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Research experience of the plant development stability in areas with a high anthropogenic load

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Abstract. A multi-year assessment of the impact of the mining industry anthropogenic stress on a stable development of white birch (*Betula pendula* Roth.) and green strawberries (*Fragaria viridis*) has been carried out. The results showed that the stable development of the white birch is annually decreasing, which is explained both by the influence of climatic conditions and the increase in anthropogenic load. In contrast to birch, green strawberries demonstrate a strong fluctuation in the indicators of a stable developmental depending on the climatic conditions of the year, which most likely have a decisive influence on the development homeostasis. This species is better used to detect local pollution.

In Belgorod region, the Gubkinsko-Starooskolskiy industrial region is the center of the mining and steel industry and has the largest iron ore open-pit in Europe. High concentration of production and the urbanization create an increased anthropogenic load on natural complexes in the region. Since 2006, studies of the stable development of white birch (*Betula pendula* Roth.) and since 2012 of green strawberries (*Fragaria viridis*) have been conducted here.

One of the promising developmental approaches for the integral characteristic of the quality of the environment is the assessment of the state of living organisms according to the development homeostasis. Inefficiencies of homeostasis give rise to minor random deviations from the normal structure of various morphological features. Such changes can be identified on the basis of an analysis of the level of fluctuating asymmetry, which is considered as a characteristic of the stable development of organisms in certain living conditions. A number of studies have shown a high degree of sensitivity and reliability of this method [1, 2, 3, 4, 5, and 6]. For 12 years, 29 integrated observation stations were installed, where the stable development of green strawberry was studied. In 19 of these stations, white birch grows in artificial plantations in relatively homogeneous conditions. Both species are well studied and have a quite distinct symmetry of the leaf plate, which led to their choice as objects for assessing the quality of the natural environment.

The purposes of this study are:

- the analysis of the value of integral indicators of the stable development of woody and herbaceous plants growing at different distances from the source of pollution;
- the detection of the least polluted stations for the organization of background monitoring;
- the clarifying the dynamics of environmental health in the zone of influence of the mining industry.



The stable development of birch trees was determined on the basis of the analysis of the level of fluctuating asymmetry of the leaf plate, the leaf collection was carried out from June to August according to the method developed by V.M. Zakharov with co-authors [7] (figure 1).

All measurements are made by the author using a compass, metal ruler and protractor. An integral indicator of the stable development is the average value of the relative distinction between the parties on the indicator.

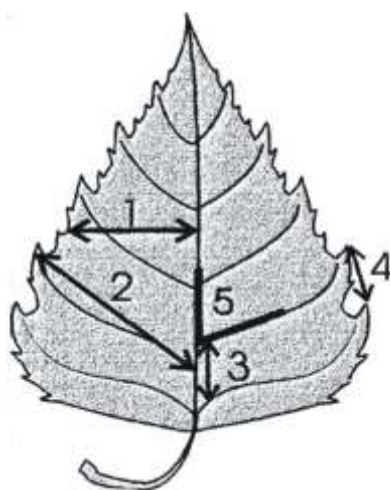


Figure 1. Diagram of morphological features of a white birch leaf (*Betula pendula* Roth.) to analyze the stable development:

- 1 - width of a half of a leaf (measurement was carried out in the middle of a leaf plate);
- 2 - the length of the second vein 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 tops of the first and second veins of the second order;
- 5 - the angle between the main vein and the second vein from the base.

The statistical significance of the differences between the integral indices was determined by the Student's *t* – test.

In the figure 2, the results of the study of the stable development of white birch for 2018 are presented in the form of a diagram, which shows the absence of a direct dependence of the value of the integral indicator on the distance to the pollution epicenter. It is likely that the terrain has an influence on the spread of pollution.

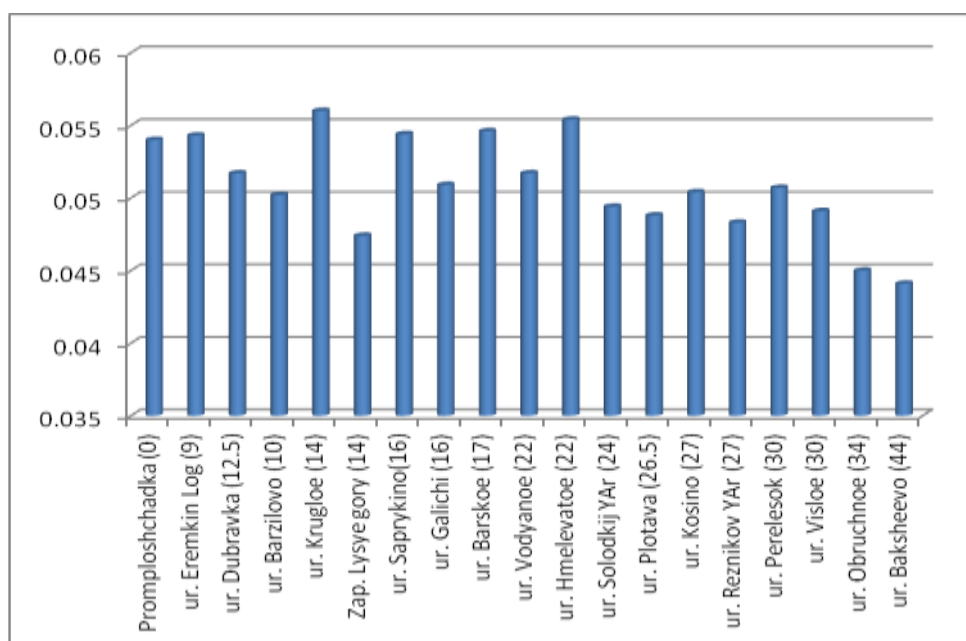


Figure 2. Integrated indexes of the stable development of white birch at varying distances from the enterprise facilities.

It can be argued that the zone of strong anthropogenic influence extends to 17-20 km to the south and up to 20 km to the south-west of the industrial facilities. At a distance of 30 km, the influence is significantly reduced. In the basin of the river Halan, 40 km to the south and south-west of the industrial facilities, plants are also considered to have satisfactory condition.

In this study, the question of choosing inspection areas with minimal anthropogenic influence was particularly acute. Initially, it was suggested choosing the Visloe area, located 30 km away from the pollution epicenter, far from industrial enterprises, with a minimum transport load, with an integrated index corresponding to I point in 2006. However, in 2011 it was equal to III points, and in 2013 it was V. It is possible that local pollution is present in this area, which makes it impossible to use it as an inspection area. It should be noted that areas with an integrated index corresponding to 1 point (contingent standards) have not been found since 2017. This leaves open the question of finding inspection observatory. It is considered that it is more logical to choose a control platform not just with a low, but with a consistently low integrated index, which can be identified only through years of research. To date, the area Obruchnoe, located 34 km south of the epicenter of pollution, has such a stable indicator,

We calculated the average integrated index over the entire research area from 2006 to 2018, which makes it possible to observe the temporal dynamics of the environmental health in the 45-kilometer zone of influence of the gubkinsko-starooskolskaya industrial agglomeration. If we apply the five-rating deviation assessment of the condition of organism from the contingent standards, then the integrated indexes of the stable development of the white birch population growing on the researched area correspond to the III-IV score from year to year. In addition, the trend line shows a tendency to increase the integrated index (figure 3). This trend is most likely a consequence of climate change in the region, rather than an increase in the influence of industry. So, wet and relatively cool summer seasons cause stabilization of the average integrated indexes of the researched area, and an increase in the average temperature contributes to its growth.

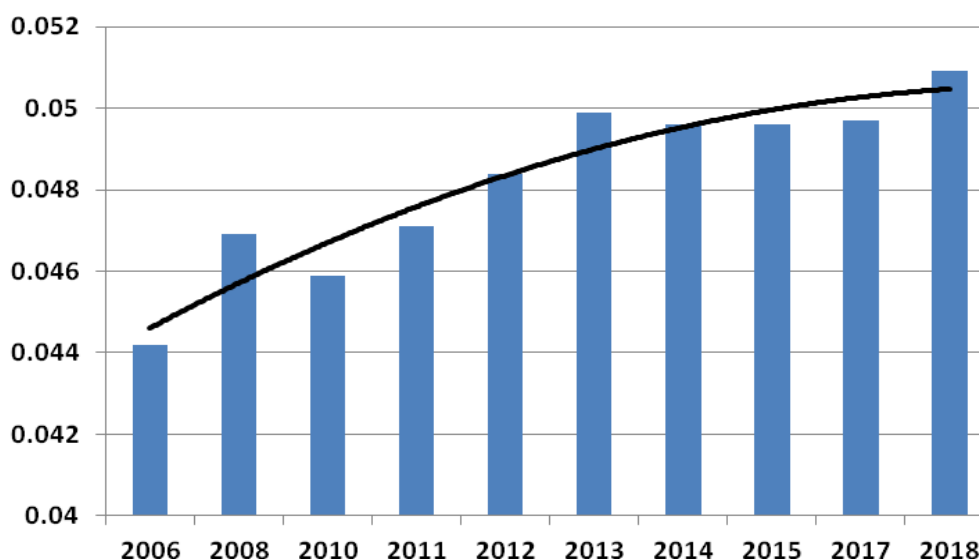


Figure 3. Average values of integrated indexes of the stable development of white birch at all observation areas for 2006-2018.

In the figure 4, the research results of the stable development of green strawberry in 2018 are presented in the form of a diagram, which also shows the absence of a linear dependence of the value of the integrated index on the distance to the pollution epicenter.

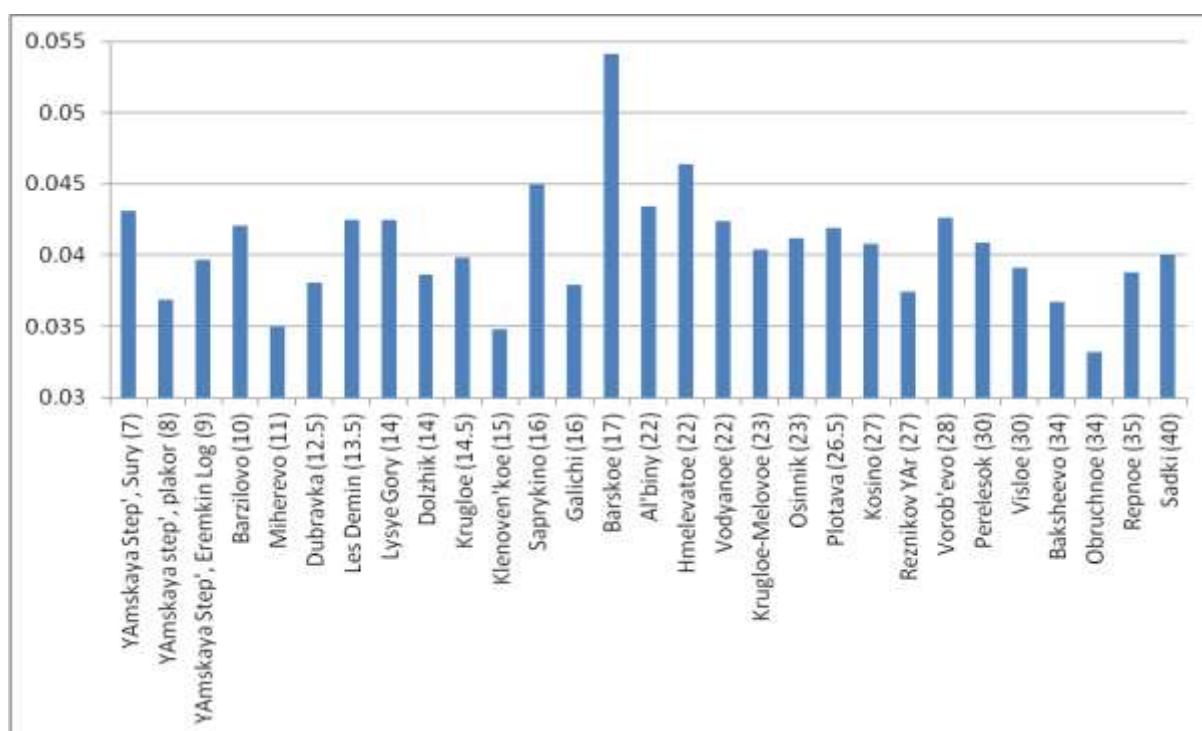


Figure 4. The values of the integrated indexes of the stable development of strawberry green at different distances from the epicenter of pollution.

Strawberries show a considerable diversity of performance than birch. Thus, the use of herbaceous plants as test objects should be carried out with strict consideration of microclimatic conditions, which most likely have a decisive influence on the development homeostasis of strawberries.

Significant annual fluctuations in the integrated index do not allow identifying an evident trend in the environmental state at particular observation stations. However, the trend line superimposed on the chart showing average integrated indicators for all observation stations over 6 years (figure 5) indicates a slow improving homeostasis development of green strawberry.

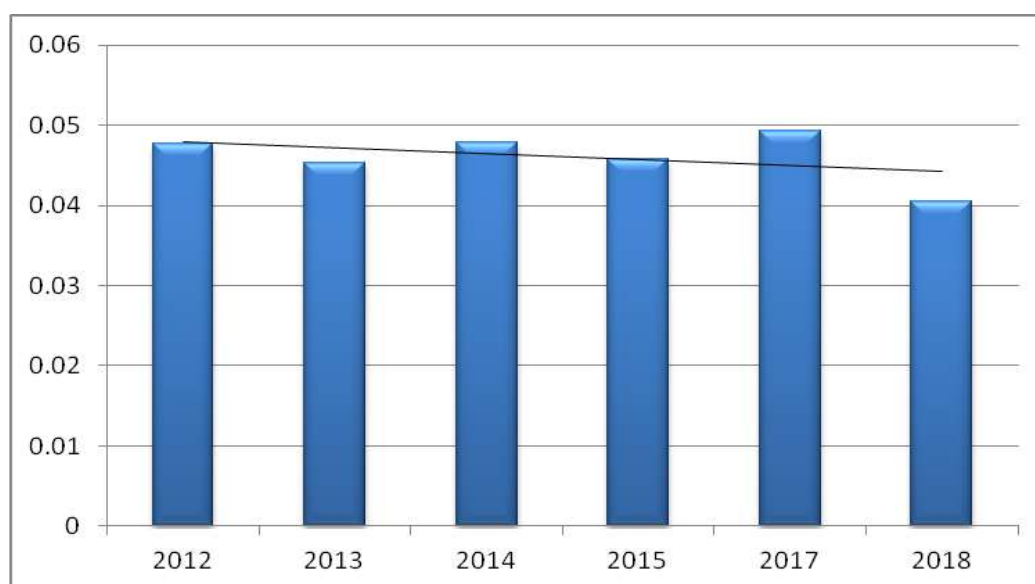


Figure 5. Average values of integrated indexes of the stable development of green strawberry for 2012-2018

Perhaps climatic factors have a stronger impact on the stable development of grassy plants, rather than the impact of pollutants. Thus, it is possible to use green strawberry as an object for monitoring local anthropogenic pollution, taking into account climatic conditions during the year.

As for the correlation of stability indicators of both plant species, it has an average positive degree in 2018. In previous years, no correlation was observed in these two species. Most likely, these species react differently to the presence of anthropogenic pollution and changing climatic conditions.

The conducted research makes it possible to draw several conclusions:

- The quality of the environment in the zone of influence of the gubkinsko-starooskolskaya industrial agglomeration can be assessed as relatively unfavorable, as evidenced by the level of integrated indexes of the stability of plant development and its dynamics. Taken into account the geographical location of the areas, it can be assumed that industrial emissions are partly the cause of this deterioration. At a distance of more than 30 km from the industrial facilities, their influence is significantly reduced.
- Since areas with normal indicators of the stability of plant development in the researched area are not found, the question of finding an observation point that could be used as a control remains relevant.
- In 2018, there continues to be a slight increase in the average integrated index of birch development homeostasis throughout the researched area, which may indicate intensively ongoing processes of adaptation of tree plants to anthropogenic stress.
- Green strawberry plants demonstrate a large variation of integrated indexes and a strong dependence on microclimatic conditions. Averaged data indicates a slow improvement in the development of homeostasis in these plants in recent years, which may be due to the influence of climatic factors. Therefore, their use as bio indicators is possible only to detect local pollution, taking into account the weather conditions of the season.

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