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THE CHARACTERISTICS AND INTERCONNECTIONS OF ADAPTIVE RESPONSE OF TILIA CORDATA AFFECTED BY TECHNOGENESIS

SUMMARY. This paper deals with ecological and biological features of Tilia cordata (all classes of age) affected by petrochemical pollution of Ufa industrial centre. The study shows that Tilia cordata (Small-leaved Lime) is characterized by a «weak» ability to adapt. Significant reduction of leaf plates and relative length of veins under the influence of pollution are observed. Stomatal index and relative water content are increased in the pollution zone. An increase of the weight and length of roots and higher percentage of skeletal and absorbing roots have also been observed. It has been found that the accumulating ability of vegetative organs does not diminish with age. A hypothetical scheme of realization of adaptive capacity is suggested in the paper. It is established that the adaptive capacity of Tilia cordata is implemented on various structural and functional levels of the organization. Similar adaptive response is observed throughout all age classes of Tilia cordata, the adaptive capacity does not reduce with age. The interconnection of adaptive response of overground and underground vegetative organs and their role in ensuring high survival rate of this species under a long-term anthropogenic impact are shown. Ecobiological features of Tilia cordata revealed by the study can be used when creating sanitary protective green zones or renewing existing plantations in Ufa industrial centre.

KEY WORDS. Petrochemical pollution, assimilation apparatus, root systems, adaptive response.

Introduction

Studying tree species adaptations to technogenic factors is one of the key issues of modern dendroecology [1-7]. However, most works approach these issues by addressing the characteristics of overground vegetative organs (mainly assimilatory apparatus) or root systems in a fragmented manner. Moreover, due to various reasons, age dynamics of adaptive response is not described. This question is a crucial one, as it is impossible to predict adaptive changes happening on different stages of a tree growth and maturity.

Ufa industrial center is one of the largest industrial zones of the before-Urals region. Technogenic pollution in this region is of the mixed type with a great amount of petrochemical and automotive contamination [8]. Small-leaved lime (Tilia cordata

Mill.) is one of the dominant species in the structure of forest stands in general and on the territory of Ufa industrial centre in particular [9]. However, firstly, the impact of technogenic pollution on this species remains poorly studied and, secondly, the plantations of Ufa industrial center and other pertochemical industrial zones have entered the stages of mature (41-50 years) and overaged (over 50 years) age periods. Thus, it is necessary to assess the potential of the small-leaved lime for creating sanitary-protective green zones in large industrial centers of the before-Ural region affected by petrochemical pollution [10]. Other age classes and their adaptive potential have not been yet observed.

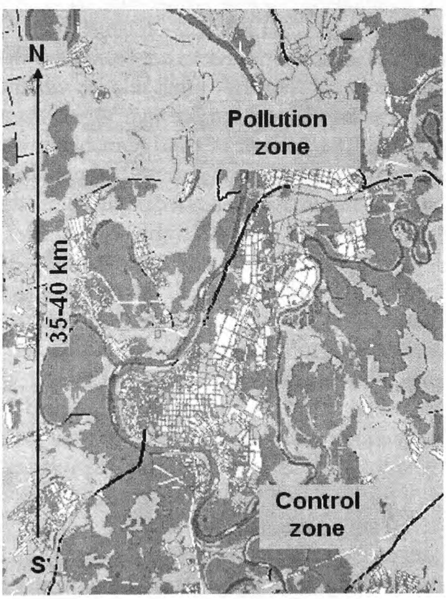
Earlier we studied features of vegetative organs formation and adaptation in the 31-40 year age classes of small-leaved lime affected by Ufa industrial center

Material and methods

The research was carried out on the territory of Ufa industrial center and its surroundings.

The research centered on small-leaved lime stands of all age classes: 0-10 years, 11-20 years, 21-30 years, 31-40 years, 41-50 years and over 50 years of age [11].

Basing on the data from some sources [8] and the results of our previous research [12], the area under study was divided into two parts: pollution zone and control zone (scheme 1).



Scheme 1. Pollution zones in the area under study

In both zones of small-leaved lime stands we established a number of permanent and temporary sample plots. To define the tree age standard dendrochronological techniques were employed [13]. Research material was sampled from model trees which were selected in each age group according to the taxation criteria [14].

The assessment of relative vital status of forest stands was done using the method of V.A. Alekseev, leaf area was measured with the help of the palette technique, stomatal index and relative leaf nerve length was measured using wet mount slide observed at 100x magnification on Carl Zeiss Jena microscope (Germany) and Digimicro USB-microscope (China); water regime was studied in the field by quick weighing technique using Zaklady mechaniki precyzyjnej (Poland) and ML–A05 (China) electronic scales; monolith method was employed for describing root systems, and toxic content was measured by nuclear-absorption method [11].

Statistical processing of the data obtained was performed by variational methods using Excel and Statistics for Windows computer programs.

Results and discussions

Ecobiological characteristics of small-leaved lime affected by Ufa industrial centre.

In preceding works one can find detailed information on ecobiological characteristics and accumulating capacity of vegetative organs of the small-leaved lime (all classes of age) affected by petrochemical pollution in Ufa industrial centre [12, 15]. In general assimilatory apparatus development and root systems of the small-leaved lime under conditions described can be characterized in the following way.

Relative vital status of small-leaved lime stands affected by petrochemical pollution is characterized as "weak" (L_N=70.2-71.8%; L_N – relative vitality index). Forest stand deaths are not registered. Vital status of trees does not decrease with age. All stands under discussion were assessed as being "healthy" (with relative vitality index L_N exceeding 80%). Assimilatory apparatus impairment is more than 30% in the pollution zone, in the control zone less than 10%. The amount of dead branches is more than 35% in the pollution zone and less than 15% in the control zone. It should be noted that increasing age does not correspond to a rise in leaf area affected by chlorosis and necrosis.

Leaf surface area is decreasing in general (from 31-33 to 20-23 sq cm) in response to increasing pollution with the exception of 11-20 and 21-30 years age classes which are characterized by a reversed trend (21-26 sq cm in the pollution zone and 18-19 sq cm in the control zone). In the conditions of Ufa industrial centre the higher number of stomata corresponds to an increase in pollution (on average from 78 to 288 stomata per sq cm). Relative leaf nerve length is shorter with higher pollution levels (from 14 to 5 mm per sq mm). The leaves of small-leaved lime are characterized by higher relative water content (minimal leaf water content is 73%). This parameter does not change significantly with older age. We found regularities of the way pollution levels affect intensity of transpiration processes. Younger trees of 0-10 years of age and mature trees of 41-50 and overaged trees of more than 50 years of age increase transpiration rates in response to higher pollution levels by 48.3-69.4 mg for g per hour. Trees in the 11-20 and 21-30 age classes have a reverse tendency as the transpiration rate decreases in the pollution zone by 29.9-35.8 mg for g per hour.

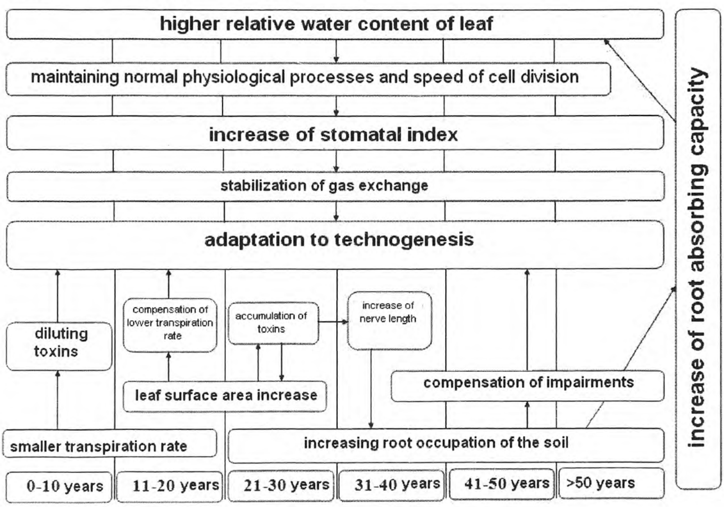
The root occupation of the soil is increased (from 200-7000 to 15000 g/10^{-1} m^3), the amount of absorbing (from 12 to 30%) and woody (from 35 to 55%) roots is increased as well.

It has been found that accumulatory ability of leaves and roots does not decrease with age. Thus, tree leaves sulphur content of individuals older than 10 years ranges between 0.122-0.172 mg/g without significant changes (± .07 mg/m) as the trees grow and become mature. Benzopyren content in woody and semi-woody roots increases with tree age (from 50 ng/g in young individuals to 450 ng/g in mature individuals).

The realization of adaptive potential of small-leaved lime in the conditions of Ufa industrial centre

Affected by petrochemical pollution of Ufa industrial centre, small-leaved lime stands develop certain adaptive response. It is crucial that adaptive capacity does not diminish with growing and aging of tree stands.

The plants start experiencing stress caused by technogenic pollution from early stages of their ontogenic development. As the organs of young trees are forming and developing when they are 0-10 years of age, it is crucial for them to minimize the negative impact of toxic substances. The most important adaptive response for this age group is diminishing the intensity of transpiration processes. Lower transpiration rate promotes retaining more moisture, and, in turn, dilution of toxic substances and decreasing their concentration (Scheme 2).



Scheme 2. Realization of adaptive potential of small-leaved lime affected by petrochemical pollution of Ufa industrial centre

Trees of 11-20 years of age are also characterized by decreased transpiration rate. This turns out to be a negative factor for this age group as the trees are mostly formed at this age and transpiration plays a major role in regulating the speed and manner of physiological processes in the organism. The tree stands require some way to compensate for the decrease of transpiration rate. This is achieved by increasing the leaf surface area.

The leaf surface area has proved to be increased in trees of middle age (21-30 years old). Vegetative organs of a tree are usually fully developed by this age and the tree can perform its environmental function of accumulating technogenic contaminants. When an individual tree reaches this age the accumulating capacity of its leaves grows considerably. It seems likely that when an individual tree reaches the 31-40 year age class, toxic substances serve to accelerate the speed of meristematic cells division. As a result the trees at this age lengthen their leaf nerves. As compared to other age classes, 31-40 year old trees have the highest concentration of toxins in their leaves. Leaf nerves lengthening causes redistribution of toxins from leaves into roots. Toxic substances are then accumulated in parenchymal cells of semi-woody and especially woody roots [12].

High relative water content in leaves maintains normal physiological processes in plant organisms which are bound to suffer from technogenic stress. Optimization of physiological processes in turn leads to normal activity of initial cells in meristematic tissue. This, together with accumulation of contaminants, which, as was mentioned earlier, serve as catalysts, seems to cause an increase of the stomatal index [16]. This feature, as well as increased root occupation of the soil, is a very important adaptive response aimed at stabilization of gas exchange in technogenic conditions. Sufficient water content creates auspicious conditions for photosynthesis, breathing, fermentation activity of plants and ratio of minerals [17].

In general, root occupation of the soil in small-leaved lime forest stands (according to the root mass, general and fractional) is observed from the middle age of the trees (21-30). Increased root occupation is a very important adaptive response aimed at compensating the impairments of overground vegetative organs, especially leaves, being one of the most ecologically sensitive plant organs.

The increased root occupation of the soil concerns not only semi-woody (1-3 mm diameter) and woody (>3 mm diameter) roots, but also absorbing roots which are the thinnest, used for absorbing moisture from the soil. Thus increasing root occupation performs not only compensatory function but also an important physiological one. It promotes high water leaf content in trees of middle age and older (from 21 years of age), since younger individuals keep high relative water content mainly through diminishing transpiration rate.

Conclusion

Thus, we see that adaptive potential of small-leaved lime affected by petrochemical pollution is realized on different structural and functional levels. The adaptive response developed by overground and underground vegetative organs in closely interrelated. This ensures high survival rate of small-leaved lime which experiences heavy technogenic stress for many years.

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