BIO Web of Conferences **128**, 00034 (2024) https://doi.org/10.1051/bioconf/202412800034
Problems of Industrial Botany of Industrially Developed Regions 2024

Features of the water regime of some species of the genus Dianthus L. in the South-Ural Botanical Garden (Ufa)

Antonina Reut[1*], *Lyaysan* Uzyanbaeva[1]

[1]South-Ural Botanical Garden-Institute of Ufa Federal Research Centre of Russian Academy of Sciences, 450080 Ufa, Russia

Abstract. The results of studies of the characteristics of the water regime of 18 species of the genus *Dianthus* L. (*D. acicularis*, *D. anatolicus*, *D. andrzejowskianus*, *D. borbassii*, *D. deltoides f. rubra*, *D. carthusianorum*, *D. chinensis*, *D. crossopetalus*, *D. giganteus*, *D. gratianopolitanus*, *D. hypanicus*, *D. japonicus*, *D. knappii*, *D. nardiformis*, *D. oshtenicus*, *D. plumarius*, *D. seguieri*, D. *uralensis*) in the conditions of the South-Ural Botanical Garden-Institute of the UFRC RAS. The experiments were carried out during the growing seasons 2021-2023 on the basis of the laboratory of introduction and selection of flower plants. During the research, the seasonal dynamics of such water regime indicators as total water content, water-holding capacity and leaf water deficit were determined. The analysis of water regime parameters is based on the method of artificial wilting and the technique of saturation of plant samples. The obtained data were processed using standard statistical methods using Microsoft Excel 2003. It was revealed that as a result of the study, the studied taxa are characterized by high water-holding capacity. All of them are adapted to dry periods under cultivation conditions in the forest-steppe zone of the Bashkir Cis-Urals.

1 Introduction

Under normal conditions of life of higher plants, there is a constant exchange of water between the plant organism and the external environment. This water exchange depends both on environmental conditions and on the biological characteristics of plants, and in many cases is the most important factor determining reproductive and decorative qualities. Therefore, it is important to know not only the ecological environment that determines this water exchange, but also the biological characteristics of the plants themselves in relation to this process or their water regime under certain environmental conditions.

The ability of introduced plants to tolerate drought conditions is often critical when selecting ornamental species for landscaping. Water is one of the main factors influencing various physiological processes in the life of plants. One of the indicators of plant

* Corresponding author: cvetok.79@mail.ru

resistance to unfavorable environmental conditions is the characteristics of the water regime [1].

Recently, in connection with the development of landscape style in ornamental gardening, the expansion of the range of floral and ornamental plants through the use of perennial, long-growing unpretentious species has become increasingly active. In this regard, there is increasing interest in ornamental plants of natural flora, which differ favorably from cultivated plants in a number of characteristics and properties. These plants include the genus *Dianthus* L. (family Caryophyllaceae Juss.), many species of which are distinguished by highly decorative characteristics and unpretentiousness to growing conditions. However, in areas of introduction with more continental climatic conditions, including in the Southern Ural, the biology of carnations has not yet been sufficiently studied. This determines the relevance of these studies. Our earlier initial assessment of the prospects for the introduction of the genus *Dianthus* [2, 3] needs to be supplemented with data on the impact of drought and resistance to it on the studied genus, and identification of the characteristics of the water regime in new environmental conditions.

The genus *Dianthus* L. (family Caryophyllaceae Juss.) has 338 species that grow in Europe, extratropical Asia, and North Africa [4]. The genus is most richly represented in the Mediterranean. Representatives of the genus are annual, biennial and perennial herbaceous plants or subshrubs growing on slopes, meadows, and sometimes in sparse forests and tundra. There are 126 species found on the territory of Russia [5]. Carnations are decorative throughout the growing season due to their spectacular greenery and the formation of multi-shoot clumps with numerous small flowers. The flowers are white, pink-purple, hot pink, yellowish-green. Some species can be used as ground cover plants [6].

The purpose of this work was to study the characteristics of the water regime of some species of the genus *Dianthus* growing in the collection of the South-Ural Botanical Garden-Institute of the Ufa Federal Research Center of the Russian Academy of Sciences (hereinafter referred to as SUBGI UFRC RAS).

2 Materials and Methods

The objects of research were 18 species of the genus *Dianthus* L.: *D. acicularis*, D. *anatolicus*, *D. andrzejowskianus*, *D. borbassii*, *D. deltoides f. rubra*, *D. carthusianorum*, *D. chinensis*, *D. crossopetalus*, *D. giganteus*, *D. gratianopolitanus*, *D. hypanicus*, *D. japonicus*, *D. knappii*, *D. nardiformis*, *D. oshtenicus*, *D. plumarius*, *D. seguieri*, *D. uralensis*.

Table 1 presents the initial data of introduced carnation species.

Table 1. Background data on introduced species of the genus *Dianthus* L.

Name of species	Homeland	Place of growth	Point of receipt of material	Year of introduction	Type of source material
D. acicularis	subendemic of the Ural (from the Southern to the southern part of the Northern) and adjacent parts of the East European and West Siberian plains	open coastal outcrops (upper and lateral parts of slopes), crevices of coastal rocks, outcrops of southern exposure	Republic of Bashkortostan	1996	seeds
D. anatolicus	Türkiye (Mountains of Anatolia)	rocky slopes, cliffs, crevices	Leipzig	2009	seeds

D. andrzejowskianus	Eastern Europe, non-chernozem zone of the center of the European part of Russia, the Caucasus	dry and steppe meadows, grassy and rocky slopes	Izhevsk	2016	seeds
D. borbasii	Europe, Caucasus, Western Siberia, Central Asia	pine forests, meadow steppes, sand dunes and water meadows	France	2014	seeds
D. deltoides L. f. *rubra*	Europe, Western Siberia, Far East, Republic of Bashkortostan	meadows, sparse forests, forest edges	Germany	2004	seeds
D. carthusianorum	Central Europe, Western Mediterranean, Balkans	dry meadows and pine forests	Ukraine	2016	seeds
D. chinensis	Eastern China	ravines, river banks, forest edges, sand dunes, steppes and meadows	Germany	2000	seeds
D. crossopetalus	Caucasus	rocky slopes	France	2014	seeds
D. giganteus	South-Eastern Europe	meadows and calcareous rocky slopes	France	2014	seeds
D. gratianopolitanus	Central and Western Europe	rocky slopes, pine forests	Izhevsk	2016	seeds
D. hypanicus	Eastern Europe	on granite rocks and granite-gneiss outcrops	Samara	2011	seeds
D. japonicus	Korea (Jukdo), Central and Southern Japan to Nansei-Shoto	sandy soil along the coast of Honshu, Shikoku, Kyushu and Okinawa in Japan	Moscow	2000	seeds
D. knappii	Hungary, Romania, northern part of Italy	grassy slopes, among shrubs	Moscow	2000	seeds
D. nardiformis	Southeastern Europe (Bulgaria, Romania)	mountains	Dagestan	2016	seeds
D. oschtenicus	Northwestern Caucasus in the basins of the Belaya and Laba rivers, mainly on the Lagonaki Highlands (Mount Oshten, Azish-Tau, Guana ridges, etc.)	subalpine and alpine meadows, glades and mountain forests	Germany	2014	seeds
D. plumarius	Eastern Europe, Central and Southern Russia	limestone slopes of the mountains	Volgograd	2002	seeds
D. seguieri	Southern and Central Europe	dry meadows at an altitude of 100-1000 meters above sea level	Italy	2003	seeds
D. uralensis	Endemic to the Southern Urals	rocky and gravelly areas of mountain steppes, on rocks, stony slopes and rock outcrops of various compositions	Republic of Bashkortostan	1996	seeds

The main climatic characteristics of the area where the research was carried out are as follows: the average annual air temperature is +2.6°C, the average monthly air temperature in the winter months ranges from −12°C to −16.6°C, the absolute minimum was noted at −42° C, the average monthly air temperature in the summer months ranges from +17.1°C to +19.4°C, the absolute maximum reaches up to +37°C, the average monthly precipitation in the summer months is 580 mm, the frost-free period lasts an average of 144 days. The predominant soil types in Ufa are gray and dark gray forest soils [1].

To assess the water regime, methods were used by N.A. Gusev [7], V.A. Tarenkova, L.N. Ivanova [8]. The experiment was carried out at the beginning of June (during budding), at the end of June (during flowering), and at the end of July (during fruiting). For the experiment, between 9 and 10 a.m., a sample of 20 pieces was taken leaves (medium size). Leaf samples were left in air to dehydrate. Repeated weighing was carried out after 24 hours. Next, samples of carnation leaves were kept in an oven at 110°C for 2 hours and final weighing was carried out. Then the total water content (W), water-holding capacity (R), and the content of "mobile" moisture (L) in the samples were calculated using the formulas:

$W=100*(M-M_2)/M$,

$R=100*((M-M_2)-(M-M_1))/M=100*(M_1-M_2)/M$,

$L=W-R$,

where M − is the mass of the fresh sample; M_1 – sample weight after 24 hours; M_2 − is the mass of the sample after drying.

The rate of water loss by plant leaves (water-holding capacity of leaves) is one of the most important physiological indicators diagnosing plant resistance to drought. It is known that, depending on the water supply, plants exhibit different resistance to atmospheric drought. The higher the content of mobile moisture in leaf cells, the lower their water-holding capacity. The water content of the leaves is an indicator of the low frost resistance of the species [9, 10].

Comparison of water inflow and outflow is called the plant water balance. If water consumption exceeds its inflow, then water deficiency occurs. To determine the water deficiency of plants, 5...10 leaves were cut off, weighed on a scale (M_1) and placed for complete saturation in Petri dishes filled with 1/3 water. Petri dishes with leaves were covered with lids and were left to saturate with water for 24 hours. Then the turgid leaves were removed from the cups, carefully and quickly dried outside with filter paper and weighed on the same scales (M_2). To control the completeness of saturation, the leaves were again placed in cups with water and after 30 minutes the weighing was repeated. If the mass has not changed, then the leaves are completely saturated with water. After complete saturation, the leaves are dried with filter paper, placed in bottles, weighed and dried in an oven at a temperature of +105...+110°C to constant weight. Then the mass of absolutely dry tissue (M_3) and water deficit are calculated using the formula:

$WD=(M_2-M_1) / (M_2-M_3)*100\%$,

where WD − is water deficit, %; M_1 – leaf mass up to 24-hour saturation in g; M_2 – leaf mass after 24-hour saturation in g; M_3 – mass of dry sample in g.

All weighings were carried out using electronic scales of the Gosmeter VLTE 1100 brand. Samples were dried in an ShS-80-01 SPU drying cabinet. Statistical processing of the obtained data was carried out using standard methods using Microsoft Excel 2003.

3 Results

When analyzing the characteristics of the water regime of the leaves of the studied carnation species, it was revealed that the total water content in early June (in the budding phase) ranges from 53.7 (*D. hypanicus*) to 81% (*D. giganteus*); at the end of June (flowering) − from 58.9 (*D. crossopetalus*) to 78.5% (*D. carthusianorum*); at the end of July (fruiting) − from 50 (*D. nardiformis*) to 79.3% (*D. carthusianorum*). The total water content of leaves is species specific.

Based on the data presented in Table 2, the following series were constructed:

a) in early June: *D. giganteus* > *D. carthusianorum* > *D. gratianopolitanus* > *D. japonicus* > *D. chinensis* > *D. plumarius* > *D. seguieri* > *D. knappii* > *D. deltoides f. rubra* > *D. oshtenicus* > *D. anatolicus* > *D. nardiformis* > *D. borbassii* > *D. uralensis* > *D. crossopetalus* > *D. andrzejowskianus* > *D. acicularis* > *D. hypanicus*.

b) at the end of June: *D. carthusianorum* > *D. chinensis* > *D. gratianopolitanus* > *D. plumarius* > *D. knappii* > *D. japonicus* > *D. borbassii* > *D. seguieri* > *D. oshtenicus* >

D. anatolicus = *D. deltoides f . rubra* > *D. uralensis* > *D. andrzejowskianus* > *D. hypanicus* > *D. giganteus* > *D. acicularis* > *D. nardiformis* > *D. crossopetalus*.

c) at the end of July: *D. carthusianorum* > *D. plumarius* > *D. chinensis* > *D. gratianopolitanus* > *D. deltoides f. rubra* > *D. oshtenicus* > *D. seguieri* > *D. uralensis* > *D. knappii* > *D. borbassii* > *D. hypanicus* > *D. anatolicus* > *D. acicularis* > *D. crossopetalus* > *D. japonicus* > *D. giganteus* > *D. andrzejowskianus* > *D. nardiformis*.

Table 2. Total water content of leaves of representatives of the genus *Dianthus*

Species	Water content M±m, %		
	beginning of June	end of June	end of July
D. acicularis	57,1±0,28	62,9±0,46	64,6±0,83
D. anatolicus	68,3±0,39	66,7±0,67	64,9±0,27
D. andrzejowskianus	60,1±0,57	65,6±0,58	58,8±0,56
D. borbassii	65,7±0,24	70,0±0,42	66,2±0,68
D. deltoides f.rubra	71,1±0,45	66,7±0,58	71,1±0,50
D. carthusianorum	79,4±0,98	78,5±0,63	79,3±0,28
D. chinensis	77,7±0,78	76,8±0,87	76,0±0,35
D. crossopetalus	61,6±0,54	58,9±0,58	61,7±0,81
D. giganteus	81,0±0,43	63,6±0,73	60,1±0,84
D. gratianopolitanus	78,5±0,97	73,7±0,94	71,2±0,57
D. hypanicus	53,7±0,47	64,3±0,77	66,1±0,60
D. japonicus	78,2±0,29	70,2±0,69	61,1±0,47
D. knappii	72,5±0,86	71,1±0,47	68,4±0,68
D. nardiformis	66,3±0,65	60,8±0,96	50,0±0,98
D. oshtenicus	69,2±0,58	69,0±0,58	69,9±0,9
D. plumarius	77,6±0,79	73,5±0,78	78,2±0,75
D. seguieri	75,6±0,46	69,8±0,86	69,3±0,48
D. uralensis	65,3±0,79	65,8±0,31	69,2±0,80

The highest water-holding capacity in early June (36.1−47.5%) is characterized by *D. acicularis*, *D. anatolicus*, *D. carthusianorum*, *D. chinensis*, *D. giganteus*, *D. gratianopolitanus*, *D. japonicus*, *D. plumarius*. These species have the highest resistance to drought. Water holding capacity in early June ranged from 7.5 (*D. knappii*) to 47.5 (*D. japonicus*); at the end of June − from 3.3 (*D. borbassii*) to 47.5 (*D. japonicus*); at the end of July − from 2.7 (*D. knappii*) to 43.6% (D. gratianopolitanus) (Table 3).

The water-holding capacity is maximum at the beginning of June; by the end of July it decreases significantly, that is, as the seeds form and ripen, the water-holding capacity of the leaves decreases.

According to the water-holding capacity of leaves:

a) in early June: *D. japonicus* > *D. gratianopolitanus* > *D. anatolicus* > *D. carthusianorum* > *D. giganteus* > *D. acicularis* > *D. plumarius* > *D. chinensis* > *D. uralensis* > *D. seguieri* > *D. andrzejowskianus* > *D. deltoides f. rubra* > *D. oshtenicus* > *D. nardiformis* > *D. borbassii* > *D. hypanicus* > *D. crossopetalus* > *D. knappii*.

b) at the end of June: *D. japonicus* > *D. gratianopolitanus* > *D. anatolicus* > *D. carthusianorum* > *D. plumarius* > *D. chinensis* > *D. uralensis* > *D. seguieri* > *D. deltoides f. rubra* > *D. andrzejowskianus* > *D. acicularis* > *D. oshtenicus* > *D. nardiformis* > *D. giganteus* > *D. crossopetalus* > *D. hypanicus* > *D. knappii* > *D. borbassii*.

c) at the end of July: *D. gratianopolitanus* > *D. carthusianorum* > *D. anatolicus* > *D. chinensis* > *D. plumarius* > *D. japonicus* = *D. uralensis* > *D. seguieri* > *D. deltoides f. rubra* > *D. acicularis* > *D. oschtenicus* > *D. nardiformis* > *D. andrzejowskianus* > *D. giganteus* > *D. crossopetalus* > *D. hypanicus* > *D. borbassii* > *D. knappii*.

Thus, when observing the water exchange of carnation leaves during the growing season, it was found that the water-holding capacity decreases due to tissue aging and a decrease in the amount of water available to plant roots in the soil. Moreover, this decrease occurs to varying degrees and depends on the hereditary biological properties of carnations, on adaptability to high summer soil and air temperatures, as well as low air and soil humidity during the growing season.

Table 3. Assessment of the water regime of the studied species of the genus *Dianthus* (%)

Species	beginning of June			end of June			end of July		
	WC	WD	DL	WC	WD	DL	WC	WD	DL
D. acicularis	37,5	13,2	19,6	16,7	15,8	46,3	15,1	15,0	49,5
D. anatolicus	43,7	7,1	24,5	41,9	12,3	24,8	33,6	20,8	31,3
D. andrzejowskianus	23,5	10,8	36,7	18,5	12,5	47,0	12,1	24,5	46,7
D. borbassii	15,3	15,8	50,4	3,3	21,5	66,7	3,3	21,6	62,9
D. deltoides f.rubra	22,2	11,5	48,9	18,8	13,9	47,9	15,5	23,1	55,5
D. carthusianorum	41,9	5,5	37,4	36,4	10,2	42,1	34,5	15,4	44,8
D. chinensis	36,1	13,0	41,5	31,5	15,3	45,4	30,4	16,5	45,6
D. crossopetalus	12,8	12,2	48,8	8,9	15,2	50,0	5,0	20,6	56,7
D. giganteus	39,0	12,2	41,8	12,1	15,2	51,5	11,6	20,6	48,5
D. gratianopolitanus	45,8	8,5	32,7	44,3	13,6	29,7	43,6	21,9	27,6
D. hypanicus	14,8	12,7	38,9	8,6	14,5	55,7	4,6	23,4	61,5
D. japonicus	47,6	8,3	30,6	47,5	11,5	22,7	24,6	22,9	36,6
D. knappii	7,5	10,1	65	6,6	13,3	64,4	2,7	14,4	65,7
D. nardiformis	15,7	15,8	50,6	15,2	18,2	45,6	14,2	20,9	35,7
D. oshtenicus	18,8	13,4	50,4	15,5	16,7	53,6	14,4	18,9	55,4
D. plumarius	36,8	6,1	40,8	31,9	12,2	41,5	29,6	12,5	48,5
D. seguieri	23,6	13,5	52,03	19,1	22,8	50,7	18,5	18,8	50,8
D. uralensis	29,3	12,0	36,0	26,8	20,3	39,0	24,6	22,4	44,6

Note: WS – water holding capacity, WD – water deficit, DL – daily loss

During the growing season, an assessment was made of the water deficit of carnation leaves (Table 3). It was found that at the beginning of June in 8 species this indicator ranged from 5.5 (*D. carthusianorum*) to 10.8% (*D. andrzejowskianus*), i.e. was within normal limits and did not cause harm to plants. In 10 species, the lack of saturation varied from 11.2 (*D. hypanicus*) to 15.8% (*D. borbassii*), i.e. was slightly above normal, but did not reach critical values.

At the end of June, in most species the magnitude of water deficit increased by 1.1–1.4 times, in 6 species (*D. anatolicus*, *D. carthusianorum*, *D. gratianopolitanus*, *D. plumarius*, *D. seguieri*, *D. uralensis*) − in 1.5–2.0 times (did not reach critical values).

At the end of July, *D. seguieri* showed a decrease in the magnitude of water deficit by 1.2 times compared to the indicators at the end of June. In *D. acicularis*, *D. borbassii* remained at the same level. In other species, the saturation deficit increased by 1.1−2 times compared to the data at the end of June.

Water deficit increases especially strongly in hot weather due to increased transpiration rates during drought or lack of water in the soil. Water deficiency not exceeding 10% is normal and does not cause harm to the plant. Water deficiency, reaching 25% or more, leads to the closure of stomata, wilting of leaves, a decrease in the intensity of growth and photosynthesis, disruption of energy metabolism and synthetic activity of cells.

When determining the water deficit of leaves, it was noted that in these types of carnations during the studied period there was no such moisture deficit in the tissues that could lead to irreversible damage to the assimilating organs.

4 Conclusions

As a result of the assessment to identify the characteristics of the water regime of carnation leaves, a high level of water content, a large degree of variation in water-holding capacity and a low percentage of water deficiency were noted. Water holding capacity values ranged from 2.7% to 47.5%. All taxa showed a higher water-holding capacity in early June, which decreased significantly by August. The studied cultivars are characterized by low levels of water deficiency. Based on the above described features of the water regime of the leaves of the studied carnation taxa, we can conclude that all the studied plants are adapted to dry periods under cultivation conditions in the forest-steppe zone of the Bashkir Cis-Ural.

Acknowledgments: The work was carried out under the Program of Basic Research of the Presidium of the Russian Academy of Sciences "Biodiversity of Natural Systems and Plant Resources of Russia: Assessment of the State and Monitoring of Dynamics, Problems of Conservation, Reproduction, Increase and Rational Use" and within the framework of the State Assignment of the SUBGI UFRC RAS on topic No. 122033100041-9.

References

1. F.K. Murzabulatova, O.Yu. Zhigunov, Features of the water regime of some species of the genus *Deutzia* Thunb. in the South Ural Botanical Garden (Ufa). Bulletin of the State Nikitsky Botanical Garden. **10,** 136 (2019)
2. L.Kh. Uzyanbaeva, A.A. Reut, Elemental composition of plant materials of some representatives of the genus *Dianthus* L. in the collection, in Proceedings of the Research by young scientists in biology and ecology. Collection of scientific articles. Saratov, 138 (2021)
3. L.Kh. Uzyanbaeva, A.A. Reut, S.F. Davletbaeva, Assessment of decorative characteristics of some representatives of the genus *Dianthus* L. Fruit growing and berry growing in Russia. **55**, 213 (2018)
4. Flora of the USSR, (M.; L.: Publishing house of the USSR Academy of Sciences, 1936)
5. S.K. Cherepanov, Vascular plants of Russia and neighboring states (within the former USSR) (St.-Petersburg: Mir and family, 1995)
6. O.V. Kotenko, Review of the collection of the genus *Dianthus* in the Amur branch of the Botanical Garden-Institute of the Far Eastern Branch of the Russian Academy of Sciences, in Proceedings of the Plants in monsoon climates: anthropogenic and climatogenic transformation of flora and vegetation. Materials of the VIII All-Russian Scientific Conference, Appatity, 91 (2018)
7. N.A. Gusev, Some methods for studying the water regime of plants, (L.: USSR Academy of Sciences, All-Union Botanical Society, 1960)
8. V.A. Tarenkov, L.N. Ivanova, Water-holding capacity of hawthorn leaves in connection with drought resistance, (Kuibyshev: Kuibyshev State University, 1990)
9. S.G. Denisova, A.A. Reut, Study of the influence of adaptogens on the water regime of some varieties of the genus *Chrysanthemum* L. during introduction in the Bashkir Cis-Ural, Agrarian Bulletin of the Urals. **11,** 2 (2020)
10. A.A. Reut, A.R. Biglova, I.N. Allayarova, Comparative assessment of the water regime of daffodils in the forest-steppe zone of the Bashkir Cis-Ural, in Proceedings of the Introduction, conservation and use of biological diversity of flora. Materials of the international scientific conference dedicated to the 90th anniversary of the Central Botanical Garden of the National Academy of Sciences of Belarus. Miinsk, 459 (2022)