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Ecological-cohenological analysis of Eastern Podillya flora

O.V. Mudrak[1], H.V. Mudrak[2], S.F. Razanov[2], Zh.A. Kavun[3]

[1]KHEI "Vinnytsia Academy of Continuing Education", 13 Hrushevskyi st., Vinnytsia, 21050, Ukraine,
E-mail: ov_mudrak@ukr.net
[2]Vinnytsia National Agrarian University, 3 Soniachna st., Vinnytsia, 21008, Ukraine;
[3]Vinnytsia Trade and Economic College of KNTEU, 80 Kyivska st., Vinnytsia, 21000.
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Using the herbarium data, literary and cartographic sources and our own field studies, an inscription on the flora of the Eastern Podillia comprising 1210 species belonging to 526 genera and 123 families has been compiled. The ecological-coenotic analysis of the state of the region's higher vascular plants by the ratio of species to the water and light modes has been analyzed. On the basis of the conducted research, it has been found that 35.7% and 25.9% of species belong to Xeremosophytes (432) and Mezoxerophytes (313), respectively. 390 species (32,2%) of the total belong to Sithophytes and Heliosciphytes, 386 species (32%) - to Heliophytes. Investigating the ecological-coenotic structure of the region's flora, it has been established that it consists of 16 categories, where the dominant group is presented by meadow-steppe - 191 species (15.8%), meadow - 185 species (15.3%) and forest nemoralis vegetation - 183 species (15.1%). The conducted ecological-coenotic analysis of the flora of the Eastern Podillia reveals the patterns of organization, development and resistance of ecosystems, underlying the conservation of biodiversity, and allows to solve the problems of introduction, selection, agriculture and the balanced use of the region as a whole.
Key words: species; flora; phytodiversity; ecological-coenotic analysis; biodiversity; Eastern Podillia

Introduction

The urgency of the comprehensive study and research of the flora comes from the global problem of biodiversity conservation, which has become key to solve not only general biological and environmental, but also a large extent of socio-economic aspects of the development of society. The human, as a biological species, must realize that its survival depends from the survival of other species, from preserving the fullness of the gene pool in ecosystems and landscapes as a guarantee of maintaining their sustainable relationship. This task was defined in 1992 by the Rio de Janeiro Program "Agenda for XXI century", the UN Convention on Biological Diversity, the World Health Summits (Rio+10, Rio+20), the All European Strategy for the Conservation of Biological and Landscape Diversity (Sofia, 1995), the Framework Convention on Implementation (Kyiv, 2003) (Mudrak, 2012). The solution of the problem of conservation and reproduction of phytodiversity at the biosphere level originates from regional econets, which are a kind of framework for the ecological balance, which underlies the protection of the coenotic reserves and gene pool. Therefore, the issue of the protection of phytodiversity, which forms the basis of the eco net, has become very urgent for the Eastern Podillia, where the smallest number of reserved objects of polyfunctional significance is concentrated, the lowest indicator of reservation in the conditions of the increased anthropogenic impact on natural ecosystems, which is only 2.28% of the total area. The Eastern Podillia belongs to the most cultivated regions of the Ukrainian Forest-steppe. A high percentage of arable land – 65.2% (85.7% of the area of agricultural land) and few forests – 14.3% testify the level of fragmentation of the vegetation (Mudrak, Mudrak, 2013, 2015, 2016; Polishchuk et al., 2015). The investigation of the vegetation at the junction of floristics, phytocenology, ecology and sozology has a special socioeconomic significance for the region's development; it reveals the patterns of ecosystems' organization, development and resistance underlying the conservation of biodiversity; and allows to solve the problems of introduction, selection, agriculture, balanced nature management and economy in general.

Phytodiversity includes the definition of its species composition, which is impossible without a clear idea of natural and anthropogenic factors forming the diversity of the territory. A variety of species diversity as a component of biodiversity, which is proportional to the number of typological elements (taxa, syntaxa, etc.) of a particular biosystem and to the degree of their variability, has to be studied and investigated in the Eastern Podillia (Goncharenko, 2003;, Grigora et al., 2006; Mudrak, 2014). It is known that the nature conservation value of an area is directly proportional to the wealth of its phytobiota with a significant presence of rare objects and it is inversely proportional to the significant anthropogenic influences (Andrienko et al., 1981, 1999). The wealth of flora is determined by the number of taxa within a certain territory (Goncharenko, 2003). The species level of phytodiversity is taken as the basis to study the other kinds of diversity (Didukh, 2009).

The inventory of flora, its ecological-coenotic analysis, protection and the balanced use are the priority tasks in the study, conservation and reproduction of biodiversity, which provides a variety of landscapes and acts as structural elements in the formation of regional econetwork (Grigora, Solomacha, 2005; Mudrak et al., 2016).

Material and methods

To define the state of phytodiversity of the Eastern Podillia, the vegetation of the studied area was initially analyzed as well as a systematic list and quantitative compositions of plants were determined. After having conducted the geo-botanical research, a common floristic list was compiled in a systematic or alphabetical order. The advantage was given to the first method of writing taxa. For this purpose, the system of A. Takhtadzhian (Takhtadzhian, 1987), adopted in the most modern Ukrainian floristic works, was used. The divisions, classes and families of higher vascular plants are given according to this system, while the families and species – by the alphabet of Latin names. After that, a systematic analysis of the flora was carried out, its wealth was assessed, compared with neighboring and distant vegetative groups. The correlation between different groups of higher vascular plants was considered as the main indicators of the systematic structure. These correlations were expressed by figures representing the number of species of each systematic group within the defined flora. The floristic spectrum was composed under various characteristics, the most important of which are the spectra reflecting the composition and the sequence of arrangement: families by the number of species; families by the number of generations; genera by the number of species. On the basis of this, a comparison and a final analysis of the state of one or another territory of the Eastern Podillia were carried out.

The study of the originality of vascular plants and the patterns of their distribution in nature, depending on the geographical and environmental conditions of existence, is currently relevant. Among many methods and approaches in the research process, a certain place belongs to the biota's taxonomic-typological assessment, in which only ecological and ecological-coenotic structures were regarded.

The ecological-coenotic structure of the flora of vascular plants of the Eastern Podillia is based on archival and herbarium data, cartographic and literary sources, field research with subsequent critical and systematic processing of the collected material. The materials of the National Herbarium of Ukraine (the Institute of Botany named after M. Kholodnyi of the National Academy of Sciences of Ukraine), the herbarium funds of the National Botanic Gardens named after Mykola Hryshko of NAS of Ukraine, the State Museum of Natural Science of Ukraine, the National Scientific and natural Museum of NAS of Ukraine, the local history museums, the National Natural Park (NNP) "Karmeliuk's Podillia" and other reservations, as well as scientific justifications for the creation of NNP "Central Podillia", "Dniester", "Murafa", "Middle Pobuzhzhia", "Nemyriv Pobuzhzhia" have been worked out (Flora of the UkrSS, 1936-1965; Andrienko et al., 1985, Protopopova, 1991; Didukh et al., 2000, 2002, 2004; Volovik, Mudrak, 2007; Mudrak, 2008, 2012-2016; Didukh, 2009). All taxa are characterized by the system of S. Mosiakin and M. Fedoronchuk, which is cited in "Vascular Plants of Ukraine" (Mosyakin, Fedoronchuk, 1999).

Results and Discussion

According to the Geobotanical Zoning of Ukraine (2003), the Eastern Podillia lies within the Eurasian steppe area belonging to the Holarctic Dominion. It includes the Forest-steppe subregion of the Eastern European Forest-steppe zone of oak forests, steppe meadows and meadow steppes of the Ukrainian Forest-steppe zone consisting of the central and northern part of the Northern Podillia, the northeastern part of the Northern Right Bank of hornbeam-oak and oak forests, steppe meadows and meadow steppes, the eastern part of the Central Right Bank of hornbeam-oak and oak forests as well as meadow steppes, the southern part of the Southern Podillia of oak forests and meadow steppes and the entire territory of the Central Podillia of hornbeam-oak and oak forests as well as land meadows (Didukh, Shelyagh-Sosonko, 2003).

According to the Physical and Geographical Zoning of Ukraine (2005), the territory of the Eastern Podillia belongs to the Eastern European Plains Landscape of the Forest-steppe zone. It consists of the Dniester-Dnipro Forest-steppe area, including parts of the north-western and north-eastern Subdnipro highland, the Central Dnipro and the Southern Podillia Forest-steppe, and the entire territory of the Transdniester-Eastern Podillia and the Middle Buh Forest-steppe (Marinich, Shishchenko, 2005).

The ecological structure reflects the distribution of flora species by different ecological groups, depending on the environmental conditions and the norms of reaction to them. An ecological analysis allows us to determine the dependence of the flora structure on the environmental factors. Water and soils are the most important for determining the regularities of flora formation, more precisely, the level of plants provision with moisture and nutrients. We have analyzed the state of vegetation of the Eastern Podillia by the ratio of species to the water (Fig. 1) and light modes (Fig. 2).

Considering the ecological structure of the studied region's phytobiote, it should be noted that 35.7% (432) and 25.9% (313) of species belong to Xeremosophytes and Mezophytes, respectively. The predominance of these groups characterizes the studied area, which is typical to the Right Bank Forest-steppe. Due to the fact that the studied areas belong to different types of ecosystems, the Xerophytes and Mezoxerophytes group of plants is spread in the steppe areas and within them, while Mezophytes and Mezoxerophytes group – in the forest, meadow and coastal regions. Within the Right Bank Forest-steppe, where the forest and steppe agro ecosystems are located next to each other, the predominance of an ecological group of plants may fluctuate either towards Mezophytes or Xerophytes phytobiota.

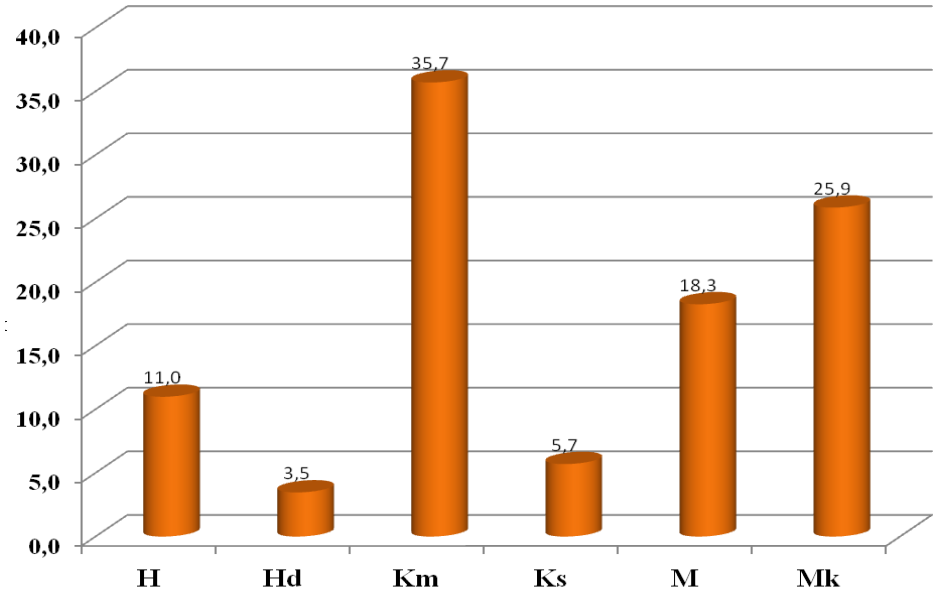

Figure 1. Ecological structure of the Eastern Podillia's flora in relation to the water mode (Hygromorpha): H – Hygrophyte, Hd – Hydrophyte, Km – Xeremosophyte, Ks – Xerophyte, M – Mezophyte; Mk – Mezoxerophyte

The most widespread Mezophytes are *Adonis vernalis* L., *Agrimonia eupatoria* L., *Anemone sylvestris* L., *Anthriscus sylvestris* (L.) Hoffm., *Chelidonium majus* L., *Geum urbanum* L., *Rosa canina* L., *Rubus idaeus* L., *Urtica dioica* L., *Viola odorata* L. They can be found in the forest, phytocenoses and other ecotypes.

Xerophytes are spread mostly in the steppes. Their typical representatives are *Agropiron pectinatum* (Bieb) Beauv., *Astragalus austriacus* Jacq., *Astragalus dasyanthus* Pall., *Centaurea pseudocoriacea* Dobrocz., *Digitaria ischaemum* (Schreb.) Muehl., *Euphorbia pseudoglareosa* Klokov, *Leopoldia tenuiflora* (Tausch) Heldr., *Marrubium peregrinum* L., *Muscari neglectum* Guss., *Nonea pulla* DC., *Nonea rossica* Steven, *Stipa capillata* L., *Stipa lessingiana* Trin. & Rupr., *Teucrium polium* L., *Tribulus terrestris* L., *Trinia multicaulis* Schischk., *Veronica sublobata* M.A. Fisch., *Viola ambigua* Waldst. & Kit and others.

One of the main sources of energy for all living organisms is the energy of the sun. Only one group of organisms – green plants and photosynthesizing organisms can directly utilize the solar energy. In effect, all other organisms absorb the energy of the sun, converted by green plants into the energy of chemical bonds. The value of light for the vegetation is very important: both for the development of life forms and phytocoenoses, and for the local distribution of plants. Changes in light intensity and the duration of lighting have a significant effect on plants. In the case of insufficient lighting, plants grow poorly, are depleted and die.

Investigating the structure of the flora in relation to the light mode, we have defined that most species belong to the Sithophytes – types of shadow-tolerant habitats and Heliosithophytes – species of plants that feel better in shaded places, but can tolerate sufficient light (Figure 2). The number of species of the studied flora belonging to this group is 390 or 32.2% of the total. Heliophytes are light-loving species and make up about 32% in the studied flora. These are mainly species of meadow and steppe ecosystems.

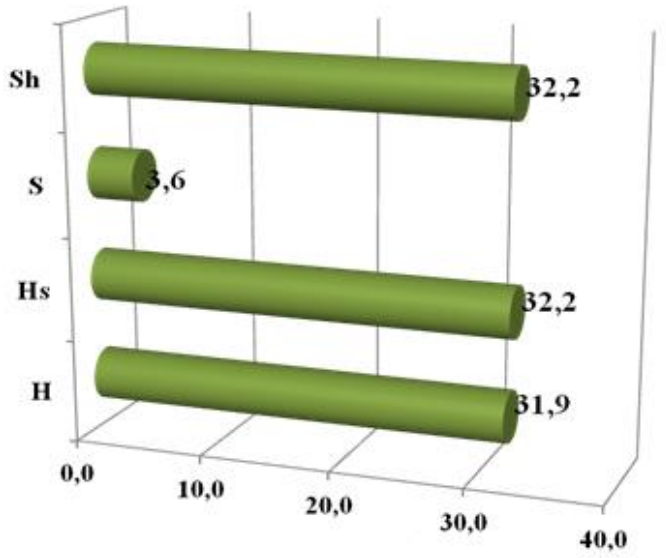

Figure 2. Ecological structure of the Eastern Podillia's flora in relation to the light mode (Heliomorpha): H – Heliophyte, Hs – Heliosithophyte, Sh – Sithoheliophyte, S – Sithophyte

The ecological structure of the Eastern Podillia's flora in relation to the water mode belongs to the vegetation of the Right Bank Forest-steppe with predominance of Xeremosophytes and Mezoxerophytes phytobiota in the groups, and of Sithophytes, Heliosithophytes and Heliophytes in relation to the light mode. The studied territory is characterized as a transition from the Mezoxerophytes group of vegetation to the Xerophytes one. This indicates that it is a zone of the Right Bank Forest-steppe.

The ecological-coenotic structure of vegetation reflects the quantitative correlation of the species of phytobiota belonging to certain phytocoenotypes. According to the phytocenosis type, we distinguish the following categories: psammophyte, halophyte, meadow, meadow-steppe, meadow-swamp, margin, forest boreal, forest nemoralis, forest-swamp, swamp, water, coastal water, ruderal, segetal, species with wide ecological amplitude, petrophyte, limestone, chalk and others, crops (Figure 3).

The geographical location, the heterogeneity of landscape (geomorphological and geological structure), the hydrographic network, soil cover, zonal-climatic, edaphic and other environmental factors have caused a large variety of natural vegetation in the region. The main core of modern flora is the group of forest plants (forests, forest boreal, forest nemoralis, forest-swamp ecological-coenotic groups) –27.5%, meadow – 15.3%, meadow-steppe – 15.8%, meadow-swamp – 10.4%, swamp – 3.1%, coastal water – 2.2%, water – 3.7%, ruderal (segetal) – 13.6%, petrophyte-limestone – 1.8%, crops – 1.6%, the other – 5%. Unfortunately, most of the natural vegetation is lost, 65.2% of the region are an arable land. Among natural and semi-natural vegetation, forest ecosystems predominate and occupy 14.3% of the territory, meadows (hayfields, pastures) together with steppe areas occupy about 10%, and swamps – 1.1% (Mudrak, Mudrak, 2015).

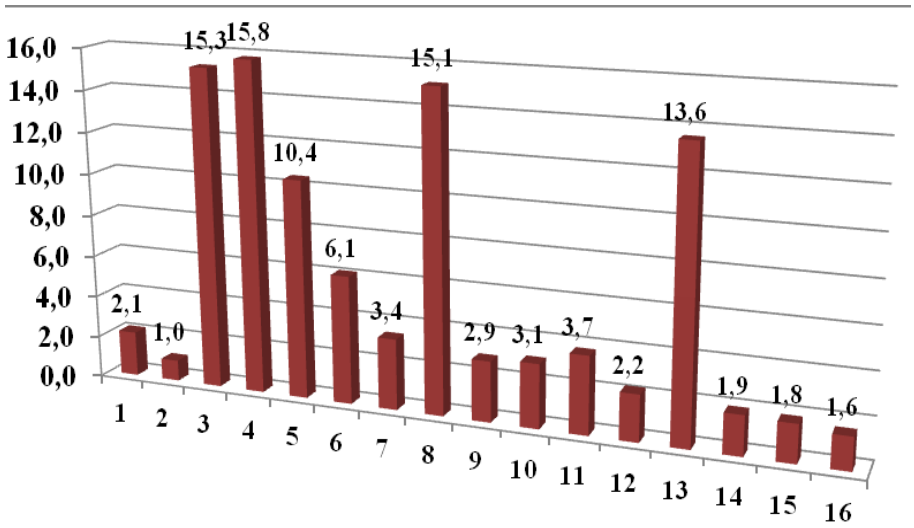

Figure 3. Ecological-coenotic structure of the Eastern Podillia's phytobiota: 1 – Psammophyte; 2 – Halophyte, 3 – Meadow, 4 – Meadow-steppe, 5 – Meadow-swamp, 6 – Margin, 7 – Forest boreal, 8 – Forest nemoralis, 9 – Forest-swamp, 10 - Swamp, 11 – Water, 12 – Coastal water, 13 - Ruderal, segetal, 14 – Species with wide ecological amplitude, 15 - Petrophyte, limestone, chalk and others, 16 - Cultural.

As a result of studies of the ecological-coenotic structure of the region's flora, it has been determined that the dominant group is represented by the following vegetation: meadow-steppe – 191 species (15.8%), meadow – 185 species (15.3%) and forest nemoralis – 183 species (15.1%). The predominance of forest nemoralis and meadow-steppe vegetation is typical for this territory.

The presence of petrophyte, limestone, halophyte and psammophyte groups of plants indicates the diversity and fragmentation of the studied area. *Linaria genistifolia, Myosotis micrantha, Vulpia myuros* can the most often be found among psammophytes, *Alyssum calycinum, Asparagus verticillatus, None apulla*, *Silene longiflora* – among petrophytes, *Althaea officinalis, Juncus gerardii, Ononis intermedia, Trifolium fragiferum* – among halophytes.

The representatives of forest and meadow-steppe vegetation acquire the widest spread in the studied phytocoenoses. Among them there are *Adonis vernalis, Althaea officinalis*, *Allium ursinum*, *Anemone sylvestris, Anemone ranunculoides*, *Carex ericetorum, Carex leporina*, *Carex praecox*, *Convallaria majalis*, *Corydalis cava*, and *Lotus arvensis*.

Close to 13.6% of the studied flora belong to the ruderal-segetal group. *Anagallis arvensis, Cannabis ruderalis*, *Capsella bursa-pastoris*, *Carduus acanthoides, Cirsium setosum, Consolida regalis, Elytrigia repens*, *Galium aparine*, *Senecio vernalis*, *Setaria glauca*, *Sinapis arvensis*, *Sonchus arvensis*, *Thlaspi arvense*, *Veronica persica*, and*Viola arvensis* are found in all types of the research antropogenic landscapes.

Crops are represented by 19 species (1.6%) in the agrolandscapes of the Eastern Podillia. Among them there are crops, which are grown on this territory: *Amorpha fruticosa, Caragana arborescens, Populus italica, Spiraea alba* and other species of trees and bushes belonging to crops and can often be seen in the gardens and parks of the region. They were found in the anthropogenically-modified tracts of the studied territories.

Thus, the ecological-coenotic analysis of flora sufficiently reflects the specificity of the vegetation of the research region. The predominance of species of meadow-steppe, forest nemoralis, meadow-swamp and meadow ecological-coenotic groups indicates the relative conservation of ecosystems (Mudrak, Mudrak, 2016). A considerable part of the species of meadow,

meadow-swamp, swamp, water and coastal-water groups make up almost half of the total, which indicates the hydrophilic nature of the flora in general. Therefore, the ecological-coenotic structure of the flora is typical for Holarctic areas with moderate climate.

Conclusions

The general characteristic of the floristic diversity of the Eastern Podillia is particularly important for its evaluation in the areas with a high level of anthropogenic fragmentation of vegetation, since it represents the flora of the coenoses from different parts of the territory. It allows to conduct floristic zoning of the territory, to find out the main directions of anthropogenic transformation of phytobiota and to develop effective ways of its conservation in the structure of the regional econet. The analysis of the flora's ecological-coenotic structure is appropriate for the conservation of habitats, the system of which will create a physical network of natural and semi-natural sozological territories in space and time. It has a very important ecological and environmental significance because the combination of natural habitats will ensure the effective and integrated environmental monitoring, the implementation of measures for the restoration of degraded ecosystems, the increase of natural resource potential of the Eastern Podillia, the preservation of its landscape and biotic diversity, flora and fauna's gene pool, it will promote to maintain a stable natural balance in the region's ecosystems (Nagorniuk et al., 2017).

The present state of the Eastern Podillia's phytodiversity needs to be preserved and protected, as it is evidenced by a significant anthropogenic burden on natural ecosystems. They are kept in the least modified form on the lands occupied by forests (814,300 ha, 13.36% of the territory), shrubs (27,300 ha, 0.45%), wetlands (158,500 ha, 2.6%), ecosystems and pastures (469,600 ha, 7.7%), hayfields (214,800 ha, 3.52%), fallows (17,000 ha, 0.28%), open lands with no or insignificant vegetation (68,200 ha, 1.11%), field-protected forest strips (22,900 ha, 0.38% of the territory). Their total area is 29.4% of the region's territory (Mudrak, Mudrak, 2013).

Acknowledgements. In order to preserve the Eastern Podillia's phytodiversity, it is expedient to carry out a series of measures, introducing the EU Directives in the field of nature protection and the shedule for their realization. To do this, it is necessary to introduce economic incentives for landowners and land users, to develop biological agriculture, to implement ecologically safe economic activities, the well-balanced use of nature and the education for sustainable development. This will allow to preserve and recreate phytodiversity, create new and expand existing reservations, optimize the area of agricultural land and support the regional econet implementation program.

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