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Ruderal vegetation in Kryvyi Rih (Ukraine) – the class of *Robinietea*

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Key words: syntaxonomy, classification, synphytoindication, associations, derivate communities, Ukraine, disturbed ecotopes, alien species.

Ključne besede: sintaksonomija, klasifikacija, sinfitoindikacija, asociacije, izpeljane združbe, Ukrajina, moteni ekotopi, tujerodne vrste.

Abstract

The present paper studies the ruderal vegetation of the class of *Robinietea* in Kryvyi Rih. We present the spontaneous woody vegetation of parks and other artificial plantations. Urban landscapes remain unstudied phytosociologically despite the highly diverse habitat niches. We have carried out the comparisons of communities from other regions of Ukraine and adjacent territories. In total, four associations and one derivate community, belonging to three alliances, were identified and categorized as follows: *Chelidonio-Acerion negundi* (synanthropic tree communities with *Acer negundo*), *Chelidonio majoris-Robinion pseudoacaciae* (artificial and spontaneous plantations of *Robinia pseudoacacia*), *Geo-Acerion platanoidis* (artificial plantations of broad-leaved tree species). The ordination analysis indicates ecological differentiation of syntaxa investigated in Kryvyi Rih. The most important of them are soil aeration (Ae), the cryo-climate (Cr) and nitrogen content in soil (Nt). Critical revision of the class *Robinietea* syntaxonomy demands further current research.

Izvleček

V članku predstavljamo ruderalno vegetacijo razreda *Robinietea* v mestu Kryvyi Rih. Preučevali smo gozdno vegetacijo, ki spontano uspeva v parkih in drugih umetnih nasadih. Urbana krajina je pogosto fitocenološko neraziskana kljub zelo raznolikim življenjskim prostorom. Naredili smo tudi primerjavo s podobnimi združbami v drugih predelih Ukrajine in sosednjih območjih. Ugotovili smo štiri asociacije in eno izpeljano združbo, ki jih uvrščamo v zveze: *Chelidonio-Acerion negundi* (sinantropne drevesne združbe z vrsto *Acer negundo*), *Chelidonio majoris-Robinion pseudoacaciae* (umetni nasadi in spontani sestoji vrste *Robinia pseudoacacia*), *Geo-Acerion platanoidis* (umetni nasadi plementih listavcev). Rezultati ordinacije kažejo ekološke razlike med obravnavanimi sintaksoni. Najpomembnejši rastiščni dejavnik je prezračenost tal Ae), sledita krio-klimat (Cr) in vsebnost dušika v tleh (Nt). Kritičen pregled sintaksonomije razreda *Robinietea* nakazuje potrebo po nadaljnjih raziskavah.

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Introduction

The class *Robinietea* Jurko ex Hadač et Sofron 1980 combines spontaneous tree vegetation of park and other artificial plants (Solomakha 2008). It includes the communities with domination of *Acer negundo* L., *Robinia pseudoacacia* L., and cultivated tree plantings, with species of the genus of *Betula* Roth, *Pinus* L., *Populus* L., and others. Coenoses of *Robinietea* serve as an adventive species reserve. A significant proportion among the diagnosed and characterized species occupies the invasive ones: *Acer negundo*, *Anisantha tectorum* (L.) Nevski, *Conyza canadensis* (L.) Cronq., *Robinia pseudoacacia* L., *Solidago canadensis* L., and *Ulmus pumila* L.

The syntaxonomy of the class is not well developed even in the Central Europe where it is described. The communities of its species composition are considered to be independent vegetation classes (Jurko 1964, Solomakha 1996, Solomakha 2008, Solomakha et al. 2017, Vítková, Kolbek 2010, Mucina et al. 2016). However, some other European authors (Mucina 1997, Chytrý & Tichý 2003) refer them to the class of *Rhamno-Prunetea* Rivas Rhino Goday and Borja Carbonell ex Tx. 1961. Certain authors classify the communities with *Robinia pseudoacacia* without taking into account tree dominant layer, only as herb vegetation (Kohl 1986).

Smetana (2002) investigates the spread of spontaneous woody vegetation on the iron ore dumps in the northern part of Kryvyi Rih area. The author attributes it to 15 associations, three alliances and order *Chelidonio-Robinietalia* Jurko ex Hadač et Sofron 1980. He identifies the communities as associations corresponding to separate successional stages of overgrowing and regeneration of the vegetation and derivate coenoses. Korshikov and Krasnoshtan (2012) pay considerable attention to the study of spontaneous formation of tree communities on the iron ore dumps as a prerequisite for the successful conduct of remediation activities. Due to the wide ecological amplitude and intensive vegetative reproduction, wood stands successfully development in ecotopes with degraded soils as it fixes the surface and reduces soil erosion. Phytocoenological studies of this vegetation class have not been conducted on the territory of Kryvyi Rih. Therefore, there is uncompleted syntaxonomy of the class in this urban-industrial complex. The detection of syntaxonomic composition and ecological differentiation of communities is the scientific basis of ecological management for the development of plant cover in the city.

The aim of the research is the ecological-coenotic characteristic of syntaxa of *Robinietea*.

Materials

Study area

Kryvyi Rih is located in the central part of the Ukrainian crystalline massif in the steppe zone of Ukraine at the confluence of the rivers Ingulets and Saksagan that are part of the Dnipro river basin (Figure 1). Kryvyi Rih

Figure 1: Location of investigated territory in Ukraine.
Slika 1: Lokacija preučevanega območja v Ukrajini.

differs from the most Ukrainian cities with the specifics of its town planning: it extends more than 100 km in the meridian direction. The number of inhabitants is about 650,500. Urban area is 430 km^2, only 24% of which is used for residential development. About 330 km^2 is occupied by the enterprises for the processing of iron raw materials along with the other related enterprises and industrial waste, etc (Paliy 2000).

The city territory belongs to the Atlantic-continental European insufficiently humid warm region of the temperate climate zone (Alisov 1969). Atmospheric precipitation is distributed unevenly; most of it falls in summer. The average annual rainfall is 400–450 mm (Mykhaylenko 1982). Over-transformed chernozem (black earth) (3.5–5.5% humus) is the basis of the soil cover of the city (Tykhonenko 2001). Average air temperature in July is 22.2 °C, in January – -5.1 °C, and annual average +8.5 °C. The urban landscape is changed because of an intensive development of iron ore industry. Its main forms are tailings, quarries, territories of industrial enterprises, road, residential landscapes, wastelands, etc. (Yarkov 2013).

Data collection

The classification of the ruderal vegetation of the class *Robinietea* in Kryvyi Rih is based on our phytocoenological research carried out in Kryvyi Rih during 2017. We sampled 66 of 16 to 100 m^2 plot size relevés in the study area according to the Braun-Blanquet approach (Braun-Blanquet 1964, Westhoff & van der Maarel 1973). Most importantly, the vegetation samples had to meet the criterion of homogeneous community structure. Plant cover was assessed in percentages (%), converting to values on the Braun-Blanquet combined scale: r – the species is extremely rare; + – the species is rare, the degree of plant cover; 1 – plant cover up to 5%; 2 – covered from 6% to 25%; 3 – covered from 26% to 50%; 4 – covered from 51% to 75%; 5 – more than 75% (Mirkin & Solomeshch 1989). The layers in community were distinguished by height: the first is tree and shrub, the second is upper herb, and the third is lower herb layer.

Data analysis

The vegetational classification was conducted by means of Modified TWINSPAN (Roleček et al. 2009), implemented in the software package JUICE 7.0 (Tichý 2002). We used the default settings of TWINSPAN (with three pseudospecies cut levels: 0%, 5% and 15%; minimum group size: 5; Whittaker's beta). The analysis was done in two steps. Firstly, the entire data set was processed with Modified TWINSPAN to identify the high-level syntaxa at alliance level. Secondly, each cluster with relevés from the study area was analysed separately using Modified TWINSPAN with the same parameters as above. Thirdly, the associations were identified. To identify diagnostic species the phi fidelity index was used (Chytrý et al. 2002). Fidelity was calculated using presence-absence data with standardization of all groups of relevés to equal size. Non-significant values of fidelity (less than 0.001) were removed using Fischer's exact test. Fidelity indices were calculated first for the level of association and subassociation. The diagnostic species for the alliance level were calculated after merging associations in alliances.

The proportion of affinity species of different classes in the coenoses composition was accounted when making a syntaxonomic classification of communities regarding the membership of the association to the alliance or order. The diagnosed species of the class were determined by the List of diagnostic species of classes of the plant communities dominated by vascular plants (Mucina et al. 2016). There are some recommendations regarding the wider character of diagnostic properties because of the differences in the coenotic behaviour of species on the territory of Ukraine (Solomakha et al. 2017). The necessity to review and add species to the list of species was used as diagnostic demand in surveys of the vegetation classes in Ukraine (Solomakha et al. 2017).

The identified syntaxa is compared with those previously allocated in different regions (Osypenko 1997, 1999, Golovanov & Abramova 2013, Arepeva 2013, Davydov 2013).

We used deductive method to distinguish the derivate community because of the impossibility of identifying the association (Kopecký & Hejný 1974). The sets of the stands, which are capable of self-reproduction in various localities with a similar species composition, can be recognized as a new community type (Kopecký 1992).

The method of DCA ordination was used to identify the features of communities' ecological differentiation by using the R-project program (R Core Team 2012) with the Vegan package (Oksanen et al. 2012). To reflect ecological amplitude of the specific plant communities (syntaxa) and their relation to the most important environmental factors a basic static analysis was applied in program STATISTICA 10.0 using Didukh ecological indicator values (Didukh 2011). Based on comparative analysis of scale and estimation of species distribution concerning ecological factor changes, Didukh (2011) elaborated basic indicator values, in which amplitude characteristics of species of flora of Ukraine are reflected. These characteristics have to be examined, specified and elaborated based on field and experimental data. Twelve factors are used in study

and are divided into edaphic and climatic. Some of them were used by the researchers traditionally (humidity, acidity, and nitrogen content in soil), others (carbonate content in soil and plant concerning them) were elaborated firstly. Indicator values are calculated by using species presence / absence in community.

Syntaxa names are specified according to the International Code of Phytosociological Nomenclature (Weber et al. 2000). Species names are given by "Vascular plants of Ukraine. A nomenclatural checklist" (Mosyakin & Fedoronchuk 1999).

Results and discussion

Vegetation of the class of *Robinietea* in the territory of Kryvyi Rih city is represented by 4 associations, 1 derivate communities (DC), belonging to three alliances and order (Table 1, 2, 3).

The classification scheme of *Robinietea* vegetation in Kryvyi Rih:

Robinietea Jurko ex Hadač et Sofron 1980
- *Chelidonio-Robinietalia pseudoacaciae* Jurko ex Hadač et Sofron 1980
  - *Chelidonio-Acerion negundi* Ishbirdina L. et Ishbirdin A.1989
    - *Chelidonio-Aceretum negundi* Ishbirdina L. et Ishbirdin A. 1991
  - *Chelidonio majoris-Robinion pseudoacaciae* Hadač et Sofron 1980
    - *Chelidonio-Robinietum* Jurko 1963
    - *Elytrigio repentis-Robinietum pseudoacaciae* Smetana 2002
  - *Geo-Acerion platanoidis* L. Ishbirdina et A. Ishbirdin 1991
    - *Geo-Aceretum platanoidis* L. Ishbirdina et A. Ishbirdin 1991
    - DC *Ballota nigra+Ulmus pumila* [*Balloto nigrae-Robinion pseudoacaciae* Hadač et Sofron 1980]

Class *Robinietea* and alliance *Robnietalia*

Class *Robinietea* consists of anthropogenic thickets on nutrient-rich soils of temperate Europe (Mucina et al. 2016). It is characterized by the presence of species of genus *Acer* (*A. negundo, A. platanoides* L.), *Ulmus* (*U. pumila, U. minor* Mill.) and *Robinia pseudoacacia*. The features of the class include a stable but simplified structure, depleted floristic composition and the absence of specific species of plant stands. It prefers periodically disturbed roadsides, abandoned residential areas, sports grounds, and the iron ore dumps. It may be found along railways. Communities belonging to three alliances were identified and categorized as follows: *Chelidonio-Acerion negundi* (the communities with the dominance of *Acer negundo*), *Chelidonio majoris-Robinion pseudoacaciae* (the artificial and spontaneous plantations of *Robinia pseudoacacia*), *Geo-Acerion platanoidis* (the communities of artificial plantations of *Acer platanoides*). The syntaxonomy of last alliances is in debatable. Some authors consider it to be in the class of *Querco-Fagetea* Br.–Bl. et Vlieg. 1937 (Ishbirdina & Ishbirdin 1991, Chytrý et al. 2013). We classify them into the *Robinietea* due to the predominance of the synanthropic elements in the floristic composition and xerophytic communities.

The association *Chelidonio-Aceretum negundi* L. Ishbirdina et A. Ishbirdin 1991 (Table 3, relevés 1–6; Figure 2)

The association in Kryvyi Rih region consists of stands where the North American invasive phanerophyte – *Acer negundo* dominates. The communities have a three-layer structure. Shrubby layer is composed of *Acer negundo* undergrowth, with insignificant part of *Parthenocissus quinquefolia* (L.) Planch. Woody layer hinders the development of herbaceous plant cover. It is formed by *Arctium tomentosum* Mill., *Chelidonium majus* L., *Dactylis glomerata* L., *Elytrigia repens* (L.) Nevski, *Hordeum murinum* L. and *Polygonum aviculare* L. s.str. Communities are relatively abundant in the studied region, growing predominantly along the roads, in abandoned territories, rail slopes, waste deposits, on the riverbanks. Substrate is chernozem, sometimes with proportion of crushed stones and anthropogenous waste. In the succession series, they replace the communities of *Arction lappae* Tx. 1937 and *Onopordion acanthii* Br.-Bl. in Br.-Bl. et al 1936. In the absence of anthropic influence in time, the communities tend to increase the area.

In comparison to the similar stands recorded in the north-eastern parts of Ukraine (Didukh & Kuzemko 2005, Davydov 2013, Smahlyuk 2016), it lacks a few mesophytic species, such as *Fumaria schleicheri* Soy.-Will., *Urtica dioica* L., *Anthriscus sylvestris* (L.) Hoffm. and *Alliaria petiolata* (M. Bieb.) Cavara & Grande. When compared to the relevés from Cherkassy region (Osypenko, Shevchyk 2001, Osypenko 2006), it misses species *Iva xanthiifolia* Nutt., *Impatiens parviflora* DC, *Bidens tripartita* L. Communities from Russia (Ishbirdina, Ishbirdin 1991, Bulokhov, Kharin 2008, Golovanov, Abramova 2013, Arepeva 2013) contain nitrophilous species, such as *Sambucus nigra* L., *S. racemosa* L. The association is subdivided into two subassociations: *-sambucetosum nigrae* Arepeva 2015, *-sambucetosum racemosae* L. et A. Ishbshbirdin in L. Ishbshbirdina et al. 1989. Communities of the described subassociation - *sambucetosum nigrae*

Figure 2: *Chelidonio-Aceretum negundi*, Kryvyi Rih, waste dumps near railway station «Mudriona», 10.07.2017 (Photo: N. Yeremenko).
Slika 2: *Chelidonio-Aceretum negundi*, Kryvyi Rih, odlagališče odpadkov pri železniški postaji «Mudriona», 10.07.2017 (foto: N. Yeremenko).

grow on soils enough provided with mineral nitrogen, communities of - *sambucetosum racemosae* form on friable substrate. We did not subdivide it into subassociations as in literature.

The association *Chelidonio-Robinietum* Jurko 1963 (Table 3, relevés 7–12)

The association includes woody stands with dominant species *Robinia pseudoacacia*. It usually has two or three well defined layers. The first (tree) layer is formed by dominant species, the middle (upper herb) layer is composed of species of the classes *Artemisietea vulgaris* Lohmeyer et al. in Tx. ex von Rochow 1951 (*Achillea millefolium* L., *Elytrigia repens*) and *Stellarietea mediae* Tx. et al. in Tx. 1950 (*Ambrosia artemisiifolia* L., *Chenopodium album* L.). The ground layer consists of species such as *Atriplex patula* L., *Chelidonium majus*, *Taraxacum officinale* aggr., *Plantago major* L. Stands of the association *Chelidonio-Robinietum* may be found on abandoned areas near buildings, along roads, on waste deposits, in abandoned gardens. Substrate is chernozem and often contains gravel. Communities are rather common in the studied region. While many stands were planted for wood production or erosion protection, others are established spontaneously, either generatively or vegetatively.

The association is rather common and well documented from various parts of Ukraine (Didukh et al. 2011, Davydov, 2013, Smahluk, 2016) and in the Czech Republic (Vítková & Kolbek 2010, Chytrý et al. 2013). Relevés made in Kryvyi Rih region floristically resemble those ones made in the other parts of Ukraine, even though they lack a few mesophytic species, such as *Aristolochia clematitis* L., *Dactylis glomerata* and *Glechoma hederacea* L. Communities from central part of Ukraine (Osypenko 1997, 1999, 2006) contain characteristic species of the class *Artemisietea vulgaris*, such as *Ballota nigra* L., *Berteroa incana* (L.) DC. Species of *Stellarietea mediae* (*Galinsoga parviflora* Cav., *Solanum nigrum* L.) are also more prominent. Relevés from the Czech Republic contain other species, such as *Prunus spinosa* L., *Rubus fruticosus* agg. and *Impatiens parviflora* which are not present in Kryvyi Rih. The Czech authors assign *Robinia pseudoacacia groves* to scrub vegetation class *Rhamno-Prunetea* (Chytrý et al. 2013).

The association *Elytrigio repentis-Robinietum pseudoacaciae* Smetana 2002 (Table 3, relevés 13–18; Figure 3)

Stands of this association are usually dominated by *Robinia pseudoacacia* while the other species usually appear like subdominants – *Elytrigia repens*, *Ballota nigra*, *Artemisia absinthium* L., *Chenopodium album,* and *Cirsium setosum* (Willd.) Besser.

Herb layer may be developed with species of the class *Artemisietea vulgaris* – *Galium aparine* L., *Poa angustifolia* L. Species *Taraxacum officinale* and *Viola hirta* L. are frequent. These stands occur on ruderal sites around human settlements, on older abandoned lands, along roads and riverbanks. Substrate is chernozem, loam or loam-sand, often with proportion of anthropogenous waste. In succession series, they replace the communities of *Convolvulo arvensis-Agropyrion repentis* Görs 1967, *Arction lappae* (*Artemisietea vulgaris*). In the absence of human influence in time, the communities tend to increase the area and distribution.

The communities of the association are probably quite widespread, though yet not very well documented (Smetana 2002, Davydov 2013). Relevés made in Poltava region, in the northeastern part of Ukraine, floristically resemble those made in the other parts Ukraine even though they lack a few characteristic species of the class *Robinietea*, such as *Anthriscus sylvestris* (L.) Hoffm., *Lapsana communis* L. (Davydov 2013). When compared to the relevés from Kryvyi Rih region made in stands planted for protection against erosion processes of the industrial

Figure 3: *Elytrigio repentis-Robinietum pseudoacaciae*, Kryvyi Rih, Central-Town district, along the road, 28.06.2017 (Photo: N. Yeremenko).
Slika 3: *Elytrigio repentis-Robinietum pseudoacaciae*, Kryvyi Rih, Center mesta, ob cesti, 28.06.2017 (foto: N. Yeremenko).

sites near the factory it misses species *Atriplex sagittata* Borkh., *Conium maculatum* L., *Heracleum sibiricum* L., *Rumex confertus* Willd., *Fumaria schleicheri* Soy.-Willem. (Smetana 2002). It is subdivided into four subassociations: - *atriplicetum nitentis* Smetana 2002, - *conietosum maculati* Smetana 2002, - *rumicietosum conferti* Smetana 2002, - *fumarietosum schleicheri* Smetana 2002.

The association of *Geo-Aceretum platanoidis* L. Ishbirdina et A. Ishbirdin 1991 (Table 3, relevés 19–24)

The association consists of the stands of nitrophilous species, dominated by *Acer platanoides* in the first layer, accompanied by *Chelidonium majus, Lapsana communis, Ballota nigra, Chenopodium album* in the herb layer. Lower leaves of the dominant herb species, together with *Taraxacum officinale*, *Glechoma hederacea* and *Viola hirta* form the lower herb layer. The community creates thin stands along walls of old buildings and other constructions, usually on the shady side, along the riverbanks and in the parks. Substrate is weakly aerated chernozem. In succession series, these communities replace the coenoses of *Arction lappae* and *Onopordion acanthii*. In the absence of anthropic influence, the communities are stable in time.

Ishbirdina and Ishbirdin (1991) divide the association into two subassociations: - *typicum* L. et A. Ishbirdin in L. Ishbirdina et al. 1989, and xerothermophilous - *aceretosum negundi* L. et A. Ishbirdin in L. Ishbirdina al. 1989. Recorded relevés in Kryvyi Rih are floristically similar to those made in Ufa, the Republic of Bashkortostan (Ishbirdina and Ishbirdin 1991). Relevés made in Poltava region (Davydov, 2013) include species *Acer campestre* L., *Alliaria petiolata* (M.Bieb.) Cavara &Grande, *Elisanthe noctiflora* (L.) Rupr. and *Fraxinus excelsior* L., which are absent in Kryvyi Rih.

BC *Ballota nigra* + *Ulmus pumila* [*Robinietea*] (Table 4, relevés 1–4)

Two-layered community of trees and forbs, dominated by *Ulmus pumila*. In communities there are *Achillea millefolium, Carduus acanthoides* L., *Elytrigia repens, Grindelia squarrosa* (Pursh) Dunal from the class *Artemisietea vulgaris*. The community was not documented in other localities in Ukraine. It is found usually along roads and in the surroundings of railway stations, on abandoned territories near buildings, and waste deposits, but it was recorded as well on the river bank in Kryvyi Rih. Substrate is weakly aerated chernozem, with proportion of crushed stones. In succession series, communities replace coenoses of *Onopordion acanthii*. In the absence of anthropic influence monodominant communities of *Ulmus pumila* are formed.

The ordination analysis is carried out to establish the ecological specificity of the communities' sites and to assess the differences in the ecotopic characteristics of the studied areas. The DCA ordination of original relevés shows that the ecological differentiation of syntaxa of the class *Robinietea* is determined by the complex of basic ecological factors. Soil aeration (Ae), the cryo-climate (Cr) and nitrogen content in soil (Nt) are the most important. Vectors of these factors are close to the DCA1 and DCA2 axes (Figure 4).

The phytoindication analysis of the relation of plant species to soil water regime (Hd) showed that plants of the class *Robinietea* adapted to rather dry habitats (Wnp = 75–100 mm) (Table 1) (variables ranging from 9.22 to 11.69). According to the results of the evaluation of the variability of damping (fH) , it is revealed that plants adapted to dry habitats with irregular wetting of soil layer where plant roots penetrate, or with soil small drenched by precipitations or melted waters (the variables range from 6 to 7.5). The results of phytoindication of the communities by relation to acidity (Rc) indicate that plants grow on acidulous and neutral (pH=6.5–7.1) soils. The values of soil acidity range from 8.14 to 9. By the relation of plant species to total salt regime (Sl) it is indicated they grow on

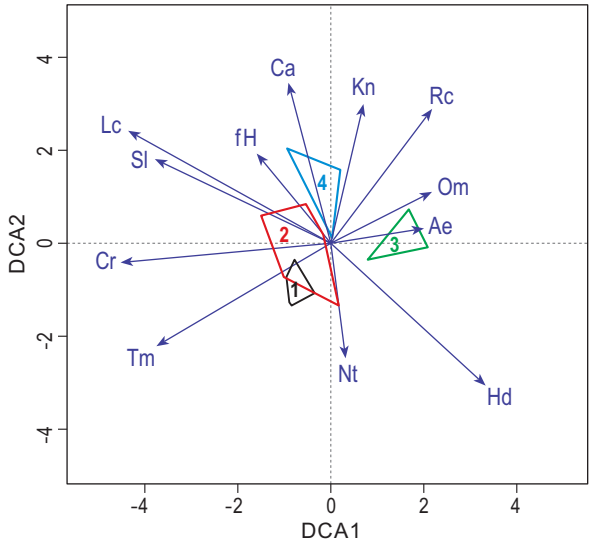

Figure 4: Results of DCA ordination of syntaxa of the class of *Robinietea* with ecological factors: Hd – soil water regime, fH – variability of damping, Rc – soil acidity, Sl – total salt regime, Ca – carbonate content, Nt – nitrogen content, Ae – soil aeration, Tm – the thermal climate (thermoregime), Om – humidity, Kn – the continentality of climate, Cr – the cryo-climate, Lc – the light. Legend: numbers indicate centroids of syntaxa: 1 – *Chelidonio-Acerion negundi,* 2 – *Chelidonio-Robinion*, 3 – *Geo-Acerion platanoidis*, 4 – DC *Ballota nigra* + *Ulmus pumila* [*Balloto nigrae-Robinion*].

Slika 4: Rezultati DCA ordinacije razreda *Robinietea* z rastiščnimi dejavniki: Hd – vodni režim v tleh, fH – spremenljivost vlažnosti, Rc – kislost tal, Sl – režim soli, Ca – vsebnost karbonata, Nt – vsebnost dušika, Ae – prezračenost tal, Tm – termorežim, Om – vlažnost zraka, Kn – kontinentalnost podnebja, Cr – krioklimat, Lc – svetloba. Legenda: številke prikazujejo centroide posameznih sintaksonov: 1 – *Chelidonio-Acerion negundi,* 2 – *Chelidonio-Robinion*, 3 – *Geo-Acerion platanoidis*, 4 – DC *Ballota nigra*+*Ulmus pumila* [*Balloto nigrae-Robinion*].

soils enriched with salt (150–200 mg/l) with content of HCO_3^- 4–16 mg/100 g of soil, and trace of SO_4^- and Cl^- in some types. The values range from 7 to 8.75. The results of synphytoindication analysis by the relation of plant species to carbonate content in soil (Ca) indicate that, on the one hand, plants of neutral habitats sustained to small carbonate content in soil (CaO, MgO = 0.5–1.5%). On the other hand, they grow on chernozems, enough enriched with carbonates (CaO, MgO = 1.5–5%), which are washed and can occur in forms of inclusions. The limits of the variables range from 6.31 to 8.5). Distribution of associations by the relation of plant species to nitrogen content in soil (Nt) showed that they grow on soils enough provided with mineral nitrogen (0.3–0.4%). Range of environmental values is from 6.11 to 7.67). The wide ecological amplitude (range 1.5 points) for the indicated factor has communities of the alliance *Chelidonio-Robinion*. Ecological values for aeration of soil (Ae) indicate that communities grow on weakly aerated soils.

The thermal climate (Tm) is estimated basing on radiation balance (the quantity of heat, which falls on 1 cm^2 during a year). This value varies from several to 100 kcal per cm^2. Based on results of synphytoindication, plants grow in conditions with 40–50 kcal/cm^2. The humidity (Om) is one of the most important ecological factors reflecting aridity – climate humidity. This factor characterizes air humidity and is linked with precipitation quantity, flowing, evaporation and transpiration, soil humidity, level of grounds waters. The humidity index integrates precipitation influence and thermal resources of the territory. This index in Kryvyi Rih is sub-aridophytic (-400 – -200). The continentality of climate (contrast regime) (Kn) is the sum of environmental properties, determined by the influence of big area of sea and land atmospheric processes and climate formation. Kryvyi Rih is situated in sub-continental climate (150%). The cryo-climate (Cr) reflects cryoregime of climate. The main meteorological elements, influencing plant hibernating, are air temperature and cloak of snow. The characteristic of winter extreme conditions is average temperature of the coldest month (it is mainly January, uncommonly February in Ukraine). The results correspond to warm types of winters (-10– -6σ). According to the results of synphytoindication on the light (Lc) communities are light forest and shrubberies.

Wide ranges of the dispersion of the values (1.75 and 2.2) have total salt regime (Sl) and carbonate content in soil (Ca) respectively. The salt regime is very significant charactetistic of soil, as it influences different processes of soil formation and defines plant adaptation (Didukh 2011). Carbonate content in soil is one of the edaphic factors that determines species distribution in Steppe zone. When comparing the results of synphytoindication of communities in Kyiv and in Kryvyi Rih, it is established that nitrogen content in soil is the leading factor.

Conclusions

The *Robinietea* vegetation class in Kryvyi Rih comprises four associations and one derivate community, belonging to four alliances. It shows a relatively low syntaxonomic diversity but covers large areas with communities belonging to the class. The phytoindication evaluation of ecotopes carried out and the most important ecological factors influencing the differentiation of communities are soil aeration (Ae), the cryo-climate (Cr) and nitrogen content in soil (Nt). The developed classification scheme will contribute to the further elaboration of syntaxa of *Robinietea*, a critical review of the syntaxonomy of investigated class, in particular the clarification of the alliance of *Geo-Acerion platanoidis* is demanded. The formation and

development of communities with alien species are an anthropic evolution of vegetation cover in urboecosystems. They form the environment in city and fix the substrate. The forecasts of dynamic processes, in particular under the influence of anthropic factors should be made. These issues become urgent in connection with the constant influence of anthropic factors. When optimizing the ruderal communities, attention should be paid to preventing the distribution of *Acer negundo*. It leads to a decrease in biodiversity and the aesthetic appearance of the city.

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Appendix Table 3:

Others species: *Parthenocissus quinquefolia* – 105 (+); *Oxalis stricta* – 105 (+), 107 (+); *Berteroa incana* – 111 (1), 264 (+); *Bromopsis inermis* – 107 (+), 108 (1); *Centaurea diffusa* – 49 (1), 55 (+); *Poa angustifolia* – 49 (2), 361 (1); *Amaranthus retroflexus* – 354 (+), 479 (+); *Atriplex tatarica* – 153 (1), 241 (+); *Setaria viridis* – 354 (+), 479 (+); *Sonchus arvensis* – 111 (+), 530 (+); *Portulaca oleracea* – 49 (+); 108 (+).

Localities of relevés: 1, 13 – along the road near rubbish dump, 30 m², (47°54'51"N, 33°24'06"E; 47°54'52"N, 33°23'58"E, 14.07.17); 2, 3, 14, 19 – on the bank of Ingulets river, 20 m² (47°53'07"N, 33°20'35"E; 47°53'25"N, 33°20'46"E; 47°53'40"N, 33°20'44"E; 47°53'45"N, 33°19'37"E; 16.07.17); 4 – along the dirt road, 20 m² (47°54'40"N, 33°19'47"E, 18.07.17); 5 – near abandoned kindergarden, 20 m², (47°53'4018"N, 33°20'03"E, 25.07.17); 6 – near abandoned building Halturina Str. 25 m², (47°53'11"N, 33°20'17"E, 01.08.17); 7 – roadside of Halturina street, 20 m², (47°53'09"N, 33°20'22"E 14.07.17); 8 – abandoned plot near the hospital, Ploshcha Vyzvolennya (Square of Liberation), 20 m², (47°54'31"N, 33°20'28"E ,27.07.17); 9 – along the road, near the church on Starovokzalna Str., 20 m², (47°53'25"N, 33°19'31"E 02.08.17); 10 – backyard of the gymnasium, 16 m², (47°53'59"N, 33°20'15"E 19.08.17); 11 – along the road, Dnipro highway, 25 m², (47°54'51"N, 33°25'34"E, 27.08.17); 12 – the slope, bypass road, 20 m², (47°53'37"N, 33°20'23"E 31.09.17); 15, 16, 17 – the abandoned in the microdistrict «Makulan», 20 m², (47°53'27"N, 33°19'08"E, 47°53'30"N, 33°18'59"E 02.08.17); 18 – along the roadside, Mykolaiv highway, 30 m², (47°54'29"N, 33°18'05"E 28.08.17); 20 – Mershavcev park, 30 m², (47°53'49"N, 33°19'40"E 16.07.17); 21, 22 – tha adandoned plot in Mershavcev park, 30 m², (47°54'04"N, 33°20'06"E, 27.07.17); 23, 24 – the near the military unit, 25 m², (47°53'01"N, 33°22'28"E, 02.08.17).

Appendix Table 4:

Species found occasionally: *Betula pendula* – 474 (1); *Hordeum murinum* – 109 (2); *Humulus lupulus* – 141 (+); *Carduus acanthoides* – 141 (+); *Trifolium repens* – 494 (+); *Atriplex patula* – 109 (+); *Viola odorata* – 534 (+); *Setaria viridis* – 534 (+); *Cirsium arvense* – 534 (+); *Daucus carota* – 494 (+); *Poa angustiufolia* – 109 (1); *Artemisia absinthium* – 474 (+), 493 (+); *Melilotus albus* – 493 (+), 494 (+); *Chenopodium album* – 259 (+), 534 (1).

Localities of relevés: 1 – the adandoned sports ground, boulvar Vechirny, 30 m² (47°56'23"N, 33°25'13"E, 14.07.17); 2 – sports ground near sports school № 10, 25 m² (47°53'29"N, 33°19'49"E, 18.09.17); 3, 4 – sports ground near school № 70, 30 m² (47°54'45"N, 33°24'07"E, 47°54'47"N, 33°24'05"E, 23.08.17); 5 – along the roadside on the bank of Ingulets river, 25 m² (47°53'24"N, 33°20'42"E, 16.07.17); 6 – along the roadside on Shyrokivska Str., 25 m² (47°53'14"N, 33°21'17"E, 17.07.17); 7 – the abandoned plot near children library, 25 m² (47°53'44"N, 33°20'12"E, 27.07.17); 8 –along the railway, microdicistrict Chervona, 20 m² (47°53'10"N, 33°23'12"E, 27.08.17).

Table 1: Generalized characteristics of ecological conditions of ruderal plots with *Robinietea* communities in Kryvyi Rih.
Tabela 1: Značilnosti ekoloških razmer ruderalnih združb razreda *Robinietea* v mestu Kryvyi Rih.

Eco-logical factors	The scale of factors (points)	*Chelidonio-Acerion negundi*			*Chelidonio-Robinion*			*Chelidonio-Acerion platanoides*			DC *Ballota nigra* + *Ulmus pumila*		
		min	max	aver.	min	max	aver.	min	max	aver.	min	max	aver.
Hd	23	10.6	11.2	10.8	9.2	11.1	10.4	10.5	11.7	11.2	9.5	11.1	10.4
fH	11	6.0	7.1	6.4	6.7	7.5	7.0	6.2	6.7	6.6	6.2	7.5	7.0
Rc	15	8.1	8.7	8.4	8.1	8.9	8.5	8.4	8.9	8.8	8.6	9.0	8.8
Sl	19	7.7	8.4	8.1	7.8	8.6	8.2	7.6	7.9	7.7	8.0	8.8	8.3
Ca	13	6.7	7.7	7.1	6.3	7.9	7.3	6.8	7.5	7.7	7.3	8.5	7.7
Nt	11	6.6	7.4	7.0	6.1	7.7	7.2	6.2	7.5	7.0	6.1	6.9	6.5
Ae	15	6.1	6.9	6.6	5.6	6.6	6.1	6.1	6.9	6.6	6.1	7.0	6.6
Tm	17	9.1	10.0	9.5	8.9	10.0	9.3	8.7	9.3	8.9	8.9	9.7	9.2
Om	23	11.3	11.8	11.5	10.8	12.3	11.5	11.6	12.6	12.0	10.6	12.1	11.5
Kn	17	8,2	9.4	8.9	8.3	9.3	8.7	8.5	9.1	8.9	9.1	9.7	9.4
Cr	15	8.1	9	8.5	8.2	9.1	8.7	7.6	8.8	8.1	7.8	8.9	8.4
Lc	9	6.7	7.3	7.0	6.9	7.8	7.3	6.2	6.7	6.4	6.9	7.4	7.2

Legend: Mean values of ecofactor on the Ya. Didukh scale. Average (median) values show the optimal values of ecofactor for species in coenoses, the minimum and maximum values are the amplitude.

Table 2: Shortened synoptic table of *Robinietea* communities of the study area with percentage frequencies and phi fidelity indices (in the superscript).
Table 2: Skrajšana sinoptična tabela združb razreda *Robinietea* s frekvencami v odstotkih in fi indeksom navezanosti (nadpisano).

Group No.	1	2	3	4	5
Number of relevés	15	12	9	8	12
D. s. ass. *Chelidonio-Aceretum negundi*					
Acer negundo	100 ^{100}	---	---	---	---
Arctium tomentosum	20 $^{41.5}$	---	---	---	---
Chelidonium majus	96 $^{53.4}$	89 $^{53.4}$	---	---	---
Taraxacum officinale	80 $^{41.2}$	33 $^{1.6}$	43 $^{1.6}$	22	38
D. s. ass. *Chelidonio-Robinietum*					
Achillea millefolium	10	56 $^{25.5}$	14	---	38
Atriplex patula	---	44 $^{44.9}$	14	---	25
Chenopodium album	---	89 $^{64.2}$	43 $^{4.6}$	33 $^{0.7}$	
Plantago major	40 $^{7.9}$	67 $^{29.5}$	43 $^{5.5}$	22	
Robinia pseudoacacia	---	100 $^{63.2}$	100 $^{63.2}$	---	
D. s. ass. *Elytrigio repentis-Robinietum pseudoacaciae*					
Ballota nigra	30	33	100 $^{43.2}$	56 $^{3.4}$	100 $^{43.2}$
Elytrigia repens	60	67	100 $^{25.8}$	56	100
Galium aparine	---	---	86 $^{84.5}$	---	---
D. s. ass. *Geo-Aceretum platanoidis*					
Acer platanoides	---	---	---	100 ^{100}	---
Geum urbanum	20	---	---	100 $^{83.3}$	---
Glechoma hederacea	---	---	---	67 $^{79.1}$	---
Lapsana communis	---	---	---	44 $^{63.2}$	---
Torilis japonica	---	---	---	92 $^{43.2}$	---
D. s. comm. *Ballota nigra+Ulmus pumila*					
Ulmus pumila	10	---	---	---	100 $^{94.4}$
D. s. *class Robinietea*					
Lactuca serriola	---	22 $^{21.8}$	---	---	25 $^{26.6}$
Lapsana communis	---	---	---	44 $^{62.5}$	---
Other species					
Conyza canadensis	20 $^{10.6}$	33 $^{30.5}$	---	11	---
Elytrigia repens	60	67	100 $^{26.5}$	89 ^{13}	75
Berteroa incana	---	---	---	11 $^{15.1}$	13 $^{18.3}$
Anisantha tectorum	20 $^{14.5}$	22 $^{18.1}$	---	---	13 $^{2.5}$
Grindelia squarrosa	10	11	29 $^{11.2}$	11	38 $^{22.4}$
Arctium tomentosum	30 $^{39.6}$	---	---	11 $^{5.3}$	---
Setaria viridis	10 $^{1.8}$	22 $^{23.3}$	---	---	13 $^{6.2}$

Table 3: Phytocoenological table of syntaxa of the class *Robinietea*.
Tabela 3: Fitocenološka tabela sintaksonov razreda *Robinietea*.

Number of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Tree cover (%)	30	20	20	30	40	20	40	20	20	20	40	20	60	30	30	40	30	20	35	30	30	20	40	30
Herb cover (%)	40	70	70	40	40	50	35	50	70	60	55	70	20	60	60	40	60	70	45	60	50	50	55	60
D. s. *of the ass. Chelidonio-Aceretum negundi*																								
Acer negundo	3	3	2	3	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Arctium tomentosum	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chelidonium majus	2	2	1	2	2	2	2	2	3	3	2	2	.	.	.	.	.	.	2	.	.	.	.	.
Taraxacum officinale	2	1	.	+	.	+	.	+	1	1	+	+	1	.	+	1	+	1	.	+	.	.	.	.
D. s. *of the ass. Chelidonio-Robinietum*																								
Achillea millefolium	.	.	.	.	.	.	.	.	1	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.
Atriplex patula	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Chenopodium album	.	.	.	.	.	.	+	+	1	+	1	2	.	.	.	.	.	.	.	.	.	.	+	1
Plantago major	.	.	.	.	.	.	1	.	.	.	1	1	.	.	.	.	.	.	+	.	.	.	.	.
Robinia pseudoacacia	.	.	.	.	.	.	3	3	2	2	3	3	3	2	3	4	3	3	.	.	.	.	.	.
D. s. of the ass. *Elytrigio repentis-Robinietum pseudoacaciae*																								
Ballota nigra	.	.	.	.	.	.	.	.	.	.	.	.	1	+	2	2	1	2	1	.	+	+	.	+
Elytrigia repens	.	.	.	.	.	.	.	.	.	.	.	.	1	2	2	1	2	2	.	2	1	1	1	2
Galium aparine	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	1	1	.	.	.	.	.	.
D. s. of the ass. *Geo-Aceretum platanoidis*																								
Acer platanoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	4	3	3	3	4
Geum urbanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	2	2	2	2
Glechoma hederacea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	1	1
Lapsana communis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
Torilis japonica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2
D. s. of the al. *Chelidonio-Acerion negundi*																								
Humulus lupulus	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viola odorata	.	+	1	.	.	.	.	.	.	.	.	+	.	.	.	1	1	+	1	1	.	+	.	.
D. s. of the al. *Chelidonio-Robinion*																								
Lactuca serriola	.	.	.	.	.	.	+	.	1	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.
D. s. of the al. *Geo-Acerion platanoidis*																								
Dactylis glomerata	.	.	+	1	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	1	+	2	1
D.s. of the cl. *Robinietea*																								
Erigeron annuus	.	.	.	.	.	.	+	.	.	.	1	.	1	.	.	+	.	.	.	.	.	.	.	.
D. s. of the cl. *Stellarietea mediae*																								
Ambrosia artemisiifolia	.	.	.	+	.	+	.	.	.	+	+	.	.	.	.	.	.	1	.	.	.	.	+	+
Anisantha tectorum	.	1	+	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Conyza canadensis	.	.	+	.	1	.	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cirsium arvense	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hordeum murinum	.	.	.	+	.	1	.	+	.	.	.	.	.	1	.	.	.	.	+	.	.	1	.	.
Diplotaxis muralis	.	.	.	.	1	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
D. s. of the cl. *Artemisietea vulgaris*																								
Arctium lappa	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Bromus squarrosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	.	.	.	.	.	.	.
Cichorium intybus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.
Crepis tectorum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
Grindelia squarrosa	.	1	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	+	+	.	.	.	.	.
D. s. of the cl. *Polygono-Poetea annuae*																								
Polygonum aviculare	+	+	.	+	.	+	.	.	.	1	.	.	.	+	.	.	.	.	+	+	.	.	.	.

Table 4: Phytocoenological table of DC *Ballota nigra + Ulmus pumila* [*Robinietea*].
Tabela 4: Fitocenološka tabela IZ *Ballota nigra + Ulmus pumila* [*Robinietea*].

Number of relevé	1	2	3	4
Tree cover (%)	30	20	20	20
Herb cover (%)	60	70	60	60
D. s. DC *Ballota nigra + Ulmus pumila [Robinietea]*				
Ballota nigra	2	3	3	3
Ulmus pumila	3	2	2	2
D. s. cl. *Robinietea*				
Chelidonuim majus	.	.	+	1
Galium aparine	.	1	+	.
Geum urbanum	.	.	.	.
Lactuca serriola	.	+	.	.
D. s. cl. *Artemisietea vulgaris*				
Achillea millefolium	+	.	.	.
Anisantha tectorum	1	1	.	.
Crepis tectorum	.	.	.	.
Grindelia squarrosa	1	.	.	.
Elytrigia repens	.	.	1	+
D. s. cl. *Stellarietea mediae*				
Ambrosia artemisiifolia	.	.	.	+
Diplotaxis muralis	.	+	.	.
D. s. cl. *Polygono-Poetea annuae*				
Plantago major	.	.	+	+
Polygonum aviculare	+	.	+	.
Taraxacum officinale	+	.	+	1
Other species				
Dactylis glomerata	1	.	.	.
Plantago lanceolata	.	.	.	.