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VARIABILITY OF MORPHOLOGICAL SIGNS OF POPULATIONS *SOLIDAGO CANADENSIS* L. AND *SOLIDAGO GIGANTEA* AIT. IN DIFFERENT ECOLOGICAL CONDITIONS

The anthropophytisation processes pose a real threat to the phytodiversity on the territory of Ukraine. To study the interpopulation variability and to analyze the factors leading to the excessive increase in quantity of the adventive species individuals in the conditions of anthropogenic transformation, we took as a model the invasion species on the territory of Ukraine: *Solidago canadensis* L. and *Solidago gigantean* Ait. According to the study of the morphological signs variability in local populations *S. canadensis* and *S. gigantea* in different ecological conditions, we have revealed that the morphometric signs (length of the ramet, number of leaves, length of inflorescences, number of flowers in the inflorescences) of the *S. canadensis* ramets are characterized by medium and high intrapopulations variability (V = 11.46-68.67 %), and *S. gigantea* ramets are characterized by insignificant and high levels of intrapopulation variability (V = 7.01-90.04 %), which correlates with unfavourable conditions of anthropogenically transformed habitats. According to the study results, we have discovered that the depressive vitality type, and, correspondingly, the low vitality level is common for the local populations of *S. canadensis* for ruderal biotopes of anthropogenic herb stands, ruderal biotopes of fallows on sand, highly artificial broadleaved deciduous forestry plantations and fruit and nut tree orchards. Such a vitality type of *S. canadensis* populations is probably explained by the high level of digression of the above-mentioned biotopes. The local population of the ruderalized thickets of bushes is characterized by the comparatively high value of the vitality index, which is due to the favorable edaphic conditions. On the other hand, the local populations of *S. gigantea* of ruderal biotopes of anthropogenic herb stands, ruderal biotopes of fallows on sand, highly artificial broadleaved deciduous forestry plantations, fruit and nut tree orchards and ruderalized thickets of bushes are characterized by a prosperous vitality type and, accordingly, a high level of vitality.

Keywords: fitoinvasion; plant population; adventive plants; coefficient of variation; vitality.

Introduction. The anthropophytisation processes pose a real threat to the phytodiversity on the territory of Ukraine. Every year, the quantity of invasive plants increases along with the rates of their distribution and naturalization, the spectrum of their habitat expands. The flora of Ukraine occupies quite a high rank among other flora of the world by the level of anthropophytisation (species of adventive plants represent at least 14 % of the country's flora total number of species). The spontaneous fraction of the adventive flora of Ukraine comprises at least 830 species of vascular plants, among which about 50 species are dangerously invasive (Protopopova et al., 2002).

The natural biogeographic process of species migration in vascular plants provides for the presence of at least three components: recipient environment, colonizer species and vector of transferring. The natural process of plants migration ensures continuity and discreteness of the vegetation. Anthropogenic migrations of vascular plants are characterized by the fact that they are caused by the abrupt transformations of one, two or all three mentioned elements because of unintentional or purposeful human activity. The process of vascular plant migration accelerates, assuming global dimensions. Alien species of plants, adapting to the changing conditions, quickly enter new spaces, sometimes intensively increase the number of individuals resulting in phytoinvasion. Rapid adaptation of new local populations of anthropophytes provides widespread distribution regardless of phytocenotic environment (Burda et al., 2015). Thus, while exploring the plant populations, it is highly important to study intrapopulation and interpopulation variability of morphological signs in individuals. Such data give us the opportunity to learn want mechanisms ensure the viability of populations, as well as the peculiarities of their adaptations to the changing conditions of the altered natural and anthropogenic environment. (Chuj & Shumskaja, 2014).

To study the interpopulation variability and to analyze the factors leading to the excessive increase in quantity of the adventive species individuals in the conditions of anthropogenic transformation, we took as a model the invasion species on the territory of Ukraine: *Solidago canadensis* L. (kenophyte of the North American origin, epicophyte, European and North American habitat, herbaceous polycarpic, mesophyte, scioheliophyte, anemochore, weeds) and *Solidago gigantea Ait.* (kenophyte of the North American origin, ergasiophyte, European and North American habitat, herbaceous polycarpic, mesophyte, scioheliophyte, anemochore, weeds) (Protopopova, 1991).

Material and methods of research. Population analysis of local populations *S. canadensis* та *S. gigantea* was consistent with their phenological spectra (was conducted

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during the flowering phase, in August-September of 2015 and 2017). We selected the partial sprout (hereinafter the ramet) as the phytopopulation statistical unit to analyze the local populations *S. canadensis ma S. gigantea,* which are characterized by seed and vegetative regeneration (clones of different types are formed).

All the populations selected for the analysis, are localized within the boundaries of biotopes of Kyiv city: I 2.21 Ruderal biotopes of anthropogenic herb stands; I 2.242 Ruderal biotopes of fallows on sand; I 4.12 Ruderalized thickets of bushes; I 1.4.11 Highly artificial broadleaved deciduous forestry plantations; I 4.22 Fruit and nut tree orchards. Types of biotopes are given according to the classification of biotopes for forest and forest-steppe zones of Ukraine (Didukh et al., 2011).

We took the field material (ramets) for further cameral treatment in a very short period of time, to minimize the impact of ontogenetic drift on the results of the study. The sample size for each local population amounted to 25 ramets in the reproductive state. We estimated the morphological status of individuals by 4 static metric parameters (Table 1).

Table 1. Morphometric parameters of *Solidago canadensis* L. and *Solidago gigantea* Ait.

Metric parameters	Notation keys and calculation formula	Unit of measurement
The length of the generative shoot	*h*	cm
Length of inflorescence	*hfl*	cm
Number of flowers in the inflorescence	*Nfl*	pcs./ind
Number of leaves	N_f	pcs./ind

We processed the the value of morphometric features by generally accepted statistical methods. (Burda, Ignatiuk, 2011). We used the coefficient of variation (*V*, %) as a measure of the characteristics variability. Depending on the value of the variation coefficient, the variability of the characteristics was evaluated on the following scale: $V < 10$ % – variation is negligible; $10 < V < 20$ % – variation is average; $V > 20$ % – variation is considerable (Zlobin, 2009).

To explore the interpopulation variability of *S. canadensis* and *S. gigantea*, we compared the average arithmetic values of the studied characteristics and defined the difference of reliability using the Student's t-criterion. To determine the links between parameters, we conducted the correlation analysis. To establish the morphological integrity of individuals in the investigated local populations, we defined the index of individuals integrity according to U. A. Zlobin (Zlobin, 2009). The maximum value of the index corresponds to the best conditions for the implementation of growth potentials, and the minimum – for worse conditions or increased stress.

The statistical treatment of the output data is carried out with the help of software MS Excel 2010 and Statistica 7.0.

Results and discussion. According to the study of the morphological signs variability in local populations *S. canadensis* та *S. gigantea* in different ecological conditions, we established, that the morphometric signs (length of the ramet, number of leaves, length of inflorescences, number of flowers in the inflorescences) of the *S. canadensis* ramets are characterized by medium and high intrapopulations variability (V = 11,46–68,67 %), and *S. gigantea* ramets are characterized by insignificant and high levels of intrapopulation variability (V = 7,01–90,04 %), which correlates with unfavorable conditions of anthropogenically transformed habitats (Table 2).

Table 2. Variations coefficient (*V*, %) of morphological signs of local populations *Solidago canadensis* L. and *Solidago gigantea* Ait. in different biotopes

Biotopes	Morphological parameters			
	h	N_f	*hfl*	*Nfl*
I 2.21		52.13 52.49	42.13 24.64	57.74 57.57
I 2.242	15.56 14.57	18.49 33.59	27.94 15.13	27.94 42.16
I 4.12	19.25 7.01	25.64 40.96	36.69 16.90	64.23 33.82
I 1.4.11	11.46 11.66	36.44 86.41	39.17 31.54	46.06 90.04
I 4.22	20.23 10.95	24.58 52.41	45.27 34.07	68.67 49.33

Note: I 2.21 Ruderal biotopes of anthropogenic herb stands, I 2.242 Ruderal biotopes of fallows on sand, I 4.12 Ruderalized thickets of bushes, I 1.4.11 Highly artificial broadleaved deciduous forestry plantations, I 4.22 Fruit and nut tree orchards; *h* – the length of the generative shoot, N_f – Number of leaves, *hfl* – length of inflorescence, *Nfl* – number of flowers in the inflorescence; above the dash – the parameters of local populations *S. canadensis*, below the dash – the parameters of local populations *S. gigantea.*

In all the studied populations of *S. canadensis* the lowest values of coefficient of variability are typical for the length of the generative shoot (V = 11,46–20,23 %), they correspond to the average values of variability. The variability analysis of number of leaves of the individual in the anthropogenic biotopes has shown that the local populations of ruderal biotopes of fallows on sand are characterized by the average variability level. But, it was discovered, that ruderal biotopes of anthropogenic herb stands, ruderalized thickets of bushes, highly artificial broadleaved deciduous forestry plantations and fruit and nut tree orchards are characterized by the high level of variability, because they are more developed and structured. The length of inflorescence and number of flowers are marked by the biggest variable (V = 27,94÷45,27 and V = 46,06÷68,67 % respectively).

In all the studied local populations of *S. gigantea* the lowest value of the variation coefficient is attributed to the length of the generative shoot (V = 7,01÷16,86 %), it corresponds to the low and average values of the variation. The variability analysis of the length of inflorescence in the anthropogenic biotopes showed that the local populations of the ruderal biotopes of fallows on sand are characterized by the average level of the variability, but the ruderal biotopes of anthropogenic herb stands, ruderalized thickets of bushes, highly artificial broadleaved deciduous forestry plantations and fruit and nut tree orchards are characterized by the high level of variability. The number of leaves and the number of flowers are marked by the most considerable variable (V = 33,59÷86,41 and V = 33,82÷90,04 % respectively).

The variation coefficient rates in number of leaves of ramets of all the studied local populations of *S. gigantea* are higher than the similar rates of the local populations of *S. canadensis.* However, the variation coefficient rates of the length of inflorescence in the ramets of the studied local populations of *S. gigantea* are lower than the similar rates of the local populations of *S. canadensis.* The considerable morphological variability of the individuals of *S. canadensis* та *S. gigantea* is one of the survival mechanisms of local populations in conditions of significant anthropogenic pressure.

The morphological structure of plants depends to a large extent on ecological and cenotic factors of the environment.

The study analysis of the interpopulation variability of parameters of *S. canadensis* та *S. gigantea* ramets has shown that there is no significant difference between populations in number of leaves, length of inflorescence and number of flowers in the inflorescence. There is an insignificant difference (with accuracy of 95 %) in the length of the ramets in the studied local populations. We conducted the correlation analysis of the parameters of individuals within the frames of populations to examine the internal linkages between plants. We marked from 0 to 4 statistically significant direct proportional correlations at the probability level of 99 % in each correlation matrix (Table 3).

Table 3. Correlation between morphometrical signs and vitality index of the local populations *Solidago canadensis* L and *Solidago gigantea* Ait.

Biotopes	Morphological parameters						
	h/N_f	h/hfl	h/Nfl	N_f/hfl	N_f/Nfl	hfl/Nfl	IVC
I 2.21	0.70 / 0.39	0.73 / 0.29	0.70 / –0.14	0.89 / 0.80	0.79 / 0.32	0.86 / 0.20	1.07 / 1.14
I 2.242	0.50 / 0.36	0.72 / 0.56	0.31 / –0.0005	0.54 / 0.68	0.38 / 0.41	0.69 / 0.62	0.93 / 1.42
I 4.12	0.70 / 0.67	0.78 / 0.50	0.61 / 0.19	0.62 / 0.80	0.46 / 0.60	0.70 / 0.63	1.37 / 1.34
I 1.4.11	0.61 / 0.10	0.84 / 0.49	0.75 / 0.14	0.75 / 0.47	0.61 / 0.96	0.86 / 0.42	0.81 / 1.32
I 4.22	0.83 / 0.52	0.62 / 0.63	0.62 / 0.59	0.62 / 0.96	0.69 / 0.92	0.82 / 0.91	0.75 / 1.3

Note: I 2.21 Ruderal biotopes of anthropogenic herb stands, I 2.242 Ruderal biotopes of fallows on sand, I 4.12 Ruderalized thickets of bushes, I 1.4.11 Highly artificial broadleaved deciduous forestry plantations, I 4.22 Fruit and nut tree orchards; IVC – index of vitality of coenopopulations; h – the length of the generative shoot, N_f – Number of leaves, hfl – length of inflorescence, Nfl – number of flowers in the inflorescence; $P > 0{,}01$; above the dash – the parameters of local populations *S. canadensis*, below the dash – the parameters of local populations *S. gigantea.*

The length of the inflorescence and the number of flowers in the inflorescence are the most correlated morphometric signs of local populations of *S. canadensis* with other signs. They have from 1 to 3 reliable correlations. The number of leaves and the number of flowers in the inflorescence are the most correlated morphometric signs of local populations of *S. gigantea* (from 1 to 3 reliable correlations as well).

The viability of the population is a very important complex and diagnostic attribute of the population level. By this notion we mean the integral effect of the basic population functions, such as renewal (cyclicity), retention and expansion of the territory (resettlement) and preservation of evolutionary perspectives (Tsarik, 2001). The individuals of the studied populations of *S. canadensis* are characterized by the low vitality, that is proved by their depressive vitality type (table 3). However, the presence of the individuals with low vitality is necessary for the population existence, as they can faster realize their reproductive potential and leave behind offspring (Tsarik, 2001).

According to the study results, we discovered that the depressive vitality type, and, correspondingly, the low vitality level is common for the local populations of *S. canadensis* for ruderal biotopes of anthropogenic herb stands, ruderal biotopes of fallows on sand, highly artificial broadleaved deciduous forestry plantations and fruit and nut tree orchards. Perhaps, such a vitality type of *S. canadensis* populations is explained by the high level of digression of the above-mentioned biotopes (Table 3). The local population of the ruderalized thickets of bushes is characterized by the comparatively high value of the vitality index, which is due to the favorable edaphic conditions. (Table 3).

On the other hand, the local populations of *S. gigantea of* ruderal biotopes of anthropogenic herb stands, ruderal biotopes of fallows on sand, highly artificial broadleaved deciduous forestry plantations, fruit and nut tree orchards and ruderalized thickets of bushes are characterized by a prosperous vitality type and, accordingly, a high level of vitality. (Table 3).

Belonging of all the studied populations of *S. gigantea* to the prosperous type of vitality structure testify to an ecological optimum for them on the investigated areas of the secondary habitat. However, different values of IVC index prove that edaphic factor plays a significant role in shaping the populations structure and leads to their differentiation.

Conclusions. We found that, depending on the environment conditions and the effects of anthropogenic factors, the adaptation mechanisms of the local populations of *S. canadensis* та *S. gigantea* consist in changing the vitality and phenotypic variability in order to survive, reproduce and develop in the conditions of anthropogenically transformed biotopes.

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ВАРІАБЕЛЬНІСТЬ МОРФОЛОГІЧНИХ ОЗНАК ПОПУЛЯЦІЙ *SOLIDAGO CANADENSIS* L. ТА *SOLIDAGO GIGANTEA* AIT. У РІЗНИХ ЕКОЛОГІЧНИХ УМОВАХ

За результатами дослідження варіабельності морфологічних ознак локальних популяцій *S. canadensis* та *S. gigantea* у різних екологічних умовах встановлено, що морфометричні ознаки (довжина рамет, кількість листків, довжина суцвіть, кількість квіток у суцвітті) рамет *S. canadensis* характеризуються середнім та високим рівнями внутрішньопопуляційної мінливості (V = 11,46–68,67 %), а рамет *S. gigantea* – незначним та високим рівнями внутрішньопопуляційної мінливості (V = 7,01–90,04 %), що корелює із несприятливими умовами антропогенно трансформованих біотопів. За результатами дослідження встановлено, що для локальних популяцій *S. canadensis* рудеральних біотопів трав'яних багаторічників, рудеральних біотопів перелогів на пісках, штучно створених біотопів листяних дерев та плодових та декоративних садів характерний депресивний віталітетний тип і, відповідно, низький рівень життєвості. Порівняно високим значенням індексу віталітету характеризується локальна популяція рудералізованих заростей кущів, що зумовлено сприятливими едафічними умовами. Натомість локальні популяції *S. gigantea* рудеральних біотопів трав'яних багаторічників, рудеральних біотопів перелогів на пісках, штучно створених біотопів листяних дерев, плодових та декоративних садів, рудералізованих заростей кущів характеризуються процвітаючим віталітетним типом і, відповідно, високим рівень життєвості.

Ключові слова: фітоінвазії; популяція рослин; адвентивні рослини; коефіцієнт варіації; життєвість.

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ВАРИАБЕЛЬНОСТЬ МОРФОЛОГИЧЕСКИХ ПРИЗНАКОВ ПОПУЛЯЦИЙ SOLIDAGO CANADENSIS L. И *SOLIDAGO GIGANTEA* AIT. В РАЗНЫХ ЭКОЛОГИЧЕСКИХ УСЛОВИЯХ

В результате исследования вариабельности морфологических признаков локальных популяций *S. canadensis* и *S. gigantea* в различных экологических условиях установлено, что морфометрические признаки (длина рамет, количество листьев, длина соцветий, количество цветков в соцветии) рамет *S. canadensis* характеризуются средним и высоким уровнями внутрипопуляционной изменчивости (V = 11,46–68,67 %), а рамет *S. gigantea* – незначительным и высоким уровнями внутрипопуляционной изменчивости (V = 7,01–90,04 %), что коррелирует с неблагоприятными условиями антропогенно трансформированных биотопов. По результатам исследования установлено, что для локальных популяций *S. canadensis* рудеральных биотопов травяных многолетников, рудеральных биотопов залежей на песках, искусственно созданных биотопов лиственных деревьев, плодовых и декоративных садов характерен депрессивный виталитетный тип и, соответственно, низкий уровень жизненности. Сравнительно высоким значением индекса виталитета характеризуется локальная популяция рудерализованых кустарников, что обусловлено благоприятными эдафическими условиями. Однако локальные популяции *S. gigantea* рудеральных биотопов травяных многолетников, рудеральных биотопов залежей на песках, искусственно созданных биотопов лиственных деревьев, плодовых и декоративных садов, рудерализованых кустарников характеризуются процветающим виталитетным типом и, соответственно, высоким уровень жизненности.

Ключевые слова: фитоинвазии; популяция растений; адвентивные растения; коэффициент вариации; жизненность.