TECHNOSPHERE SAFETY
ТЕХНОСФЕРНАЯ БЕЗОПАСНОСТЬ

UDC 581.9
https://doi.org/10.23947/2541-9129-2024-8-2-17-25

Research Article

Assessment of the Allergenic Potential of Urban Woody Flora of Rostov-on-Don

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Abstract

Introduction. Plant pollen causes various allergic reactions in humans, including respiratory diseases, immune system disorders, bronchitis, conjunctivitis, dermatitis, and hay fever. These diseases affect up to 30% of the world's population. In large cities, trees and shrubs used in landscaping are significant sources of allergenic dust. Despite this, the greening of cities worldwide often occurs without considering the allergenic properties of plants. With the development of proteomics, it has become possible to assess the degree of allergenicity of proteins that make up plant pollen in detail. Based on this information, a scale of potential allergenicity for woody plants has been developed. The aim of this study is to assess the allergenic potential of woody plants in the urban flora of Rostov-on-Don.

Materials and Methods. The object of the study was trees and shrubs used in the landscaping of Rostov-on-Don. The analysis of floristic data was based on the materials obtained during field work in 2023 on the territory of Rostov-on-Don. The author also used the lists of the city's dendroflora compiled between 2007 and 2022. The assessment of the potential allergenicity of woody plant species was conducted on a five-point scale, with 0 indicating plants that did not pose an allergic hazard, 1 indicating a low allergenicity level, 2 indicating a medium class, 3 indicating a high level, and 4 indicating a very high level of allergenicity.

Results. In the flora of woody plants in Rostov-on-Don, 61 species of potentially allergenic plants were identified, posing varying levels of danger to human health. The share of all types of potentially allergenic woody plants was 30% of the total number of urban woody flora species in the city. The most powerful sources of allergenic pollen included nine species (*Fraxinus Excelsior, Betula Pendula, B. Verrucosa, Platycladus Orientalis,* etc.), which posed the greatest threat of hay fever and other allergic reactions. As a rule, these were typically wind-pollinated plants that produced maximum amounts of pollen. The list of potentially allergenic species included a significant number of adventitious species (24 species), which made it difficult to control their spread. A taxonomic analysis of potentially allergenic species was carried out at the order level, for which specific protein reactions were identified and detailed approaches to the prevention and treatment of hay fever were developed. The orders Pinales and Fagales form the bulk of allergenic pollen in the winter-spring period.

Discussion and Conclusion. For the first time, studies were conducted on the allergenic activity of urban woody flora in the southern regions of Russia. An assessment of their allergenic potential allowed us to determine the level of threat of allergic reactions in humans. The greatest danger comes from both allergenic and invasive species that can spread actively and increase in numbers. Representatives of the Pinales and Fagales orders have proven to be significant sources of allergenic pollen, as they often have high ornamental qualities and play a prominent role in design projects. In some cases, it may be possible to replace these cultures with less allergenic alternatives, such as representatives of the Rosales order, to reduce the risk of allergic reactions.

Keywords: pollen of woody plants, allergies to pollen, urban flora, flora of Rostov-on-Don, adventive species

Acknowledgements. The author would like to thank the Editorial board of the journal and the reviewer for their competent expertise and valuable recommendations that improved the quality of the article.

For Citation. Sereda MM. Assessment of the Allergenic Potential of Urban Woody Flora of Rostov-on-Don. *Safety of Technogenic and Natural Systems.* 2024;8(2):17–25. https://doi.org/10.23947/2541-9129-2024-8-2-17-25

Научная статья

Оценка аллергенного потенциала древесной урбанофлоры города Ростова-на-Дону

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Аннотация

Введение. Пыльца растений вызывает у человека разнообразные аллергические реакции, в том числе респираторные заболевания, нарушения иммунной системы, бронхит, конъюнктивит, дерматит, сенную лихорадку. Ими страдает до 30 % населения мира. В крупных городах мощными источниками аллергенной пыльцы являются деревья и кустарники, используемые в зеленом строительстве. Тем не менее, озеленение большинства городов в мире проводится без учета аллергенности применяемых культур. С развитием протеомики появилась возможность детально оценить степень аллергенности различных белков, входящих в состав пыльцы. На этих сведениях сформированы шкалы потенциальной аллергенности древесных растений. Целью данного исследования явилась оценка аллергенного потенциала древесных растений урбанофлоры города Ростова-на-Дону.

Материалы и методы. Объектом исследования послужили деревья и кустарники, используемые в озеленении донской столицы. Анализ флористических данных основан на материалах, полученных в ходе полевых работ в 2023 году на территории города. Также автором использовались списки дедрофлоры города, составленные в период с 2007 по 2022 год. Оценка потенциальной аллергенности видов древесных растений проводилась по пятибалльной шкале, где 0 — растения, не представляющие аллергенной опасности; 1 — низкий класс аллергенности; 2 — средний класс; 3 — высокий класс; 4 — очень высокий класс аллергенности.

Результаты исследования. В составе флоры древесных растений Ростова-на-Дону выявлен 61 вид растений, представляющих разные уровни аллергенной опасности для здоровья человека. Доля исследуемых видов составляет 30 % от общего числа древесной урбанофлоры города. Самыми мощными источниками аллергенной пыльцы являются девять видов (*Fraxinus Excelsior*, *Betula Pendula, B. Verrucosa*, *Platycladus Orientalis* и др.), они представляют наибольшую угрозу возникновения поллинозов и других аллергических реакций. Как правило, это ветроопыляемые растения, продуцирующие максимальное количество пыльцы. Среди потенциально аллергенных видов отмечается значительное количество адвентивных видов (24 вида), что затрудняет контроль над их распространением. Проведен таксономический анализ потенциально аллергенных видов растений на уровне порядков, для которых выявлены специфические реакции белков и разработаны детальные подходы к профилактике и лечению поллинозов. Порядки Pinales и Fagales формируют основную массу аллергенной пыльцы в зимне-весенний период.

Обсуждение и заключение. Исследования аллергенной активности древесной урбанофлоры на юге России проведены впервые. Оценка ее аллергенного потенциала позволила определить степень угрозы возникновения аллергических реакций у людей. Наибольшую опасность представляют одновременно аллергенные и инвазионные виды, способные к активному распространению и увеличению своей численности. Мощными источниками аллергенной пыльцы оказались представители порядков Pinales и Fagales. Они же, как правило, обладают высокими декоративными качествами и играют ведущую роль в дизайнерских проектах. В ряде случаев эти культуры можно замещать менее аллергенными, например, представителями порядка Rosales.

Ключевые слова: пыльца древесных растений, аллергия на пыльцу растений, урбанофлора, флора города Ростова-на-Дону, адвентивные виды

Благодарности. Автор благодарит редакционную команду журнала и рецензента за компетентную экспертизу и ценные рекомендации по улучшению содержания статьи.

Для цитирования. Середа М.М. Оценка аллергенного потенциала древесной урбанофлоры города Ростова-на-Дону. *Безопасность техногенных и природных систем.* 2024;8(2):17–25. https://doi.org/10.23947/2541-9129-2024-8-2-17-25

Introduction. Respiratory diseases associated with atmospheric plant pollen are currently a global public health problem, as they affect about 30% of the world's population [1]. In Russia, allergic rhinitis, as the most common allergic disease, affects from 11 to 24% of the population, depending on the region [2, 3]. Allergic reactions can affect the human immune system and disrupt its work [4]. Pollen allergy can also cause a number of other diseases (bronchitis, conjunctivitis, dermatitis, hay fever). Prolonged exposure to its high concentrations can lead to chronic bronchitis and bronchial asthma [5].

Quite often, pollen allergy is associated only with the flowering of ambrosia (*Ambrosia sp.*) and some types of cereal plants (oats, wheat, corn). However, there are many more sources of allergenic pollen. It is necessary to add to this list cultivated plants (sugar beet, clover, sorrel, sunflower), weeds (dandelion, plantain, nettle, sagebrush, orach) and various types of woody plants. Pollen containing simple alkaloids, amines, saponins, and essential oils most often causes various grass pollen allergies [6]. There is disagreement among scientists about the allergenicity of pollen from coniferous plants such as cypress, yew and pine. Some authors [7] are of the opinion that pollen of coniferous plants has the least pronounced allergenic properties. Other experts [8] note that coniferous species have very high allergenic activity. It is obvious that the landscape and the nature of vegetation play a crucial role in the set of allergenic factors. Undoubtedly, in the conditions of large cities, the allergenic situation will be formed mainly due to woody plants.

There are few studies of urban vegetation as a source of allergens [9, 10]. In some countries of the world, there are aerobic stations that collect data on the content of allergens in the atmosphere. This allows a systematic approach to the study of the problem of identifying allergenic species and determining their level of danger.

One of the first initiatives in the field of determining the allergenicity of garden plant species is the study of T. Ogren [11], who developed the Ogren Plant Allergy Scale (OPALs), a system for measuring the ability of a plant to cause allergic reactions in humans. K. Hruska [12] established the phytoallergenic potential of various plant species present in urban ecosystems of Italy, based on their biological and phenological characteristics. More recent projects are [8, 13] with lists of characteristics and signs of allergenicity of the 100 most used types of urban landscaping. They were compiled in order to identify allergenicity problems in the population. Based on the above-mentioned works, as well as with the involvement of molecular studies of protein compounds in pollen [14], a list of 150 common trees and shrubs of Mediterranean cities was developed with an assessment of their potential allergenicity on a scale from 0 to 4 (VPA).

With the development of molecular biology, in particular proteomics, it was possible to approach the molecular mechanisms of human allergic reactions to pollen particles [15]. It has been established that the most powerful sources of allergens were representatives of the orders Fagales, Lamiales, Proteales and Pinales. The aim of the study presented today is to characterize the allergenicity of woody plants that make up the urban flora of Rostov-on-Don.

Materials and Methods. The object of the study was trees and shrubs that were in a stable and continuous urban landscaping culture. The analysis of floral data was based on materials obtained during field work in 2023 in the city. In addition, during the assessment of urban flora, the authors used the works of Ogorodnikova T.K., Pokhilko L.O., Fedorinova O.I. [16], Kozlovskii B.L., Kuropyatnikov M.V. [17], Berezin V.V. [18]. Invasiveness of plant species was determined in accordance with the data collected by Vinogradova Yu.K., Maiorov S.R., Khorun L.V. [19]. The assessment of the potential allergenicity of woody plant species was carried out on a scale [14], where 0 indicated that the plants did not present an allergenic risk, 1 represented a low allergenic class, 2 was a medium allergenic class, 3 was a high allergenic class, and 4 was a very high allergenic class.

Rostov-on-Don is located in a temperate continental climate zone with mild winters and hot, dry summers. The average air temperature, according to long-term observations, is +11.0°C. The coldest month is January (with an average temperature of –2.0°C). The warmest month is July (with an average temperature of +23.4°C). The average annual precipitation in Rostov-on-Don is 618 mm. The zonal type of vegetation surrounding the urban landscape are steppes [20].

Results. 61 species of potentially allergenic plants representing different levels of danger to human health have been identified in the flora of woody plants of Rostov-on-Don. According to [17], the so-called real assortment of woody plants in the city included 200 species of gymnosperms and angiosperms belonging to 97 genera from 43 families. The species that were in a stable and continuous urban gardening culture were taken into account. Thus, the proportion of all potentially allergenic woody plant species (VPA species) was 30% of the total urban woody flora (Table 1).

Table 1

Potentially allergenic species of woody plants in the urban flora of Rostov-on-Don

Genus (species)	Number of species in the genus	Adventitious	Invasive	VPA	Order
Acer (except *A. negundo*)	4	2		2	Sapindales
Acer negundo		North America	Transformers	2+	Sapindales
Aesculus hippocastanum		Central Europe		1	Sapindales
Ailanthus altissima		Asia	Transformers	3	Sapindales
Betula	2			4	Fagales
Campsis radicans		North America		1	Lamiales
Catalpa bignonioides		North America		1	Lamiales
Cercis siliquastrum		Asia		1	Fabales
Corylus avellana				4	Fagales
Cotoneaster	3			1	Rosales
Crataegus (except *C. monogyna*)	4			1	Rosales
Crataegus monogyna			Invasive plants		Rosales
Elaeagnus angustifolia			Naturalized plants	1	Rosales
Fraxinus excelsior				4	Lamiales
Ginkgo biloba		China		3	*Ginkgoales*
Gleditsia triacanthos		North America		1	Fabales
Hibiscus syriacus		Asia		1	Malvales
Juglans nigra		North America		3	Fagales
Juniperus	2	1		4	Pinales
Ligustrum vulgare				2	Pinales
Malus domestica				1	Rosales
Morus alba		Asia		3	Rosales

Morus nigra		Asia		4	Rosales
Paulownia tomentosa		China		1	Lamiales
Picea pungens		North America		1	Pinales
Pinus sylvestris				2	Pinales
Platanus x acerifolia		Asia		3	Proteales
Platycladus orientalis		China		4	Pinales
Populus alba			Transformers	3	Malpighiales
Populus deltoides				1	Malpighiales
Prunus	2			1	Rosales
Pseudotsuga menziesii		North America		1	Pinales
Pyrus comminis				1	Rosales
Quercus robur				2	Fagales
Rhus typhina		Africa		1	Sapindales
Robinia pseudoacacia		North America		1	Fabales
Rosa canina				1	Rosales
Salix alba				3	Malpighiales
Sambucus nigra				1	Dipsacales
Sophora japonica		Asia		1	Fabales
Sorbus aucuparia				1	Rosales
Spiraea x vanhouttei				1	Rosales
Tamarix tetrandra				2	Caryophyllales
Thuja occidentalis		North America		4	Pinales
Tilia cordata				2	Malvales
Ulmus	3			3	Rosales
Viburnum lantana				1	Dipsacales

It should be noted that the list of VPA species was rather heterogeneous in terms of allergenicity (Fig. 1).

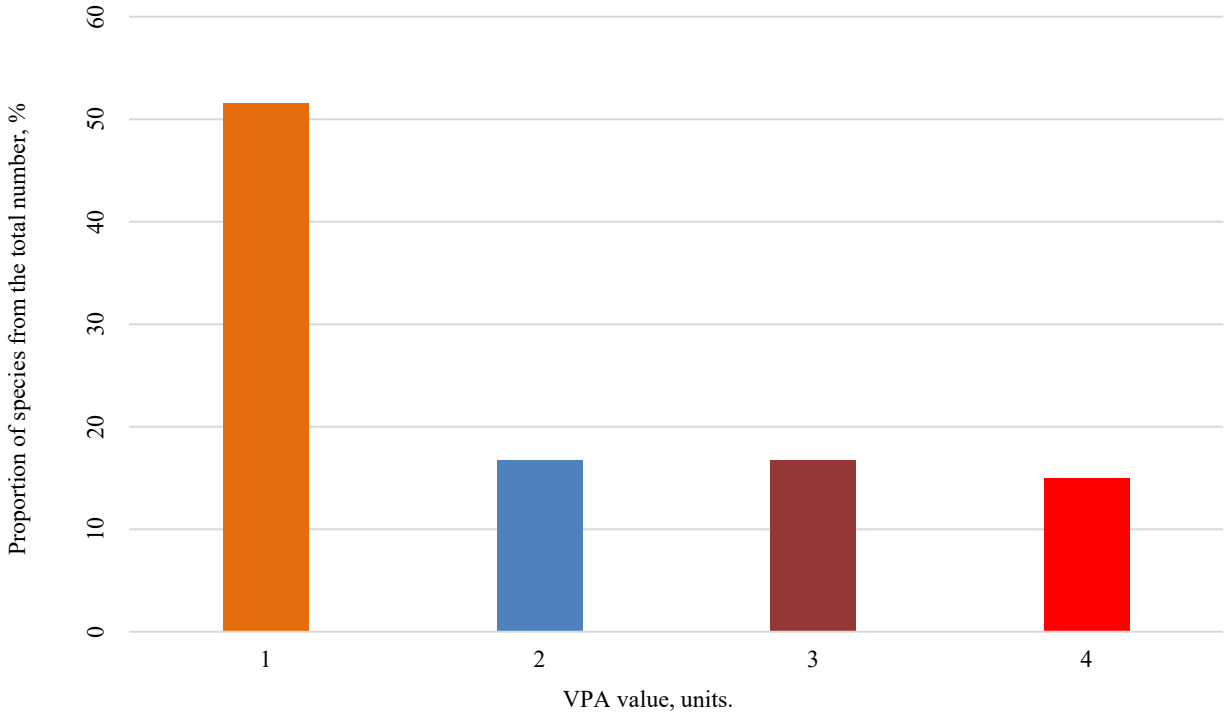

Fig. 1. Distribution of VPA species of urban woody flora of Rostov-on-Don by allergenicity levels

Group No. 1 turned out to be the most numerous, with 31 species, which was 51.6% of the total number of VPA species. They carried a minimal risk of allergic reactions. Nevertheless, this group included quite common breeds in the city, such as *Aesculus hippocastanum, Catalpa bignonioides, Gledicia triacanthos, Robinia pseudoacacia,* etc. These species were entomophilic and produced significantly less pollen than wind-pollinated plants. In some species of this group, only pollen showed allergenic activity, other parts of the plant might have the opposite effect. According to the authors [21], extracts of the fruits of *Gleditsia triacanthos* exhibited pronounced anti-allergenic properties.

Ten species (16.7%) were assigned to the second class of allergenicity. In particular, these were *Acer, Tilia cordata, Pinus sylvestris,* etc. By the nature of pollination, these were mixed species, i.e. insects were used to transfer pollen, but small portions of pollen entered the air in an anemophilic way to attract them [14].

The third category also included ten species (16.7%), which were characterized by a high degree of allergenicity. Among them were *Ulmus, Morus alba, Populus alba, Ailanthus altissima,* etc. When determining the allergenicity of *Ailanthus altissima*, experts could not come to a consensus, since the strategy of its pollination has not yet been clarified, namely whether it is pollinated amphiphilically or anemophilically. In the latter case, there was every reason to place it in the third category of VPA species.

The fourth category included nine species (15%) that posed the greatest potential threat of the occurrence of pollinosis and other allergic reactions. Among them *Fraxinus excelsior, Betula pendula, B. verrucosa, Platycladus orientalis* were well known and widespread, i.e. typically wind-pollinated plants, therefore producing maximum amounts of pollen.

The analysis of the identified potentially allergenic species showed a fairly high percentage of adventitious (alien to local communities) species. It was obvious that pollen from such plants caused more acute and less predictable reactions of the human body, and this happened for at least two reasons. Firstly, it was the lack of immune mechanisms to combat new proteins in the pollen of foreign plants [15], and secondly, some adventitious species aggressively captured new habitats, which led to a sharp increase in their numbers and, consequently, to an increase in pollen mass in the atmosphere. Thus, the proportion of adventitious species in the list of VPA species might carry additional information about the potential allergenic danger of urban flora (Table 1). 24 adventitious potentially allergenic species were found in the urban flora of Rostov-on-Don, which was 12% of their total number. Almost half of these species (45.8%) were from North America, the rest were from Asia or Africa. In addition, allergenic species included five invasive species with different invasive statuses. These species could be introduced into natural cenosises and transform natural ecosystems. It was necessary to control the spread of these species by urban flora monitoring.

Taxonomic analysis of VPA species showed the distribution of potentially allergenic species in orders for which specific protein reactions were identified and detailed approaches to the prevention and treatment of pollinosis were developed (Fig. 2).

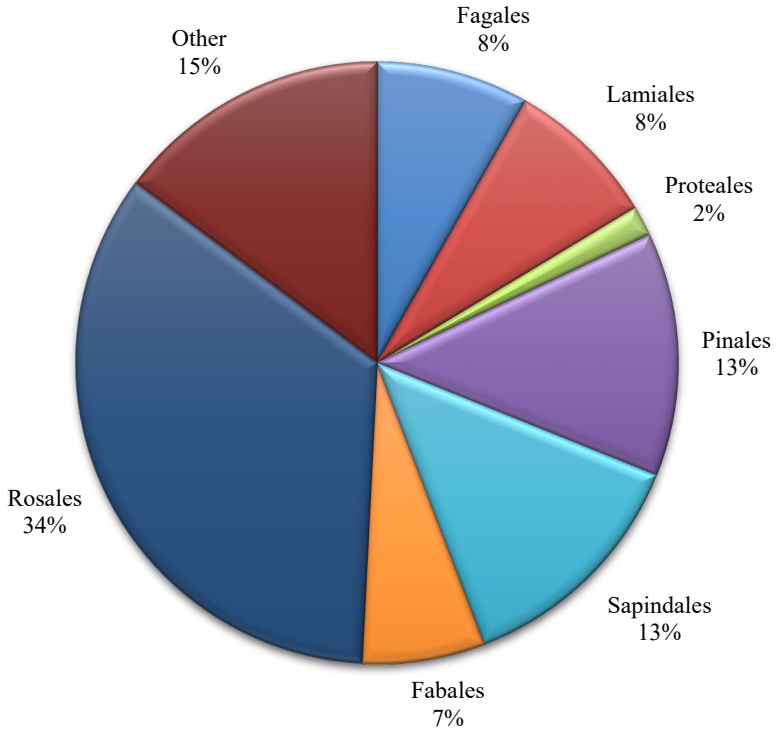

Fig. 2. Distribution of VPA species of urban woody flora of Rostov-on-Don in taxa at the level of orders

Pinales (13.1%) and Sapindales (13.1%) were the leaders in the spectrum of orders. The Pinales order included *Juniperus virginiana, J. sabina* widespread in green construction, which, according to the VPA scale, belonged to a class with a very high content of allergens. According to [22], the allergens Cry j 1 and Cup a 1, which belonged to the family of pectatliase proteins and demonstrated high levels of cross-reactivity, were found in juniper pollen. Pectatliase allergens were identified as major allergens not only in the pollen of Cupressaceae trees, but also in Asteraceae weeds, which brought them closer to ambrosia from this point of view.

The second place in the number of species was shared by the orders Lamiales (8.2%) and Fagales (8.2%). Pollen from Fagales trees was the main cause of winter-spring pollinosis in the temperate climatic zone of the Northern Hemisphere [23]. The order included the families Betulaceae, Juglandaceae, and Fagaceae, which most often caused allergies. A recent study has revealed the similarity of proteins in birch pollen with proteins of the lipocalin family, to which most allergens of animal origin belonged.

In the Lamiales order, only the Oleaceae family included species with allergenic activity. Thus, *Fraxinus excelsior* was a fairly powerful source of allergens. Its pollen productivity could reach the same level as that of birch, while the flowering seasons of both trees overlaped significantly. *Syringa vulgaris* and *Ligustrum vulgare* were two representatives of the Oleaceae family that caused allergies and asthma. Both plants were widely introduced into the culture of green spaces in Rostov-on-Don. Interestingly, *Ligustrum vulgare* was a tree pollinated by insects, so the concentrations of its pollen in the environment were usually very low. Nevertheless, there was evidence that *Ligustrum vulgare* could act as a sensibilizer for allergies to all Lamiales [24].

The Proteales order included only one species, *Platanus x acerifolia*. Platanus was a common species in southern cities, including Rostov-on-Don. The breed had high pollen productivity. For example, in Spain, during the flowering season, the released pollen could reach a level of 14% of the total amount of pollen [25, 26].

The Rosales order included 21 species (34.4%) of woody potentially allergenic plants from the families Rosaceae, Moraceae, Ulmaceae, etc. In this series, the most powerful sources of allergens were representatives of the Moraceae and Ulmaceae, and these were plants with either a mixed type of pollination, such as mulberry, or exclusively anemophilic — elm.

In the other orders, which accounted for 14.8%, only the Malpighiales deserved attention, which included *Populus* and *Salix*. These cultures had moderate allergenic activity.

Discussion and Conclusion. The assessment of the allergenic potential of woody plants of urban flora of Rostov-on-Don allowed us to establish the degree of threat of allergic phenomena among citizens. Determining the level of allergenic activity of each type of arboreal urban flora opens up new opportunities for further design of landscaping facilities that exert minimal stress on the respiratory organs and the human immune system. The greatest danger is posed by both allergenic and invasive species capable of active distribution and an increase in their numbers. The use of such species in the landscape design of the city, as well as the introduction of new similar species in landscaping should be under the control of arborists. The most powerful sources of allergenic pollen were representatives of the Pinales and Fagales orders. They, as a rule, have high decorative qualities and play a leading role in design projects. In some cases, these cultures can be replaced with less allergenic ones, for example, representatives of the Rosales order.

In the future, it is necessary to develop clear recommendations for urban landscape architects to limit the spread of allergenic tree species.

The study of the allergenic activity of arboreal urban flora for the cities of southern Russia was conducted for the first time. Further research will be related to the arboreal urban flora of cities in neighboring regions in order to conduct a comparative analysis.

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Conflict of Interest Statement: the author does not have any conflict of interest.

The author has read and approved the final version of manuscript.

Received 07.03.2024
Revised 25.03.2024
Accepted 02.04.2024

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Конфликт интересов: автор заявляет об отсутствии конфликта интересов.

Автор прочитал и одобрил окончательный вариант рукописи.

Поступила в редакцию 07.03.2024
Поступила после рецензирования 25.03.2024
Принята к публикации 02.04.2024