Morphological and biochemical characteristics of Dendranthema zawadskii growing on industrial dumps and in introduction (Middle Ural)

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Abstract. The paper presents the results of a study of *Dendranthema zawadskii* (Herb.) Tzvel., growing on the dumps of the Anatol-Shilovsky asbestos deposits and on experimental plots in the botanical garden of the Ural Federal University. The morphological characteristics of generative individuals, the quality and germination of seeds has been investigated. It has been shown that plants introduced into the Middle Urals region are characterized by high ornamental properties and good seed and vegetative propagation. In the leaves and inflorescences of *D. zawadskii* plants, both in anthropogenically disturbed habitats and in botanical garden, biological active substances such as phenols, flavonoids and ascorbic acid accumulated.

1 Introduction

Over the long history of the negative impact of mining and processing of mineral resources on the natural landscape, disturbed territories have formed in the Urals. It is characterized by a poor species composition of plant communities. In such areas with reduced phytocoenotic stress, rare plants, including relict ones, can habitat [1].

One of these plants species is *Dendranthema zawadskii* (Herb.) Tzvel (family Asteraceae). It is pleistocene relict, the populations of which are declining on Ural region. It is a perennial herbaceous plant 15–50 cm high, with a single or a few stems. Single or 2–5 inflorescences at the top of the stem or at leafy lateral branches [2].

D. zawadskii is a medicinal plant. Its chemical composition contains essential biological active substances, including tannins, flavonoids, ascorbic acid, amino and organic acids, macro- and microelements. This makes it possible to use these plants as valuable pharmaceutical raw materials [3–6].

It is known that antioxidants which reduce the concentration of reactive oxygen species are synthesized in large quantities in plants under stress conditions. For plants growing in technogenic habitats the main stressors are: a high insolation, water deficiency and

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imbalance of micro- and macroelements in substrates. It has been established that in plants under such conditions, as a rule, the synthesis of low molecular weight antioxidants is enhanced, which provides plant adaptation to adverse conditions [7].

The aim of the research was to study morphological and biochemical parameters of *D. zawadskii* plants growing under conditions of anthropogenic stress (industrial dump) and in introduction (botanical garden), and to evaluate the seed productivity of the species.

2 Materials and Methods

Coenopopulations of *D. zawadskii* were found in heavily rocky sites of dumps of the Anatol'sko-Shilovsky deposit of asbestos (S1), located on the eastern slope of the Middle Urals, 132 km north of Yekaterinburg, 2.5 km from the Novoasbest town (taiga zone, subzone of the southern taiga). From the seeds of *D. zawadskii* growing on dumps, plants were grown in experimental plots of the botanical garden of the Ural Federal University (S2) under high agricultural conditions (watering, weeding, loosening).

The dumps substrates had an alkaline reaction (pH=7.9) in contrast to the slightly acidic soils from the botanical garden (pH=5.6). Technogenic subsrates contained significantly smaller of total organic carbon (0.52% and 7.92%, respectively) and phosphorus (3.17 mg/100 g and 24.87 mg/100).

The studies were carried out in august 2023. Morphological analysis of 2-year-old generative individuals of *D. zawadskii* was carried out according to the following morphological parameters: height of the individual (cm), number of the second order shoots, (pcs.), total number of leaves on the stem (pcs.), length and width of leaf (cm), leaf weight (g), number of inflorescences (pcs.), weight of inflorescences (g).

Seed productivity of plants was studied using standard methods [8]. The number of generative shoots, the number of inflorescences and fruits per shoot were taken into account. Also, the number of seeds and ovules in fruits was counted.

The content of ascorbic acid in plants was determined according to the method of [9]. Fresh leaves were ground in a mixture of HPO_3 and Na_3PO_4 (3:2). Extracts were measured on spectrophotometre at 265 nm. To determine total soluble phenolic compounds (in leaves and inflorescences), the Folin-Ciocalteu reagent was used, using gallic acid as a standart [10]. The concentration of flavonoids was determined by reaction with $AlCl_3$ (2%), the calculation was made using quercetin [11]. The concentrations of phenols and flavonoids were measured spectrophotometrically at 760 nm and 415 nm, respectively. The content of antioxidants was calculated on a dry weight (DW).

The data was processed in Microsoft Excel and StatSoft STATISTICA 12 and presented in the tables as the means ± standard errors (X±SE).

3 Results

It was shown, that the morphological parameters of generative individuals of *D. zawadskii* growing in the conditions industrial dumps (S1) and in introduction of botanical garden (S2) depended on edaphic factors (Table 1).

It is known that the species ability to self-reproduction makes it possible to characterize its reproductive capabilities: the potential seed productivity (PSP) and the actual seed productivity (ASP). The last one, as a rule, constitutes an insignificant part of the PSP and depends on many factors (method and conditions of pollination, the presence of phytophages, variability of weather conditions, etc.), which leads to its significant variability.

Table 1. Some morphological parameters of generative individuals *D. zawadskii* on the studied sites

Parameters	Sites			
Characteristics	S1		S2	
	X ± SE	min-max	X ± SE	min-max
Height of the individual, cm	22.9±2.3	14.1–34.2	72.1±4.0	45.0–99.0
Number of second order shoots, pcs.	0.3±0.2	0–2	17.1±2.9	7–35
Number of leaves on the stem (per individual), pcs.	17.3±1.1	12–22	194.1±12.4	8–23
Leaf length, cm	2.1±0.1	0.7–4.3	4.0±0.2	2.9–6.0
Leaf width, cm	1.3±0.1	0.15–2.5	2.5±0.1	1.7–3.4
Leaf weight, g	0.02±0.01	0.01–0.03	0.04±0.01	0.05–0.02
Number of inflorescences (per individual), pcs.	1.3±0.2	1–3	18.5±3.9	2–46
Inflorescence diameter, cm	3.3±0.2	2.7–3.6	3.9±0,2	2.3–4.9
Inflorescenc weight, g	0.04±0.01	0.03–0.05	0.20±0.02	0.26–0.16

Studies had shown that introduced plants of *D. zawadskii* produces in botanical garden more number of inflorescenc and seeds than individuals under anthropogenic conditions (1.4 and 6.6 times, respectively) (Table 2).

Table 2. Seed productivity of *D. zawadskii* on the studied sites

Parameters	Site			
	S1		S2	
	X ± SE	min-max	X ± SE	min-max
Potential seed productivity in fruit, pcs.	253,0±31,8	66–644	346,5±28,20	183–560
Actual seed productivity in the fruit, pcs	18,8±4,9	0–72	124,5±26,8	0–312
Semenification share, %	9,5±2,8	0–37	32,1±6,3	0–66,4
Seed germination, %	53,0		82,0	
Proportion of affected seeds, %	9,0		6,0	

Analysis of the quality of *D. zawadskii* seeds and healthy seeds germination in laboratory conditions showed that the proportion of affected seeds matured in dump conditions was 9.0% in averaged, the laboratory germination – 53.0%. For seeds collected from introducted plants these indicators were significantly better: 6.0% and 82.0%, respectively.

Well known that low-molecular weight antioxidants are represented in plants by a large group of different nature substances. For instence flavonoids are among the known phenolic compounds. They are formed in every plant and contained in different organs and tissues, such as roots, stems, leaves, flowers, fruits, seeds. Flavonoids and other phenolic compounds increase plant resistance to abiotic and biotic stressors: they participate in phytoimmunity reactions; protect plants from excess of solar radiation, etc. Their ability to protect plant cells from stress caused by heavy metals and other pollutants has been well established. Ascorbic acid is also an important antioxidant in protecting plants from a wide range of abiotic stresses, such as ozone, drought and metals [12].

Studies of the biochemical composition of *D. zawadskii* showed that in the leaves of plants from the dumps of the Anatol-Shilovsky asbestos deposits, there was an increase (on average, 2 times) accumulation of total phenolic compounds, including flavonoids, as well as ascorbic acid, compared with the introduced plants from botanical garden (Table 3). In flowers of individuals growing under dump conditions, the synthesis of phenolic

compounds also increased, but the accumulation of flavonoids did not differ in both habitats (Table 3).

More phenolic compounds and flavonoids accumulated in the inflorescences than in the leaves of *D. zawadskii* plants, regardless of the growing conditions.

Table 3. Content of low-molecular weight antioxidants in leaves and inflorescence on the studied sites

Characteristics	Site	
	S1	S2
	X ± SE	X ± SE
Content of low-molecular weight antioxidants in leaves		
Phenolics, mg gallic acid/g DW	25,76±0,3	10,03±0,24
Phenolics in leaves (per individual), mg gallic acid	8,91±0,1	77,89±1,0
Flavonoids, mg quercetin/ g DW	12,68±0,22	6,89±0,3
Flavonoids in leaves (per individual), mg quercetin	4,39±0,08	53,46±2,35
Ascorbic acid, mg/g DW	34,00±3,45	17,85±0,74
Ascorbic acid in leaves (per individual), mg	11,76±1,19	138,85±5,75
Content of low-molecular weight antioxidants in inflorescens		
Phenolics, mg gallic acid/g DW	34,56±0,46	15,60±0,47
Phenolics in inflorescens (per individual), mg gallic acid	2,93±0,04	57,71±1,74
Flavonoids, mg quercetin/ g DW	41,43±1,37	40,58± 1,009
Flavonoids in inflorescens (per individual), mg quercetin	3,23± 0,11	150,16± 4,03

Due to the fact that the introduced plants were distinguished by a significantly larger number of leaves and inflorescens, the total biomass of these organs per individual was significantly greater (Table 1) compared to plants from dumps. Consequently the average content of low-molecular antioxidants in leaves and inflorescences per individual was tens of times higher than in plants from dumps. Thus, the content of phenolic compounds in inflorescences was 20 times higher, and flavonoids – 46 times higher. The content of phenolic compounds, flavonoids, and ascorbic acid in the leaves of an individual plant from the botanical garden was, on average, 10 times higher than in the leaves of plants from dump. (Table 3).

4 Conclusion

The present study revealed that *D. zawadskii* plants, which are introduced in botanical garden are highly ornamental property, with a good seed productivity. In favorable soil conditions (sufficient amounts of mineral nutrition and water supply), *D. zawadskii* plants has an increase morphological parameters compared to disturbed habitats: increasing the height of individuals (2–3 times), shoot formation (up to 50 times) and the number of inflorescences (up to 40 once). The biomass of leaves and flowers in individuals of introduced plants is significantly greater.

In the leaves and inflorescences of *D. zawadskii* plants, both under the stress conditions of transformed habitats and under favorable conditions of botanical gardens, the accumulation of low molecular weight antioxidants, such as ascorbic acid, phenolic

compounds, including flavonoids, occurred. Despite the lower content of these metabolites in the organs of introduced plants, it accumulation in the biomass of an individual significantly exceeded the storage of biological active substances in plants on the technogenic environment.

The obtained results indicate the possibility of using introduced plants of the genus *D. zawadski*i as medicinally valuable raw materials for pharmaceutical preparations.

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