Photosynthetic pigments in herbaceous plants on the territory of Railway Stations in the Kola Peninsula cities

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Abstract

For the first time, a study on photosynthetic pigments found in native (*Chamaenerion angustifolium* (L.) Scop., *Taraxacum officinale* F. H. Wigg) and introduced herbaceous plants (*Primula elatior* (L.) Hill, *Trollius asiaticus* L.) growing in subarctic regions is presented. Plant species were collected close to railway stations in five cities of the Kola Subarctic (Murmansk, Olenegorsk, Apatity, Polyarnye Zori, Kandalaksha). The leaves for pigment analysis were collected at comparable times during the growing season of plants. In the leaves of *Ch. angustifolium*, the content of pigments (chlorophyll *a*, chlorophyll *b* and carotenoids) was higher than in *T. officinale* (except Murmansk). In *T. asiaticus* the content of photosynthetic pigments was comparable to native species. *P. elatior* was inferior to other species in terms of the content of chlorophyll *b* and carotenoids. In the leaves of *T. asiaticus* on the territory of the railway stations Polyarnye Zori and Kandalaksha, shifts in the ratio of the main groups of pigments were noted. Application of maximum permissible concentrations Ni, Cu, Cd, Pb for comparison with the actual content of the pollutants in soils of railway stations showed that the soils contaminated only by Ni and Cu (3-6 times), with a maximum in Olenegorsk. Low soil contamination with Pb was found only in Kandalaksha. The impact of soil pollution with heavy metals on native species was not revealed. For introduced species, a weak non-significant positive relationship was found (r = 0.56). A high correlation coefficient was obtained for the total content of chlorophylls in the leaves of *T. asiaticus* (r = 0.83) and *P. elatior* (r = 0.89) in Kandalaksha, caused by the content of nitrogenous compounds in the soil associated with the use of fertilizers in the flower garden.

Key words: herbaceous plants, pigment fund, railway stations, Murmansk region

DOI: 10.5817/CPR2023-1-7

Received April 12, 2023, *accepted* August 24, 2023.

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Acknowledgements: This work was supported by state task AAAAA 18–118050390076–8 “Collection funds of the Polar-Alpine Botanical Garden-Institute as the basis for biodiversity conservation, development of biotechnologies, optimization of urban environment conditions, phytorehabilitation, and environmental education”.

Introduction

The operation of different types of transport leads to the deterioration of the regional ecological situation (Wiłkomirski et al. 2012, Barinov et al. 2017, Babkina et al. 2019). Rail transport can cause a number of environmental problems (violation of environmental conditions, pollution of water bodies, soil, vegetation, the introduction of alien plants, *etc*.). The flora of railways has attracted the attention of many researchers (Borisova 2002, Senator et al. 2016, Barinov 2018, Kurskoy and Zelenkova 2020). It was noted that under the influence of this anthropogenic factor, the introduction of alien species into the flora of regions and the extinction of some native species occur. This leads to the formation of anthropogenically transformed floristic complexes, the composition of which is already significantly different from the natural flora of the area (Burda 1991) and is mainly represented by plants characterized by a wide amplitude environmental tolerance (Gorchakovsky 1979).

The environmental factors in the formation of the flora of railways include physical and geographical factors (*e.g.* geographical location, nature of roadside biotopes, exposure of slopes, vegetation cover of adjacent territories) and technical and operational factors (*e.g.* time of road construction, nature of ballast material, subgrade and soil composition, electrification, intensity traffic and linear characteristics of the road, features of transportation, maintenance and repair) (Senator et al. 2012).

The Oktyabrskaya railway has been operating in the Murmansk region for more than 100 years. Most of its stations have been operating since 1916. Modern station buildings were built in the cities of Murmansk, Olenegorsk, Apatity, Kandalaksha in the 1960s and Polyarnye Zori in the 1980s. In the region, more than 60% of cargo transportation is carried out by rail. Mining and industrial enterprises are local sources of pollution and most of the extracted raw materials and products are transported by rail as well. In addition to the transportation of chemicals, hazardous materials are used in the maintenance and operation of rolling stock, the leakage of which leads to environmental pollution. Anthropogenic pollution can lead to a deviation of the main physiological parameters of plant organisms from their optimal state (Kaur and Nagpal 2017, Athira et al. 2022, Choudhary et al. 2022).

The plant communities formed in the territories of the region's railway stations are of particular interest. Attention is drawn to the grassy ground cover, among which flower plants are introduced, used for landscaping the railway station areas. Emissions from rolling stock contain pollutants, including heavy metals (Ni, Cu, Pb, Cd, Fe). There is a sufficient number of works devoted to the negative effect of heavy metals on the content of photosynthetic pigments (Prasad 2004, Bukharina and Dvoeglazova 2010, Dymova and Golovko 2018, Łuczak et al. 2021, Singh et al. 2021). The main reasons for the decrease in the amount of chlorophylls *a* and *b* in the presence of heavy metals are: suppression of chlorophyll biosynthesis, increased degradation of chlorophyll, violation of the ultrastructure of chloroplasts (Sheoran et al. 1990, Molas 1997).

Unfortunately, we did not find studies on the effect of rail transport on the pigment fund of herbaceous plants. However, the study of this issue deserves more attention, especially in relation to introduced species of ornamental perennial herbaceous plants. The natural flora of the cities of the Murmansk region is very poor, therefore, a special role is given to introducers that can decorate the northern cities.

The aim of this study was to conduct a comparative analysis of the pigment found of ornamental herbaceous introducents (*P. elatior, T. asiaticus*) with the most common native species (*Ch. angustifolium, T. officinale*) in the area affected by railway transport to identify the stability and adaptation of their pigment system.

Material and Methods

Service in the Murmansk region of the Oktyabrskaya railway includes 5 main railway stations (Murmansk, Olenegorsk, Apatity, Polyarnye Zori, Kandalaksha), each of which have railway station buildings. The largest transport hubs are located in Murmansk and Apatity; Olenegorsk and Kandalaksha are junction stations with an average traffic load; Polyarnye Zori has a minimum traffic load. The plant nursery of the Polar Alpine Botanical Garden-Institute (PABGI), located near the city of Apatity, was chosen as the conditional control zone.

Climate characteristics of the research areas

Most of the territory of the Murmansk region is located beyond the Polar Circle. The climate in the region is classified as continental, temperate cold, and wet (Dfb according to the Köppen-Geiger system). Murmansk is the regional center located in the north of the Kola Peninsula; the climate is formed by the proximity of the Barents Sea (Kottek et al. 2006). The warmest month is July, its average air temperature is about +13.3°C, the average annual rainfall in 600 mm[1]. Olenegorsk is a city beyond the Arctic Circle, 94 km south of Murmansk. The average air temperature in July is +14.0°C. The average annual precipitation is 600 mm[1]. The city of Apatity is located 160 km to the south of the city of Murmansk. The maximum average monthly temperature was recorded in July as +13.8°C, and the average annual rainfall is about 800 mm[1]. The city of Polyarnye Zori is located 180 km south of Murmansk. Its average air temperature in July +14.7°C, and its average annual rainfall is 676 mm[1] Kandalaksha is the southernmost of the cities in the region (210 km from Murmansk). Because it is far from the Barents Sea, its climate is more continental and is transitional from temperate to subarctic, with an average air temperature in July of +14.9°C and an average annual precipitation of about 700 mm[2].

Experimental species

The objects of the study were decorative herbaceous introduced plants (*P. elatior, T. asiaticus*) used in the flower decoration of railway stations, and widespread native plants (*Ch. angustifolium, T. officinale*), growing in the areas adjacent to railway stations (at a distance of 5-10 m from the tracks) (Fig. 1).

T. asiaticus is naturally distributed in the forests and meadows of Siberia and the Urals, preferring moist, well-drained areas that are sunny or with light partial shade. Introductory trials of this species began in 1934 at PABGI. In 1941, *T. asiaticus* was included in the landscaping assortment for the regions of the Far North (Avrorin 1941). Because of its stability in urban plantings and self-renewal, this species occupies one of the leading places in the floral design of polar cities. The bush is compact with erect, slightly ribbed stems that are 50–60 cm high. Flowers are yellow-orange and solitary. It is especially decorative during the flowering period (from mid-June, within 15–20 days depending on weather conditions) due to bright orange flowers. Its seeds ripen annually in August (Gontar et al. 2010).

T. asiaticus was found in flowerbeds near the railway stations of Olenegorsk, Apatity, Polyarnye Zori, and Kandalaksha. At the time of the survey, it was noted in flowering state in Olenegorsk only. In other territories, it had already faded. Railway services did not take care of flower beds (fertilization, weeding), except for Kandalaksha (railway station staff 2-3 times during the growing season carried out weeding of the flower garden, and at the beginning of the season they applied fertilizer (ammonium nitrate at a dose of 40 g m^{-2}).

P. elatior is a perennial herbaceous mountain plant that is widespread in Central Europe. PABGI has been engaged in the introduction of this species to the region since 1939. Because of its decorativeness and stability in planting, it was introduced into the landscaping assortment in 1970. It is a perennial with a dense rosette of oblong-oval basal leaves and a leafless flowering stem that is 25–30 cm high. Bright yellow flowers with a diameter of 1.8 to 2.5 cm are collected 10–20 pieces in an umbrella inflorescence. The flowering period is from the beginning of June for 15–20 days. Its seeds ripen annually at the end of August and give good self-sowing (Gontar et al. 2010).

P. elatior was present in the flower beds of the railway station territories of the cities of Apatity, Polyarnye Zori, and Kandalaksha and faded at the time of the examination.

Ch. angustifolium is a perennial plant, and the area of its distribution is extremely extensive. It has a tall, straight stem that does not branch and densely filled with leaves, and it can reach 150 cm. The leaves are alternate, narrow, have a shape resembling a narrow wedge, and can reach up to 12 cm in length. The denticles at the end of the leaf are not clearly marked. In the Murmansk region, it blooms in late July to early August. The plant is not whimsical. It grows in all surveyed railway station areas but in small numbers (<10%).

T. officinale is a perennial herbaceous plant that is 10–40 cm tall, with leaves in a basal rosette and a flower arrow that is hollow. The species is found in all zones and belts of a significant part of Eurasia, with the exception of the tundra zone and high mountains. In the Murmansk region it usually blooms in July. As an adventive plant, it is known on almost all continents. In areas adjacent to railway stations, its occurrence is higher than *Ch. angustifolium* and is rather abundant in Murmansk and Kandalaksha.

Sampling

Quantitative assessment of the content and qualitative composition of photosynthetic pigments, as well as changes in their ratios in plant leaves are used as biological indicators of environmental pollution and can be used to diagnose the functional state of plants.

In the forecourt areas of 5 railway stations, leaf samples of each species were collected in late June to early July 2022. The period for the collection was selected because of the maximum development of native plants before their first mowing. After sampling, fresh samples were delivered to the laboratory on the same day, where alcohol extracts were immediately prepared, which were then placed in a dark place in a refrigerator. The next day, the obtained samples were analyzed. The content of leaf plastid pigments was determined in alcohol extracts (96%) from the optical density at the absorption maxima of chlorophylls *a* and *b* and carotenoids, using a UV-1800 spectrophotometer (Shimadzu, Japan), at wavelengths of λ = 665, 649, and 470, respectively (Lichtenthaler and Wellburn 1983, Maslova and Popova 1993). Samples of leaves of each species were taken in 5-fold biological replication, then analysed in 3-fold analytical replication. Calculations were made according to the formulas for wet weight.

To evaluate content of nutrients and heavy metals in soils, samples were taken (sampling depth up to 15 cm) under native plant species and on flower beds under cultivated introduced plants. These soil samples were ground to powder and decomposed with a mixture of the HF, HNO_3 and $HClO_4$ acids (3:2:1). Then the acidity (by the potentiometric method), the content of nitrate (disulfophenol method), and ammonium (with Nessler's reagent) nitrogen exchange forms of phosphorus (by the Kirsanov method) and potassium (by the flame photometric method) (Arinushkina 1970), as well as the total content of heavy metals (Ni, Cu, Pb, Cd, Fe) by the atomic absorption method on a Shimadzu AA-6800 spectrophotometer were evaluated.

Mathematical processing of the results was carried out using standard software packages for statistical calculations (Microsoft Office Excel 2019). The correlation coefficient (r) was calculated by the method of squares (Pearson's method) for a significance level of 0.05.

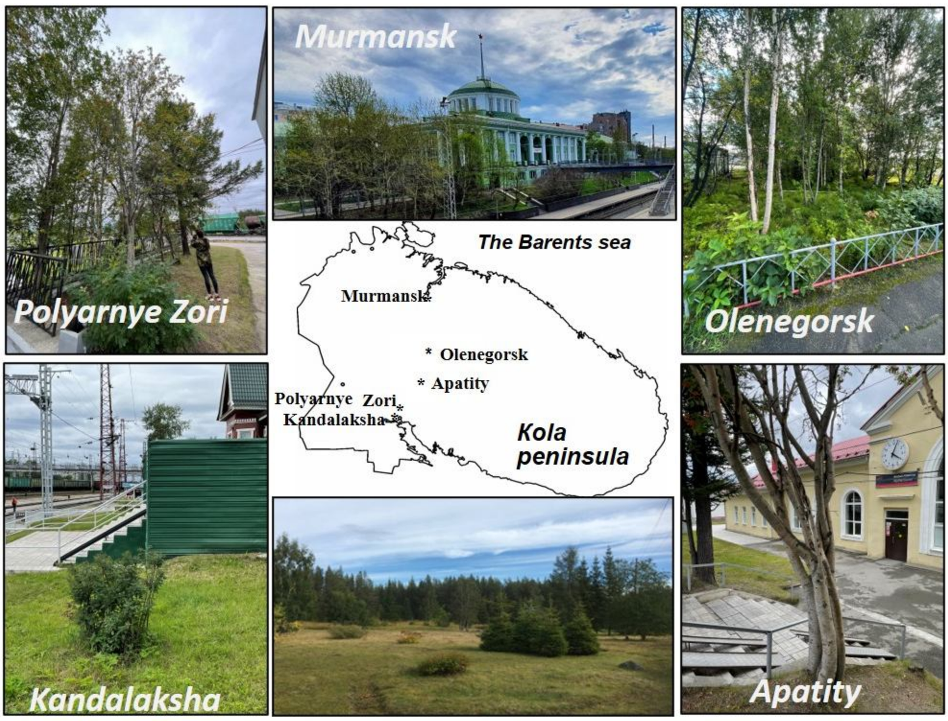

Fig. 1. Objects and location of observation plots.

Results and Discussion

Analysis of the content of chlorophyll *a* in the leaves of herbaceous plants in the studied areas showed its variation in a wide range in *T. officinale* from 1007.97 (Polyarnye Zori) to 2251.25 (Murmansk) μg g^{-1} (Fig. 2A). In relation to the conditional control zone, this indicator was higher in Olenegorsk and Kandalaksha and significantly higher in Murmansk.

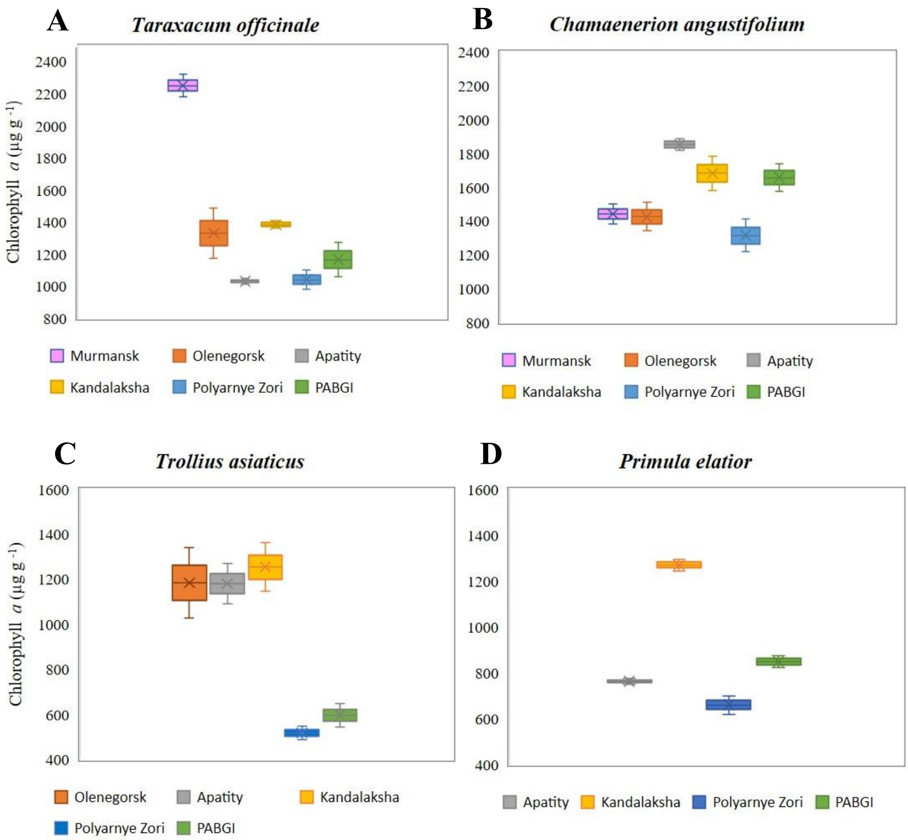

Fig. 2. Distribution of chlorophyll *a* content (μg g^{-1} wet weight) in leaves of herbaceous plants.

The content of chlorophyll *b* and carotenoids in the leaves of *T. officinale* was also the highest in Murmansk, and the minimum was mainly in Apatity (Fig. 3 – 4). It should be noted that in Apatity, carotenoids prevailed over chlorophyll *b* in average values. In general, in the leaves of *T. officinale*, which grows on the territory of railway stations in Murmansk, Olenegorsk, and Kandalaksha, the content of pigments of the photosynthetic complex was higher than in the control.

The high content of pigments in the leaves of *T. officinale* in Murmansk can be explained by the earlier start of vegetation (at the time of the survey, the initial phase of flowering), whereas, in other areas, only the budding phase was found for the species.

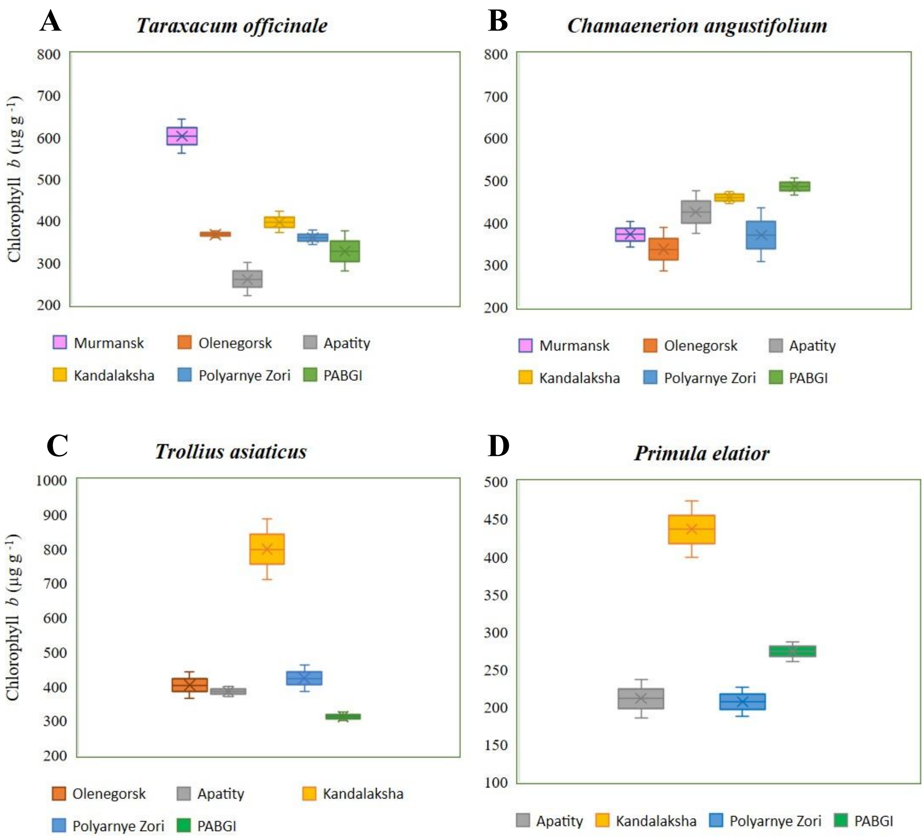

Fig. 3. Distribution of chlorophyll *b* content in leaves of herbaceous plants.

Some researchers, when studying the process of accumulation of chlorophyll in plants during the growing season, showed that its maximum content was timed to the beginning of flowering (Pokorny et al. 2013). It can be assumed, that an increase in chlorophyll synthesis can be used as an indicator of plant readiness for flowering.

The results of our study demonstrated a higher pigment content in *T. officinale* compared to the data of similar studies (Golovko et al. 2007, Shenderova 2018, Ozola et al. 2019, Paduret et al. 2021). This may be due to the method of extracting pigments because alcohol was used as an extracting agent for the quantitative determination of chlorophylls and carotenoids. It has been shown that the content of pigments in alcohol extracts is higher than in acetone ones (Shenderova 2018). The climatic and weather features of the region (length of the polar day, temperature, humidity, *etc.*) also influence the course of photosynthetic processes. High chlorophyll content in plants in the north regions has been shown in a number of studies (Shvetsova 1987, Shmakova et al. 2021).

In the leaves of *Ch. angustifolium*, the content of chlorophyll *a* was less variable (1315.50 – 1853.76 µg g^{-1}) with a minimum value found in Polyarnye Zori and a maximum in Apatity (Fig. 2B).

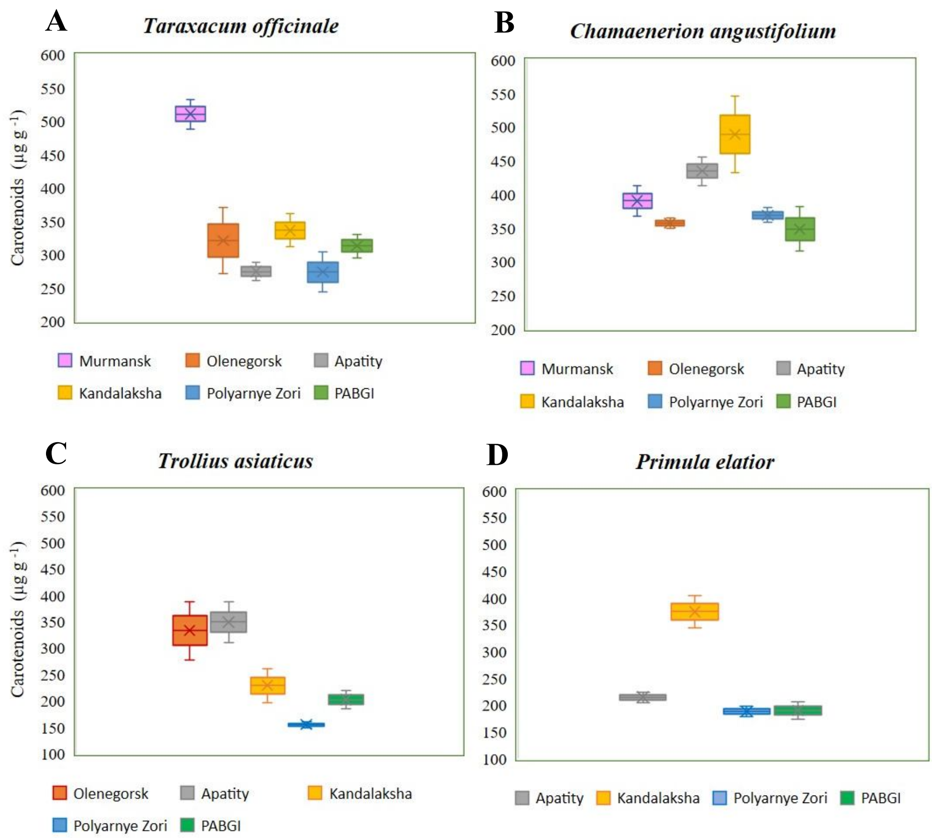

Fig. 4. Distribution of carotenoids content in leaves of herbaceous plants.

The distribution of chlorophyll *b* differed from chlorophyll *a*, where its highest value was found in the conditional control zone and the lowest in Olenegorsk. The content of carotenoids, on the contrary, was the lowest in the control and the highest in Kandalaksha. Thus, the content of chlorophylls was estimated as the highest mainly in the conditional control zone against the background of the minimum content of carotenoids that perform a protective function in the plant organism. In general, the content of photosynthetic pigments in leaves of *Ch. angustifolium* was higher than that of *T. officinale* (Figs. 2 – 4).

In the introduced species *T. asiaticus*, the content of chlorophyll *a* was clearly distributed in two ranges of values: in Olenegorsk, Apatity, and Kandalaksha from 1028.95 to 1362.11 μg g^{-1}, with a pronounced decrease in the city of Polyarnye Zori and in the conditional control zone (487.31 – 649.26 μg g^{-1}; Fig. 2A). The content of chlorophyll *b* was high values only in Kandalaksha; in other railway station areas it was lower and varied insignificantly (Fig. 3A). Its minimum content was noted in the PABGI nursery. For carotenoids, the distribution pattern was different, with a maximum in Olenegorsk and Apatity and a minimum in Polyarnye Zori (Fig. 4A).

In *P. elatior*, the content of chlorophyll *a* varied from 659.85 to 1269.73 μg g^{-1}, whereas it was higher than in the leaves of the previous species, except for the city of Apatity. The content of chlorophyll *b* was already estimated to be much lower than in the *T. asiaticus*, with a maximum in Kandalaksha and a minimum in Apatity. The content of carotenoids in the railway station areas of Polyarnye Zori and Apatity corresponded to the level in the control area, and only in Kandalaksha was it twice as high (Figs. 2 – 4).

Interspecific comparative analysis showed that the content of the main chlorophyll in introduced plants was generally comparable with native species, with the exception of the city of Polyarnye Zori and the conditional control zone, which had lower values. The amount of chlorophyll *b* in the leaves of *T. asiaticus* varied within the same limits as in *Ch. angustifolium* and *T. officinale*, except for Kandalaksha, where it was much higher. In *P. elatior*, the content of chlorophyll *b* and carotenoids was lower than in other species, and only was comparable to them in Kandalaksha city. Thus, in cultivated introduced plants in the territory of railway station of Kandalaksha, the pigment contents was at its maximum in comparison with other cities and the control plot due to the possibly higher content of the main nutrient (nitrogen) in the soil of the flower garden (Table 1). The positive effect of nitrogen fertilizers on the content of chlorophyll in plant leaves has been shown in a number of studies (Muhammad et al. 2022).

In order to analyze the differences in pigment contents, two ratios are used: (1) the content of chlorophyll *a* to chlorophyll *b* (*a/b*) and (2) the total amount of chlorophylls to carotenoids (*a+b/car*). According to the literature, the ratio between chlorophylls can characterize the potential photochemical activity, and it is considered optimal in the range 2.0 – 3.5 (Lebedeva 1986, Dymova and Golovko 2018).

Among the studied plants, *T. asiaticus* stood out because in its leaves, for most of the experimental sites, the minimum values of this indicator were revealed (Fig. 5) due to a decrease in chlorophyll *a* (Polyarnye Zori) and an increase of chlorophyll *b* (Kandalaksha). It should be noted that in the conditional control zone this value was not much higher. The maximum values were noted for *Ch. angustifolium* in Olenegorsk and Apatity. The greatest variability of ratio *a/b* is typical for *T. asiaticus* (Fig. 5).

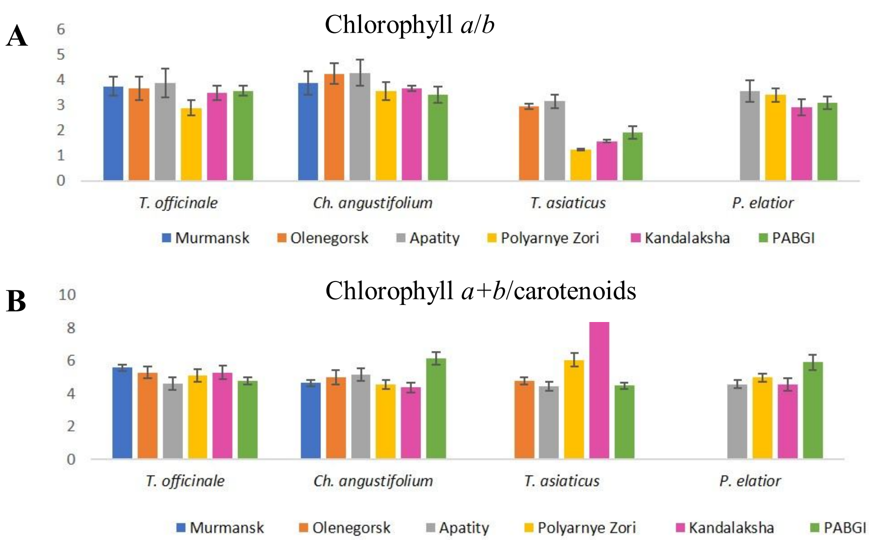

Fig. 5. The values of the ratio of photosynthetic pigments in herbaceous plants.

The ratio of total chlorophylls to carotenoids is considered as an indicator of aging, stress and damage to the plant (Ozola et al. 2019). The range of values 4.2 – 5.0 is considered physiological for plants (Lichtenthaler and Buschman 2001). Lower values in the range of 2.5 – 3.5 or too high (>7) indicate stressful state of the plant organism (Salehi and Arzani 2014, Shubina 2011). In the work of Kurenkova (1998), this indicator in herbaceous plants under natural conditions was labile and varied from 1.8 to 6.2. In our study, this value was estimated in the range from 4.38 to 8.95. High values were typical for *T. asiaticus* growing in the railway station area of Kandalaksha (8.95). The ratio of *a* + *b* / carotenoids in the leaves of *T. officinale* between sites was relatively even, and *T. asiaticus* varied the most.

It has been shown that when the soil is contaminated with heavy metals and its mixtures, the ratio of *a*/*b* decreased and the ratio chlorophylls (*a*+*b*) / carotenoids increased in plants (Korotchenko 2011). A similar trend was revealed in the *T. asiaticus* growing in Kandalaksha. In Olenegorsk, however, this species did not show such a shift in the ratios with higher level of pollution. It has been shown that changes in ambient temperature and humidity can also cause shifts in the pigment composition of plant leaves (Esteban et al. 2015). The experimental plots differed from each other in the level of illumination (the plants grow under the canopy of trees and in open areas), in terms of moisture conditions (in relief depressions and on a slope). It can be assumed that for the *T. asiaticus*, the factors of moisture and illumination determined the high variability of these two ratios.

Our data showed low level of nitrogen (bot ammonium and nitrate) and a high level of phosphorus and potassium. High contents of nitrogen found in the flower garden near the railway station in Kandalaksha was caused by a spring application of nitrogen fertilizers (ammonium nitrate). The content of heavy metals in flower beds and under native plants did not differ significantly; therefore, averaged data are given. For all the studied soils, an excess of approximate permissible concentration (APC) for Ni (including in the control) and Cu was revealed, with a maximum in Olenegorsk (Table 1). The content of Pb exceeded APC only in Kandalaksha, and for Cd all values were below the APC.

Location plots		mg $100g^{-1}$				mg kg^{-1}				g kg^{-1}
	pH (KCl)	NO_3^-	NH_4^+	P_2O_5	K_2O	Ni	Cu	Cd	Pb	Fe
Murmansk	6.7	0.62	0.73	129.5	23.5	57.8	59.3	0.18	11.5	25.7
Olenegorsk	4.4 5.0	0.84 0.92	0.98 1.50	223.2 280.5	25.0 18.6	125.0	101.9	0.47	31.7	120.3
Apatity	6.1 5.9	1.24 1.67	2.04 2.98	387.8 404.5	250.0 203.5	49.8	50.1	0.23	20.9	52.3
Polyarnye Zori	6.4 6.5	1.32 1.44	1.02 0.98	94.0 101.2	75.0 92.0	75.2	57.1	0.25	15.6	72.6
Kandalaksha	7.1 6.9	1.39 4.53	0.94 6.32	152.7 203.8	32.5 28.9	92.2	48.5	0.29	41.0	40.4
The plant nursery PABGI	5.3	0.29	3.74	156.8	62.8	39.1	25.8	-	9.0	49.6
APC	-	-	-	-	-	*20.0*	*33.0*	*0.5*	*32.0*	-

Table 1. Chemical composition of soil (mean data). *Note*: - – no date, APC – approximate permissible concentration. Above the line are areas under native plants; under the line – flower beds.

The correlation analysis between the content of pigments in the leaves of the studied herbaceous plants and the main nutrients in the soil did not reveal significant dependencies. The exception was the Kandalaksha railway station area, where high significant correlation coefficients were obtained between ammonium nitrogen and the total content of chlorophylls in leaves of *T. asiaticus* (r = 0.83) and *P. elatior* (r = 0.89). It is possible that the use of fertilizers led to an imbalance in the distribution of pigments in the *T. asiaticus* during the period of active growth.

Between the total content of heavy metals in the root layer and green pigments (sum of chlorophylls) in the leaves, multidirectional trends were revealed (Fig. 6). Thus, for *T. officinale*, the absence of such dependence was shown. A similar trend was reflected in the work of Fazlieva and Kiseleva (2013), where no suppression of photosynthetic activity from the level of technogenic load was found. This species has a wide range of ecological tolerance to heavy metals, and as a result, it cannot be used to indicate environmental pollution by rail transport.

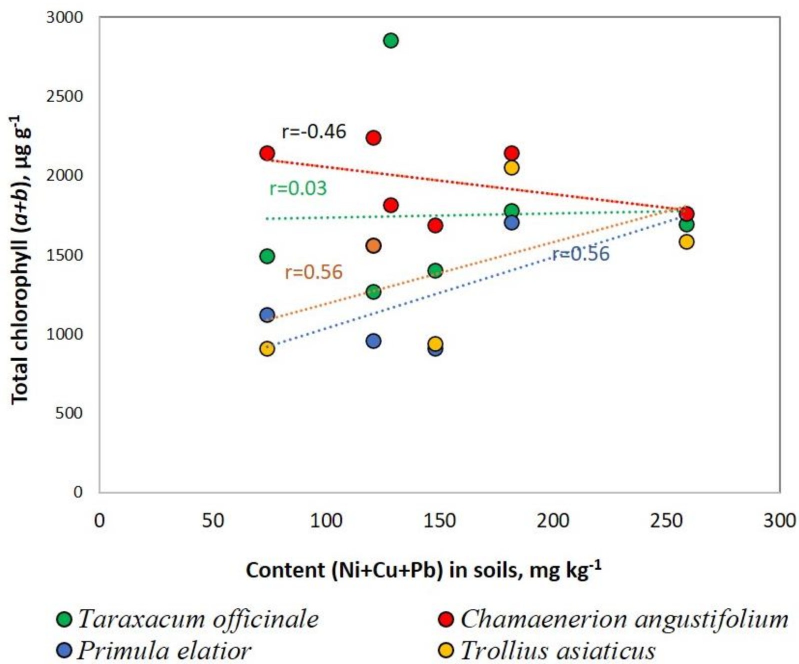

Fig. 6. The relationship between the content of chlorophylls (*a*+*b*) and heavy metals content in the leaves.

For *Ch. angustifolium*, a weak unreliable relationship between these two parameters was shown towards a decrease in the number of pigments with increasing pollution (r = -0.46). For most plants, a basal metal tolerance was shown when facing heavy metals (Clemens 2006). General tolerance mechanisms are based on exclusion, chelation and sequestration processes (Viehweger 2014). The scale and character of changes observed in plants upon heavy metals poisoning depend on the toxicity of the metal, the dose of exposure, and the tolerance of plants (Hossain et al. 2012).

In herbaceous introduced plants, on the contrary, an insignificant growth of green plastid pigments was revealed with an increase in the content of heavy metals in the soil (r = -0.56). High significant correlation coefficients were obtained only between the content of Fe and total chlorophyll (r = 0.95) and carotenoids (r = 0.96) in the leaves of *P. elatior*. In other species of herbaceous plants, a highly reliable correlation of coefficients was not found.

Conclusion

As a result of the research, it was shown that the native species *Ch. angustifolium* and *T. officinale* had different levels of accumulation of plastid pigments. In the leaves of *T. officinale*, which grows on the territory of railway stations in Murmansk, Olenegorsk, and Kandalaksha, the content of pigments of the photosynthetic complex was higher than in the control; in the leaves of *Ch. angustifolium*, it was mainly lower in the cities (except for carotenoids). The pigment fund in the leaves of *Ch. angustifolium* was higher than that of *T. officinale*, with the exception of station Murmansk. In introduced plant *T. asiaticus*, the content of chlorophyll *a* was comparable to native species, except for the railway station of Polyarnye Zori and the control plot, where it was much lower. The content of chlorophyll *b* also corresponded to native species and even significantly exceeded it in Kandalaksha. In *P. elatior*, the content of the main chlorophyll was higher than in *T. asiaticus*, except for the railway station of Apatity; the amount of chlorophyll *b* and carotenoids was lower than in other species, and it was commensurate with them only in Kandalaksha. It was revealed that in cultivated introduced plants on the territory of the railway station in Kandalaksha, the pigment content was found higher than in other cities and the control area. It was possibly due to a relatively high nitrogen content in the soil due to the use of nitrogen fertilizers.

It has been established that the level of soil contamination with heavy metals at railway stations does not affect the content of pigments of the photosynthetic complex in the leaves of herbaceous plants. It is shown that the minimum contents of chlorophylls and carotenoids in the leaves of plants were typical for the railway station territory of the city of Polyarnye Zori with a minimum level of railway exposure. In the conditional control zone, in the absence of railway transport, the content of photosynthetic pigments differed little from that in urban areas. Therefore, the use of the above decorative perennial herbaceous plants was expedient on the railway station territories of the cities of the Murmansk region.

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