International Journal of Economic Perspectives, 2017, Volume 11, Issue 3, 480-489.

Influence Of Local Microenvironment On Vital State And Timing Attack Woody Plants Phases Of Development In Urban Plantings

Petr Anatolievich Kuzmin
Kazan Federal University, Yelabuga Institute, Russia Federation, Elabuga, 423600, 89 Kazan str.
1E-mail: petrkuzmin84@yandex.ru

Irina Leonidovna Bukharina
Udmurt State University, Russian Federation, 426034, Izhevsk, 1 Universitetskay str.

Aigul Mukhametnagimovna Kuzmina
Izhevsk State Agricultural Academy, Russian Federation, 426069, Izhevsk, 11 Student str.

ABSTRACT

This paper presents the parameters of the abiotic habitat in various types of urban plantations: air and soil surface temperature, relative air humidity. In comparison with natural phytocenoses, higher air and soil temperatures were noted on sample plots in plantations of sanitary protection zones of industrial enterprises and sidewalk plantations. During the vegetation season, the highest relative air humidity is recorded in the conditional control zone, which is represented by a higher density plantation, as compared with urban landscapes. All studied species of woody plants growing under intense man-induced impact, with the exception of balsam poplar (*Populus balsamifera* L) have earlier coloring of their dying leaves observed compared to plants in the conditional control zone. Also, in urban plantations, there were increased malformations, a decrease in vital state associated with severe damage to leaf laminas, the formation of leaf necrosis, a decrease in the index of the living area of the leaves, which is a consequence of intensive man-induced stress on woody plants.

Keywords: microenvironment conditions, phenological phase, vital state, woody plant malformations, Acer platanoides L., Tilia cordata Mill., Betula pendula Roth., Acer negundo L., Populus balsamifera L.

1.INTRODUCTION

All large industrial regions, which consist of certain natural and climatic conditions and at the same time combine a peculiar type of economic management, attract attention from an ecological point of view. Modern problems of the man-made environment are associated with excessive concentration of the population, transport and numerous industrial facilities negatively affecting plants, reducing their vital state, modifying their morphological, physiological and biochemical structure, contributing to the emergence of numerous diseases and pests [Kulagin, 2005; Terho, 2005; Prosper, 2011; Niinemets, 2006; Robin, 2009; Bukharina, 2013].

Great damage is observed in areas where the natural environment shows low self-purification activity from man-made pollutants. The increased resistance of plants to urban conditions is determined by the ability to change their physiological processes, the manifestation of adaptation mechanisms formed in phylogenesis (preadaptation) to protect against other unfavorable environmental factors. Consequently, the resistance of plants to industrial pollution depends both on environmental factors (illumination, temperature, humidity, nutrient supply) and on the plant state itself (species tolerance, age of the leaves, age of the whole plant, etc.) [Bukharina, 2014; Nagamitzu, 2006; Flexas, 2008].

An important factor in optimizing the anthropogenic environment is the organization of green plantations. For the optimal selection of the species composition of plantations, it is required to study the phenological and morphological features of different species of woody plants, determine their vital state, taking into account local micro-conditions in each type of plantation, as well as the ecological and functional zoning of the urban area.

2.MATERIALS AND METHODS

Object of the study was woody plants: native species – Norway maple (*Acer platanoides* L.), small-leaved lime (*Tilia cordata* Mill.) and silver birch (*Betula pendula* Roth.); introduced species – ash-leaved maple (*Acer*

negundo L.) and balsam poplar (*Populus balsamifera* L.). The studied species grow in the city as a part of plantations of various ecological categories: highway plantations (HP) (major highways "Avto-1" and Mira Avenue) and sanitary protection zones (SPZ) of industrial enterprises - KamAZ OJSC, forging and foundry plants, which are the main polluters of the city. Chelynskoye forest-division was chosen as the zones of conditional control (CCZ) for silver birch, small-leaved lime and Norway maple. The introduced species – ash-leaved maple and balsam poplar – were studied in the territory of the city park "Grenada" [Atlas, 2005].

The sample areas were regularly demarcated (5 areas in each district, with a size of at least 0.25 hectares). Within one sample area, the record woody plants (10 plants of each type) were sampled and numbered. The record species had a good vital and middle-aged generative ontogenetic state (g_2).

During our phenological observations, we recorded the following stages of seasonal changes: Bb^2 - bud bursting (appearance of leaf cone), F^2 - beginning of flowering, F^3 - end of flowering, Fr^3 - ripening of fruits, seeds, L^3 - coloring of dying leaves, L^4 - leaf fall.

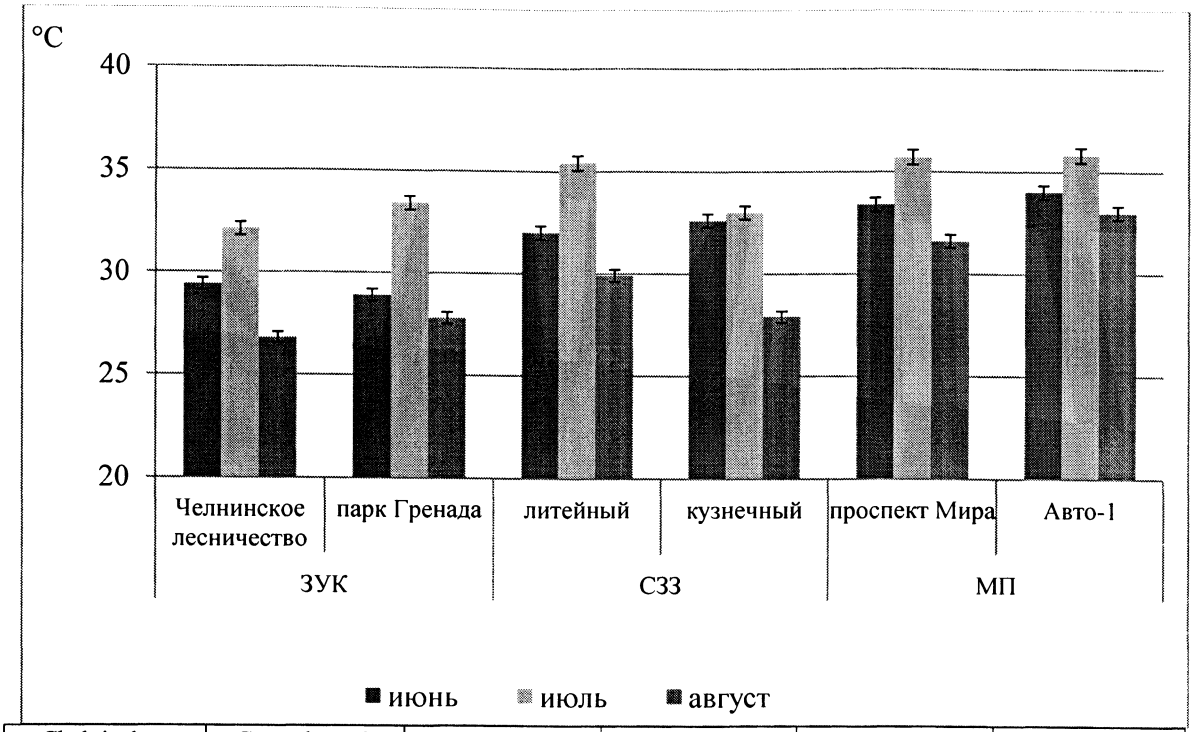
The vital state of the woody plants was estimated visually according to the degree of destruction of the assimilation apparatus and the crowns of the plants. According to the methodology, we used a ten-point scale to assess the number of living branches in tree crowns (P1), the degree of crown leaf coverage (P2), the number of live (without necrosis) leaves in crowns (P3), and the average number of leaf living area (P4) [Nikolaevskii, 2002].

Analysis of micro-conditions of habitat: the determination of the parameters of the soil and atmospheric air temperature regime; and atmospheric air humidity. For this purpose, a portable Meteoscope-M instrument was used.

3.RESULTS AND DISCUSSIONS

We analyzed some parameters of the abiotic habitat in different types of plantations, where the studied plant species grow. During the active vegetation period, we recorded the temperature of the air and soil surfaces, and the relative air humidity (Figures 1, 2 and 3).

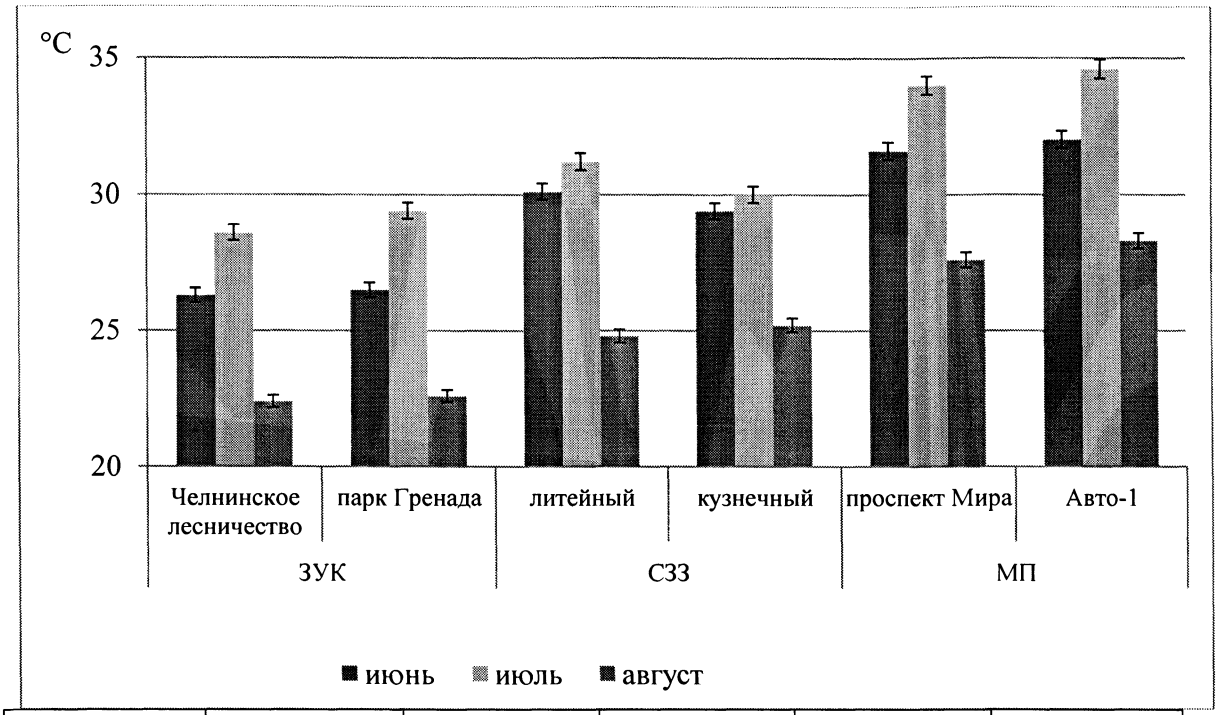
In comparison with natural phytocenoses, a higher air temperature was noted on sample plots located in the plantations of the sanitary protection zone of industrial enterprises and in highway plantations. The maximum temperature difference was 7°C in August in the conditional control zone and in the highway plantations. Higher air temperatures in the urban environment, and in particular in the sanitary protection zones of industrial enterprises, form specific micro-conditions and increase the negative impact of the anthropogenic factor on plant organisms.



Chelninskoe forest-division	Grenada park	Foundry plant	Forging plant	Mira Avenue	Avto-1
CCZ		SPZ		HP	
June		July		August	

Note: CCZ – conditional control zone, SPZ – sanitary protection zone, HP - highway plantations.

Fig. 1 – air temperature dynamics in the studied districts, °C



Chelninskoe forest-division	Grenada park	Foundry plant	Forging plant	Mira Avenue	Avto-1
CCZ		SPZ		HP	
June		July		August	

Fig. 2 – soil surface temperature dynamics in the studied districts, °C

The soil surface temperature had different values in the plantations, based on the location of the sample plots (Fig. 2). The maximum values of this indicator, regardless of the location of sites, were recorded in July. Higher soil surface temperatures are common to man-made landscapes. We should note the sample plots in the highway plantations, where the soil surface temperatures were higher than in the other investigated plantations. The temperature difference was 6-7°C.

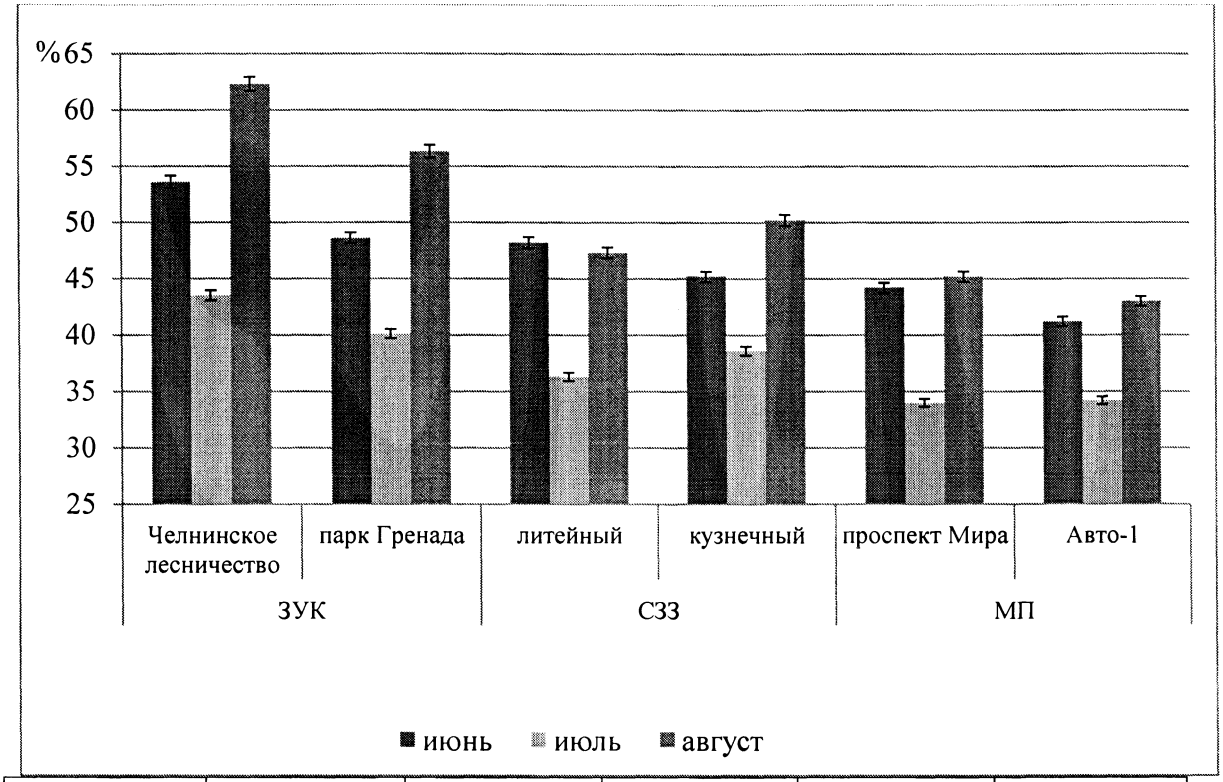


Fig. 3 – air relative humidity dynamics in the studied districts, %

The air relative humidity dynamics during active vegetation period is shown in Figure 3. Regardless of the vegetation period, the highest values of the indicator were recorded in plantations of the conditional control zone represented by areas with a high stand density, in comparison with urban plantations. In all types of plantations, except for the SPZ plantations of the foundry plant, the maximum values of the relative humidity were recorded in August. Thus, the plant component in anthropogenic environment is an essential factor that performs environmental regulatory functions, influencing the formation of local micro-conditions of the habitat.

Abnormal phenological rhythms of growth and development of woody plants were observed under the most intensive anthropogenic load. Pollutants affect the plant organism, causing its premature aging. Carrying out phenological observations of plants growing in plantations of sanitary protection zones of large industrial enterprises of KamAZ and in the highway plantations (city motorways Avto-1 and Mira Avenue) is an important part of the overall monitoring of the state of the natural environment in the region.

The earliest development in the spring was in silver birch and balsam poplar in the plantations of the conditional control zone: at the end of the second - beginning of the third decade of April, there was a green cone of leaves. On the contrary, the appearance of the green cone of leaves in Norway maple was noted only at the end of the third decade of April (Table 1).

We noted differences in the appearance of individual phenophases in the plants under study in plantations of sanitary protection zones of industrial enterprises and in the highway plantations in comparison with CCZ. The green leaf cone in silver birch appears earlier for 3-6 days, in ash-leaved maple - for 1-3 days, in Norway maple - for 2-4 days, in small-leaved lime - for 1-3 days, and in balsam poplar - for 1-2 days. Silver birch, ash-leaved maple, Norway maple and small-leaved lime start flowering earlier than in the CCZ. Balsam poplar had no differences observed. The duration of flowering of silver birch, ash-leaved maple, Norway maple and small-leaved lime growing in the highway plantations is reduced to 3, 4, 5 and 4 days, respectively, while the flowering time of balsam poplar remains unchanged. A different picture is observed in representatives of the

genus *Acer* in SPZ plantations of industrial enterprises. The duration of flowering of ash-leaved maple does not differ from the CCZ, and in Norway maple exceeds this period.

Table 1 – Average dates of the onset of phenological phases in woody plants in (Naberezhnye Chelny)

Functional zones		Phenological phase						
		Bb^2	F^2	F^3	Fr^3	L^3	L^4	Bb^2-L^4, days
Betula pendula Roth.								
CCZ	GP	21.04	25.04	2.05	26.05	8.09	15.10	178
	ChF	22.04	28.04	4.05	30.05	13.09	17.10	179
SPZ	FouP	16.04	21.04	27.04	19.05	3.09	22.10	190
	ForP	16.04	21.04	26.04	19.05	4.09	20.10	186
HP	MA	18.04	24.04	29.04	21.05	4.09	25.10	191
	Avto-1	17.04	22.04	27.04	19.05	2.09	24.10	191
Acer negundo L.								
CCZ	GP	27.04	16.04	24.05	23.09	17.09	30.09	167
SPZ	FouP	26.04	16.04	24.04	17.09	6.09	4.10	171
	ForP	25.04	16.04	24.04	15.09	7.09	3.10	170
HP	MA	22.04	16.04	21.04	15.09	3.09	2.10	169
	Avto-1	22.04	16.04	21.04	12.09	2.09	3.10	170
Acer platanoides L.								
CCZ	GP	28.04	23.04	3.05	3.10	23.09	15.10	171
	ChF	27.04	22.04	3.05	3.10	23.09	15.10	172
SPZ	FouP	24.04	20.04	3.05	27.09	22.09	18.10	178
	ForP	24.04	19.04	3.05	26.09	21.09	19.10	179
HP	MA	26.04	21.04	30.04	26.09	19.09	19.10	177
	Avto-1	25.04	21.04	30.04	23.09	18.09	21.10	180
Tilia cordata Mill.								
CCZ	GP	25.04	09.06	18.06	22.09	10.09	3.10	162
	ChF	25.04	11.06	19.06	19.09	8.09	1.10	160
SPZ	FouP	24.04	07.06	14.06	19.09	10.09	3.10	163
	ForP	23.04	08.06	14.06	17.09	9.09	1.10	162
HP	MA	23.04	08.06	13.06	30.08	25.08	12.09	143
	Avto-1	22.04	06.06	11.06	11.09	7.09	27.09	159
Populus balsamifera L.								
CCZ	GP	19.04	26.04	30.04	31.05	24.08	13.09	148
SPZ	FouP	18.04	25.04	29.04	28.05	28.08	27.09	163
	ForP	18.04	26.04	30.04	27.05	29.08	26.09	162
HP	MA	17.04	26.04	30.04	26.05	28.08	21.09	158
	Avto-1	18.04	25.04	30.04	25.05	28.08	21.09	157

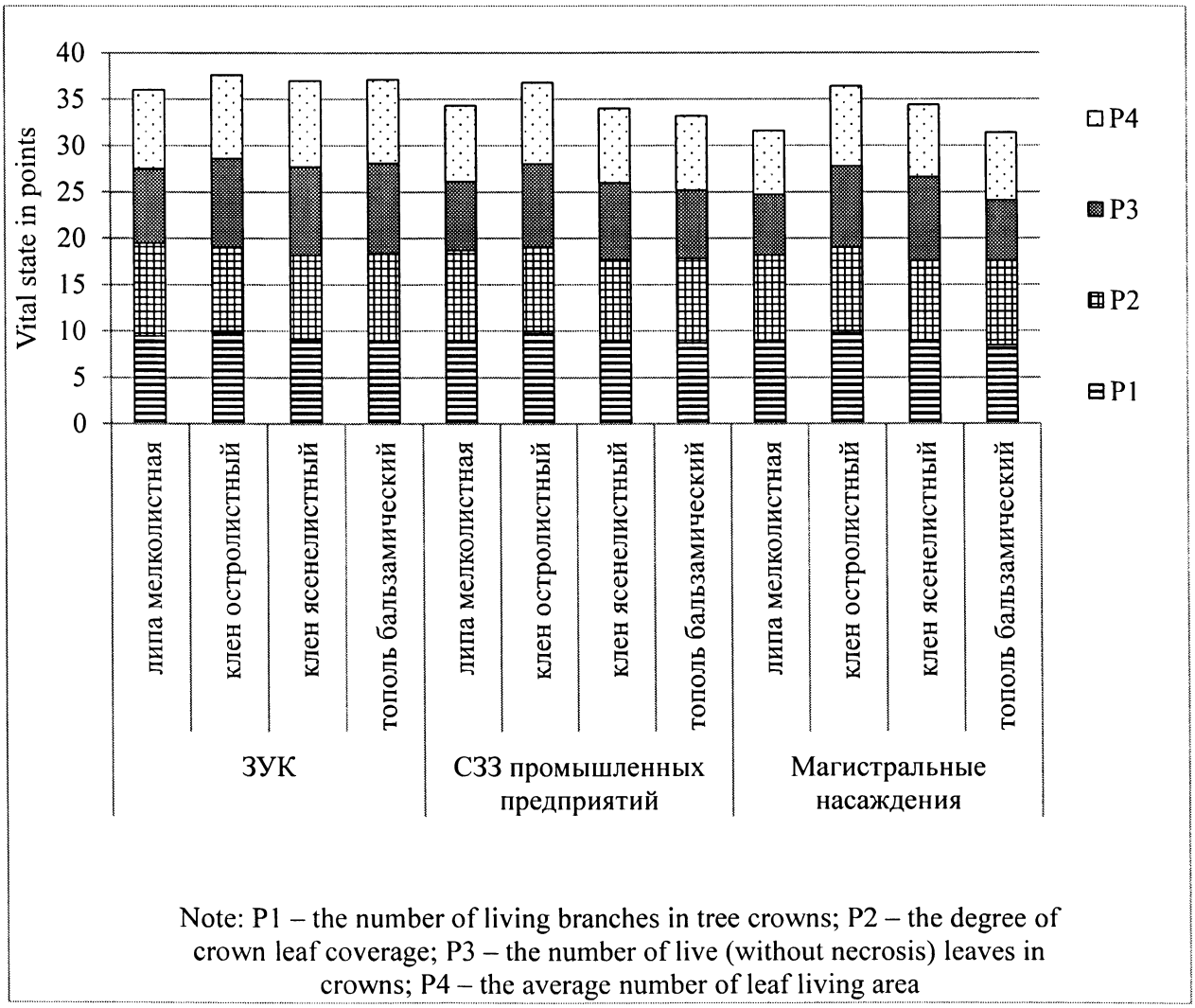
Note: CCZ – conditional control zone, SPZ – sanitary protection zone, HP - highway plantations; GP – Grenada park; ChF – Chelninskoe forest-division; FouP – foundry plant; ForP – forging plant; MA – Mira Avenue; Avto-1 – highway No.1.

All studied species of woody plants growing under intense man-induced stress, except for balsam poplar, show an earlier onset of the phase of dying leaves coloring as compared with the species in the CCZ plantations. The early appearance of autumn coloring was observed in ash-leaved maple, Norway maple and small-leaved lime, growing in the highway plantations, as opposed to the plants growing in CCZ and SPZ plantations of industrial enterprises.

The longest periods of vegetation are common to silver birch, and make up 190 days in the SPZ plantations of the foundry plant, 186 in the SPZ plantations of the forging plant, and 191 days in the highway plantations of

Avto-1 and Mira Avenue. And the shortest periods of active vegetation are common to small-leaved lime in the highway plantations (143 days), which is due to a significant temperature effect. The increase in the duration of vegetation is associated, in our opinion, with a large number of artificial light sources and higher air temperature, but also depends on the specific features.

The analysis of the vital state of the plants showed that Norway maple in the CCZ plantations has a good vital state (38 points of 40 maximum), and the remaining species under study have a satisfactory state: small-leaved lime (36), ash-leaved maple and balsam poplar (37 points) (Fig. 1). In the SPZ plantations of industrial enterprises and highway plantations, the species with unsatisfactory state are represented by small-leaved lime (32-34), ash-leaved maple (34) and balsam poplar (31-33 points). Norway maple in these categories of plantations is in satisfactory condition (37 points). The decrease in the vital state of species of woody plants growing in urban plantations of different ecological categories is associated with severe damage to leaf laminas and the formation of leaf necrosis, with a decreasing index of the living leaf area. The obtained results are comparable with the previous taxation studies conducted in the city of Izhevsk, which also noted a decline in the vital state of woody and herbaceous plants in urban plantations [Bukharina, 2012].

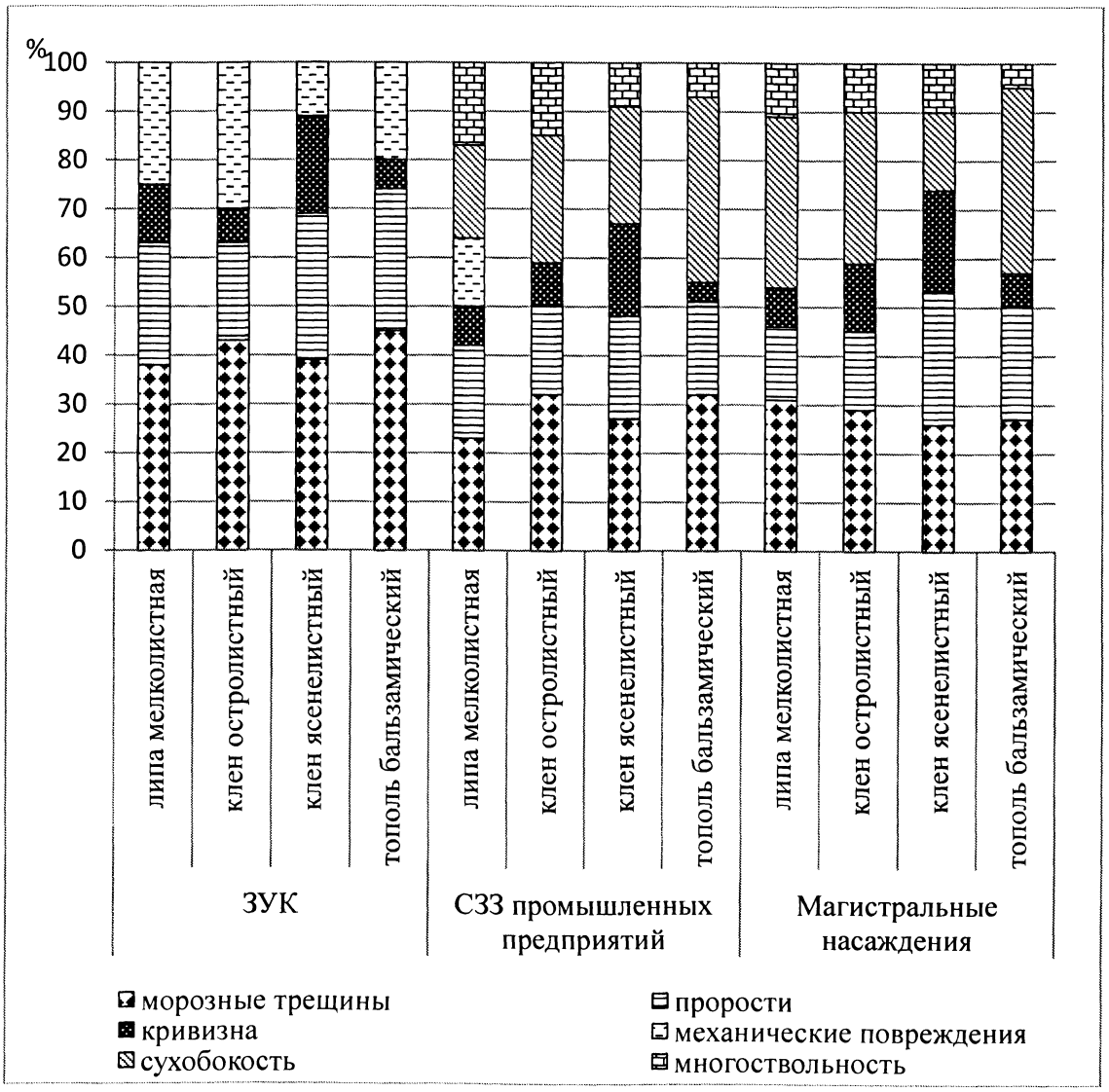


Note: P1 – the number of living branches in tree crowns; P2 – the degree of crown leaf coverage; P3 – the number of live (without necrosis) leaves in crowns; P4 – the average number of leaf living area

Small-leaved lime	Norway maple	Ash-leaved maple	Balsam poplar	Small-leaved lime	Norway maple	Ash-leaved maple	Balsam poplar	Small-leaved lime	Norway maple	Ash-leaved maple	Balsam poplar
CCZ				SPZ of industrial enterprizes				Highway plantations			

Fig. 1. The vital state of woody plants in various types of plantations (Naberezhnye Chelny)

The following abnormalities (defects) of woody plants were found in the urban woody plants: frost cracks, open and closed inbarks, crooked trunk, mechanical damages, side drought, polygonality, presence of dry branches in the crown, marginal leaf necrosis (Fig. 2). In the CCZ plantations the most common were frost cracks (42% of the individual trees), inbarks (27), and mechanical damage (23% of the individual trees). Frozen cracks and side drought (28% of individual trees), inbarks (22), crooked trunk and polygonality (11% each) prevailed in plantations of the sanitary protection zones of industrial enterprises and highway plantations.



Small-leaved lime	Norway maple	Ash-leaved maple	Balsam poplar	Small-leaved lime	Norway maple	Ash-leaved maple	Balsam poplar	Small-leaved lime	Norway maple	Ash-leaved maple	Balsam poplar
CCZ				SPZ of industrial enterprizes				Highway plantations			
Frost cracks Crooked trunk Side drought				Inbarks Mechanical defects Polygonality							

Fig. 2. Defects of woody plants in various types of plantations (Naberezhnye Chelny)

Thus, an increase in defects in the studied species of woody plants was noted in the urban plantations, which is a consequence of the mutual influence of micro-conditions of plant growth and man-made load.

4.CONCLUSION

As a result of the conducted studies it was established that higher air and soil surface temperatures are typical for the plants of sanitary protection zones of industrial enterprises and highway plantations, as compared with park plantations and natural phytocenoses. During plant vegetation, the highest values of relative air humidity were recorded in the plantations of the conditional control zone, which have a higher stand density in comparison with urban plantations.

All studied species of woody plants growing under intense man-induced stress, except for balsam poplar, show an earlier onset of the phase of dying leaves coloring as compared with the plants in the plantations of the conditional control zone. The longest periods of vegetation are common to silver birch, and the shortest – for small-leaved lime in the highway plantations. In general, the majority of the studied species of woody plants showed an increase in the vegetation periods, which we associate with a large number of artificial light sources and a higher air temperature, and, of course, with the specific features of plants. At the same time, small-leaved lime showed a significant reduction in the period of active vegetation in the highway plantations.

Under conditions of intensive man-made load, we noted an increase in plant defects (abnormalities) in plants, worsening of the vital state, which was associated with severe damage to leaf laminas, the formation of leaf necrosis, and a decrease in the index of the living leaf area.

Thus, micro-conditions in combination with intensive anthropogenic load have a significant influence on the growth and development of woody plants, which manifests itself in terms of the onset and duration of the main phenological phases, worsening of the vital state of plants, and the formation of various defects.

ACKNOWLEDGEMENTS

The work is performed according to the Russion Government Program of Competitive Growth of Kazan Federal University. Studies are conducted with the financial support of the grant of the President of the Russian Federation for young candidates of sciences No. 1955.2017.11.

5.REFERENCES

Kulagin A.A., Shagieva Iu.A. Woody plants and biological preservation of industrial pollutants. – M.: Nauka, 2005. - p. 190.

Terho M., Hallaksela A.M. Potential hazard characteristics of Tilia, Betula, and Acer trees removed in the Helsinki City Area during 2001-2003 // Urban Forestry and Urban Greening. 2005. V.3. №.2. P. 113-120.

Prosper o S., Fors ter B. Chestnut gall wasp (Dryocosmus kuriphilus) infestations: new opportunities for the chestnut blight fungus Cryphonectria parasitical / New Disease Reports 2011 - № 23. - 35 p.

Niinemets U, Sack L. Structural determinants of leaf light-harvesting capacity and photosynthetic potentials // Progress in Botany. 2006. V. 67. P. 385-419.

Robin C., Capdevielle X, Martin M. and al. Cryphonectria parasitica vegetative compatibility type nalysis of populations in south-western France nd northern Spain // Plant Pathology 2009. Vol. 58. - P. 527-535

Bukharina I.L., Kuzmin P.A. Vital state and content of tannins in leaves of woody plants in urban environment (Naberezhnye Chelny) // Vegetable resources. 2013. Ed.1. P. 77-84.

Nagamitzu T., Kawahara T., Kanazashi A. Endemic dwarf birch Betula apoiensis (Betulaceae) is a hybrid that originated from Betula ermanii and Betula ovalifolia//Plant Species Biology. 2006. V. 21. P. 19-29.

Flexas J., Ribas-Carbo' M., Diiaz-Espejo A., Galme' J., Medrano H. / Mesophyll conductance to C02: current knowledge and future prospects // Plant Cell and Environment. 2008. V. 31. P. 602-621.

Bukharina I.L., Zhuravleva A.N., Dvoeglazova A.A., Kamasheva A.A., Sharifullina A.M. and Kuzmin P.A. Physiological and Biochemical Characteristic Features of Small-Leaved Lime (Tilia Cordata Mill.) in Urban Environment. Research Journal of Pharmaceutical, Biological and Chemical Sciences. 5/5, 2014. P. 1544-1548.

Atlas of the Republic of Tatarstan / Ch. Ed. G.V. Pozdniak. M.: PKO "Kartografiia", 2005. p. 700.

Nikolaevskii V.S. Environmental assessment of environmental pollution and the state of terrestrial ecosystems using phytoindication (augmented and revised edition). – Pushkino: VNIILM, 2002. – p. 220.

Bukharina I.L., Zhuravleva A.N., Bolyshova O.G. Urban plantations: environmental aspect: monograph. - Izhevsk: Udmurtia University, 2012. - p. 204.