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*Article*

## **The Trans-Siberian Flora at the border of continents (section Perm – Kungur)**

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**Abstract.** The Trans-Siberian Railway connects Europe and Asia making the flora at this intersection of particular interest. When studying five railway stations and several spans of Perm Krai, 134 species of vascular (19 woody and 115 herbaceous) plants were identified. For comparison of local floras of the regions located along the Trans-Siberian Railway and adjacent to Perm Krai, we used the Sørensen's similarity coefficient. The Perm section (Perm – Kungur) showed the best flora similarity with the European one and by the aboriginal fraction – with the West Siberian site.

**Keywords:** Sørensen similarity, local flora, Perm Krai, alien species, invasive species

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*Научная статья***Флора Транссибирской железнодорожной магистрали на границе частей света (участок Пермь – Кунгур)**

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**Аннотация.** Транссибирская магистраль соединяет Европу и Азию, и особенный интерес представляет флора ее участка на стыке этих континентов. В ходе проведенных исследований пяти железнодорожных станций и нескольких перегонов Пермского края отмечено 134 вида сосудистых растений: 19 древесных и 115 травянистых. Выполнено сравнение локальных флор соседних с Пермским краем регионов на протяжении Транссибирской магистрали с помощью коэффициента сходства Сьеренсена. Максимальное сходство флоры пермского участка наблюдается с европейским участком Транссибирской магистрали. Однако сравнение аборигенных фракций флоры показало, что наибольшим сходством обладают пермский и западносибирский участки.

**Ключевые слова:** сходство по Сьеренсену, локальные флоры, Пермский край, чужеродные виды, инвазионные виды

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## Introduction

Having no natural analogues, trunk-railways are technogenic ecotopes characterized by the expected high proportion of alien plants in the flora (Ballesteros et al., 2021; Dubyna et al., 2021; Kotenko et al., 2022; Lozhnikova et al. 2023; Nikolin et al., 2022; Pyšek and Hulme, 2005; Pollock et al., 2017; Senator et al., 2016).

The Trans-Siberian Railway is one of the world's largest transport arteries and the unique study site connecting two continents with a diverse range of native species. Previously, we have studied the "railway" flora of the European, Ural and West Siberian sections of the Trans-Siberian Railway (Tokhtar et al., 2022; Vinogradova et al., 2020). For regional biodiversity, railways have a dual significance. On the one hand, they provide plant dissemination over long distances, and on the other – serve as "donor" foci, from which unintentionally introduced alien species spread into the nearby phytocenoses (Christen and Matlack, 2006; Galkina et al., 2021; Hansen and Clevenger, 2005; Rashid et al., 2021; Wagner et al., 2021).

Perm Krai is a floristically interesting region with the natural border (the Ural Mountains) between the continents. The geographic location of the Urals with the plentiful industrial enterprises has contributed to the railway transport development and the formation of a developed system of railway tracks with a length of more than three thousand kilometers (Tretyakova, 2010).

The purpose of this study is to inventory alien plants of the flora of the Ural-West Siberian section of the Trans-Siberian Railway and to analyze their similarity with those from other railway sites.

## Materials and methods

A vegetation cover was studied at the Komsomolskaya, Perm-1, Perm-2, Lipovaya Gora and Kungur stations, as well as at several stages of Perm Krai (Fig. 1). Geo-botanical descriptions were carried out on 21 sample areas in accordance with the standard methods (Abramova et al., 2011). Photographs of some species were posted on the iNaturalist platform (Seregin, 2020).

The study section of the Trans-Siberian Railway is located in the Cis-Ural southern taiga biome. The European section mainly passes through the Ladoga-Vycheгда southern taiga biome. Beyond the Urals, the Trans-Siberian Railway crosses several biomes with forest-steppe vegetation, which differ markedly by sets of native species (Map "Biomes of Russia", 2018).

Using the Sjörensén Index, we compared the floras of the Trans-Siberian section located in Perm Krai with European, Ural (Sverdlovsk oblast) and Western Siberian (from Tyumen to Novosibirsk) ones.

## Results and discussion

In the studied sites, we identified 134 species of vascular (19 woody and 115 herbaceous) plants (Table 1) from 37 families, among which Asteraceae (29 species), Poaceae (20 species) and Rosaceae (13 species) were most widely represented. The studied Perm and European (which unites the northern (Moscow – Yaroslavl – Kostroma – Kirov) and central (Moscow – Vladimir – Nizhny Novgorod) parts of the Railway) sections of the Trans-Siberian Railway demonstrate the highest similarity (Table 2). At the same time, the situation a bit changes if the native and non-native fractions of the flora are considered separately. For instance, the native flora consists of 34 families. Amaranthaceae, Oleaceae and Balsaminaceae are represented exclusively by alien plants (1–3 species per family) from 12 families, 9 of which include the native flora representatives as well. In terms of alien species (including invasive ones), the similarity of the Perm and European sites is much higher than that with the Urals and Western Siberia sections (37% versus 22 and 21%, respectively). As for the native flora, the best similarity (up to 50%) was established between the Perm and Western Siberia sections (Table 2).

At the Perm section of the Trans-Siberian Railway, 20 alien species were identified (Table 1). Among alien species (being invasive throughout the Trans-Siberian RR and included in the list of the Top 100



Fig. 1. Study sites at the Perm – Kungur section of the Trans-Siberian Railway.

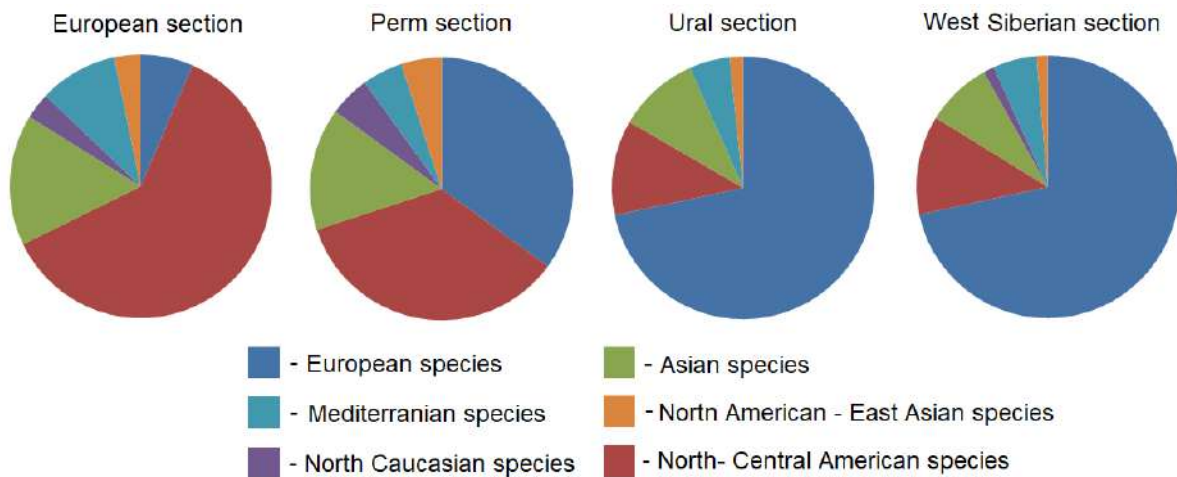


Fig. 2. The origin of invasive and alien species in different sections of the Trans-Siberian Railway.

most aggressive invasive species in Russia (Dgebuadze et al., 2018)), the species of North American origin (*Acer negundo*, *Fraxinus pennsylvanica*, *Amaranthus retroflexus*, *Epilobium adenocaulon*, *Erigeron canadensis*, *Hordeum jubatum*, *Oenothera biennis*), one species of North Caucasian (*Heracleum sosnowskyi*) and one of Central Asian origin (*Impatiens parviflora*) predominated. When moving to the east, the share of European alien species increased, whereas the species with natural North and Central American, Asian, Mediterranean and Caucasian ranges appeared approximately in equal proportions (Fig. 2). This is, probably, due to the fact that the species native to the European area but alien for the Urals and Siberia were found in the synanthropic habitats and along railways, through which, apparently, they still continue dispersion to the east.

The “escaped” from cultivation European species of lilac *Syringa vulgaris* and *S. josikaea* were noted growing not in plantings but on railway or steep city slopes. Another shrub – *Caragana arborescens*, was also referred to alien species of introduced origin (Tretyakova, 2011).

In recent decades, the range of *Lactuca serriola* has expanded to the east. In the Urals, this species is alien (Tretyakova, 2011). We also consider as alien species *Bunias orientalis*, *Cichorium intybus*,

**Table 1.** Plant species identified along the Trans-Siberian Railway at the Perm – Kungur section. “+” – species present at the specified sections, \* – alien species, # – species included in the Top 100 invasive species of Russia.

Plant species	Occurrence at the European section of the Trans-Siberian RR	Occurrence at the Ural section of the Trans-Siberian RR	Occurrence at the West Siberian section of the Trans-Siberian RR
<b>Tree layer</b>			
<i>Acer negundo</i> L. *#	+*#	+*#	+*#
<i>A. platanoides</i> L.	+		
<i>Betula pubescens</i> Ehrh.	+		+
<i>B. verrucosa</i> Ehrh.	+	+	+
<i>Caragana arborescens</i> Lam. *			
<i>Fraxinus pennsylvanica</i> Marshall *#			
<i>Picea obovata</i> Ledeb.			
<i>Populus nigra</i> L.	+		+
<i>Prunus padus</i> L.	+		
<i>Ribes rubrum</i> L.	+		
<i>Rosa majalis</i> Herrm.			
<i>Salix aurita</i> L.			
<i>S. caprea</i> L.	+		+
<i>Sambucus racemosa</i> L.	+		+
<i>Sorbus aucuparia</i> L.	+	+*	
<i>Syringa josikaea</i> J. Jacq. ex Reichenb. *	+*		
<i>S. vulgaris</i> L. *			
<i>Tilia cordata</i> Mill.			
<i>Ulmus glabra</i> Huds.	+		
<b>Herbaceous-suffruticous layer</b>			
<i>Achillea millefolium</i> L.	+	+	+
<i>Aegopodium podagraria</i> L.	+	+	
<i>Agrimonia pilosa</i> Ledeb.	+		
<i>Agrostis canina</i> L.			
<i>A. gigantea</i> Roth			
<i>A. tenuis</i> Sibth.			
<i>Alchemilla vulgaris</i> L.	+		
<i>Amaranthus retroflexus</i> L. *#	+*#	+*#	+*#
<i>Anthriscus sylvestris</i> (L.) Hoffm.			
<i>Arctium lappa</i> L.		+	+
<i>A. minus</i> (Hill) Bernh.			
<i>A. tomentosum</i> Mill.		+	+

Plant species	Occurrence at the European section of the Trans-Siberian RR	Occurrence at the Ural section of the Trans-Siberian RR	Occurrence at the West Siberian section of the Trans-Siberian RR
<i>Artemisia absinthium</i> L.		+	+
<i>A. sieversiana</i> Willd.		+	+
<i>A. vulgaris</i> L.		+	+
<i>Asparagus officinalis</i> L.			
<i>Athyrium filix-femina</i> (L.) Roth			
<i>Atriplex sagittata</i> Borkh.			
<i>A. tatarica</i> L.			+
<i>Avena sativa</i> L.			
<i>Berteroa incana</i> (L.) DC	+	+	+
<i>Brassica napus</i> L.		+	+
<i>Bromus inermis</i> Leyss.	+	+	+
<i>Bunias orientalis</i> L.*	+	+	+
<i>Calamagrostis epigeios</i> (L.) Roth	+	+	+
<i>Capsella bursa-pastoris</i> (L.) Medik.	+	+	
<i>Carduus crispus</i> L.	+	+	+
<i>Centaurea scabiosa</i> L.	+	+	+
<i>Cerastium arvense</i> L.	+		
<i>Chamaenerion angustifolium</i> (L.) Scop.	+	+	+
<i>Chamomilla suaveolens</i> (Pursh.) Rydb.	+		
<i>Chelidonium majus</i> L.	+	+	+
<i>Chenopodium album</i> L.	+	+	+
<i>Cichorium intybus</i> L.*	+	+	+
<i>Cirsium arvense</i> (L.) Scop.	+	+	+
<i>C. vulgare</i> (Savi) Ten	+	+	
<i>Convolvulus arvensis</i> L.	+	+	
<i>Crepis tectorum</i> L.		+	+
<i>Dactylis glomerata</i> L.	+	+	+
<i>Elytrigia repens</i> (L.) Nevski	+	+	+
<i>Epilobium adenocaulon</i> Hausskn.**	+		+
<i>Equisetum arvense</i> L.	+	+	+
<i>E. pratense</i> Ehrh.	+		
<i>Erigeron canadensis</i> L.**	+	+	+
<i>Fagopyrum esculentum</i> Moench	+		+
<i>Festuca ovina</i> L.			
<i>F. pratensis</i> Huds.	+	+	

Plant species	Occurrence at the European section of the Trans-Siberian RR	Occurrence at the Ural section of the Trans-Siberian RR	Occurrence at the West Siberian section of the Trans-Siberian RR
<i>F. rubra</i> L.	+	+	
<i>Fragaria moschata</i> Duchesne			
<i>Galeobdolon luteum</i> Huds.			
<i>Galeopsis bifida</i> Boenn.	+	+	+
<i>Galium mollugo</i> L.	+		
<i>G. rivale</i> (Sibth. & Sm.) Griseb.			
<i>Geranium sibiricum</i> L.	+	+	+
<i>Geum urbanum</i> L.	+		
<i>Glechoma hederacea</i> L.	+		+
<i>Heracleum sosnowskyi</i> Manden <sup>**</sup>	+**		+**
<i>Hieracium umbellatum</i> L.	+	+	
<i>Hierochlōe repens</i> (Host.) P. Beauv.			
<i>Hordeum jubatum</i> L. <sup>**</sup>	+**	+**	+**
<i>Hyoscyamus niger</i> L.			
<i>Impatiens parviflora</i> DC. <sup>**</sup>	+**	+**	
<i>Lactuca serriola</i> L. <sup>*</sup>	+	+*	+*
<i>L. tatarica</i> (L.) C.A. Mey	+	+*	+*
<i>Lappula squarrosa</i> (Retz.) Dumort.	+	+*	+*
<i>Lathyrus pratensis</i> L.	+	+	+
<i>Lemna minor</i> L.			
<i>Leontodon hispidus</i> L.			
<i>Leonurus villosus</i> Desf. ex D'Urv.	+		
<i>Lepidium ruderale</i> L. <sup>*</sup>	+*		
<i>Leucanthemum vulgare</i> Lam.	+		+
<i>Linaria vulgaris</i> Mill.	+	+	+
<i>Malva pusilla</i> Sm. <sup>*</sup>		+*	
<i>Medicago falcata</i> L.	+		+*
<i>M. lupulina</i> L.	+		+
<i>Melilotus albus</i> Medik.	+	+*	+*
<i>Myosotis arvensis</i> (L.) Hill	+		
<i>Nardus stricta</i> L.			
<i>Oenothera biennis</i> L. <sup>**</sup>	+**		
<i>Phleum pratense</i> L.	+	+	+
<i>Plantago major</i> L.	+	+	+
<i>Poa annua</i> L.	+		+
<i>P. compressa</i> L.			

Plant species	Occurrence at the European section of the Trans-Siberian RR	Occurrence at the Ural section of the Trans-Siberian RR	Occurrence at the West Siberian section of the Trans-Siberian RR
<i>P. palustris</i> L.			
<i>P. pratensis</i> L.	+	+	+
<i>Polygonum aviculare</i> L.	+	+	+
<i>P. bistorta</i> L.			
<i>Potentilla anserina</i> L.	+	+	+
<i>P. argentea</i> L.	+	+	+
<i>P. intermedia</i> L.			
<i>P. recta</i> L.	+		
<i>P. supina</i> L.*	+	+	+
<i>Ranunculus cassubicus</i> L.			
<i>Rorippa palustris</i> (L.) Besser	+		
<i>Senecio vulgaris</i> L.	+	+	+
<i>Seseli libanotis</i> (L.) W.D.J. Koch	+		
<i>Silene alba</i> (Mill.) E.H.L. Krause	+	+	+
<i>Sinapis arvensis</i> L.			
<i>Solanum dulcamara</i> L.	+		+
<i>Stellaria graminea</i> L.		+	+
<i>S. media</i> (L.) Vill.	+	+	
<i>Symphyotrichum novi-belgii</i> (L.) G.L. Nesom*			
<i>Tanacetum vulgare</i> L.	+	+	+
<i>Taraxacum officinale</i> F.H. Wigg.	+	+	+
<i>Trifolium hybridum</i> L.	+	+	+
<i>T. repens</i> L.	+	+	+
<i>Triplerospermum inodorum</i> (L.) Sch. Bip.	+	+	+
<i>Triticum aestivum</i> L.		+	+
<i>Tussilago farfara</i> L.	+	+	+
<i>Typha latifolia</i> L.			+
<i>Urtica dioica</i> L.	+	+	+
<i>Veronica officinalis</i> L.			
<i>V. persica</i> Poir. ex Lam.*			
<i>Vicia cracca</i> L.	+	+	+
<i>Viola arvensis</i> Murray	+		+



**Table 2.** Sørensen similarity of local floras for different sections of the Trans-Siberian Railway. The Sørensen coefficients for alien species (including the invasive fraction) are highlighted in red and for native – in green, black font indicates coefficients for the total flora without regard for natural ranges of species.

	European section	Perm section	Ural section	West Siberian section
European section		46%	38%	51%
Perm section	45% 37%		43%	41%
Ural section	39% 25%	41% 22%		52%
West Siberian section	40% 28%	50% 21%	52% 49%	

*Malva pusilla* and *Potentilla supina*, which are native to the European part but recognized as alien in the Urals and Western Siberia (Tretyakova, 2011).

In addition, three alien plant species – *Veronica persica*, *Symphyotrichum novi-belgii* and *Lepidium ruderae*, are invasive throughout the central European part of Russia (Mayevsky, 2014), but not widely introduced into natural phytocenoses and not included in the regional Black Books.

Differences in the species composition of the alien and native fractions of local floras can be explained by the fact that in Siberia (and partly in the Urals) a number of species (native to the European part) have been included in the flora as alien only in recent decades (archaeophytes are not considered as invasive and alien plants). For instance, alien species beyond the Urals are native to Middle Russia: *Artemisia absinthium*, *Atriplex tatarica*, *Berteroa incana*, *Chelidonium majus*, *Convolvulus arvensis*, *Fagopyrum esculentum*, *Lactuca tatarica*, *Lappula squarrosa*, *Medicago falcata*, *Melilotus albus*, *Senecio vulgaris*, *Sorbus aucuparia*, *Triticum aestivum* (Table 1). When calculating the Sørensen coefficient (Table 2), these species have been included in the sample of native and alien species for the European and West Siberian sections, respectively.

## Conclusion

The “railway” flora of Perm Krai is European in nature that is evidenced by the highest Sørensen similarity coefficient (46%) for the set of species of the European and Perm sections of the Trans-Siberian Railway. As for the aboriginal flora fraction, the maximum similarity is noted between the Perm and West Siberian sections. The presence and spread of alien plant species from west to east are responsible for the “railway” flora transformation in Perm Krai.

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