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Research Article

Morphostructure of *Moehringia hypanica* Gryn & Klokov in the Buzky Gard National Nature Park, Ukraine

Liudmyla Dzhus[1], Tatiana Kovalchuk[2], Inna Didenko[2*], Marharyta Parubok[3], Larysa Rozborska[3]

[1] Department of Herbaceous Plants of the Sofiyivka National Dendrological Park of the National Academy of Sciences of Ukraine, UKRAINE
[2] Department of Herbaceous Plants of the Sofiyivka National Dendrological Park of the National Academy of Sciences of Ukraine, UKRAINE
[3] Department of Biology Uman National University of Horticulture, UKRAINE

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Ioannis Bazos

****Corresponding Author:***
Inna Didenko
fritillaria2007@gmail.com

ORCID iDs of the authors:
LD. 0000-0003-3586-7432
TK. 0000-0002-8545-8496
ID. 0000-0002-4198-3432
MP. 0000-0002-7228-4669
LR. 0000-0003-2002-6438

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Abstract: The ecological-edaphic and morphological features and the state of populations of the endemic species *Moehringia hypanica* Gryn & Klokov within the steppe zone of Ukraine were investigated. According to the results of laboratory studies, the humus content of the soil where *M. hypanica* grows is high, amounting to 7.35-8.23%. According to the results of our research, the availability of soil mobile nutrients showed that the concentrations of Mg, and P_2O_5 were very high, and 8.5-15.0 mg/kg, 129.6-164.5 mg/kg, respectively, and Ca concentration was high and very high, which corresponds to 12.5-27.5 mg/kg. The N concentration of the substrate increased in the samples (256.2-268.8 mg/kg), and the S concentration varied between very low and low (1.3-4.8 mg/kg). This indicated high concentrations of Mg, P_2O_5, and Ca in the substrate and as a limiting factor for the successful growth of the studied plants. The analysis of the cationic and anionic composition of the water extract showed that the soil was classified as non-saline (the sum of salts did not exceed 0.1%). The content of all salts did not exceed the toxicity thresholds. It has been established that in order to preserve the populations of this endemic plant, it is necessary to maintain a stable chemical composition of the substrate and prevent human intervention. During the expeditionary research, we noted that the populations are dominated by young generative and medium generative plants, with a small number of old generative and virgin individuals.

Özet: Ukrayna'nın bozkır bölgesindeki endemik *Moehringia hypanica* Gryn & Klokov türünün ekolojik-edafik ve morfolojik özellikleri ile popülasyonlarının durumu araştırılmıştır. Laboratuvar çalışmalarının sonuçlarına göre, *M. hypanica* türünün yetiştiği toprağın humus içeriği yüksektir ve %7,35-8,23 arasındadır. Araştırmamızın sonuçlarına göre, toprağın hareketli besin maddelerinin mevcudiyeti, Mg, P_2O_5 konsantrasyonlarının çok yüksek ve sırasıyla 8,5-15,0 mg/kg, 129,6-164,5 mg/kg'dır. Ca konsantrasyonu yüksek ve çok yüksek olduğunu ve 12,5-27,5 mg/kg'a karşılık geldiğini göstermiştir. Substratın N içeriği her iki örnekte de yüksektir (256,2-268,8 mg/kg) ve S konsantrasyonu çok düşük ila düşük arasında değişmiştir (1,3-4,8 mg/kg). Bu, substratta yüksek miktarda Mg, P_2O_5, Ca bulunduğunu ve incelenen bitkilerin başarılı bir şekilde büyümesi için sınırlayıcı bir faktör olduğunu göstermektedir. Su özütünün katyonik ve anyonik bileşiminin analizi, toprağın tuzsuz olarak sınıflandırıldığını göstermiştir (tuzların toplamı %0,1'i geçmez). Tüm tuzların içeriği toksisite eşiklerini aşmamaktadır. Bu endemik bitkilerin popülasyonlarını korumak için, substratın istikrarlı bir kimyasal bileşimini korumak ve insan müdahalesini önlemek gerektiği tespit edilmiştir. Keşif araştırması sırasında, popülasyonlara genç generatif ve orta generatif bitkilerin hakim olduğunu, az sayıda yaşlı generatif ve bakir bireylerin bulunduğu gözlemlenmiştir.

Introduction

One of the most urgent tasks within the framework of biodiversity conservation is the protection of endemic plant species as the most vulnerable component of the gene pool. The risk of extinction is always higher for endemic species in comparison with non-endemic species with a wider range.

One of the narrow-range endemic relict species is *Moehringia hypanica* Gryn & Klokov. which has a high international and national, at Ukraine level, sozological

status (Fedoronchuk 2009). According to the Important Plant Areas (IPA) programme, which aims to identify and protect a network of the best sites for plant conservation in Europe and the rest of the world, using agreed criteria (Anderson 2002), *M. hypanica* falls under Criterion A - presence of threatened plant species: the site contains significant populations of one or more species of global or regional conservation importance (Onyshchenko 2017). The main repository of the *M. hypanica* gene pool is the Buzky Gard National Nature Park (NNP). It is one of the territories of the Southern Bug River valley of the steppe zone of Ukraine, which is protected at the national and European levels (Shiryaeva *et al.* 2021).

The history of the study of *M. hypanica* can be divided into three periods: the middle of the nineteenth century-mid-20th century, the second half of the twentieth century, and the beginning of the twenty-first century, and four directions: chorological, systematic, ecological, and ethnographic. The first period is characterized by the emergence of primary information about the morphological characteristics of plants, their distribution and systematic position. During this period, *M. hypanica* was described as a new species and its geographical distribution was studied. The first references to *M. hypanica* are found in Pachosky (1915, 1917), Klokov (1953), Green & Klokov (1950).

The second period is characterized by the emergence of many researchers with the position of the need to protect *M. hypanica in situ*. This area of research combines works on the study of ecological and biological features of *M. hypanica* and measures for their *ex situ* protection. In this area of research we find the works of Sobko (1972, 1993), Sobko & Gaponenko (1999), Osychniuk (1973), Derkach (1990), Derkach *et al.* (1994), Novosad *et al.* (1996), Krytska *et al.* (1999).

During the third period, the status of *M. hypanica* populations, their ecological and cenotic features, and the state of protection were studied. The results of research in this area can be found in the works of Grevtsova (2003), Mykhailiuk *et al.* (2003), Mykhailiuk (2006), Minarchenko *et al.* (2003), Baranovsky & Loza (2005), Shcherbakova (2005, 2009), Partyka *et al.* (2006), Niporko (2006), Fitsailo (2007), Onyshchenko & Andrienko, (2012), Drabyniuk (2012) and Solomakha *et al.* (2006, 2017).

The location of *M. hypanica* is an isolated area in the canyon of the Mertvovod River near the village of Aktove (Chichkaliuk 2007). The Aktove canyon, which belongs to the Trykratske branch, is located between the Petropavlivskyi (in the upper reaches of the Mertvovod River) and Arbuzynskyi (the Arbuzynka River at its confluence with the Mertvovod River) canyons. This is a gap in the middle of the bare steppe, the extreme abyss of the Ukrainian crystalline shield, which is a unique complex of granite rocks, boulders, steppe and aquatic ecosystems. The canyon covers an area of more than 250 hectares.

The first mention of *M. hypanica* is found in the works of Green and Klokov (1950). The authors point to the ecological similarityof *M. hypanica* with *M. pendula* Fenzl. as, in their opinion, *M. hypanica* grows only on granite outcrops of the Prydniprovska Upland, which indicates its ancient Pliocene connections with the flora of the Balkans (Green & Klokov 1950). Chychkaliuk (2007) and Ovsienko (2016) reported the growth *M. hypanica* in Buzky Gard NNP. Artamonov & Kolomiets (2017), Artamonov *et al.* (2018) and Shiryaeva *et al*. (2021) found *M. hypanica* in two locations, one on the rocks Sova, Brama, Pugach (left bank of the Southern Bug) and the other between the villages of Bohdanivka and Vynohradnyi Sad (right bank of the Southern Bug). Shiryaeva *et al.* (2021) indicated that *M. hypanica* is endemic to the granite outcrops of Buzky Gard NNP, and its worldwide distribution is limited to only three local populations in the park. In Ukraine, five local populations of the species are known in the canyons of the Pivdennyi Buh and Mertvovod rivers (Akimov 2009). Artamonov & Kolomiets (2017) noted that *M. hypanica* grows in cracks in granite rocks and has only a few localities.

Kucherevskyi *et al.* (2009) suggested that in the Neogene, including the Miocene and Pliocene epochs, endemic mesophilic plants such as *Silene hypanica* Klov, *Sedum borissovae* Balk. and others appeared on the southern spurs of the Prydniprovska Upland, followed by the xenomorphic species, including *M. hypanica* among others. Green & Klokov (1950) believed that *M. hypanica* is related to the Balkan meringia (*M. pendula* Fenzl). The researchers noted that the growth of *M. hypanica* in the flora of granite outcrops of the Prydniprovska Upland indicates its ancient Pliocene connections with the flora of the Balkans (Sobko 1972).

Solomakha *et al.* (2017) indicate that *M. hypanica* belongs to the chasmophytic vegetation of granite outcrops of the Ukrainian Crystal Shield (UCS) (stone outcrop vegetation). According to the Brown-Blanke classification of the vegetation of Ukraine, *M. hypanica* is a member of the Asplenietea trichomanis class (Akimov 2009, Shcherbakova *et al*. 2009).

The aim of our research was to find out the ecological, edaphic and morphological features of *M. hypanica* and the state of its population in situ in the Buzky Gard NNP.

Materials and Methods

The study was carried out, both in the field taking and in the laboratory, in the second decade of July from 2011 to 2014, in the Aktivsky Canyon, near the village of Aktove (Fig. 1) located on the territory of the NNP “Buzky Gard”. “The Buzky Gard” is located in the valley of the Pivdenny Bug River from Pervomaisk to Oleksandrivka village in Voznesenk district, in the valley of the Velyka Korabelna River from Blahodatne village to Semenivka village in Arbuzyn district (main part) and the Mertvovod River from Petropavlivka village in Bratsk district to Aktove village (separate section) (from 200 to 300 above sea level, with an angle of inclination from 15

to 90%). The studied location is located on the southwestern slope of the largest geostructural region of Ukraine - the Ukrainian Crystal Shield, which is composed of a thick layer of fractured rocks of the Lower Proterozoic, their weathering products, and is covered, with sedimentary formations of varying degrees of water content. The main soil-forming rock in the area is loess, covering the entire interfluve from north to south (Sverdlov 2013). According to the administrative-territorial zoning, the territories of Arbuzynskyi, Bratskyi, Voznesenskyi, Domanivskyi and Pervomaiskyi districts belong to Mykolaiv region. The total area of the territory is 6,138.13 hectares, including 2,650.85 hectares of land that are withdrawn in accordance with the established procedure and provided to the park for permanent use, and 3,487.28 hectares of land that are included in its composition without withdrawal from land owners and land users (Drabyniuk 2012). The area includes three environmental research departments as Myhiyske, Bohdanivske and Trykratske.

The climate of the study area is temperate continental with features typical of the steppe zone. The region is located in the northern steppe subzone. It is characterised by snowy, relatively warm, unstable winters, hot summers with insufficient and unstable moisture, and frequent droughts and dry windstorms (Boychenko 2017). In terms of precipitation and evaporation conditions, it belongs to the zone of insufficient moisture.

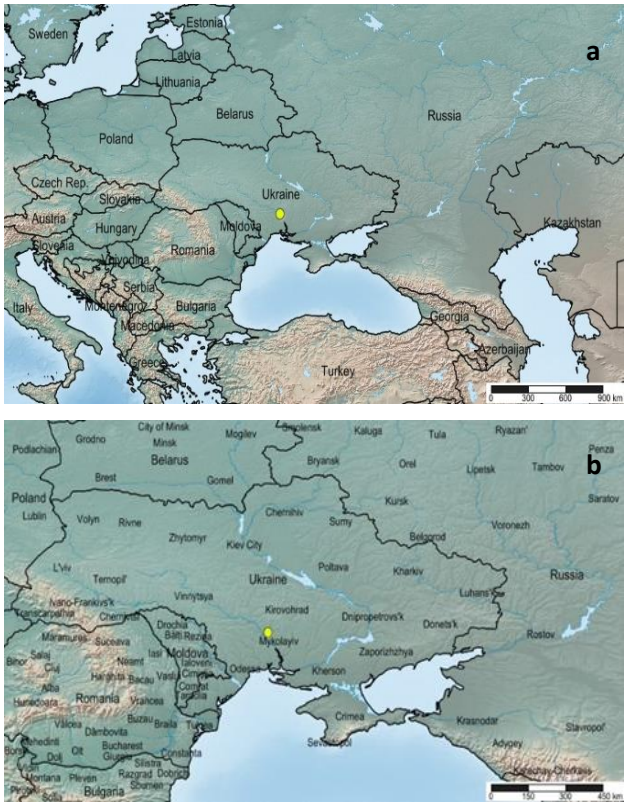

Fig. 1. Map showing the distribution of *M. hypanica*. **a.** General location, **b.** closer location at Ukraine level.

The average annual air temperature ranges from +8 to +10°C, the average temperature in July from +21.2 to +22.9°C, in January from -3.2 to -5.0°C, with the absolute maximum between +38 and +39°C, and the absolute minimum between -29 and -33°C. The isotherm of the study area is characterised by an average value of 45 kcal/cm². The duration of the frost-free period is 160-205 days, and the growing season is 215-225 days. The amount of precipitation per year is 380-500 mm, the bulk of which (65-70%) falls in the warm season in the form of showers (daily amount can reach 60-70 mm), resulting in the bulk of precipitation being spent on surface runoff and a small amount on infiltration. Autumn and winter periods are usually characterised by prolonged, low-intensity rains. Along with the amount of precipitation, the distribution of it over time is extremely important for plant life, especially the moisture supply of the growing season and the correlation of precipitation with the annual temperature course. The combination of moisture and heat supply to plants is well reflected in climatograms compiled by the Walter-Gossen method (Goryshina 1979).

The geographical distribution of the species was mapped using the point method. The terminology and description of morphological characters are given according to the Illustrated Guide to the Morphology of Flowering Plants (Ziman *et al.* 2004, 2012) and the Atlas of Descriptive Morphology of Higher Plants (Artyushenko & Fedorov 1986). The flower formula contains the following abbreviations: K - calyx, C - corolla, A - androecium (stamens), G - gynoecium (pistil). The number of members is indicated by numbers, for example, $_1$, $_2$, etc. Fruit and seed sizes and the nature of the seed surface were determined using a Levenhuk MED Series microscope. The weight of 1000 seeds were determined using electronic scales CERTUS CBA - 300. Climatograms, comparing the annual course of air temperatures with the course of precipitation, were compiled using the Walter-Gossen method (Goryshina 1979), where on the ordinate axis, 10ºC corresponds to 20 mm of precipitation.

The soil content was determined directly in the places of growth (in niches under stones and microcracks in granite rocks). The soil analysis was carried out by the employees of the enterprise “Agroanalysis” Ltd in Kakhovka, Kherson region. Soil samples were taken in the places of growth of a large group of *M. hypanica* plants, which consisted of 20 individuals (sample I) and a small group of 7 individuals (sample II). The humus content was determined by the Tiurin method in the modification of Scale value GOST 26213-84 (1984), lightly hydrolysed nitrogen - according to DSTU 7863: 2015 (2019), exchangeable calcium and magnesium - by the trilonometric method in a salt extract (mmol/100 g of soil) according to Scale value GOST 26487-85 (1986), mobile forms of sulphur - by the turbidimetric method (mmol/100 g of soil) according to Scale value GOST 26490-85 (1985), mobile forms of phosphorus and potassium - by the Machigin method in the CINAO

Table 1. Grouping of soils according to the degree of mineral and humus supply.

Degree of security	Minerals (mg/kg)						Humus (%)
	Ca	Mg	S	P_2O_5	K_2O	N	
very low	0-2.5	>0-0.5	<3	-	-	>100	>1.1
low	2.6-5.0	0.6-1.0	3-6	>15	>100	101-150	1.1-2.0
medium	5.1-10.0	1.1-2.0	6-9	16-30	101-200	151-200	2.1-3.0
elevated	10.0-15.0	2.1-3.0	9-12	31-45	201-300	<200	3.1-4.0
high	15.1-20.0	3.1-4.0	12-15	46-60	301-400	-	4.1-5.0

Note: - no sign

modification (mmol/100 g of soil) GOST 26205-91 (1996), cationic-anionic composition of the water extract (mmol/100 g of soil) GOST 26423-85-26428-85 (1985) (Table 1).

In the plant life cycle, four ontogenetic periods and eleven ontogenetic states are usually distinguished (Table 2) (Burda & Ignatyuk 2011).

Imaturals (from the latin *immaturus* - similar, resembling) are individuals that have transitional characteristics between juvenile and adult individuals.

Virginal (from the Latin *virga* - branch, branching) - adults in outline (morphological characteristics), but do not yet form generative organs.

Hidden generative - this ontogenetic state is distinguished only in some cases, for perennial plants in which generative buds are laid in autumn and, accordingly, have hidden generative organs.

Generative (from the latin *genero* - giving birth) - plants that have clearly formed generative organs.

Senile plants are plants with clearly formed generative organs.

Table 2. Periodisation of the ontogeny of flowering plants.

Ontogenetic period	Ontogenetic state (Gatsuk *et al.* 1980)	Symbolic designation
Latent	Seeds	*sm*
Virgin or pregenera-tive	Seedlings	*p*
	Juvenile plants	*j*
	Imitation plants	*im*
	Virginal plants	*v*
Generative	Hidden generative	g_0
	Young generative	g_1
	Mature generative	g_2
	Old generators	g_3
Senile or post-genera-tive	Subsensitive growth	*ss*
	Subsensitive plants	*s*
	Dying plants	*sc*

Sometimes, according to the intensity of the dying process, a distinction is made between sub-senile and senile states of individuals. In both cases, flowering and fruiting are absent or rudimentary. Dying plants have no living aboveground shoots in general.

The developmental features of *M. hypanica* individuals in populations were studied by the biochronological method, i.e. by recognizing a set of biomorphic characteristics of plants during the flowering period. This helped to determine the pre-reproductive, reproductive and post-reproductive stages, depending on branching and readiness for flowering. To identify the age states, 10.7+1.6 individuals were visually marked on the research area.

Statistical data was evaluated using Microsoft Office Excel 2007 (arithmetic mean, standard deviation).

Results

Since *M. hypanica* is a southern Bug, narrow-range endemic species, knowledge of the ecological and edaphic conditions of plant growth is of particular importance.

M. hypanica grows in cracks in granite rocks, with southern, southeastern and northeastern exposures and with steepnesses of 15 to 90%, mostly filled with small stones (rock erosion products) with little soil, and in niches under or on stones in microcracks (Fig. 2). The highest soil content is in niches under stones (25%), and the lowest - in microcracks of granite rocks (5%) of the total volume.

Fig. 2. A generative individual of *M. hypanica* in a crack found in the Aktovsky Canyon.

According to the results of laboratory studies, the humus content in the soil where *M. hypanica* grows is high, amounting to 7.35-8.23% (Table 2). The higher the humus content, the better the soil retains moisture. This is due to the fact that a significant part of humus substances is in the form of gels, and actively binds water entering the upper layer of the soil, gradually giving it to the plants. Humic compounds, being mineralized, are absorbed by the plants slowly, prolonged and evenly, providing them with balanced nutrition. This is confirmed by the fact that a large group of plants (20 individuals) grows in a substrate with a higher humus content of 8.23% (sample I), and a smaller group (7 individuals) grows in a substrate with a low humus content of 7.35% (sample II) (Table 2).

Mineral substances (K, Na, Mg, Ca, S, P_2O_5, Cl, SO_4 and others) perform structural, catalytic and electrochemical functions in plant life. Knowledge about the content of nutrients in the substrate indicates the limits of their necessity for the successful growth and development of plants. The results of studies of soil availability of mobile nutrients showed that the content of Mg and P_2O_5 is very high, with 8.5-15.0 mg/kg and 129.6-164.5 mg/kg, respectively, and Ca is high, which corresponds to 12.5-27.5 mg/kg (Table 3, 4).

The N content of the substrate is elevated in both samples (256.2-268.8 mg/kg), and the S content is very low to low (1.3-4.8 mg/kg). Thus, this indicates that the high content of Mg, P_2O_5, and Ca in the substrate is a limiting factor for the successful growth of the plants under study.

Table 2. Soil content of mobile nutrients (mg/100g) and humus (%).

Content	Weight	
	I	II
Ca	2.75	1.25
Mg	1.5	0.85
S	0.48	0.13
P_2O_5	12.96	16.45
K_2O	34.28	16.04
N	26.88	25.62
humus	7.35	8.23

I - A soil sample taken from the habitats of 20 *M. hypanica* specimens, **II** - A soil sample taken from the habitats of 7 *M. hypanica* specimens.

Another important factor in the analysis of the substrate is its salinity. The analysis of the cationic and anionic composition of the water soil extract showed that it is non-saline in terms of the amount of salts (the amount of salts does not exceed 0.1%). The content of all salts does not exceed the toxicity thresholds (Table 4).

To preserve the populations of these endemic plants, it is necessary to maintain a stable chemical composition of the substrate and prevent interference from human activity. The biomorphological features and geographical distribution of *M. hypanica* correlate with environmental factors, which together determine their ecological niche and determine their existence strategy. The curves of the graphs constructed by us reflect the comparison of the annual course of air temperatures with the course of precipitation and allow us to identify dry periods of the year when the precipitation curve lies below the temperature curve (Fig 3).

Table 3. Analysis of the levels of soil supply with mobile nutrients and humus.

Elements of nutrition		Batch	
		I	II
Ca	Content mg/100g	2.75	1.25
	availability	low	very low
Mg	content mg/100g	1.5	0.85
	availability	low	very low
S	content mg/100g	0.48	0.13
	availability	low	low
P_2O_5	content mg/100g	12.96	16.45
	availability	low	low
K_2O	content mg/100g	34.28	16.04
	availability	low	low
N	content mg/100g	26.88	25.62
	availability	very low	very low
humus	content mg/100g	7.35	8.23
	availability	very low	very low

The summer months July and August were the driest periods in 2011-2012. The year 2013 was characterised by a prolonged lack of moisture during the last month of spring and summer, and 2014 by a lack of moisture during April, May and August. The hottest months were July, with an average daily temperature of 22.80±1.42°C, and August with 22.28±1.41°C. Thus, during the flowering and fruiting period, the plants under study lack moisture in the air and in the substrate. The ability of plants to grow and develop fruit formation in conditions of drought and heat indicates their drought tolerance and thermophilicity.

Table 4. Analysis of the cationic and anionic composition of soil water extract.

Batch No	HCO_3, mg/100g$^-$	Cl^-, mg/100g	Amount of Ca^{2+} and Mg^{2+}, mg/100g	Na^+, mg/100g	K^+, mg/100g	SO_4^2, mg/100g$^-$	Amount of salts, %	pH (H_2O)
1	0.23	0.15	0.3	0.1608	0.0359	0.117	0.04	4.70
2	0.24	0.12	0.4	0.1586	0.0391	0.238	0.04	4.41

Fig. 3. Climate diagrams of the study area.

In the studied conditions, *M. hypanica* plants grow singly or in groups of 2 to 20 individuals (Fig. 4).

During the expeditionary research, we noted that the populations are dominated by young generative (g_1) and medium generative plants (g_2), with a small number of old generative (g_3) and virgin individuals (v) (Fig. 5).

The presence of the aged individuals given in Fig. 5 indicates sufficient seed reproduction. Therefore, we focused on the study of the morphological characteristics of *M. hypanica* plants. It is a branched perennial herb that forms rather fragile sods up to 12.0 cm long and 5.0 cm high.

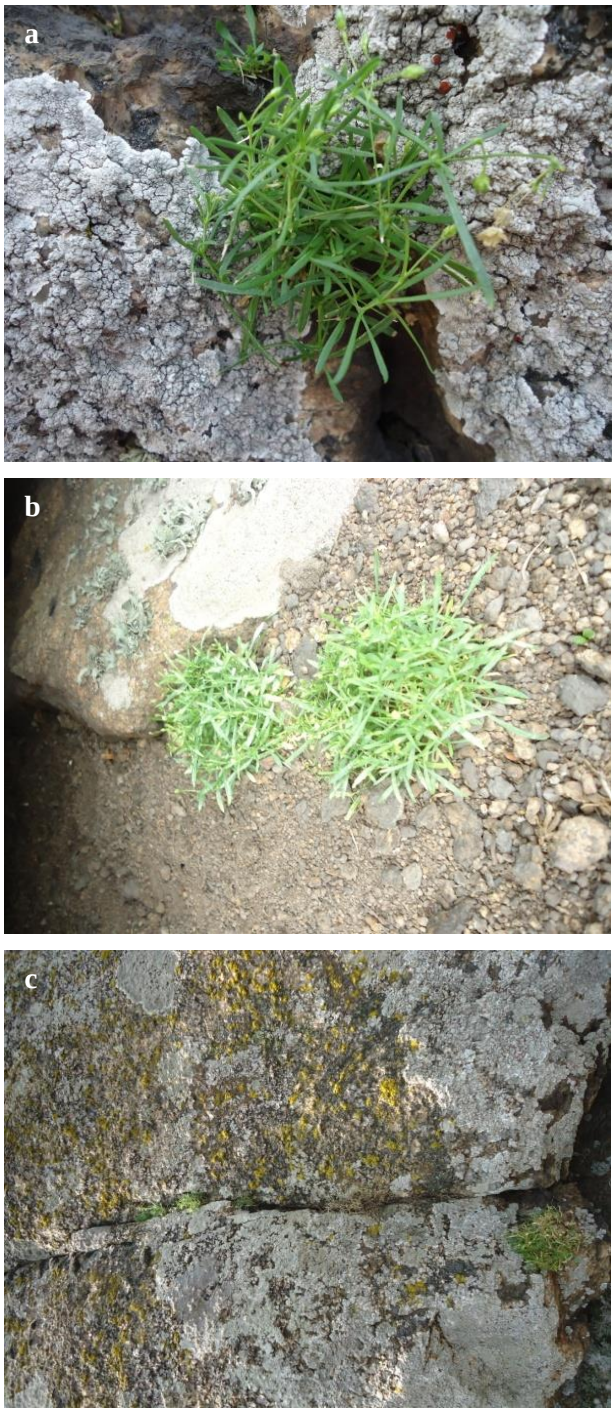

Fig. 4. Populations of *M. hypanica* plants in the Aktovsky Canyon. **a.** Single presence, **b-c.** plants grown together.

The stem is plagiotropic, rosette-free, creeping, thin, very branched, glabrous. Branching of shoots is monopodial. The main shoot in the basal part is lignified, its transverse section is flattened. On one side of the first-order shoot, second- and third-order shoots develop. The first two shoots of the second order are shortened to 0.4 cm, and then the length increases to several centimetres starting from the third shoot (Table 3).

Fig. 5. Age states of *M. hypanica*. **a.** Virgin individual, **b.** young generative, **c.** medium generative plants (g_2), **d.** old generative (g_3).

The sessile, linear, whole-edged leaves are opposite on the shoot. They are the widest in the upper quarter or third, slowly tapering to the base, shortly pointed at the apex, with a drawn blunt tip; flat above, with a very prominent midrib from below. Leaf venation is reticulate. In the axils of the stem leaves, shoots of the second and third orders develop, bearing several pairs of smaller leaves. Inflorescences are 3-flowered or in double racemes, sometimes reduced to single flowers. Pedicels are 5.0-12.0 mm long, glabrous, bent downwards after flowering. The formula of the actinomorphic flower is $K_5C_5A_{10}G_1$. Calyx is divided, formed by five elliptic-lanceolate sepals, with a drawn-out blunt tip, 2.0-2.5 mm long. The corolla is formed by five entire, white, ovate-lanceolate petals. The androecium is formed by ten stamens, the gynoecium is syncarpic, the ovary is upper (Fig. 6).

In the second decade of July, we noted the simultaneous flowering and fruiting of generative plants. On g_1, flowering prevailed over fruiting (in a percentage ratio of 95.5%), and g_2 (40:60%) and g_3 (12:88%) - fruiting).

Fig. 6. A general view of a flower of *M. hypanica*

The fruit-capsules of the studied plants are spherical, 2.5 mm in diameter (Table 6). They open with 6 oval-shaped flaps, widened at the base, and the apex is sharp. At the widest point, the scales are 1.08±0.23 mm wide and 2.2±0.32 mm long. When the fruit is opened, the flaps are bent to the outside (Table 6, Fig. 7).

One fruit contains 4 to 7 seeds (Table 7). In our studies, we noted a variation in the shape of *M. hypanica* seeds from round to ovoid. In the fruit, the seeds are arranged so that their appendages (elyosomes) are directed towards the centre of the fruit.

The genetically determined biomorphological traits of *M. hypanica* and its geographical distribution are correlated with environmental factors, which together determine their ecological niche and their strategy of existence.

Table 5. Morphological features of age states of *M. hypanica* plants (n - from 2 to 20 individuals).

Organ name	Considered feature	Age state			
		v	g_1	g_2	g_3
stem	shoot length of the first order, cm	6.1±2.74	12.1±2.74	20.6±3.05	26.6±4.45
	shoot length of the second order, cm	2.05±0.94	2.47±1.76	4.54±3.62	6.54±3.66
	shoot length of the third order, cm	-	1.7±0.95	2.40±1.48	3.43±1.67
leaf	length, cm	1.52±0.25	1.69±0.38	1.70±0.40	1.74±0.28
	width, cm	1.02±0.11	1.12±0.17	1.22±0.19	1.22±0.16
flower	quantity on one plant, pcs.	-	13.6±11.89	20.40±15.93	4.50±2.08
fruit	quantity on one plant, pcs.	-	0.40±0.89	28.43±19.94	29.50±20.62

±average standard deviation

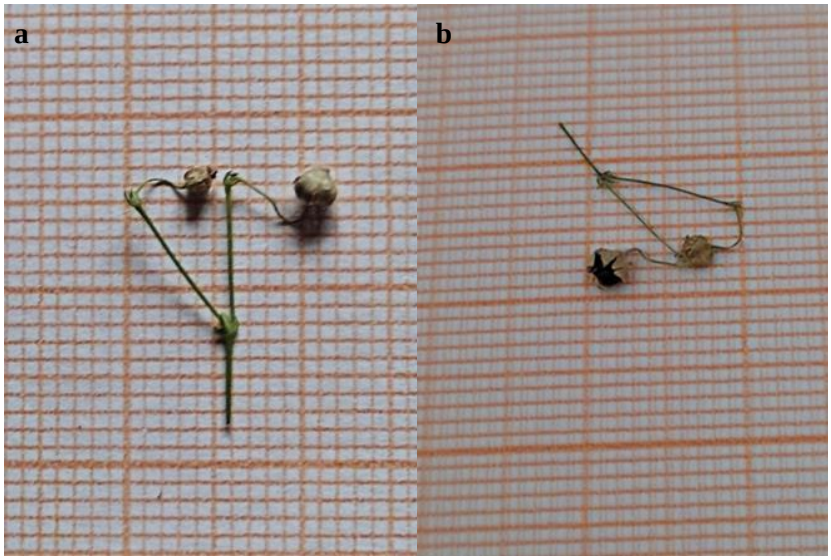

Fig 7. Fruits of *M. hypanica.* **a.** Closed capsule, **b.** open capsule.

Table 6. Biomorphological characteristics of *M. hypanica* fruits (n= from 2 to 20 individuals).

Signs		Characteristics
Depending on the number of nests		unilocular (unilocularis)
Depending on the number of seeds		small-seeded (oligosperma)
Depending on the position in space		bent downwards (recurvata)
Depending on the consistency of the pericarp		papery (papyraceae)
Depending on the surface		scarred (angulata)
Depending on the method of opening		Longitudinal (papyraceae), with sca-
Shape		rounded
Size	length (mm)	2.32±0.33
	width (mm)	2.22±0.22
Colour		light brown

Table 7. Biomorphological characteristics of *M. hypanica* seeds (n= from 2 to 20 individuals).

Signs		Characteristics
Depending on the nature of the surface		tuberous (tuberculatum, gibbosum)
Shape		ovoid (ovatum)
Colour		dark brown
Depending on the presence of an appendage		present
Depending on the size		very small (minimum, minutissimum)
Size	length (mm)	1.33±0.26
	width (mm)	0.91±0.11
Weight of 1000 seeds (g)		0.005 ± 0.02

Discussion

In characterising the environmental factors, Solomakha *et al.* (2006) indicated that the communities develop mainly in the upper and middle, rarely lower parts of the slope in cracks in granite rocks filled with black earth (chernozem) with a significant admixture of gravel (sometimes only small stones), as well as in niches under or on stones, more often of northern, rarely southeaster exposure with a steepness of 15 to 90%. The size of the rocky areas ranges from 0.05 to 1.3 m² with the depth of the soil-moss cushion from 0.05 to 0.2 m. As a result of our research, we found that *M. hypanica* grow in cracks in granite rocks with southern, southeaster and northeaster exposures and with a steepness of 15 to 90%, mostly filled with small stones (rock erosion products) with a low soil content, as well as in niches under stones or on stones in microcracks. The highest soil content is in niches under stones (25%), and the lowest - in microcracks of granite rocks (5%) of the total volume.

Shiryaeva *et al.* (2019) indicated that the Aktovsky Canyon, where *M. hypanica* individuals grow, consists of old weathered granites with fine-grained porphyry-like granites of grey, grey-pink and pink colour with admixtures of biotite and biotite gneiss. The granites are acidic, with a high alumina content and alkalinity, which is confirmed by the results of laboratory tests (pH (KCl) in two samples is 3.71 and 3.36, respectively, pH (hydrolytic) is 11.00 and 6.69).

We have analysed the substrate taken directly from the habitats of the studied species. Our laboratory studies confirm the data of Fedoronchuk & Didukh (2002) which characterise the relationship of the studied plants to the soil. According to the acid regime of the soil, the studied species are acidophiles, plants of acidic sod-podzolic soils, according to the general salt regime of the soil - semioligotrophs, salt-poor, highly leached soils, in relation to the carbonate (Ca) content - carbonatophobes, nitrophiles, relatively nitrogen-rich soils, humophiles in relation to the content of nitrogen compounds in the soil (Nt), and humic phytes in relation to the content of humus. According to our research, the nitrogen content is very low.

Shcherbakova (2005) refers *M. hypanica* to the monocentric type of biomorph, semi-bushy. The self-sustenance of populations of this biomorph type occurs exclusively by seed.

Shcherbakova *et al.* (2009) pointed out the vulnerability and sensitive response to deviations from the normal gradients of light, moisture and temperature conditions (Akimov 2009). In the conditions of excessively dry years, massive die-off of individual cushions is observed with increased insolation. Minarchenko (2017) noted that high summer temperatures and lack of precipitation often result in the death of *M. hypanica* the plants under study. This also points out that the main threat to the conservation of plant populations is a change in the ecological conditions of the plant habitat.

Solomakha *et al.* (2006) highlighted in their paper "Adaptive features of the South Bug endemics *Dianthus hypanicus* Andrz. and *M. hypanica*" the results of studies of granite-petrophytic complexes with the participation of *M. hypanica* in the regional landscape park "Granite-Steppe Pobuzhzhia", in the area we studied, which since 2009 has been a part of the NNP "Buzky Gard".They described *M. hypanica* communities in the middle part of the granite rock on the right bank of the Mertvovod River in the suburbs of the village of Aktove. Therefore, we focused on the study of the ecological and edaphic conditions of *M. hypanica*. The authors noted that the grass stand is mostly formed by a single species of *M. hypanica*, the total coverage of which varies from single individuals to 70%. It is often observed that single individuals of *M. hypanica* are found on vertical rocks in cracks 2.5-3.0 m long at a fairly large distance from each other. The moss layer is unevenly represented, its projective coverage is 1-70%, and in some places it is completely absent. The lichen layer is not expressed. Individuals of *M. hypanica* grow in small loose groups (5-25, sometimes up to 40) or singly, in cracks. It is dominated by well-developed generative plants (up to 5 cm tall), with a sufficient number of juvenile and young vegetative individuals, but a small number of senescent ones.

Shcherbakova & Barmak (2013) pointed out that *M. hypanica* populations are vulnerable or endangered, so their further existence will depend on active protection.

In our studies, we observed single growth of *M. hypanica* plants or groups of 2 to 20 individuals. The populations were dominated by young generative and medium generative plants, with a small number of old generative and virgin individuals. Shcherbakova *et al.* (2009) noted that plant populations in the habitats in Ukraine are small, characterised by negative dynamics and low numbers of individuals (from 50 to 300) (Akimov 2009). Individuals of the pre-generative period are very rare.

Individuals at the early stages of ontogenetic development are the most vulnerable. We found that the driest periods during our studies were July and August, in 2011-2012, May, June, July and August in 2013 and April, May and August in 2014. The hottest months are July, with an average daily temperature of 22.80±1.42°C, and August 22.28±1.41°C. During the research, we did not observe the death of plants of the senile period. According to Fedoronchuk & Didukh (2002), *M. hypanica* the studied species belongs to submesotherms in terms of thermoregime, i.e. plants grow in conditions where the average value of isotherms is 45 kcal/m², and in terms of moisture variability, they are subaridophytes, i.e. in these conditions, precipitation falls less than can be evaporated by the potentiation, so there is a deficit of precipitation, which causes a period

of drought. In terms of cryo regime, *M. hypanica* is a hemicryophyte.

The morphological characteristics of the vegetative organs of *M. hypanica* were studied by Fedoronchuk (2009). He pointed out that the leaves have a wide lamina and well-developed petioles, and the fruit has a kidney-shaped shape, where seeds with a convex back are distinguished. As a result of our research, we provide a more detailed morphological characterisation of *M. hypanica*.

Conclusion

The ecological, edaphic and morphological features and population status of the endemic species *M. hypanica* were studied within the steppe zone of Ukraine. For the first time, soil analysis, which was taken directly from the places of growth of specimens, was carried out. The highest soil content was found in niches under stones (25%), and the lowest in microcracks of granite rocks (5%) of the total volume. The analysis of the cationic and anionic composition of the water extract of the soils showed that *M. hypanica* belongs to the non-saline soils (the amount of salts does not exceed 0.1%). The content of all salts does not exceed the toxicity thresholds. The results of the soil analysis showed that, in order to preserve the populations of these endemic plants, it is necessary to maintain a stable chemical composition of the substrate and prevent human interference.

We reported, for the first time that during flowering and fruiting, *M. hypanica* plants lack moisture in the air and substrate. The ability of plants to grow and develop fruit formation in drought and heat conditions indicates their drought tolerance and thermophilicity.

During the expeditionary research, we noted that the populations are dominated by young generative and medium generative plants, with a small number of old generative and virgin individuals. The presence of these aged individuals indicates sufficient seed reproduction. The morphological characteristics of seeds, fruits and age states of *M. hypanica* plants were determined for the first time. It was proved that genetically determined biomorphological traits of *M. hypanica* and its geographical distribution correlate with ecological factors, which together determine their ecological niche and their strategy of existence.

Ethics Committee Approval: Since the article does not contain any studies with human or animal subject, its approval to the ethics committee was not required.

Data Sharing Statement: All data are available within the study.

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References

1. Akimov, I.A. 2009. *Red Book of Ukraine. Flora of Ukraine*. 2009. Globalconsulting, Kyiv, 900 pp.
2. Anderson, S. 2002. *Identifying Important Plant Areas: a site selection manual for Europe, and a basis for developing guidelines for other regions of the world*. Summerfield Books, London, 52 pp.
3. Artamonov, V. & Kolomiets, G. 2017. NATURE 2000 network as an innovative system for the protection of rare species and habitats in Ukraine, 15-17. Paper presented at the Materials of the scientific and practical seminar. Series: Conservation Biology in Ukraine, 15 February 2017, Kyiv-Ukraine.
4. Artamonov, V., Biatov, A., Kolomiets, G., Kuzemko, A. & Shiryaeva, D. 2018. Rare species and habitats of the Buzky Gard NNP and its adjacent areas threatened with extinction under the condition of raising the level of the Oleksandrivka reservoir to the NRH of 20.7 m, 159-161. Paper presented at the Materials of the V International Conference: Flora in the Red Data Book of Ukraine: Implementation of the Global Strategy for Plant Conservation, 25-28 June, Kherson-Ukraine.
5. Artyushenko, Z. & Fedorov, A. 1986. *Atlas of descriptive morphology of higher plants. Fruits.* Nauka, Leningrad, 392 pp.
6. Baranovsky, B. & Loza, I. 2005. *Delphinium Sergii* Wissjul. (Ranunculaceae) - a new species for the Right-Bank Ukraine. *Ukrainian Botanical Journal*, 62(6): 833-836.
7. Boychenko, S., Movchan, Y. & Tyshchenko, O. 2017. Modern tendencies of climate, water resources and ecosystems changes in the Middle-Lower part of southern Bug river, Ukraine. *Proceedings of the National Aviation University.* 3(72): 78-89.
8. Burda, R. & Ignatyuk, O. 2011. *Methodology for studying the adaptive strategy of alien plant species in urbanised environments*. NCEBM NAS of Ukraine, CJSC “Vipol”, Kyiv, 112 pp.
9. Chychkaliuk, T. 2007. Establishment of the Nature Reserve Fund of Mykolaiv Region as a Major Factor in the Development of Tourist Infrastructure. *Economy and management*, 4-5: 41-45.
10. Derkach, O. 1990. Additions to the flora of the Right Bank Steppe of Ukraine. *Ukrainian Botanical Journal*, 47(6): 84-85.
11. Derkach, O., Tarashchuk, S. & Kholypenko, V. 1994. Scientific substantiation of the necessity to create a regional landscape park "Granitostepove Pobuzhzhia". *Optimisation of the Nature Reserve Fund of Ukraine*, 1: 80-87.

12. Drabyniuk, H. 2012. Buzky Gard National Park. pp. 49-60. In: Onyshchenko, V. & Andrienko, T. (eds). *Phytodiversity of reserves and national nature parks of Ukraine. Vol. 2. National natural parks*. Phytosociological Centre, Kyiv, 580 pp.

13. DSTU 7863: 2015. 2019. Soil quality. Determination of easily hydrolysed nitrogen by the Kornfield method. Kyiv: UkrNDNC. 9 p.

14. Fedoronchuk, M. & Didukh, Y. 2002. *Ecoflora of Ukraine*. 3. Phytosociological Centre, Kyiv, 496 pp.

15. Fedoronchuk, M. 2009. Analysis of the endemism of Caryophyllaceae Juss. in the flora of Ukraine. *Ukrainian Botanical Journal*, 66(4): 541-549.

16. Fitsailo, T. 2007. Synphyto-indicative characteristics of shrubby vegetation of the class Rhamno-Prunetea Rivas Godey et Carb. 1961 of Ukraine. *Ukrainian Botanical Journal*, 64(1): 88-98.

17. Gatsuk, L. Smirnova, O., Vorontzova L., Zaugolnova, L. & Zhukova, L. 1980. Age states of plants of various growth forms: a review. *Journal of Ecology*, 68: 675-696.

18. Goryshina, T. 1979. *Ecology of plants: a textbook.* Vysshaya shkola, Moscow, 368 pp.

19. GOST 26205-91. 1996. Soils. Determination of mobile phosphorus and potassium compounds by the Machigin method in the CINAO modification. Resolution of the Committee for Standardisation and Metrology of the USSR, 3 p.

20. GOST 26213-84. 1984. Soils. Methods for determining the humus content by the Turin method in the CINAO modification. Moscow: Izd-vo standardov, 8 p.

21. GOST 26423-85-26428-85. 1985. Soils. Methods for determining the cationic and anionic composition of water extract: a collection of documents. Moscow: Izd-vo standardov, 39 p.

22. GOST 26487-85. 1986. Soils. Determination of exchangeable calcium and exchangeable (mobile) magnesium by CINAO methods. Moscow: Gosstandart, 15 p.

23. GOST 26490-85. 1985. Soils. Determination of mobile sulphur by the CINAO method. Moscow: Izd-vo standardov, 8 p.

24. Green, F. & Klokov, M. 1950. A new species of *Meringia* from the granites of the Southern Bug River. *Botanical Journal of the USSR Academy of Sciences*, 7(4): 55-60.

25. Grevtsova, G. 2003. Cotoneaster of the granite-steppe Pobuzhye. *Collection of scientific works of Poltava Pedagogical University*, 4(31): 54-61.

26. Klokov, M. 1953. New species of the genus *Onosma* L. Botanical Materials of the herbarium of the V.L. Komarov Botanical Institute of the USSR Academy of Sciences, Moscow-Leningrad, XV(229): 246-247.

27. Krytska, L. & Novosad, V. 2001. Florsozological peculiarities of steppe floras of the Western Black Sea region in connection with the issues of optimisation of its natural reserve network. optimisation of its natural reserve network. *Visnik Natsionalnogo naukovo-prirodnikho museum*: 147-188.

28. Krytska, L., Novosad, V., Fedoronchuk, M. & Shevera, M. 1999. Typification of vascular plant species described from Ukraine: family Caryophyllaceae Juss. (subfamilies Alsinoideae A. Br., Paronychioideae Vierh.). *Ukrainian Botanical Journal*, 56(2): 402-410.

29. Kucherevskyi, V., Tashev, O., Sirenko, T. & Schol, G. 2009. A new species of *Klasea bulgarica (*Acht. et Stoj.) Holub. for Ukraine and its distribution in Europe. *Ukrainian Botanical Journal*, 66(6): 825-832.

30. Mykhailiuk, T., Darienko, T. & Demchenko, E. 2003. Algae of granitic outcrops of the regional landscape park "Granitnosteppe Pobuzhye" (Mykolayiv region, Ukraine). *Novosti systematica of lower plants*, 7: 53-71.

31. Mykhailiuk, T. 2006. Terrestrial lithophilic algae "Bug Canyon" (Nikolaev region, Ukraine), 103-104. Paper presented at the III International Conference "Actual problems of modern algology", 20-23 April, Kharkov-Ukraine.

32. Minarchenko, V. 2017. Threatened medicinal plants of Ukraine: an assessment of the current protection status. *Journal of Plant Development*, 24: 117-131.

33. Minarchenko, V., Timchenko, I. & Drabyniuk, G. 2003. Monitoring of of *Adonis vernalis* L. and *Astragalus dasyanthus* Pall. populations in the regional landscape park "Granitic-steppe Pobuzhzhya". *Ukrainian Botanical Journal*, 60(6): 679-690.

34. Moysiyenko, I., Vynokurov, D. & Shyriaieva, D. 2021. *Thalictrum foetidum* L. in the steppe zone of Ukraine: new findings, ecological and syntaxonomical peculiarities. *Chornomorski Botanical Journal*, 17(1): 36-45. https://doi.org/10.32999/ksu1990-553x/2021-17-1-2

35. Niporko, S. 2006. Bryophytes of the test sections of granitic outcrops of the Pivdennyi Buh River canyon, 27-30. Materials of the International Conference of Young Botanists "Actual problems of botany, ecology and biotechnology", 27-30 September, Kyiv-Ukraine.

36. Novosad, V., Krytska, L. & Protopopova, V. 1996. New to science endemic species of the Granite-Steppe Pobuzhzhia, Sytnyk's broom (*Silene sytnikii* Krytzka, Novosad and Protopopova), its taxonomic, ecological and cenotic, chorological, genetic and sozological features. *Ukrainian botanical Journal*, 53(5): 578-585.

37. Onyshchenko, V. 2017. *Important Plant Areas of Ukraine*, Alterpress, Kyiv, 376 pp.

38. Onyshchenko, V. & Andrienko, T. 2012. *Phytodiversity of reserves and national nature parks of Ukraine*. Part 2. National natural parks. Phytosociological Centre, Kyiv, 580 pp.

39. Osychniuk, V. 1973. *Vegetation of crystalline rock outcrops. Vegetation of the Ukrainian SSR. Steppes, rocky outcrops, sands.* Naukova dumka, Kyiv, 380: 383-388.

40. Ovsienko, Y. 2016. Sozophytes of the Trykratsky Nature Conservation Research Department on the territory of the Buzky Gard National Nature Park. *Biological research - 2016: Collection of scientific papers.* Zhytomyr: PP Ruta. 128-131.

41. Pachosky I., 1915. *Description of the vegetation of the Kherson province. Forests.* Materials on the study of soils and soils of the Kherson province. Kherson, 258 pp.

42. Pachosky, I. 1917. *Description of vegetation of Kherson province. Steppes.* Materials on the study of soils and soils of the Kherson province. Kherson, 367 pp.

43. Partyka, L., Virchenko, V. & Niporko, S. 2006. To the bryoflora of the Regional Landscape Park "Granite-Steppe Pobuzhzhya". *Chornomorskiy Sea Botanical Journal*, 2(1): 116-122.

44. Shcherbakova, O. 2005. Peculiarities of the population structure of the narrow-leaved celandine Stachys angustifolia M. Bieb in the Granitic-Steppe Pobuzhzhia and problems of its protection. Actual problems of botany and ecology. *Collection of scientific paper*s, 1: 96-104.

45. Shcherbakova, O. & Barmak, I. 2013. Principles and approaches to sozological categorisation of rare plant species. *Issues of bioindication and ecology*, 18(1): 101-116 http://nbuv.gov.ua/UJRN/pbte_2013_18_1_13 (Date accessed: 17.08.2020).

46. Shcherbakova, O., Novosad, V. & Krytska, L. 2009. Rare florofond of the Kodymo-Yelanets Pobuzhzhya (ChKU, 2009): population and florosozological aspects, 210-214. Paper presented at the Flora in the Red Data Book of Ukraine: implementation of the Global Strategy for Plant Conservation. Materials of the international conference, 11-15 October, Kyiv-Ukraine.

47. Shiryaeva, D., Vinokurov, D., Boyko, G., Derkach, O., Didukh, Y., Kolomiets, G., Kuzemko, A., Moysiyenko, I., Mosiakin, S. & Khodosovtsev, O. 2021. Threat to the existence of rare species of flora and habitats of the Southern Bug Valley in case of another increase in the level of the Oleksandrivske reservoir. *Ukrainian Botanical Journal*, 78 (2): 145-153.

48. Shiryaeva, D., Vinokurov, D., Kolomies, G. & Artamonov, V. 2019. Findings of plants listed in the Red Book of Ukraine on the territory of the National Nature Park "Buzky Gard" and adjacent areas. *Findings of plants and fungi of the Red Data Book and the Bern Convention (Resolution 6)*. - Vol. 1 (Series: "Conservation Biology in Ukraine". - Issue 11): 448-456.

49. Sobko, V. & Gaponenko, M. 1999. The scientific and historical value of the Granitic-Steppe Pobuzhzhia Landscape Park. *Introduction of plants*, 2: 3-7.

50. Sobko, V. 1972. Endemic and relict elements of the flora of granite outcrops of the Prydniprovska Upland. *Ukrainian Botanical Journal*, 29(5): 624-630.

51. Sobko, V. 1993. *Paths of the Red Book*. Urozhay, Kyiv, 176 pp.

52. Solomakha, I., Shevchyk, V. & Solomakha, V. 2017. *Overview of higher vegetation units of Ukraine by the Brown-Blanke method and their diagnostic species.* Phytosociological Centre, Kyiv, 81 pp.

53. Solomakha, V., Drabyniuk, G., Vinichenko, T., Moisienko, I. & Derkach, O. 2006. Adaptive features of the South Bug endemics *Dianthus hypanicus* Andrz. and *Moehringia hypanica* Grynj et Klok. *Ukrainian Phytocoenotic Collection*, Series C, 24: 70-86.

54. Sverdlov, V. 2013. National Nature Park (NNP) "Buzky Gard". *Mezyn region*, 23: 6.

55. Ziman, S., Mosiakin, S., Grodzinsky, D., Bulakh, O. & Dremliuga, N. 2012. *Illustrated guide to the morphology of flowering plants. Study guide. Second edition, corrected and supplemented.* Phytosociological Centre, Kyiv, 176 pp.

56. Ziman, S., Mosyakin, S., Bulakh, O., Tsarenko, O. & Felbaba-Klushyna, L. 2004. *Illustrated handbook of plant morphology. Educational and methodological manual.* Medium, Uzhhorod, 156 pp.