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Vascular flora of railway junctions in the Upper Tracian Lowland (Bulgaria)

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Abstract. Floristic studies have been carried out in the Upper Thracian Lowland in 14 railway stations: Dimitrovgrad, Knizhovnik, Malevo, Maslinovo, Most, Stara Zagora, Yabalkovo, Uzundzhovo, Harmanli, Skobelevo, Karadzhalovo, Stalevo, Plovdiv and Haskovo during the period 2017 to 2019. A total of 267 species, 174 genera and 53 families of higher vascular plants were identified. Alien and invasive species make up for a relatively high percentage of 9.4% in the railway flora. This indicates that the railway network plays an important role in the penetration and further dispersal of alien species in Bulgarian. The long-distance spread of railway areas is most common with passing trains and people moving. The largest number of alien species were found at stations with more intensive movement of passengers and cargo, where maneuvers are performed, stay of freight trains, such as Dimitrovgrad, Haskovo, Plovdiv, Stara Zagora. The alien species found at several of the studied railway stations were: *Convolvulus arvensis* L., *Erigeron canadensis* L., *Fallopia convolvulus* (L.) Á. Löve, *Amaranthus hybridus* L., *Amorpha fruticosa* L. Individual plants of strongly invasive *Ambrosia artemisifolia* L. have been identified in the railway station in the Haskovo City.

Key words: invasive alien species, railway flora, Tracian Lowland.

Introduction

The main feature of the flora in urban areas is the high participation of synathropic species, which have found conditions for establishment and secondary settlement there. The most common transport systems created by human activity are primary habitats and a corridor for the dispersal of several allochthonous and invasive species (Hayasaka et al., 2012). So far, in Bulgaria studies of the road and rail synanthropic flora are very fragmentary or refer only to a particular group of plants (Petrova & Vladimirov, 2009; Vladimirov & Petrova,

2009a; b). Litowski (1993) in a single inventory of the flora on the railway system in Plovdiv, reported 232 species, some of which were new to the area and a result of accidental transportation. In the last 10-15 years, more than 30 alien species of plants have settled in our antropophytes habitats (Petrova et al., 2012). These are the most common areas around rivers, railways and roads – generally anthropogenous heavily damaged areas. To date the invasive plants in Bulgaria were studied with numerous floristic notes (Petrova & Vladimirov, 2012), and summary information about 60 invasive and potentially invasive alien plant species in our flora has been given by Petrova et al. (2012). In this regard adventive and invasive species with the greatest impact are best studied, but more studies of species that are naturalized but not (yet) invasive are needed to improve understanding of the mechanisms leading to successful invasion (Pyšek et al., 2008).

The main purpose of this study was an inventory of vascular plants occurring at the railway stations of the Upper Tracian Lowland. The objectives associated with the main goal included and analysis of the railway flora and occurrence of alien and invasive species.

Material and Methods

The Thracian Lowland has developed as a crossroads for routes of goods and passenger transport. This study was carry out from spring to autumn in 2017- 2019, along with transect plots randomly selected 14 stations that fall on the territory of the Upper Thracian Lowland (Table 1). The sampling of study areas are represented (Fig. 1) on the BG-Mountains map (2019). At each site the investigated area was only the station proper (the part between the rails, between the lines, near railway buildings and platforms), up to the end of the stone embankments, but not only used but also abandoned lines were investigated.

For identifying the species was used standard keys, books and guides (Delipavlov & Cheshmedjiev, 2011; Tutin et al., 1964; Tutin et al., 1968-1980; Flora of Bulgaria (Yordanov, 1963-1979; Velchev, 1982-1989; Kozhuharov, 1995; Kozhuharov & Anchev, 2012). An inventory of the deposited available materials of Agricultural University-Plovdiv (SOA) from the studied area was made. In the course of this study, a 50 herbarium samples were collected and preserved, which is now stored at same herbarium. The origin of the adventive species is according to Assyov & Petrova (2012). Several species with cosmopolitan distribution were considered invasive, according to Petrova et al. (2012). In the analysis of species, the spectrum of life form was noted (Raunkiaer, 1934).

Results and Discussion

Flora of the investigated areas

The number of identified species families are provided in Table 1, for each of the stations, visited. On the railway network in the territory of the Upper Thracian Lowland a total of 267 species were identified, representing 174 genera in 53 families (Table 2). The analysis of the taxonomic structure of the railway flora in the studied area shows that the division Equisetophyta is represented by 1 species. In general, spore plants are poorly represented as a permanent element of the studied railway network. The species was found in the city of Plovdiv and the rail stations in the village of Malevo, where places with higher humidity have been registered. The lack of wet habitats is the reason for the absence of representatives of ferns (Pteridophyta). Quite logically, the seed plants (Magnoliophyta) take the largest share, of which the dicotyledons occupy 87.68%, and the monocotyledons are represented by 2 families, 23 genera and 33 species or 10.32%. The gymnosperms include 1 family, 1 genus and 1 species - *Cupressus sempervirens* L., introduced as an ornamental plant. In terms of taxonomic diversity, the largest number of species

belong in the families: Asteraceae - 49 species, followed by Poaceae - 33 species, Fabaceae - 29 species, Caryophyllaceae - 11 species, Polygonaceae - 10 species, Lamiaceae - 9 species, Brassicaceae - 9 species, Apiaceae - 9, Rosaceae - 8 species, Chenopodiaceae - 8 species, Euphorbiaceae - 8, Scrophulariaceae - 7 species, Boraginaceae - 6, etc. 21 of the established families are represented by one genus and one species (Table 2).

The relatively high presence participation of species from the families Euphorbiaceae, Polygonaceae, Chenopodiaceae on the railway network. This is explained by the fact that these families include a large number of weed and ruderal species which grow in habitats with anthropogenic influence such as railway networks, roadside pavements, suburban habitats, landfills and others. As expected, the species richness was lowest in the relatively new and maintained rail stations - e.g. Stalevo, Yabalkovo, Karadzhalovo. Most species were found at the following stations: Most (68 species), Maslinovo (67 species), Knizhovnik (61 species), Plovdiv (59 species), Dimitrovgrad (54 species), Haskovo (48 species) - Table 1. This is explained on the one hand by the presence of more diverse habitats at these stations, and on the other hand by the reduced treatment of weeds in the end sections of the stations, where denser vegetation is found, including perennial herbaceous plants, sometimes shrubs and single tree species. *Tribulus terrestris* L. was found at all of the studied rail stations. Apart from this, the most frequently found species were: *Chenopodium album* L., *Centaurea solstitialis* L., *Cynodon dactilon* (L.) Pers., *Erigeron canadensis* L., *Convolvulus arvensis* L., *Crepis foetida* L., *Cichorium intybus* L., *Bromus sterilis* L., *Bromus tectorum* L., *Ballota nigra* L., *Avena fatua* L, *Amaranthus retroflexus* L., *Dasypyrum villosum* (L.) Borbás, *Eryngium campestre* L., *Fallopia convolvulus* (L.) Á. Löve and *Hordeum murinum* L. Species distribution over far linear distances by rail space takes place mostly with passing trains and people movement. At short distances, apart from trains and human activity, diasporas are carried by ants, rodents, wind, running water in heavy rain and more other. In some cases, the transfer of species takes place during construction and reparation works on railway lines and stations.

Ecological and biological structure of the floral elements

Among the most frequently noted plants were species that have a wide range of ecological preferences, such as: *Cynodon dactylon* (L.) Pers., *Poa bulbosa* L., *Galium aparine* L., *Bromus sterilis* L., *Stelaria media* (L.) Vill., *Capsella bursa-pastoris* (L.) Medik., *Thlaspi praecox* Wulfen, *Melilotus officinalis* (L.) Pall., *Trifolium arvense* L., *Euphorbia helioscopia* L., *Centaurea diffusa* Lam., *Chelidonium majus* L., *Eryngium campestre* L., *Cardaria draba* (L.) Desv., *Brassica nigra* (L.) K. Koch, *Raphanus raphanistrum* L., *Geum urbanum* L., *Cirsium ligulare* Boiss., *Phleum pratense* L., *Alopecurus pratensis* L., *Poa pratensis* L., etc. Most of these species usually occurred on abandoned railway tracks and therefore were not the result of strong anthropogenic influence.

Tree and shrub vegetation in the studied railway stations is poorly represented. There are single *Salix alba* L., *Sambucus ebulus* L., *Rosa canina* L., *Rubus sp.*, *Prunus spinosa* L., *Prunus cerasifera* Ehrh., *Pyrus communis* L., *Rubus caesius* L., seedlings of *Populus nigra* L., *Platanus orientalis* L., *Gleditsia triacanthos*, etc.

Analysis of the life cycle indicated therophytes were dominant in the life form spectrum – 44.36%. They are a typical element of the temperate zone. Hemicryptophytes comprised 27.44% in the investigated areas (Table 3). Most of these species were annuals plants. The high percentage of therophytes is mainly due to the specific regime of maintenance of the railway pavement - by mowing, treatment with chemicals, separation of plants from passing train compositions, etc., which gives an advantage to ephemeral species with a

persistent seedbank. The development of annual species is also favored by large areas without vegetation, i.e. without competition. The least frequent were chamaephytes and geophytes – 0.36%. Altogether 17 species of phanerophytes were found, but most of these species were represented by seedlings or juveniles only. Anyway, the further growth of phanerophytes on active railway tracks is very difficult or even impossible.

Alien and invasive species

In the habitats of railways, 25 alien plant species were recorded (Table 4) and they constituted 9.4% of the total flora. This is not surprising as railway areas are considered both an entry for invasive species and the kind of habitats that accelerate the dispersal and migration of invasive plant species (Rutkovska et al., 2013). The natural region of origin of the major part of the alien species was North America (48%). Fewer species are from Asia (28%) and South America (20%). The remaining 4% includes species originating in cultivation and known from culture only. They are found on the railway embankments and near railways in most of the studied areas.

Table 1. List of the studied railway stations in the Upper Tracian Lowland.

No	Location (Train station)	Coordinates (begin and the end of studied area)		Alti-tude	No of Familia/ species
1	Dimitrovgrad	42.05569º N 25.58916º E	42.05407º N 25.59642º E	125 m	21/54
2	Knizhovnik	41.82726º N 25.59791º E	41.82585º N 25.59664º E	245 m	25/61
3	Malevo	41.86435º N 25.61650º E	41.86418º N 25.61532º E	158 m	18/43
4	Maslinovo	41.76920º N 25.54334º E	41.77008º N 25.54509º E	365 m	21/67
5	Most	41.74130º N 25.53047º E	41.74046º N 25.53036º E	450 m	21/68
6	Stara Zagora	42.41944º N 25.63429º E	42.41487º N 25.62784º E	196 m	24/47
7	Yabalkovo	42.07613º N 25.44704º E	42.07320º N 25.45202º E	199 m	16/28
8	Uzundzhovo	41.96711º N 25.63515º E	41.96827º N 25.63374º E	170 m	17/37
9	Harmanli	41.92371º N 25.92154º E	41.92142º N 25.92808º E	61 m	15/31
10	Skobelevo	42.09689º N 25.36891º E	42.09719º N 25.36519º E	130 m	12/24
11	Karadzhalovo	42.10309º N 25.31302º E	42.10230º N 25.32415º E	134 m	14/29
12	Stalevo	42.09615º N 25.39519º E	42.09610º N 25.39786º E	180 m	9/24
13	Plovdiv (st. Trakia)	42.12961º N 24.79967º E	42.14041º N 24.80346º E	160 m	30/59
14	Haskovo	41.93305º N 25.58411º E	41.93333º N 25.57601º E	194 m	22/48

Table 2. Number of genera and species by families.

Familia	Genera		Species	
	Number	% of investigated flora	Number	% of investigated flora
Equisetophyta				
Equisetaceae	1	0.57%	1	0.37%
Polypodiophyta	-		-	
Pinophyta				
Cupressaceae	1	0.57%	1	0.37%
Magnoliophyta				
Magnoliopsida				
Amaranthaceae	1	0.57%	3	1.74%
Apiaceae	9	5.2%	9	3.38%
Araliaceae	1	0.57%	1	0.37%
Asteraceae	34	19.65%	49	18.43%

Boraginaceae	4	2.31%	6	2.26%
Brassicaceae	6	3.47%	9	3.38%
Caesalpiniaceae	2	1.15%	2	0.75%
Cannabaceae	1	0.57%	1	0.37%
Caprifoliaceae	2	1.15%	2	0.75%
Caryophyllaceae	8	4.62%	11	4.13%
Chenopodiaceae	2	1.15%	4	1.5%
Convolvulaceae	1	0.57%	1	0.37%
Crassulaceae	1	0.57%	1	0.37%
Cucurbitaceae	1	0.57%	1	0.37%
Cuscutaceae	1	0.57%	1	0.37%
Dipsacaceae	2	1.15%	2	0.75%
Euphorbiaceae	2	1.15%	8	3.01%
Fabaceae	12	6.93%	29	10.9%
Fumariaceae	1	0.57%	1	0.37%
Geraniaceae	2	1.15%	5	1.88%
Hypericaceace	1	0.57%	1	0.37%
Lamiaceae	8	4.62%	9	3.38%
Malvaceae	3	1.73%	3	1.74%
Moraceae	1	0.57%	1	0.37%
Oleaceae	1	0.57%	2	0.75%
Onagraceae	3	1.73%	4	1.5%
Oxalidaceae	1	0.57%	1	0.37%
Papaveraceae	2	1.15%	2	0.75%
Plantaginaceae	1	0.57%	2	0.75%
Platanaceae	1	0.57%	1	0.37%
Polygonaceae	3	1.73%	10	3.75%
Portulacaceae	1	0.57%	1	0.37%
Primulaceae	1	0.57%	1	0.37%
Ranunculaceae	4	4.62%	4	1.5%
Resedaceae	1	0.57%	1	0.37%
Rosaceae	6	3.47%	8	3%
Rubiaceae	2	1.15%	4	1.5%
Salicaceae	1	0.57%	1	0.37%
Sapindaceae	1	0.57%	1	0.37%
Scrophulariaceae	2	1.15%	7	2.63%
Simaroubiaceae	1	0.57%	1	0.37%
Solanaceae	3	1.73%	4	1.5%
Tiliaceae	1	0.57%	1	0.37%
Ulmaceae	2	1.15%	3	1.74%
Urticaceae	1	0.57%	1	0.37%
Verbenaceae	1	0.57%	1	0.37%
Violaceae	1	0.57%	3	1.74%
Vitaceae	1	0.57%	1	0.37%
Zygophyllaceae	1	0.57%	1	0.37%
Liliopsida				
Cyperaceae	1	0.57 %	1	0.37%
Poaceae	22	12.14 %	33	12.03%
Total	**174**		**267**	

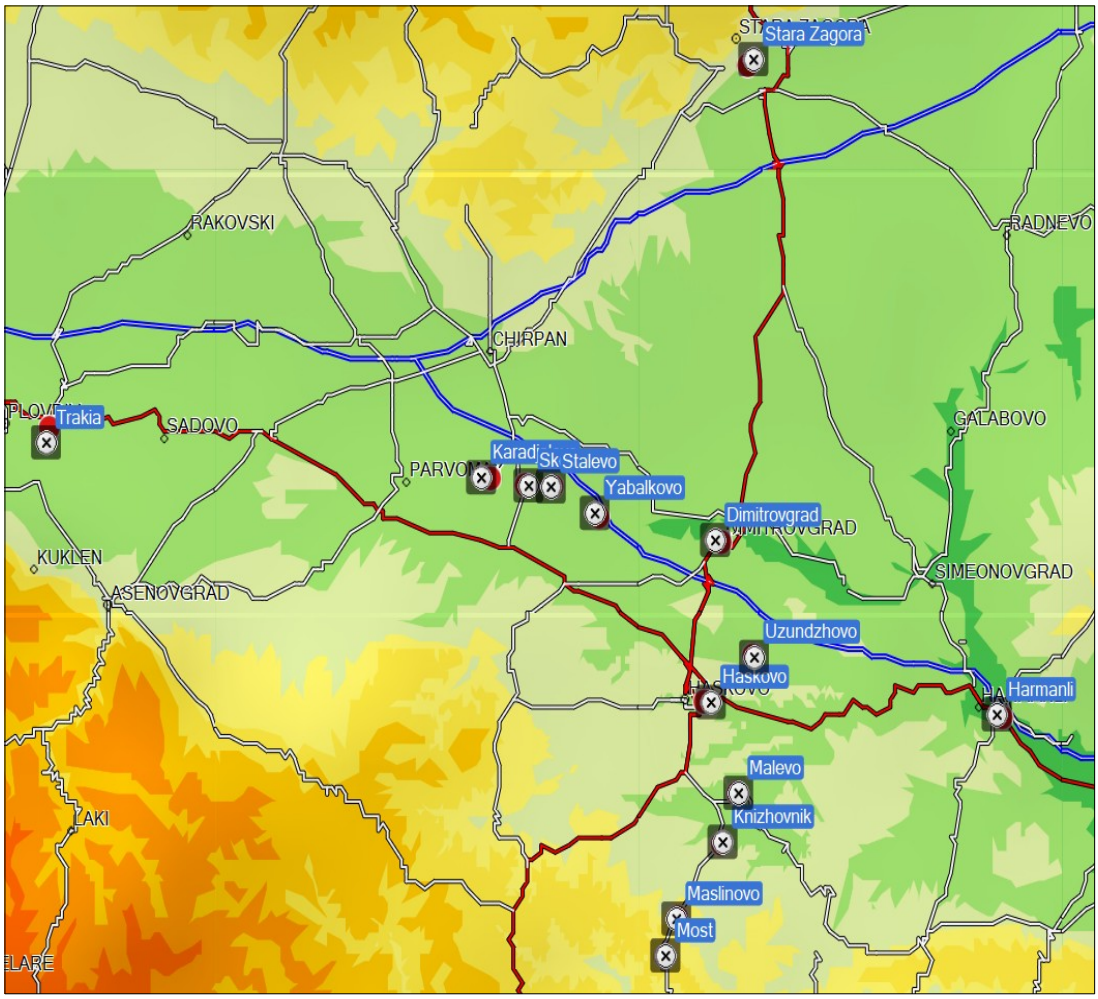

Fig. 1. Location map of the studied railway junctions of the Upper Tracian Lowland.

Ambrosia artemisiifolia has a native distribution range in North America. It is one of the most aggressive invasive alien species in SE Europe with a strong negative impact on human health and agriculture. In recent years, it has spread rapidly, also in Bulgaria, and its spread is facilitated by climate change (Thuiller et al., 2007). In our study, the species was found only at the city of Haskovo rail station. The species shows a tendency to spread in Tracian Lowland and has already been reported from the region (Petrova et al., 2012). It has previously also been reported from the Black Sea Coast and Northeast Bulgaria (Vladimirov & Petrova, 2009b), the Danubian Plain, Forebalkan, Valley of Mesta River, and the Valley of River Strouma floristic regions (Assyov & Petrova, 2012).

Settlers exclusively on the rails are *Bidens bipinnata*, *Erigiron acris*, and *Galinsoga parviflora*, which were found in a small number of stations. The invasive species *Euphorbia maculata* was found at Most Railway Station. *Xanthium spinosum* was represented by several individuals in three of the studied stations. At the end of the railway lines, seeds of *Robinia pseudoacacia*, *Amorpha fruticosa*, *Ailanthus altissima*, *Gleditsia triacanthos* successfully germinate, young individuals and seeds of *Morus alba, Platanus orientalis*, *Tilia* sp., and *Prunus cerasifera* are less common.

The highest number of alien taxa was found at the stations Haskovo, Dimitrovgrad

and Plovdiv. This is related to the more intensive movement of passengers and freight at these stations, as well as to the performance of maneuvers and the stay of freight trains. The lowest share of alien species was found in Yabalkovo, Karazhdalovo and Stalevo, which is explained by the lower load of these stations, the lack of maneuvers, loading, and unloading activities, and better maintenance of the station area. Twelve species are included in the lists of dangerously invasive species in Europe (Daisie, 2009; Larsson et al., 2007). Although all stations carry out activities to control vegetation through mowing and herbicide treatment, in most places these activities are not very effective. This is due to both the one-time treatment of the species and the treatment in an inappropriate phenological phase e.g. often at the end of the growing season, when the seeds are ripe and invulnerable to the pesticides used, or the efficacy of mechanical control is limited by the ability of grasses to produce new stems after cutting).

Table 3. Divided of studied species by life form (by Raunkiaer).

Life form	Number of species	% of investigated flora
H	72	27.44%
Th	119	44.36%
Ph	17	6.19%
Th-H	51	19.17%
G	1	0.36%
H-Th	4	1.64%
Ha	1	0.36%
Ha-H	1	0.36%
Ha-G	1	0.36%
Total	**267**	

Table 4. Alien and invasive species of the investigated railway stations.

Species	Origin	Status	Occurrence (№ of stage in table 1)
Ailanthus altissima (Mill.) Swingle	Asia	Invasive	2, 6, 9, 13
Ambrosia artemisiifolia L.	N America	Invasive	14
Amaranthus hybridus L.	S America	Invasive	1, 2, 7, 8
Amaranthus albus L.	N America	Adventive	1, 5
Amorpha fruticosa L.	N America	Invasive	2, 9, 11, 13
Bidens bipinnata L.	N America	Potential invasive	3, 12, 14
Dysphania ambrosioides (L.) Mosyakin & Clemants	S America	Invasive	13
Dysphania pumilio (R.Br.) Mosyakin & Clemants	Australia	Invasive	10, 12, 14
*Erigeron annuus (*L.) Desf.	N America	Adventive	1, 10
Erigeron canadensis L.	N America	Invasive	4, 6, 8, 10, 13,14
Datura stramonium L.	S America	Invasive	7, 12
Euphorbia maculata L.	N America	Invasive	5
Galinsoga parviflora Cav.	N America	Invasive	10, 13
Gleditsia triacanthos L.	N America	Invasive	3, 13, 14
Bassia scoparia (L.) A.J.Scott.	Asia	Potential invasive	9
Koelreuteria paniculata Laxm.	SE Asia	Adventive	1

Lycium barbarum L.	Central Asia	Potential invasive	13
Medicago sativa L.	C Asia C Europe	Adventive	1, 6, 8
Morus alba L.	SE Asia	Adventive	1,13
Oenothera biennis L.	N America	Invasive	1
Portulaca oleraceae L.	S America	Potential invasive	6, 7, 9, 14
Robinia pseudoacacia L.	N America	Invasive	2, 4
Symphoricarpos albus (L.) S.F.Blake	N America	Potential invasive	7, 12
Helianthus annuus L.	N America (cultivar)	Adventive	1, 9
Xanthium spinosum L.	S America	Invasive	2, 4, 14

In general, the proportion of invasive species was high, indicating that the examined zones are highly antropophytic. As for the invasive spectrum, the richest group of species was the family Asteraceae – 7 species (25.9%) of identified alien species. A significant part was also made up of genera with invasive ruderal plants, e.g. *Chenopodium* - 2 species, *Amaranthus* - 2 species. Some species have been intentionally introduced and are widely used for landscaping and as ornamentals e.g. *Symphoricarbus albus*, *Koelreuteria paniculata, Oenothera biennis*.

Conclusions

The railway zones of the stations are artificial, relatively homogeneous ruderal habitats, which provide suitable conditions for secondary emergence and further resettlement not only of synanthropic but also of adventive and alien species, despite the regular management activities such as plant reaping, burning, and application of herbicides of the vegetation in the area of the railway stations. The plants typical of railway facilities and species strongly concentrated in operating railway areas are mainly therophytes with a short life cycle, comprising 44.36% of species in the present study. The participation of hemicryptophytes is relatively high (27.44%) and alien and adventive species make up for 9.4%. Among the most frequently found plants were species that have a wide range of ecological preferences. The above groups of species are dominated by plants adapted to dry habitats. Plant characteristics such as short life cycle and the ability to persist under dry conditions enable these plants to grow and thrive along operational rail tracks.

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