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Variability of leaves of *Betula pendula* Roth during the growing season in the recreation area in the industrial center

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Abstract. Research was carried out at the Ufa Industrial Center on the territory of recreational zone. Morphological changes in birch leaves (*Betula pendula* Roth) during the growing season of 2019 are shown. Model birch trees grow on a permanent trial plot. On the trees, 10 leaves were numbered. During the growing season (June – September) photographs of each leaf were taken. The integral indicator of the stability of leaf development is calculated on five grounds. Statistical processing of the data obtained. It has been established that there are deviations in the morphological development of birch leaves. It is shown that an individual trajectory of morphological development is characteristic of leaves. The phenomenon of adaptive polymorphism of birch leaves is noted. Moreover, the morphological and functional features of the leaf are inextricably linked.

Keywords: birch, integral indicator, leaf polymorphism, industrial center

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Изменчивость листьев *Betula pendula* Roth в течение вегетационного периода в рекреационной зоне промышленного центра

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Аннотация. Исследования проводились в Уфимском индустриальном центре на территории рекреационной зоны. Показаны морфологические изменения листьев березы (*Betula pendula* Roth) в вегетационный период 2019 г. Модельные березы растут на постоянном опытном участке. На деревьях были пронумерованы 10 листьев. Во время вегетационного периода (июнь – сентябрь) сделаны фотографии каждого листа. Интегральный показатель устойчивости развития листьев рассчитывается по пяти признакам. Выполнена статистическая обработка полученных данных. Установлено, что имеются отклонения в морфологическом развитии листьев березы. Показано, что для листьев характерна индивидуальная траектория морфологического развития. Отмечается феномен адаптивного полиморфизма листьев березы. При этом морфологические и функциональные особенности листа неразрывно связаны.

Ключевые слова: береза, интегральный показатель, полиморфизм листьев, промышленный центр

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Introduction

The features of leaf growth [1] during the growing season are not well understood. Peculiarities of morphological changes in leaves during the growing season should be taken into account when organizing monitoring studies [2].

In assessing the resistance of plants, depending on the conditions of their growth, the method of assessing the development stability and asymmetry is used [3–10].

The aim of the work was to study the morphological changes in *Betula pendula* Roth leaves under environmental pollution.

The subject of the research is *Betula pendula* plantations.

Materials and methods

The studies were conducted in the recreation area on the territory of the Ufa Industrial Center. A general description of the stands has been presented previously [2].

Objects of study – model trees *Betula pendula* Roth. One tree is large-leaved, the other is small-leaved. In the crown of each tree, 10 leaves are numbered. Each leaf was photographed during the growing season (June – September). In August, reconstruction activities were carried out in the park. Small-leaved tree was cut down. Therefore, data on small-leaved tree are presented for June, July and August. Used a Nikon D40 digital camera. Photographs of the leaves were computer processed using standard programs.

A method was used to study the morphological characters of leaves [11; 12]. The stability of the development of leaves of tree stands is estimated. The studies were carried out in 2019, which was characterized by average values of weather and climatic conditions.

The actual material for assessing the stability of development of birch leaves is the morphological characteristics of the right and left halves of the leaf according to 5 signs [13]:

1) the width of the left and right halves of the sheet;

2) the length of the vein of the second order from the base of the leaf;

3) the distance between the bases of the first and second veins of the second order;

4) the distance between the ends of these veins;

5) the angle between the main vein and the second vein of the second order from the base of the sheet.

Statistical processing of the research results was carried out in the programs: STATISTICA, GraphPad Prism, Microsoft Excel.

Results

Shown are changes in birch leaves during the growing season [14]. The integral indicator of the stability of leaf development (small-leaved tree and large-leaved tree) was calculated according to five criteria [15] (Figures 1–5). The obtained data were statistically processed, 1-way ANOVA, ANOVA (Tables 1–15).

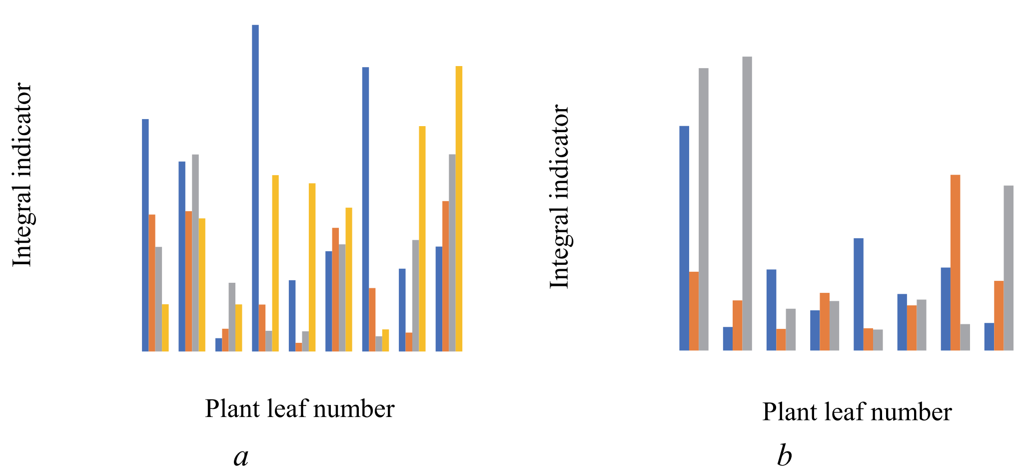


Figure 1. Integral index of stability of leaf development (the 1st sign):
a – large-leaved tree; *b* – small-leaved tree

Table 1

Column statistics (the 1st sign)

Month	June		July		August		September	
Tree	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved
Number of values	9	8	9	8	9	8	9	–
Minimum	0.005	0.012	0.003	0.011	0.006	0.011	0.009	–
Maximum	0.132	0.117	0.061	0.092	0.080	0.154	0.116	–
Mean	0.063	0.042	0.032	0.034	0.038	0.061	0.056	–
Std. Deviation	0.043	0.034	0.024	0.026	0.029	0.060	0.036	–
Std. Error	0.014	0.012	0.008	0.009	0.010	0.021	0.012	–
Lower 95% CI of mean	0.030	0.014	0.014	0.013	0.016	0.011	0.029	–
Upper 95% CI of mean	0.096	0.071	0.050	0.055	0.060	0.111	0.083	–
Coefficient of variation	68.28%	80.93%	74.00%	75.48%	75.69%	98.86%	63.48%	–
Sum	0.569	0.338	0.289	0.272	0.340	0.488	0.505	–

Table 2

1-way ANOVA (the 1st sign)

Parameter	**Value**	
	Large-leaved tree	**Small-leaved tree**
P value	0.180	0.445
P value summary	ns	ns
Are means signif. different? (P < 0,05)	No	No
Number of groups	4	3
F	1.735	0.841
R squared	0.140	0.074

Table 3

ANOVA (the 1st sign)

ANOVA Table	**SS**	**df**	**MS**
Large-leaved tree			
Treatment (between columns)	0.00587	3	0.00196
Residual (within columns)	0.03611	32	0.00113
Total	0.04199	35	
Small-leaved tree			
Treatment (between columns)	0.00306	2	0.00153
Residual (within columns)	0.03825	21	0.00182
Total	0.04131	23	

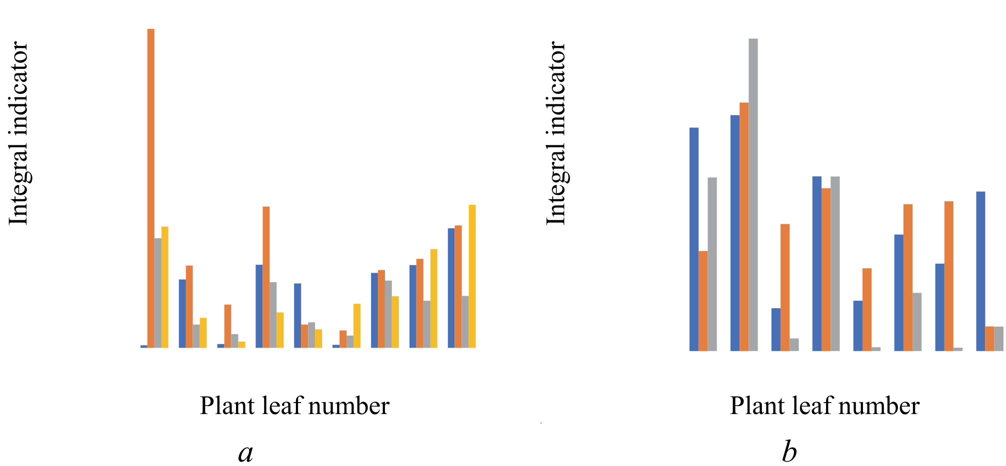


Figure 2. Integral index of stability of leaf development (the 2nd sign):
a – large-leaved tree; *b* – small-leaved tree

Table 4

Column statistics (the 2nd sign)

Month	June		July		August		September	
Tree	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved
Number of values	9	8	9	8	9	8	9	–
Minimum	0.001	0.007	0.005	0.004	0.003	0.001	0.002	–
Maximum	0.033	0.039	0.088	0.041	0.030	0.051	0.039	–
Mean	0.016	0.022	0.028	0.021	0.013	0.016	0.017	–
Std. Deviation	0.012	0.012	0.025	0.011	0.009	0.018	0.013	–
Std. Error	0.004	0.004	0.008	0.004	0.003	0.007	0.004	–
Lower 95% CI of mean	0.007	0.012	0.009	0.012	0.006	0.000	0.007	–
Upper 95% CI of mean	0.025	0.033	0.047	0.030	0.019	0.031	0.027	–
Coefficient of variation	75.32%	55.30%	90.32%	50.51%	69.22%	117.91%	78.57%	–
Sum	0.140	0.179	0.252	0.171	0.113	0.125	0.150	–

Table 5

1-way ANOVA (the 2nd sign)

Parameter	**Value**	
	Large-leaved tree	**Small-leaved tree**
P value	0.207	0.600
P value summary	ns	ns
Are means signif. different? (P < 0,05)	No	No
Number of groups	4	3
F	1.609	0.523
R squared	0.131	0.047

Table 6

ANOVA (the 2nd sign)

ANOVA Table	**SS**	**df**	**MS**
	Large-leaved tree		
Treatment (between columns)	0.00124	3	0.00041
Residual (within columns)	0.00819	32	0.00026
Total	0.00943	35	
	Small-leaved tree		
Treatment (between columns)	0.00021	2	0.00011
Residual (within columns)	0.00426	21	0.00020
Total	0.00448	23	

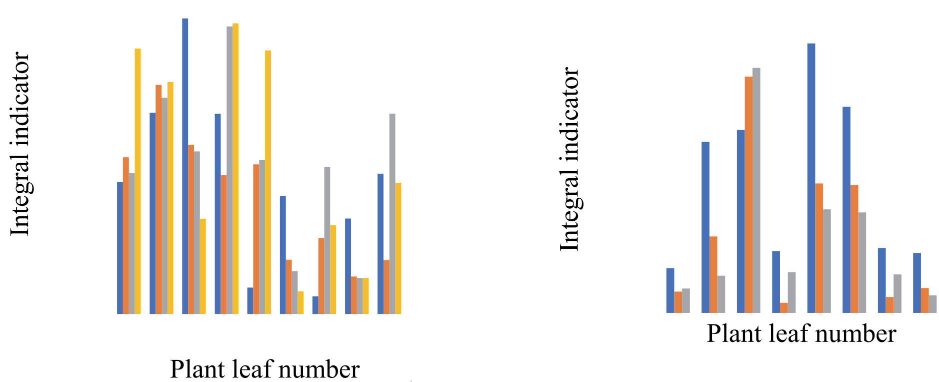
1st sign – the width of the left and right halves of the leaf. Bartlett’s test for equal variances. Large-leaved tree: bartlett’s statistic (corrected) 3.014; P value 0.389; P value summary “ns”; Do the variances differ signif. ($P < 0.05$) – “No”. Small-leaved tree: bartlett’s statistic (corrected) 5.063; P value 0.080; P value summary “ns”; Do the variances differ signif. ($P < 0.05$) – “No”.

2nd sign – the length of the vein of the second order from the base of the leaf. Bartlett’s test for equal variances. Large-leaved tree: bartlett’s statistic (corrected) 10.1; P value 0.018; P value summary “ns”; Do the variances differ signif. ($P < 0.05$) – “Yes”. Small-leaved tree: bartlett’s statistic (corrected) 2.128; P value 0.345; P value summary “ns”; Do the variances differ signif. ($P < 0.05$) – “No”.

3rd sign – the distance between the bases of the first and second veins of the second order of the leaf. Bartlett’s test for equal variances. Large-leaved tree: bartlett’s statistic (corrected) 1.746; P value 0.627; P value summary “ns”; Do the variances differ signif. ($P < 0.05$) – “No”. Small-leaved tree: bartlett’s statistic (corrected) 0.086; P value 0.958; P value summary “ns”; Do the variances differ signif. ($P < 0.05$) – “No”.

4th sign – the distance between the ends of the first and second veins of the second order of the leaf. Bartlett's test for equal variances. Large-leaved tree: bartlett's statistic (corrected) 2.054; P value 0.561; P value summary "ns"; Do the variances differ signif. ($P < 0.05$) – "No". Small-leaved tree: bartlett's statistic (corrected) 0.158; P value 0.924; P value summary "ns"; Do the variances differ signif. ($P < 0.05$) – "No".

5th sign – the angle between the main vein and the second vein of the second order from the base of the leaf. Bartlett's test for equal variances. Large-leaved tree: bartlett's statistic (corrected) 0.808; P value 0.848; P value summary "ns"; Do the variances differ signif. ($P < 0.05$) – "No". Small-leaved tree: bartlett's statistic (corrected) 2.52; P value 0.284; P value summary "ns"; Do the variances differ signif. ($P < 0.05$) – "No".



a *b*

Figure 3. Integral index of stability of leaf development (the 3rd sign):
a – large-leaved tree; *b* – small-leaved tree

Table 7

Column statistics (the 3rd feature)

Month	June		July		August		September	
Tree	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved
Number of values	9	8	9	8	9	8	9	–
Minimum	0.008	0.036	0.017	0.008	0.016	0.014	0.010	–
Maximum	0.130	0.214	0.101	0.188	0.127	0.195	0.128	–
Mean	0.060	0.106	0.052	0.064	0.068	0.060	0.070	–
Std. Deviation	0.039	0.068	0.029	0.064	0.035	0.060	0.046	–
Std. Error	0.013	0.024	0.010	0.022	0.012	0.021	0.015	–
Lower 95% CI of mean	0.030	0.049	0.030	0.011	0.041	0.010	0.034	–
Upper 95% CI of mean	0.090	0.162	0.074	0.117	0.095	0.111	0.105	–
Coefficient of variation	64.24%	63.97%	55.21%	99.23%	51.41%	99.83%	66.29%	–
Sum	0.541	0.845	0.470	0.512	0.612	0.483	0.628	–

Table 8

1-way ANOVA (the 3rd feature)

Parameter	**Value**	
	Large-leaved tree	**Small-leaved tree**
P value	0.746	0.310
P value summary	ns	ns
Are means signif. different? (P < 0.05)	No	No
Number of groups	4	3
F	0.411	1.241
R squared	0.037	0.106

Table 9

ANOVA (the 3rd feature)

ANOVA Table	SS	df	MS
	Large-leaved tree		
Treatment (between columns)	0.00175	3	0.00058
Residual (within columns)	0.04547	32	0.00142
Total	0.04722	35	
	Small-leaved tree		
Treatment (between columns)	0.01012	2	0.00506
Residual (within columns)	0.08562	21	0.00408
Total	0.09573	23	

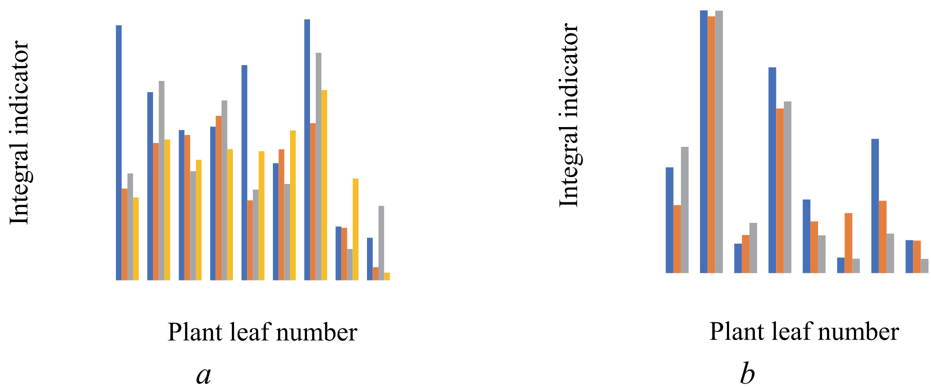


Figure 4. Integral index of stability of leaf development (the 4th sign):
a – large-leaved tree; *b* – small-leaved tree

Table 10

Column statistics (the 4th sign)

Month	June		July		August		September	
Tree	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved
Number of values	9	8	9	8	9	8	9	–
Minimum	0.022	0.010	0.007	0.022	0.016	0.010	0.004	–
Maximum	0.136	0.175	0.086	0.171	0.119	0.175	0.099	–
Mean	0.083	0.072	0.056	0.062	0.065	0.060	0.061	–
Std. Deviation	0.041	0.059	0.027	0.052	0.034	0.060	0.026	–
Std. Error	0.014	0.021	0.009	0.018	0.011	0.021	0.009	–
Lower 95% CI of mean	0.051	0.022	0.036	0.018	0.039	0.010	0.041	–
Upper 95% CI of mean	0.115	0.121	0.077	0.105	0.091	0.110	0.081	–
Coefficient of variation	49.68%	82.85%	48.02%	83.99%	52.01%	99.89%	43.46%	–
Sum	0.748	0.574	0.508	0.495	0.582	0.478	0.548	–

Table 11

1-way ANOVA (the 4th sign)

Parameter	Value	
	Large-leaved tree	**Small-leaved tree**
P value	0.341	0.905
P value summary	ns	ns
Are means signif. different? (P < 0,05)	No	No
Number of groups	4	3
F	1.157	0.101
R squared	0.098	0.009

Table 12

ANOVA (the 4th sign)

ANOVA Table	SS	df	MS
Large-leaved tree			
Treatment (between columns)	0.00371	3	0.00124
Residual (within columns)	0.03417	32	0.00107
Total	0.03787	35	
Small-leaved tree			
Treatment (between columns)	0.00066	2	0.00033
Residual (within columns)	0.06858	21	0.00327
Total	0.06923	23	

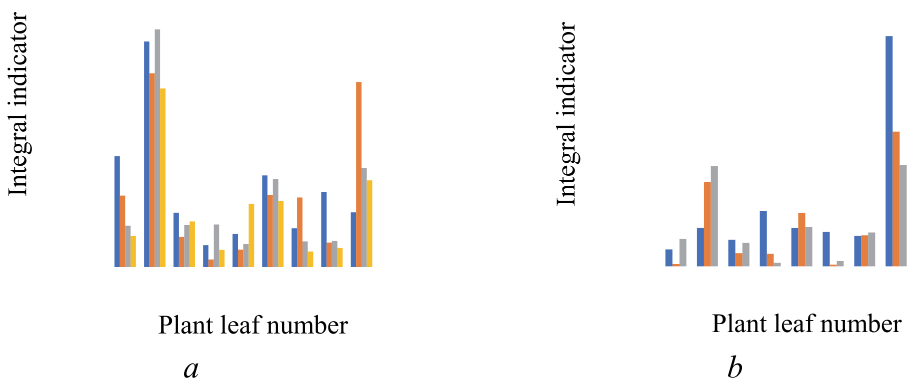


Figure 5. Integral index of stability of leaf development (the 5th sign):
a – large-leaved tree; *b* – small-leaved tree

Table 13

Column statistics (the 5th feature)

Month	June		July		August		September	
Tree	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved	Large-leaved	Small-leaved
Number of values	9	8	9	8	9	8	9	–
Minimum	0.015	0.014	0.005	0.001	0.015	0.003	0.010	–
Maximum	0.150	0.193	0.129	0.113	0.158	0.085	0.119	–
Mean	0.052	0.049	0.050	0.035	0.046	0.035	0.039	–
Std. Deviation	0.041	0.059	0.046	0.040	0.046	0.032	0.034	–
Std. Error	0.014	0.021	0.015	0.014	0.015	0.011	0.011	–
Lower 95% CI of mean	0.020	0.000	0.014	0.002	0.011	0.008	0.012	–
Upper 95% CI of mean	0.084	0.098	0.085	0.068	0.081	0.062	0.065	–
Coefficient of variation	79.04%	119.82%	93.14%	113.74%	99.09%	92.32%	88.61%	–
Sum	0.470	0.393	0.447	0.278	0.415	0.280	0.349	–

Table 14

1-way ANOVA (the 5th feature)

Parameter	Value	
	Large-leaved tree	**Small-leaved tree**
P value	0.914	0.768
P value summary	ns	ns
Are means signif. different? (P < 0,05)	No	No
Number of groups	4	3
F	0.173	0.268
R squared	0.016	0.025

Table 15

ANOVA (the 5th feature)

ANOVA Table	SS	df	MS
Large-leaved tree			
Treatment (between columns)	0.00092	3	0.00031
Residual (within columns)	0.05690	32	0.00178
Total	0.05780	35	
Small-leaved tree			
Treatment (between columns)	0.00108	2	0.00054
Residual (within columns)	0.04250	21	0.00202
Total	0.04358	23	

Discussion

ANOVA analysis of variance showed that there are no differences between the average values of the compared groups on five grounds.

Using the Bartlett test, an approximate criterion was determined to assess the uniformity of variance for equal deviations on five grounds.

To the question whether these deviations differ significantly between large leaves (according to the first, third, fourth and fifth characteristics), the answer is received – there are no differences. According to the second criterion (the length of the vein of the second order from the base of the leaf), these deviations differ.

To the question whether these deviations differ significantly in small leaves, the answer is received – there are no differences.

The formation of an individual development trajectory occurs at each leaf. This can be seen in the figures presented. It is associated with growing conditions – a recreation area in an industrial center with a high recreational load. Under extreme growing conditions, an adaptive reaction of the leaves is manifested. The phenomenon of adaptive polymorphism was noted in birch leaves. However, the morphological and functional features of the leaf are inextricably linked.

Conclusion

During the growing season on the territory of the recreation zone in the Ufa industrial center, deviations in the development of *Betula pendula* leaves were noted.

It was noted that leaf asymmetry indices can be used to characterize the state of *Betula pendula* trees.

The need to monitor the state of the stands, as well as the timely detection of violations and changes in the condition of individual trees, is associated with the development of measures for the care of the stands and for the reconstruction of the stands.

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