Botanica Pacifica. A journal of plant science and conservation. 2022. 11(1): 58–66
DOI: 10.17581/bp.2022.11117 EDN: JTDANV

RESEARCH PAPER

Alien and aboriginal flora of the Amur section of the Trans-Siberian Railway and its relationships with the characteristics of natural biomes

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Manuscript received: 11.04.2021
Review completed: 14.05.2022
Accepted for publication: 16.05.2022
Published online: 18.05.2022

ABSTRACT

An inventory of alien and native species of vascular plants was taken along the Trans-Siberian Railway, from the settlement of Yerofey Pavlovich to Kundur-Khabarovskiy railway station, with the total length of 1043 km (11 % of the TSR) explored. The study encompassed sixteen railway stations located in two biomes, including Amur-Zeya Boreal Taiga with variants southern taiga and subtaiga, and Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe ones. The highest similarity was displayed by south taiga and subtaiga variants of the Amur-Zeya Boreal Taiga biome, with Sørensen's coefficient equaling to Ks = 46 % on embankment slopes and Ks = 45 % for rail bed, while a low measure of similarity was detected in the railway right of way (Ks = 24 %). The number of railway flora species displays a strong positive correlation with average annual temperature and average annual precipitation within the biome, and a strong negative correlation with the total number of vascular plants recorded within the biome, as well as with the biome area.

Keywords: alien plant species, Amur region, flora, invasive alien plant species, natural biomes, the Russian Far East, the Trans-Siberian Railway

РЕЗЮМЕ

Котенко О.В., Пергл Я., Тохтарь В.К., Данилова Е.С., Виноградова Ю.К. Заносная и аборигенная флора Амурского участка Транссибирской железнодорожной магистрали и ее сопряженность с характеристиками естественных биомов. Проведена инвентаризация чужеродных и аборигенных видов сосудистых растений вдоль Транссибирской железнодорожной магистрали от станции Ерофей Павлович до станции Кундур-Хабаровский общей протяженностью 1043 км (11 % Транссиба). Обследовано 16 железнодорожных станций, расположенных в двух естественных биомах: Амуро-Зейском бореальной тайги (с вариантами южная тайга и подтайга) и Зее-Буреинском неморальных широколиственных лесов и лесостепей. Наиболее высокое сходство наблюдается между вариантами южной тайги и подтайги биома Амуро-Зейского бореальной тайги для откосов (Ks = 46 %) и железнодорожного полотна (Ks = 45 %), низкое сходство (Ks = 24 %) наблюдается для полосы отчуждения. Количество видов железнодорожной флоры имеет сильную положительную корреляцию со среднегодовой температурой и среднегодовым количеством осадков в пределах биома и сильную отрицательную корреляцию с общим количеством сосудистых растений, зарегистрированных в пределах биома, а также с площадью биома.

Ключевые слова: чужеродные виды растений, Амурская область, флора, инвазионные чужеродные виды растений, естественные биомы, российский Дальний Восток, Транссибирская железнодорожная магистраль

Railways are a specific type of technogenic plant habitats. They serve as migration paths for plants, contributing to alien species penetration and dissemination, and at the same time being the habitat of rare and protected plant populations.

There are close relationships between alien plant species dissemination and railway density (Benedetti & Morelli 2017, Szillassi et al. 2021). Despite the prevalence of native species along railways, the share of alien plants is larger there than in local floras (Jehlik et al. 2017). The "hot spots" are represented by railway stations where passengers are serviced, and commercial operations with cargos and cargo carriages are performed (Majekova et al. 2021). More alien species occur at railway stations than beyond (Jasprica et al. 2017, Rendeková et al. 2020). The share of invasive species among alien ones is quite large. As a rule, they are represented by annual herbaceous plants with a high seed productivity (Denisow et al. 2017). Invasive plant species occurring along railways can spread to adjacent areas and pose a threat to natural biodiversity (Tokhtar et al. 2020, Rashid et al. 2021, Wagner et al. 2021). They affect the dynamics of native populations and disrupt ecosystem processes (Mararakanye et al. 2017).

Various factors influence the development of railway flora diversity (Senator et al. 2012). These may include geographical ones, such as latitude, the specifics of roadside biotopes, slope exposure, vegetation on adjacent areas (Pourrezaei et al. 2017, Stajerova et al. 2017). Engineering and operational factors may also exert their influence. These are: the time of construction, ballast material type, electricity supply, traffic intensity, routing, haul length, technical condition and repair, the type of traffic – passenger or cargo transportation.

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Within the latter, the type of cargo may also be considered as an influence factor. Climate change influences the number of alien species (Dainese et al. 2017), as well as the ability of alien species to be established in the future and shrinking of the area occupied by native species. The data available testify to the correlation of railway flora species diversity with climatic variables: average annual air temperature and average annual precipitation (Wrzesien & Denisow 2017).

The Trans-Siberian Railway is the longest railroad in the world. It runs across two subcontinents: Europe (from 0 to 1777th km) and Asia (from 1778th to 9289th km). As much as 19.1 % of the TSR runs across Europe, while its length in Asia amounts to 80.9 %. The total length of the TSR in the Far Eastern federal district is almost 4,000 km (43 %). Earlier, we took an inventory of alien and native vascular plant species in the Baikal section of the TSR, along the length from Taishet to Ulan-Ude (Galkina et al. 2021a) and in the Ussurian section, along the length from Tel'man to Vladivostok (Galkina et al. 2021b). In the Baikal section, 266 species were found: 36 woody ones, 169 perennial herbaceous species and 61 species representing annual and biennial herbaceous plants. The share of alien species amounted to 23 % (62 species), with 4 % being invasive species. Four species are included in the top-100 most aggressive invasive species of Russia (Dgebuadze et al. 2018). In the Ussurian section, we detected 210 plant species, of which 22 are woody ones, 117 are perennial herbaceous species, and 71 species are annual and biennial herbaceous ones. The share of species which are alien for the Far Eastern flora equals to 35 % (73 species). As much as 66 % of them (48 species) are invasive ones, with 11 species included in the list of most dangerous invasive species of Russia (Dgebuadze et al. 2018).

Prior to our research, no study of Amur section of the TSR within natural biomes had been undertaken. No data were available on the specific diversity of vascular plants in various habitats: along the rail bed, on embankment slopes and in infiltration trenches. At the same time, Amur section is among the longest parts of the TSR, equaling to 1043 km, or 11 % of the total length. It was constructed in 1907–1916, when Amur railway was being laid from the town of Sretensk to the city of Khabarovsk (Kuzmin 2018). Today, this part of the TSR running across Amur Region includes 56 railway stations, 122 flag stations, 11 platforms, 3 pointsman's towers and 2 railway junctions.

Amur section of the TSR begins in the urban settlement of Yerofey Pavlovich (with the population of 4,368 people) and runs past the following localities: the town of Skovorodino (with the area of 22 km^2 and population of 8,745 people), the urban settlement of Magdagachi (population number equaling to 9,804), the urban settlement of Ushumun (1,859 people), the town of Shimanovsk (total area of 50 km^2 and population number equaling to 18,513), the town of Svobodny (225 km^2 in area and 52,918 residents), the urban settlement of Seryshevo (population number 9,575), the town of Belogorsk (total area of 117.6 km^2 and population number of 66,183), the urban settlement of Yekaterinoslavka (9,562 residents), the town of Zavitinsk (11.5 km^2 in area and population of 9,957), the urban settlement of Bureya (population of 3,942), and the urban settlement of Arkhara (14.4 km^2 in area and 8,437 residents) (TRANSSIB.RU 2022).

Local floras of the TSR in Amur region were explored incidentally, in the course of other studies. There is a cadastre of native and alien plant species for Amur Region (Starchenko 2008, Aistova 2009). It is necessary to explore the Amur section of the TSR within natural biomes, in order to assess the degree of impact produced by natural ecosystems on its local floras.

Our research aims at identifying alien and native plants species diversity in railway stations within Amur section of the TSR, as well as at analyzing the role of natural and climatic factors contributing to the dissemination of alien species and comparing railway floras of Amur, Baikal and Ussurian sections of the TSR.

MATERIAL AND METHODS

In 2020 and 2021, we conducted field studies with a view to identifying alien and native species composition of TSR stations, from the railway station of Yerofey Pavlovich to that of Kundur-Khabarovskiy (Fig. 1). Thus, the length explored amounted to 1,043 km (11 % of the total TSR length).

We studied parts of rail bed, embankment slopes and infiltration trenches at 16 railway stations (Table 1) and provided geobotanical relevés of 56 sample plots.

We recorded the vascular species composition of each sample plot, and determined the projective cover of woody, perennial, and annual and biennial plants, their average height, phenophase, the type of natural phytocenosis which is adjacent to the railway, as well as landscape specifics and precipitation character. Geobotanical relevés were prepared at the railway stations or at some distance there from.

Amur Region which is crossed by the TSR is located in two natural biomes: Amur-Zeya boreal taiga (AZBT) with variants southern taiga and subtaiga and Zeya-Bureya nemoral broadleaved forests and forest-steppe (ZBNF) one (Fig. 1). The climatic and floristic characteristics of natural biomes are shown, based on the "Biomes of Russia" map (Ogureeva et al. 2018).

Latin names of the plants are provided in compliance with the World Flora Online database (http://www.worldfloraonline.org/). For determining whether vascular plants represent native or alien species, we were guided by the monograph "Flora of the Amur region and its protection" (Starchenko 2008). Invasive species are provided in compliance with the Black book of flora in the Far Eastern Federal District (Vinogradova et al. 2021). We used Sørensen's coefficient to assess the degree of similarity between vascular plants species composition in various biomes within the TSR sections. Version 4.08 of PAST software was applied for statistical processing of the data obtained.

RESULTS AND DISCUSSION

The inventory revealed 243 vascular plant species, including 27 woody species, 138 perennial herbaceous plant species, and 78 annual and biennial ones (Table 2). A significant number of them occur in all the three ecotopes: along the rail bed, on embankment slopes and in infiltration trenches,

which is why the sum of the digits in the "Total of vascular plants" line (Table 2) and in the lines "Total of woody plants", "Total of perennial herbaceous plants" and "Total of annual and biennial herbaceous plants" (Table 2) for each biome exceeds the number of species found in one or another section under study. As much as 20 % of the total number of the species revealed occur in all the three TSR sections explored, that is, both in Amur and Baikal sections (marked as *in Table 2) and in the Ussurian section (marked as **).

In the Amur Region, the TSR runs through two natural biomes located in the taiga zone, the zone of coniferous and deciduous forests and the forest-steppe zone, respectively. As we move eastward, average annual air temperature tends to be higher (from -4.0°C in the west to -0.6°C in the east). Average annual precipitation also increases in areas farther to the east (from 437 to 623 mm). As for the total number of vascular plants in the biomes, it decreases farther to the east (Ogureeva 2018), with 1260 species recorded in the variant south taiga of the AZBT biome, 1170 ones in the variant subtaiga of the same biome and 1075 species in ZBNF biome. The number of vascular plants per 100 km^2 is higher in the variants south taiga and subtaiga of the AZBT biomes (500–600), while in the ZBNF biome it amounts to 400–550 species.

The highest number of species (172) was recorded on railways in the ZBNF biome; the number for the subtaiga variant of the AZBT is a little lower (115), while the inventory of the south taiga of the AZBT biome is almost twice as little as the former (99). We arranged biomes in terms of the total number of vascular plants recorded therein, as follows: south taiga variant of the AZBT biome (99) → subtaiga variant of the AZBT biome (115) → ZBNF biome (172).

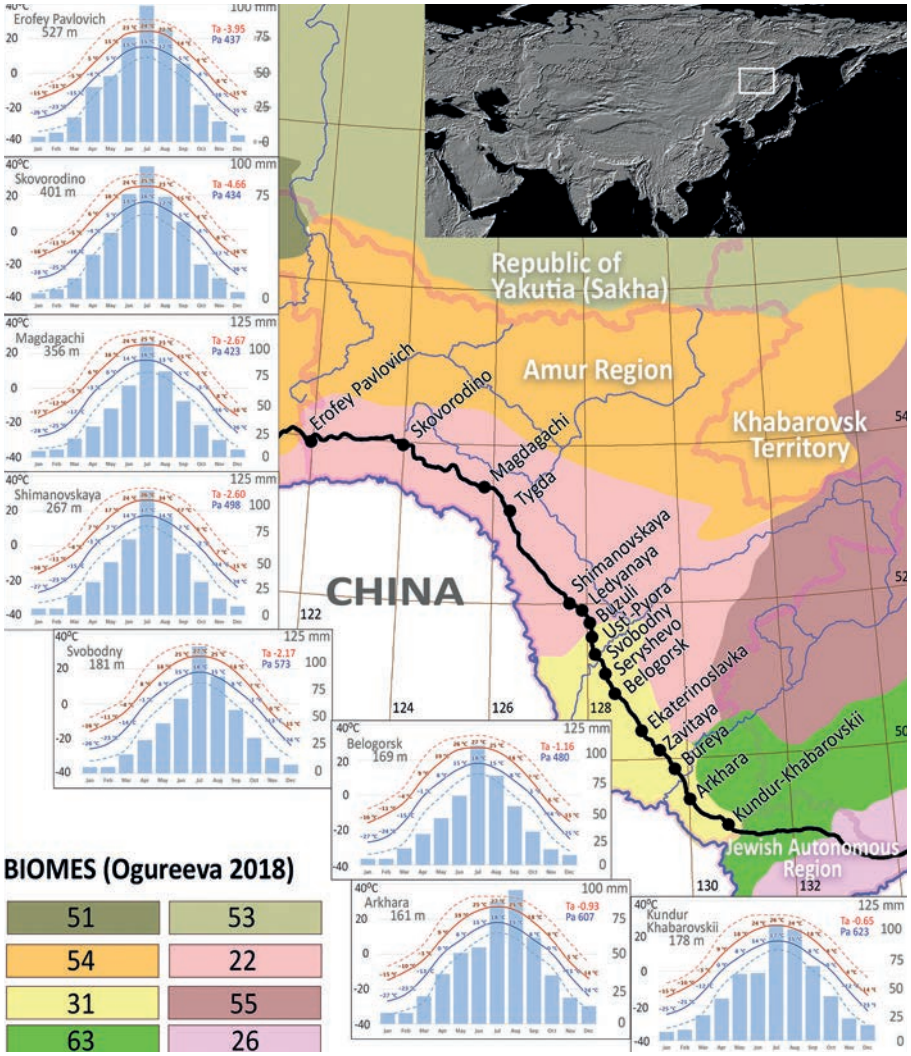

Figure 1 Study area. The Amur sector of the Trans-Siberian Railway (black line) with the railway stations, where data were collected. Selected stations are provided with climadiagrams, generated with Meteoblue resource (https://www.meteoblue.com/). Colors shade the biomes deleneated by Ogureeva (2018): 22 Amur-Zeya Boreal Taiga; 26 – Amur-Ussuri Hemiboreal Broad-Leaved-Coniferous and Small-Leaves Forests (Subtaiga); 31 – Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe; 51 – Northeastern Transbaikalian Taiga; 53 – Aldan-Maya Taiga; 54 – Yankan-Dzhagdy Taiga; 55 – Southern Okhotsk Taiga; 63 – Sakhalin-Sikhote-Alin Nemoral Coniferous-Deciduous and Deciduous Forests

Table 1. The list of railway stations explored within Amur section of the Trans-Siberian Railway

Biome name	Railway station	Geographic coordinates
Amur-Zeya Boreal Taiga: variant southern taiga	Yerofey Pavlovich	53.954533N 121.948879E
	Skovorodino	53.986951N 123.937445E
	Magdagachi	53.451149N 125.807323E
	Tygda	53.112822N 126.332973E
Amur-Zeya Boreal Taiga: variant subtaiga	Shimanovskaya	52.003579N 127.683294E
	Ledyanaya	51.747333N 128.070732E
	Buzuli	51.650419N 128.145833E
Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe	Ust'-Pyora	51.450520N 128.134900E
	Svobodny	51.392506N 128.138310E
	Seryshevo	51.091606N 128.379729E
	Belogorsk	50.920478N 128.461352E
	Yekaterinoslavka	50.372295N 129.104655E
	Zavitaya	50.117184N 129.450834E
	Bureya	49.811149N 129.810807E
	Arkhara	49.420566N 130.075047E
	Kundur-Khabarovskiy	49.107596N 130.755300E

This series is opposite to the distribution pattern of the total number of vascular plants for the biomes under study. Forty species occur in all the three biomes, including 26 native ones and 14 alien ones, 12 of the latter being invasive species.

Farther to the east, species become more abundant in railway infiltration trenches in all the three biomes, which falls in line with the pattern of an eastward increase in average annual temperature and precipitation. Rail bed and embankment slopes display another vascular plants' distribution pattern. The maximum number of species on the rail bed and embankment slopes was recorded in the ZBNF biome, which is the southern-most of the three (99 and 127 species, respectively). The variant subtaiga of the AZBT biome contains the minimum number, amounting to 42 species on rail bed and 71 on embankment slopes. In the variant south taiga of the AZBT biome, 43 species were recorded on the rail bed and 76 on embankment slopes.

Equal numbers of woody species were recorded in the variant subtaiga of the AZBT and ZBNF biomes (13 species in each one). The highest number of perennial herbaceous plants was found in the ZBNF biome (90 species), while that in the variant subtaiga of the AZBT biome amounted to 71 and in the south taiga of the same biome – to 62 species. The maximum number of annual and biennial herbaceous plants was recorded in the ZBNF biome (69 species), while in the variant south taiga of the AZBT biome it was lowest (25 species). In in the variant subtaiga of the tatter biome, we found 31 annual and biennial herbaceous plants species.

The largest share of alien species, inclusive of invasive ones, is represented by annual and biennial herbaceous plants, amounting to 66 species (27 %). In the group of perennial herbaceous plants, the number of alien species equals to 49 (20 %). The share of alien species among woody plants is lowest – 1 % (3 species).

Sørensen's coefficient (Table 3) revealed the highest similarity bet-

Table 2 Plant species occurring in various ecotopes of the Amur section of the TSR within natural biomes

BIOME	Flora fraction	Amur-Zeya Boreal Taiga (AZBT)						Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe (ZBNF)		
Variant and number of relevés		southern taiga, 14 relevés			subtaiga, 11 relevés			31 relevés		
Habitat type		RB	ES	IT	RB	ES	IT	RB	ES	IT
Column number	1	2	3	4	5	6	7	8	9	10
Woody plants										
Acer negundo L.*,**	I*A							+	+	
Betula platyphylla Sukacz.	N	+				+	+			
Crataegus dahurica Koehne et Schneid.	N		+							
Elaeagnus rhamnoides (L.) A. Nelson*	IA					+				
Larix gmelinii (Rupr.) Rupr.	N		+							
Lespedeza bicolor Turcz.**	N							+		
L. davurica (Laxm.) Schindl.	N							+		
L. juncea (L. f.) Pers.	N							+		
Malus baccata (L.) Borkh.*	N		+						+	
Pinus sylvestris L.*	N		+			+	+			
Populus alba L.	A						+			
P. suaveolens Fisch.*	N	+	+							
P. tremula L.*,**	N					+				
Prunus padus L.	N	+	+		+	+		+	+	
Rosa acicularis Lindl.*,**	N		+							
R. davurica Pall.	N					+	+			+
Rubus idaeus subsp. *melanolasius* Dieck ex Focke	N							+		
Salix kangensis Nakai	N								+	+
S. miyabeana Seemen**	N						+			
S. nipponica Franch. et Savat.**	N		+							
S. pierotii Miq.	N						+	+		+
S. schwerinii E. Wolf*,**	N					+				
Sorbaria sorbifolia (L.) A. Br.	N		+						+	
Spiraea media Franz Schmidt*	N		+			+	+			
S. salicifolia L.	N						+			
Ulmus davidiana var. *japonica* (Rehd.) Sarg.	N							+	+	
U. pumila L.*,**	N		+		+	+		+	+	+
Perennial herbaceous plants										
Achillea acuminata (Ledeb.) Sch. Bip.	N		+				+			+
A. millefolium L.*,**	IA	+	+	+	+	+	+	+	+	+
Aegopodium alpestre Ledeb.	N			+						
Agrimonia pilosa Ledeb.*,**	N	+	+			+	+	+	+	+
Agrostis gigantea Roth	N								+	+
A. scabra Willd.	N							+		
Allium strictum Schrad.	N								+	
Alopecurus arundinaceus Poir.	A									+
Angelica dahurica (Hoffm.) Benth. et Hook. f. ex Franch. et Savat.	N						+			
Artemisia commutata Besser*	N	+								
A. dubia L. ex B.D. Jacks.	N								+	+
A. integrifolia Richards.	N			+						
A. leucophylla (Turcz. ex Bess.) Pamp.	N				+					
A. mongolica (Fisch. ex Besser) Fisch. ex Nakai*	N					+				
A. rubripes Nakai	N						+			
A. vulgaris L.*,**	IA	+	+		+	+	+	+	+	+
Beckmannia syzigachne (Steud.) Fernald**	N								+	+
Bromus inermis Leyss.*,**	N		+						+	
B. pumpellianus Scribn.	N	+				+			+	
Calamagrostis epigejos (L.) Roth*,**	N			+				+	+	+
C. purpurea (Trin.) Trin.	N						+			
Caltha palustris L.**	N						+			
Calystegia inflata G. Don	N					+			+	+
Carex appendiculata (Trautv. et C.A. Mey.) Kük.	N			+						
C. bohemica Schreb.	N								+	+
C. capricornis Meinsh. ex Maxim.	N			+			+			
C. cespitosa L.	N			+			+			
C. duriuscula C.A. Mey.*	N	+	+	+			+			
C. laevissima Nakai**	N								+	
C. leiorhyncha C.A. Mey.**	N									+
C. limosa L.	N						+			
C. obtusata Lilj.	N		+							
Cerastium fontanum subsp. *vulgare* (Hartm.) Greuter et Burdet**	IA		+						+	+
C. pauciflorum Steven ex Ser.**	N								+	
Chelidonium asiaticum (Hara) Krachulc.*,**	N	+	+		+			+	+	
Cirsium arvense (L.) Scop.*,**	IA		+			+		+	+	+
C. pendulum Fisch. ex DC.	N				+					
Clematis fusca Turcz.	N								+	+
Convolvulus arvensis L.*,**	IA								+	
Dianthus chinensis L.	N		+							
Eleocharis palustris (L.) Roem. et Schult.	N									+
Elymus repens (L.) Gould*,**	N		+		+	+		+	+	
E. sibiricus L.*,**	N	+				+	+	+	+	+

Table 2 Continued.

Column number	1	2	3	4	5	6	7	8	9	10
Epilobium angustifolium L.*	N		+				+			
E. palustre L.	N	+						+	+	
Equisetum arvense L.*,**	N		+	+	+	+		+	+	+
E. fluviatile L.	N						+			+
E. palustre L.	N					+				+
E. pratense Ehrh.**	N					+			+	
E. sylvaticum L.	N		+	+		+				
Eriophorum chamissonis C.A. Mey.	N						+			
Erodium stephanianum Willd.	N				+					
Erysimum odoratum Ehrh.	A		+							
Festuca pratensis Huds.*	IA							+	+	+
F. rubra L.*,**	N						+			
Fragaria orientalis Losinsk.	N		+	+		+	+		+	
Geranium wilfordii Maxim.	N									+
G. wlassovianum Fisch. ex Link*	N						+			
Galium boreale L.	N			+						
G. spurium L.*	IA								+	
G. verum L.	N		+					+	+	
Geum aleppicum Jacq.*,**	N	+	+	+		+	+	+	+	+
Glycine max subsp. *soja* (Siebold et Zucc.) H. Ohashi	N					+	+		+	+
Gypsophila pacifica Kom.	N								+	
Hieracium umbellatum L.*	N		+		+	+			+	+
Hierochloe glabra Trin.	N	+								
Hordeum jubatum L.*,**	I*A						+	+	+	
Humulus lupulus L.	IA								+	+
Hypochaeris ciliata (Thunb.) Makino	N						+			
Inula britannica L.	N						+	+	+	+
I. linariifolia Turcz.	N					+	+	+	+	
Iris sanguinea Donn ex Hornem.	N			+						
I. setosa Pall. ex Link	N		+							
Ixeris chinensis subsp. *versicolor* (Fisch. ex Link) Kitam.	N					+				
Juncus articulatus L.	N									+
J. compressus Jacq.**	N									+
J. tenuis Willd.	IA								+	+
Kalimeris integrifolia Turcz. ex DC.	N					+				
Lactuca indica L.**	N					+		+		
L. sibirica (L.) Benth. ex Maxim.*,**	N					+				+
Leonurus deminutus V.I. Krecz.	N		+							
Lilium pensylvanicum Ker Gawl.**	N						+			
Linaria vulgaris Mill.*,**	IA					+	+	+	+	+
Luzula multiflora (Ehrh.) Lej.	N								+	
Maianthemum bifolium (L.) F.W. Schmidt	N			+						
M. dahuricum (Turcz. ex Fisch. et C.A. Mey.) LaFrankie	N				+	+	+			
Medicago falcata L.*,**	N					+	+	+		+
Melilotus albus Medik.*,**	IA					+	+	+	+	
M. suaveolens Ledeb.*,**	N	+	+					+	+	
Metaplexis japonica (Thunb.) Makino**	N							+	+	
Phleum pratense L.**	IA		+	+					+	+
Phragmites australis (Cav.) Trin. ex Steud.**	N								+	+
Ph. australis subsp. *altissimus* (Benth.) Clayton	N									+
Plantago depressa Willd.**	N	+	+		+	+	+	+	+	
P. major L.*,**	IA	+						+	+	+
Poa compressa L.**	IA								+	
P. palustris L.*	N								+	
P. pratensis L.*,**	N									+
Polemonium chinense (Brand) Brand	N			+			+			
Polygonum angustifolium Pall.	N								+	
P. divaricatum L.*	N					+	+		+	
Potentilla anserina L.*	N	+	+	+	+	+				+
P. argentea L.*	A					+	+	+	+	
P. chinensis Ser.**	N	+	+			+		+	+	+
P. × collina Wibel	A							+		
P. fragarioides L.	N		+						+	
P. multifida L.	IA	+	+		+	+			+	
P. tanacetifolia Willd. ex Schltdl.*	N					+	+	+	+	
Pulsatilla dahurica (Fisch. ex DC.) Spreng.**	N	+	+		+	+	+	+	+	
Ranunculus acris L.**	N	+	+	+						
R. japonicus var. *propinquus* (C.A. Mey.) W.T. Wang	N		+							
Rumex acetosella L.*	N									+
R. crispus L.*,**	A									+
Sanguisorba × tenuifolia Fisch. ex Link	N						+			
Saussurea amara (L.) DC.	A							+		
Scabiosa comosa Fisch. ex Roem. et Schult.	N	+	+			+	+	+	+	
Sedum aizoon L.**	N	+	+		+			+	+	+
Silene vulgaris (Moench) Garcke	N	+	+	+		+				
Sonchus arvensis L.*,**	A					+		+	+	+
Stachys palustris L.	A			+						
Stellaria filicaulis Makino	N	+	+							
S. radians L.	N					+	+			
Taraxacum campylodes G.E. Haglund*,**	IA	+	+	+	+	+	+	+	+	
T. dissectum (Ledeb.) Ledeb.*	N	+	+							
T. stenolobum Stschegl.	A		+							
Th. aquilegiifolium var. *sibiricum* Regel et Tiling	N	+	+		+			+	+	+
Th. petaloideum L.	N		+							
Trifolium pratense L.*,**	IA	+	+			+	+	+	+	+
T. repens L.*,**	IA	+	+		+	+		+		+
Valeriana officinalis L.	N								+	
Vicia amoena Fisch.	N			+	+		+	+	+	
V. amurensis Oett.**	N					+			+	
V. cracca L.*,**	N				+				+	
Vicia pseudorobus Fisch. et C.A. Mey.	N					+				
V. woroschilovii N.S. Pavlova	N							+	+	
Viola arcuata Blume	N								+	

ween the embankment slopes in the variants south taiga and subtaiga of the AZBT biome (Ks = 46 %). The similarity between local floras in the same biomes was a little lower on rail bed (Ks = 45 %), and in the railway right of way (Ks = 24 %). The lowest similarity was that between the railway right of way in the variant south taiga of the AZBT biome and in ZBNF one (Ks = 13 %). The above two biomes do not border on each other, and their average annual precipitation and temperature values also differ. On the whole, Ks values in the Amur section display fewer variations than in the Baikal section (13–53 % for the former and 12–57 % for the latter) (Galkina et al. 2021b). However, the variation range in the Amur section is wider than in the Ussurian one (28–45 % for the latter) (Galkina et al. 2021a). Ks values for the Amur section are similar to those of the European part of the TSR (20–53 %) (Vinogradova et al. 2020).

We also calculated the coefficient of correlation between the number of species recorded in the Amur section of the TSR and climatic and floristic characteristics of the biomes (Table 4).

Pearson correlation coefficient revealed a strong positive correlation between average annual temperature and average annual precipitation, whereas the biome area and the total number of "railway flora" species (as well as with separate groups thereof) are showed a strong negative correlation with the total number of vascular plants in the biome and the number of "railway flora" species (Table 5).

Of the 243 species recorded in the Amur section of the TSR, 32 % (77 species) represent alien ones, and 18 % (44 species) are invasive ones. Eight taxa are included in the top-100 most aggressive invasive species of Russia, namely: *Acer negundo* L., *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Bidens frondosa* L., *Erigeron canadensis* (L.) Cronq., *Hordeum jubatum* L., *Impatiens glandulifera* Royle, *Oenothera biennis* L. (Dgebuadze et al. 2018).

The above species occur most frequently on the rail bed, or in infiltration trenches, which is more seldom. Three of them (*A. artemisiifolia*, *E. canadensis*, *H. jubatum*) were recorded in two biomes, and five species (*A. negundo*, *A. retroflexus*, *B. frondosa*, *I. glandulifera*, *O. biennis*) – were found in one biome only (see Table 6). The number of most aggressive invasive species in the Amur section is twice as high as that in the Baikal section (4 species). However, it is lower than in the Ussurian section of the TSR (11 species). Comparing the number of aggressive invasive species in the biomes, we have obtained the following ascending sequence: south taiga variant of the AZBT biome (1) → subtaiga variant of the AZBT biome (2) → ZBNF biome (8).

As we move to the west, we see a decrease in the number of "railway flora" species, including alien and invasive ones, while the total number of vascular plants in the biome increases (Fig. 2).

CONCLUSION

Our research of the flora in the Amur section of the TSR enabled us to find 243 vascular plant species, including: 27 woody ones, 138 perennial herbaceous species, and 78 species representing annual and

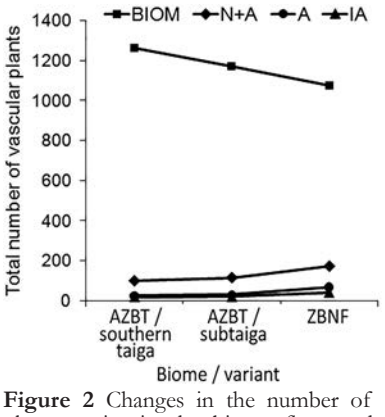

Figure 2 Changes in the number of plant species in the biome flora and its particular fractions from the west, eastward. AZBT – Amur-Zeya Boreal Taiga; ZBNF – Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe. BIOM – the total number of vascular plants in the biome, N+A – the total number of "railway flora" species, A – the number of alien species in the "railway flora", IA – the number of invasive species in the "railway flora"

Table 2 Continued.

Column number	1	2	3	4	5	6	7	8	9	10
Viola gmeliniana Roem. et Schult.	N		+							
V. philippica Cav.	N							+	+	
Annual and biennial herbaceous plants										
Acalypha australis L.	A							+	+	+
Amaranthus albus L.	A							+	+	
A. retroflexus L.*,**	I*A							+	+	+
Ambrosia artemisiifolia L.**	I*A		+					+		
Amethystea caerulea L.	N					+	+	+	+	
Androsace septentrionalis L.*	N	+	+		+	+				
Artemisia scoparia Waldst. et Kitam.*	N		+		+	+	+	+	+	+
A. sieversiana Ehrh.*,**	IA	+	+		+	+	+	+	+	
Bassia scoparia (L.) A.J. Scott*,**	A							+	+	
Bidens frondosa L.**	I*A									+
Brassica juncea (L.) Czern.	IA	+								
Carduus crispus Guirão ex Nyman**	A				+			+	+	
Carum carvi L.*	IA	+								
Centaurea pseudomaculosa Dobrocz.	A								+	
Chamaerhodos erecta (L.) Bunge*	N					+		+	+	
Chenopodium album L.*,**	N		+		+			+	+	+
Ch. glaucum L.*,**	N				+			+	+	+
Ch. rubrum L.**	A							+	+	
Cnidium monnieri (L.) Cusson	N					+				+
Commelina communis L.**	N							+	+	+
Crepis tectorum L.*	IA				+	+		+	+	+
Cuscuta campestris Yunck.	IA								+	
Digitaria ischaemum (Schreb.) Muhl.	A							+		+
Draba nemorosa L.*	N	+	+		+	+		+	+	
Echinochloa crus-galli (L.) P. Beauv.	N							+	+	+
Eragrostis pilosa (L.) P. Beauv.	N									+
Erigeron acris L.**	A					+		+	+	
E. canadensis L.*,**	I*A				+			+	+	+
Erodium cicutarium (L.) L'Hér.*	A		+			+				
Fagopyrum esculentum Moench*,**	A				+				+	
F. tataricum (L.) Gaertn.	N								+	
Galeopsis bifida Boenn.*,**	A							+	+	+
Geranium sibiricum L.*,**	N	+	+		+	+	+	+	+	+
Glycine max (L.) Merr.**	A							+	+	
Gypsophila muralis L.	N								+	
Helianthus annuus L.	A									+
Impatiens glandulifera Royle**	I*A									+
I. noli-tangere L.**	N									+
Kummerowia striata (Thunb.) Schindl.	N				+	+	+	+	+	+
Lactuca sativa L.	A							+		
Lappula squarrosa (Retz.) Dumort.*,**	N	+	+					+	+	+
Leonurus japonicus Houtt.	N								+	+
Lepidium densiflorum Schrad.*,**	IA	+	+			+	+	+	+	
L. virginicum L.	A							+		
Linum usitatissimum L.	A	+	+		+			+	+	
Medicago lupulina L.*,**	IA							+		
Melilotus officinalis (L.) Pall.	N							+	+	
Odontites vulgaris Moench*	IA						+	+	+	+
Oenothera biennis L.	I*A							+	+	
O. villosa subsp. *strigosa* (Rydb.) W. Dietr. et P.H. Raven	A								+	
Orostachys malacophylla (Pall.) Fisch.*	N					+		+		
Pastinaca sativa L.	IA								+	+
Persicaria maculosa Gray	A							+		+
Picris davurica Fisch. ex Hornem.	N		+		+	+		+	+	
Plantago indica L.	A							+		
Poa annua L.*	IA							+	+	
Polygonum aviculare L.*,**	N									+
Portulaca oleracea L.	A							+		
Potentilla supina L.	N	+	+		+			+	+	+
Ranunculus cantoniensis DC.	N		+							
Rorippa palustris (L.) Besser**	N									+
Rubus arcticus L.	N	+								
Rumex maritimus L.	N								+	+
Salsola collina Pall.*	N				+				+	
Secale cereale L.	A				+					
Senecio dubitabilis C. Jeffrey et Y.L. Chen	N		+							
S. viscosus L.*,**	IA							+		
S. vulgaris L.*,**	IA	+			+	+		+	+	
Setaria pumila (Poir.) Roem. et Schult.*	N							+	+	+
S. viridis (L.) P. Beauv.*,**	N		+		+	+	+	+	+	
Sibbaldianthe bifurca subsp. *orientalis* (Juz.) Kurtto et T. Erikss.*	N		+							
Sisymbrium officinale (L.) Scop.	IA							+	+	+
Sonchus oleraceus (L.) L.*,**	IA		+		+			+	+	
Tragopogon orientalis L.*	A		+					+	+	
Trifolium arvense L.	IA					+		+	+	
T. campestre Schreb.	IA		+	+			+	+	+	+
Vicia hirsuta (L.) Gray	A		+			+			+	
Xanthium albinum (Widd.) Scholz et Sukopp	IA								+	
Total of woody plants: 27		3	11	0	2	9	8	9	7	4
Total of perennial herbaceous plants: 138		28	44	23	20	43	42	41	69	47
Total of annual and biennial herbaceous plants: 78		12	21	1	20	19	9	49	51	31
Total of vascular plants (243 species)		43	76	24	42	71	59	99	127	82

Note: * – the species occurs in the Baikal section of the TSR, along the length from Taishet to Ulan-Ude; ** – the species occurs in the Ussurian section of the TSR, from Tel'man to Vladivostok; N – native species; A – non-invasive alien species; IA – invasive alien species included in the Black list of flora of the Far Eastern federal district (Vinogradova et al. 2021); I*A – invasive species included in the top-100 most dangerous invasive species of Russia. Habitat type: RB – rail bed; ES – embankment slope; IT – infiltration trench.

Table 3. Sørensen's similarity coefficient (%) for various habitats associated with different biomes along the TSR.

Biome: variant	Habitat type		
	Rail bed	Embankment slopes	Infiltration trenches
Amur-Zeya Boreal Taiga: variant southern taiga / Amur-Zeya Boreal Taiga: variant subtaiga	45	46	24
Amur-Zeya Boreal Taiga: variant southern taiga / Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe	43	45	27
Amur-Zeya Boreal Taiga: variant southern taiga / Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe	38	43	13

Table 4. Physico-climatic and floristic characteristics of the biomes crossed by the Amur section of the TSR.

Biome	Amur-Zeya Boreal Taiga		Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe
Variant	south taiga	subtaiga	—
Area, thousand km²	93.7	37.5	35.6
Physical-and-climatic characteristics:			
average annual temperature, °C	-4.0	-3.6	-0.6
average annual precipitation, mm	421	540	641
floristic characteristics			
total number of vascular plants in the biome	1260	1170	1075
number of vascular plants per 100 km²	500–600	500–600	400–550
total number of vascular plants recorded along the TSR including:	99	115	172
woody plants	12	13	13
perennial herbaceous plants	62	71	90
annual and biennial plants	25	31	69

Table 5. Correlation between biome characteristics and the population of various "railway flora" groups (Pearson correlation coefficient)

Biome characteristics	Average annual temperature, °C	Average annual precipitation, mm	Total number of vascular plants in the biome	Total number of vascular plants per 100 km²	Biome area
Total number of vascular plants recorded in the Amur section of the TSR	0.9948	0.9356	-0.9559	-0.9780	-0.69067
Number of woody plants	0.5903	0.8886	-0.8581	-0.5001	-0.99959
Number of perennial herbaceous plants	0.9775	0.9688	-0.9824	-0.9492	-0.76603
Number of annual and biennial herbaceous plants	0.9998	0.9027	-0.9279	-0.9921	-0.62758
Number of native species	0.9656	0.9801	-0.9906	-0.9320	-0.79755
Number of alien species	0.9999	0.8941	-0.9205	-0.9943	-0.61224
Number of invasive species	0.9996	0.8813	-0.9092	-0.9969	-0.58991

Table 6. The occurrence rate of vascular plant species included into the top-100 most dangerous invasive species of Russia, at the TSR stations explored

Biome	Amur-Zeya Boreal Taiga							Zeya-Bureya Nemoral Broadleaved Forests and Forest-Steppe								
Variant	south taiga			sub-taiga				—								
Railway stations	Yerofey Pavlovich	Skovorodino	Magdagachi	Tygda	Shimanovskaya	Ledyanaya	Buzuli	Ust'-Pyora	Svobodny	Seryshevo	Belogorsk	Yekaterinoslavka	Zavitaya	Bureya	Arkhara	Kundur-Khabarovskiy
Acer negundo											+			+		
Amaranthus retroflexus															+	+
Ambrosia artemisiifolia			+													+
Bidens frondosa												+				
Erigeron canadensis					+			+	+	+	+	+			+	+
Hordeum jubatum						+			+				+	+	+	+
Impatiens glandulifera															+	
Oenothera biennis															+	
Total plant species in stations:	0	0	1	0	1	1	0	1	2	1	2	2	1	2	5	4
Total plant species in the biome / variant	1				2			8								

biennial herbaceous species. The highest species diversity was recorded on railway embankment slopes. The three biomes under study share 40 species, of which 26 are native ones and 14 represent alien species, 12 of the latter being invasive ones.

Flora of the Amur section of the TSR displays a strong relationships with the characteristics of natural biomes: a positive correlation was found with average annual temperature and average annual precipitation within the biome, and a strong negative correlation with the total number of vascular plants recorded within the biome, as well as with the biome area.

The share of species which are alien for the flora of the Amur region amounted to 32 % (77 species), 8 of which represent the top-100 most aggressive invasive species of Russia. The share of alien species was lowest among woody plants (1 %), and highest among annual and biennial plants (27 %).

Thus, we have found two major differences between the flora of the Amur section of the TSR and that of the Baikal and Ussurian sections: 1) a lack of correlation between the number of species

and average annual precipitation, and 2) a higher similarity between the biomes in terms of species diversity on the rail bed and on embankment slopes.

ACKNOWLEDGEMENTS

The research was carried out under the State Assignment of the Botanical Garden-Institute of Far East branch of the RAS (122040800085-4) and Tsitsin Main Botanical Garden RAS (19-119080590035-9), supported by RFBR grant No. 19-54-26010 and by the Czech Science Foundation, grant No. 20-10349J. The authors would like to express their gratitude to G.F. Darman, research fellow of the Amur branch of the Botanical Garden-Institute FEB RAS for her assistance in identifying individual taxa.

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