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ORIGINAL ARTICLE

Vegetation of the railways of the Kyiv urban area (Ukraine)

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Abstract

Phytosociological research of the vegetation of Kyiv railways has been completed. Based on the analysis of 379 relevés using modified TWINSPAN and PC-ORD algorithms, it was found that the syntaxonomical structure of the study area includes 7 classes (*Artemisietea vulgaris, Festucetea vaginatae*, *Galio-Urticetea*, *Plantaginetea majoris*, *Polygono-Poetea annuae*, *Robinietea*, *Stellarietea mediae*), 12 orders, 18 alliances, 35 associations, 13 derivate and basal communities. The development of vegetation in man-made habitats leads to its significant complexity. It is manifested by changes in plant associations, their fragmentation and the formation of overgrowth type coenoses dominated by individual plant species. A significant degree of synanthropization, and in particular adventization, of the studied phytocoenoses was established. The participation of highly invasive species reduces local plant diversity and destroys their floristical and phytocoenotic structure. On the other hand, fragmented railway landscapes can function as new habitats or distribution corridors for local natural species. Trends of anthropogenic changes in the vegetation of the railways of Kyiv are the transformation and reduction of areas of natural vegetation, a decrease in its productivity, as well as an increase in the number of derivate plant communities, which are the successive stages of ecosystem development. The ecological features of the vegetation of the railways of the Kyiv urban area are discussed in comparison with the ruderal vegetation outside the railways. Comparative ordination analysis of these phytocoenoses shows that communities on the railways develop in extreme conditions of ecotopes poor on soil moisture and nitrogen content. The results of our research can be used for effective management of biodiversity on railways, and for the monitoring and development of control measures for the spread of non-native species. They can also be useful for sustainable planning and management of urban landscapes.

Keywords Alien species · Ecology · Ordination · Syntaxonomy · Transport routes · Ukraine

Introduction

The increasing anthropogenic impact over the past few centuries has led to global consequences for natural ecosystems and the formation of new man-made habitat types, especially in cities (Gilbert 1989). The history of urban ecology has evolved rapidly over the past few decades (Sukopp 2002; McDonnell and Niemelä 2011) and relied mainly on floristic studies of urban habitats (Chocholoušková and Pyšek 2003; Wittig 2004). The increase in urbanization in the world indicates a pattern of change in biodiversity, in particular urban vegetation (Cai et al. 2019). In a rapidly urbanizing world, understanding the response of ecosystems to urbanization is essential for planning urban space to ensure sustainable development of residents and nature and the management of urban landscapes (Niemelä et al. 2011).

Within the metropolis, urban cenoses, which are railways, perform a functional role and have special characteristics. Railroad tracks are an artificial habitat. They are standard objects, the building and exploitation of which takes place according to certain schemes. Their roadsides, as human-made habitats, serve as corridors for the spread of animals and plant species, the migration of dangerous alien weeds, and a place for the formation of new ecosystems (Hobbs et al. 2006). Plant diasporas are transported by vehicles and with transported material, so railways have become a major factor in flora and vegetation synanthropization (Rabitsch and Essl 2006; Wiłkomirski et al. 2012; Májeková et al. 2016; Bonthoux et al. 2019). They often remain cells of natural vegetation, albeit overly transformed (Arenas et al.

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2017; Toffolo et al. 2021). The diversity of biotopes on railways often contributes to the secondary appearance and further spread of not only synanthropic or invasive, but also rare and endangered plant species (Májeková et al. 2014). The plant communities that form here are distinguished by their originality and are of significant interest for the phytocenology of anthropogenically transformed ecotopes and artificial habitats.

A large amount of work has been carried out on the floristic diversity of railway transport routes in European countries, in particular, in Germany (Brandes 2005; Junghans 2011, 2016), France (Brandes 2003), Slovakia (Jehlík et al. 2017; Májeková et al. 2021; Rendeková et al. 2020), Poland (Galera et al. 2011, 2012, 2014; Wrzesień et al. 2016), the Czech Republic (Stařecká 2010), Italy (Filibeck et al. 2012; Alessandrini, 2018), Austria (Hohla et al. 2000, 2002, 2005), Finland (Tikka et al. 2000, 2001), the Balkans (Jasprica et al. 2017) and Russia (Senator et al. 2011; Palkina 2012; Vinogradova et al. 2017).

Much less attention is paid to the plant communities that develop along with the transport communications. Syntaxonomical studies of the vegetation of railways are presented in Finland (Niemi 1969; Suominen 1969), Slovakia (Eliáš 1979a, b), Germany (Brandes 1979, 1983, 1984; Wittig and Lienenbecker, 2004), the Czech Republic (Jehlík 1986, 1995; Grűll 1990), United Kingdom (Sargent 1984; Hill et al. 2002), Poland (Fornal-Pieniak and Wysocki 2011), Italy (Filibeck et al. 2012), Croatia and Bosnia and Herzegovina (Jasprica et al. 2014), Russia (Arepieva 2017; Popova 2020).

In Ukraine, the vast majority of research on railway habitats also has a floristic character. New localities of alien species on the railways have been published by Dvirna (2012), Zvyagintseva (2013), Shevera et al. (2018) and other authors (Tokhtar 1995a, b; Konoplia and Drel' 1998; Kolesnyk and Kolesnyk 2009; Karmyzova 2016; Wrzesień et al. 2016; Mamchur et al. 2017). Recently, scientists have been paying increasing attention to the spread and potential danger of invasive alien weeds by rail (Besarabchuk 2018; Tokaryuk et al. 2018; Orlov 2019; Didukh et al. 2019; Májeková et al. 2021; Fedoronchuk et al. 2020). Some researchers have included relevés made on railways to the syntaxa of the ruderal vegetation in general (Bredikhina 2015; Tokaryuk et al. 2018). But targeted phytosociological studies of railway vegetation in Ukraine have not yet been carried out.

Kyiv, as the capital and largest metropolis of Ukraine, is a major railway hub through which all domestic and international trains run. The length of the tracks within the city is over 60 km, their roadsides characterized by significant phytodiversity. Despite the fact that the railway lines of Kyiv are defined urban habitats with specific management, their vegetation has remained unexplored (Dziuba et al. 2019). Knowledge of the phytocenotic structure of railways is very important in terms of assessing their biodiversity, formation processes, ecological features, phytoinvasions, as well as future urban planning and management. The purpose of this work is to establish the syntaxonomical structure and features of the organization of the vegetation cover of the railways within the Kyiv metropolitan area, carry out a comparative ordinal ecological analysis of the studied communities with other ruderal phytocenoses, identify the adventive fraction of coenofloras and general trends of anthropogenic changes in the vegetation of Kyiv railways.

Material and methods

Study area

The key areas of the studies were the Kyiv city ring railway line and large railway stations with adjacent territories in five main directions: Fastiv (southwest), Korosten (northwest), Nizhyn (northeast), Hrebinka (southeast) and Myronivka (south) (Fig. 1). The railway tracks (in particular, gaps between rails), platforms, stations, roadsides (embankments, slopes and ditches) were examined.

Kyiv's urban area is located in the northern part of Ukraine, on the border of Polissia and Forest-Steppe on both banks of the Dnieper River in its middle part. The area of the city is 836 km^2, length along the coast is more than 20 km. Kyiv is crossed by important transport routes, international highways and railways. The relief of the territory of Kyiv was formed at the border of the Dnieper Upland, as well as the Polissia and Prydniprovska Lowlands. Most of the city lies on the high (up to 196 m above sea level) right bank of the Dnieper – Kyiv Plateau. Geomorphologically, the northern part of the city is located in the Polissia lowland, the southwestern (right bank) – on the Dnieper Upland, the southeastern (left bank) – in the Dnieper Lowland (Barshchevsky et al. 1989; Barshchevsky 1993).

The Dnieper River flows 400–600 m wide and 6–12 m deep within the city. Small rivers (Lybid, Syrets, Vita, etc.) also flow through the territory of Kyiv. The climate of Kyiv is temperate-continental, with relatively mild winters and warm summers. The average temperature in January is −6.1°C, in July ±19.1°C. Precipitation is about 600 mm per year (from 551 to 628 mm) (National Atlas of Ukraine 2007).

The peculiarities and diversity of the natural conditions in Kyiv are associated with its location in the forest-steppe and mixed forest zones. In the north, northwest and west, in the zone of mixed forests, coniferous and broad-leaved forests on podzolic soils are common. In the forest-steppe zone, under deciduous forests, dark gray podzolic, gray and light gray forest soils predominate (Bortnyk et al. 2016).

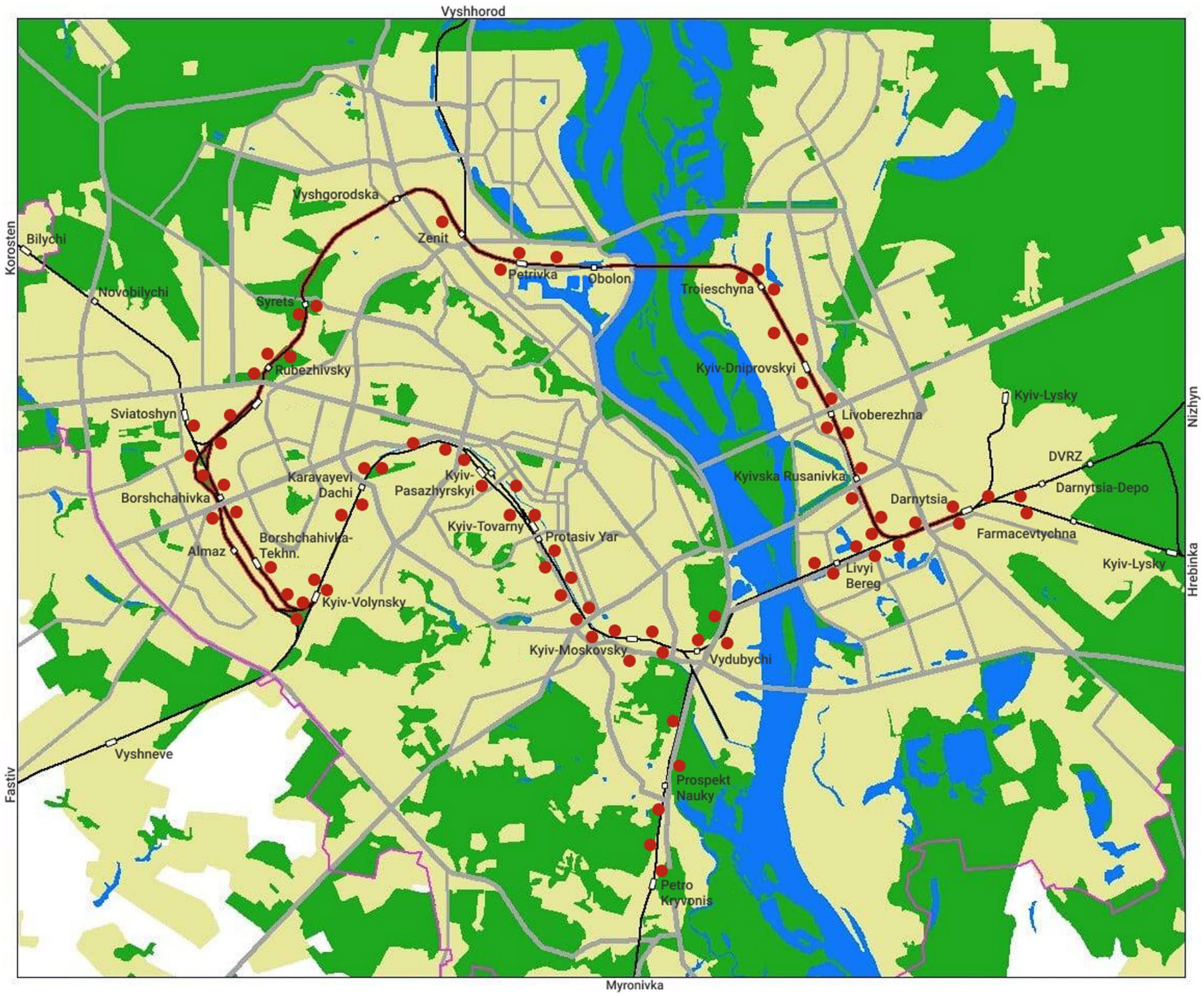


Fig. 1 Distribution map of localities of communities on railways of Kyiv

Vegetation along transport communication is common on significantly transformed natural landscapes, which are more often the valleys of the Dnieper and small rivers. These landscapes have been transformed, in particular for railways, by forming embankments, ditches, adjacent flat areas and opposing slopes, as well as reserve tracks – new habitats for significantly transformed natural vegetation (Fig. 2). The substrates are also significantly modified. They often contain building rubble (stone fragments 3–10 cm in size), pebbles (stones 2–3 cm in size with smoothed edges) and gravel (stone fractions smaller than 1 cm), especially between the tracks and on the side of the tracks.

The dataset

Phytosociological relevés according to floristic criteria were made during 2016–2019 according to the method of J. Braun-Blanquet (Braun-Blanquet 1964; Westhoff and van der Maarel 1973). The relevés size varied from 4 to 100 m^2 and depended on the area and form of the outlines of its phytocoenoses. Most sites had a standard size of 16 m^2. In cases where the communities were in the form of lines, the plots were laid out in an elongated form of 1 × 4 or 2 × 5 m. A total of 379 relevés were made.

Analysis

The relevés were entered into the phytosociological database using TURBOVEG software (Hennekens 1995). For comparison and more precise processing, we combined it with the “Database of ruderal vegetation of Ukraine”, which has more than 8000 relevés (GIVD № EU-UA-011). The selection of phytocoenones was carried out using a modified version of TWINSPAN algorithm (Roleček et al. 2009),

Fig. 2 The structure of railways' habitats

implemented in the JUICE 7.0 program package, as well as PC-ORD software (McCune and Mefford 2016). In the first stage, the entire database (8382 relevés) was processed using a modified TWINSPAN (Tichý 2002), which made it possible to divide it into smaller groups based on their floristic differences. The cut off level for "pseudo-species" was 0, 5, 15, 30%. The degree of heterogeneity of the clusters was Whittaker beta (Whittaker 1978) as the ratio of the total number of species of all relevés of the cluster to their average number per relevé. In the second stage, groups with diagnostic species corresponding to the classes of synanthropic vegetation were analyzed separately using PC-ORD. Sörensen's coefficient (Sörensen 1948) was chosen as a measure of similarity. Groupings were made according to the "flexible" beta method at −0.25. This made it possible to obtain phytocoenones, approximately corresponding to the association rank. In the third stage, the relevés of the vegetation of Kyiv's railways were separated within the identified syntaxa. After rejecting a certain number of the relevés, 337 phytosociological relevés were selected to construct the classification scheme of vegetation. Vegetation was classified using the Braun-Blanquet approach (Braun-Blanquet 1964) and by the Kopecký-Hejný deductive method (for basal and derivate communities) (Kopecký and Hejný 1974). By basal communities we mean those in which a species from "its own" class dominates, in contrast to derivative communities, where the dominant species are species from different classes of vegetation with subordination directly to the class (or classes). Such non-rank communities highlight cases when they represent a successional stage and identification of an association is impossible (Mirkin et al. 2007). The affiliation of the basal and derrivate communities to the syntaxa of the highest rank was determined by the participation of the diagnostic species of these classes. By adventitization we mean the process of introduction and naturalization of non-native (alien, adventive) species into plant communities.

Diagnostic species of syntaxa were determined according to the phi-coefficient (Willner et al. 2009), the threshold values of which were set at 25. Fidelity values from 20 to 30 are mostly standard for such analyzes (Tichý and Chytrý 2006; Willner et al. 2017; Slezák et al. 2020). All groups of relevés were standardized to equal size, and insignificant fidelity values were removed based on Fisher's extract test. The clusters were identified by analyzing their species composition and comparing them with diagnostic combinations of syntaxa from foreign and national publications (Chytrý 2009; Mucina et al. 2016; Dubyna et al. 2019). The classification of syntaxa was adopted according to the "Prodrome of the Vegetation of Ukraine" (Dubyna et al. 2019).

The ordination of the plant communities along the axes of soil moisture gradient and their nutrient on the territory of the railways and outside them was built using the STATISTICA 7.0 program. In most cases, relevés belonging to the same association of ruderal vegetation of Kyiv were used for comparison. If there were no such relevés for a certain syntaxa, relevés of this association were taken from other nearby territories. The ecological states of coenoses according to these factors were determined using Y. Didukh's ecological scales (Didukh 2011).

Nomenclature

The names of vegetation units were verified in accordance with the "International Code of Phytosociological Nomenclature" (Theurillat et al. 2021).

Species identification was carried out mainly using the "Manual of Higher Plants of Ukraine" (Dobrochaeva et al. 1987). The nomenclature of taxa follows "Flora Europaea" (Tutin et al. 1964, 1968–1980).

Results

Syntaxonomy

The vegetation of Kyiv's urban area railways is represented mainly by ruderal and semi-natural phytocoenoses. Natural vegetation (aquatic, psammophytic) is very rare and fragmented on railways. Significant disturbance of this type of habitat leads to the formation of derivate plant communities. Species of aboriginal flora, which in nature create an aspect of vegetation and determine its physiognomy, are less common on the railways. Instead of them the background is often determined by ruderal species, in particular alien ones. The diversity of vegetation that spreads along the railways is also due to the significant breadth of the ecological amplitude of habitats (from wet to arid, from nutrient-poor to nutrient-rich soils, etc.).

Syntaxonomic vegetation survey of the railways within Kyiv includes 7 classes, 12 orders, 18 alliances, 35 associations and 13 rankless communities (basal and derivate).

Classification scheme of the vegetation of Kyiv urban area railways

STELLARIETEA MEDIAE TX. ET AL. IN TX. 1950

Atriplici-Chenopodietalia albi (Tx. 1937) Nordhagen 1940

Panico-Setarion Sissingh in Westhoff et al. 1946

Setario pumilae-Echinochloetum cruris-galli Felföldy 1942 corr. Mucina in Mucina et al. 1993
Setario-Digitarietum Felföldy 1942
Digitarietum ischaemii R. Tx. et Preising (1942) 1950
Setario viridis-Erigeronetum canadensis Šomšák 1976
DC *Koeleria macrantha-Setaria pumila* [*Stellarietea mediae*]

Eragrostietalia J. Tx. ex Poli 1966

Eragrostion Tx. in Oberd. 1954

Portulacetum oleracei Felföldy 1942

Salsolion ruthenicae Philippi ex Oberd. 1983

Plantagini indicae-Digitarietum sanguinalis Papucha 1991
Salsoletum ruthenicae Philippi 1971
DC *Cenchrus incertus-Digitaria sanguinalis* [*Stellarietea mediae*]

Papaveretalia rhoeadis Hüppe et Hofmeister ex Theurillat et al. 1995

Chenopodio albi-Descurainion sophiae Solomakha et al. in Solomakha 1988

Fallopio convolvuli-Chenopodietum albi Solomakha 1990

Sisymbrietalia sophiae J. Tx. ex Görs 1966

Atriplicion Passarge 1978

Ambrosietum artemisiifoliae Viţălariu 1973
Chenopodietum stricti (Oberd. 1957) Passarge 1964
Kochietum densiflorae Gutte et Klotz 1985
DC *Atriplex patula-Polygonum aviculare* [*Stellarietea mediae-Polygono-Poetea annuae*]

Hordeion murini Br.-Bl. in Br.-Bl. et al. 1936

Brometum tectorum Bojko 1934

Sisymbrion officinalis Tx. et al. ex von Rochow 1951

Conyzo canadensis-Lactucetum serriolae Lohmeyer in Oberd. 1957
Lactuco serriolae-Diplotaxietum tenuifoliae (Oberd. 1957) Mucina 1978
Sisymbrietum loeselii Gutte 1972

ARTEMISIETEA VULGARIS LOHMEYER ET AL. IN TX. EX VON ROCHOW 1951

Agropyretalia intermedio-repentis T. Müller et Görs 1969

Convolvulo arvensis-Agropyrion repentis Görs 1967

Agropyretum repentis Felföldy 1942
Anisantho-Artemisietum austriacae Kostylev 1985
Calamagrostietum epigei Kostylev in Solomakha et al. 1992
DC *Poa angustifolia-Aristolochia clematitis* [*Artemisietea vulgaris*]

Onopordetalia acanthii Br.-Bl. et Tx. ex Klika et Hadač 1944

Arction lappae Tx. 1937

Arctio lappae-Artemisietum vulgaris Oberd. ex Seybold et T. Müller 1972

Dauco-Melilotion Görs et Rostański et Gutte 1967

Berteroetum incanae Sissingh et Tideman ex Sissingh 1950
Echio-Verbascetum Sissingh 1950
Melilotetum albo-officinalis Sissingh 1950
Asclepiadetum syriacae Láníková in Chytrý 2009
DC *Arrhenatherum elatius-Equisetum hyemale* [*Artemisietea vulgaris-Molinio-Arrhenatheretea*]

DC *Arrhenatherum elatius-Taraxacum officinale* [*Artemisietea vulgaris-Molinio-Arrhenatheretea*]

Onopordion acanthii Br.-Bl. et al. 1936

Achilleo millefolii-Grindelietum squarrosae Kostylev in Solomakha et al. 1992
Onopordetum acanthii Br.-Bl. 1926
Potentillo argenteae-Artemisietum absinthii Faliński 1965
DC *Artemisia absinthium-Partenocissus quinquefolia* [*Artemisietea vulgaris*]

GALIO-URTICETEA PASSARGE EX KOPECKÝ 1969

Convolvuletalia sepium Tx. ex Moor 1958

Senecionion fluviatilis Tx. ex Moor 1958

Rudbeckio laciniatae-Solidaginetum canadensis Tüxen et Raabe ex Anioł-Kwiatkowska 1974

Galio-Alliarietalia Oberd. in Görs et T. Müller 1969

Aegopodion podagrariae Tx. 1967

Oenothero biennis-Helianthetum tuberosi de Bolós et al. 1988
Urtico dioicae-Rubetum caesii Golovanov 2017
Leonuro-Urticetum dioicae (Solomeshch in Mirkin et al. 1986) A. Ishbirdin et al. 1988
DC *Phragmites australis-Rubus caesius* [*Galio-Urticetea*]

PLANTAGINETEA MAJORIS TX. ET PREISING EX VON ROCHOW 1951

Potentillo-Polygonetalia avicularis Tx. 1947

Potentillion anserinae Tx. 1947

Potentilletum reptantis Eliáš 1974

POLYGONO-POETEA ANNUAE RIVAS-MARTÍNEZ 1975

Polygono arenastri-Poetalia annuae Tx. in Géhu et al. 1972 corr. Rivas-Martínez et al. 1991

Polygono-Coronopodion Sissingh 1969

Polygonetum arenastri Gams 1927 corr. Láníková in Chytrý (2009)
Eragrostio minoris-Polygonetum arenastri Oberd. 1954 corr. Mucina in Mucina et al. 1993

ROBINIETEA JURKO EX HADAČ ET SOFRON 1980

Chelidonio-Robinietalia pseudoacaciae Jurko ex Hadač et Sofron 1980

Chelidonio-Acerion negundi L. Ishbirdina et A. Ishbirdin 1991

Chelidonio-Aceretum negundi L. Ishbirdina et A. Ishbirdin 1991
DC *Humulus lupulus-Acer negundo* [*Robinietea*]

Chelidonio majoris-Robinion pseudoacaciae Hadač et Sofron ex Vítková in Chytrý 2013

Chelidonio majoris-Robinietum pseudoacaciae Jurko 1963

FESTUCETEA VAGINATAE SOÓ EX VICHEREK 1972

Festucetalia vaginatae Soó 1957

Festucion beckeri Vicherek 1972

BC *Festuca beckeri-Artemisia campestris* subsp. *campestris* [*Festucetea vaginatae*]
DC *Centaurea arenaria* subsp. *borysthenica-Potentilla neglecta* [*Festucetea vaginatae*]
DC *Artemisia campestris* subsp. *campestris-Medicago sativa* subsp. *falcata* [*Festucetea vaginatae*]
DC *Anchusa officinalis-Medicago sativa* subsp. *falcata* [*Festucetea vaginatae*]

Stands of the class *Stellarietea mediae* are formed in areas that undergo periodic transformation by mechanical damage and burning, less often mowing. There are 18 associations and derivate communities are mentioned in the territory of Kyiv (Table 1).

The *Panico-Setarion* alliance includes four associations and one derivate community. The *Setario pumilae-Echinochloetum cruris-galli* association is common on the Right Bank and the Left Bank of the Dnieper. It was recorded on sections of railway stations Kyivska Rusanivka, Livoberezhna, Borshchahivka in the direction of Rubezhivsky and between stations Petrivka and Zenit (Fig. 8a). Stands occupied the lower sections of the embankments on sandy gravelly substrates. Coenoses were usually located in lines 0.5–1.0 m wide and 20 to 100–150 m long. Their coverage was medium dense (30–40%). Phytocoenoses of the association *Setario-Digitarietum* were recorded in the area of the Kyiv-Moskovsky station on gravelly substrates. The total area was 1×20 m, coenoses were fragmented. Their total coverage was from 15–20% to 60%. *Digitarietum*

Table 1 Synoptic table of the class *Stellarietea mediae*

No. of syntaxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Number of relevés	17	5	8	4	4	18	1	4	5	2	18	5	5	5	21	12	7	1
Chelidonium majus	33.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sedum acre	29.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sonchus arvensis	–	62.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Medicago lupulina	–	59.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Amaranthus blitoides	–	57.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Digitaria ischaemum	–	–	89.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bromus squarrosus	–	–	69.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Erigeron annuus	–	–	53.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Medicago sativa subsp. *falcata*	–	–	40.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Grindelia squarrosa	–	–	–	60.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Atriplex nitens	–	–	–	48.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Buglossoides arvensis	–	–	–	48.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Centaurea arenaria subsp. *borysthenica*	–	–	–	46.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Koeleria macrantha	–	–	–	–	88.8	–	–	–	–	–	–	–	–	–	–	–	–	–
Scabiosa ochroleuca	–	–	–	–	82.5	–	–	–	–	–	–	–	–	–	–	–	–	–
Trifolium arvense	–	–	–	–	69.7	–	–	–	–	–	–	–	–	–	–	–	–	–
Dianthus borbasii	–	–	–	–	48.9	–	–	–	–	–	–	–	–	–	–	–	–	–
Populus nigra (juv.)	–	–	–	–	48.9	–	–	–	–	–	–	–	–	–	–	–	–	–
Dianthus deltoides	–	–	–	–	48.9	–	–	–	–	–	–	–	–	–	–	–	–	–
Portulaca oleracea	–	–	–	–	–	39.6	–	–	–	–	–	–	–	–	–	–	–	–
Tribulus terrestris	–	–	–	–	–	36.7	–	–	–	–	–	–	–	–	–	–	–	–
Bromus sterilis	–	–	–	–	–	–	93.2	–	–	–	–	–	–	–	–	–	–	–
Tragopogon dubius subsp. *major*	–	–	–	–	–	–	84.3	–	–	–	–	–	–	–	–	–	–	–
Plantago arenaria	–	–	–	–	–	–	83.6	–	–	–	–	–	–	–	–	–	–	–
Anthemis arvensis	–	–	–	–	–	–	–	97.2	–	–	–	–	–	–	–	–	–	–
Poa bulbosa	–	–	–	–	–	–	–	66.3	–	–	–	–	–	–	–	–	–	–
Elymus repens	–	–	–	–	–	–	–	29.5	–	–	–	–	–	–	19.3	–	–	–
Cenchrus incertus	–	–	–	–	–	–	–	–	100.0	–	–	–	–	–	–	–	–	–
Secale sylvestre	–	–	–	–	–	–	–	–	62.2	–	–	–	–	–	–	–	–	–
Bassia laniflora	–	–	–	–	–	–	–	–	62.2	–	–	–	–	–	–	–	–	–
Silene borysthenica	–	–	–	–	–	–	–	–	62.2	–	–	–	–	–	–	–	–	–
Eragrostis minor	–	–	–	–	–	–	–	–	58.8	–	–	–	–	–	–	18.7	–	–
Polygonum arenarium	–	–	–	–	–	–	–	–	44.5	–	–	–	–	–	–	–	–	–
Salsola kali	–	–	–	–	–	–	–	–	43.7	–	–	–	–	–	–	–	–	–
Tragopogon brevirostris subsp. *podolicus*	–	–	–	–	–	–	–	–	43.7	–	–	–	–	–	–	–	–	–
Amaranthus retroflexus	–	–	16.6	–	–	–	–	–	–	86.7	–	–	–	–	–	–	–	–
Linaria vulgaris	–	–	–	–	–	–	–	–	–	80.1	–	–	–	–	–	–	–	–
Picris hieracioides	–	–	–	–	–	–	–	–	–	78.1	–	–	–	–	12.9	–	–	–
Sonchus oleraceus	–	–	–	–	–	–	–	–	–	77.8	–	–	–	–	–	–	–	–
Anagallis arvensis	–	–	–	–	–	–	–	–	–	69.7	–	–	–	–	–	–	–	–
Cirsium arvense	–	–	–	–	–	–	–	–	–	66.3	–	–	–	–	–	–	–	–
Convolvulus arvensis	–	–	–	–	–	–	–	–	–	59.0	–	–	–	–	–	–	19.6	–
Rubus caesius	–	–	–	–	–	–	–	–	–	55.6	–	–	–	–	–	–	–	–
Fallopia convolvulus	18.5	–	–	–	–	–	–	–	–	52.0	–	–	–	–	–	–	–	–
Oenothera biennis	–	–	–	–	–	–	–	–	–	–	34.8	–	–	–	–	–	–	–
Solanum nigrum	–	–	–	–	–	–	–	–	–	–	32.5	–	–	–	–	–	–	–
Ambrosia artemisiifolia	–	–	22.4	–	–	–	–	–	–	–	28.6	–	–	–	–	–	–	–
Chenopodium album agg.	–	–	–	–	–	–	–	–	–	–	–	93.9	–	–	–	–	–	–
Medicago sativa	20.2	–	–	–	–	–	–	–	–	–	–	62.6	–	–	–	–	–	–
Lolium perenne	–	–	–	–	–	–	–	–	–	–	–	50.0	–	–	–	–	–	–
Reseda lutea	–	–	–	–	–	–	–	–	–	–	–	43.7	–	–	–	–	–	–
Anchusa officinalis	–	–	–	–	–	–	–	–	–	–	–	39.4	–	–	–	–	–	–
Taraxacum officinale agg.	–	–	–	–	–	–	–	–	–	–	–	34.7	–	–	–	–	–	–
Crepis foetida subsp. *rhoeadifolia*	–	–	20.0	–	–	–	–	–	–	–	–	26.3	–	–	–	–	–	–

Table 1 (continued)

Bassia scoparia	–	–	–	–	–	–	–	–	–	–	–	–	93.9	–	–	–	–	–
Atriplex patula	–	–	–	–	–	–	–	–	–	–	–	–	–	94.6	–	–	–	–
Polygonum aviculare	–	–	–	–	–	–	–	–	–	–	21.4	–	–	39.5	–	–	–	–
Festuca pratensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	47.7	–	–	–
Oxalis europaea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	36.9	–	–	–
Xanthium strumarium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	36.9	–	–	–
Capsella bursa-pastoris	–	–	–	–	–	–	–	–	–	–	–	–	–	–	30.1	–	–	–
Parthenocissus quinquefolia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	30.1	–	–	–
Artemisia vulgaris	–	–	–	–	–	–	–	–	–	–	–	–	–	–	29.4	–	–	–
Conyza canadensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	26.8	–	–
Berteroa incana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	38.6	–
Astragalus glycyphyllos	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	36.9	–
Achillea collina	–	–	–	–	–	16.0	–	–	–	–	–	–	–	–	–	–	30.9	–
Sisymbrium loeselii	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	100.0
Digitaria sanguinalis	–	62.4	–	–	–	10.5	–	–	48.1	–	–	–	–	–	–	–	–	–
Ballota nigra	–	–	28.7	–	–	–	–	–	–	–	–	–	–	–	–	–	33.4	–
Setaria viridis	–	–	–	39.7	–	–	–	–	–	39.7	–	–	–	–	–	–	–	–
Potentilla argentea	–	–	–	32.3	–	–	–	–	–	–	–	–	–	–	–	–	38.0	–
Euphorbia cyparissias	–	–	–	–	34.1	–	–	–	–	–	–	–	–	–	–	–	–	75.9
Chondrilla juncea	–	–	–	–	–	–	57.1	–	–	–	–	16.6	–	–	–	–	–	57.1
Salsola kali subsp. *ruthenica*	–	–	–	–	–	–	–	67.7	–	–	–	–	–	–	–	–	–	67.7
Diplotaxis tenuifolia	–	–	–	–	–	–	–	31.4	–	–	–	–	–	–	18.1	–	46.1	–
Bromus tectorum	–	–	–	–	–	–	–	30.8	–	–	–	–	–	–	30.8	22.4	–	–
Setaria pumila	30.4	30.4	–	–	–	–	–	–	–	–	–	30.4	–	–	–	22.1	–	–

Tables 1–3 shows in an abbreviated form. Only diagnostically significant indicators of the phi coefficient are indicated. Numbers mark syntaxa: 1 – *Setario pumilae-Echinochloetum cruris-galli*; 2 – *Setario-Digitarietum*; 3 – *Digitarietum ischaemii*; 4 – *Setario viridis-Erigeronetum canadensis*; 5 – DC *Koeleria macrantha-Setaria pumila*; 6 – *Portulacetum oleracei*; 7 – *Plantagini indicae-Digitarietum sanguinalis*; 8 – *Salsoletum ruthenicae*; 9 – DC *Cenchrus incertus-Digitaria sanguinalis*; 10 – *Fallopio convolvuli-Chenopodietum albi*; 11 – *Ambrosietum artemisiifoliae*; 12 – *Chenopodietum stricti* ; 13 – *Kochietum densiflorae* ; 14 – DC *Atriplex patula-Polygonum aviculare*; 15 – *Brometum tectorum* ; 16 – *Conyzo canadensis-Lactucetum serriolae*; 17 – *Lactuco serriolae-Diplotaxietum tenuifoliae*; 18 – *Sisymbrietum loeselii*

ischaemii stands occur on the Right and the Left Bank of the Dnieper near the railways of Vydubychi, Darnytsia (in the Yagotyn direction) stations and between stations Petrivka and Zenit. They were distributed on flat areas with chernozem-like loams. They occupied areas up to 160–200 m^2 and were characterized by dense herb cover (90%). Coenoses of *Setario viridis-Erigeronetum canadensis* were confined to sites between tracks with an area of about 3×50 m on gravelly substrates. They were recorded between Darnytsia and Darnytsia-Depo platforms, near Vydubychi station. Near the Sviatoshyn railway station they occupied the top of the slopes 20° and about 2 m high, and an area of $3–4 \times 80$ m. Derivate community *Koeleria macrantha-Setaria pumila* was identified in Borshchahivka station in the direction of Rubezhivsky between the embankments on the dark gray sandstone, as well as on railway slopes 2 m high with light gray sandy soils. Total area was 2×100 m, herb coverage was 40–60%.

The alliance *Eragrostion* includes one association – *Portulacetum oleracei*. Its stands are confined to nitrified, mostly chernozem soils mixed with gravel, at the foot and on the slopes of embankments along most of the city's railways. Phytocoenoses were recorded in the area of Kyiv-Moskovsky, Vydubychi, between Sviatoshyn and Borshchahivka stations. Coenoses were located in lines about 1 m wide and up to 40 m long. With herb coverage of 30–40 to 70–80%. Communities with the co-dominance of *Portulaca oleracea* and *Tribulus terrestris* were found in the mowed areas on the outside of the tracks on a mixture of pebbles, rubble and gravel near the Kyiv-Moskovsky railway station (Fig. 8b).

The alliance *Salsolion ruthenicae* unites two associations. Coenoses of *Plantagini indicae-Digitarietum sanguinalis* were found between the platforms of Prospekt Nauky and Petro Kryvonis on sandy soils near tracks with a small gravel embankment. The total area was 150 m^2. The plant communities *Salsoletum ruthenicae* were recorded between Darnytsia and Livoberezhna stations on a slope with a steepness of 30° with sandy soil. The stands were medium dense with 30–40% coverage. Derivate community *Cenchrus incertus-Digitaria sanguinalis* was recorded near Kyiv-Dniprovskyi station on a sandy-gravel embankment, where it occupied an area of about 300 m^2. Herb coverage was 30–40%, with separate moss synuziums.

The alliance *Chenopodio albi-Descurainion sophiae* includes one association – *Fallopio convolvuli-Chenopodietum albi*. It was recorded 2 km from the Vydubychi platform towards the station Prospekt Nauky, on a 2 m wide embankment with gray loamy soils. The total area of the community was 2 × 20 m, coverage was 90%. It was also recorded on the railways of the Left Bank.

The alliance *Atriplicion* includes three associations and 1 derivate community. Coenoses of the association *Ambrosietum artemisiifoliae* occur frequently, along all railway tracks of the city. The plant communities were recorded in the railways of Darnytsia, Troieschyna and between Protasiv Yar and Kyiv-Moskovsky stations (Fig. 8c). They were located on the sides of railways with sandy and gravelly soils and oil pollution, and also occupied the lower parts of the railway slopes. Plots are mowed. Areas of the communities varied from 16–25 to 150 m^2. The density of stands ranged from 30–40 to 60–70 (100)%. Phytocoenoses of *Chenopodietum stricti* occur along the railway tracks of both the Right and Left Banks. They were recorded on the flat sites near the railway embankment on chernozems with a slight admixture of rubble. The herb layer is mowed. They occupied an area of up to 100 m^2, and were characterized by coverage of up to 70%. Stands of the association *Kochietum densiflorae* are confined to areas of sandy soils littered with building waste. They were found in the area of The Left Bank station, and covered an area of about 30 m^2. Derivate community *Atriplex patula-Polygonum aviculare* were recorded in the area of Vydubychi station. It had a ribbon shape 1 m wide and 10 m long and was located on a slope near the tracks with dark gray sandy soils.

The alliance *Bromo-Hordeion murini* includes 1 association – *Brometum tectorum*. Stands of this associations are widespread on the railways of Kyiv. They were found on steep slopes on clayey black soils with an admixture of sand, as well as on sandy localities near railway tracks. The total herb coverage varied from 30% to 80%, the area was up to 120 m^2 and often included moss synusiae.

The *Sisymbrion officinalis* alliance includes three associations. The stands of *Conyzo canadensis-Lactucetum serriolae* are distributed on the railways of the Right Bank and the Left Bank. They were found in the territories of Darnytsia, Livyi Bereg, Vydubychi stations, between the platforms of Prospect Nauky and Petro Kryvonis on flat sites and slopes on gray and chernozem-like sands with a small admixture of pebbles and gravel. The communities were fragmented, their areas ranged from 30 to 300 m^2. Herb coverage ranged from 20–30 to 80 (100) %, moss layer sometimes reached 20%. Coenoses of *Lactuco serriolae-Diplotaxietum tenuifoliae* occur near the railways of the Right Bank and the Left Bank. They were recorded near the Kyiv-Moskovsky and Sviatoshyn stations where they occupied gaps between tracks with gravelly substrates, flat areas covered with large rubble, as well as flat areas near the railway slopes 0.5 m high on gray sands with pebble admixture. The area of the communities reached 200 m^2, the herb coverage was quite dense, from 50–60% to 90%. The plant communities of the association *Sisymbrietum loeselii* were recorded in the Yagotyn direction near Darnytsia station on the railway side. The soil was sandy-chernozem, humus. Herb coverage was 80%.

Phytocoenoses of the class *Artemisietea vulgaris* occupy large areas and are quite common. We have differentiated 15 syntaxa of the association rank and derivate communities (Table 2).

The alliance *Convolvulo arvensis-Agropyrion repentis* includes three associations and one derivate community. Coenoses of the association *Agropyretum repentis* are found mainly on the slopes opposite the embarkment, with gravelly and sandy soils. They often occur in the territories of the railway stations and gaps between tracks. They are less common on the roadsides and areas near railway lines with loamy soils and gravel. Stands of the association were distributed along the railways of both the Right and the Left Bank of the Dnieper. They occupied areas from 40 to 100 m^2 and were recorded on Vydubychi, Kyiv-Moskovsky, Borshchahivka, Sviatoshyn, Syrets, Kyiv-Volynsky, Rubezhivsky and other railway stations. The herb coverage was usually dense, with total coverage of 50–70 to 100%. Stands of *Anisantho-Artemisietum austriacae* were noted between Darnytsia and Livoberezhna stations on a slope with a steepness of 35°. The soils are sandy with a small admixture of pebbles. The total area of the communities was 20 × 20 m, total coverage 40%. The association *Calamagrostietum epigei* is common on drier sections of slopes, especially their lower parts, with sandy and loamy soils, which include gravel. They also occupy sections along the railway tracks on chernozems. We found the association on The Left Bank, Kyiv-Dniprovsky, Kyiv-Volynsky stations, between the platforms Darnytsia and Darnytsia-Depo, Sviatoshyn and Borshchahivka, in the Yagotyn direction (Fig. 8d). They occupied an area of up to 600 m^2 with coverage ranging from 60% to 80–90%. The *Poa angustifolia-Aristolochia clematitis* community was found on the lower parts of railway slopes on sandy soils mixed with chernozem, near Troieschyna station. The total area of the community was 10 × 30 m. The herb coverage was dense (60–80%).

Coenoses of *Arctio lappae-Artemisietum vulgaris*, belonging to the alliance *Arction lappae*, are common on the Right and Left Banks. They were recorded on sections of the railway between Protasiv Yar and Kyiv-Moskovsky stations, as well as in the Yahotyn direction on Darnytsia station on slopes with sandy soils mixed with pebbles. Mentioned plant communities are periodically mowed. Herb coverage was from 80% to 100%.

The alliance *Dauco-Melilotion* includes four associations and two derivate communities. Coenoses of the association

Berteroetum incanae occur in the railways of the Right Bank and the Left Bank, where they occupy the areas between the tracks and the roadside on sandy and gravelly soils. They were found on the Vydubychi platform and between the Prospekt Nauky and Petro Kryvonis platforms. The total coverage was from 40% to 70–80%. In some cases, we recorded moss synusiae up to 20%. The areas of coenoses reached 450 m^2. Stands of the association *Echio-Verbascetum* are not common on the railways. They were found near the Petro Kryvonis platform and Sviatoshyn station on the roadside with sandy and gravelly soils, where they occupied areas from 30 to 90 m^2. The herb coverage was dense (80–90%). Phytocenoses of *Melilotetum albo-officinalis* are mostly confined to the territories of the Left Bank railway. They were found between Darnytsia and Livoberezhna stations near the railway slopes on the sandstone with a slight admixture of pebbles. The total area of the coenoses was 400 m^2. The total coverage of stands was 30–40%. Communities of the association *Asclepiadetum syriacae* are distributed along the railways of all regions of the city. They were recorded on Petrivka, Kyiv-Dniprovskyi, Vydubychi stations, where they occupied the slopes, more often abandoned lines up to 80 m^2. Soils are loamy chernozem mixed with gravel. The total coverage of the communities was 60–80%. The derivate community *Arrhenatherum elatius-Equisetum hyemale* was recorded on the Kyiv-Volynsky station on the lower parts of railway slopes between abandoned railway tracks on chernozem soil with high humidity, covered with gravel. The areas of particular stands ranged from 90 to 600 m^2. The herb coverage was dense (60–80 (95)%). Derivate community of *Arrhenatherum elatius-Taraxacum officinale* with an area of 200 m^2 and coverage of 70–80% were found in the flat areas of Karavayevi Dachi station, on humid chernozems with a mixture of gravel.

The alliance *Onopordion acanthii* included three associations and one derivate community. Coenoses of the association *Achilleo millefolii-Grindelietum squarrosae* are confined to the low parts of railway slopes on chernozems (sometimes mixed with sand), as well as gravelly-pebble substrates. They were recorded on the Left Bank, between Darnytsia and Livoberezhna stations, in areas from 4 to 160 m^2. Herb coverage was 30–40 (60)%. Stands of *Onopordetum acanthii* were recorded only in the Yahotyn direction on Darnytsia station with an area of about 10 m^2 and 60% total coverage. Phytocoenoses of the association *Potentillo argenteae-Artemisietum absinthii* are more common on the Right Bank. Found near Kyiv-Volynsky, Vydubychi and between Sviatoshyn and Borshchahivka stations, where they occupy flat areas along the tracks with loamy and sandy gravelly soils and slopes of abandoned railway lines. Areas of the plant community varied from 25–30 to 100 m^2. Herb coverage was from 30–40% to 50–80%, sometimes the moss layer is fixed (up to 80%). Derivate community *Artemisia absinthium-Partenocissus quinquefolia* occurs frequently along the city's railways, especially in shady habitats on the walls of mechanical structures and fences. The community was also observed on flat areas of railway slopes on loamy and sandy chernozem-like soils. They were found on the territory of Vydubychi platform, where they occupied an area of 30 m^2 and were characterized by 100% coverage.

Communities of the class *Galio-Urticetea*, which belong to the alliance *Senecionion fluviatilis*, are distributed mainly on the territories of the railways on the Right Bank (Table 3). They are represented by the association *Rudbeckio laciniatae-Solidaginetum canadensis*. Such phytocoenoses have been recorded in wet habitats 10 m from the railway slope of Kyiv-Volynsky station and on the slopes near Vydubychi platform where they occupied areas from 15–20 to 45–60 m^2. The herb coverage was mostly dense, from 60–80% to 100%. *Aegopodion podagrariae* plant communities are represented by three associations and one derivate community. Coenoses of *Oenothero biennis-Helianthetum tuberosi* were found between Protasiv Yar and Kyiv-Moskovsky station on flat with sandy soils mixed with gravel. Herb layer density reached 50–80%, total area 150 m^2. *Urtico dioicae-Rubetum caesii* plant community with a density of 100% are quite common. Stands of this community were recorded between the platforms of Prospect Nauky and Petro Kryvonis on the railway slopes. Coenoses of the association *Leonuro-Urticetum dioicae* are more common on the Right Bank on the railway slopes of the northern exposure in shady habitats along fences and buildings. They occupied an area of 18–25 m^2 near Borshchahivka station on the lower parts of the gravelly slope and on the railway slopes with chernozem-like soils near Vydubychi station in the shades of *Acer negundo* stands. The herb coverage was dense (60–70 to 90%). The derivate community *Phragmites australis-Rubus caesius* was noted near Vydubychi station on the railway slope with sandy soils. It was located in fragments, with a total area of about 20 m^2.

Coenoses of the class *Plantaginetea majoris*, in particular the association *Potentilletum reptantis*, occur infrequently on railway tracks. They were recorded near Kyiv-Volynskyi station on the railway slope on chernozem-like soils mixed with gravel. The stands occupied an area of 15–20 m^2 and had herb coverage of 60–80%.

Phytocoenoses of the class *Polygono-Poetea annuae* belong to the *Polygono-Coronopodion* alliance and include two associations (Table 3): *Polygonetum arenastri* and *Eragrostio minoris-Polygonetum arenastri*. They are usually confined to flat areas with sandy soils, where trampling is observed. They were observed on the territories of Kyiv-Petrivka and between Protasiv Yar and Kyiv-Moskovsky stations. Occupying areas from 6 to 80 m^2, with herb coverage from 30–40% to 60–70%.

Table 2 Synoptic table of the class *Artemisietea vulgaris*

No. of syntaxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of relevés	21	1	10	3	4	6	2	5	6	4	5	6	1	7	10
Fallopia convolvulus	52.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Galium aparine	26.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Elymus repens	26.7	–	21.3	–	–	–	–	–	–	–	–	–	–	–	–
Ballota nigra	25.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Artemisia austriaca	–	100.0	–	–	–	–	–	–	–	–	–	–	–	–	–
Calamagrostis epigeios	–	–	69.6	–	–	–	–	–	–	–	–	–	–	–	–
Sedum telephium	–	–	43.5	–	–	–	–	–	–	–	–	–	–	–	–
Aristolochia clematitis	–	–	–	100.0	–	–	–	–	–	–	–	–	–	–	–
Trifolium arvense	–	–	–	80.7	–	–	–	–	–	–	–	–	–	–	–
Odontites vulgaris	–	–	–	56.4	–	–	–	–	–	–	–	–	–	–	–
Rumex acetosa	–	–	–	56.4	–	–	–	–	–	–	–	–	–	–	–
Trifolium pratense	–	–	–	56.4	–	–	–	–	–	–	–	–	–	–	–
Verbascum thapsus	–	–	18.5	51.7	–	–	–	–	–	–	–	–	–	–	–
Artemisia campestris subsp. *campestris*	–	–	–	45.0	–	–	–	–	–	–	–	–	–	–	–
Crepis foetida subsp. *rhoeadifolia*	–	–	–	–	50.8	–	–	–	–	–	–	–	–	–	–
Polygonum aviculare	–	–	–	–	44.5	–	–	–	–	–	–	–	–	–	–
Setaria pumila	–	–	–	–	42.4	–	–	–	–	–	–	–	–	–	–
Poa compressa	–	–	–	–	–	52.3	–	–	–	–	–	–	–	–	–
Berteroa incana	–	–	–	–	–	35.6	–	–	–	–	–	–	–	–	–
Daucus carota	–	–	–	–	–	–	83.5	–	–	–	–	–	–	–	–
Plantago arenaria	–	–	–	–	–	–	59.1	–	–	–	–	–	–	–	–
Melilotus alba	–	–	–	–	–	–	–	74.3	–	–	–	–	–	–	–
Melampyrum arvense	–	–	–	–	–	–	–	–	56.4	–	–	–	–	–	–
Euphorbia cyparissias	–	–	–	–	–	–	–	–	39.5	–	–	–	–	–	–
Humulus lupulus	–	–	–	–	–	–	–	–	35.2	–	–	–	–	–	–
Solidago canadensis	–	–	–	–	–	–	–	–	–	90.1	–	–	–	–	–
Equisetum hyemale	–	–	–	–	–	–	–	–	–	85.8	–	–	–	–	–
Carex hirta	–	–	–	–	–	–	–	–	–	69.5	–	–	–	–	–
Acer negundo (juv.)	–	–	–	–	–	–	–	–	–	57.4	–	–	–	–	–
Arctium lappa	–	–	–	–	–	–	–	–	–	48.7	–	–	–	–	–
Phragmites australis	–	–	–	–	–	–	–	–	–	48.7	–	–	–	–	–
Stellaria graminea	–	–	–	–	–	–	–	–	–	48.7	–	–	–	–	–
Agrostis stolonifera	–	–	–	–	–	–	–	–	–	48.7	–	–	–	–	–
Oxalis europaea	–	–	–	–	–	–	–	–	–	48.7	–	–	–	–	–
Impatiens parviflora	–	–	–	–	–	–	–	–	–	48.7	–	–	–	–	–
Dactylis glomerata	–	–	–	–	–	–	–	–	–	40.0	–	–	–	–	–
Sonchus oleraceus	–	–	–	–	–	–	–	–	–	–	76.4	–	–	–	–
Taraxacum officinale agg.	–	–	–	–	–	–	–	–	–	–	60.0	–	–	–	–
Anthemis arvensis	–	–	–	–	–	–	–	–	–	–	–	85.6	–	–	–
Grindelia squarrosa	–	–	–	–	–	–	–	–	–	–	–	77.3	–	–	–
Festuca beckeri	–	–	–	–	–	–	–	–	–	–	–	56.4	–	–	–
Lepidium ruderale	–	–	–	–	–	–	–	–	–	–	–	33.8	–	–	–
Salsola kali subsp. *ruthenica*	–	–	–	–	–	–	–	–	–	–	–	–	100.0	–	–
Sisymbrium loeselii	–	–	–	–	–	–	–	–	–	–	–	–	100.0	–	–
Onopordum acanthium	–	–	–	–	–	–	–	–	–	–	–	–	100.0	–	–
Silene latifolia subsp. *alba*	–	–	–	–	–	–	–	–	–	–	–	–	97.5	–	–
Lolium perenne	–	–	–	–	–	–	–	–	–	–	–	–	–	74.5	–
Plantago lanceolata	–	–	–	–	–	–	–	–	–	–	–	–	–	36.7	–
Chondrilla juncea	–	–	–	–	–	–	–	–	–	–	–	–	–	28.0	–
Parthenocissus quinquefolia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	92.9
Secale sylvestre	–	–	–	–	–	–	–	–	–	–	–	–	–	–	56.4
Chenopodium rubrum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	35.9
Poa angustifolia	–	–	–	59.1	41.3	–	–	–	23.5	–	–	–	–	–	–
Achillea setacea	–	–	–	52.5	–	–	–	46.4	–	–	–	–	–	–	–
Erigeron annuus	–	–	–	51.0	–	29.3	–	–	–	–	–	–	–	–	–
Asclepias syriaca	–	–	–	44.0	–	–	–	–	71.1	–	–	–	–	–	–
Artemisia vulgaris	–	–	–	–	64.5	–	–	–	51.9	–	–	–	–	–	–
Portulaca oleracea	–	–	–	–	–	58.8	–	–	–	–	–	42.1	–	–	–
Lactuca serriola	–	–	–	–	–	32.7	–	–	–	–	–	–	–	–	32.7
Tragopogon dubius subsp. *major*	–	–	14.8	–	–	31.3	72.4	–	–	–	–	–	–	–	–
Ambrosia artemisiifolia	–	–	–	–	–	27.6	–	27.6	–	–	–	18.6	–	–	–
Equisetum arvense	–	–	–	–	–	–	63.9	–	–	45.2	–	–	–	–	–
Picris hieracioides	–	–	–	–	–	–	62.3	–	–	43.8	–	–	–	–	–
Echium vulgare	–	–	–	–	–	–	59.8	–	–	–	–	47.8	–	–	–
Arrhenatherum elatius	–	–	–	–	–	–	–	–	–	59.8	59.8	–	–	–	–
Conyza canadensis	–	–	–	–	–	–	–	–	–	–	39.7	30.0	–	–	–
Potentilla argentea	–	–	–	–	–	–	–	–	–	–	–	33.5	–	39.6	–
Artemisia absinthium	–	–	–	–	–	–	–	–	–	–	–	–	–	40.0	30.4
Bromus tectorum	–	–	–	–	–	35.3	–	33.3	–	–	–	45.5	–	–	–

Table 2 (continued)

Numbers mark syntaxa: 1 – *Agropyretum repentis*; 2 – *Anisantho-Artemisietum austriacae*; 3 – *Calamagrostietum epigei*; 4 – DC *Poa angustifolia- Aristolochia clematitis*; 5 – *Arctio lappae-Artemisietum vulgaris*; 6 – *Berteroetum incanae*; 7 – *Echio-Verbascetum*; 8 – *Melilotetum albo-officinalis*; 9 – *Asclepiadetum syriacae*; 10 – DC *Arrhenatherum elatius-Equisetum hyemale*; 11 – DC *Arrhenatherum elatius-Taraxacum officinale*; 12 – *Achilleo millefolii-Grindelietum squarrosae*; 13 – *Onopordetum acanthii*; 14 – *Potentillo argenteae-Artemisietum absinthii*; 15 – DC *Artemisia absinthium-Partenocissus quinquefolia*

Class *Robinietea* includes two associations and 1 derivate community (Table 3). Coenoses of the association *Chelidonio-Aceretum negundi* were found on the lower parts of slopes 1–4 m high on gravelly substrates. The height of the tree layer reached 4 m, the density was 0.8–0.9, herb coverage was sparse. The total area of the coenoses was 150–200 m^2. They have been found near Kyiv-Volynsky and Sviatoshyn stations. The derivate community *Humulus lupulus-Acer negundo* is quite common both on the Right and Left Bank of the Dnipro. In particular, stands were found on the territories of Sviatoshyn, Kyivska Rusanivka, Vydubychi, Livyi Bereg, Kyiv-Pasazhyrskyi and Protasiv Yar stations (Fig. 8e). Mentioned phytocoenoses occupied the sides of tracks, sections of the steep slopes and areas under the walls of roadside buildings on dark gray humus soils. Areas of coenoses – from 20 to 100 m^2, total coverage – 60–80 (100)%. The *Chelidonio majoris-Robinietum pseudoacaciae* community occupied flat areas near railway slopes on humus-dark sandy soil with gravel and pebbles. They were more often observed in strips of up to 10 m wide and 500 m long on the Borshchahivka railway station. *Robinia pseudoacacia* stands had a closure of 0.9–1.0, height 6–8 (10–15) m, diameter 8–10 cm. Herb coverage was sparse.

Natural and semi-natural, excessively transformed vegetation on the territory of the railway lines occupies small areas that have survived after the construction of the railway. It is represented by four communities of the class *Festucetea vaginatae* (Table 3). The affiliation of the identified phytocoenoses to this class was established by the participation in their composition of diagnostic species *Festuca beckeri*, *Artemisia campestris* subsp. *campestris*, *Centaurea arenaria* subsp. *borysthenica*, *Medicago sativa* subsp. *falcata*, *Bromus squarrosus*, *Plantago arenaria*, *Dianthus borbasii*, *Trifolium arvense*, *Anchusa gmelinii*, *Achillea setacea*, *Euphorbia cyparissias*. The basal community *Festuca beckeri-Artemisia campestris* subsp. *campestris* was recorded near Kyivska Rusanivka, Livoberezhna stations and between the platforms of Prospekt Nauky and Petro Kryvonis. It was found in flat areas near the railway slopes on gray sandstone and between old tracks on the sand with gravel and pebbles. Phytocoenoses occupied an area of 20–300 m^2, herb coverage reached 30–60%. The derivate community *Centaurea arenaria* subsp. *borysthenica-Potentilla neglecta* was recorded on the Left Bank station. Their stands were found near the slopes on humus-rich sands with an admixture of pebbles and gravel. The total area was 60 m^2. Herb coverage was 60–80%, sometimes a moss-lichen layer was present. Coenoses of *Artemisia campestris* subsp. *campestris-Medicago sativa* subsp. *falcata* were recorded on the flat sections of the railway slopes of Kyiv-Moskovsky and Kyiv-Dniprovsky stations. Soils – sandy, chernozems with gravel and pebbles. The total area of the community was 150–200 m^2, total coverage was 70–90%. The derivate community of *Anchusa officinalis-Medicago sativa* subsp. *falcata* was recorded near Vydubychi station towards the Dnipro. It was detected on the leveled top of the slope (10 m high) of a remote embankment on dark gray sand mounds. The total area of the fragmentary coenoses was 30 m^2, the herb coverage was 50–60%.

In addition to these syntaxa, many other communities have been recorded along the railways of Kyiv, in particular with the dominance of *Amaranthus blitoides*, *A. retroflexus*, *Carex hirta*, *Oxybaphus nyctagineus*, *Sedum acre*, *Salix acutifolia*, *Vicia cassubica* and *Vitis sylvestris* which indicates, on the one hand, the diversity of vegetation, and on the other – its significant disturbance and fragmentation due to constant human impact.

One of the important characteristics of the vegetation of the railways is the participation and potential danger of its non-native component, as a powerful source of diaspores of alien plant species. As part of the coenoflora of the studied plant communities, we identified 55 alien species, which is 28.6% of the total species number. Such a significant proportion of alien plants indicates active migration processes that affect the formation of vegetation on railways. Among the identified alien species, were many highly invasive ones (*Acer negundo*, *Ambrosia artemisiifolia*, *Amorpha fruticosa*, *Asclepias syriaca*, *Bromus tectorum*, *Cenchrus incertus*, *Centaurea diffusa*, *Conyza canadensis*, *Erigeron annuus*, *Galinsoga parviflora*, *Grindelia squarrosa*, *Helianthus tuberosus*, *Impatiens parviflora*, *Portulaca oleracea*, *Robinia pseudacacia*, *Solidago canadensis* etc.). Such species pose a significant danger to the territory of the Kyiv metropolis and region, fixing first in transformed habitats, and then penetrating natural coenoses. The apophytic fraction of coenoflora consisted of 57 (29.7%) mostly eurytopic species. In total the synanthropic element was 58.3%. Synanthropic plants very often predominate in railway plant communities (*Acer negundo*, *Ambrosia artemisiifolia*, *Digitaria ischaemum*, *D. sanguinalis*, *Helianthus tuberosus*, *Portulaca* *oleracea*, *Robinia pseudacacia*, *Setaria pumila*, *Sisymbrium loeselii*, *Solidago canadensis* and other).

On Kyiv railways, we also found species of native flora, for which the shoulders of the railway tracks in the conditions of anthropogenic urban landscapes have become an important habitat. They are *Astragalus glycyphyllos*, *Centaurea arenaria* subsp. *borysthenica*, *Chondrilla juncea*, *Clematis vitalba*, *Dianthus borbasii*, *Elytrigia intermedia*, *Equisetum hyemale*, *E. pratense*, *E. telmateia*, *Festuca beckeri*, *Helichrysum arenarium*, *Hypericum perforatum*, *Juncus effusus*, *Koeleria macrantha*, *Polygonum arenarium*, *Silene borysthenica* etc.

Ordination analysis

To identify the ecological differences between the communities located on the railways and outside them, we carried out their ordination according to the gradients of soil humidity and mineral nitrogen richness. The results of ordination of the class *Stellarietea mediae* showed that plant communities on the railways develop on the nutrient-poor soils with less moisture compared to ruderal communities located outside the railways (Fig. 3). Stands in railways of *Artemisietea vulgaris* showed that they also were mainly confined to less moist and nitrogen-poor soils compared to phytocoenoses located outside the railways (Fig. 4).

The results of ordination analysis of *Galio-Urticetea* by the same factors showed that coenoses on railways and outside them, develop in different conditions, depending on the origin of their habitats (roadsides or slopes, etc.) (Fig. 5). The comparative ordination analysis of the class *Polygono-Poetea annuae* showed that mentioned phytocoenoses often develop on substrates poor on moisture and nitrogen compounds (Fig. 6). Ecological assesment of *Robinietea* communities by the same factors showed that compared to the same communities located outside the railways, the railway habitats were less supplied with nitrogen and moisture (Fig. 7).

Discussion

Transport routes cause multiple ecological impacts, changing biotic and abiotic conditions that affect the structure and functioning of ecosystems from local to regional scale (Lázaro-Lobo and Ervin 2019). Phytocoenoses found along the railways of Kyiv are the result of their spontaneous formation in technogenic habitats. Due to the constant impact of road management and maintenance practices, unstable fragmented phytocoenoses and derivate communities are formed, which represent successive stages of ecosystem development. On the other hand, for many of the native species, road and railway sides may function as new main habitats or as distribution corridors in fragmented landscapes (Suárez-Esteban et al. 2016; Bernes et al. 2017; Borda-de-Água et al., 2017; Fekete et al. 2019), serve as refugia for natural vegetation in urban areas (Vandevelde and Penone 2017; Jakobsson et al. 2018; Lázaro-Lobo and Ervin 2019). This should be taken into account when developing recommendations for the management of the urban areas. Of course, rural and suburban roads have greater floristic and phytocoenotic pecularities (Gianguzzi and Bazan 2020). From the floristic and phytosociological aspects, plant species diversity on railway lines depends on succession processes, in particular on surrounding areas (Brandes 2001; Kryszak et al. 2006; Święs and Majkut 2006; Fornal-Pieniak and Wysocki 2010, 2011). These communities, even if they are autonomous, have floristic connections and affinity both with natural phytocoenoses and with plant communities of ruderal habitats of the city, which develop in contact with each other within the boundaries of their areals. In this regard, and also due to the significant differentiation of the habitat of railways, their role in preserving urban biodiversity and performing ecological functions as green spaces with parks, gardens and squares is irreplaceable (Penone et al. 2012; Vergnes et al. 2012; Capotorti et al. 2020).

Within the framework of adventization processes, which are relevant in studies of the flora of transport roads (Wrzesień and Denisow 2017), our results confirm the tendency of active participation of these habitats in the distribution and penetration of alien species into plant communities, first into ruderal phytocoenoses, and then into natural ones (Vinogradova et al. 2017; Follak et al. 2018; McDougall et al. 2018). This is facilitated by the transfer of diaspores by transport, the presence of suitable disturbed substrates, anthropogenic disturbances and a specific microclimate (Jehlík 1995, 1998; Ferus et al. 2015; Denisow et al. 2017; Jehlík et al. 2017). The dependence of the distribution of invasive plant species on microclimatic conditions, when thermophilic alien plants are introduced into urbanized ecosystems of European regions with a temperate climate, was confirmed by Géron et al. (2021). On the railways of Kyiv, we also registered the presence of thermophilic species from more southern regions of Ukraine, in particular *Bromus commutatus*, *B. sterilis*, *B. squarrosus*, *Cenchrus incertus*, *Clematis vitalba*, *Erysimum repandum*, *Polygonum arenarium*, *Secale sylvestre*, *Silene borysthenica*, *Tribulus terrestris* and some others, since railway substrates provide suitable conditions for the growth of thermophilic plants due to the high temperature of the rails and gravel (Májeková et al. 2014, 2016; Májeková and Limánek 2016). The composition and structure of local communities is also influenced by the species whose diasporas are carried by vehicles in the latitudinal direction. From the western regions to the Kyiv region penetrated, for example, *Cardamine hirsuta*,

Table 3 Synoptic table of the classes *Galio-Urticetea, Plantaginetea majoris, Polygono-Poetea annuae, Robinietea, Festucetea vaginatae*

No. of syntaxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of relevés	10	3	1	8	4	4	10	9	2	1	29	11	5	6	5
Equisetum pratense	67.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lythrum salicaria	61.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Solidago canadensis	56.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cirsium arvense	53.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Epilobium roseum subsp. *subsessile*	53.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Galium aparine	50.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scrophularia nodosa	43.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Epilobium roseum	43.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Helianthus tuberosus	–	95.0	–	–	–	–	–	–	–	–	–	–	–	–	–
Artemisia vulgaris	–	94.8	–	–	–	–	–	–	–	–	–	–	–	–	–
Lactuca serriola	–	55.7	–	21.4	–	–	–	–	–	–	8.4	–	–	–	–
Ambrosia artemisiifolia	–	43.2	–	–	–	–	–	23.3	–	–	–	–	–	–	–
Coronilla varia	–	–	100.0	–	–	–	–	–	–	–	–	–	–	–	–
Saponaria officinalis	–	–	98.2	–	–	–	–	–	–	–	–	–	–	–	–
Clematis vitalba	–	–	–	59.9	–	–	–	–	–	–	–	–	–	–	–
Urtica dioica	–	–	–	50.5	–	–	–	–	–	–	–	–	–	–	–
Pastinaca sativa subsp. *sylvestris*	–	–	–	48.7	–	–	–	–	–	–	–	–	–	–	–
Phragmites australis	–	–	–	–	100.0	–	–	–	–	–	–	–	–	–	–
Eupatorium cannabinum	–	–	–	–	70.3	–	–	–	–	–	–	–	–	–	–
Fallopia convolvulus	–	–	–	–	60.8	–	–	–	–	–	–	–	–	–	–
Juncus effusus	–	–	–	–	48.7	–	–	–	–	–	–	–	–	–	–
Potentilla anserina	–	–	–	–	48.7	–	–	–	–	–	–	–	–	–	–
Odontites vulgaris	–	–	–	–	48.7	–	–	–	–	–	–	–	–	–	–
Potentilla reptans	–	–	–	–	–	100.0	–	–	–	–	–	–	–	–	–
Crepis foetida subsp. *rhoeadifolia*	–	–	–	–	–	64.5	–	–	–	–	–	–	–	–	–
Linaria vulgaris	–	–	–	–	–	62.5	–	–	–	–	–	–	–	–	–
Lepidium ruderale	–	–	–	–	–	62.2	19.9	–	–	–	–	–	–	–	–
Amaranthus blitoides	–	–	–	–	–	48.7	–	–	–	–	–	–	–	–	–
Bromus japonicus	–	–	–	–	–	48.7	–	–	–	–	–	–	–	–	–
Polygonum arenarium	–	–	–	–	–	48.7	–	–	–	–	–	–	–	–	–
Medicago lupulina	–	–	–	–	–	48.7	–	–	–	–	–	–	–	–	–
Polygonum aviculare	–	–	–	–	–	–	65.5	–	–	–	–	–	–	–	–
Lolium perenne	–	–	–	–	–	–	53.5	–	–	–	–	–	–	–	–
Capsella bursa-pastoris	–	–	–	–	–	–	36.7	–	–	–	–	–	–	–	–
Sonchus oleraceus	–	–	–	–	–	–	36.5	–	–	–	–	–	–	–	–
Taraxacum officinale agg.	–	–	–	–	–	–	36.2	–	–	–	–	–	–	–	–
Diplotaxis tenuifolia	–	–	–	–	–	–	29.9	–	–	–	14.8	–	–	–	–
Grindelia squarrosa	–	–	–	–	–	–	–	73.4	–	–	–	–	–	–	–
Eragrostis minor	–	–	–	–	–	–	–	64.1	–	–	–	23.1	–	–	–
Portulaca oleracea	–	–	–	–	–	–	–	56.9	–	–	–	–	–	–	–
Amaranthus retroflexus	–	–	–	–	–	–	–	50.6	–	–	–	–	–	–	–
Digitaria ischaemum	–	–	–	–	–	–	–	48.6	–	–	–	–	–	–	–
Acer negundo	–	–	–	–	–	–	–	–	88.6	–	–	–	–	–	–
Cornus sanguinea	–	–	–	–	–	–	–	–	69.5	–	–	–	–	–	–
Erysimum repandum	–	–	–	–	–	–	–	–	69.5	–	–	–	–	–	–
Ulmus laevis	–	–	–	–	–	–	–	–	69.5	–	–	–	–	–	–
Carex hirta	–	–	–	–	–	–	–	–	69.5	–	–	–	–	–	–
Juglans regia	–	–	–	–	–	–	–	–	69.5	–	–	–	–	–	–
Robinia pseudacacia	–	–	–	–	–	–	–	–	–	100.0	–	–	–	–	–
Alliaria petiolata	–	–	–	–	–	–	–	–	–	100.0	–	–	–	–	–
Geum urbanum	–	–	–	–	–	–	–	–	–	100.0	–	–	–	–	–
Acer negundo (juv.)	–	–	–	–	–	–	–	–	–	–	41.4	–	–	–	–
Humulus lupulus	–	–	–	–	–	–	–	–	–	–	37.2	–	–	–	–
Poa annua	–	–	–	–	–	–	–	–	–	–	31.2	–	–	–	–
Festuca beckeri	–	–	–	–	–	–	–	–	–	–	–	90.6	–	–	–
Silene latifolia subsp. *alba*	–	–	–	–	–	–	–	–	–	–	–	51.5	–	–	–
Erodium cicutarium	–	–	–	–	–	–	–	–	–	–	–	40.2	–	–	–
Plantago lanceolata	–	–	–	–	–	–	–	–	–	–	–	36.9	–	–	–
Poa angustifolia	–	–	–	–	–	–	–	–	–	–	–	–	92.0	–	–

Table 3 (continued)

Potentilla neglecta	–	–	–	–	–	–	–	–	–	–	–	–	90.6	–	–
Bromus squarrosus	–	–	–	–	–	–	–	–	–	–	–	–	76.4	–	–
Dianthus borbasii	–	–	–	–	–	–	–	–	–	–	–	–	61.9	–	–
Poa bulbosa	–	–	–	–	–	–	–	–	–	–	–	–	61.9	–	–
Trifolium arvense	–	–	–	–	–	–	–	–	–	–	–	–	61.9	–	–
Chondrilla juncea	–	–	–	–	–	–	–	–	–	–	–	–	–	84.8	–
Calamagrostis epigeios	–	–	–	–	–	–	–	–	–	–	7.1	–	–	31.2	–
Erigeron annuus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	79.4
Anchusa officinalis	–	–	–	–	–	–	20.0	–	–	–	–	–	–	–	67.1
Convolvulus arvensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	65.0
Achillea setacea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	55.2
Cichorium intybus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	50.8
Lavatera thuringiaca	–	–	–	–	–	–	–	–	–	–	–	–	–	–	43.5
Ulmus glabra	–	–	80.2	–	–	–	–	–	35.6	–	–	–	–	–	–
Equisetum arvense	–	–	63.6	–	–	–	–	–	63.6	–	–	–	–	–	–
Elymus repens	–	–	–	–	–	38.5	–	–	–	–	–	–	–	29.0	–
Setaria pumila	–	–	–	–	–	–	26.0	30.7	–	–	–	22.2	–	–	–
Chenopodium rubrum	–	–	–	–	–	–	–	34.2	–	–	–	25.7	–	–	–
Acer platanoides	–	–	–	–	–	–	–	–	35.6	80.2	–	–	–	–	–
Bromus tectorum	–	–	–	–	–	–	–	–	–	–	–	31.2	44.1	–	–
Medicago sativa	–	–	–	–	–	–	–	–	–	–	–	29.4	–	–	58.8
Centaurea arenaria subsp. *borysthenica*	–	–	–	–	–	–	–	–	–	–	–	–	70.8	43.9	–
Medicago sativa subsp. *falcata*	–	–	–	–	–	–	–	–	–	–	–	–	–	62.9	62.9
Berteroa incana	–	–	–	–	–	–	19.6	–	–	–	–	–	–	33.5	31.5
Conyza canadensis	–	42.3	–	–	–	–	18.6	29.1	–	–	–	31.5	–	–	–
Rubus caesius	–	–	56.4	–	39.1	–	–	–	–	56.4	–	–	–	–	–
Artemisia campestris subsp. *campestris*	–	–	–	–	–	–	–	–	–	–	–	29.3	40.3	53.7	–

Numbers mark syntaxa: 1 – *Rudbeckio laciniatae-Solidaginetum canadensis*; 2 – *Oenothero biennis-Helianthetum tuberosi*; 3 – *Urtico dioicae-Rubetum caesii*; 4 – *Leonuro-Urticetum dioicae*; 5 – *DC Phragmites australis-Rubus caesius*; 6 – *Potentilletum reptantis*; 7 – *Polygonetum arenastri*; 8 – *Eragrostio minoris-Polygonetum arenastri*; 9 – *Chelidonio-Aceretum negundi*; 10 – DC *Humulus lupulus-Acer negundo*; 11 – *Chelidonio majoris-Robinietum pseudoacaciae*; 12 – BC *Festuca beckeri-Artemisia campestris subsp. campestris*; 13 – DC *Centaurea arenaria subsp. borysthenica-Potentilla neglecta*; 14 – DC *Artemisia campestris subsp. campestris-Medicago sativa subsp. falcata*; 15 – DC *Anchusa officinalis-Medicago sativa subsp. falcata*

Melampyrum arvense, *Tragopogon brevirostris* subsp. *podolicus*, from the eastern regions – *Crepis foetida* subsp. *foetida*, *Euphorbia davidii*, *Ulmus minor*.

It has been shown that the ecological conditions of anthropogenic micro-habitats created by road construction reflect the adaptive specialization of species and the plant communities that have settled in them (Gianguzzi and Bazan 2020). The anthropogenic changes in the vegetation of the railway tracks, which we recorded, are also consistent with the hypothesis of intermediate disturbances in the context of invasions of alien plants, when the latter ones change the course of successions, causing various disturbances (Hansen and Clevenger 2005; Catford et al. 2012). Thus, our research can contribute to understanding the role of indigenous (local) and invasive species in the processes of general synanthropization of vegetation. This data should also be taken into account during the development of management strategies, which should include methods for limiting the acclimatization of invasive species

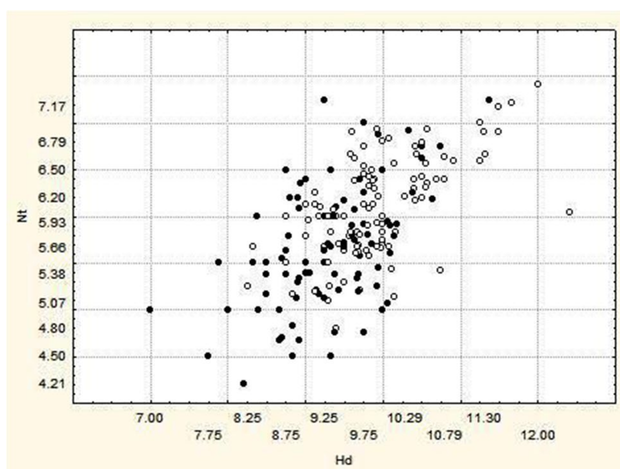


Fig. 3 Ordination of the communities of the class *Stellarietea mediae*. ● – communities on railways, ○ – communities outside railways. Key to Figs. 4–7: Hd-axis – soil humidity, Nt-axis – nitrogen content in soils

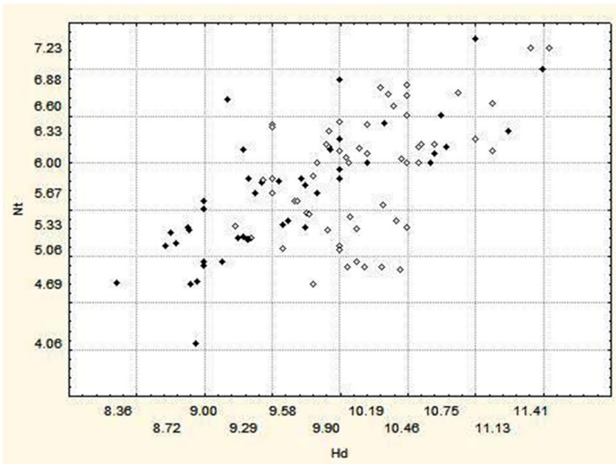


Fig. 4 Ordination of the communities of the class *Artemisietea vulgaris*. ▲ – communities on railways, Δ – communities outside railways

and replacing them with suitable local plants (Rentch et al. 2005).

Considering the floristic and syntaxonomic features of the studied plant communities of urban areas (Vinogradova et al. 2017; Májeková et al. 2021) and intercity railways as special habitats (Filibeck et al. 2012; Arepieva 2017), high levels of synanthropization and adventitization of the coenofloras of the Kyiv railways confirm the greater impact of urbanization on the presence of alien species than the presence of unfilled ecological niches (Penone et al. 2013; Toffolo et al. 2021).

The results of a comparative ordination analysis of the ruderal coenoses on the railways and outside them according to the gradients of soil humidity and nitrogen content show that, in general, communities on the railways develop under extreme conditions. Other authors studying the floristic composition and structure of communities in similar ecotopes have obtained similar results (Galera et al. 2014; Wrzesień et al. 2016; Wrzesień and Denisow 2017; Borda-de-Água et al. 2017; Arepieva 2017 et al.).

Conclusions

Phytosociological study of the vegetation of the Kyiv railways revealed its considerable richness and diversity. The syntaxonomical structure of these habitats includes 7 classes, 12 orders, 18 alliances, 35 associations and 13 rankless communities. This is due to their considerable length, specificity of environmental conditions and the constant anthropogenic impact to which most weed and ruderal plants adapt. The wide ecological spectrum and the increasing anthropogenic transformation of habitats, as well as the high level of urbanization of the research area, contribute to the formation of a significant number

Fig. 5 Ordination of the communities of the class *Galio-Urticetea*. ◆ – communities on railways, ◇ – communities outside railways

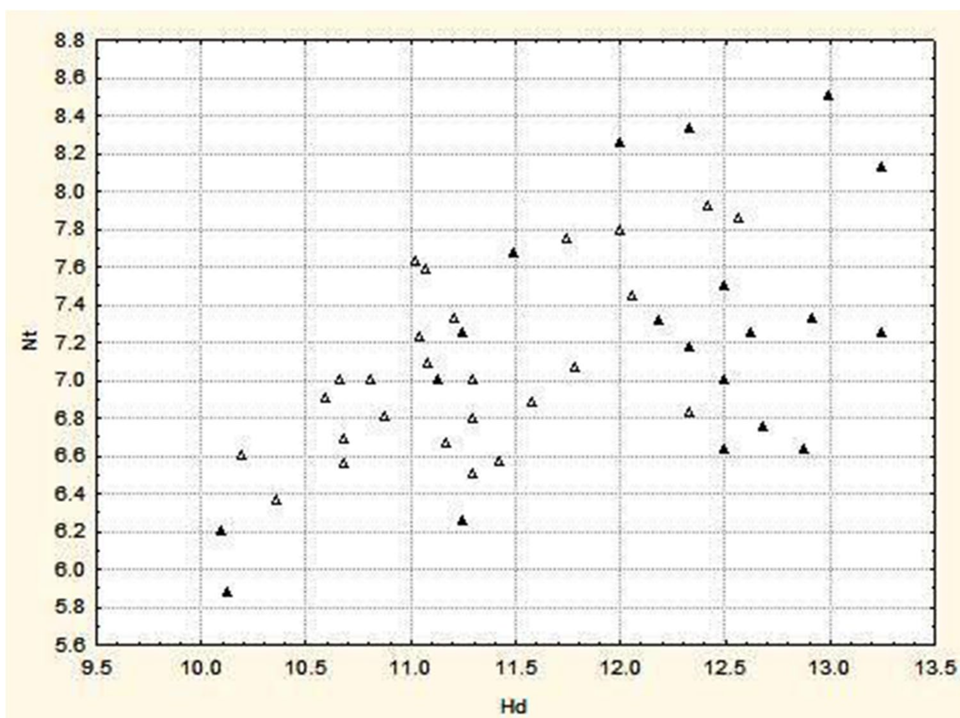
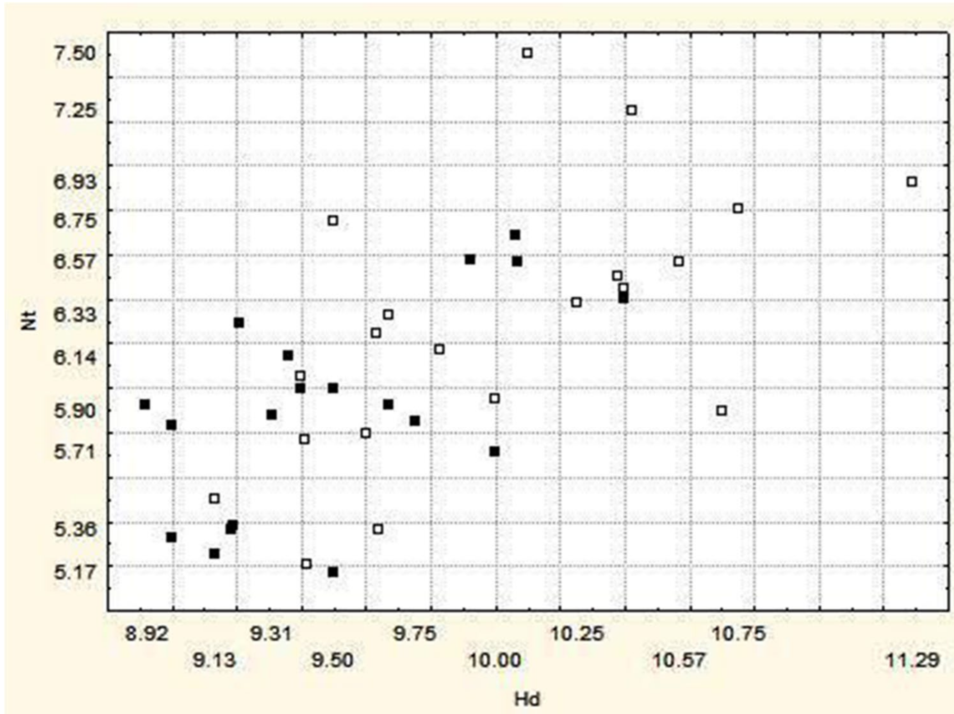


Fig. 6 Ordination of the communities of the class *Polygono-Poetea annuae*. ■ – communities on railways, □ – communities outside railways



of phytocoenoses of the rank of association and rankless (derivate) plant communities.

Periodic mowing and burning of areas adjacent to roads lead to the formation of unstable ecosystems. Habitat's substrates, which often contain building rubble, pebbles, gravel, especially on railway tracks or between them, as well as pollution by oil, metal dust and industrial debris cause significant complexity of vegetation. It is shown by changes in plant associations, their fragmentation and the formation of plant communities with the dominance of separate plant species. Physiognomically homogeneous coenoses are often structurally inhomogeneous: they consist of diagnostic species of different syntaxa. On the other hand, fragmented railway landscapes can function as new habitats or distribution corridors for local native species, especially in urban conditions.

The main trends of anthropogenic changes of vegetation of the railways of Kyiv were determined. These include the transformation and reduction of areas of natural vegetation, a decrease in its productivity, as well as an increase in the number of derivate communities, which are the successive stages of ecosystem development.

A significant degree of adventization and synanthropization of the studied coenoflora was established. The participation of highly invasive species reduces local diversity at the scale of phytocoenoses and changes their structure. Therefore, management objectives should include methods to limit the distribution of these species and replace them with suitable local ones.

Comparative ordination analysis of phytocoenoses along and outside of railways shows that communities on railways develop in the extreme conditions of ecotopes poor on moisture and mineral nitrogen compounds.

Our research can be used to effectively manage the biodiversity of urban habitats, monitor and develop measures to control the spread of non-native species. It can also be

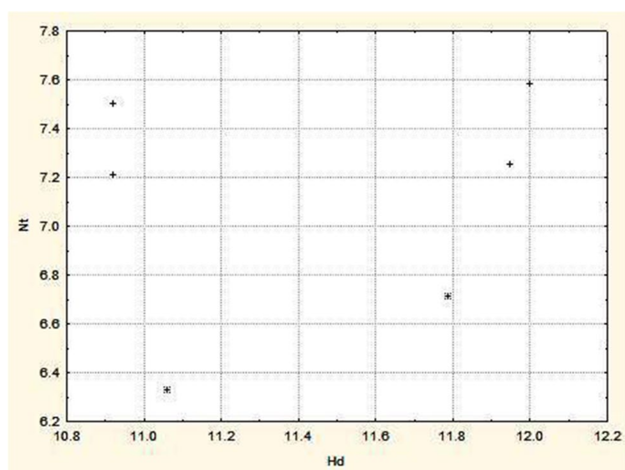


Fig. 7 Ordination of the communities of the class *Robinietea*. ⁎ – communities on railways, + – communities outside railways

Fig. 8 Plant communities of railways of Kyiv: *a – Setario pumilae-Echinochloetum cruris-galli* on abandoned railway track Borshchahivka station, *b* – community with the co-dominance of *Portulaca oleracea* and *Tribulus terrestris* near Kyiv-Moskovsky station (photo by T. Dziuba), *c – Ambrosietum artemisiifoliae* near Protasiv Yar station, *d – Calamagrostietum epigei* near Vydubychi station, *e* – community *Humulus lupulus-Acer negundo* on the Petrivka station (photo by P. Tymoshenko)

useful for sustainable planning and management of urban landscapes themselves.

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Declarations

Ethical approval All ethical standards are met.

Informed consent Informed consent is not required.

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References

Alessandrini A (2018) Flora degli ambienti ferroviari. Lo Scalo San Donato a Bologna. Quaderni del Museo Civico di Storia Naturale di Ferrara 6:37–44. https://www.researchgate.net/publication/330194233_Flora_degli_ambienti_ferroviari_Lo_Scalo_San_Donato_a_Bologna_Flora_of_railway_environments_The_San_Donato_railway_yard_in_Bologna . [Accessed May 22 2021]

Arenas JM, Escudero A, Mola I, Casado MA (2017) Roadsides: an opportunity for biodiversity conservation. Appl Veg Sci 20(4):527–537. https://doi.org/10.1111/avsc.12328

Arepieva LA (2017) The vegetation on railway embankments of the Kursk region. Veg Russia 30:3–28. https://doi.org/10.31111/vegrus/2017.30.3

Barshchevsky NE (1993) Relief of the Kiev Dnieper region (morphogenetic analysis). Naukova Dumka, Kiev

Barshchevsky NE, Kuprash RP, Shvydkiy YN (1989) Geomorphology and relief-forming deposits of the Kiev region. Naukova Dumka, Kiev

Bernes C, Bullock JM, Jakobsson S, Rundlöf M, Verheyen K, Lindborg R (2017) How are biodiversity and dispersal of species affected by the management of roadsides? A systematic map. Environ Evid, 6(1). https://doi.org/10.1186/s13750-017-0103-1

Besarabchuk IV (2018) The role of railway transport in the distribution of adventive plant species in the city of Lutsk (Volyn region). In: Biol. research – 2018: Coll. Science. Works. Zhytomyr, pp. 345–346

Bonthoux S, Voisin L, Bouché-Pillon S, Chollet S (2019) More than weeds: spontaneous vegetation in streets as a neglected element of urban biodiversity. Landsc Urban Plan 185:163–172. https://doi.org/10.1016/j.landurbplan.2019.02.009

Borda-de-Água L, Barrientos R, Beja P, Pereira HM (eds) (2017) Railway ecology. SpringerOpen. https://doi.org/10.1007/978-3-319-57496-7

Bortnyk SY, Lavruk TM, Tymulyak LM (2016) Soil cover of the territory of Kyiv: current state and regularities of spatial organization. Phys Geogr Geomorph (Sci Collect) 4(84):44–49

Brandes D (1979) Bahnhofe als Untersuchungsobjekte der Geobotanik. Mitt. Tech. Univ. Carola-Wilhelmina. Braunschweig 14 (3/4):49–59

Brandes D (1983) Flora und Vegetation der Bahnhofe Mitteleuropas. Phytocoenologia. Stuttgart-Braunschweig 11(1):31–115

Brandes D (1984) Flora und Vegetation von Bahnhofen im nordlichen Deutschland. Acta Bot Slov 1:9–16

Brandes D (2001) Die Ruderalflora der Kleinstadt Lüchow (Niedersachsen). Vascular flora of the Luchow raiway station (Lower Saxony, Germany). Braunschweiger Naturkundliche Schriften 6(2):455–483

Brandes D (2003) Some contributions to the urban flora of Strasbourg (France). http://opus.tu-bs.de/opus/volltexte/2003/517/. Accessed 10 February 2020

Brandes D (2005) Kormophytendiversität innerstädtischer Eisenbahnanlagen. Tuexenia 25:269–284

Braun-Blanquet J (1964) Pflanzensociologie. Grundzuge der Vegetationskunde, 3rd edn. Springer Verlag, Wien

Bredikhina YL (2015) Spontaneous vegetation of Melitopol: syntaxonomy, phytomeliorative importance and ways of optimization. Dissertation, National Forestry University of Ukraine, Lviv

Cai D, Fraedrich K, Guan Y, Guo S, Zhang C, LMV C, Zhu X (2019) Causality of biodiversity loss: climate, vegetation and urbanization in China and America. Sensors 19:4499. https://doi.org/10.3390/s19204499

Capotorti G, Bonacquisti S, Abis L, Aloisi I, Attorre F et al (2020) More nature in the city. Plant Biosyst 154(6):1003–1006. https://doi.org/10.1080/11263504.2020.1837285

Catford JA, Daehler CC, Murphy HT, Sheppard AW, Hardesty BD, Westcott DA, Rejmánek M, Bellingham PJ, Pergl J, Horvitz CC, Hulme PE (2012) The intermediate disturbance hypothesis and plant invasions: implications for species richness and management. Perspect Plant Ecol Evol Syst 14:231–241. https://doi.org/10.1016/j.ppees.2011.12.002

Toffolo Ch, Gentili R, Banfi E, Montagnani Ch, Caronni S, Citterio S, Galasso G (2021) Urban plant assemblages by land use type in Milan: floristic, ecological and functional diversities and refugium role of railway areas. Urban Urban Green 62. https://doi.org/10.1016/j.ufug.2021.127175

Chocholoušková Z, Pyšek P (2003) Changes in composition and structure of urban flora over 120 years: a case study of the city of Plzeň. Flora 198:366–376. https://doi.org/10.1078/0367-2530-00109

Chytrý M (ed) (2009) Vegetation of the Czech Republic. 2, Ruderal, weed, rock and scree vegetation. Vyd. 1. Academia, Praha

Denisow B, Wrzesień M, Mamchur Z, Chuba M (2017) Invasive flora within urban railway areas: a case study from Lublin (Poland) and Lviv (Ukraine). Acta Agrobot 70:1727. https://doi.org/10.5586/aa.1727

Didukh YP (2011) The ecological scales for the species of Ukrainian flora and their use in synphytoindication. Phytosociocentre, Kyiv

Didukh YP, Protopopova VV, Kucher OO, Zavyalova LV, Shevera MV (2019) Actual tasks of researches of phytoinvasions in Ukraine. In: Synanthropization of the vegetation cover of Ukraine: III All-Ukrainian Scientific Conference, 26–27 September 2019, Kyiv, Ukraine, pp 47–49

Dobrochaeva DN, Kotov MI, Prokudin YN et al (1987) The determination key of vascular plants of Ukraine, 2nd edn. Phytosociocentre, Kyiv

Dubyna DV, Dziuba TP, Iemelianova SM, Bagrikova NO, Borysova OV, Borsukevych LM, Vynokurov DS, Gapon SV, Gapon YV, Davydov DA, Dvoretsky TV, Didukh YP, Zhmud OI, Kozyr MS, Konishchuk VV, Kuzemko AA, Pashkevych NA, Ryff LE, Solomakha VA et al (2019) Prodrome of the vegetation of Ukraine. Naukova dumka, Kyiv

Dvirna TS (2012) Finds of alien plants on the territory of the Romensko-Poltavsky geobotanical region. Ukr Bot J 69(6):847–852

Dziuba TP, Dubyna DV, Tymoshenko PA, Iemelianova SM (2019) Ruderal vegetation of the railways of the city of Kyiv In: Synanthropization of the vegetation cover of Ukraine: III All-Ukrainian Scientific Conference, 26–27 September 2019, Kyiv, Ukraine, pp 42–47

Eliáš P (1979a) *Linario-Brometum tectorum* na železničnej stanici Cífer (západné Slovensko). Biológia (Bratislava) 34:329–333

Eliáš P (1979b) The association *Conyzo-Cynodontetum dactyloni* in western Slovakia, Czechoslovakia. Preslia 51:349–362

Fedoronchuk MM, Zavialova LV, Kucher OO, Kolomiychuk VP, Koniakin SM, Lysohor LP, Priadko OI (2020) Synanthropization of the flora and vegetation – a serious threat to biodiversity. III All-Ukrainian Scientific Conference "Synanthropization of the Plant Cover of Ukraine". Visn Nac Akad Nauk Ukr 1:62–67. https://doi.org/10.15407/visn2020.01.062

Fekete R, Löki V, Urgyán R, Süveges K, Lovas-Kiss Á, Vincze O, Molnár AV (2019) Roadside verges and cemeteries: comparative analysis of anthropogenic orchid habitats in the Eastern Mediterranean. Ecol Evol 9(11):6655–6664. https://doi.org/10.1002/ece3.5245

Ferus P, Sîrbu C, Eliáš P Jr, Konôpková J, Ďurišová Ľ, Samuil C, Oprea A (2015) Reciprocal contamination by invasive plants: analysis of trade exchange between Slovakia and Romania. Biologia 70:893–904

Filibeck G, Cornelini P, Petrella P (2012) Floristic analysis of a high-speed railway embankment in a Mediterranean landscape. Acta Bot Croat 71:229–248

Follak S, Eberius M, Essl F, Fürdös A, Sedlacek N, Trognitz F (2018) Invasive alien plants along roadsides in Europe. EPPO Bull 48:256–265. https://doi.org/10.1111/epp.12465

Fornal-Pieniak B, Wysocki C (2010) Flora of a non-used railway embankment near Sokolow Podlaski (in Polish). Woda–Środowisko–Obszary Wiejskie 10(3):85–94

Fornal-Pieniak B, Wysocki C (2011) Vegetation on the railway-line embankment at Tarnów. Ekológia (Bratislava) 30(4):414–421. https://doi.org/10.4149/ekol_2011_04_414

Galera H, Sudnik-Wójcikowska B, Wierzbicka M, Wiłkomirski B (2011) Encroachment of forest species into operating and abandoned railway areas in North-Eastern Poland. Pl Biosyst 145:23–36

Galera H, Sudnik-Wójcikowska B, Wierzbicka M, Wiłkomirski B (2012) Directions of changes in the flora structure in the abandoned railway areas. Ecol Quest 16:29–39

Galera H, Sudnik-Wójcikowska B, Wierzbicka M, Jarzyna I, Wiłkomirski B (2014) Structure of the flora of railway areas under various kinds of anthropopression. Polish Bot J 59(1):121–130. https://doi.org/10.2478/pbj-2014-0001

Géron C, Lembrechts J, Borgelt J, Lenoir J, Hamdi R, Mahy G, Nijs I, Monty A (2021) Urban alien plants in temperate oceanic regions of Europe originate from warmer native ranges. Biol Invasions. https://doi.org/10.1007/s10530-021-02469-9

Gianguzzi L, Bazan G (2020) The vegetation of a historic road system in the suburban area of Monte Pellegrino (Palermo, Sicily). Plant Sociol 57(2):71–103. https://doi.org/10.3897/pls2020572/02

Gilbert OL (1989) Ecology of urban environment. Chapman & Hall, London

Grűll F (1990) Rostlinná společenstva železničního uzlu Brno v oblasti seřaďovacího nádraží v letech 1970–1986. Preslia 62(1):73–90

Hansen MJ, Clevenger AP (2005) The influence of disturbance and habitat on the presence of non-native plant species along transport corridors. Biol Conserv 125:249–259. https://doi.org/10.1016/j.biocon.2005.03.024

Hennekens SM (1995) TURBO(VEG). Software package for input processing and presentation of plantsociological data. User's guide. IBN-DLO Wageningen et University of Lancaster

Hill MO, Roy DB, Thompson K (2002) Hemeroby, urbanity and ruderality: bioindicators of disturbance and human impact. J Appl Ecol 39(5):708–720. https://doi.org/10.1046/j.1365-2664.2002.00746.x

Hobbs RJ, Arico S, Aronson J, Baron JS, Bridgewater P, Cramer VA, Epstein PR, Ewel JJ, Klink CA, Lugo AE, Norton D (2006) Novel ecosystems: theoretical and management aspects of the new ecological world order. Glob Ecol Biogeogr 15:1–7. https://doi.org/10.1111/j.1466-822X.2006.00212.x

Hohla M, Kleesadl G, Melzer H (2000) Neues zur Flora des oberösterreichischen Bahnanlagen – mit Einbeziehung einiger grenznaher Bahnhöfe Bayerns. Beitr Naturk Oberösterreichs 9:191–250

Hohla M, Kleesadl G, Melzer H (2002) Neues zur Flora der oberösterreichischen Bahnanlagen – mit Einbeziehung einiger Bahnhöfe Bayerns – Fortsetzung. Beitr Naturk Oberösterreichs 11:507–578

Hohla M, Kleesadl G, Melzer H (2005) Neues zur Flora der oberösterreichischen Bahnanlagen. Beitr Naturk Oberösterreichs 14:147–199

Jakobsson S, Bernes C, Bullock JM, Verheyen K, Lindborg R (2018) How does roadside vegetation management affect the diversity of vascular plants and invertebrates? A systematic review. Environ Evid 7(17) https://doi.org/10.1186/s13750-018-0129-z

Jasprica N, Milović M, Lasić A, Dolina K (2014) Flora and vegetation of the railway areas in Croatia and Bosnia and Herzegovina. In: First Croatian Symposium on Invasive Species with International Participation. Book of Abstracts. Jelaska, Sven (ur.). Zagreb, pp. 57–58

Jasprica N, Milović M, Dolina K, Lasić A (2017) Analyses of the flora of railway stations in the Mediterranean and sub-Mediterranean areas of Croatia and Bosnia and Herzegovina. Nat Croat 26(2):271–303. https://doi.org/10.20302/NC.2017.26.21

Jehlík V (1986) The vegetation of railways in northern Bohemia (eastern part). Vegetace ČSSR Ser A 14:1–368

Jehlík V (1995) Současný výskyt cizích expanzivních druhů rostlin v železničních uzlech České republiky. Ochr Rostl 31(2):149–160

Jehlík V (ed) (1998) Cizí expanzivní plevele České republiky a Slovenské republiky. Academia, Praha

Jehlík V, Zaliberová M, Májeková J (2017) The influence of the eastern migration route on the Slovak flora – a comparison after 40 years. Tuexenia 37:313–332

Junghans TH (2016) Flora und Vegetation der Bahnanlagen im Raum Paderborn. Natur und Heimat 76(4):155–168

Karmyzova LO (2016) Bio-ecological analysis of flora of the biotope of railways in the Dnipro. Questions of Steppe forestry and forest. Recultivation Lands 45:29–44

KL MD, Lembrechts J, Rew LJ, Haider S, Cavieres LA, Kueffer C et al (2018) Running off the road: roadside non-native plants invading mountain vegetation. Biol Invasions 20(12):3461–3473. https://doi.org/10.1007/s10530-018-1787-z

Kolesnyk OB, Kolesnyk AV (2009) Railways as eco-corridors for the penetration of invasive plant species into the phytosystems of Transcarpathia. In: Functioning of protected areas in modern conditions of Ukraine. Materials International. scientific-practical conf. "Uzhhorod Entomological Readings", 1–3 October 2009, Synevyr, Ukraine. Uzhhorod, pp. 40–43

Konoplia M, Drel' V (1998) Adventive flora of railways of Lugansk region. Shlyakh, Lugansk

Kopecky K, Hejny S (1974) A new approach to the classification of anthropogenic plant communities. Vegetatio 29:17–20

Kryszak A, Kryszak J, Czemko M, Kalbarczyk M (2006) Vegetation of railway embankments (examples) (in Polish). Zeszyty Naukowe Uniwersytetu Przyrodniczego we Wrocławiu. Rolnictwo 545:157–164

Lázaro-Lobo A, Ervin GN (2019) A global examination on the differential impacts of roadsides on native vs. exotic and weedy plant species. Glob Ecol Conserv 17:e00555. https://doi.org/10.1016/j.gecco.2019.e00555

Májeková J, Limánek J (2016) Diverzita flóry železničných staníc na trati Poprad – Plaveč (východné Slovensko). Bull Slov Bot Spoločn 38(1):37–45

Májeková J, Letz DR, Slezák M, Zaliberová M, Hrivnák R (2014) Rare and threatened vascular plants of the railways in Slovakia. Biodiv Res Conserv 35:75–85

Májeková J, Jehlík V, Zaliberová M (2016) Railway stations vs. thermophilous species (example from eastern Slovakia). Thaiszia – J Bot, 26 (2):173–188

Májeková J, Zaliberová M, Andrik EJ, Protopopova VV, Shevera MV, Ikhardt P (2021) A comparison of the flora of the Chop (Ukraine) and Čierna nad Tisou (Slovakia) border railway stations. Biologia 76:1969–1989. https://doi.org/10.2478/s11756-020-00592-x

Mamchur Z, Chuba M, Drach Y (2017) Mosses and vascular plants on the territory of the Lviv urban railway. Visn. Lviv. un-tu. Ser Biol 75:54–65

McCune B, Mefford MJ (2006) PC-ORD. Multivariate analysis of ecological data. Version 5. MjM Software, Gleneden Beach, Oregon, U.S.A.

McDonnell MJ, Niemelä J (2011) The history of urban ecology. Urban Ecol 9:34–49

Mirkin BM, Yamalov SM, Naumova LG (2007) Synanthropic plant communities: models of organization and features of classification. Zh Obshch Biol 68(6):435–443

Mucina L, Bültmann H, Dierßen K, Theurillat P, Raus T, Čarni A et al (2016) Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Appl Veg Sci 19:3–264. https://doi.org/10.1111/avsc.12257

National Atlas of Ukraine (2007). Kartografiya, Kyiv

Niemelä J, Breuste JH, Guntenspergen G, NE MI, Elmqvist T, James P (eds) (2011) URBAN ecology: patterns, processes and applications. OUP, Oxford

Niemi A (1969) On the railway vegetation and flora between Esbo and Inge, S. Finland. Acta Bot Fennici 83:1–28

Orlov OO (2019) Modern trends of adventization of the flora of Zhytomyr Polissya. In: Synanthropization of the vegetation cover of Ukraine: III All-Ukrainian Scientific Conference, 26–27 September 2019, Kyiv, Ukraine, pp 123–127

Palkina TA (2012) About synanthropic flora of the transport routes of the Ryazan region. Bull N.G. Lobachevsky Nizhny Novgorod Univ 6(1):86–91

Penone C, Machon N, Julliard R, le Viol I (2012) Do railway edges provide functional connectivity for plant communities in an urban context? Biol Conserv 148:126–133. https://doi.org/10.1016/j.biocon.2012.01.041

Penone C, Kerbiriou C, Julien J-F, Julliard R, Machon N, Le Viol I (2013) Urbanisation effect on Orthoptera: which scale matters? Insect Conserv Divers 6:319–327. https://doi.org/10.1111/j.1752-4598.2012.00217.x

Popova E (2020) Assessment of the impact of railway traffic on the state of plant communities. E3S Web Conf 164:03048. https://doi.org/10.1051/e3sconf/202016403048

Rabitsch W, Essl F (2006) Biological invasions in Austria: patterns and case studies. Biol Invas 8:295–308

Rendeková A, Mičieta K, Randáková Z et al (2020) Flora of the tram tracks of Bratislava. Urban Ecosyst 23:875–891. https://doi.org/10.1007/s11252-020-00952-0

Rentch JS, Fortney RH, Stephenson SL, Adams HS, Grafton WN, Anderson JT (2005) Vegetation-site relationships of roadside plant communities in West Virginia, USA. J Appl Ecol 42(1):129–138. https://doi.org/10.1111/j.1365-2664.2004.00993.x

Roleček J, Tichý L, Zelený D, Chytrý M (2009) Modified TWINSPAN classification in which the hierarchy respects cluster heterogeneity. J Veg Sci 20:596–602

Sargent C (1984) Britain's railway vegetation. Institute of Terrestrial Ecology, Cambridge

Senator SA, Rakov NS, Saxonov SV, Nikitin NA, Vasjukov VM, Ivanova AV, Bobkina EM (2011) Materials to the flora of railways of the Samara region. Izvestija Samara Scientific Center of Russian Acad Sci 13(5/2)):224–229

Shevera MV, Zaliberová M, Protopopova VV, Jehlík V, Andrik EJ, Kohut E, Májeková J (2018) Flora of selected railways station of the Transcarpathian lowland (Transcarpathia region, Ukraine). In: XII international conference Synanthropization of Flora and Vegetation, 20–22 September 2018, Uzhhorod – Berehove, Ukraine. Book of Abstracts. AUTDOR–SHARK Press, Uzhhorod, p 60

Slezák M, Jarolímek I, Kochjarová J, Hrivnák R (2020) Floodplain forest vegetation in the northern part of the Western Carpathians. Biologia 75(11):1789–1799. https://doi.org/10.2478/s11756-020-00527-6

Sörensen TA (1948) A method of establishing groups of equal amplitude inplant sociology based on similary of species content, and its application to analyses of the vegetation Danish commons. Kongelige Danske Videnskabernes Selskabs Biologiske Skrifter 5:1–34

Stařecká C (2010) Diverzita flóry železničních tratí v středních Čechách. Stud Oecol 4:70–76

Suárez-Esteban A, Fahrig L, Delibes M et al (2016) Can anthropogenic linear gaps increase plant abundance and diversity? Landscape Ecol 31:721–729. https://doi.org/10.1007/s10980-015-0329-7

Sukopp H (2002) On the early history of urban ecology in Europe. Preslia 74:373–393

Suominen J (1969) The plant cover of Finnish railway embankments and the ecology of their species. Ann Bot Fennici 6:183–235

Święs F, Majkut A (2006) Rare vascular plants on railaway areas in Sandomierska basin (Part I. North part of this region) (in Polish). Annales Universitatis Mariae Curie-Skłodowska Lublin-Polonia 61:19–43

Junghans TH (2011) Über einige bemerkenswerte floristische Neufunde im Raum Paderborn. Natur und Heimat 71(1):32–34

Theurillat JP, Willner W, Fernández-González F, Bültmann H, Čarni A, Gigante D, Mucina L, Weber H (2021) International code of phytosociological nomenclature. 4th edition. Appl Veg Sci 24(1):1–62. https://doi.org/10.1111/avsc.12491

Tichý L (2002) JUICE, software for vegetation classification. J Veg Sci 13:451–453

Tichý L, Chytrý M (2006) Statistical determination of diagnostic species for site groups of unequal size. J Veg Sci 17:809–818

Tikka PM, Koski PS, Kivelä RA, Kuitunen MT (2000) Can grassland communities be preserved on road and railway verges? Appl Veg Sci 3:25–32. https://doi.org/10.2307/1478915

Tikka PM, Högmander H, Koski PS (2001) Road and railway verges serve as dispersal corridors for grassland plants. Landsc Ecol 16:659–666

Tokaryuk AI, Chorney II, Budzhak VV, Protopopova VV, Shevera MV, Korzhan KV, Volutsa OD (2018) Invasive plants of Bukovinian Cis-Carpathian. Druk Art, Chernivtsi

Tokhtar VK (1995a) On the question of anthropogenic migration of plants by railways. Ukr Bot J 51(6):145–148

Tokhtar VK (1995b) Ecotopological structure of the flora of railways of south-eastern of Ukraine. Ukr Bot J 52(1):33–38

Tutin TG, Heywood VH, Burges NA, Valentine DW, Walters SM, Webb DA (eds) (1964) Flora Europaea, vol 1. Cambridge University Press, Cambridge

Vandevelde JC, Penone C (2017) Ecological roles of railway verges in anthropogenic landscapes: a synthesis of five case studies in Northern France. In: Borda-de-Água L, Barrientos R, Beja P, Pereira H (eds) Railway ecology. Springer, Cham. https://doi.org/10.1007/978-3-319-57496-7_16

Vergnes A, Viol IL, Clergeau P (2012) Green corridors in urban landscapes affect the arthropod communities of domestic gardens. Biol Conserv 145:171–178

Vinogradova YK, Bochkin VD, Mayorov SR, Teplov K, Barinov AV (2017) Historical flora of Moscow's railway junction (until 2012). Hortus Bot 12:88–136. https://doi.org/10.15393/j4.art.2017.3402

Westhoff V, van der Maarel E (1973) The Braun-Blanquet approach. 2nd edition. In: Whittaker R. (ed) Classification of plant communities: 287–399

Whittaker RH (ed) (1978) Approaches to classifying vegetation on classification of plant communities, 2nd edn. Junk, The Hague

Wiłkomirski B, Galera H, Sudnik-Wójcikowska B, Staszewski T, Malawska M (2012) Railway tracks – habitat conditions, contamination, floristic settlement – a review. Environ Nat Resour Res 2(1):86–95

Willner W, Tichy L, Chytry M (2009) Effects of different fidelity measures and contexts on the determination of diagnostic species. J Veg Sci 20:130–137. https://doi.org/10.1111/j.1654-1103.2009.05390.x

Willner W, Kuzemko A, Dengler J, Chytrý M, Bauer N, Becker T, Biţă-Nicolae C, Botta-Dukát Z, Čarni A, Csiky J, Igić R, Kącki Z, Korotchenko I, Kropf M, Krstivojević-Ćuk M, Krstonošić D, Rédei T, Ruprecht E, Schratt-Ehrendorfer L et al (2017) A higher-level classification of the Pannonian and western Pontic steppe grasslands (Central and Eastern Europe). Appl Veg Sci 20:143–158. https://doi.org/10.1111/avsc.12265

Wittig R (2004) The origin and development of the urban flora of Central Europe. Urban Ecosyst 7:323–329

Wittig R, Lienenbecker H (2004) Ruderalvegetation von Bahnhöfen im Raum Bielefeld/Gütersloh. Ber Naturwiss Verein für Bielefeld u Umgegend 44:213–243

Wrzesień M, Denisow B (2017) Factors responsible for the distribution of invasive plant species in the surroundings of railway areas. A case study from SE Poland. Biologia (Bratislava) 72:1275–1284

Wrzesień M, Denisow B, Mamchur Z, Chuba M, Resler I (2016) Composition and structure of the flora in intra-urban railway areas. Acta Agrobot 69(3):1666. https://doi.org/10.5586/aa.1666

Zvyagintseva KA (2013) Analysis of the flora of railways of Kharkiv. Visn Khark Univ Ser Biol 17(1056):37–46