKARSKA-GUZIŁ et al. 2012). It grows in anthropogenic habitats, e.g. along roadsides or in the ruins of old settlements (BARTOSZEK et al. 2006). It may also occur in marshy sites, along rivers and streams, as in the case of the investigated population in Niepołcko (SMOCZYK 2005, GUMIENIAK 2007).

It is difficult to estimate the time of the first introduction of *Polygonum polystachyum* to the examined area. Presumably, it was brought there in the first half of the 20th century, by the landowners of the mansion and park (von Kehler family), as an ornamental plant. Similarly, botanical gardens have significantly contributed to the propagation of *Reynoutria japonica* and *R. sachalinensis*, which are currently invasive species in Poland (BAILEY and CONOLLY 2000).

The only one *Polygonum polystachyum* locality in West Pomerania was recorded in the manor park in Niepołcko (BACIECZKO 1997). Its population was found in 1997 for the first time, then there were only 50 specimens. Currently it has remarkably increased in size, as well as its area of occurrence. In Poland there is lack of wider research on the distribution of this species, as well as population investigations – this study fills this deficit.

The aim of this study was to identify the status and edaphic conditions of the *Polygonum polystachyum* population, as well as to introduce its selected inter-individual and group attributes.

Material and Methods

Polygonum polystachyum was recorded in a manor park in Niepolcko. According to the administrative location, this village belongs to the Barlinek municipality, Myślubórz county, and West Pomerania voivodeship. According to the physical-geographical partition of Poland, it is situated in the Myślubórz Lakeland mesoregion (KONDRACKI 2001). According to the geobotanical regionalization of Poland it is located in the Lipiany Subregion of the Myślubórz Region (MATUSZKIEWICZ 2008). Finally, according to the ATPOL cartographic system, the site of investigation is positioned in the AC-27 square (ZAJĄC and ZAJĄC 2001).

Polygonum polystachyum population grows in the north-west section of the park, in the close vicinity of the Płonia river. Damaged drainage system influences the park's structure. Park's canopy and woody understory layer are mostly composed of native species, e.g.: *Quercus robur*, *Tilia cordata*, *Acer platanoides*, *Fraxinus excelsior*, *Corylus avellana*, *Euonymus europaeus*, and *Sambus nigra*. The population however, grows in the exposed spot, with the lack of tree cover. In the lush undergrowth, many herbaceous plant species are present, amongst which *Polygonum polystachyum* is being distinguished by its physiognomy. It coexists with such species, as: *Urtica dioica*, *Rubus caesius*, *Deschampsia caespitosa*, *Aegopodium podagraria*, *Cirsium oleraceum*, *Rumex obtusifolius*, *Galium aparine*, *Geum urbanum*, and *Acer platanoides* seedlings.

Field research and laboratory analysis was conducted in 2014, in two steps. In the first stage, the area covered by the population was estimated, number of specimens and their density per 1 m² was determined, population's type of spatial structure was identified through observation, and the dispersion coefficient (TROJAN 1975) was calculated. Also the mean crowding of specimens was determined, which was expressed in the Lloyd's index (COLLIER et al. 1978).

In the second step, the biometric measurements were conducted on 50 randomly selected adult and juvenile specimens of *Polygonum polystachyum*. The measured attributes were: 1 – height of plant shoot, 2 – width of plant stem, 3 – number of nodes on a stem, 4 – number of leaves on a shoot, 5a and 5b – length of the leaf from the bottom and the top of the shoot, 6a and 6b – width of the leaf from the bottom and the top of the shoot, 7a and 7b – length of the leaf petiole from the bottom and the top of the shoot, 8a and 8b – area of lamina of the leaf from the bottom and the top of the shoot, 9 – number of inflorescence primary branches. Photo-optical measurement of leaves' assimilation surface area was conducted in laboratory, with Delta

I Device Image Analysis System. Uniformed measurement process was used, in order to limit sources of errors.

Subsequently, *Polygonum polystachyum* intrapopulation variability was analysed on the basis of the calculated maximum, minimum values, arithmetic mean, standard deviation, and coefficient of variation. Pearson product-moment correlation was used to assess the relations between the selected morphological attributes. Statistical analyses were made using STATISTICA® 10.0 for Windows software (StatSoft, Inc 2010).

In order to determine edaphic conditions of the investigated population, Egner's sampling stick was used to collect the soil sample from the rhizosphere. 4 subsamples were collected and mixed into a composite soil sample. Afterwards, dried soil substrate was delivered to the Regional Chemical-Agricultural Station in Szczecin for physical-chemical analysis. Soil pH (pH_{KCl}) was assessed using the potentiometric method – with potassium chloride (KCl) of the concentration of 1 mole dm^{-3} C (KCl). Calcium carbonate content was calculated with Scheibler method, the carbon content – with Turin's method, whereas total nitrogen content – with Kjeldahl method. Bioavailable potassium forms (K_2) content was assayed using flame emission spectroscopy according to the Polish Standard PN-R-04022:1996, while bioavailable phosphorus (P_2O_5) content – using spectrophotometry according to the Polish Standard PN-R-04023:1996. Bioavailable magnesium (Mg) content was assayed using spectrophotometry with Titan Yellow according to the Polish Standard PN-R-04020:1994. Humus content was determined with gravimetric analysis.

Botanical names of vascular plants used in this study were adopted after MIREK et al. (2002), with the exception of *Polygonum polystachyum* which follows WEBB & CHATER (1964).

Results

Group attributes of the population of *Polygonum polystachyum* Wall. ex Meissner

Polygonum polystachyum population in the manor park in Niepołcko currently occupies the area of 38 m^2 . It numbers 609 specimens grouped together in one spot. Their mean density amounts to 27.8 spec./1 m^2 (max. 38 spec./1 m^2). The population has a clustered spatial distribution type (dispersion coefficient > 1). Mean crowding expressed in the Lloyd's index equals 26.2, which is slightly lower than the population mean density (tab. 1).

Table 1
Group attributes of the population of *Polygonum polystachyum* wall. et Meissner recorded in Niepołcko manor park

Total number of specimens	Density of specimens per 1 m ²			Mean crowding	Dispersion coefficient
	min.	max.	mean		
609	22	38	27.8	26.2	1.41

Population variability of *Polygonum polystachyum* Wall. ex Meissner

Mean values of the investigated inter-individual attributes, as well as the further population data, are presented in Table 2.

Examined *Polygonum polystachyum* shoots achieve the height from 163 to 222 cm and width from 6.0 mm (lower height specimens) to 19.5 mm (taller specimens). In order to precisely characterise the height of investigated population specimens, they were divided into 7 range classes (Figure 1). The majority of specimens' height is placed in the 170-200 cm range, which cumulatively constitutes 46% of the population. Participation of specimens in the remaining range classes is lower, it fluctuates from 1 to 8 individuals. Height of shoots attains the lowest value of the coefficient of variation ($V=7.4\%$). This attribute follows normal distribution according to the Shapiro-Wilk test for normality ($p=0.98$).

Table 2
Main statistical characteristics of the specimens of *Polygonum polystachyum* Wall. et Meissner

No.	Characteristic	x_{\min}	x_{\max}	\bar{x}	SD	V
1	height of plant shoot	163.0	222.0	193.0	14.2	7.4
2	width of plant stem	6.0	19.5	10.2	2.3	22.6
3	number of nodes on a stem	18.0	28.0	23.0	2.1	9.1
4	number of leaves on a shoot	28.0	112.0	64.7	19.6	30.3
5a	length of the leaf from the bottom of the shoot	20.0	29.9	25.3	2.1	8.4
5b	length of the leaf from the top of the shoot	18.9	28.0	24.1	2.3	9.7
6a	width of the leaf from the bottom of the shoot	5.7	9.9	7.5	1.0	12.3
6b	width of the leaf from the top of the shoot	4.3	9.4	7.2	1.1	15.0
7a	length of the leaf petiole from the bottom of the shoot	1.2	2.5	1.8	0.3	17.0
7b	length of the leaf petiole from the top of the shoot	0.9	2.6	1.4	0.4	24.1
8a	area of lamina of the leaf from the bottom of the shoot	64.3	169.7	111.5	23.6	21.2
8b	area of lamina of the leaf from the top of the shoot	54.1	152.7	105.1	23.4	22.3
9	number of inflorescence primary branches	0	8	3.0	2.3	75.5

Explanations: x_{\min} – minimal value, x_{\max} – maximal value, \bar{x} – arithmetic mean, SD – standard deviation, V – coefficient of variation

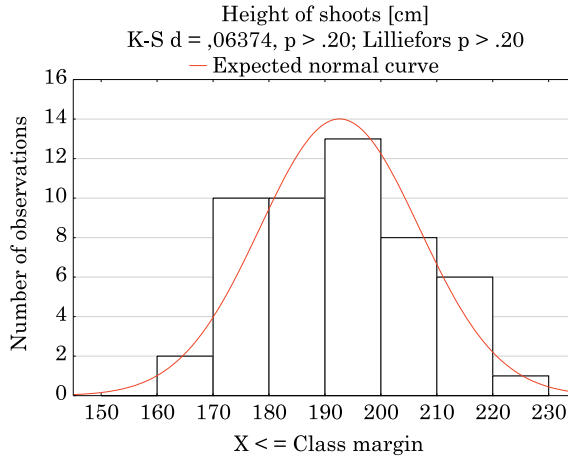


Fig. 1. Height structure of the population of *Polygonum polystachyum* Wall. et Meissner in Niepołtcko

Number of leaves on a shoot is a subject to fairly large variability, with the coefficient of variation $V=30.3\%$. Leaves from the bottom of the shoots are larger than the top leaves in terms of their length, width, and their assimilation surface area. The mean values of the length of the bottom and top leaves average 25.4 and 24.1 cm respectively. Higher coefficients of variation of the width of the examined leaves ($V=12.3\%$ and $V=15\%$) indicates that their width variability is greater than their length variability (8.4% and 9.7%). Furthermore, investigated attributes achieve similar maximal and minimal values (Figure 2).

Great participation of blooming specimens in the examined sample (86%), including the great number of specimens with 4 inflorescence primary branches (53%), indicates the advanced age of the studied population. This attribute has the highest coefficient of variation ($V=75.5\%$), because of the presence of non-blooming specimens in the tested sample.

Mean area of lamina of the bottom leaves equals 111.5 cm^2 and it is larger than the top leave's one (105.1 cm^2). Probability distribution of the specimens that are situated in each range class, in terms of the examined attribute, is fairly diverse. The majority of the specimens has both bottom and top leaves with the area of lamina situated in the $100\text{-}120 \text{ cm}^2$ range class, whereas the minority – in the marginal range classes (Figure 3). High coefficient of variation ($V=21.2\%$ and $V=22.3\%$) and high standard deviation ($SD=23.6$ and $SD=23.4$) indicate a high dispersion of the examined attribute (Table 2).

The results of Pearson correlation analysis between the examined inter-individual attributes are presented in Table 3. It was found that there is a statistically significant positive correlation between the width of stems

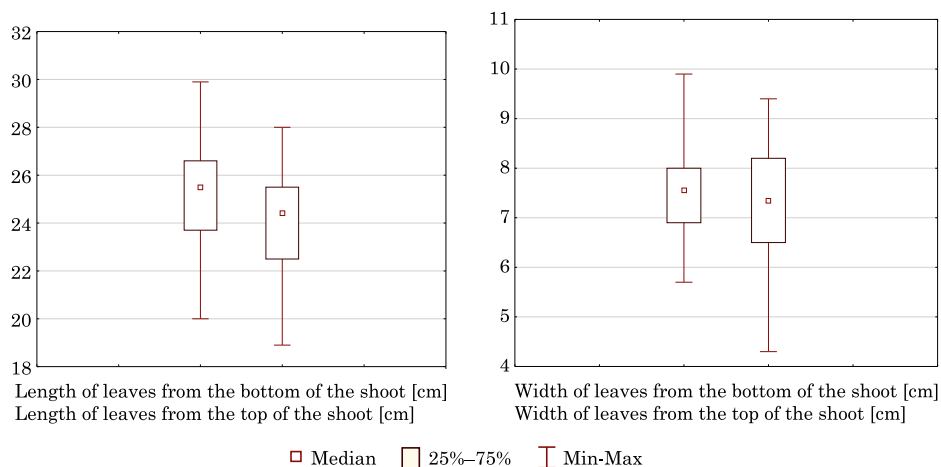


Fig. 2. Variability of length and width of leaves from the bottom and the top of the shoot of *Polygonum polystachyum* Wall. et Meissner

of *Polygonum polystachyum* specimens and the length of the leaves from the top of the shoot ($r=0.949367$). Furthermore, highly significant correlation was found between the number of nodes on a stem and the width of the leaves from the bottom of a shoot ($r=0.928528$), stem's width and top leaves' width ($r=0.873273$), top leaves' length and their width ($r=0.827928$), as well as between the width of top leaves and their petioles' length ($r=0.772151$).

Edaphic conditions

Chemical analysis of the soil surface layer from the *Polygonum polystachyum* locality revealed that soil pH is 7.1, therefore the examined soil was classified as alkaline. Soil reaction has influence as well on the growth of soil microorganisms, and on the mineralization process, which in the examined samples is being reflected by moderate degree of organic matter and humus accumulation. C_{org} content is correlated with the examined soil's fertility – it equals 2.8%. Total nitrogen content is related to organic matter and humus abundance. It reaches 0.26% in soil surface layer, which indicates that the substrate is nitrogen-poor. Proportion of C:N content equals 1.6, which implicates a difference in the mineralization rate of organic carbon and nitrogen compounds. The content of all bioavailable elements, according to the IUNG standards, is very high. Bioavailable potassium (K_2O) content reaches $38.5 \text{ mg} \cdot 100 \text{ g}^{-1}$ soil, bioavailable phosphorus (P_2O_5) content amounts to $52.4 \text{ mg} \cdot 100 \text{ g}^{-1}$ soil, whereas magnesium content equals $18.2 \text{ mg} \cdot 100 \text{ g}^{-1}$ soil.

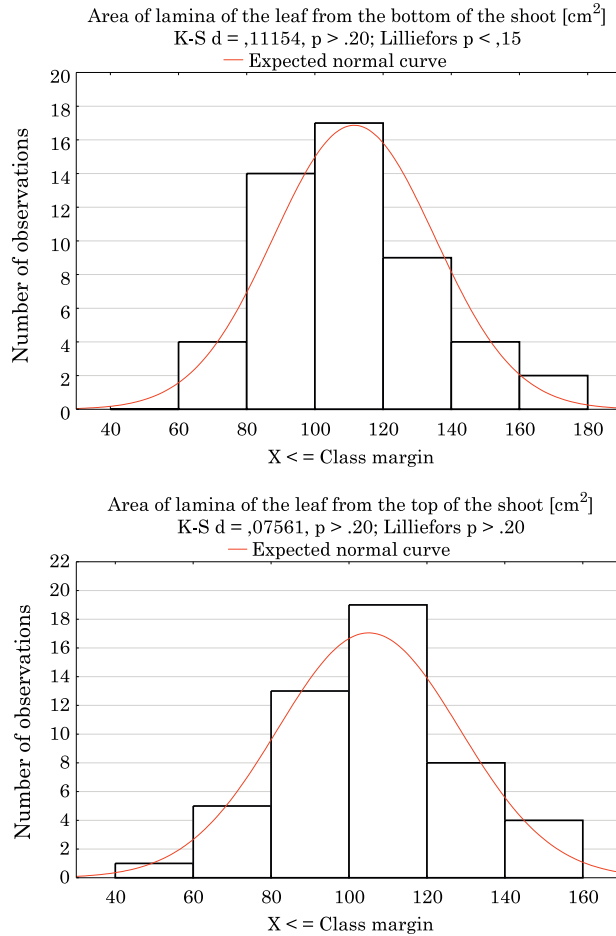


Fig. 3. Histograms of the area of lamina of the leaf from the bottom and the top of the shoot of *Polygonum polystachyum* Wall. et Meissner

Discussion

The investigated locality was recorded in 1997 for the first time. *Polygonum polystachyum* population numbered 50 specimens of approximately 1.3 m height back then (BACIECZKO 1997). The examined population have been devastated several times in the past 2 years due to restoration works performed on the 18th century mansion. Currently, the size of the population have increased over 30-times in comparison to 1997. The only *Polygonum polystachyum* population known in Poland, that is larger than the one recorded in Niepołcko, was observed in the Jałowiec ridge. It covers the area

Table 3
Coefficients of Pearson product-moment correlation between the examined biometric attributes of the specimens of *Polygonum polystachyum* Wall. et Meissner (significance level $\alpha = 0.05$)

Characteristic	1	2	3	4	5a	5b	6a	6b	7a	7b	8a	8b
9	0.606474	0.327879	0.598474	0.033638	0.339386	0.342871	0.461009	0.417883	0.546524	-0.026906	0.325465	0.377246
8b	0.603192	0.503553	0.604612	0.216746	0.231369	0.512889	0.591650	0.488488	0.608260	0.419420	0.549813	-
8a	0.412106	0.478054	0.515731	0.345367	0.116941	0.400424	0.499244	0.489787	0.436342	0.459639	-	-
7b	0.259999	0.525182	0.417260	0.408019	0.091606	0.485321	0.468019	0.389072	0.425134	-	-	-
7a	0.629045	0.658139	0.850129	0.275599	0.231713	0.609994	0.772151	0.713412	-	-	-	-
6b	0.566029	0.873273	0.674329	0.422928	0.262278	0.827928	0.679822	-	-	-	-	-
6a	0.712456	0.745504	0.928528	0.270701	0.290227	0.709101	-	-	-	-	-	-
5b	0.585487	0.949367	0.678224	0.494379	0.338770	-	-	-	-	-	-	-
5a	0.428551	0.260075	0.323466	0.081858	-	-	-	-	-	-	-	-
4	0.265814	0.504944	0.268235	-	-	-	-	-	-	-	-	-
3	0.733532	0.723025	-	-	-	-	-	-	-	-	-	-
2	0.561850	-	-	-	-	-	-	-	-	-	-	-

Explanations (1–9) as in Table 2.

of 320 m² and numbers about 900 specimens (GUMIENIAK 2007). Rapid growth of the investigated population is mostly determined by the vegetative propagation of the *Polygonum polystachyum* specimens. Regardless of the intensive development, the population does not manifest the spontaneous long-distance expansion trend: no additional localities of the species have been found in the surroundings. It may be caused by the impossibility to produce fruit, related with the late flowering time (September-October: BARTOSZEK et al. 2006).

The number of *Polygonum polystachyum* shoots in randomly selected plots varied from 22 to 38, with the mean value of 27.8 per 1 m². Comparable with this, *Reynoutria japonica* specimens achieve the higher value – 41.8 individuals per 1 m² (maximum of 73 specimens per 1 m²), according to ŚLIWIŃSKI and CZARNIECKA (2011).

Furthermore, the maximal height of *Polygonum polystachyum* shoots was 222 cm, which is higher than in the study of BARTOSZEK et al. (2006). Consequently, the leaves were also longer with the maximum of 29.9 cm. Only the leaves' width of the investigated specimens corresponds to the range presented in the study of BARTOSZEK et al. (2006).

Little is yet known about edaphic preferences of the investigated species. In India, its localities have been recorded at the elevation of 3000 m (KALA 2004), while in Afghanistan – above 3400 m.a.s.l (POLUNIN and STANTON 1984). In Poland, the highest altitude *Polygonum polystachyum* locality that have been recorded is located in the Jałowiec ridge, at 500–599 m.a.s.l. (GUMIENIAK 2007). Unlike the investigated population in Niepołcko, in India this species grows on acid soils (pH 3.8–6.2), with significantly higher content of nitrogen (0.3–4.5%) and organic carbon (4–34%) (KALA 2004). This leads to the conclusion, that *Polygonum polystachyum* is able to adapt to soils with lower organic compounds content.

Conclusions

Since there is a limited number of *Polygonum polystachyum* localities in Poland, as well as restricted amount of data on the species, and its populations biology, it is recommended to ensure a proper monitoring of the only locality recorded in West Pomerania. Long-term observations would allow to determine whether the species should be classified as potentially invasive neophyte (epikophyte or hemiagriophyte), and whether it is required to use some control management in order to restrict its further spread.

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