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The effect of the year on the steppe peony´s morphological and ornamental traits

Prijić Željana[1], Marković Tatjana[1], Radanović Dragoja[1], Jingqi Xue[2], Xiuxin Zhang[2]
Gordanić Stefan[1], Mikić Sara[1], Dragumilo Ana[1], Čutović Natalija[1], Batinić Petar[1]

[1]Institute for medicinal plants research "Dr Josif Pančić" Belgrade, Tadeuša Košćuška 1
[2]Key Laboratory of Biology and Genetic Improvement of Horticultural Crops, Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences, Ministry Agriculture and Rural Affairs, Beijing 100081, China
e-mail: zprijic@mocbilja.rs

SUMMARY

The steppe peony (*Paeonia tenuifolia* L.) is an endangered medicinal plant species that occurs in Serbia in three habitats, of which the Deliblato Sands is the richest. Based on the results of research conducted at Deliblato Sands in 2023, it was found that the development of the flowering stems of *Paeonia tenuifolia* was not affected by the slightly higher average winter temperatures. One hundred randomly selected plants were measured in the field, including height, plant girth, number of branches per plant bush, the ratio of flowering to non-flowering branches, shoot-to-root ratio, and stem-to-branch-to-flower ratio. The results showed that the root-to-shoot ratio was 1:2.5, the average height of the tested plants was 41±6 cm, ranging from 30-60 cm, and the girth of the plant bush was 121±30 cm, ranging from 40-170 cm, and was positively correlated with the number of branches. The average number of branches per plant was 8±2.5. Based on the measurement of the absolute dry plant material, it was found that the mass of a branch contained on average 22.5% of the stem, 73.5% of the leaf twigs, and 4% of the flower mass. The petals make up, on average, 34.3% of the mass of the flower.

Keywords: *Paeonia tenuifolia* L., shoot, root ratio, temperature, humidity, Deliblato Sands, medicinal and ornamental species.

INTRODUCTION

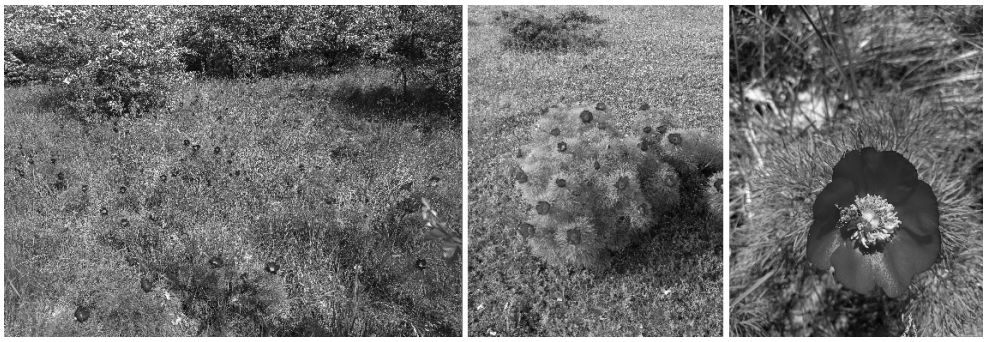
From ancient times, peonies have been highly appreciated worldwide (Toma et al., 2013; Yang et al., 2020) due to their ornamental (Zhang et al., 2019; Sun et al., 2022) and medicinal values (He et al., 2011; Batinić et al., 2022; Ćutović, 2022). Although they are appreciated and respected, they are threatened in their natural habitats (Suleymanova et al., 2019; Marković et al., 2022).

According to Hong (2021), the subdivision of Paeonia consists of 2 subgenera (Montian and herbaceous peonies) and 7 sections, with a total of 34 species. The herbaceous peonies belong to the subgenus Paeonia, which consists of 5 sections, of which 4 sections are distributed in southern Europe, north-western Africa, and western Asia. Although categorizing the species of sect. Paeonia is particularly challenging due to polyploidization (Yang et al., 2020), this is not the case for *Paeonia tenuifolia*, which Linnaeus first described in 1759 (Hong, 2010), because of its characteristic leaves that are finely divided into almost filiform segments that grow close together on the stems. *Paeonia tenuifolia*, commonly called fernleaf or steppe peony, is native to Armenia, Azerbaijan, Bulgaria, Georgia, Romania, Russia, Serbia, Turkey, and Ukraine (Hong, 2010). Its occurrence in Serbia ranges from 100 m above sea level in the Deliblato Sands to about 700 m at Bogovo Guvno near Skrobnica. The highest altitude in the entire Balkan Peninsula is in Golemi Vrh on the Vidlic Mountains, where the steppe peony occurs on a calcareous, south-exposed plateau (between 1050-1300 m above sea level) (Lazarević and Stojanović, 2012) near the village of Gulenovci (Zlatković, 2005). Of the three natural habitats of the steppe peony in Serbia mentioned above, the population in the Deliblato Sands is the largest and best preserved. The steppe peony has the greatest biodiversity and environmental tolerance, but is very intolerant of competition (Rudaya et al., 2021). Due to the low plant population of the habitat and the fact that it also provides pasture for cattle and sheep, high competition with other plant species is not observed in the Deliblato Sands. From the perspective of understanding the needs of the plant species itself, studying the population of an endangered plant species in its natural environment, where it develops best, is of particular interest, considering that conservation through cultivation is an effective way to protect threatened species. Since there is not much data on the cultivation of steppe peonies, the aim of the research was to start with the determination of the minimum conditions for their efficient growth and development by determining the morphological parameters and how they interact depending on weather conditions. Determination of the shoot-to-root ratio was conducted so that, in the future, it would be easier to estimate the size of the root in the peony habitat based on the above-ground area. In view of the fact that this is also an ornamental species, special attention has been paid to monitoring the above-ground part of the plant as well as how much area is covered by one plant.

MATERIAL AND METHODS

Locality of the collected plant material. On April 28, 2023 plant material was collected from the naturally growing habitat of *Paeonia tenuifolia* in Deliblato Sands, Serbia (Picture

1). Using a meter stick, the height and diameter of 100 plants were determined in the field (Zhejiang Yuyao Sanxin Measuring Tools Co., Ltd., China). On the same plants, the number of twigs per branch and the number of branches per plant with or without a flower was also counted. In order to evaluate the quantity of moisture in the plant material, 50 branches from various plants were gathered, along with five whole plants of comparable sizes. Collecting from the native habitat was conducted with the permission of the Ministry of Environmental Protection of the Republic of Serbia (No. 353-01-121/2023-04, issued on March 3rd, 2023).



Picture 1. *P. tenuifolia* at the Deliblato Sands
Slika 1. *P. tenuifolia* u Deliblatskoj peščari

Meteorological conditions. Temperature and humidity were measured with a data logger (LogTag HAXO-8), which was placed at the abovementioned location. The device was installed three years ago at a height of two meters, protected from direct sunlight, and programmed to read the data every two hours. The data was analyzed using the methodology of the Hydrometeorological Institute of Serbia. Precipitation data were used from the meteorological station Banatski Karlovac, 5 km from the research site.

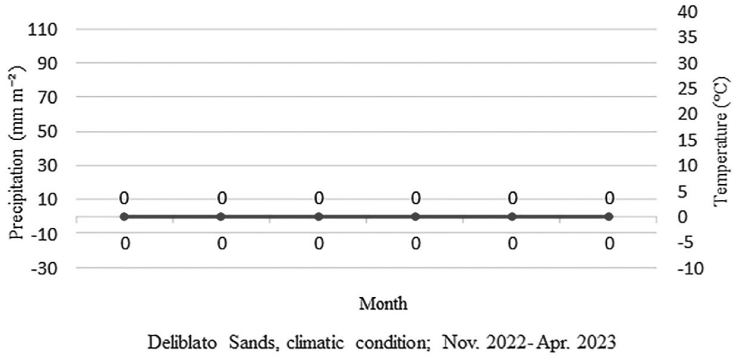


Figure 1. Meteorological conditions for the period of November 2022 - April 2023 in the Deliblato Sands
Grafik 1. Meteorološke prilike na području Deliblatske peščare u periodu april-novembar 2022. godine

Measurement of morphological parameters. The moisture content of the plant material was measured by drying in the oven, that is 25 g of each plant organ per plant was dried in an oven at 105°C until no change in weight could be detected. The measurement was thus taken before drying and then after 24, 36 and 48 hours in the oven. The following formula was used to calculate the moisture content of the plant material:

$$\% \text{ Moisture content} = \frac{\text{Weight of fresh plant material} - \text{Weight of dry plant material}}{\text{Weight of fresh plant material}} \text{ X } 100$$

RESULTS AND DISCUSSION

The growth and development of peonies are determined by the age of the plant, habitat, location, position in the habitat, and annual conditions. *Paeonia* spp. require a critical chilling period to release from dormancy and re-sprout, grow, and flower in the spring (Din et al., 2015; Marković et al., 2022).

The test period from November 2022 to March 2023 had higher temperatures than the multi-year average. In particular, December 2022 and January 2023 were warmer, 2.9 and 4.0 °C above normal temperatures, respectively. In the spring period of 2023, March was warmer, while April was somewhat colder compared to the multi-year average (Figure 1). The average annual air temperature in the period 1981-2010 was 11.5°C, with the highest of 13.2°C (2000) and the lowest of 10.1°C (1985). The annual trend of air temperature in this long-term period was increasing (Bohajar, 2016). Since the plants at the tested location produced an average number of flowering branches per plant that was not statistically different from last year's results (data not published), slightly higher temperatures this winter had no influence on the development of the flowering branches. In view of the fact that winter temperatures are rising, it is essential that further studies are carried out to determine the optimum temperature range or the minimum amount of low winter temperatures that are sufficient not to affect the development of the flowering branches.

In addition to temperature, humidity also affects the growth and development of the peony. Although the steppe peony tolerates drought well, our results from last year (Prijić et al., 2023) showed that the proportion of stunted seeds was greater than usual, which could be related to the drought of the tested year. According to the research by Sehgal et al. (2018), impact of drought on the early stages of seed development might reduce seed productivity. This finding is in line with previous studies indicating that the tested species is not tolerant to prolonged drought, and a significant water deficit could affect normal peony growth and development (Li et al., 2020). During the period from November 2022 to April 2023, monthly precipitation in autumn at the Deliblato Sands was in line with the multi-year average, while precipitation in winter and early spring was above average, especially in April when precipitation was 86% higher than usual. According to Liu (2021), roots of herbaceous peonies become black and the foliage turns yellow or red due to temporary waterlogging. While waterlogging had no effect on plant height, leaf length or leaf area, it reduced the root-shoot ratio of tested herbaceous

peony (*Paeonia lactiflora* Pall.) cultivars (Liu et al., 2021). The average annual rainfall for the 1981-2010 period at the Deliblato Sands is 618 millimetres, with a high of 1038 mm (1999) and a low of 295 mm (2000). The trend of total annual precipitation during this period is positive, indicating a slight tendency to increase (Bohajar, 2016).

Due to the fact that the Deliblato sands has a high sand content in its soil texture, the soil has a lower water capacity than ordinary chernozems and serves as a dry medium for plant roots. As a result, the limited steppe flora and the few hawthorn shrubs are deprived of physiologically active water and nutrients throughout the summer, slowing down their lush development and occasionally threatening their existence. The optimal mechanical composition of the soil, on the other hand, ensures good growth and development of the relatively shallow root systems. The shallow root systems make peonies more susceptible to drought and other environmental stresses. Our research has shown that the tuberous root of tested species is well developed and contains up to 20 rhizomes, ranging in shape from oblong to spherical, which is consistent with the research of Hong (2010).

The root to shoot ratio is an important physiological parameter that influences the growth and development of plants. The ratio is defined as the ratio of the dry weight of roots to the dry weight of shoots. The ratio between the underground and the above-ground parts of the plant is mainly influenced by the age of the plant. Considering that most of the tested plants had 5-9 above-ground branches (Table 1), five plants with this number of branches were selected, absolutely dry plant material was measured, and the ratio was calculated, giving an average shoot-to-root ratio of 1:2.5. Compared to the shoots, roots had a moisture content that was three times greater. Meanwhile, the flowers had the highest amount of moisture in its shoots.

The average height of the tested plants was 41±6 cm, ranging from 30-60 cm where the juvenile plants were lower, which agrees with the findings of Hong (2010). The girth of the plant bush was 121±30 cm, ranging from 40-170 cm. The girth was positively correlated with the number of branches. According to the measurement of absolute dry plant material, it was found that the mass of a branch contained on average 22.5% of the stem, 73.5% of the leaf twigs, and 4% of the flower mass. The petals make up, on average, 34.3% of the mass of the flower.

Table 1. Number of branches of *P. tenuifolia* per plant in percentage
Tabela 1. Broj grana *P. tenuifolia* po biljci u procentima

Number of branches per plant	Percentage (%)
1-4	20
5-9	50
10-13	14
14-20	16

Although literature states that steppe peony flowers from mid-April to the end of May (Hong, 2010), in Serbia it can be found from late April to mid-May, depending on the year.

The flowers appear on sturdy stems above the foliage. The flower of the steppe peony is simple. The petals have a deep red colour that fades as the flower ages, fading can also be observed in other peony species (Zhang et al., 2023). Under our conditions, the flowering period lasts 5-7 days per flower. Our results show that the average number of petals per flower is 8, with a range of 5-12, although Hong (2010) states it to be 6-8 petals. Not all flowering branches flower at the same time. In the phase of full flowering, on older plants, i.e. plants with several flowering branches, one can see buds, flowering stems, and finished flowers at the same time, which extends the flowering time of the plant, which lasts on average for about two weeks. Each plant has one or more flowerless branches. In the year of observation, the plants had an average of 8±4 branches per plant (Table 1), most of which were flowering (Table 2).

Table 2. Percentage of branches with and without flower of *P. tenuifolia*
Tabela 2. Procenat grana sa i bez cvetova *P. tenuifolia*

	Flowering stage	**Percentage (%)**
	With bud	26.6
With flower	In flowering stage	43.3
	Overbloomed	11.6
Without flower		18.5

CONCLUSION

Conservation through cultivation is a successful strategy to protect threatened species. As there is not much data on the cultivation of steppe peonies, it is important to monitor the impact of climatic conditions over a longer period to obtain more accurate data on the parameters required for its cultivation. Prolonged droughts and/or heavy rainfall over a short period are becoming more frequent as a result of climate change. Monitoring such conditions is necessary to determine how such extreme conditions affect the growth and development of steppe peonies and thus discover the possible reasons for their susceptibility.

Preliminary results have shown that the number of steppe peony plants in the Deliblato sands is at a satisfactory level. The population consists of plants of different ages with 14% of juvenile plants. It was found that the development of the flowering stems was not affected by the slightly higher winter temperatures in the experimental period.

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REFERENCES

Batinić, P., Milošević, M., Lukić, M., Prijić, Ž., Gordanić, S., Filipović, V., Marinković, A., Bugarski, B., Marković, T.: In vitro evaluation of antioxidative activities of extracts of *Paeonia lactiflora* and *Calendula officinalis* L. petals incorporated in the new forms of biobased carriers. Food and Feed Research, 49, 23-35, 2022. doi: 10.5937/ffr0-36381

Bohajar, A. M. Y.: Droughts and the Process of Aridification as Soil Degradation Factor in Deliblato Sands, Doctoral Dissertation, Belgrade, 2016.

Čutović, N., Marković, T., Kostić, M., Gašić, U., Prijić, Ž., Ren, X., Lukić, M., Bugarski, B.: Chemical Profile and Skin-Beneficial Activities of the Petal Extracts of *Paeonia tenuifolia* L. from Serbia. Pharmaceuticals, 15 (12), 1537, 2022. https://doi.org /10.3390/ph15121537

Din, G. Y., Cohen, M., Kamenetsky, R.: Database for Herbaceous Peony Cultivated in Warm Climate Regions: Effects of Temperature on Plant Dormancy and Growth. Journal of Horticulture, 2 (3), 1-7, 2015. DOI: 10.4172/2376-0354.1000147

He, D. Y., Dai, S. M.: Anti-inflammatory and immunomodulatory effects of *Paeonia lactiflora* Pall., a traditional Chinese herbal medicine. Frontiers in Pharmacology, 2, 10, 2011.

Hong, D. Y.: Peonies of the World: Taxonomy and Phytogeography; Missouri Botanical Garden: St. Louis, MI, USA, 2010; p. 302.

Hong, D. Y.: Peonies of the world. Part III: Phylogeny and evolution. Kew Publishing: Royal Botanic Gardens Kew, 2021.

Lazarević, P., Stojanović, V.: Wild peonies (*Paeonia* L.) in Serbia - The distribution, state of populations, threats and protection. Nature Conservation, 62, 19-44, 2012.

Li, T., Wang, R., Zhao, D., Tao, J.: Effects of drought stress on physiological responses and gene expression changes in herbaceous peony (*Paeonia lactiflora* Pall.). Plant Signaling and Behavior, 1746034. 2020. doi: 10.1080/15592324.2020.174603

Liu, M., Zhang, Q., Xu. J., Bao, M., Zhang, D., Xie, A., Sun, X.: Effects of Waterlogging Stress on the Physiological Characteristics and Secondary Metabolites of Herbaceous Peony (*Paeonia lactiflora* Pall.). American Journal of Plant Sciences, 12, 536-557, 2021. doi: 10.4236/ajps.2021.124035.

Marković, T., Prijić, Ž., Xue, J., Zhang, X., Radanović, D., Ren, X., Filipović, V., Lukić, M., Gordanić, S.: The Seed Traits Associated with Dormancy and Germination of Herbaceous Peonies, Focusing on Species Native in Serbia and China. Horticulturae, 8, 585, 2022. doi.org/10.3390/horticulturae8070585

Prijić, Ž., Mikić S., Filipović, V., Gordanić, S., Dragumilo, A., Batinić, P., Čutović, N., Marković, T.: Seed weight and optimal imbibitions period for some herbaceous peony (*Paeonia* spp.) species native to Serbia, XII International Symposium of Agricultural Sciences "AgroReS 2023", Book of Proceedings, 2023. (in press)

Rudaya, O. A., Chesnokov, N. N., Kirina, I. B., Tarova, Z. N., Bobrovich, L. V., Kiriakova, O. I.: The research of seed reproduction peculiarities of wild-growing *Paeonia* L. genus and perspectives of using peony seeds in food-processing industry. IOP Conference Series: Earth and Environmental Science, 845, 012002, 2021.

Suleymanova, G., Boldyrev, V., Savinov, V.: Post-fire restoration of plant communities with Paeonia tenuifolia in the Khvalynsky National Park (Russia). Nature Conservation Research, 4, 57-77, 2019.

Sun, J., Guo, H., Tao, J.: Effects of harvest stage, storage, and preservation technology on postharvest ornamental value of cut peony (*Paeonia lactiflora*) flowers. Agronomy, 12, 230, 2022.

Toma, F., Şelaru, E., Georgescu, M. I., Petra, S., Pădure, I. M., Zamfirvasca, D., Venat, O.: Studies to Support the Proclamation of Peony as Romania's National Flower. AgroLife Scientific Journal, 2 (1), 103-112, 2013. ISSN 2285-5718.

Yang, Y., Sun, M., Li, S., Chen, Q., Teixira da Silva, J. A., Wang, A., Yu, X.: Germplasm resources and genetic breeding of Paeonia: a systematic review. Horticulture Research, 7, 107, 2020. https://doi.org/10.1038/s41438-020-0332-2.

Zhang, D., Xie, A., Yang, X., Yang, L., Shi, Y., Dong, L., Lei, F., Sun, L., Bao, M., Sun, X.: Analysis of Physiological and Biochemical Factors Affecting Flower Color of Herbaceous Peony in Different Flowering Periods. Horticulturae, 9 (4), 502, 2023. doi.org/10.3390/horticulturae9040502.

Zhang, J., Zhang, D., Wei, J., Shi, X., Ding, H., Qiu, S., Guo, J., Li, D., Zhu, K., Horvath, D. P., et al.: Annual growth cycle observation, hybridization and forcing culture for improving the ornamental application of *Paeonia lactiflora* Pall. in the low-latitude regions. PLoS ONE, 14, e0218164, 2019.

Zlatković, B., Ranđelović, V., Jusković, M., Marković, M.: New floristic records in Serbia and northern Macedonia. VIII Symposium on the flora of Southeastern Serbia and neighbouring regions, Niš. Book of Proceedings, pp. 1-4, 2005.

Efekat godine na morfološka i ornamentalna svojstva stepskog božura

REZIME

Stepski božur (*Paeonia tenuifolia* L.) je ugrožena lekovita biljna vrsta koja se u Srbiji javlja na tri staništa, od kojih je Deliblatska peščara najbogatije stanište. Na osnovu rezultata istraživanja izvedenih u Deliblatskoj peščari 2023. godine, utvrđeno je da na razvoj cvetnih grana *Paeonia tenuifolia* nisu uticale nešto više prosečne zimske temperature. Na lokalitetu je izmereno 100 nasumično odabranih biljaka, uključujući visinu, obim biljke, broj grana po biljnom grmu, odnos cvetnih i necvetajućih grana, odnos nadzemnog dela i korena, kao i stabla prema lisnim granama i cvetu. Rezultati su pokazali da je odnos korena i nadzemnog dela 1:2,5, prosečna visina ispitivanih biljaka 41±6 cm, u rasponu od 30-60 cm, a obim biljnog žbuna 121±30 cm, u rasponu od 40-170 cm, koji je u pozitivnoj korelaciji sa brojem grana. Prosečan broj grana po biljci bio je 8±2,5. Na osnovu merenja apsolutno suvog biljnog materijala utvrđeno je da je masa grane u proseku sadržala 22,5% nadzemnog izdanka (stabla), 73,5% lisnih grančica i 4% cvetne mase. Latice čine u proseku 34,3% mase cveta.

Ključne reči: *Paeonia tenuifolia* L., nadzemni deo:koren, temperatura, vlažnost, Deliblatska peščara, lekovite i ukrasne biljne vrste.