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Ecological Monitoring of Medicinal Plants Populations under Different Ecological-Cenotic and Anthropogenic Environmental Conditions

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ABSTRACT

Phytocoenotic conditions of growth and anthropogenic management of natural phytocoenoses have a significant impact on the population characteristics and stocks/reserves of medicinal plant raw material. The article presents the results of the peculiarities of the response of spatial, dimensional, ontogenetic and vitality structures of populations of the official species - *Hypericum perforatum* L., and establishes a dependence that allows predicting the reserves of medicinal plant material *Hyperci herba* by the height of individuals. With the aim of forecasting the dynamics of the resource potential of this species, geobotanical descriptions were conducted, and classical population methods were applied: morphometric, ontogenetic and vitality analyses, as well as a number of statistical methods (correlation, factorial, dispersion, and regression analyses). It was established that the population density of *H. perforatum* averaged from 3 to 12, but sometimes reached 20 to 30 individuals/m^2, with the maximum observed under conditions of random mowing. The minimum indicators of the vegetative sphere: height of generative individuals (h, cm), aboveground phytomass (W, g), photosynthetic effort (LWR, %) were noted in populations used as hayfields, pastures, and in agrophytocenosis. The maximum indicators were in populations that were generally or almost unaffected by anthropogenic influences. Research on the dynamics of the main morphological parameters showed that while the maximum and minimum parameters of vegetative structures differed by approximately 2.1 times, generative parameters differed by 4.6 times. Statistically significant differences were observed among *H. perforatum* populations in terms of the number, mass of generative organs, and the reproductive effort of plants. A statistically significant correlation was found between plant height (h, cm) and the productivity of aboveground dry phytomass, which forms the herbal raw materials (HRM, g). It is described by the Equation: $HRM = 0.167h - 3.28$. In hayfield-pasture areas and in agrophytocenosis, up to 60–75% of individuals were of small size and low vitality, their contribution to the production of medicinal plant raw material was insignificant. Overall, the conducted research showed that *Hypericum perforatum* L. exhibited significant phytocenotic diversity, which depended on a complex of ecologo-cenotic factors and types of anthropogenic management.

Keywords: *Hypericum perforatum* L., anthropogenic influence, population monitoring, medicinal plant raw material resources, vitality structure, ontogenetic structure.

INTRODUCTION

Medicinal plants constitute the stock of exhaustive renewable natural resources in Ukraine [Mirzoieva et al., 2021], thus phytocenotic and population approaches in medicinal plant resource management are important components of biodiversity conservation and maintenance of key ecosystem processes [Grime, 1979; Didukh, 2018]. In recent years, there has been growing concern about the pace of global biodiversity loss [Chusova et al., 2022] and its consequences for the healthy functioning of ecosystems [Zhang, 2017]. At the same time, the future use of medicinal plants and the acquisition of medicinal plant raw materials may be significantly limited due to the reduction in their biodiversity, shrinking species ranges, and deterioration of their populations [Minarchenko, 2000; Kuzemko & Kozyr, 2011]. This underscores the relevance of developing issues related to ensuring rational use of medicinal plant resources from their natural habitats for the long–term and stable functioning of their populations [Zlobin, 2021; Kuzemko et al., 2023].

Currently, with the intensive development of official medicine, there is an increasing demand for drugs derived from medicinal plant raw materials [Agapouda et al., 2019; Karbivska et al., 2023]. Traditionally, the first direction in medicinal plant research focuses on the analysis of their chemical structure [Anjum, 2022] and phytotherapeutic effects [Nobakht, 2022; Brankiewicz et al., 2023; Sherif et al., 2023].

Hypericum perforatum L. belongs to the officinal medicinal plants. In Ukraine, there are 7 species of this genus. The species used for the raw material *Hyperici herba* (St. John's Wort Herb) are *Hypericum perforatum* L. or *Hypericum maculatum* Crantz (*H. quadrangulum* auct. non L.) or a mixture of these species [State Pharmacopoeia of Ukraine, 2008; European Pharmacopoeia 9.0, 2017]. Considerable attention is paid to studying the dynamics of the biochemical composition of this species [Zeb et al., 2010; Kwiecien et al., 2023], its phytotherapeutic properties [Scholz et al., 2021], and the dynamics of the ontogenesis of *H. perforatum* L. [Cirak et al., 2022] in a number of works.

Moreover, the adaptation possibilities of this species to various ecological conditions are currently relevant. In particular, features of this species such as drought resistance and its genomic determinants are revealed in the publication by Zhou et al. [2023]. Data on the peculiarities of *H. perforatum* L. seed germination in vitro collected under different growth conditions are presented in the scientific literature [Heidari Sureshjani et al., 2022], which once again confirms the important phytotherapeutic significance of this species and medicinal raw material, which is of interest to the entire world phytopharmacological industry. A detailed algorithm for microscopic and macroscopic identification of raw material–forming species of *Hypericum* is provided in the publication by Minarchenko et al. [2020]. Second place in the research on medicinal plants in general and St. John's Wort, in particular, belongs to determining the resource potential of this species [Alekseiev, 2013; Minarchenko, 2020]. The dependence of the phytomass structure and productivity of medicinal plants on abiotic, biotic, and anthropogenic conditions is noted in the works of several authors [Kaundal, 2021; Avasiloaiei et al., 2023].

Equally important in determining the resources of medicinal plants, based on geobotanical surveys of their habitats [Kuzemko & Kozyr, 2011], is the analysis of the population structure of plants, features of their formative processes, and reproduction under different phytocenotic conditions [Zubtsova, 2017; Skliar et al., 2019]. Detailed population studies of medicinal plants within the Shostka geobotanical region were conducted by Penkovska [2020]. These and other studies [Karbivska et al., 2020; Kovalenko et al., 2022] confirmed the statistically significant influence on morphological parameters characterizing the vegetative and generative spheres of medicinal plants of a complex of ecologo–cenotic factors. The important indicative role of population structure, demonstrated on the example of *Asarum europaeum* L., is shown in the series of articles [Kovalenko et al., 2019; Yaroshenko & Skliar, 2022]. Since the content of biologically active substances in medicinal plants significantly depends on the ontogenetic phase in which the raw material is collected [Piatti et al., 2023; Şenkal & Uskutoglu, 2023], the study of the ontogenetic structure of populations acquires additional practical significance.

In connection with the above, the study of growth features, formative processes, reproduction, ontogenetic and vitality structure of *H. perforatum* L. populations under conditions of different types and degrees of anthropogenic management for the purpose of predicting the dynamics of the resource potential of this species remains relevant and timely.

MATERIAL AND METHODS

A comprehensive population analysis of the growth dynamics, formative processes, reproduction, ontogenetic and vitality structure of six typical model populations of *H. perforatum* in different types of plant communities in the Northeast of Ukraine within the Sumy region was conducted, and their resistance to various types and degrees of anthropogenic influence in the form of mowing and grazing by cattle was assessed. Research plots were located under the following phytocenotic and anthropogenic conditions (Table 1).

Currently, a variety of tools and techniques are used for species identification and research on medicinal plant resources [Minarchenko et. al., 2020]. During the study of the features of *H. perforatum* populations, a number of classical methods of medicinal plant identification [Vynokurov et al., 2024], geobotanical, population, and statistical methods for collecting and further processing primary data were applied [Zlobin et al., 2021; Goncharenko et al., 2022].

For the study of growth features, production processes, and reproduction of *H. perforatum*, a morphometric method was applied [Hunt, 1978]. For detailed morphometric analysis, 30–40 individuals were selected from each sample plot, taking into account the main static morphometric parameters: above–ground weight (*W*, g), shoot height (*h*, cm), leaf mass (W_L, g), generative organ mass (W_G), number of generative organs (N_G), and static allometric parameters: photosynthetic effort (*LWR* – leaf weight ratio, %), as the ratio of leaf mass to total phytomass, reproductive effort (*RE*, %), as the ratio of generative organ mass to total phytomass [Kvet, 1971]. Above–ground phytomass productivity was calculated per unit area (m^2).

To identify the features of the ontogenetic structure of populations, sample plots with an area of 1.0 m^2 were established and described. Plots measuring 0.25 m^2 were used to count the number of small individuals and seedlings within them. On each sample plot, individuals of the studied species were selected to determine their ontogenetic stage, and their total number and the number of representatives of each ontogenetic stage were counted: *j* – juvenile plants, *im* – immature, *v* – virginal\vegetative, *g*1 – young generative, *g*1 – medium generative, *g*3 – old generative, *ss* – subsenile, *s* – senile individuals. The obtained data were used to construct ontogenetic spectra of populations and analyze their completeness and symmetry, determining the belonging of each population to a certain ontogenetic category: young, transitional, mature [Zlobin et al., 2022].

The data of morphometric analysis were used to determine according to the system of Zlobin et al. [2009, 2018]. First, based on correlation and factor analysis, key morphometric parameters (determining the level of vitality) were identified for each population. These features were selected according to the following algorithm: (a) their biological–ecological significance for the studied species was determined; (b) from the original set of parameters, features that were highly correlated with each other were excluded based on the

Table 1. Phytocenotic and anthropogenic conditions for the study of *H. perforatum* L. populations

Research plots, population number	Phytocenotic conditions	Type and degree of anthropogenic influence
Population I	Slope of the ravine. Dry meadow. Phytocenosis with the dominance of *Festuca pratensis* Huds., *Bromopsis inermis* (Leyss.) Holub and mixed herbs. The herbaceous cover included *Phleum pratense* L., *Dactylis glomerata* L., *Poa pratensis* L., *Trifolium pratense* L.	Regular mowing
Population II	Central part of the floodplain. Phytocenosis with the dominance of *Phleum pratense* L., *Dactylis glomerata* L., and *Festuca pratensis* Huds., with the participation of *Bromopsis inermis* (Leyss.) Holub. Mixed herbs included: *Plantago lanceolata* L., *Filipendula vulgaris* Moench., *Euphorbia virgata* Waldst. et Kit., *Melilotus officinalis* L., etc.	Without anthropogenic influence
Population III	Slope of the ravine. Dry meadow. Phytocenosis with the dominance of *Festuca pratensis* Huds., with significant participation of *Phleum pratense* L., *Dactylis glomerata* L. Herbaceous plants present were *Poa pratensis* L., *Trifolium pratense* L., *Melilotus officinalis* L.	Occasional mowing
Population IV	Central part of the floodplain. Phytocenosis with the dominance of *Phleum pratense* L., *Dactylis glomerata* L., and *Poa pratensis* L., with a significant proportion of *Festuca rubra* L. In herbage there were presented: *Deschampsia cespitosa* (L.) Beauv., *Agrostis stolonifera* L., and *Rumex thyrsiflorus* Fingerh.	Regular grazing
Population V	Sowing of *Hordeum vulgare* L., infested with *Elytrigia repens* (L.) Nevski and annual weeds.	Agrophytocenosis
Population VI	Dry meadow on the slope of the ravine. Phytocenosis with the dominance of *Bromopsis inermis* (Leyss.) Holub, with *Phleum pratense* L., *Festuca pratensis* Huds. as co–dominants. Also present were *Alopecurus pratensis* L., *Dactylis glomerata* L., *Poa pratensis* L., *Trifolium pratense* L., and mixed herbs.	Moderate mowing and occasional grazing

results of correlation analysis, as they duplicate each other; (c) features that have the greatest contribution to the first and second factors were selected based on the results of factor analysis. For *H. perforatum*, these were: above–ground phytomass (W, g); shoot height (h, cm), and reproductive effort (RE, %). Based on these morphometric parameters, the level of vitality of each individual was assessed. Based on the representation of plants of higher (class A), intermediate (class B), lower (class C) vitality, the vitality structure of populations was determined and the population quality index (Q) was calculated: $Q = ½ (A + B)$. Populations were classified as prosperous, balanced or depressive.

For statistical analysis we calculated P–value using Two–way ANOVA with Tukey's multiple comparisons test as well as ordinary one–way ANOVA. $P < 0.05$ was employed to determine statistical significance.

RESULTS AND DISCUSSION

Based on the study of six model populations of *H. perforatum*, it was established that their population density usually ranged from 3 to 12, but sometimes 20–30 individuals/m^2, with the maximum in population III (random mowing). The productivity of raw above–ground phytomass ranged from 2.75 g to 10.1 g per m^2 (Table 2). Maximum values were observed under conditions of random mowing (populations III and IV) and in the absence of anthropogenic influence (population II). The height of generative individuals also varied noticeably, ranging from 35 to 76 cm (Table 3).

Minimal indicators of vegetative sphere were observed in populations: I, IV, V, which were used for regular mowing, grazing and andagrophytocenosis. Maximum indicators were observed in populations II, III, and VI, which generally or almost did not undergo anthropogenic influences. All recorded differences in morphometric parameter values are statistically significant at the 95% and higher levels.

The above parameters characterizing the vegetative sphere of plants varied – their values depended on eco–coenotic and anthropogenic conditions. Thus, the size of the photosynthetic effort (LWR, %) of individuals of the studied populations differed (Fig. 1). This indicator was highest in populations I and II and lowest in populations IV and V. It was noted that optimal values of parameters of the vegetative sphere of *H. perforatum* were observed under conditions of moderate or irregular anthropogenic influence.

Parameters of the generative sphere of *H. perforatum* individuals were characterized by more significant changes depending on the type and degree of anthropogenic influence (Table 4). At the same time, while the maximum and minimum parameters of vegetative structures differed by approximately 2.1 times, the generative ones differed by 4.6 times. Statistically significant differences were observed between *H. perforatum* populations in terms of the number, mass of generative organs, and the reproductive effort of plants overall.

Table 2. Dynamics of productivity of raw above-ground phytomass (W, g/m^2) of generative plants *H. perforatum* under different phytocenotic and anthropogenic growth conditions ($x \pm$ SD, $34 \leq n \leq 41$)

Population	Measurement periods											
	10.05–20.05		1.06–10.06		20.06–30.06		10.07–20.07		1.08–10.08		20.08–30.08	
I	0.62 ± 0.12^{d}	$n = 35$	1.11 ± 0.21^{c}	$n = 35$	1.31 ± 0.31^{e}	$n = 40$	2.62 ± 0.61^{d}	$n = 42$	3.62 ± 0.51^{e}	$n = 35$	3.51 ± 0.41^{d}	$n = 40$
II	1.31 ± 0.11^{c}	$n = 38$	1.62 ± 0.31^{b}	$n = 34$	2.01 ± 0.42^{d}	$n = 37$	3.74 ± 0.71^{c}	$n = 35$	7.91 ± 1.03^{b}	$n = 40$	9.23 ± 1.81^{b}	$n = 35$
III	1.82 ± 0.31a	$n = 40$	1.71 ± 0.31^{b}	$n = 38$	3.12 ± 0.61^{b}	$n = 35$	6.14 ± 0.51^{b}	$n = 40$	7.12 ± 0.91^{c}	$n = 40$	10.24 ± 1.31^{a}	$n = 32$
IV	0.51 ± 0.08^{d}	$n = 41$	0.82 ± 0.11^{d}	$n = 36$	2.63 ± 0.51^{c}	$n = 40$	5.73 ± 0.91^{b}	$n = 35$	4.51 ± 0.62^{d}	$n = 37$	4.52 ± 0.51^{c}	$n = 38$
V	1.21 ± 0.11^{c}	$n = 38$	1.83 ± 0.41^{b}	$n = 38$	1.02 ± 0.21^{e}	$n = 34$	2.11 ± 0.51^{e}	$n = 36$	2.41 ± 0.32^{f}	$n = 34$	2.83 ± 0.22^{d}	$n = 34$
VI	1.51 ± 0.21^{b}	$n = 37$	4.11 ± 0.62^{a}	$n = 40$	8.51 ± 1.21^{a}	$n = 38$	8.32 ± 0.61^{a}	$n = 38$	9.21 ± 0.61^{a}	$n = 30$	9.32 ± 1.12^{b}	$n = 30$

Note: Statistical significance of the difference was calculated using Tukey's multiple comparisons test for every measurement period separately. $P < 0.05$ was employed to determine statistical significance. Letters a–f are compact letter display labels (same letter – difference not significant, different letters – significant difference).

Table 3. Dynamics of height (h, cm) of generative plants *H. perforatum* under different phytocenotic and anthropogenic growth conditions (x ± SD, $30 \leq n \leq 42$)

Population	Measurement periods											
	10.05–20.05		1.06–10.06		20.06–30.06		10.07–20.07		1.08–10.08		20.08–30.08	
I	15.31 ± 0.11^{e}	*n* = 35	23.12 ± 1.71^{d}	*n* = 35	27.52 ± 2.82^{d}	*n* = 40	34.52 ± 2.51^{e}	*n* = 42	47.03 ± 2.81^{c}	*n* = 35	55.12 ± 2.51^{c}	*n* = 40
II	24.62 ± 1.21^{b}	*n* = 38	27.32 ± 1.61^{c}	*n* = 34	31.81 ± 2.41^{c}	*n* = 37	45.63 ± 4.04^{c}	*n* = 35	63.02 ± 2.41^{b}	*n* = 40	72.63 ± 3.31^{b}	*n* = 35
III	29.12 ± 1.91^{a}	*n* = 40	29.72 ± 2.83^{b}	*n* = 38	43.64 ± 3.01^{b}	*n* = 35	61.21 ± 2.41^{b}	*n* = 40	75.62 ± 2.51^{a}	*n* = 40	74.14 ± 2.92^{b}	*n* = 32
IV	13.91 ± 0.93^{f}	*n* = 41	22.81 ± 1.21^{d}	*n* = 36	22.82 ± 1.81^{e}	*n* = 40	34.83 ± 1.62^{e}	*n* = 35	35.63 ± 1.31^{e}	*n* = 37	38.72 ± 1.31^{d}	*n* = 38
V	17.62 ± 0.91^{d}	*n* = 38	22.92 ± 1.71^{d}	*n* = 38	28.02 ± 1.31^{d}	*n* = 34	37.54 ± 1.81^{d}	*n* = 36	39.94 ± 1.51^{d}	*n* = 34	40.24 ± 1.62^{d}	*n* = 34
VI	23.31 ± 1.12^{c}	*n* = 37	39.73± 2.52^{a}	*n* = 40	73.12 ± 2.03^{a}	*n* = 38	74.12 ± 1.91^{a}	*n* = 38	75.23 ± 1.72^{a}	*n* = 30	76.53 ± 0.91^{a}	*n* = 30

Note: Statistical significance of the difference was calculated using Tukey's multiple comparisons test for every measurement period separately. $P < 0.05$ was employed to determine statistical significance. Letters a–f are compact letter display labels (same letter – difference not significant, different letters – significant difference).

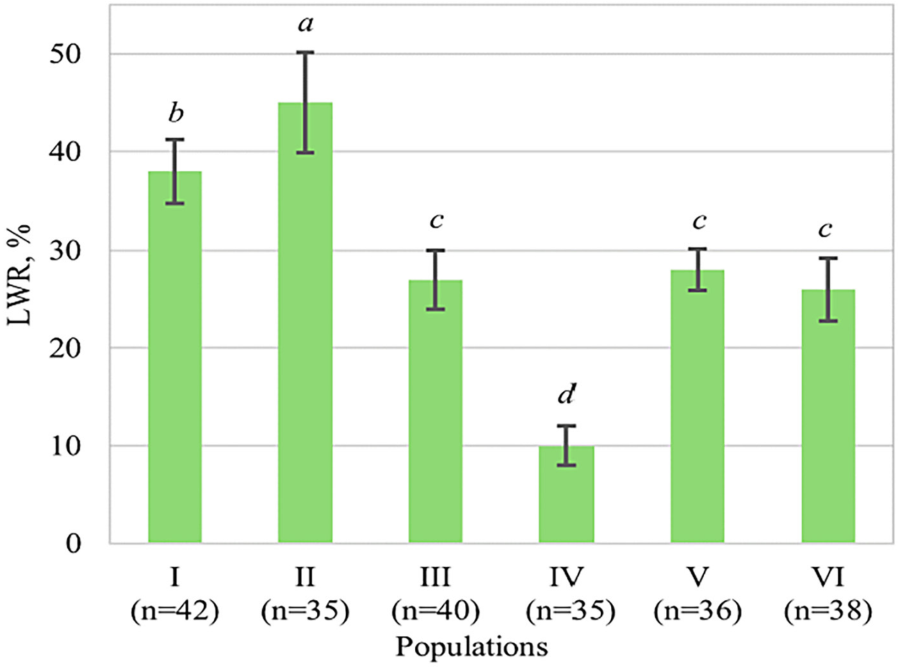


Figure 1. Photosynthetic effort (LWR, %) - ratio of leaf phytomass (W_L, g) to total above-ground phytomass (W, g) of *H. perforatum* individuals in the studied populations: I – dry meadow (regular mowing); II – central part of floodplain (without anthropogenic influence); III – dry meadow (random mowing); IV – central part of floodplain (regular grazing); V – sowing of *Hordeum vulgare* L. (agrophytocenosis); VI – dry meadow (moderate mowing and occasional grazing). Letters *a–d* are compact letter display labels (same letter – difference not significant, different letters – significant difference)

The number of seeds in *H. perforatum* capsules averaged 33.5 ± 4.5, however, no significant differences in this indicator among plants of different populations were found. The seed yield depended on the number of generative plants and their life state. It was highest in populations II, IV, and VI, where a significant proportion of well–developed generative plants were present. Furthermore, as a result of the research, a statistically significant correlation between plant height and the productivity of above–ground dry phytomass, which is important as a medicinal plant material – *Hyperici herba*, was established. During the flowering period, the correlation coefficient

Table 4. Variation in the main reproductive parameters of *H. perforatum* across different populations as influenced by phytocenotic and anthropogenic growth conditions (x ± SD, $35 \leq n \leq 42$)

Population	Morphometric values			
	Static metrics		Static allometric	*n*
	Number of generative organs (N_G, units)	Mass of generative organs (W_G, g)	Reproductive effort (RE, %)	
I	17.64 ± 4.41^{a}	0.54± 0.12^{d}	5.52 ± 0·81^{e}	42
II	37.71 ± 6·11^{b}	1.32 ± 0·21^{b}	12.94 ± 1·61^{d}	35
III	66.72 ± 8·01^{c}	1.83 ± 0.22^{a}	16.32 ± 1.11^{c}	40
IV	44.82 ± 5·21^{d}	1.43 ± 0.22^{b}	33.23 ± 1.81^{ab}	35
V	32.72 ± 3.01^{e}	0.84 ± 0.13^{c}	33.14 ± 1.91^{b}	36
VI	50.72 ± 5.81^{f}	1.71 ± 0.21^{a}	34.21 ± 2.0^{a}	38

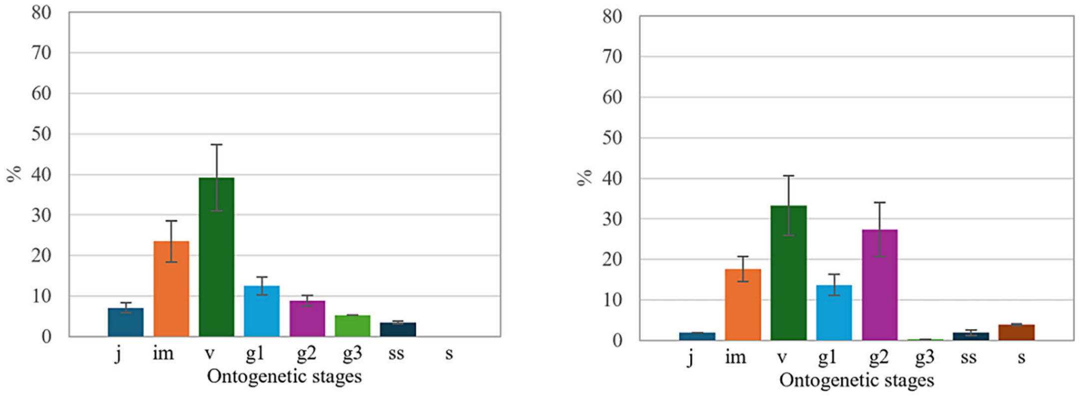
Note: Statistical significance of the difference was calculated using Tukey's multiple comparisons test for every morphometric value separately. $P < 0.05$ was employed to determine statistical significance. Letters a–f are compact letter display labels (same letter – difference not significant, different letters – significant difference).

was +0.84 (with a significance level of over 95%). This made it possible to predict the raw material productivity of plants based on the average height of shoots using simple regression equations. In the conditions of dry and floodplain meadows in the Northeast of Ukraine (Sumy region), the forecast of raw material productivity (HRM – herbal raw materials, (g) based on plant height (h, cm) with a confidence level of 95% can be calculated by the equation: HRM = 0.167h – 3.28 ($r^2 = 0.49$).

Studies of population age characteristics showed that ontogenetic spectra were specific for each of the studied populations (Fig. 2). In populations I and II, they were complete, representing all ontogenetic categories of plants, with predominance of pre–generative (young individuals) – these are young populations. The age spectra of other populations were right–skewed. They were characterized by a small number of generative individuals from groups *g*1–*g*2 and an increased proportion of aging individuals from groups *g*3–ss. This populations belonged to the transitional and mature categories, indicating unfavourable conditions for the existence of plants in these populations. The age spectrum of population IV (grazing area) was the least harmonious: here, juvenile, immature, and senile plants were completely absent. The population was dominated by the *g*2–*g*3 group. It was noted that with intensified grazing, *H. perforatum* gradually disappears from the herbage.

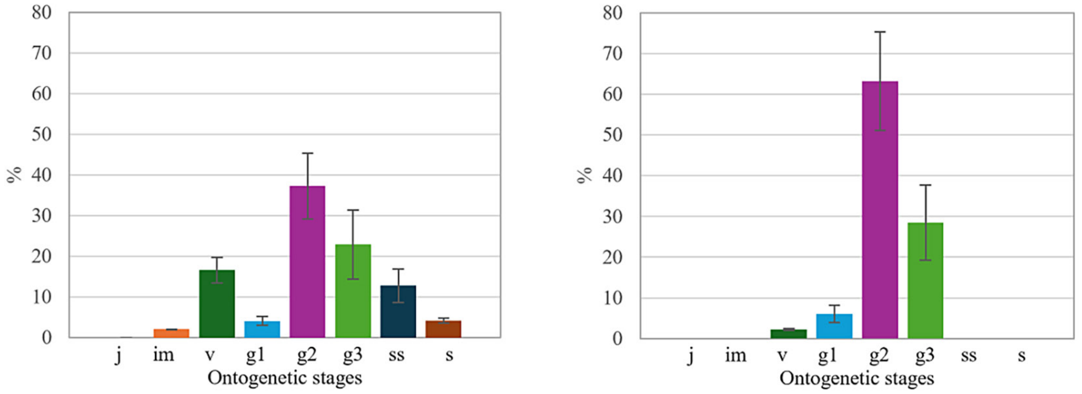
Results of vitality analysis are presented in Figure 3. Similarly to growth, formative features, and reproduction, the vitality structure of *H. perforatum* populations differed under different growth conditions. Population II belonged to the prosperous category with a quality index (*Q*) of 0.34. Populations III, IV, and VI belonged to the balanced category with index *Q* ranging from 0.21 to 0.31. Populations I and V belonged to the depressive category with quality indices of 0.12 and 0.13, respectively.

One of the important indicators characterizing the distribution of individuals within the population field is population density [Sprihger, 2021]. In the studied populations, the number of plants usually ranged from 3 to 12, but sometimes reached 20–30 individuals per m^2. Each population has its own density limit, which is determined by the carrying capacity of the environment in which it forms [Pannell, 2012]. In our study, the environmental capacity was determined by the peculiarities of the phytocenotic environment and anthropogenic impact on the populations. Notably, the highest population density was observed in populations subjected to random mowing, which can be explained by the ecological and biological features of *H. perforatum*. This species is capable of population regeneration through vegetative propagation, which is not affected by the removal of aboveground biomass during mowing. Additionally, random mowing often allows generative individuals to produce seeds before being cut. Similar results regarding the impact of anthropogenic management on population density were obtained by I. Zubtsova



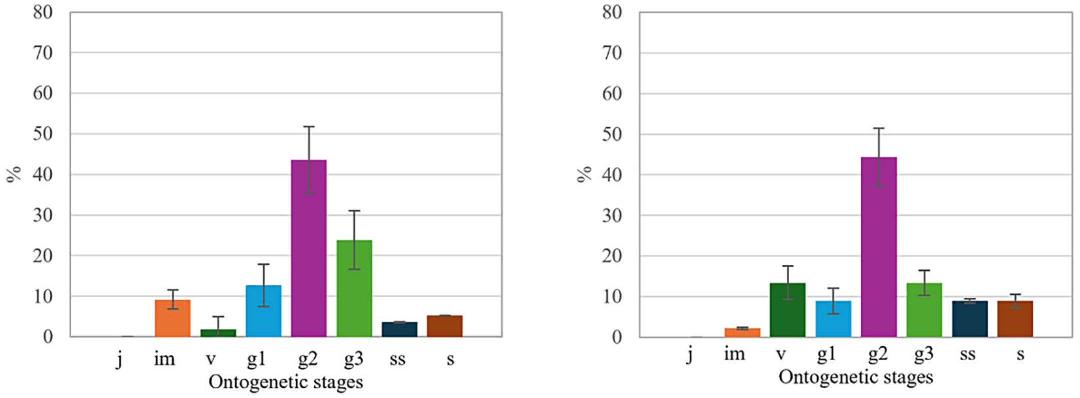
a I - dry meadow (regular mowing)

b II - central part of the floodplain (without anthropogenic influence)



c III - dry meadow (random mowing)

d IV - central part of the floodplain (regular grazing)



e V – sowing of *Hordeum vulgare* L. (agrophytocenosis)

f VI – dry meadow (moderate mowing and occasional grazing)

Figure 2. Change in ontogenetic spectra of *Hypericum perforatum* L. populations (*a*–*f*) under different phytocenotic and anthropogenic conditions. Ontogenetic stages: *j* – juvenile, *im* – immature, *v* – virginal, *g*1 – young generative, *g*2 – medium generative, *g*3 – old generative, *ss* – subsenile, *s* – senile. The proportion of individuals in different ontogenetic states is indicated in percentages

with with co–authors while studying *H. perforatum* populations in the adjacent region, where the population density of this species usually did not exceed 10 individuals per square meter [Zubtsova et al., 2019] and was highest under conditions of moderate or irregular anthropogenic influence.Furthermore, we observed a tendency toward uneven distribution of individuals within the population field, forming distinct groups. This pronounced tendency towards contagious spread is likely associated with its rhizomatous growth [Rapisarda and Ragusa, 2003], although significant plant clones are not formed, although by the type of individual formation, it belongs to individual clones [Zlobin, 1997]. For plants with resource significance, including the

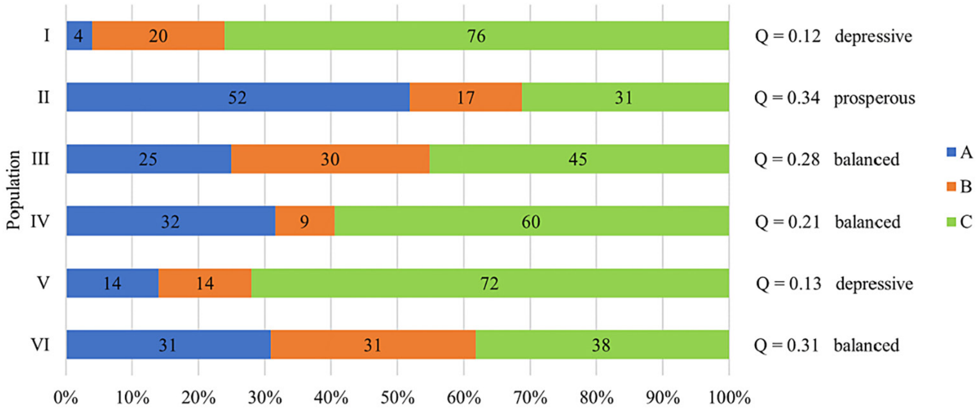


Figure 3. Changes in the vitality spectra (proportions of individuals in different vitality classes: *A* – higher, *B* – intermediate, *C* – lower); population quality index ($Q = ½ (A + B)$ and vitality categories (Zlobin et al., 2021) of *Hypericum perforatum* L. populations under different phytocenotic and anthropogenic conditions: I – dry meadow (regular mowing); II – central part of the floodplain (without anthropogenic influence); III – dry meadow (random mowing); IV – central part of the floodplain (regular grazing); V – sowing of *Hordeum vulgare* L. (agrophytocenosis); VI – dry meadow (moderate mowing and random grazing)

officinal species – *H. perforatum*, the method of determining population density is typically based on phytomass reserves per unit area [Begmatova et al., 2024]. The obtained regression equation describing the relationship between dry phytomass reserves per unit area and plant height allows assessing the resource significance of specific H. *perforatum* populations without cutting and weighing aboveground parts.

All morphometrical indicators of the vegetative sphere of plants showed pronounced plasticity – their values changed depending on the ecological–cenotic conditions of growth and the type of anthropogenic management. Overall, optimal development of vegetative and generative parameters of *H. perforatum* individuals was observed under conditions of moderate or occasional anthropogenic load.

The predominance of degenerative individuals in population I (regular mowing) and in population II (without anthropogenic influence) indicates a fairly good adaptation of the studied species to periodic mowing. However, it should be considered that this process can be quite dynamic over the years [Dubyna & Kordyum, 2015] and reflect the phytocoenotic and anthropogenic conditions of the populations' existence at the time of the studies. At the same time, the general multi–year trend towards changing the ontogenetic characteristics of local populations may indicate trends of their rejuvenation or ageing under the influence of abiotic or anthropogenic conditions. Thus, the intensive ageing of populations under conditions of regular grazing (population IV) indicates the low resilience of this species to soil compaction and rhizome destruction due to trampling, which, over time, may lead to the gradual disappearance of this population from the phytocoenosis.

Unlike ontogenetic changes, which often have a unidirectional character (populations rejuvenate, age, or remain balanced), the morphostructural features and the life state of plant individuals are reversible – the quality of individuals over time in any ontogenetic state can improve or deteriorate [Kyyak, 2014]. That is, the indicators of the vitality structure of populations determined in our study are a more reliable and sensitive indicator of individuals' response to the existing anthropogenic impact or eco–coenotic conditions that have formed at the present time. Population II, which is located in the central part of the floodplain and has formed without anthropogenic influence, consists predominantly of young individuals with high vitality. Obviously, such a population structure indicates an improvement in the ecological and anthropogenic conditions of its existence recently and the prospects of this population in terms of maintaining the number of individuals. Therefore, this area can be considered as a place with a sufficient reserve of medicinal plant raw materials, provided it is used rationally.

Populations III (dry meadow, random mowing), IV (central part of the floodplain, regular grazing), and VI (dry meadow, moderate mowing and random grazing), which are balanced in vitality, have right–sided ontogenetic spectra, indicating problems with the restoration of numbers lately. Therefore, even considering the quite balanced vitality structure and the presence of a fairly large number of individuals, they cannot be recommended as places for raw material harvesting, at least for the near future – until the stabilization of the processes of self–renewal of populations under conditions of regulated anthropogenic impact in the form of hay–pasture use. This particularly concerns population IV – pastures. Population I (dry meadow, regular mowing), classified as depressive with a predominance of young degenerative individuals, also requires some time to restore its vitality and form full–fledged ontogenetic spectra. Likely, regular early and multiple mowings throughout the season within this area deprive meadow species of the possibility to fully increase vegetative mass and seed. Therefore, this area also cannot be considered as a place for harvesting *H. perforatum* soon.

In general, growth rates, plant size, reproductive processes, ontogenetic and vitality structures of the population are reliable indicators of differences in the ecological–cenotic and anthropogenic conditions of their existence, which was confirmed by the results of our research. This feature is traced not only for *H. perforatum* but also for species associated with different types of phytocenoses, in particular: forest [Skliar et al., 2020; Kovalenko et al., 2020; Yaroshenko, 2023] and meadow [Bondarieva et al., 2019; Bondarieva and Kyrylchuk, 2023].

For *H. perforatum*, as well as for other medicinal plant species [Jagodzinski et al., 2016], phytocenotic diversity is characteristic. The results of the study of ontogenetic and vitality structures of populations coincide with the opinion of Minarchenko and Syvoglaz [Minarchenko & Syvoglaz, 1996] that meadow steppes and steppe meadows of the Left Bank of Ukraine are optimal for the studied medicinal plant species [Weigelt et al., 2020] and are characterized by significant resource potential of this species.

CONCLUSIONS

H. perforatum, within the range of its habitats, is characterized by sporadic distribution and a fairly wide range of population density, which is determined by morphobiological characteristics and eco–anthropogenic conditions of growth. Maximum values of parameters characterizing the vegetative and generative sphere of *H. perforatum* (above–ground phytomass, height, photosynthetic effort, reproductive effort) were observed under conditions of present, but moderate anthropogenic load, mainly in the form of mowing. There is a statistically significant correlation (with a correlation coefficient of +0.84) between the height of individuals (h, cm) and the productivity of herbal raw materials (HRM, g), which is described by the regression equation: $HRM = 0.167h - 3.28$.

In the studied populations of *H. perforatum*, which were formed without anthropogenic influence and under conditions of random mowing, complete left–skewed ontogenetic spectra with a significant proportion of young (juvenile and immature) individuals were typical. With increasing anthropogenic pressure, the proportion of old generative and subsenile individuals increased in populations, ontogenetic spectra became right–skewed, and populations transitioned to the transitional and mature category, indicating unfavorable conditions for the existence of plants in the presence of grazing and in conditions of agrophytocenosis.

By vitality structure, depending on the type of anthropogenic management, the status of populations varied from prosperous to depressive. In mowing and grazing areas, up to 60–75% of individuals of small size and low vitality contributed insignificantly to the production of medicinal plant material. Thus, for *H. perforatum* under the conditions of floodplain and dry meadow herbal phytocenosis typical for the Northeast of Ukraine and Sumy region, significant phytopopulation diversity is characteristic, which is determined by a complex of ecological–cenotic factors, as well as anthropogenic management conditions.

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