

Bioecological features of *Rosa rugosa* Thunb. in urban ecosystems of the Kola North

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Abstract. This study presents the results of an assessment of photosynthetic activity and morphometric parameters of *Rosa rugosa* leaves and their Ni and Cu content from 2015 to 2017 in cities with different anthropogenic loads: Apatity, Murmansk, Monchegorsk. Over 3-year observation cycle we found that the amount of chlorophyll *a* and *b* in the leaves of *Rosa rugosa* increased in cities starting in 2016, relative to the control condition, with the highest values in Monchegorsk and Apatity. The carotenoids content in cities also increased and often prevailed over chlorophyll *b*. The Ni content in the leaves of *Rosa rugosa* was estimated to be higher than in the background territory (2.52 mg/kg) and varied from 4.16 mg/kg (Apatity) to 72.67 mg/kg (Monchegorsk). With regard to the amount of Cu, relative to the background (5.88 mg/kg), the excess was less significant: the highest values were found in Monchegorsk (11.98–23.25 mg/kg) and the lowest in Apatity (4.95–8.28 mg/kg). The morphometric analysis of the leaves showed different dynamics in the distribution of indicators in the cities and in the background territory. It was revealed that species is stable and has a high adaptive potential to the urban environment conditions of the Kola North.

1 Introduction

The ecological state of the environment in the cities of the Kola North encompasses the activities of city-forming industrial enterprises and environmental vehicular pollution. Improving the microclimate of technogenic zones is impossible without integrated organization of the green spaces. An important element in improving the green profile of polar cities is the introduction of tree plantings that are more adapted to the urban environment than native plants [1]. *Rosa rugosa* has been successfully used in the landscape design of cities in the Murmansk region. Due to its fragrant aroma and decorative appearance, this species has a favorable effect on northerners.

To assess the functionality of woody plants in urban environments, we studied the physiological and morphological parameters of the leaves, because they are the assimilative apparatus of the plants and thus the indicators of the organism that are most sensitive to external influences. The purpose of this study was to observe the work of the photosynthetic apparatus, assessing the morphometric parameters of *Rosa rugosa* leaves

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and the content of priority pollutants (Ni and Cu) in them for the observation period from 2015 to 2017 in cities with different anthropogenic loads.

2 Object and methods

Three cities of the Murmansk region were selected for the study: Monchegorsk, with a maximum atmospheric pollution index (API = 3.39) due to the long-term activities of the mining and metallurgical industries; Murmansk (API = 2.84), where various enterprises are concentrated, including cargo handling and storage; and Apatity (API = 1.88). In each city, two experimental plots were allocated, one located in the plantations near the trunk road and the other more distant from the roads. As a conditional background territory, we used the nursery of the Polar–Alpine Botanical Garden and Institute (PABGI), located 1 km north of the city of Apatity. The object of the study was *Rosa rugosa*, one of the most commonly used woody species in the landscaping of northern cities.

At the end of each growing season (August) in 2015–2017, we took samples of *Rosa rugosa* leaves. We determined the content of the photosynthetic pigments (chlorophylls *a*, *b* and carotenoids) using the spectrophotometric method at wavelengths $\lambda = 665, 649, \text{ and } 470$, respectively, in alcoholic extracts (96% ethanol) of fresh samples calculated according to the formulas for wet weight [2]. After herbarization of the leaves, we took measurements of their length, width, and area. We analyzed the content of metals (Ni, Cu) using the atomic absorption method after dissolving dry samples (2015) in concentrated nitric acid.

3 Results and Discussion

In order to exist at all in an unstable urban environment, urban flora must have a certain plasticity and variability, influenced by a whole complex of factors, both natural and anthropogenic. The plant organism adapts to these environmental conditions, which affects the characteristics of the pigment apparatus. Intensive air pollution that includes industrial toxicants affects the content and ratio of pigments in the assimilation organs of woody plants in different ways, and photosynthesis is one of the physiological processes of plants most sensitive to external influence [3].

This analysis of the photosynthetic pigments content in the leaves of *Rosa rugosa* over a 3-year observation period shows that those in the PABGI nursery were characterized by decreased chlorophyll and carotenoid content, whereas in cities the dynamics of these indicators were different (Fig 1).

Rosa rugosa in Apatity was characterized by growth for all pigments with the highest chlorophyll content in 2017. In Monchegorsk, we detected an increase in the amount of chlorophyll *a* and carotenoids, and the content of chlorophyll *b* varied slightly. In Murmansk, the parameters of the pigment complex were inconsistent. Of note, in 2016, the content of carotenoids prevailed over chlorophyll *b* in comparison with 2015 in all the studied areas. In 2017, this trend was revealed only in Murmansk and Monchegorsk. Carotenoids in the plant organism have been shown to have a protective function, which increases the resistance of plants to stressful effects [4].

The degree of formation of the photosynthetic apparatus is characterized by the ratio of chlorophyll *a* to chlorophyll *b* (*a/b*). This ratio is associated with the activity of the “main” chlorophyll *a*: the higher it is the more intense the photosynthesis. Normally, this indicator should correspond to 2.2/3.0. The calculated values of this indicator in our study were above normal, mainly in Murmansk and Monchegorsk (Table 1). Therefore, the increase in the chlorophyll *a* content in these samples can be considered an adaptation of the plants to adverse environmental conditions.

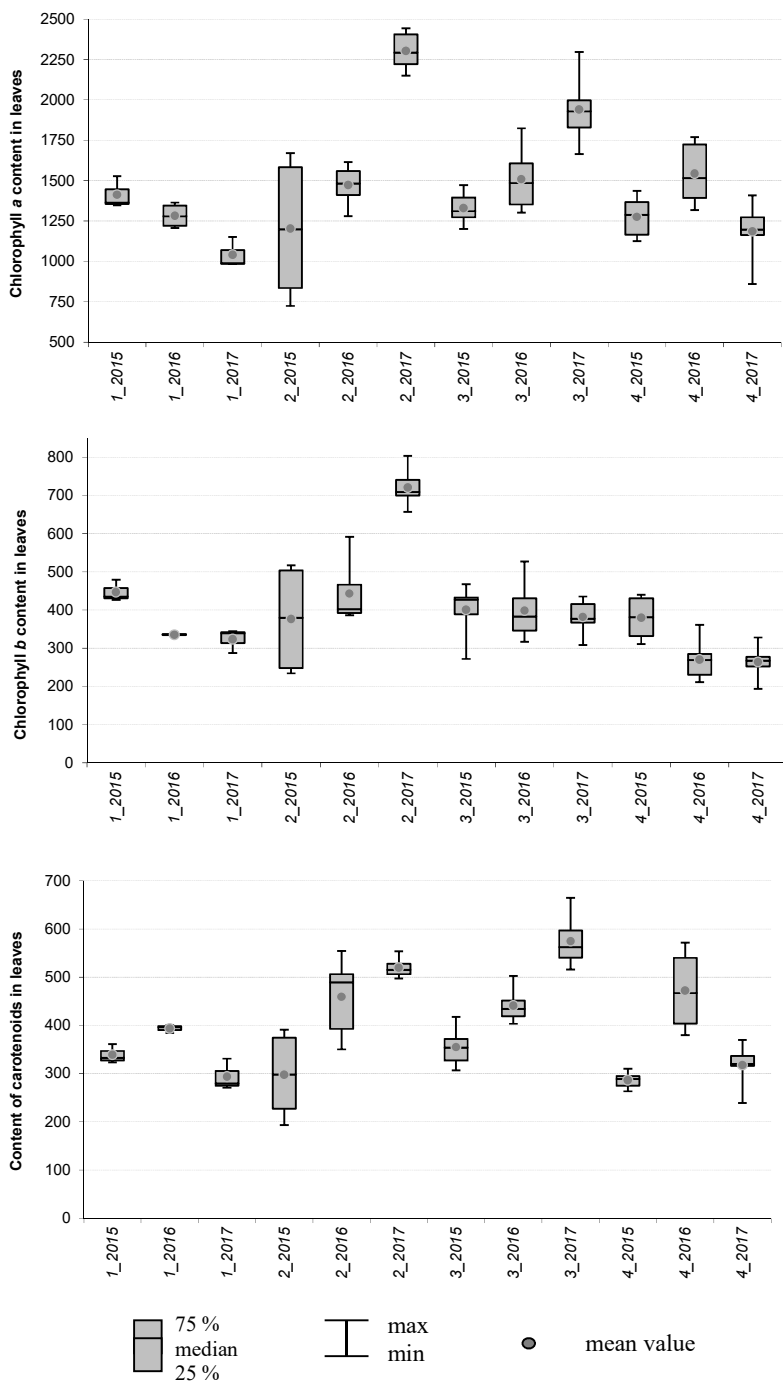


Fig. 1. Statistical parameters content ($\mu\text{g g}^{-1}$ wet weight) of chlorophyll *a*, *b*, carotenoids in leaves *Rosa rugosa* for period from 2015 to 2017. Note: 1 – The tree nursery PABGI, 2 – Apatity, 3 – Monchegorsk, 4- Murmansk.

We utilized the ratio of the sum of chlorophylls (*a*+*b*) to carotenoids, which is normally stable, to evaluate the work of the photosynthetic apparatus. A decrease in the ratio

($a+b$ /carotenoids) can indicate a decrease in the light-collecting function of the pigment complex due to adverse factors. By comparison, for *Rosa rugosa* in Monchegorsk, this indicator was less variable, especially in areas more distant from the roads, and it corresponded more closely to that of the conventional background. In other cities, it was unstable and elevated. In general, activation of pigment synthesis may be associated with the need to maintain photosynthetic processes at a certain level in adverse growing conditions.

Table 1. Indicators of morphological features, the ratio of pigment complex, content Ni, Cu in leaves of *Rosa rugosa*.

	Year	Length, sm	Width, sm	Area, sm ²	$a+b$, μg/g	$a+b$	$\frac{a/b}{car^{***}}$	Ni, mg/kg	Cu, mg/kg
1	2015	12.60±0.67	9.27±0.84	63.60±7.91	1859.6	5.5	3.2	2.52	5.88
	2016	11.43±0.46	5.69±0.36	34.72±4.47	1618.0	4.1	3.8		
	2017	12.76±0.55	5.80±0.34	35.97±3.42	1363.9	4.6	3.2		
2_s*	2015	12.86±0.64	8.03±0.50	38.41±5.03	1055.6	4.9	3.2	4.16	4.95
	2016	14.05±0.45	9.86±0.45	56.68±4.61	1910.4	3.9	3.9		
	2017	12.28±0.61	8.14±0.47	34.25±3.91	2983.2	5.8	2.9		
2_r**	2015	12.80±0.54	8.18±0.49	41.50±5.01	2102.8	5.6	3.2	7.42	8.28
	2016	11.75±0.58	8.13±0.41	39.66±3.11	2002.3	4.7	2.5		
	2017	14.09±0.63	9.88±0.52	53.27±5.61	3066.2	5.8	3.5		
3_s	2015	11.68±0.66	7.30±0.51	55.18±7.76	1690.8	4.4	3.7	29.99	11.98
	2016	14.27±1.18	8.57±0.76	68.7±11.02	1698.3	4.1	4.0		
	2017	15.68±1.44	8.49±0.84	55.31±8.58	2168.3	4.1	4.8		
3_r	2015	13.82±0.82	9.51±0.06	63.12±7.65	1770.4	5.5	3.0	72.67	23.25
	2016	14.06±0.69	8.88±0.48	63.67±4.81	2115.4	4.5	3.7		
	2017	14.69±0.95	10.16±0.53	60.88±6.15	2473.5	4.0	5.3		
4_s	2015	16.08±1.36	7.11±0.46	52.57±6.55	1493.7	5.5	3.6	7.31	8.26
	2016	14.92±1.55	7.80±0.48	56.41±7.64	1993.7	3.7	6.2		
	2017	15.84±0.76	7.38±0.52	48.85±5.93	1599.0	4.6	4.5		
4_r	2015	12.85±1.17	5.99±0.54	37.37±7.56	1815.6	6.1	3.2	11.99	10.27
	2016	13.14±0.66	6.27±0.34	39.44±4.51	1633.5	4.1	5.2		
	2017	14.13±0.90	7.09±0.44	39.47±5.65	1300.1	4.5	4.5		

Note: 1 – The tree nursery PABGI, 2 – Apatity, 3 – Monchegorsk, 4 – Murmansk.

*s – plot located more distant from the roads; **r – plot located near trunk road, ***car – carotenoids.

In cities, we estimated the Ni content in the leaves of *Rosa rugosa* to be higher than in the conventional background area (Table 1). It varied from 4.16 mg/kg to 72.67 mg/kg. The excess amount of Cu relative to the background was less significant: the highest values were found in Monchegorsk (11.98–23.25 mg/kg) and the lowest in Apatity (4.95–8.28 mg/kg). We detected the highest levels of Ni and Cu pollution in the leaves of *Rosa rugosa* in plants in Monchegorsk, especially in areas located near the trunk road. The correlation analysis showed low and unreliable values of coefficients between the metal content and chlorophyll *a* (r (Ni)= 0.13–0.39; r (Cu)=0.23–0.41), chlorophyll *b* (r (Ni)=–0.19–0.23; r (Cu) =–0.28–0.32), and carotenoids (r (Ni)= 0.04–0.55; r (Cu) =0.02–0.56), as well as their ratios: a/b (r (Ni)= –0.16–0.37, r (Cu) =–0.09–0.53); ($a+b$)/carotenoids (r (Ni)=–0.10–0.43, r (Cu) =0.06–0.46). In the cities, there is a predominant increase in the pigment fund, probably due to the inclusion of compensatory mechanisms leading to the activation of assimilative activity.

Plant organisms constantly interact with their environments; under adverse pollution conditions, changes in the morphometric parameters of the leaves can be observed. A

number of studies have shown that, under conditions of long-term industrial pollution, both a decrease in the length and area of leaf lamina [5] and their increase can be observed [6].

This analysis of the morphometric parameters of *Rosa rugosa* leaves over a 3-year observation cycle showed different dynamics regarding the distribution of indicators in the cities under study and in the background territory. In general, in Monchegorsk in 2016 and 2017, we found the highest values of leaf length, width, and area, whereas, by contrast, we found the lowest values in the zone of conditional control during this same period. The correlation analysis of the dependence of morphological indicators on the content of metals in the leaves revealed an unreliable average relationship between the leaf area and the metal content ($r(\text{Ni}) = 0.51\text{--}0.74$; $r(\text{Cu}) = 0.47\text{--}0.77$). We also noted a positive relationship between the leaf width and the number of carotenoids ($r=0.56\text{--}0.86$). Plants' morphological signs are influenced by a complex of factors, of which environmental pollution with heavy metals may play a secondary role within certain limits.

4 Conclusion

The analysis of the correlation among the pigment content, their ratio, and the accumulation of metals in the leaves of *Rosa rugosa* did not reveal functional relationships. The morphometric analysis of the leaves over a 3-year observation period showed different dynamics in the distribution of indicators in the cities and in the background territory. The lack of a strong correlation between the photosynthetic pigment content and morphometric parameters of the leaves and the level of technogenic load indicates the stability of *Rosa rugosa* and its high adaptive potential to the conditions of the urban environment of the Kola Polar region.

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