

Dependence of Asymmetry of *Betula pendula* Roth Leaves on Soil Indicators

ANNA SERGEEVNA OLKOVA* AND TATYANA ANATOLYEVNA ADAMOVICH¹

Department of Ecology and Nature Management, Vyatka State University, Russia, Kirov

*(e-mail: usr08617@vyatsu.ru; Mobile: +7 95313 39321)

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ABSTRACT

Bio-indicative parameters can change both in responses to environmental pollution and in response to natural environmental factors. The purpose of the present work was to determine the correlation between the fluctuating asymmetry (FA) of leaves of the birch *Betula pendula* Roth and soil parameters. The 10 study sites were located in the vicinity of the city of Ukhta (Russia, northern taiga zone). FA was determined by five morphological parameters (n=100), as well as pH (water and salt extracts), the content of organic matter and the accumulation of mobile forms of metals in the soil. The Pearson correlation coefficient (r) was calculated. The FA varied from 0.064 to 0.076, while the norm was less than 0.04. It was shown that a decrease in the content of organic matter in the soil and a decrease in the pH level (salt extract) increased the FA in *B. pendula*: $r = -0.49$ and $r = -0.42$, respectively. The content of Pb, Mn and Cu also affected the FA of the leaves ($r = 0.6, 0.36, 0.35$, respectively), despite the fact that the standards were not exceeded. Thus, the asymmetry of birch leaves depended not only on air pollution, but also on the natural indicators of the soil and its pollution.

Key words: *Betula pendula*, fluctuating asymmetry, bio-indication, soil, heavy metals

INTRODUCTION

Adverse environmental factors affect the vital signs and morphological characteristics of living organisms. Numerous methods of bio-indication of environmental quality are based on them. The fluctuating asymmetry (FA) of plant organs, less often animals, is effectively used to assess the ecological situation and the level of environmental pollution (Barišić Klisarić *et al.*, 2019; Kozlov and Pushkarev, 2020).

The ethics of ecological research restricts the use of animals to detect their morphological asymmetries. Only mass species are suitable for this. For example, Zhelev *et al.* (2019) showed that 10 morphological features of *Pelophylax ridibundus* frogs became asymmetric in response to anthropogenic pollution and can be used as reliable biomarkers.

Plants are more convenient for bio-indication than animals, not only from the ethical point of view. They perceive the anthropogenic impact in a strictly defined area for a long-term mode. To assess the FA values, the part of the plant that remains viable after bio-sampling is sufficient. The following year, the same

plants can be observed, which increase the reliability of obtained scientific data.

Most often, scientists associate an increase in the FA with air pollution. For example, the highest FA values were in *Cecropia pachystachya* Trécul plants in areas with severe dust pollution, and the lowest values were in plants of the control site (Mendes *et al.*, 2018). Prihod'ko and Shtirc (2018) and Shadrina *et al.* (2020) noted a statistically significant dependence of the FA of *Betula pendula* Roth and *Aser pseudoplatanus* L. on the traffic load in cities.

However, the dependence of the plant FA on soil indicators and the level of soil pollution have not been disclosed in scientific works. Therefore, the purpose of the present study was to determine the relationship between the asymmetry of the birch *B. pendula* leaves and such soil indicators as pH, organic matter content and concentration of mobile forms of metals.

MATERIALS AND METHODS

The study was carried out in the urban agglomeration of Ukhta (Russia), latitude

¹Department of Fundamental Chemistry and Methods of Teaching Chemistry, Vyatka State University, Russia, Kirov.

63°34'01" N, longitude 53°41'00" E. The climate is temperate continental. Winter is long and cold: the average January temperature is -18°C. Summer is short and cool: the average temperature in July is 14.6°C. In different directions of the light from the conditional center of the study area, 10 sites were laid where the birch *Betula pendula* Roth grew.

At each study site, 10 *B. pendula* trees were selected. Ten leaves were collected from each tree. From the collected leaves the fluctuating asymmetry coefficient (FA) was determined using five parameters. Further, the ecological state of the sites was ranked according to the scale: FA < 0.055 clean environment; FA 0.056-0.6 relatively clean environment; FA 0.06-0.065 polluted environment; FA 0.065-0.07 dirty environment; FA > 0.070 very dirty environment.

At each study site, soil samples were taken from the depth of 0-20 cm and analyzed. The determination of the pH of water and salt extracts from the soil was carried out by the potentiometric method. The content of organic matter was analyzed by the spectrophotometric method. The determination of the content of the mobile form of heavy metals in soil samples was carried out using the atomic absorption spectroscopy.

Laboratory determination of indicators was carried out in triplicate. During statistical processing of the obtained data, the mean values (M) and standard deviation (δ) were determined. The significance of differences between the compared data series was assessed by Student's t-test at $P < 0.05$.

RESULTS AND DISCUSSION

The FA coefficients in the studied areas varied from 0.064 to 0.076. According to the scale most of the sites were characterized as a polluted environment, 30% of the sites were very dirty (Fig. 1).

The natural and climatic conditions of the city of Ukhta were not optimal for the growth of *B. pendula*, but it successfully grew up to the tundra zone. The influence of the cardinal direction on the FA of the birch was not established. The maximum asymmetry coefficients were set for both the northern and southern sites. Shadrina *et al.* (2020) confirmed that climatic factors did not significantly affect

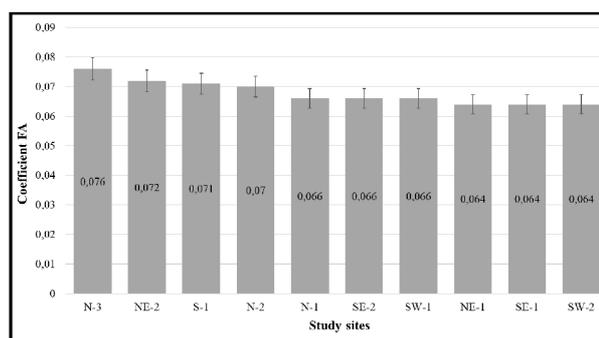


Fig. 1. Coefficients of fluctuating asymmetry of birch leaves in the study areas.

the sustainability of *B. pendula* development in urban environments.

Anthropogenic pollution of the territory is due to the fact that there are operating coals and oil mines in Ukhta. It is known that the FA of birch increases depending on the anthropogenic load. Thus, near a pharmaceutical enterprise, the FA of the birch reached 0.053 (Turmukhametova *et al.*, 2021). In industrial zones of cities, the FA of the birch can reach 0.061-0.667 (Gubasheva *et al.*, 2022). On the contrary, in relatively clean areas, the asymmetry of birch leaves is small. For example, in Western Yakutia, which is close in natural and climatic conditions to the study area, in the background areas, scientists previously set the FA of birch 0.04 (Shadrina and Vol'pert, 2018).

In 2022, the level of air pollution in Ukhta was low. The annual average concentrations of all pollutants in the atmospheric air of the city were below sanitary standards. There were no cases of high and extremely high levels of air pollution (State Report, 2023). Therefore, it is necessary to search for other anthropogenic factors that caused a significant asymmetry of birch leaves in the vicinity of the city of Ukhta. Wood plants are highly dependent on soil conditions, including pollution (Table 1).

The reaction of the soil medium was weakly acidic (60% of samples for the analysis of water extraction) and acidic (80% of samples for the analysis of salt extraction) in most areas. The soils were not rich in organic matter: 70% of the studied sites were classified as poor in organic matter. The analysis of the content of mobile forms of HMs in soils showed that in all study sites, their concentration was significantly below the established standards. The maximum concentrations were noted for

Table 1. Physical and chemical characteristics of the soil

Sampling site	pH _{HR20}	pH _{KCl}	Organic matter (%)	Content of HMs (mg/kg)					
				Cd	Pb	Fe	Zn	Cu	Mn
N-1	6.8	6.3	0.26	0.001	0.55	0.72	0.59	0.28	1.63
N-2	6.7	5.0	0.26	0.007	0.74	3.0	0.22	0.01	0.87
N-3	6.8	6.0	0.22	0.009	0.27	1.56	0.24	0.17	1.25
NE-1	6.9	5.8	0.27	0.053	0.05	0.59	0.32	0.16	1.46
NE-2	6.8	6.0	0.22	BDL	0.22	0.98	0.35	0.18	1.52
SE-1	5.5	5.5	0.37	0.022	0.52	0.81	0.43	0.30	1.57
SE-2	5.1	5.1	0.34	0.007	2.68	0.73	0.34	0.27	1.73
S	6.0	6.0	0.38	0.062	0.55	0.68	0.61	0.25	1.66
SW-1	5.7	5.7	0.50	0.067	0.22	1.10	0.37	0.21	1.64
SW-2	5.6	5.6	0.45	0.005	0.27	1.23	0.29	0.14	1.32

Deviations from the average when measuring pH were not more than 5% (n=3), when determining the concentration of organic matter, they were not more than 2% (n=2), and when determining HM, they were not more than 20%. BDL–Below detection limit.

iron, manganese and zinc, which were typical for northern soils (Opekunova *et al.*, 2019).

B. pendula belongs to undemanding tree crops, however, the combination of acidic soil and low content of organic matter in it led to an increase in the bioavailability of HMs (Dalcorsio *et al.*, 2019). The negative effect of HMs at low concentrations when combined was also known (Kabata-Pendias, 2010). The results of determining the dependence of the birch FA on various soil indicators are shown in Fig. 2.

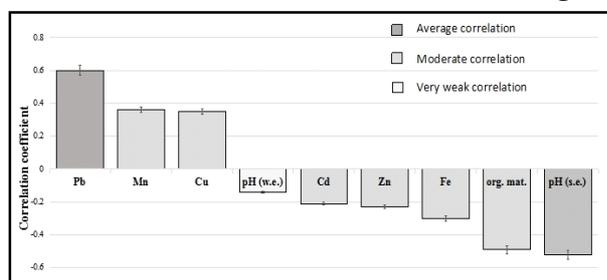


Fig. 2. Correlation coefficient of asymmetry of birch leaves and soil indicators.

The maximum positive correlation between the asymmetry of birch leaves was with the content of mobile lead in the soil ($r = 0.6$). The presence of this metal in the soil was largely due to the anthropogenic activities (Karande *et al.*, 2020), for example, in the study, the extraction of coal and oil, as well as transport load. Also, positive correlations of a moderate degree were observed between FA and the content of mobile manganese ($r = 0.36$), FA and the content of mobile copper ($r = 0.35$). Copper, manganese and zinc can enhance the action of each other (Piper, 2019), so the relatively low content of these metals in the soil affects the state of *B. pendula*.

A moderate negative correlation was observed between FA and soil pH in terms of salt extract ($r = -0.52$), as well as FA and the content of organic matter in the soil ($r = -0.49$). This is quite natural. The lower the soil pH and the less organic matter, the more extreme the soil conditions for the plant. Other soil parameters (pH of water soil extract, content of mobile copper, zinc and iron) had a weak correlation with FA of birch leaves. This was probably due to a more objective reflection of the pH level in the soil when using a salt extract, since natural salts passed into the solution in natural soil. The absence of a significant correlation between FA and the content of Cu, Zn and Fe in the soil was explained by the tolerance of *B. pendula* to these metals in the detected concentrations.

CONCLUSION

The birch *B. pendula* is certainly a valuable bio-indicator, as it is often used in urban landscaping in Europe, Asia, North and South America, and northern parts of Africa. Using the example of the north taiga zone, it was shown that the asymmetry of the leaves of *B. pendula* depended not only on the air environment, but also on the characteristics of the soil. The leaf asymmetry increased when the content of organic matter in the soil and the pH level decreased.

Soil contamination with heavy metals was not detected in the study sites. However, the influence of determined metals (mobile forms) on FA was divided into two groups. An increase in the content of three metals led to an

increase in the level of FA: Pb > Mn = Cu. Metals Cd, Zn and Fe did not affect the FA index ($r < 0.35$).

Climatic conditions within the north taiga zone did not affect the leaf asymmetry of *B. pendula*. High FA values in the vicinity of the city of Ukhta (0.064-0.076) may indicate both the combined action of HMs and the influence of those pollutants that were not identified in the course of present work. Further work on increasing the database on the correlation between *B. pendula* leaf asymmetry and soil parameters and its pollution was the perspective of this study.

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