Analysis of patterns of light interception by the crowns of *Cotoneaster lucidus* Schlecht bushes. in various ontogenetic states in the Kalinovsky Forest Park of Yekaterinburg

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Abstract. In the forest park area of Yekaterinburg *Cotoneaster lucidus* Schlecht. found as a naturalized introduced species in various forms of plantings. With increasing anthropogenic pressure on suburban forests, it is important to study the biological characteristics of invasive species and their intraspecific differentiation to preserve the gene pool, therefore, studying the patterns of manifestation of the size, ontogenetic and structural parameters of cotoneaster in coenopopulations makes it possible to identify the peculiarities of the dynamics of their development and give a complete picture of the processes of adaptation of this species to the conditions growth. The article studied the lighting parameters in different parts of the crowns of *C. Lucidus* bushes of various ontogenetic states, and analyzed their ability to intercept light. The parameters of lighting and its interception largely depend on the structural features and size of the crowns of bushes, their age and ontogenetic state. With age (transition to later ontogenetic states), the parameter of illumination received above the crown increases, the interception of illumination by entire crowns of bushes increases from 33.2% for j to 68.4% in the late generative state (at the same time, the interception of illumination by the lower parts of the crowns is relatively stable, varying from 10.7% to 16.7%), the correlation between the parameters of illumination and its interception in different parts of the crown becomes less pronounced. The latter is associated with the development of an increasingly complex and dense structure in the volume of the crowns of *C. lucidus* bushes.

1 Introduction

Alien invasive plants in some cases are capable of exhibiting the properties of strong edificators [1]. The impacts of invasive plant species can be realized by influencing the light regime of communities, nutrient cycles, and various components of the biota. Many

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researchers argue that alien plants create a denser leaf canopy than native plants [2-5]. The manifestations of *Cotoneaster lucidus* in relation to the shading effect on native flora in the secondary habitat in forest parks of Yekaterinburg have been little studied. The purpose of the study is to analyze the interception of the light regime in various ontogenetic states of *C. lucidus* individuals in the Kalinovsky Forest Park of Yekaterinburg.

2 Materials and methods

According to the botanical and geographical zoning of the Sverdlovsk region, the city of Yekaterinburg is located in the southern taiga boreal forest subzone [6], it is surrounded by forest parks and urban forests. A study of individuals of different ontogenetic states of *C. lucidus* was carried out in 2023 in four habitat fragments (HF) in the Kalinovsky Forest Park of Yekaterinburg. Standard methods were used to characterize habitats [7-8]. Illumination was assessed using a digital multifunctional environmental parameter meter MS-6300. The initial measurement of illumination in the clearing (at the control point) was 4270 lux, then the illumination indicators were measured: above the crown, in the middle of the height of the cotoneaster and at the base of the stems.

The average values and standard errors of the parameters of crown size of *C. lucidus*, illumination in different parts of the crown, and illumination interception were calculated. The correlations between the measured parameters of illumination and light interception with the dimensional parameters of the crowns, as well as with each other depending on the ontogenetic states of the plants, were analyzed. Differences in the values of illumination and light interception in different parts of the crowns for various ontogenetic states were assessed using parametric ANOVA (F test) and nonparametric Kruskal–Wallis analysis (H test).

3 Results

Cotoneaster lucidus Schlecht. - one of the oldest plants that originated in Southeast Asia, with many primitive characteristics. Its introduction range extends throughout Eurasia and Europe. Cotoneaster has actively invaded all forest parks in Yekaterinburg. Its spread was facilitated by the presence of edible, long-lasting fruits on the shoots, which provided food for many species of birds [9]. In the forest parks under study, the number of cotoneaster individuals ranges from 480 to 12,000 individuals per hectare with a tree canopy density of 0.6–0.7 (Table 1).

Table 1. Characteristics of fragments of cotoneaster habitats in the Kalinovsky forest park.

Habitat				
Habitat fragment number	tree stand			Total density, ind./ha
	Forest type	compound	tree canopy density	
1	Pine forest of various herbs	6C4B	0.7	750
2	Pine forest of various herbs	6C4B	0.7	480
3	Pine forest of various herbs	10C	0.6	12000
4	Pine forest of various herbs	7C3Lp	0.6	4100
$X \pm mx$			0.65	4332

When studying the interception of light, the following average parameters were obtained in different parts of the crown of *C. lucidus* (designations L, ΔL: above - illumination above the crown, inside - in the middle of the height of the stem, below - under the crown at the base) (Table 2), the values of the relative interception of radiation to illumination above the crown (Table 3).

Table 2 shows the mean values and standard errors of the dimensional parameters of the crowns of *C. lucidus* bushes, as well as lighting in different parts of the crowns. An increase in the size of the crowns with the transition between ontogenetic states is confirmed, accompanied by an increase in the initially incident light above the crowns of the bushes.

Table 2. Average values of parameters of *C. lucidus* crowns in various ontogenetic states, lighting and light interception by parts of crowns (X ± mx).

Ont. comp.	H, m	$D_{average}$, m	L_{above}, lk	L_{inside}, lk	L_{below}, lk	$L_{above} - L_{inside}$, lk	$L_{inside} - L_{below}$, lk	$L_{above} - L_{below}$, lk
J	0.47 ± 0.09	0.2 ± 0.02	190 ± 28.2	170 ± 28.3	127 ± 21.6	19 ± 8.6	44 ± 18	63 ± 15.1
Im	0.78 ± 0.04	0.54 ± 0.06	227 ± 24.7	156 ± 16.4	126 ± 12.3	71 ± 16.1	30 ± 5.9	101 ± 18.3
V	1.3 ± 0.05	1.05 ± 0.1	329 ± 18.5	204 ± 13.7	151 ± 10.7	125 ± 13.4	53 ± 7.3	179 ± 15.8
g1	1.49 ± 0.08	1.40 ± 0.11	401 ± 26.7	241 ± 21.7	173 ± 12.8	160 ± 15.9	67 ± 15.9	228 ± 24.1
g2	2.18 ± 0.11	2.75 ± 0.17	458 ± 32.9	196 ± 12.7	147 ± 10.5	262 ± 29	49 ± 8.4	311 ± 33.5
g3	2.43 ± 0.14	3.79 ± 0.32	455 ± 43.5	208 ± 29.1	144 ± 22.4	247 ± 22.3	64 ± 18.7	311 ± 28.4

Table 3 shows the values of the relative interception of illumination by the crowns of bushes, expressed as a percentage of the initial incident illumination above the crowns.

Table 3. Relative values of light interception by different parts of the crown of *C. lucidus* in different ontogenetic states as a percentage of the initial one.

Ont. comp.	Interception of lighting by the entire crown, %	Interception of illumination by the upper half of the crown, %	Interception of illumination by the lower half of the crown, %
	$(L_{above}–L_{below})/L_{above}*100\%$	$(L_{above}–L_{inside})/L_{above}*100\%$	$(L_{inside}–L_{below})/L_{above}*100\%$
J	33.2	10	23.2
Im	44.5	31.3	13.2
V	54.4	38	16.1
g1	56.9	39.9	16.7
g2	67.9	57.2	10.7
g3	68.4	54.3	14.1

The interception of illumination by the full crown of cotoneaster as a percentage of the initially incident illumination increases with the development of individuals and the transition between ontogenetic states and for plants in the generative state is 57–68%. In this case, the interception of illumination from the initial lower half of the crown of the bushes for late ontogenetic states is 10.7 – 16.7%.

Table 4 shows the correlation coefficients between the dimensional parameters of the bush crowns and the parameters of lighting and light interception in different parts of the crown. From Table 4 one can see a correlation with the height and with the average diameters of the bushes of the initially incident lighting above the crowns; one can note the correlations between the interception of lighting by the entire crown and the dimensional parameters of the crown indicated in the table.

Table 4. Correlations between canopy parameters and light and light interception parameters.

Signs	L_{above}	L_{inside}	L_{below}	$L_{above} - L_{inside}$	$L_{inside} - L_{below}$	$L_{above} - L_{below}$
H	0.552*	0.114	-0.007	0.625*	0.203*	0.611*
D_{min}	0.542*	0.114	-0.005	0.613*	0.2*	0.6*
D_{max}	0.522*	0.096	0.007	0.599*	0.155	0.573*
$D_{average}$	0.535*	0.105	0.001	0.61*	0.177	0.589*
V	0.412*	0.036	-0.065	0.497*	0.142	0.479*

* indicate significant differences at the $p<0.001$ level

Table 5 presents correlations between logarithmized parameters of illumination and its interception by bush crowns for three ontogenetic states (tables for states g_1 and g_3 are not shown due to the large volume of material). Logarithmization is necessary to reduce the variance of the illumination data.

Table 5. Correlations between logarithmic light and light intercept parameters for three ontogenetic states of *C. lucidus* (bold and).

		L_{above}	L_{inside}	L_{below}	$L_{above} - L_{inside}$	$L_{inside} - L_{below}$	$L_{above} - L_{below}$
Im	L_{above}	1.0	0.798*	0.748*	0.746*	0.701*	0.839*
	L_{inside}		1.0	0.964*	0.293	0.779*	0.49*
	L_{below}			1.0	0.233	0.617*	0.381
	$L_{above} - L_{inside}$				1.0	0.471*	0.946*
	$L_{inside} - L_{below}$					1.0	0.695*
	$L_{above} - L_{below}$						1.0
V	L_{above}	1.0	0.679*	0.523*	0.623*	0.493*	0.738*
	L_{inside}		1.0	0.866*	-0.099	0.498*	0.109
	L_{below}			1.0	-0.226	0.013	-0.153
	$L_{above} - L_{inside}$				1.0	0.253	0.942*
	$L_{inside} - L_{below}$					1.0	0.541*
	$L_{above} - L_{below}$						1.0
g2	L_{above}	1.0	0.471*	0.20	0.768*	0.41*	0.883*
	L_{inside}		1.0	0.81*	-0.122	0.313	0.073
	L_{below}			1.0	-0.248	-0.186	-0.24
	$L_{above} - L_{inside}$				1.0	0.137	0.912*
	$L_{inside} - L_{below}$					1.0	0.48*
	$L_{above} - L_{below}$						1.0

* indicate significant differences at the $p<0.05$ level

It can be seen that almost all lighting parameters correlate with the initial lighting above the crown. With plant growth and transition to later ontogenetic states, the correlation between parameters becomes less.

Figure 1 illustrates the average values and values of variation in the parameters of the initial lighting and lighting in different parts of the crown of the bushes. The corresponding patterns of changes in parameters depending on the ontogenetic state of plants have been established.

Table 6 shows the results of comparison using analysis of variance of all ontogenetic states of *C. lucidus* according to the parameters of illumination and its interception. Statistically significant differences are confirmed among the values of initial illumination above the crowns, also among the values of illumination inside the crowns, and among the values of interception of illumination - by the upper halves and all crowns as a whole. There are no statistically significant differences among the magnitudes of illumination under the crowns and among the magnitudes of interception of illumination by the lower parts of the crowns.

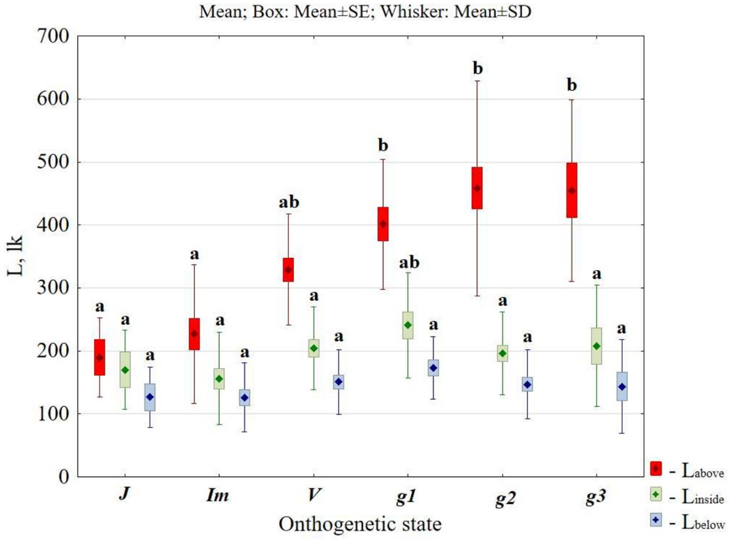

Fig. 1. Average, st. deviations and Art. errors in lighting parameters: lighting above the crowns of *C. lucidus* bushes – red, lighting in the middle of the crowns – green, lighting under the crowns – blue.

Table 6. Results of comparison of various ontogenetic states of *C. lucidus* bushes in terms of lighting and light interception parameters using analysis of variance (parametric ANOVA F, and nonparametric Kruskal–Wallis H) (cases of significant differences at the p < 0.05 level are highlighted in bold).

Parameter	Criterion	F(5;95)	KW-H(5;101)
L_{above}, lk	Meaning	**11.21**	**43.20**
	p-level	<0.00001	<0.00001
L_{inside}, lk	Meaning	**2.51**	10.41
	p-level	0.0352	0.0645
L_{below}, lk	Meaning	1.43	8.26
	p-level	0.2210	0.1426
$L_{above} – L_{inside}$, lk	Meaning	**13.87**	**51.8**
	p-level	<0.00001	<0.00001
$L_{inside} – L_{below}$, lk	Meaning	1.52	7.13
	p-level	0.1906	0.2109
$L_{above} – L_{below}$, lk	Meaning	**11.51**	**47.3**
	p-level	<0.00001	<0.00001

4 Discussion

According to the analysis of average values, with the growth of *C. Lucidus* bushes (during which the transition of individuals into subsequent ontogenetic states occurs), both the dimensional parameters of the crown and the initially incident L_{above} lighting on them increase. Apparently, this is due to the position the bushes occupy depending on their size under the canopy and the fact that taller and more developed plants occupy a more advantageous position in relation to the available light. The interception of illumination by the crowns of *C. Lucidus* bushes increases: for the juvenile j state it is equal to 33.2%, and for the late generative states g_2, g_3 it is equal to 68–68.4%. Most of the intercepted light falls on the upper half of the crown, while the interception by the lower half of the crown is small and relatively stable, accounting for 10.7 - 16.7% of the incident light. The patterns described above indicate the structural features of the crowns of *C. lucidus* bushes. There is a statistically significant correlation with the heights and diameters of the crowns of the bushes of the parameters: initial lighting above the crowns (L_{above}), interception of lighting by all crowns as a whole (L_{above} - L_{below}), interception of lighting by the upper halves of the crowns (L_{above} - L_{inside}).

Correlation analysis of lighting parameters and light interception revealed that almost all lighting parameters in different parts of the crown and light interception correlated with the initial lighting above the crowns. With the growth of bushes and the transition to later ontogenetic states, the correlation between the parameters becomes less, which is apparently due to the development of an increasingly densely filled structure with shoots and foliage in the volume of the bush crowns. It should be noted that there is no correlation between the illumination under the crowns (L_{below}) and the interception of illumination by the upper part of the crowns (L_{above} - L_{inside}), as well as the interception of illumination by all crowns as a whole (L_{above} - L_{below}). Absence or low correlation between illumination inside the crowns (Linside) and the interception of illumination by the upper part of the crowns (L_{above} - L_{inside}), as well as the interception of illumination by all crowns (L_{above} - L_{below}).

According to the results of the ANOVA analysis, statistically significant differences between plants in different ontogenetic states are confirmed in the values of initial illumination above the crowns (L_{above}), also in the values of illumination inside the crowns (L_{inside}), and among the values of interception of illumination by interception by the upper halves (L_{above} - L_{inside}) and all entire crowns (L_{above} – L_{below}). There are no statistically significant differences in the values of illumination under the crowns (L_{below}) and among the values of interception of illumination by the lower parts of the crowns (L_{inside} - L_{below}).

5 Conclusion

Based on the results of the analysis of data on lighting in different parts of the crowns of *Cotoneaster lucidus* bushes of various ontogenetic states, it can be concluded that the parameters of lighting and its interception largely depend on the structural features and sizes of the crowns of bushes, their age and ontogenetic state (this is especially true for the initial lighting parameter above the crowns), with the latter the lighting parameters in other parts of the crowns correlate. With age (transition to later ontogenetic states), the correlation between the parameters of illumination and its interception in different parts of the crown becomes less pronounced. The ability of cotoneaster to influence the grass cover is due to a strong decrease in the intensity of the light regime under the canopy of its bushes due to shading by the crown.

References

1. D.M. Richardson, P. Pysek, M. Rejmanek, M.G. Barbour, F.D. Panetta,C.J. West, Divers. Distrib, **6**, **2**, 93–107 (2000)
2. K.O. Reinhart, J. Gurnee, R. Tirado, R.M. Callaway, Ecological applications: a publication of the Ecological Society of America, **16**, **5**, 1821–1831 (2006)

3. C. Nilsson, O. Engelmark, J. Cory, A. Forsslund, E. Carlborg, For. Ecol. Manage, **255**, **5-6**, 1900–1905 (2008)
4. D.F. Cusack, T.L. McCleery, Forest Ecology and Management, **318**, 34–43 (2014)
5. C. Berg, A. Drescherl, F. Essl, TUEXENIA, **37**, 127–142 (2017)
6. P.V. Kulikov, N.V. Zolotareva,E.N. Podgaevskaya, Endemic plants of the Urals in the flora of the Sverdlovsk region (Goshchitsky, Ekaterinburg, 2013)
7. E.A. Tishkina, IOP Conf. Ser.: Earth Environ. sci., **1045**, 012069 (2022)
8. A.A. Montile, E.A. Tishkina, IOP Conf. Ser.: Earth Environ. sci., **1045**, 012118 (2022)
9. E.A. Tishkina, L.A. Semkina, I.V. Shevelina, Izv. universities Forest zhurn., **5**, 73-84 (2022)