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Synantropic flora in phytocoenoses of ecological network (the case of Vinnytsia region, Ukraine)

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The floristic diversity of the connecting areas of the four ecological corridors (further referred to as ecocorridors) of Vinnytsia region includes 262 synanthropic species (45.2%) out of 580 species of higher vascular plants in total. Apophytes are predominant: 138 of them were found at the Nemiysky, 120 – at the Dniestrovsky, 104 – at the Southern Bug, and 59 – at the Lyadivskyi eocorridors. According to the degree of adaptation to anthropogenically disturbed conditions, these apophytes belong to hemiapophytes — 85, 73, 61, and 25 species respectively at the ecocorridors. The adventive flora was evaluated on the time of entry, the naturalization degree, and the mean of distribution. It was found that archaeophytes predominate among anthropophytes according to the time of entry, epecophytes – to the naturalization degree, and akolyutophytes – to the mean of distribution. Five indices – synanthropization (IS), apophytization (IAp), anthropophyzation (IAn), archeophytization (IAr), and kenophytization (IKn) – have been determined. Moreover, it was established that apophytic processes prevail over the adventive ones at the areas studied.

Key words: synanthropic vegetation; phytocoenosis; ecological network; ecocorridors; connecting areas; apophytes; anthropophytes

Introduction

One of the outcomes of the anthropogenic pressure on the environment is the synanthropization of the vegetation, which triggers the changes of the native flora in general and the regional oner (Nichols et al., 2015, Peters et al., 2014). As a consequence, the ratio between the diversity of autochthonous and adventive plant species shifts towards the adventive ones, the dominant vegetation types are being replaced by the derivatives, and the isolation of some parts of the ranges of individual species is intensified (Cook-Patton et al., 2012, Chauhana et al., 2012, Baessler et al., 2006). Synanthropization of vegetation remains in the focus of the scientific community, what is reflected in the National Program for the Biodiversity Conservation in Ukraine for 2007–2025 (National ..., 2007). The ecological network joints biodiversity centers into the integrated spatial system with the ecological corridors as the connecting link of biodiversity conservation spots and species migration (Yatsentyuk, 2012). The regional eco-network scheme was approved by the decision N. 282 from February 14, 2012 at the 10th session of the Vinnytsia Regional Council of the 6th convocation (Regional Report ..., 2016). Vinnitsa region embraces the forest-steppe zone of the Right-bank Ukraine central part, where the antropogenically transformed agrolandscapes predominate (Mudrak, 2012, Tkach et al.,, 2017). Moreover, the vegetation in this area is highly fragmented with the pronounced synantropization processes as well as in other regions of Ukraine.

Therefore, our work was aimed to characterize the synanthropic phytobiota in the phytocoenoses of the connecting areas of the Bug (8087,73 ha), Dnistrovsky (8021,8), Lyadivskiy (742,02), and Nemiyvsky (413, 31 ha) ecological corridors of Vinnytsia region ecological network (Fig. 1). This study is the part of the research work of the Laboratory of the Ecological Evaluation of Agrotechnologies and Agroecosystems Biodiversity in frames of projects "The specificity of phytocoenoses formation within the agrolandscapes under the application of various agrotechnologies" (State registration number 0111U001619) and "The development of the scientific and methodological approaches to balanced agroecosystems in Ukraine in changing climate conditions" (State registration number 0116U001382).

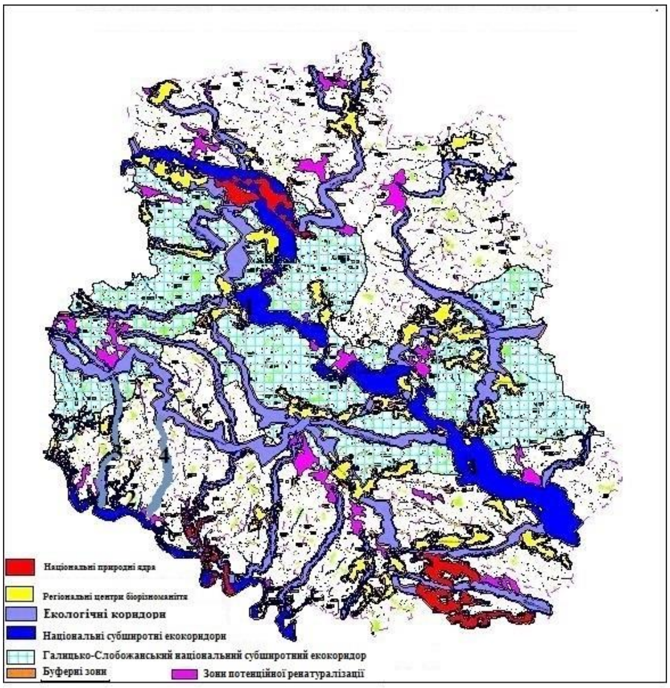

Fig. 1. Scheme ecological network of Vinnytsia region. 1 – The Southern Bug national corridor, 2 – Dniestersky national corridor, 3 – Lyadivky regional corridor, 4 – Nemiysky regional corridor.

Materials and Methods

The main materials were obtained in field research during the vegetation season of 2013-2016 in Vinnytsia region. According to geobotanical zonation of Ukraine (Didukh, 2000), the connecting areas of ecocorridors belong to the Central Podilsky district of hornbeam-oak and solely oak forests and the desert meadows of the Ukrainian forest-steppe sub-province of the Eastern European forest-steppe province of oak forests, steppe meadows and meadow steppes. We have studied semi-natural groups with different degree of vegetation' transformation (meadows, pastures, edges of the fields, and forest belts) in the connecting areas of environmental corridors: national (South-Bug and Dniestrovsky) and regional (Lyadivsky (and Nemiysky). For the analysis of phytobiotes, the traditional methods of field research of the synanthropic flora such as route surveys and records as well as plot assessment approach by R. Uiteker were used (Burda et al., 2011). All plants mentioned in this study were identified with the help of "The Key of the Higher Plants of Ukraine" (The Key..., 1987). Latin names of plant species were referred according to "The Key of the Higher Plants of Ukraine" (The Key..., 1987) and "A nomenclature checklist" (Mosyakin and Fedoronchuk, 1999). In the current study we used historical-geographical classification of synanthropic species by J. Kornas (1968) supplemented by V. Protopopova (Protopopova, 1998; 2002; 2003) considering the time and means of distribution as well as the geographical origin of plants.

All synanthropic species were divided into two groups − apophytes (aboriginal species, which were completely or partially relocated to the anthropogenically transformed areas) and anthropophytes (adventive species). For the quantitative analysis of synanthropic species five indices − synanthropization (IS), apophytization (IAp), anthropophyzation (IAn), archeophytization (IAr), and kenophytization (IKn) − were used (Kotsun, 2016). Synanthropization index (IS) is the ratio of apophytes and anthropophytes to the total number of the species studied, which characterizes the general degree of anthropogenic transformation of the flora. Apophytization index (IAp) is the ratio of apophytes to the total number of species. Anthropophyzation index (IAn) is the ratio of archeophytes and kenofites to the total number of species. Archeophytization index (IAr) is the ratio of the archeophytes to the total number of species. Kenophytization index (IKn) is the ratio between the kenophytes and the number of species. The distribution of plants in phytocoenoses with different extent of the anthropogenic transformation is classified by G. Blume and G. Sukopp (1976), what is based on the concept of hemerobity introduced by J. Jalas in 1955 (Didukh, 2000). Transformation processes were estimated according to B. Jackowiak (1990). The statistical evaluation of data was performed in Microsoft Excel 2016 and STATISTICA software.

Results and Discussion

According to the literature, there are circa 1200 species of higher vascular plants in Vinnitsya region (Regional Report ..., 2016). It was found that among 580 species of higher vascular plants (48.3% in total) 262 species represent of synanthropic flora (21.8% of the regional flora, and 45.1% in total). From the taxonomical point of view the synanthropic vegetation of the studied phytocoenoses belongs to Magnoliophyta, 24 families, 53 genera (I Division). The taxonomic analysis of synanthropic phytobiota revealed the predominant families: Asteraceae, 21 species (8%), Brassicaceae, 19 species (7.2%), Poaceae and Fabaceae, 15 species (5.7%), Lamiaceae, Chenopodiaceae, and Caryophyllaceae, 11 species (4.2%), Polygonaceae, 9 species (3.4%), and

Ranunculaceae, 5 species (2%). Among the selected synanthropic species apophytes were represented by 104 species in the Southern Bug, 120 – in the Dniestrovsky, 59 – in the Lyadivsky, and 138 species – in Nemiysky ecocorridors. Adventive species in phytocoenoses are the key part of modern flora of any region, which were introduced to native vegetation as a result of direct or indirect human activity. The anthropophytes (adventive species) are represented by 72, 98, 26, and 124 species in the respective ecocorridors. Moreover, the apophytes/anthropophytes ratio is an important diagnostic characteristic comprising 1.4/1 for the Southern Bug, 1.2/1 – for the Dnistrovsky, 2.3/1 – for the Lyadivsky, and 1.1/1 – for the Nemiysky ecocorridors. Such a ratio might be explained by the fact that the synanthropic flora in these areas was affected by the aboriginal flora, and currently the apophytic processes dominate over the adventive ones. The quantitative data on the synanthropic phytobiota of the Southern Bug, Dniestrovsky, Lyadivsky, and Nemiysky ecocorridors is shown in Table. 1.

Table 1. Historical-geographic groups of synantropic species of the connecting areas of Vinnytsia region

	The Southern Bug		Dniestersky		Lyadivky		Nemiysky	
	The number of species		The number of species		The number of species		The number of species	
	absolute	%	absolute	%	absolute	%	Absolute	%
Apophytes (general number)	**104**	**59.1**	**120**	**55**	**59**	**69.4**	**138**	**52.7**
Groups by the level of adaptation for the anthropogenically changed conditions								
hemiapophytes	61	34.6	73	33.4	25	29,4	85	32.4
evapophytes	43	24.4	47	21.5	34	40	53	20.3
anthropophytes (general number)	**72**	**40.9**	**98**	**45**	**26**	**30.6**	**124**	**47.3**
Groups by the time of entry								
archeophytes	48	27.3	51	23.4	15	17.6	77	29.4
kenophytes	19	10.8	44	20.2	8	9.5	44	16.8
eukenophytes	5	2.8	3	1.4	3	3.5	3	1.1
Groups by the mean of distribution								
akolutophytes	53	30.1	65	29.9	18	21.2	76	29
egrasiophytes	12	6.8	28	12.8	7	8.2	35	13.3
xenophytes	7	4	5	2.3	1	1.2	13	5
Groups by the degree of naturalization								
agriophytes	21	12	19	8,7	7	8.2	25	9,5
epecophytes	43	24.4	73	33.5	19	22.3	92	35.1
ephemerophytes	8	4.5	6	2.7	-	-	4	1.5
colonophytes	-	-			-	-	3	1.2
Total	**176**	**100**	**218**	**100**	**85**	**100**	**262**	**100**

The national submeridional ecocorridor of the Southern Boh is confined to the Southern Bug River valley characterized by the considerable mosaicism and heterogeneity of natural conditions and landscape complexes. The ecocorridor area is 141973.3 ha, which comprises 5.4% of total area of the region. The apophyte fraction of flora is represented by two groups: 61 species (34.6%) of hemiapophytes widespread in semi-natural or transformed ecosystems, but still keeping their positions in natural ecosystems, and 43 species (24.4%) of evapophytes completely or partially migrated to the anthropogenic ecosystems. Among the anthropophytes, the dominant group by the time of entry is archeophytes, which spreaded to the new regions at late 15th century. The common representatives of 48 archaophytic species (27.3%) are *Centaurea cyanus* L., *Consolida regalis* Gray., *Stachys annua* (L.) L., *Poa annua* L., *Urtica urens* L., *Veronica arvensis* L., etc. In turn, kenophytes are represented by 19 species (10.8%) such as *Galinsoga parviflora* Cav., *Cuscuta campestris* Yunck, *Poa trivialis* L., etc. It has to be noticed that the input of eukenofites is only 5 species (2.8%) (*Ambrosia artemisifolia* L., *Amaranthus deflexus* L., *A. blitoides* S. Wats., etc.). In turn, by the mean of entry 53 akolyutophytic species (53%) were the majourity, what suggests the high degree of anthropogenic disturbance and transformation of the studied phytocoenoses. Typical representatives of this group are *Cichorium intybus* L., *Malva sylvestris* L., *Apera spica-venti* (L.) P. Beauv., and *Reseda lutea* L. The input of so called ergasiophytes, or the species introduced by humans intentionally, is considerably less significant and comprises 12 species (6.8%). Common ergasiophytes are *Capsella bursa-pastoris* (L.) Medik., *Anagallis arvensis* L., *Bunias orientalis* L., etc. Furthermore, xenophytes are represented by 7 species (4%) such as *Xanthoxalis stricta* (L.) Smal., *Kochia laniflora* (S.G. Gmel) Borbas, *Lactuca serriola* L., etc. Epicophytes head the group of plants classified according to the degree of naturalization and include 43 species (24.4%). Typical representatives are *Bromus arvensis* L., *Lamium album* L., *Centaurea cyanus* L., *Solanum nigrum* L., and others. Agriophytes are considerably smaller in number – 21 species (12%) including *Sonchus arvensis* L., *Sisymbrium loeselii* L., *Lupinus albus* L., *Aesculus hippocastanum* L., etc. Ephemerophytes are represented by 8 species (4.5%) such as *Eragrostis pilosa* (L.) P. Beauv., *Adonis annua* L., *Amaranthus deflexus* L., etc.

Internationally important Dniester national submeridional ecocorridor covering 20599.7 ha (0.8% of the area of the region) is confined to the Dniester River valley and combines the elements of Vinnytsia region ecological network with the elements of the ecological networks of the Khmelnytsky region of Ukraine and the Republic of Moldova. We have shown that apophytes are mostly represented by 73 species of hemiapophytes (33.4%) and 47 species of evapophytes (21.5%). Archeophytes head the group classified by the time of entry in anthropogenically transformed phytocoenoses of the connecting areas (23.4%). Among 51 archaeophytic species, *Senecio vulgaris* L., *Lactuca serriola* Torner, and *Cichorium intybus* L. are the most common. Kenophytes are represented by 44 species (20.2%) and euchenophytes – the smallest group – only by 3 species (1.4%). By the mean of distribution, 65 species of acolyutophytes (29.9%), 28 species of ergasiophytes (12.8%) as well as 5 species of xenophytes (2.3%) were registered.

The Lyadivsky regional ecocorridor is formed by the valley of the Lyadova River joining Murovani Kurylivtsi and Lyadiv regional biodiversity centers with the Dniester River national submeridional ecocorridor. Synanthropic vegetation has two factions: 59 species of apophytes (69.4%) and 26 species of anthropophytes (adventive plants) (30.6%). Among apophytes, 34 species of evapophytes (40%) comprises the main group according the degree of adaptation to anthropogenically disturbed conditions namely *Urtica dioica* L., *Plantago major* L., *P. media* L., *Sisymbrium loeselii* L., *Echium vulgare* L., *Rumex acetosella* L., *Chelidonium majus* L., and others. The second position belongs to hemiapophytes – 25 species (29.4%) including *Potentilla anserina* L., *Achillea millefolium* L., *Carduus crispus* L., *Medicago falcatà* L., *Prunella vulgaris* L., etc. Apophytes prevail in the synanthropic flora not only in number, but also in their input to the formation of vegetation. Moreover, by the time of entry dominate 15 species of archeophytes (17.6%), then 8 species of kenophytes (9.5%) and 3 species of eukenofites (3.5%) among the anthropophytes. In turn, by the degree of naturalization dominate 19 species of epicophytes (22.3%) and 7 species of agriophytes (8.2%), and by the means of distribution: acolyutophytes – 18 species (21.2%), ergasiophytes – 7 species (8.2%), and xenophytes – 1 species (1.2%).

The Nemiysky ecological corridor was formed by the valley of the Nemiya River joining Yaltushkivsko-Dashivsky regional and Galitsko-Slobozhansky national ecocorridors with the Dniester national ecocorridor. The apophytes are represented by 138 species (52.7%), and leadersip role is played by hemiapophytes – 85 species (32.4%). Somewhat smaller in proportion are evapophytes comprising 53 species (20.3%). By the time of entry, the majority belongs to 77 species of archeophytes (29.4%) – species emerged in new regions by the end of the 15th century. Typical archeophytes are *Poa annua* L., *Apera spica-venti* (L.) P. Beauv., and *Consolida regalis* S.F.Gray. In second place are kenophytes – 44 species (16.8%) including *Sisymbrium loeselii* L., *Conyza canadensis* (L.) Cronq., and *Reseda lutea* L. Euchenophytes – species that immigrated from the beginning of the 20th century – are represented only by 3 species (1.1%): *Amaranthus blitoides* S.Wats., *A. deflexus* L. and *Ambrosia artemisifolia* L.

The mean of entry plays an important role in the distribution of adventitious plants. According to this criterion, 76 species of akolyutophytes (29.4%) belong the most common group. Predominantly, these are plant species accidentally introduced by humans and distributed because of the anthropogenic transformation of natural ecosystems, e.g., *Sonchus arvensis* L., *Veronica arvensis* L., and *Galinsoga parviflora* Cav. Ergaziophytes are represented by 35 species (28.2%), for instance, *Urtica urens* L., *Ranunculus arvensis* L., and *Lupinus albus* L. Kenophytes are 13 species (5%) including *Centaurea cyanus* L., *Sisymbrium loeselii* L., and *Phalacroloma annuum* (L.) Dumort. By the degree of naturalization dominate 92 species of epicophytes (35.1%) and 25 species of agriophytes (9.5%). These include *Stachys annua* (L.) L., *Crepis capillaris* (L.) Wallr., *Lamium album* L., *Anchusa officinalis* L., *Lathyrus tuberosus* L., and *Cichorium intybus* L. Ephemerophytes in the studied flora are represented by 4 species (1.5%): *Adonis aestivalis* L., *Amaranthus deflexus* L., *Amaranthus deflexus* L., and *Eragrostis pilosa* (L.) P. Beauv. Lastly, only 3 species of colonophytes (1.2%) – *Lepidotheca suaveolens* (Pursh) Nutt., *Papaver somniferum* L., and *Saponaria officinalis* L. – were presented in phytocoenoses.

Generally, the synanthropic vegetation of the studied phytocoenoses is typical for the synanthropic flora of the region. Eu- and polyhemerobes – the background species of the anthropogenically modified plant communities with wide ecological amplitude – are the prevailing groups in phytocoenoses of the connecting areas characterized by the degree of hemerobity. Such anthropophytes as *Ambrosia artemisiifolia* L. (euchenophyte, epokophyte, akolyutophyte), *Bromus arvensis* L. (arheophyte, epokophyte, akolyutophyte), *Cuscuta campestris* Yunk. (kenophyte, epecophyte, acolyuthophyte), *Amaranthus retroflexus* L.

(kenophyte, epoxy, xenophyte), *Consolida regalis* Gray. (archeophyte, epicophyte, ergasiophyte), *Apera spica-venti* (L.) P. Beauv. (archeophyte, epicophyte, akolyutophyte), *Reseda lutea* L. (kenophyte, epecophyte, acolyuthophyte), *Sonchus oleraceus* L. (archeophyte, agriophyte, acolyuthophyte) occur on the edges of the fields. The aggressive species *Galinsoga parviflora* Cav. (kenophyte, ecopofite, acolyuthophyte) migrates from the agricultural areas to the adjacent meadows able to replace aboriginal species in the new conditions. *Poa annua* L. (kenophyte, epicophyte, acolyuthophyte), *Bromus arvensis* L. (archeophyte, epokophyte, acolyuthophyte), *Anchusa officinalis* Mill. (archeophyte, agriophyte, akolyutophyte), *Urtica urens* L. (archeophyte, epicophyte, ergasiophyte,) and *Senetio vulgaris* L. (archeophyte, epicophyte, akolyutophyte) are widespread in the forest belts. *Cichorium intybus* L. (archeophyte, epicophyte, akolyuthophyte), *Myostis arvensis* (L.) Hill (archeophyte, epicophyte, ergasiophyte)., *Lamium album* L. (archeophyte, epecophyte, akolyutophyte), *L. purpureum* L. (arheophyte, epecophyte, akolyutophyte), *Cynoglossum officinale* L. (arheophyte, epecophyte, akolyutophyte), *Veronica arvensis* L. (arheophyte, epecophyte, akolyutophyte), *Viola arvensis* Murray (archeophyte, epecophyte, akolyutophyte), and *Sisymbrium loeselii* L. (kenophyte, agriophyte, acolyuthophyte) are common in pastures and meadows.

The input of individual historical and geographical flora groups is used for the evaluation of parameters characterizing anthropogenic changes in the flora of a certainarea. Five indices –synanthropization (IS), apophytization (IAp), anthropophyzation (IAn), archeophytization (IAr), and kenophytization (IKn) – were used to determine the degree of anthropogenic transformation of the flora (Table 2).

Table 2. Quantitative indices of anthropogenic changes of phytocoenoses of connecting areas of the ecological network of Vinnytsia region.

	The Southern Bug	Dniestrovsky	Lyadivsky	Nemiysky
Index	Relative indices			
Synanthropization index (IS)	30.3	37.6	14.6	45.2
Apophytization index (IAp)	18	20.7	10.2	23.8
Anthropophyzation index (IAn)	11.5	16.03	4	20.9
Archeophytization index (IAr)	8.3	8.8	2.6	13.3
Kenophytization index (IKn)	3,3	7.6	1.4	7.6

The Dniester submeridional ecocorridor has the highest synanthropization index (IS) value of 37.6%, which indicates the sufficient flora transformation and the significant anthropogenic pressure on phytobiota. This is primarily due to the increased areas of the ploughed fields as well as the possible entry of the synanthropic plant species by railway tracks. The low IS value for the Lyadivsky ecocorridor (14.6%) might be explained by lower anthropogenic pressure on the plant groups.

Apophytization index (IAp) reflects the input of aboriginal species in vegetation of anthropogenically transformed ecotops. IAp was 23.8% in Nemiysky, 20.7% in Dniestrovsky, 18% in the Southern Bug, and 10.2% in Lyadivsky ecocorridors.

Anthropophyzation index (IAn) characterizes the role of invasions of adventitious plants in the flora synantropization. IAn was 20.9% in Nemiysky, 16.03% in Dniestrovsky, 11.5% in the Southern Bug, and 4% in Lyadovsky ecocorridors. The ratio of these two characteristics indicates the processes prevailing in the studied area. It has been established that the synanthropic flora of the anthropogenically transformed phytocoenoses was formed under the influence of aboriginal flora, and now the apophytization prevail over the adventization.

Archeophytization index (lAr) represent the input of the species with high naturalization degree entered Ukraine before the 15th century. The background value was 13.3% in Nemiysky, 8.8% in Dniestrovsky, 8.3% in the Southern Bug, and 2.6% in Lyadivsky ecocorridors.

Kenophytization index (IKn) reflects the intensity of invasions from the 15th to the 20th centuries. Relatively low values – 7.6%, 3.3%, and 1.4% respectively – show the minor role of the kenophytes in the synantropy of the flora of the studied ecocorridors.

Conclusions

In the studied area we have revealed 580 species of higher vascular plants including 262 synanthropic. The ratio of apophites to anthropophytes is 1.4/1 for the South-Bug, 1.2/1 – for the Dnistrovsky, 2.3/1 – for the Lyadivsky, and 1.1/1 – for the Nemiysky ecocorridors. The relatively high IS indicates that the studied phytocoenoses of the ecocorridors connecting areas underwent the extensive anthropogenic transformation. However, the relatively low values of IAp and Ikn together with the high value of IAp determine the specificity of the flora synantropization, where apophytization prevails over the adventization. The presence of agriophytes suggests that these species naturalized in anthropogenically transformed phytocoenoses and are competitive with the local species. The dominance of akolyutophytes confirms that the studied areas were anthropogenically disturbed, and this transformation of flora optimizes the conditions for their distribution.

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