EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2022, 23(3), 23–29
https://doi.org/10.12912/27197050/147144
ISSN 2719–7050, License CC-BY 4.0

Received: 2022.02.02
Accepted: 2022.03.15
Published: 2022.04.01

Dynamics of Indicators of the Ecological State of Shrubs, Taking into Account their Taxonomic and Age Specifics for the Prediction of their Longevity

Alexandra V. Semenyutina[1*], Aliya Sh. Khuzhakhmetova[1], Victoria A. Semenyutina[1]

[1] Federal Research Centre of Agroecology, Complex Melioration, and Forest Reclamations RAS, Volgograd, Russian Federation

* Corresponding author's email: semenyutina@mail.ru

ABSTRACT

As part of a plant Group, species with different limits of individual tolerance coexist. According to the principle of emergence, in synecological studies, it is advisable to evaluate the response of biocenoses as an integral structure to changes in environmental parameters. To reveal the organizational structure of groups, their functional activity allows the study of the relationships of various hierarchical levels, as a result of which ectomorphic matrices are formed that reflect the general emergent properties of ecological groups (for example, trophic, topical their structure) since the organizational structure of groups is environmentally determined. The study of plants of cultivated species at various ecological levels allows us to obtain information on plant viability strategies that are important in managing and expanding the functionality of species and varietal diversity and harmonizing vegetation with environmental conditions. The systematic approach of plant research makes it possible to fully realize the genetic potential of productivity, establish the limits of environmental tolerance, stability, genetic flexibility, etc. So, for a complex study of a cultural plant species (variety, line, Hybrid), a systematic approach of research involves the study of plants at different levels of integration of living matter (genetic-molecular, cellular, tissue, morphological, organizational), as well as Dem –, son – and ecosystem. Given that most of the characteristics, properties, and characteristics of plant organisms are determined not only genetically, but also ecologically, it is important to study plant organisms under changing conditions in Sita, revealing the Out –, Dem –, synecological, and ecosystem levels.

Keywords: ecology, dynamic indicators, ecological state, shrubs.

INTRODUCTION

One of the levels of organization of living things as an integral phenomenon, which is an elementary unit of evolution and a component of ecosystems, through which the flow of chemical elements and energy passes and their transformation takes place, is the population (Belitskaya, 2019). It is at the population level that the features and methods of transmitting hereditary information from generation to generation and its change under the influence of endogenous and exogenous factors can be traced. In addition, the mechanisms of adaptation and specialization are better known (Chamberlain, 2020).

Mechanisms that ensure the viability of populations are aimed at maintaining the subcritical level of intra-population diversity of their system-forming elements (Döring, 2017), to identify their evolutionary prospects in the changing conditions of the natural and anthropogenic environment against the background of global climate change. Studies of the structural and functional organization of populations using molecular genetic and physiological methods are extremely relevant (Hill, 1999). The study of the functioning of populations in ecotones and anthropogenically transformed environments, the relationships between populations of autotrophic and heterotrophic organisms, the consequences of fragmentation and metapopulation organization, the role in the functioning of groups, etc. requires further development (IPNI, 2020).

No less important are Population Studies to obtain data that can be used in the development of scientifically based nature-saving methods for the exploitation of anthropogenically transformed ecosystems, protection, reproduction, reintroduction, and introduction of populations and species (Jones, 2021).

Close attention should be paid to population studies to establish differential and integral parameters of populations that can be used in organizing monitoring of the state of ecosystems, individual species, and environmental changes (biotic, abiotic) (Kattge, 2020). Both traditional and prospective studies of populations – systems of the super organizational level – allow us to obtain data that deepen the theoretical foundations of systematology, reveal the essence of such fundamental phenomena of living systems as stability and stability, adaptation and adaptability, in addition, is the actual basis for mathematical modeling of the functioning of multicomponent systems in a changing environment and the development of effective methods for the conservation, introduction, reintroduction and exploitation of biotic components of ecosystems (Pierce, 2017).

Individuals of the same species form a coenopopulation within the coenosis. Similar populations of the same species adapted to certain living conditions make up ecotypes. The object and subject of Synecology is the grouping of organisms (biocenoses) belonging to different populations, which form connections (trophic, topical, euphoric, factory, repellent, attractive, diphenhydramine, etc.), forms of symbiotic (mutualistic, photo cooperative, commensalytic), and antibiotic (amensalytic, allelopathic, competitive, predatory) connections. The theory of ecosystems of all degrees of complexity – from consort to Biosphere, their genesis, structural and functional features, evolution, and anthropogenic dynamics is considered by ecoemology. In an ecosystem, the totality of living organisms and their abiotic habitat form a functional unity, thanks to which the biotic cycle, Energy Exchange and energy accumulation occur (Schleuning, 2020). System ecology covers the structure and functioning of the ecological system and the importance of various populations (species) in it, to assess the possibility of predicting the development of the ecosystem and the dynamics of its constituent elements, as well as their management. These are quite complex problems, and to solve them it is necessary to use mathematical methods, modeling methods, and computer technologies (Semenyutina, 2019).

With the current global climate change and significant anthropic pressure, the ecosystem approach to building productivity-stable adaptive agroecosystems with a favorable phytosanitary and ecological state is becoming increasingly practical (Taran, 2018). This can be achieved by a comprehensive study of the elements of the agroecosystem, which is why the management of populations of harmful species must necessarily be coordinated with the natural processes occurring in the agroecosystems. To achieve this goal, there is insufficient knowledge both about the interrelationships of the main components of agrocenoses and the joint impact of harmful consort species on the productivity of cultivated species and about the ecosystem principle of territory organization.

Holistic the picture of the composition and functioning of agrobiogeocenoses and higher-ranking agroecosystems, field facies of the agrolandscape is still not disclosed, since studies are conducted at the level of individual populations of species that cause biotic stresses to autotrophic species. Summing up the above, you should note that modern research requires an increasingly qualitatively new level of long-term synchronous biotechnological observations and accounting of complexes of species: insects, phytopathogens, microorganisms, and weeds (Tikhonov, 2020).

The most effective way to conduct biotechnological and Ecosystem Studies of cultivated plant species is to organize agroecological hospitals. The main method of research in system ecology is System Analysis, which develops methods for studying various complex systems or situations, provided that the goals (criteria) are not set. The systematic approach uses the mathematical apparatus of the theory of operations research, methods of multidimensional statistics, and informal analysis (the method of expertise, the method of hypotheses, heuristic methods, and computer modeling). An essential part of the study of systems is the choice of how to describe the changes that occur in them, and the formalization of such a description. The complexity of formalization is determined by the overlap of various types of factors that characterize the system, for example, a combination of genetic, biological, environmental, and other factors (Tsembelev, 2018).

The development of methods of system analysis as a scientific discipline is carried out in several areas. One of the most important of them is the creation of principles for constructing and using models that simulate the course of real processes, ways to combine them into systems, and such a representation in a computer that would ensure ease of use without loss of adequacy. Another direction is related to the study of organizational structures and, above all, systems that are characterized by the hierarchical organization (Jones, 2021).

MATERIALS

To predict the durability of shrubs set dynamic parameters of eco-physiological (water deficit from 16 to 35 %, CEE – from 1.6 to 2.8), inventory and reproductive indicators, taking into account taxonomic and age specifics of the plants, as well as statistically significant differences between them (Table 1, 2). The variety specificity of quantitative indicators of the pigment complex has been established depending on the illumination, age of plant tissues, and other conditions (Table 3).

In this regard, to study the state of introduced economically valuable shrubs, we conducted studies of changes in the activity of the photosynthetic apparatus in the arid conditions of Volgograd. On the collection site (ring road. № 34:34:000000:122) when measuring the pigment content, indicators of abiotic factors were simultaneously recorded using the following devices: temperature regime – with a DUALEX SCIENTIFIC chlorophyll meter, illumination – with an LXP-10A luxmeter (Table 4).

The results of studies of the dynamics of pigment indicators in leaves showed that at noon the total content of chlorophylls decreases by 20–26%, the share of participation in the total

Table 1. Evaluation of the ecological state of shrubs Corylus pontica on the dynamics of the main parameters

Indicators	Circassian-2	President	Futcurami
Water scarcity, %	0.5–0.7	0.5–0.6	0.4–0.5
OVE*	0.6–0.7	0.5–0.6	0.4–0.6
Temperature tolerance, °C	0.7–0.9	0.7–0.8	0.7–0.8
Plant height, m	0.4–0.5	0.4–0.5	0.3–0.4
Growth of shoots, m	0.3	0.2–0.3	0.2
Number of inflorescences, fruits (coplodia), pcs.	0.3–0.4	0.2–0.3	0.2–0.3
Weight of seeds (fruits)/plant, kg	0.7–1.0	0.5–0.7	0.5–0.8

*OVE – electrolyte output (relative)

Table 2. Evaluation of shrubby plants by indicators of signs

Indicators	Values of indicators of signs									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Water scarcity, %	>46	41–45	36–40	31–35	26–30	21–25	16–20	11–15	6–10	<5
OVE*	>4.0	3.6–3.8	3.3–3.5	2.9–3.2	2.6–2.8	2.3–2.5	1.9–2.2	1.6–1.8	1.3–1.5	<1.20
Temperature tolerance, °C	-5.0	–7.0	–10.0	–15.0	–20.0	–25.0	–30.0	–35.0	–37.0	>-37.0
Plant height, m	<1.0	1.05–1.95	2.00–2.95	3.00–3.95	4.00–4.95	5.00–5.95	6.00–6.95	7.00–7.95	8.00–8.95	> 9.00
Growth of shoots, m	<0.1	0.11–0.30	0.31–0.50	0.51–0.70	0.71–0.90	0.91–1.10	1.11–1.30	1.31–1.50	1.51–1.70	>1.71
Number of inflorescences, fruits (coplodia), pcs.	< 9.9	10–34.9	35–59.9	60–84.9	85–109.9	110–134.9	135–159.9	160–184.9	185–209.5	> 210
Weight of seeds (fruits)/plant, kg	< 0.1	0.10–0.60	0.61–1.10	1.11–1.60	1.61–2.10	2.11–2.60	3.11–3.60	3.61–4.10	4.11–4.60	> 4.61

*OVE – electrolyte output (relative)

Table 3. Indicators of temperature and illumination during measurements

Measurement time	9^{40}	11^{35}	13^{35}	15^{30}	17^{15}
Temperature, °C	35.5–36.0	37.4–37.6	38.1–39.0	38.0–38.9	36.8–37.2
Illumination, lux·10^3	55–75	86–90	78–100	79–88	60–69

pigment complex decreases from 92.5 to 89.9%. During the experiment (8 hours), a monotonous decrease in the content of chlorophylls is characteristic. The inverse relationship between the quantitative indicators of chlorophylls and anthocyanins has been established. These changes occur against the background of a decrease in water content, an increase in air temperature and illumination. The remaining experimental samples showed instability in the quantitative content (an abrupt increase followed by a decrease) of chlorophylls. With prolonged exposure to high temperatures (above 35–38 ° C), the photosynthetic apparatus is destroyed due to the inactivation of enzymes and damage to membranes, which affects the morphometric and other parameters of plants.

Biometric characteristics of plants are important not only for assessing the degree of adaptation to the soil and climatic conditions of the introduction region (Chamberlain, 2020) but also for predicting the reclamation effect of plantings with their participation in the adjacent territory. During the years of studying the specifics of the growth reactions of introducers, acute arid (2010, 2012, 2013, 2015, 2017, 2019) and favorable (2014, 2016, 2018) periods in hydrological terms.

Growth processes are determined by the temperature regime (Figure 1).

The peak of the growth intensity of the main, crown-forming shoots has been established. The development of the aboveground part of shrubs is described by regression equations. They showed the relationship of changes in taxation characteristics (height – y; crown diameter – y_d) with age (x):

$$y = 0.50 \text{ Ln } (x) + 1.35, \quad y_d = 1.31 \text{ Ln } (x) + 1.56 \qquad (1)$$

at R_2 =0.95 and 0.89, respectively,

$$y = 0.32 \text{ Ln } (x) + 1.67, \quad y_d = 2{,}10 \text{ Ln } (x) + 1{,}24, \quad R^2 = 0.90,\ 0.97 \qquad (2)$$

$$y = 0.56 \text{ Ln } (x) + 1.27, \quad y_d = 1{,}21 \text{ Ln } (x) + 1.59,\ 0.90,\ 0.87 \qquad (3)$$

Table 4. Dynamics of quantitative indicators of leaf pigments under conditions of exposure to high temperatures

Measurement time				
9^{40}	11^{35}	13^{35}	15^{30}	17^{15}
Chlorophyll a+b content, mcg/cm²				
19.81±0.84* 17.19–21.70**	31.75±1.01 29.50–32.05	27.83±1.26 26.52–30.08	22.74±0.30 22.15–23.15	21.25±0.90 20.30–22.24
Flavonoid content, mcg/cm ²				
1.91±0.04 1.79–1.97	1.97±0.08 1.93–1.99	1.65±0.04 1.61–1.67	2.01±0.01 2.00–2.01	2.11±0.05 2.10–2.12
Anthocyanin content, mcg/cm ²				
0.16±0.003 0.14–0.17	0.02±0.001 0.01–0.02	0.07±0.001 0.06–0.07	0.12±0.003 0.12–0.13	0.13±0.002 0.13–0.14
Chlorophyll a+b content, mcg/cm²				
27.03±1.17 25.63–30.28	24.44±0.98 24.09–28.08	20.06±0.47 19.08–21.18	21.96±0.64 20.55–23.46	21.57±1.04 20.70–21.97
Flavonoid content, mcg/cm²				
2.05±0.10 1.92–2.15	2.01±0.007 2.003–2.01	2.02±0.01 2.00–2.03	1.97±0.20 1.78–2.18	2.09±0.07 2.01–2.16
Anthocyanin content, mcg/cm²				
0.14±0.003 0.11–0.17	0.11±0.001 0.10–0.11	0.23±0.01 0.18–0.25	0.14±0.004 0.12–0.17	0.28±0.01 0.27–0.29
Chlorophyll a+b content, mcg/cm²				
28.60±1.25 27.30–31.31	32.75±0.57 28.86–34.52	24.43±1.09 22.30–26.55	32.56±1.39 32.66–33.50	32.15±1.66 29.41–33.11
Flavonoid content, mcg/cm²				
1.77±0.06 1.70–1.88	1.88±0.02 1.83–1.92	2.30±0.08 2.29–2.32	1.55±0.02 1.51–1.61	1.54±0.03 1.50–1.66
Anthocyanin content, mcg/cm²				
0.08±0.001 0.07–0.10	0.11±0.001 0.10–0.12	0.13±0.003 0.10–0.16	0.02±0.001 0.01–0.03	0.07±0.003 0.06–0.08

* Average value and measurement error, ** minimum and maximum values.

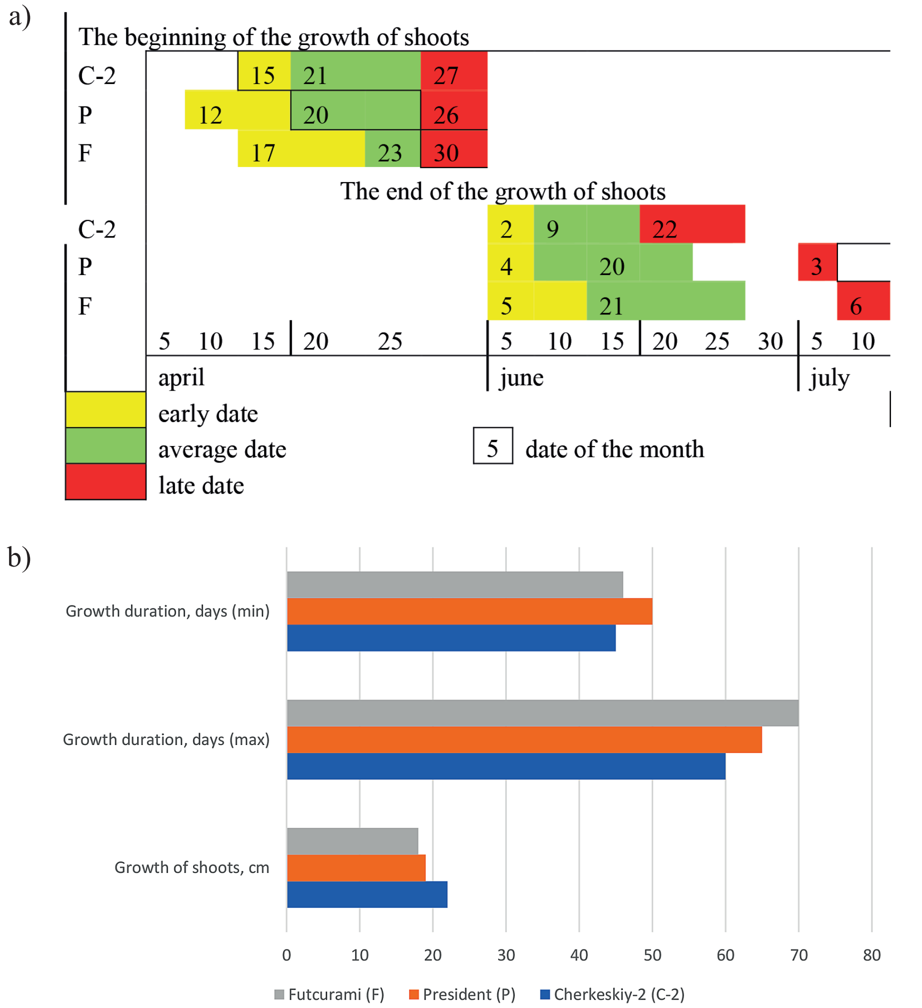

Figure 1. The specifics of growth processes: (a) by the timing and their variability of the onset and end of growth, (b) the duration of growth, growth indicators

Good illumination (from 77.0 to 108.8 kLx) with additional humidification affects the intensive formation of shoot systems, reduction of their growth duration, early transition from monopodial (tree-like growth stage) to sympodial branching type (bush-like growth stage) of shoots. Taking into account the analysis of the structure and morphogenesis of shoot systems, a volumetric model of their age composition and location is constructed. It was found that at the age of 15–20 years, uniform placement of shoots of different ages in a rounded shape with a diameter from 1.2 to 1.4 m is characteristic.

Taking into account the average longevity of the main shoots, it is possible to predict the onset of the second period – from the age of 32–35 (with the placement of shoots on the periphery of the ring formed, with a diameter of 1.6 m). For this age period, for all the studied forms, the growth-forming ability decreases – high-order axes have smaller diameter and height indicators. Taking into account the analysis of the structure and morphogenesis of shoot systems, a graphical model of their age composition and location is constructed. The criteria for the allocation of age stages of growth are the uniformity of placement, the age of shoots, the ability to resume (Figure 2). In this connection, measures are needed to extend the longevity of plants. Rejuvenating pruning can be continuous or partial and is largely determined by the intended purpose of planting.

CONCLUSIONS

The stability of plants under the influence of unfavorable environmental factors is determined by adaptive reactions at the molecular-genetic, physiological-biochemical, morphological, ontogenetic, biocenosis, population levels, which makes it necessary to study the structural-functional features and activity of metabolic processes

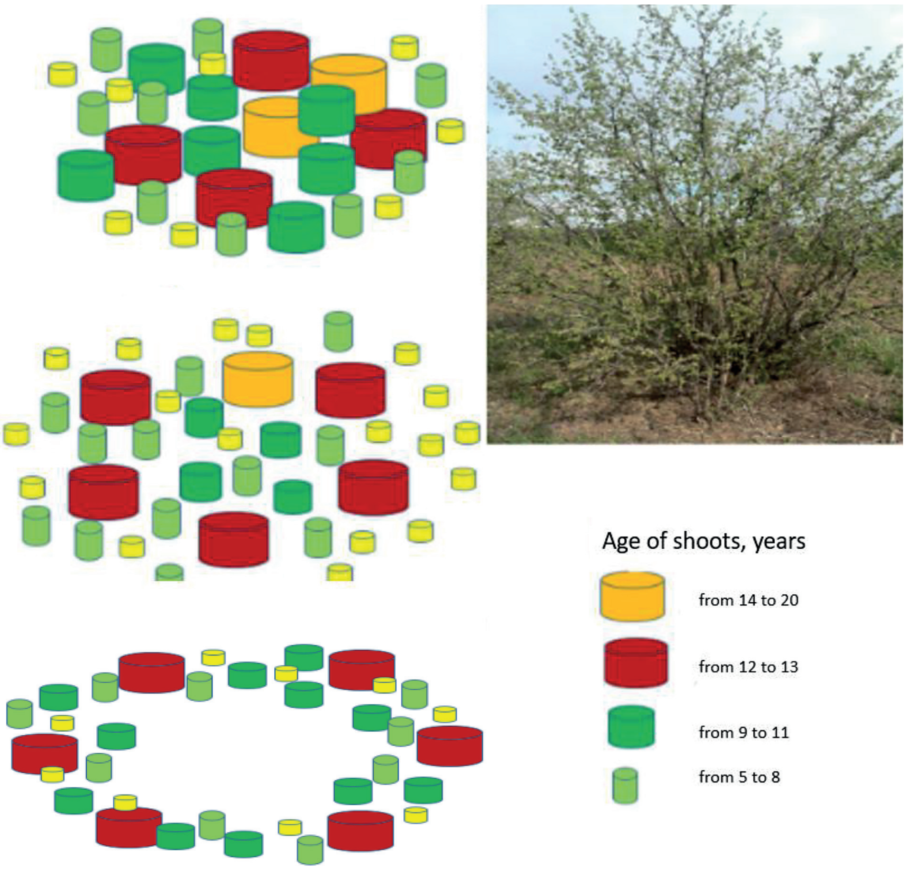

Figure 2. Features of the age structure and density of the bush:
(a) at the age of 20, (b) before 30, (c) after 35 (forecast)

in plants introduced to the region from other floral areas. Plant resistance assessment is an important final stage of introductory research. It makes it possible to identify ecological and biological features, phenotypic variability, and the feasibility of cultivating new species in the conditions of the introduction area. There are various methodological approaches to evaluating the results of the introduction, which usually use indicators of visual observations, that is, data on a qualitative (point) assessment of plant viability. Such traditional introductory studies become more important if they are supplemented with quantitative assessments (structural and functional criteria) at different levels of integration of living matter and the study of the mechanisms of stability of introducers in new growth conditions.

Biotic potential (adaptability, stability) is formed and realized due to a multi-level system of EXO-and endogenous mechanisms, such as adaptive phylogenetic and ontogenetic reactions. The intensity of their manifestation depends on the genotype, biotope, and anthropic factors. In the aspect of the interaction between two systems: the body and the environment, the main strategies of properties as criteria for structural and functional mechanisms are highlighted.

Acknowledgements

The research was carried out within the framework of the state task No. 0508–2021–0001 “Scientific foundations and technologies for enriching the dendroflora of forest reclamation complexes with economically valuable woody and shrubby plants in order to prevent degradation and desertification of territories” (Registration number: 121041200197–8) funded by the Ministry of Science and Higher Education of the Russian Federation

REFERENCES

1. Belitskaya M. 2019. Dendrophages Ulmus spp. in the forest plantation of the Volga region. World Ecology Journal, 9(1), 24–39. https://doi.org/https://doi.org/10.25726/NM.2019.77.24.002
2. Chamberlain S. et al. 2020. Taxize: Taxonomic information from around the web. R package version

0.9.98. https://github.com/ropensci/taxize.

3. Döring M. 2017. Zeigerwerte von Pflanzen & Flechten in Mitteleuropa. GBIF Secretariat https://doi.org/10.15468/tpngma
4. Hill M.O., Mountford J.O., Roy D.B., Bunce R.G.H. 1999. Ellenberg's indicator values for British plants. ECOFACT Volume 2 Technical Annex, 2. Institute of Terrestrial Ecology
5. IPNI. 2020. International Plant Names Index. Published on the Internet http://www.ipni.org, The Royal Botanic Gardens, Kew, Harvard University Herbaria & Libraries and Australian National Botanic Gardens
6. Jones L. et al. 2021. Barcode UK: A complete DNA barcoding resource for the flowering plants and conifers of the United Kingdom. Molecular Ecology Resources 21(6): 2050–2062 https://doi.org/10.1111/1755–0998.13388
7. Kattge J. et al. 2020. TRY plant trait database – enhanced coverage and open access. Global Change Biology 26, 119–188, https://doi.org/10.1111/gcb.14904.
8. Pierce S. et al. 2017. A global method for calculating plant CSR ecological strategies applied across biomes world-wide. Functional Ecology 31(2), 444–457.
9. Schleuning M. et al. 2020. Trait-based assessments of climate-change impacts on interacting species. Trends in Ecology & Evolution 35(4), 319–328.
10. Semenyutina A., Lazarev S., Melnik K. 2019. Assessment of reproductive capacity of representatives of ancestral complexes and especially their selection of seed in dry conditions. World Ecology Journal, 9(1), 1–23. https://doi.org/https://doi.org/10.25726/NM.2019.66.65.001
11. Taran S. & Kolganova I. 2018. Optimization of park plantings in the regions of Rostov-on-Don and Novocherkassk by introducing into gardening species of the genus ACER L. World Ecology Journal, 8(3), 56–70. https://doi.org/https://doi.org/10.25726/NM.2019.31.46.004
12. Tikhonov G. et al. 2020. Joint species distribution modelling with the R package HMSC. Methods in Ecology and Evolution 11(3), 442–447.
13. Tsembelev M. 2018. Studies on the drought tolerance of species of the genus CELTIS L. for forest reclamation plantations. World Ecology Journal, 8(3), 71–85. https://doi.org/https://doi.org/10.25726/NM.2019.44.92.005