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DEMOGRAPHIC STRUCTURE AND MORPHOLOGICAL FEATURES OF *MALAXIS MONOPHYLLOS* (ORCHIDACEAE) POPULATIONS COLONIZING TECHNOGENIC SUBSTRATES

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Abstract

The study of the distribution, morphological and population characteristics of orchids and their responses to the technogenic and natural factors have a great importance for the development of measures for the protection of rare and endangered plant species. The preservation of rare species of the Orchidaceae family is of particular importance in the Urals, Russia, given the high level of industrialization in this area. One of these species is *Malaxis monophyllos* (L.) Sw., which is protected in many countries, including Russia. The aim of this research was to study the demographic structure and morphological features of *M. monophyllos* populations in the anthropogenically disturbed habitats, as well as in the natural forest community of the Middle Urals, Russia. It was shown that *M. monophyllos* settles in a sparse herbaceous layer of forest phytocoenoses dominated by early succession species, such as *Pinus sylvestris* L., *Populus tremula* L. and *Betula pendula* Roth. In anthropogenic habitats, *M. monophyllos* is able to form local populations with higher abundance and density than in the natural forest community with predominance of individuals in the generative state. It was revealed that *M. monophyllos* colonizing technogenic substrates corresponded to orchids from the natural forest community with respect to the most biometric parameters. At the same time, they were characterized by reduced fruit formation per plant (2.6 time on average), as well as the percentage of fruit set (2.7 times on average) compared with the plants from natural community, possibly due to unfavourable conditions of technogenic habitats, including putative *M. monophyllos* pollinators. Suitable humidity conditions and low competition in the man-made habitats favour the growth of *M. monophyllos*. However, the population persistence time in disturbed habitats will depend on the further succession processes and anthropogenic activities.

Key words: biometric parameters, industrial dumps, orchid, rare species, stages of development.

Introduction

The problem of species diversity preservation is of great importance. Industrial, economic and recreational human activity leads to significant changes in the vegetation cover of the Earth (Bolshakov and Chibrik 2007). The consequence of this process is the reduction in the natural ranges of rare species, which entails the decrease in their population numbers up to complete elimination. At the same time, the changes human activity caused in the environment can lead to the creation of new secondary habitats that may be suitable for some rare plants (Nowak and Nowak 2006, Lundholm and Richardson 2010).

First of all, groups that need protection are plant species with a sporadic distribution, represented by small populations, confined to certain specific ecological niches with a long renewal cycle and low competitiveness in phytocoenosis (Vakhrameeva et al. 2014). Many of these traits are inherent in representatives of the Orchidaceae family (Mamaev et al. 2004). The orchid diversity of Russia includes 135 species and 13 subspecies belonging to 38 genera (Efimov 2020). Among these, about 40 orchids are found in the Middle Urals, which is one of the most industrial regions of Russia (Mamaev et al. 2004, Vakhrameeva et al. 2014). Changing natural habitats leads to the extinction of many orchid species. However, more information has been reported about the growth of certain orchid species on the anthropogenically disturbed territories. The colonization of such habitats (including lands disturbed by industry) with orchids has been lately noted by many researchers (Jakubska et al. 2006, Esfeld et al. 2008, Schefferson et al. 2008, Scheffknecht et al. 2010, Strel'nikova and Manakov 2010). The appearance of several orchid species on industrial dumps was also noted in the Middle Urals, Russia (Filimonova et al. 2018, 2020, 2022; Maleva et al. 2021). One such species is *Malaxis monophyllos* (L.) Sw., a rare orchid listed in the Red Books of 35 regions of Russia (Blinova 2013, Vakhrameeva et al. 2014) and protected in many European countries (Bilz et al. 2011) and Mongolia (Baasanmunkh et al. 2021).

Malaxis monophyllos is a boreal-mountain Eurasian species with a holarctic range, hemicryptophyte and polycarpic. The storage organs are represented by a terrestrial tuber of shoot origin (photosynthesizing pseudobulba) of an oval shape dressed with a sheath of a green leaf and lower scale-like and vaginal leaves (Vakhrameeva et al. 2014). *M. monophyllos* is a competitively weak species. It prefers to grow in a more or less sparse grass stand (total projective cover is not more than 60 %), avoiding the close proximity to large aboveground plant parts. It most often grows singly or in small groups of no more than 100 individuals (Vakhrameeva et al. 2014). This orchid plant occurs in a moderately shaded habitat in forest clearings and forest edges. It is a moesophyte, more often found in the moderate habitats avoiding dry ones (Vakhrameeva et al. 2008).

The aim of this work is to study the demographic structure and morphological features of *M. monophyllos* populations growing on industrially disturbed territories and in their natural habitat in the Middle Urals, Russia. The knowledge of the properties of secondary orchid populations is of great importance, especially in the context of the continued decline in their numbers in natural phytocoenoses.

Material and Methods

The field studies were carried out on the territory of the Middle Urals, Russia. The study area is located in the temperate continental boreal climatic zone, characterized by long cold winters (the average January temperature is -16.0 °C) and short, relatively warm summers (the average July temperature is +17.2 °C). The relief of the region is low-mountainous. Most of it is covered by coniferous forests on mountainous podzolic soils (taiga zone). In the intermountain basins, there are boggy light forests, boggy and damp meadows, as well as various types of bogs. Plains are covered by forests, swamps and meadows (Shakirov 2011).

The study of *M. monophyllos* population demographic structure and some morphometric indicators of generative individuals was carried out in mid-July between 2016 and 2018. Populations of *M. monophyllos* were studied in 6 anthropogenic habitats (Fig. 1, Table 1): at the southern dump of the South Veselovsky brown coal mine (AP1), at the fly ash dump of the Nizhneturinskaya thermal power station, NTTPS (AP2), at the dam of the Shuralino-Yagodnoye placer gold deposit (AP3), at the fly ash dump of the Verkhnetagil'skaya thermal power station, VTTPS (AP4), at the Galkinsky dump of marbleized limestone (AP5) and at the dump of the Shabrovsky talc-magnesite deposit (AP6). The age of plant communities was determined according to the mine surveying data, which corresponded to the end of dumping and the cessation of anthropogenic activities. It varied from

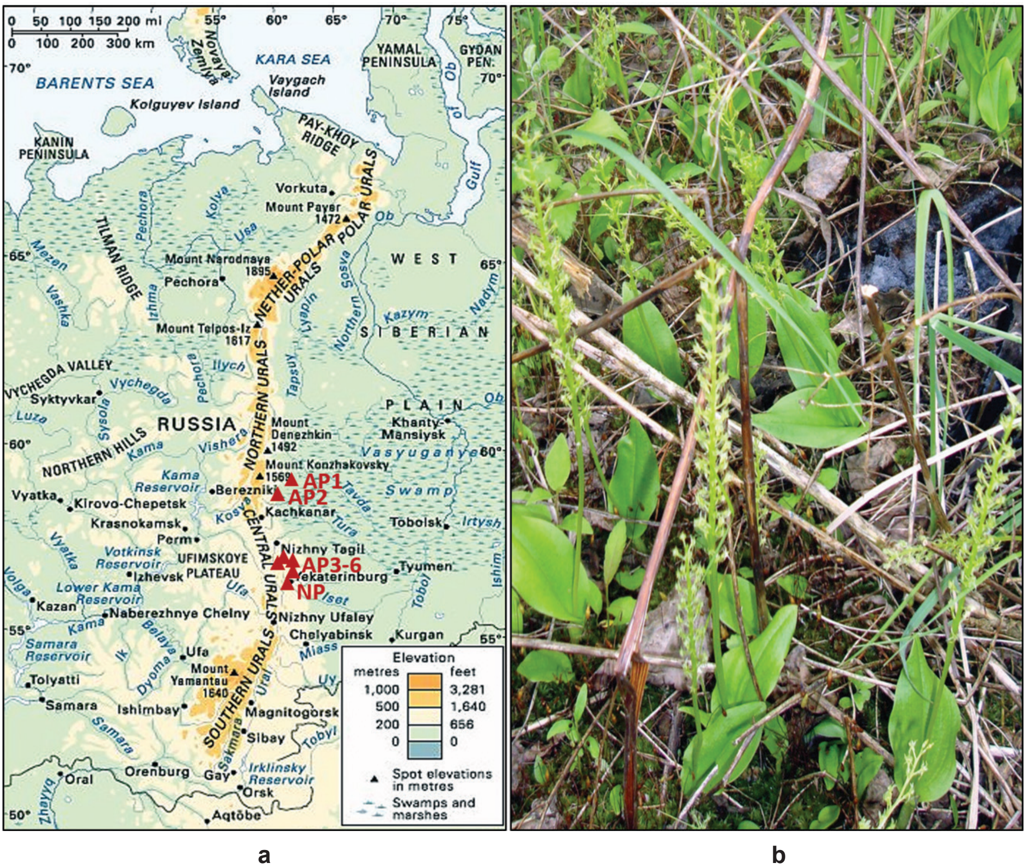

Fig. 1. Location of studied *Malaxis monophyllos* populations (a), example of a local orchid population (b).

Note: AP – population in anthropogenic habitat, NP – population in natural forest community.

Table 1. General characteristics of the studied sites.

Code	Sites	Coordinates	Type of substrate
AP1	South Veselovsky overburden dump (brown coal deposit)	59°41’20” N 59°55’28” E	Sandstones mixed with carbonaceous mudstones
AP2	Fly ash dump of Nizhneturinskaya thermal power station (non-reclaimed)	58°41’1’’ N 60°0’10’’ E	Fly ash
AP3	Hydro dump of clay rocks of the Shuralino-Yagodnoye alluvial gold deposit	57°24’34’’ N 60°10’28’’ E	Sediated clays, loams, sandy clays
AP4	Fly ash dump of the Verkhnetagil’skaya thermal power station (reclaimed)	57°20’21’’ N 59°56’30’’ E	Fly ash with clay soil application
AP5	Galkinsky dump of marbleized limestone	56°56′15″ N 59°49′06″ E	Limestones, sandy-argillaceous deposits
AP6	Dump of the Shabrovsky talc-magnesite deposit	56°37′45″ N 60°35′59″ E	Serpentines, talc-carbonate rocks
NP	Southwest forest park, Yekaterinburg	56º46’25’’ N 60º32’32’’ E	Sod-podzolic soil

Note: AP – population in anthropogenic habitat, NP – population in natural forest community.

20 to 55 years in the studied anthropogenic habitats. A more detailed description of technogenically disturbed territories was given earlier (Chibrik et al. 2011, Lukina et al. 2015).

As a reference control, we used the population of *M. monophyllos* from the natural forest community (NP) on the territory of the Southwest forest park, Yekaterinburg (Fig. 1, Table 1).

The populations of *M. monophyllos* differed according to the plant communities in which they were established. To survey the vegetation, a detailed route method was used. In places where orchids grew, geobotanical descriptions of sites (with minimum area of 100 m^2) were made. Such features as tree crown density, plant height, dominant species of the tree layer, species composition and richness of undergrowth and herb-shrub layers, the herb and shrub total projective cover (TPC) and the moss and lichen TPC of the sites surface were assessed.

To investigate the spatial and demographic structures of *M. monophyllos* populations in the studied plant communities, 50 counting plots (0.25 m^2) were randomly laid. The density of *M. monophyllos* populations was calculated as a number of individuals per 0.25 m^2.

The demographic structure of the populations was determined according to Vakhrameeva et al. (1993, 2014). *M. monophyllos* plants were divided into the following life history stages: juvenile (*j*), which have one green leaf up to 0.2–1.7 (maximum 2.0) cm long, 0.2–0.7 cm wide with 2–10 veins; immature (*im*) with a leaf up to 1.8–3.0 (maximum 3.2) cm long, 0.8–2 cm wide, with 10–14 veins; virginal (*v*) with a leaf up to 3.5–5.5 (maximum 7.0) cm long, 1.7–2 (maximum 2.5) cm wide with 16–22 veins; generative (*g*) with a leaf up to 5–8 (maximum 9.0) cm long, 2.2–4.5 (maximum 5.0) cm wide with 22–30 veins, the inflorescence is a loose narrow raceme of 30–60 (maximum 115) flowers (Vakhrameeva et al. 2014). The shoot height, the inflorescences length, the number of flowers and fruits per inflorescence were measured on generative individuals. Besides, the level of fruiting (calculated as a ratio of the number of fruits to the number of flowers) was assessed.

All calculations were done using Microsoft Excel 16.0 and STATISITICA 10.0 software. After checking the normality by Shapiro–Wilk test and the homogeneity of variance by Levene's test, the differences between the studied orchid populations were tested using the non-parametric Kruskal–Wallis H test; the correlation coefficients (r) were calculated with non-parametric Spearman Rank Order Correlations ($p < 0.05$). On Figure 2, the small solid square indicates the mean values ($n = 5–40$), the boxes present mean ± standard error (SE), the whiskers are the mean ± standard deviation (SD). Different letters indicate significant differences between the studied populations at $p < 0.05$.

Results and Discussion

The AP1 population of *M. monophyllos* of about 12 individuals was found in the forest phytocoenosis, which was formed at the southern dump of the Veselovsky brown coal mine (Table 1). The plant community was 55-year-old. The height of the tree canopy averaged 16 m. The tree crown density was 0.6–0.7 (Table 2). The dominant species were *Pinus sylvestris* L., *Betula pendula* Roth, *Populus tremula* L., *Picea obovata* Ledeb., while *Pinus sibirica* Du Tour and *Larix sibirica* Ledeb. were found in the undergrowth. Single individuals of *Juniperus communis* L., *Sorbus aucuparia* L., *Lonicera altaica* Pall., *Salix caprea* L. grew in the shrub layer. The herb-shrub layer was dominated by *Vaccinium vitis-idaea* L., *Pyrola chlorantha* Sw., *Orthilia secunda* (L.) House, *Equisetum sylvaticum* L., *Lathyrus vernus* (L.) Bernh. and others. The TPC of this layer varied from 10 to 50 % (Table 2). The single individuals of *M. monophyllos* grew in a well-developed moss-lichen layer, the TPC of which varied from 20 to 80 %. The density of *M. monophyllos* in this anthropogenic habitat was low and varied from 1 to 2 individuals per 0.25 m^2 (1.2 on average, Table 3).

The AP2 population of *M. monophyllos* of 400 individuals was found in the non-reclaimed area of fly ash dump of NTTPS in a plant community, transforming from a shrub stage to the formation of a mixed forest phytocoenosis. The plant community was about 20-year-old. The tree layer was dominated by *B. pendula* and *P. sylvestris*. The height of individual trees reached 3.5 m, the tree crown density was absent (Table 2). The undergrowth included *P. tremula*, *Betula pubescens*

Table 2. Geobotanical characteristics of the studied sites.

Code	Tree crown density	Undergrowth cover, %	Herb-shrub cover, %	Moss-lichen cover, %	Litter thickness, cm	Species diversity, number of species per 0.25 m^2
AP1	0.6–0.7	0–10	10–50	20–80	2.0–3.0	5.3
AP2	0	35–40	10–50	0–85	0.0–1.0	4.0
AP3	0.5–0.6	30–65	10–35	0–5	2.0–5.0	6.4
AP4	0.7–0.8	16–20	25–60	5–10	2.0–3.0	3.7
AP5	0	35–45	25–45	0	1.5–2.5	11.1
AP6	0.5–0.6	0	5–50	0–7	2.0–4.0	2.5
NP	0.6–0.7	10–40	45–90	10–15	3.0–7.0	11.2

Note: AP – population in anthropogenic habitat, NP – population in natural forest community.

Table 3. Area, density and demographic structure of *M. monophyllos* populations.

Code	Population area, m^2	Density of population, number of individuals per 0.25 m^2	Percentage distribution of individuals at different age stage, %			
			j	*im*	*v*	*g*
AP1	300	1.2	8.3	25.0	25.0	41.7
AP2	200	8.2	6.0	9.0	25.0	60.0
AP3	300	2.4	6.7	20.0	13.3	60.0
AP4	200	1.8	7.0	20.0	17.0	56.0
AP5	100	3.0	14.3	38.1	14.3	33.3
AP6	200	3.9	14.8	22.2	33.4	29.6
NP	200	4.8	16.0	16.0	40.0	28.0

Note: AP – population in anthropogenic habitat, NP – population in natural forest community.

Ehrh., *Abies sibirica* Ledeb., *P. obovata*, *P. sibirica* and *L. sibirica*. The projective cover of this layer varied from 35 to 40 %. The shrub layer was represented by *Salix triandra* L., *S. phylicifolia* L. and single individuals of *S. aucuparia*, *Alnus incana* (L.) Moench, *Rosa glabrifolia* C.A. Mey. ex Rupr. and *Rubus idaeus* L. The herb-shrub layer occupied open areas among woody plants, the TPC varied from 10 to 50 %.

Such species as *Calamagrostis epigejos* (L.) Roth, *Chamaenerion angustifolium* (L.) Scop., *Deschampsia cespitosa* (L.) P. Beauv. were characterized by the most uniform distribution and high abundance, while *Trifolium pratense* L. and *Equisetum arvense* L. were found in groups.

The widespread coverage of the fly ash surface with a moss-lichen cover was noted, the TPC of which in some places reached up to 100 %. The most widespread were mosses of the genera *Pohlia*, *Bryum* and such species as *Marchantia polymorpha* L. and lichens of the genera *Peltigera* and *Cladonia*.

The density of *M. monophyllos* in AP2 was high and varied from 1 to 63 individuals per 0.25 m^2 (8.2 on average, Table 3). The population with the same high number and density of individuals was noted at the sludge storage of the Baikal Cellulose Plant (Vakhrameeva et al. 2014).

The AP3 population of *M. monophyllos* of 38 individuals was found at the dam of the Shuralino-Yagodnoye hydro dump of the placer gold deposit. The age of the forest phytocoenosis was 30. The tree crown density was 0.5–0.6 (Table 2). The tree layer was represented by *B. pendula*, *P. tremula*, *P. sylvestris*, *P. obovata*, *B. pubescens*, *A. incana*. The shrub layer was dominated by *Salix caprea* L., *S. cinerea* L., *S. myrsinifolia* Salisb., the TPC varied from 30 to 65 %. The average TPC of the herbs layer was 30 %, and dominated by *Lathyrus pratensis* L., *Tussilago farfara* L., *C. epigejos*, *E. arvense, O. secunda*, *Pyrola rotundifolia* L., *Fragaria vesca* L., *Vicia sepium* L. Orchids in the AP3 population grew in small groups. The density of *M. monophyllos* population varied from 1 to 14 individuals per 0.25 m^2 (2.4 on average, Table 3).

The AP4 population of *M. monophyllos* of 42 individuals was found in the forest phytocoenosis, which was formed in the reclaimed part of the fly ash dump of VTTPS. The territory was recultivated by applying strips of clay soil to the fly ash surface (Chibrik et al. 2016). The age of the plant community at the time of the survey was about 45. The tree canopy was two-tiered. The upper layer was characterized by a high proportion *of B. pendula*, *P. tremula*, *P. sylvestris*, *B. pubescens*. The tree crown density was 0.7–0.8. *P. obovata, P. sibirica* and single individuals of *A. sibirica* and *L. sibirica* were found in the undergrowth. The shrub layer contained *S. caprea*, *S. cinerea*, *S. aucuparia* and *Prunus padus* L. In the herb-shrub layer (TPC was 25–60 %) *F. vesca*, *Trifolium repens* L., *L. pratensis*, *Poa pratensis* L. prevailed. The density of *M. monophyllos* population in this community varied from 1 to 4 individuals per 0.25 m^2 (1.8 on average, Table 3).

The AP5 population of *M. monophyllos* of 15 individuals was found on the side of the road near the Galkinsky dump of marbleized limestone (Table 1). A group of *M. monophyllos* grew among the shrubs of *S. myrsinifolia*. In the herb-shrub layer (TPC was 35–45 %), the following species prevailed: *Carum carvi* L., *Taraxacum officinale* (L.) Webb ex F.H. Wigg., *Leucanthemum vulgare* Lam., *Poa trivialis* L. The density of *M. monophyllos* AP5 population varied from 1 to 6 individuals per 0.25 m^2 (3.0 on average, Table 3).

The AP6 population of *M. monophyllos* of 39 individuals was found on the dump slope of the Shabrovsky talc-magnesite deposit. Forest community was formed with the dominance of *P. sylvestris* and *B. pendula*. The plant community was 55-year-old. The stand height reached 20 m, the tree crown density was 0.5–0.6. *P. tremula*, *S. caprea*, *S. myrsinifolia* and other species of the genus *Salix* were single occurrences in the undergrowth. The TPC of herb-shrub layer varied in different areas from 5 to 50 %, averaging 20 %. *O. secunda*, *Chimaphila umbellata* (L.) W.P.C. Barton, *Moneses uniflora* (L.) A. Gray and *Pimpinella saxifraga* L. were abundant in the herb-shrub layer. The density of *M. monophyllos* population varied from 1 to 14 individuals per 0.25 m^2 (3.9 on average, Table 3).

The NP population of *M. monophyllos* from the natural forest community was about 38 individuals. The tree layer was dominated by *P. sylvestris*, while *B. pendula* and *P. tremula* were co-dominants. The average age of the trees was about 110 years. The tree crown density was 0.6–0.7. The lower canopy consisted of *S. caprea, S. aucuparia*, *R. idaeus*, *Rosa acicularis* Lindl., *Chamaecytisus ruthenicus* (Fisch. ex Wołoszcz.) Klásk. The TPC of the herb-shrub layer varied from 45 to 90 %. *Vaccinium myrtillus* L., *V. vitis-idaea*, *Aegopodium podagraria* L., *Calamagrostis arundinacea* (L.) Roth, *P. pratensis*, *T. repens*, *T. pratense*, *Galium boreale* L., *Veronica chamaedrys* L., *Adenophora lilifolia* (L.) A. DC., *D. cespitosa*, *Elytrigia repens* (L.) Desv. ex Nevski were found in the herb-shrub layer. In the areas where *M. monophyllos* grew, the herbaceous layer was sparser. The density of NP population varied from 1 to 9 individuals per 0.25 m^2 (4.8 on average, Table 3).

It is known that in Russia *M. monophyllos* grows in moderately humid areas in the slight shading: in forest clearings and forest edges, sometimes in marsh phytocoenoses (Vakhrameeva et al. 2014). In open habitats, the species settles less frequently. Strict phytocoenotic confinement in *M. monophyllos* is not observed.

Our studies have shown that *M. monophyllos* is able to settle in forest communities that are formed on industrial dumps in the Middle Urals. The dumps are composed of different substrates and are characterized mainly by moderate moisture conditions.

It has been shown that *M. monophyllos* grows in groups in the sites studied, which is typical for this species and probably contributes to its successful pollination (Aguilar et al. 2006, Jermakowicz et al. 2015).

The number of *M. monophyllos* in most of the populations studied was small and averaged 31 individuals. The exception was the anthropogenic population AP2 of 400 individuals, found in the undergrowth of woody plants at the fly ash dump surrounded by impenetrable swamps and forests in the north of the Sverdlovsk region. Small populations by numbering up to 50 individuals are characteristic of *M. monophyllos* throughout its range, and only sometimes, especially in disturbed habitats, the species can form rather large populations of up to 800 individuals (Blinova 2013, Vakhrameeva et al. 2014, Jermakowicz et al. 2015).

The life cycle of *M. monophyllos* takes approximately 20 years (Vakhrameeva et al. 2014), including the underground phase between germination and the appearance of the first aerial leaf lasts about 5 years. The first flowering occurs on average 10–11 years after germination and can be repeated up to 4 seasons. After the flowering period, the plant dies off without turning into a senile state. One of the factors that determines the resistance of orchids is the completeness of the ontogenetic spectrum of populations (Valuiskikh and Teteryuk 2013, 2014; Jermakowicz et al. 2015). The analysis of the demographic structure of *M. monophyllos* populations revealed that all populations studied contained all age groups (Table 3). In the age classes of most populations, individuals of the generative (*g*) state accounted for a large proportion (44.0 % on average), which indicates their reproductive potential. It is known that flowering adults are one of the determining factors in the development of the population, since they can produce fruits and seeds that are important for seedlings replenishment. The larger the proportion of generative individuals, the larger probability for the development of population and the increase of the population size (Nurfadilah 2017). In most *M. monophyllos* anthropogenic populations, the proportion of generative individuals was higher by 1.7 times on average than in the natural habitat. At the same time the orchid population from natural forest community was characterized by a higher proportion of juvenile (*j*) individuals (1.9 times on average), which indicates its higher reproductive success. The closest to NP were the age spectra of AP5 and AP6 populations growing in phytocoenoses on stony substrates.

The analysis of the morphometric parameters of *M. monophyllos* generative individuals showed their significant variability (Fig. 2). On fly ash dumps, the plants reached maximum heights of 30.5 cm (AP2) and 30.8 cm (AP4), while in the natural phytocoenosis (NP) the maximum height was 29.5 cm (Fig. 2a). At the same time, on industrial dumps (AP5 and AP6) with more unfavourable conditions, this parameter was significantly ($p < 0.05$) lower than the control (1.5 times on average). In general, the results of morphological measurements are consistent with the literature data (Vakhrameeva et al. 1993, 2008; Blinova 2013).

The length of the inflorescences directly correlated with the length of the shoots ($r = 0.85$, $p < 0.05$) (Fig. 2b). The number of flowers in more humid technogenic substrates (fly ash) reached maximum 98 (AP2) and 84 (AP4) flowers per individual, averaging 46 and 50 flowers per individual, respectively (Fig. 2c). On drier stony substrates, much fewer flowers were formed: in AP5 and AP6, the maximum number of flowers was 44 and 49, respec-

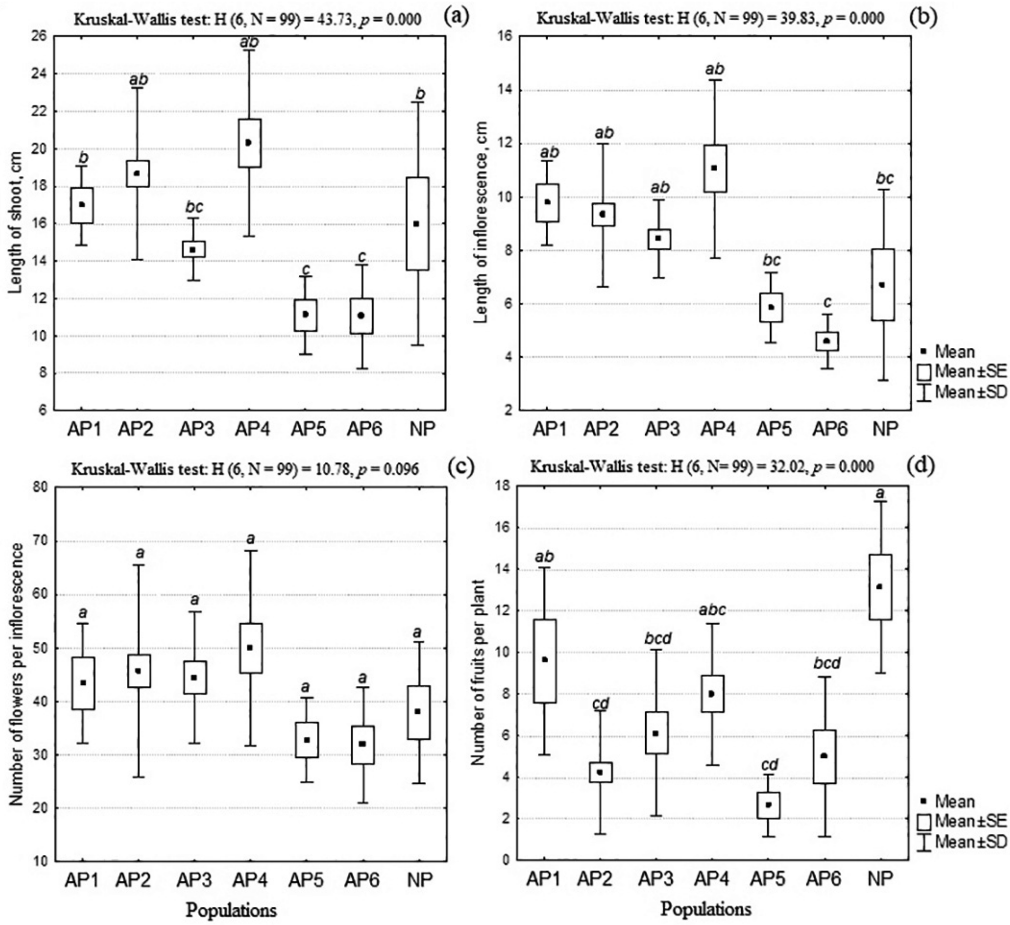

Fig. 2. Morphometric parameters of *M. monophyllos* in the studied populations: (a) the length of shoot; (b) the length of inflorescence; (c) the number of flowers per inflorescence; (d) the number of fruits per plant.

Note: The small solid square indicates the mean values (n = 5–40), the boxes are the mean ± standard error (SE), the whiskers are the mean ± standard deviation (SD). Different letters indicate the significant differences between the studied populations. AP – population in anthropogenic habitat, NP – population in natural forest community.

tively, averaging 33 and 32 flowers per individual. In the natural phytocoenosis, there were 38 flowers per individual on average and reached maximum 60. However, there were no significant differences in this parameter among the populations studied. Correlation analysis revealed a positive relationship between the number of flowers and the length of the inflorescence (r = 0.67, p < 0.05) and shoot (r = 0.60, p < 0.05).

The studies have shown that the number of fruits in orchids from the natural forest community was higher on average by 2.6 times than in individuals colonizing technogenic substrates (Fig. 2d). Similar results were obtained in a comparative study of *M. monophyllos* populations in natural and anthropogenic habitats (Jermakowicz et al. 2015, Jermakowicz and Brzosko 2016), as well as in the study of other species of the Orchidaceae family (Pellegrino and Bellusci 2014).

One possible explanation for this could be the differences in pollinator efficiency in a variety of habitats. *M. monophyllos* is a cross-pollinated plant pollinated by various small insects, including mosquitoes. Therefore, fruit set and seed production may depend on pollinators availability (Vakhrameeva et al. 2008, Claessens and Kleynen 2011). In the studied technogenically disturbed territories, zoocoenoses may differ from those in the natural habitats (Jermakowicz et al. 2015).

There is evidence that the percentage of fruit set in *M. monophyllos* is low and varies from 5 to 33 % (Vakhrameeva et al. 2014). It largely depends on weather and climatic conditions and varies greatly in the same phytocoenosis from year to year. Our studies of *M. monophyllos* populations have confirmed these results. In anthropogenic populations, the percentage of fruit setting (AP1–AP6: 22.1, 9.3, 13.8, 16.0, 8.1, and 15.7 %, respectively) was significantly lower ($p < 0.05$) than in natural population (NP: 34.7 %).

It is known that *M. monophyllos* has a two-leaved form. It was noted earlier that the same individual can form one or two leaves in different years (Vakhrameeva et al. 2014). Our studies have shown that two-leaved individuals were quite often found on anthropogenically disturbed substrates (AP1–AP6: 20.0, 63.4, 84.2, 55.6, 28.6 and 40.0 %, respectively). In addition, one 3-leaved individual was encountered in AP4. In their natural habitat (NP), the percentage of occurrence of two-leaved individuals was very low (14.3 %).

Conclusions

The studies have shown that *Malaxis monophyllos,* a rare species of the Orchidaceae family, settles in the disturbed areas of the Middle Urals (Russia) in a sparse herbaceous layer of forest phytocoenoses, dominated by early succession species, such as *Pinus sylvestris*, *Populus tremula* and *Betula pendula*. In anthropogenic habitats, *M. monophyllos* is able to form local populations with higher abundance and density than in the natural forest community with a predominance of generative individuals by an average of 1.7 times. This indicates its rather high viability and adaptability to disturbed habitats.

It was revealed that *M. monophyllos* plants colonizing technogenic substrates, according to most biometric parameters, corresponded to orchids from the natural forest community. At the same time, they were characterized by the reduced fruit formation per plant (2.6 time on average), as well as the percentage of fruit set (2.7 times on average) compared with the plants from natural community. A possible reason for this could be the unfavourable conditions of technogenic habitats, including those for the putative *M. monophyllos* pollinators. Suitable humidity conditions and low competition in man-made habitats favour the growth of *M. monophyllos*. However, population persistence time in disturbed habitats will depend on further succession processes and anthropogenic activities.

The study of the distribution, morphological and population characteristics of orchids and their responses to the technogenic and natural factors have great importance for the development of measures to protect rare and endangered plant species. New colonies of *M. monophyllos* on industrial dumps could provide the conservation of this rare species in the region.

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