Characterization of the size and spatiotemporal structure of the cenopopulation *Caragana arborescens* Lam. in the forest park of Yekaterinburg

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Abstract. The article is devoted to the study of the dimensional and space-time structure of *Caragana arborescens* Lam. in various ecological and cenotic conditions in the forest park named after. Foresters of Russia in Yekaterinburg on the basis of population and organismal parameters. For the first time, a quantitative characteristic of the manifestation of organismal indicators in each ontogenetic state of the caragana was obtained. Regularities in the manifestation of traits depending on the ontogenetic conditions of plants and forest type, as well as features of changes in traits that occur during the growth of individuals during the life period, are revealed. Features of the average values of the manifestation of traits in ontogenetic states can be associated with the number of individuals of a given state in the corresponding samples, while there is an influence of habitat conditions. A one-way analysis of variance, in which the habitat type of a coenopopulation fragment was a factor, showed a significant effect of the factor for traits of crown height and width. Significant differences in these traits of the habitat of the mixed herb meadow from other habitats and the reduced values of the traits in the forb pine forest are explained by the predominance of medium generative individuals in the first case, and juvenile individuals in the second. The ability of the species to successfully adapt in fragmented and urbanized areas affected by recreational impacts and other forms of pollution and survive in a wide range of environmental conditions has been established.

1 Introduction

Of the naturalized species of the Earth's flora - 3.9%, in regions new to them [1], the greatest threat to the diversity of aboriginal communities is associated with plants that can block the normal course of successions [2–5]. The tree caragana (*Caragana arborescens* Lam.) was chosen as the object of study not by chance, since due to the increasing rate of

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naturalization, it was included in the list (black-list) of potentially dangerous plants that tend to actively expand their secondary range in Central Russia [6]. Therefore, the study of the processes that occur in the forest park zone of Yekaterinburg during the naturalization of *Caragana arborescens* in them seems to be very relevant.

2 Materials and methods

According to the botanical and geographical zoning of the Sverdlovsk region, Yekaterinburg is located in the southern taiga boreal forest subzone [7] and is surrounded by forest parks and urban forests. The study of fragments of the cenopopulation was carried out in 2021 in four habitats in the forest park named after. Foresters of Russia (Figure 1).

The age structure was analyzed using standard methods [8–9]. The shares of plants of different ontogenetic states (*im*—immature, *v*—virginile, g_1—young generative, g_2—medium generative, g_3—late generative, *ss*—subsenile) in the total volume of samples for each forest park habitat were identified.

Fig. 1. The introduction of caragana tree in the forest park named after Lesovodov of Russia.

The characteristics of fragments of the cenopopulation of *Caragana arborescens* are given in accordance with the analysis of manifestation, variation, and observed differences depending on the type of forest or the community of dimensional features of the crown of individuals. The following traits were measured: heights H, diameters D_1 and D_2 in two perpendicular directions; the following traits were calculated: crown radii R, crown projection areas S, and volumes V. The volumes of the shares of plants of different ontogenetic states in the total volumes of samples for different types of forest or plant community were estimated. The mean values and variation indices (standard deviations) of crown size features for ontogenetic states were calculated. The nature of the relationship between the dimensional features of the crowns was revealed, graphs were plotted for

changes in the manifestation of features during the transition of individuals to the next ontogenetic state. To establish statistically significant differences in the size parameters of plant crowns, analysis of variance (ANOVA) was performed, in which the type of forest or community of the studied habitats was a factor.

3 Results

In the course of the study, the number of Caragana in various ecological and coenotic conditions in the forest park was established, this indicator varies from 247 to 1533 pieces per hectare (Table 1).

Table 1. Habitat characteristics of *Caragana arborescens* Lam. in the forest park named after Lesovodov of Russia.Formatting sections, subsections and subsubsections.

Habitat				
Cenopopulation fragment number	tree stand			Total density, ind./ha
	Forest type or plant community	compound	tightness of the tree canopy	
1	Birch forb	6B4Oc	0.5	1533
2	Herb meadow	-	-	244
3	Forb pine forest	10S	0.6	1288
4	Lipnyak herb	6Lp2S2B	0.5	1200
$X \pm mx$			0.4	1066

According to the GIS data of the AWP "Lesfond" program, it is in the forest park named after Foresters of Russia introduced and distributed the maximum number of caragana in comparison with other forest parks in Yekaterinburg. Based on the representation of ontogenetic groups in the total sample size for four habitats, one can speak about the time of naturalization of Caragana, the direction and rate of development of fragments of its cenopopulation (Table 2). It has been established that the habitats of Caragana in the pine forest, birch forest and mixed grass linden forest are young, since juvenile, immature and virginal individuals predominate in them, while in the habitat of the mixed grass meadow medium-generative plants dominate.

Table 2. Shares of representation of ontogenetic states of plants in the samples for different types of forests or plant communities.

Forest type or plant community	**Ontogenetic state**					
	j	***im***	***v***	g_1	g_2	g_3
Birch forb	0.00	0.27	0.60	0.08	0.05	0.00
Herb meadow	0.00	0.29	0.12	0.16	0.43	0.00
Forb pine forest	0.00	0.66	0.24	0.03	0.08	0.00
Lipnyak herb	0.37	0.30	0.13	0.07	0.07	0.07

As a result of the analysis of the average values and standard deviations of the dimensional features of the crown of Caragana arborescens in each ontogenetic state for habitats, it was found that the growth rate of individuals is different depending on the habitat (Table 3). The observed features of the manifestation of the average values of traits in these ontogenetic states can apparently be associated with the volume of representation of individuals of a given state in the corresponding samples.

Table 3. The average values of dimensional features of the crown of *C. arborescens* Lam. (M ± σ).

Onto-genetic state	H, m	D_1, m	D_2, m	R, m	S, m^2	V, m^3
	Birch forb					
im	0.33 ± 0.151	0.15 ± 0.058	0.14 ± 0.057	0.07 ± 0.026	0.02 ± 0.013	0.002 ± 0.003
v	1.52 ± 0.557	0.68 ± 0.352	0.56 ± 0.340	0.31 ± 0.167	0.39 ± 0.395	0.252 ± 0.320
g_1	2.19 ± 0.455	1.32 ± 0.546	1.07 ± 0.256	0.59 ± 0.178	1.22 ± 0.625	0.907 ± 0.542
g_2	2.96 ± 1.025	2.68 ± 1.286	2.61 ± 1.328	1.32 ± 0.653	6.84 ± 6.375	8.657 ± 9.596
	Herb meadow					
im	0.34	0.18	0.15	0.08	0.02	0.002
v	1.48 ± 0.578	0.68 ± 0.388	0.63 ± 0.367	0.32 ± 0.183	0.44 ± 0.457	0.298 ± 0.389
g_1	2.36 ± 0.390	1.53 ± 0.339	1.57 ± 0.411	0.77 ± 0.153	1.95 ± 0.750	1.597 ± 0.754
g_2	2.68 ± 0.459	1.79 ± 0.584	1.79 ± 0.600	0.89 ± 0.262	2.75 ± 1.408	2.634 ± 1.488
	Forb pine forest					
im	0.55 ± 0.231	0.20 ± 0.119	0.18 ± 0.131	0.09 ± 0.052	0.03 ± 0.043	0.009 ± 0.012
v	1.49 ± 0.337	0.48 ± 0.334	0.35 ± 0.201	0.21 ± 0.131	0.19 ± 0.233	0.117 ± 0.186
g_1	1.71 ± 0.236	0.53 ± 0.385	0.37 ± 0.290	0.22 ± 0.167	0.25 ± 0.334	0.155 ± 0.218
g_2	2.67	1.9	1.79	0.92	2.67	2.378
g_3	3.86 ± 0.532	2.86 ± 1.517	2.59 ± 1.634	1.36 ± 0.787	7.79 ± 8.096	10.49 ± 11.30
	Lipnyak herb					
j	0.51 ± 0.187	0.20 ± 0.060	0.27 ± 0.266	0.11 ± 0.064	0.05 ± 0.077	0.008 ± 0.008
im	1.12 ± 0.335	0.42 ± 0.224	0.28 ± 0.177	0.17 ± 0.093	0.12 ± 0.123	0.052 ± 0.058
v	1.77 ± 0.443	1.04 ± 0.234	0.83 ± 0.243	0.46 ± 0.115	0.73 ± 0.337	0.463 ± 0.266
g_1	2.5 ± 0.099	1.67 ± 0.275	1.7 ± 0.099	0.84 ± 0.093	2.26 ± 0.496	1.869 ± 0.338
g_2	2.3	1.8 ± 0.3	1.65 ± 0.350	0.86 ± 0.162	2.41 ± 0.880	1.854 ± 0.674
g_3	3.55 ± 0.450	2.5 ± 0.5	2.35 ± 0.65	1.21 ± 0.037	4.62 ± 0.285	5.510 ± 1.030

Figure 2 shows graphs of the total (individuals of all habitats participate) changes and variations in the dimensional traits of plant crowns (H, D_1), within one ontogenetic state, on the graphs, the magnitudes of the traits are sorted in ascending order. The above graphs for H and D_1 show the nature of the increase in the size of plant crowns, including the average values of traits, occurring simultaneously with their growth and their transition to the subsequent ontogenetic state. Figure 3 shows the relationship between the features D_1 and H, D_2 and D_1, in the first case the relationship is quadratic (R^2=0.741, $p<0.05$) in the second case the relationship is linear (R^2=0.873, $p<0.05$). Linear dependence means strict proportionality, in the presence of some stably manifested crown asymmetry. The quadratic dependence of diameters D_1 and heights H means a change in the proportionality coefficient between sizes in two directions of crown growth.

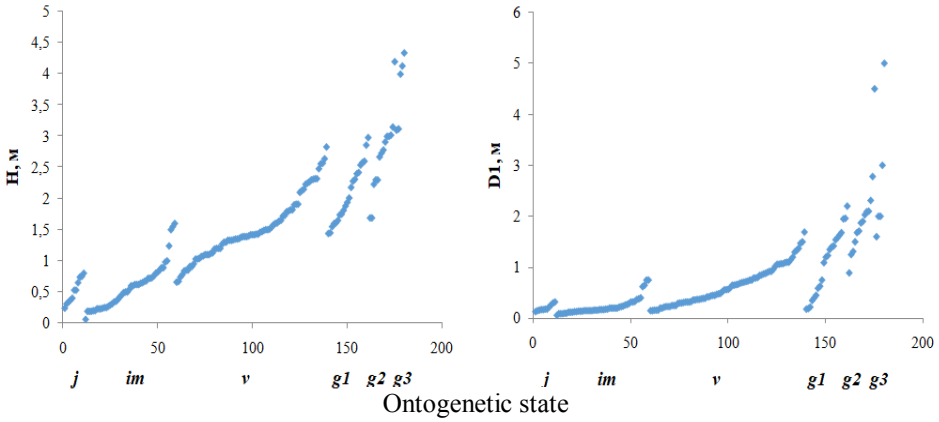

Fig. 2. Changes in traits of heights (H) and diameters (D_1) of *C. arborescens* Lam. depending on the ontogenetic state.

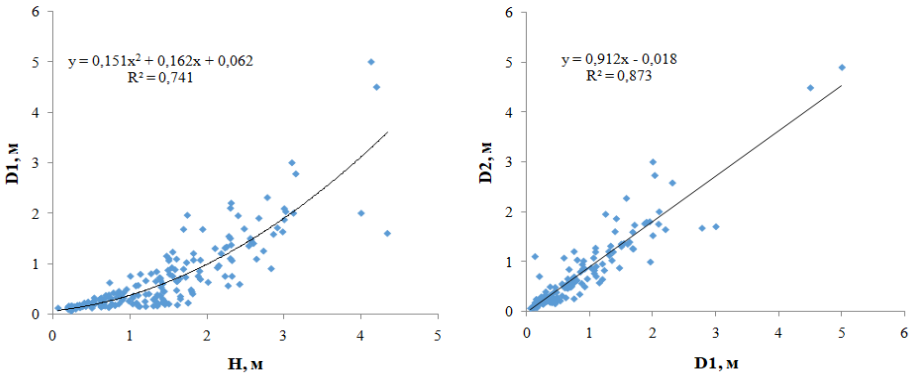

Fig. 3. Graphs of dependence of dimensional characteristics of crowns of *C. arborescens* Lam. (H, D_1, D_2).

When conducting a one-way analysis of variance (ANOVA), where the habitat type of Caragana arborescens was a factor, it was found that the effect it has on the values of crown size traits (for traits H, $D_{1,2}$ and R) is significant at a high level of significance ($p<0.01$, in table 4) (Figure 4 and Table 4).

Table 4. The results of a univariate analysis for the size characteristics of the crown of plants *C. arborescens* Lam.

Parameter	F-value	df effect	df errors	p-level
H, m	4.297	3	176	0.0059
D_1, m	4.639	3	176	0.0038
D_2, m	6.636	3	176	0.000285
R, m	5.773	3	176	0.00087
S, m^2	1.044	3	176	0.375
V, m^3	0.298	3	176	0.827

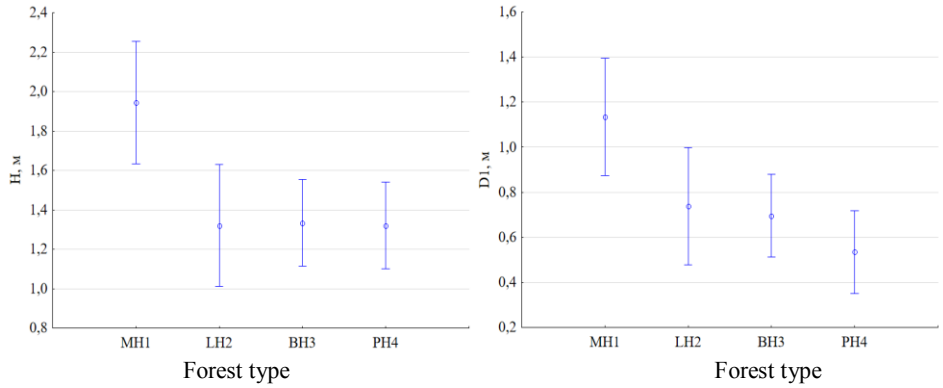

Fig. 4. Mean values of signs and 95% confidence intervals for the averages, (MH1, LH2, BH3, PH4 - respectively herb meadow, herb linden forest, herb birch forest, herb pine forest).

4 Discussion

Caragana tree according to our research naturalized in the forest park named after. Foresters of Russia and expands the secondary range in the forest parks of Yekaterinburg, this is confirmed by the data of the GIS program of the AWP "Lesfond". It grows in 14 out of 15 forest parks, occupying an area of 370.7 hectares, mainly in mixed grass pine forests. In the age structure of the caragana tree in the forest park named after. Foresters of Russia have established two periods: pregenerative and generative. Five ontogenetic states have been identified. It has been established that the habitats of Caragana in the pine forest, birch forest and linden forest of mixed herbs are young, since juvenile, immature and virginal individuals predominate in them, medium-sized plants dominate in the habitat of the mixed grass meadow. The features of manifestation of averages and variations of crown size traits for different ontogenetic states and habitats are apparently associated with the number of individuals in different states in the corresponding samples, while the ecological and cenotic conditions of the corresponding habitat also affect. One-way analysis of variance (the factor was the habitat type of the cenopopulation fragment) showed a high level of significance ($p<0.01$) of the effect of the factor for traits H, $D_{1,2}$ and R. Significant differences in these habitat traits forb meadow from other habitats (Figure 3) and lower values of the D_1 trait in the forb pine forest are explained by the presence of a large number of individuals in the medium generative and juvenile states, respectively.

5 Conclusion

As a result of studying the age parameters of fragments of the cenopopulation, their habitats and quantitative signs of the size of the crowns of *Caragana arborescens* plants in the corresponding samples in the forest park named after. Foresters of Russia have established patterns of manifestation of signs depending on the ontogenetic conditions of plants and ecological and cenotic conditions of habitats, as well as the features of changes in signs that occur during the growth of individuals during ontogenesis. The obtained age and quantitative patterns of growth of *Caragana arborescens* in the cenopopulation are of scientific interest, as they allow us to make a forecast regarding the further development of the species, and also contribute to understanding the fitness and development of this species in environmental conditions specific to the region.

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