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STREET LANDSCAPING IN CENTRAL URBAN PARTS OF THE CITY OF SOFIA – CHARACTERISTICS, TREE SPECIES AND SUITABILITY OF THE USED SPECIES

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Abstract

Sofia is a large modern city with continuously increasing air pollution. Street landscaping is one of the opportunities for improving the urban environment, especially in the central urban areas. But how far in its present state could it perform such a function? Are the used tree species suitable and do they have a future? Do past technologies and those still used for street landscaping provide the necessary conditions for normal tree development? These are questions, the answers to which require a huge future work, since Sofia has no system for monitoring urban trees, including the street ones. The purpose of this research is to launch a more extensive and systematic study on the topic. Questions about the species or variety of the used tree species and some aspects of the general performance of the landscaping were tackled with at that stage. Based on data from literary sources, an attempt was made to assess the suitability of the species and forms that were found. Their health status was also commented on.

The established conclusions should support the future practice of planning and constructing street landscaping in the city and could be of use as a reference for the need for further research. As a result of a graphical measurement of the central city streets length, it was found that those of street landscaping were 48% of the total length and 52% of them were void of planted trees. Part of the non-landscaped streets belonged to the secondary street network. The common species of established taxons were 28, of which ash, linden and horse chestnut were the most commonly used, followed by Norway maple, silver birch, and silver linden. In the first-class network streets, horse chestnut, silver birch, and ash were most commonly used and in the second- class network streets – again ash and linden.

Keywords: street trees, street landscaping, urban tree, street tree, species selection.

INTRODUCTION

Sofia is a city with more than one million population, and with that - undoubtedly distinctive with all the negatives of today's large urban areas - heavy traffic, polluted air, thermal islands formation during the summer months (airsofia.info, eea.government.bg). There is also no doubt that the green areas and the presence of greenery in the city in general, are a great opportunity to reduce or overcome these negatives. As an important natural resource with direct contact with the city's residents, street landscaping is that part of the green system that is crucial for building and maintaining a healthy and comfortable environment in urban areas.

Street trees are one of the most important components of urban green space, and they play an important role in street aesthetics. People's first impression of a city comes from cities' street landscape. So tree species selection and planting design will strengthen the feeling of identity and distinctiveness of a city. (Ying et al., 2011).

Recognizing the growing importance of urban greenery, studies of many well-known scientists and experts have focused over the last decade on the future of urban trees and in particular the street ones (Roloff, 2013). The street monitoring system has been introduced in European cities, and huge databases have been created for decades, which are a valuable source of information for ground conclusions.

The doubt of whether the used species are perspective arises from some facts that indicate a deteriorating state and a significant reduction in their life expectancy (Roloff, 2008, Rolf, 2013). As a reason, on the one hand, the conditions of the street habitat are considered, which is radically different from the conditions of the natural habitats of the used species. The phenomenon described with the term "climate change" has no lesser role (Roloff et al., 2009), and about the impact of both factors attention is drawn to the emerging tendency of reducing the sustainability of a significant part of species against pests and diseases (Kehr, 2015).

Sofia is a city that is said to have traditions in street landscaping. The first street trees mainly willows were planted in 1870. After the Liberation, in 1879 and after the first urban plan was applied (1880-1883), trees such as - *Aesculus hippocastanum* L., *Robinia pseudoacacia* L., were planted systematically and intensively on the streets. By the end of 1941, on the streets of Sofia, were planted more than 30,000 trees - globular acacias, maples, plane trees, birches, ash, pyramid poplars and other species. Of these, 17,000 were planted between 1934 and 1940.

There is information about the same practice in the subsequent periods of the city's development (Kuleliev Y., 1994), but after the changes in Bulgaria, during the transition years, it cannot be said that for the street landscaping everything is being done, both in terms on a regulatory basis and the introduction of modern technologies for construction, maintenance, and monitoring.

Without claiming completeness, this article contains the results of the collected and summarized information on street landscaping in the central parts of Sofia. The purpose of the research is to launch more extensive and systematic study on the subject, as Sofia has no system for monitoring urban trees, including the street ones. First of all, the questions about the type of the used tree species and some aspects of this landscaping's general performance are affected. Based on data from literary sources, an attempt was made to assess the suitability of the species and forms that were found. Their health status has also been commented on. The established conclusions should support the future practice of planning and construction of street landscaping in the city and serve as a reference for the need for further research.

MATERIALS AND METHODS

The study focuses on the street landscaping in the central parts of Sofia (according to the Sofia Municipality Act) and part of the group of residential areas, locked between Evlogi Georgiev Blvd., Madrid Blvd., Sitnyakovo Blvd., Peyo Yavorov Blvd. , Nikola Vaptsarov Blvd, Henrik Ibsen Blvd, Gotse Delchev Blvd, Bulgaria Blvd., Evlogi Georgiev Blvd. (Figure 1).

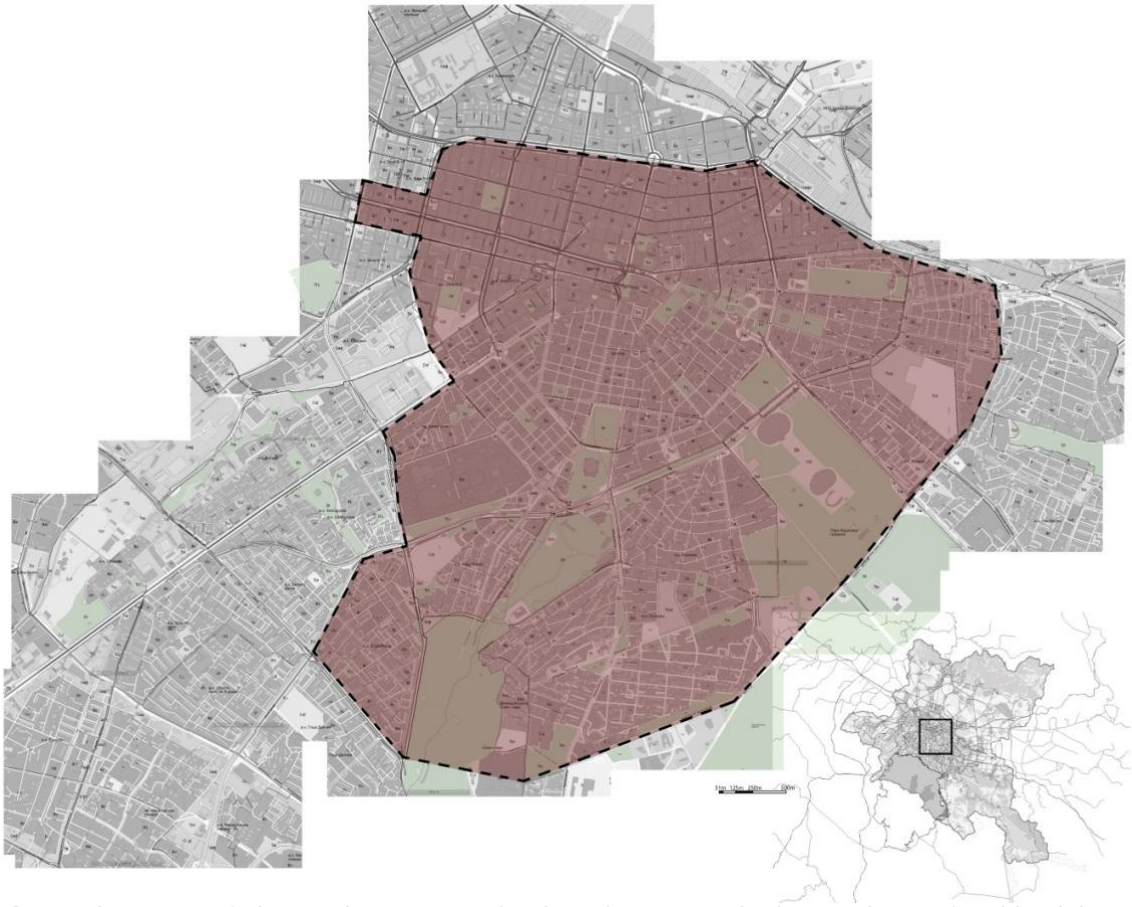

Fig. 1. *The scope of observation on street landscaping - central urban and part of residential areas*

The presented content is a result of personal observations and a complete inventory of trees in the streets within the selected area in 2017. In March and April, a list of existing species was described and then proportional to the frequency of each species' use, experimental individuals for a more detailed study were identified - a total of 1887 counts. These test individuals were examined in two more periods - June-July and August-September.

At each time, the information is rounded out with specific changes, including leafing out and health status. As essential elements for defining the street landscaping, the amount of landscaped streets and the ones without trees and also their planting technology and maintenance have been accepted.

The assessment of the suitability of the established species was made by criteria that were formulated by a thorough study of literary sources and are commented in the section about the suitability of species for street landscaping. The evaluation is supplemented with the results of a survey made among 25 landscape architects to gain insight into their subjective opinion. With using a 10th scale system, the importance of each of the 10 listed criteria for the selection of trees for street landscaping is assessed. The most important criteria have the highest score, and the most unessential - the lowest.

Sources of information on species' ecological requirements are literary ones (Kruüssmann, 1977; Sæbø et all, 2003, Ying et al., 2011, Ware 1994).

Data on established pest attacks during the vegetation season /summer months/ in 2017 is also presented.

RESULTS AND DISCUSSION

A brief characteristic of the street landscaping in the central parts of Sofia

An important point in defining the street landscaping is the number of streets with planted vegetation. It is indicative of the extent of how much of the city is "green," given that the remaining green areas are few. Figure 2 shows a scheme on which the streets with tree vegetation are marked with a green line and the ones with lack of trees - with black.

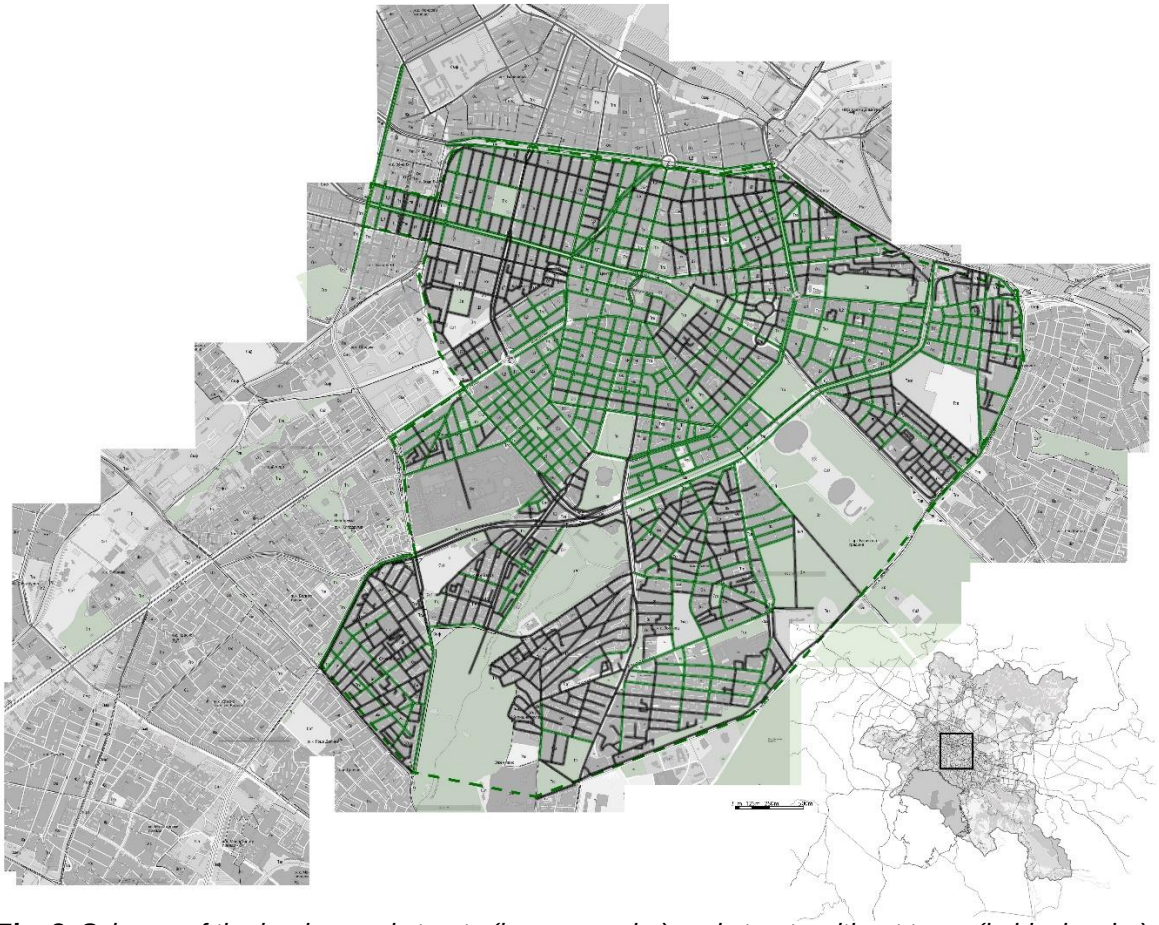

Fig. 2. *Scheme of the landscaped streets (in green color) and streets without trees (in black color).*

As a result of a graphical measurement of their length, it was found that the streets with street landscaping are 48% of the total length and 52% of them are without planted trees. Part of the non-landscaped streets belongs to the secondary street network with narrow sidewalks (up to 1.0 -1.20 m).

Due to the need to comply with the requirements for distance from curb lines and underground communications, virtually there is no possibility of planting street trees on these streets. For the rest, it can be assumed that there have been no initiatives or funding so far. However, they can be considered as a real opportunity to increase street landscaping and to reduce the amount of airborne particulate matter (PM) right in the center of the city.

As a result of the research in the observed area, it can be claimed that planting technologies are used that do not take into account the specifics of the streets as a place for trees. This also applies to new vegetation planted over the past 3-4 years. When placed in the pavement, there is usually a square hole of no more than 1.2m/1.2m around the stem.

Single examples exist from the residents nearby for maintaining this area with small decorative fences to prevent car parking or to plant the area around the tree with flowers. There are options when trees are placed in a green strip on the sidewalk, along the street, and its width is usually 1.0-1.2 m. Occasions when the area around the stem is protected from sealing, and mechanical damage with a metal grille are extremely few.

In many places, especially around public transport stops, street trees are used for hanging ads, announcements, obituaries, and so on. Traces of mechanical damage to crowns and stems are the common sight, as well as deformed pavement from the roots of adult trees.

Existing tree species

The results of the research on the species of the street trees, as well as the ways of their use (alone or with other species and depending on the class of the street), are laid out in Table. 1.

The common species of established taxons are 28, of which *Fraxinus excelsior* L., *Tilia cordata* Mill, and *Aesculus hippocastanum* L. are the most commonly used species, followed by *Acer platanoides* 'Globosum', *Betula pendula* Roth., and *Tilia tomentosa* Moench.

However, the appearance of street landscaping is determined by the first three species, since they are used as main (over 95% participation) in 105 streets (57.0%). *Fraxinus excelsior* L. was found to be used in 39.1% of the streets (72), and as a single species in 27.7% (51) of them. *Tilia cordata* Mill., participate in the landscaping with 32.6% (60) of the total number of observed streets, and as the main species in 14.1% (26).

In the first-class network streets, *Aesculus hippocastanum* L., *Betula pendula* Roth, and *Fraxinus excelsior* L. are most commonly used and in the second class network streets – again *Fraxinus excelsior* L. and *Tilia cordata* Mill.

About species diversity within one street, the trend of using single species or variety in street landscaping is outlined. Even for streets where equal shares of two or more species are defined, vegetation in individual street plots (usually from one crossroad to another or two opposite sidewalks) is planted again by a single species or variety.

There are single individuals, the presence of which can be explained by the intervention of the inhabitants or by occasional replacement of dead trees in almost all of the observed streets

Pauleit et al. (2002) showed that, throughout Europe, there existed a poor diversity of tree genera and species being planted in urban areas, especially as street trees. In comparison, although planners in Central and North-Western European countries use a relatively broad range of species, only three to four genera predominate in urban areas, namely *Platanus, Aesculus, Acer,* and *Tilia*.

In the Mediterranean countries, e.g., in Spain, 56 percent of all trees planted in paved areas are represented by only five genera (García-Martín & García-Valdecantos 2001), whereas much more are planted in parks and gardens. It can be assumed that the use of a broad genetic diversity will lead to a greater aesthetic variation and healthier trees in urban areas.

Based on the fact that only a few species comprise 60–80 percent of the trees planted in cities, a major aim for planners of urban green areas should be to decrease the reliance on the most popular species and cultivars that dominate too much of today's urban forests (Sæbø, A et all.2003)**.**

Suitability of established species for street landscaping

The choice of suitable species for planting, including for a street landscaping, is of great importance for their future development and hence for the fulfillment of their assigned function or functions. This is an important planning task towards that is not always approached reasonably and systematically. The cause may be the complexity that arises from the many possible perspectives and selection criteria - soil, environmental (abiotic and biotic), aesthetic and economic conditions.

№	Tree species / variety /	Participation in how many streets /of 184 observed/	Participation depending on quantity in one street			Participation depending on the streets' class						Observed pests
						First class street network				Second class street network		
			Main species (over 95%)	With other species, with approximately equal participation	Participation with single pieces (up to 5%)	City highways II class	Regional street arteries III A class	Regional street arteries III B class	Main streets IV class	Collec-ting streets V class	Residen-tial streets	
1	*Aesculus hippocastanum* L.	42	28	8	6	2	3	10	3	19	5	Leaf miner
2	*Acer platanoides* L.	10	-	5	5	-	-	-	3	5(1**)	2	aphids
3	*Acer platanoides* 'Schwedlerii'	2	-	2	-	-	2*	-	-	-	-	aphids
4	*Acer platanoides 'Globosum'*	26	14	9	3	2	2	1	4	17 (1**)	-	aphids
5	*Acer pseudoplatanus* L.	8	2	1	5	1	-	-	1	6	-	aphids
6	*Acer sacharrhinum* L.	2	-	1	1	-	-	-	-	2 (1**)	-	non visible
7	*Acer negundo* L.	2	-	-	2	1**	-	-	-	1	-	non visible
8	*Ailanthus altissima* Swingle	10	-	4	6	-	1	1	2	6	-	non visible
9	*Betula pendula* Roth	26	10	10	6	2	-	2	12	9	1	non visible
10	*Catalpa bignonioides* 'Nana'	1	-	-	1	-	-	-	-	1	-	aphids
11	*Celtis australis* L.	5	2	3	-	-	-	-	-	5	-	non visible
12	*Chamaecyparis lawsoniana* Parl.	1	-	-	1	1**	-	-	-	-	-	non visible
13	*Fraxinus excelsior* L.	72	51	7	14	3	-	4	8	51(1**)	6	non visible
14	*Fraxinus oxycarpa* Willd.	8	-	-	8	-	-	1	2	5	-	non visible
15	*Fraxinus americana* L.	18	-	1	17	2	-	1	2	13**	-	non visible
16	*Ginkgo biloba* L.	1	-	-	1	-	-	1**	-	_	-	non visible
17	*Gleditschia triacanthos* L.	2	-	-	2	-	-	-	1**	1**	-	non visible
18	*Morus alba* L.	1	-	-	1	-	-	-	-	1**	-	non visible
19	*Platanus occidentalis* L.	8	4	2	2	-	-	2 (1**)	1	5	-	*Phyllonorychter platani* Staudinger on few individuals
20	*Platanus x acerifolia* Willd.	1	-	-	1	-	-	-	-	1**	-	non visible
21	*Populus pyramidalis* Roz.	3	-	2	1	-	-	2	-	1	-	non visible
22	*Prunus cerasifera* Ehrh.	2	-	-	2	-	-	-	1**	1**	-	non visible
23	*Quercus rubra* L.	9	3	2	4	1	1	4	-	3	-	aphids but on very few individuals
24	*Robinia pseudoacacia* 'Umbraculifera'	16	10	1	5	1	-	-	1	13	1	Non visible on older individuals. On younger - aphids
25	*Salix babylonica* L.	3	-	-	3	-	-	-	_	3**	-	non visible
26	*Tilia cordata* Mill.	60	26	5	29	1	2	5	5	38(1**)	9	aphids, leaf edge burning, *Eriophyes tiliae* Pagenstecher
27	*Tilia tomentosa* Moench	26	2	1	23	-	2	2	4	16	2	aphids on few individuals
28	*Tilia platyphyllos* Scop.	13	-	-	13	-	1	-	2	9	1	aphids, leaf edge burning

** - new plantings; ** - the species participates as a single tree or up to 3% of the street vegetation on the relevant street*

In a publication on the selection of suitable trees for green areas and city streets in Germany, Roloff (1 - 2013) lists over 80 possible criteria but, as the most important ones, indicates drought resistance, salinisation, soil sealing and compaction, high pH soil values, sufficient winter resistance, heat resistance and resistance to pests and diseases. A similar approach is also applied by Löbel (2001), which puts soil properties and environmental factors at the forefront, after that the selection can continue according to the aesthetic criteria or the trees' function.

According to other authors, the physiology of plant stress provides important insights about which criteria to be selected for making a tree improvement program, and also they propose a choice model (Arrne, 2003). In a publication on trees selection in connection with climate change, Roloff (2009) proposes a method by introducing a matrix (Klima-Arten-Matrix-Klam) in which the most important criteria are drought resistance and winter resistance.

Miller (1997) proposed a Species Selection Model for selecting species for urban uses. Important factors in the model include the site factors, economic factors, and social factors. However, he did not give priorities for these factors. Pauleit (2003) identifies design qualities, longevity, ease of cultivation, and mass propagation as the main criteria for the selection of tree species. According to Ware, 1994; Jim, 1999; Sæbø et al., 2005; Thaiutsa et al., 2008, street trees are easily subject to stresses due to their proximity to atmospheric pollutants, poor drainage, inhospitable soil,mechanical damage, high and low ambient temperatures, and lack of space for growth. These factors should also be considered in the selection of street tree species (Ying et al., 2011).

According to the presented data in the short review on the topic and the studies of other unquoted authors, it can be concluded that the choice of objective evaluation criteria depends on the point of view. Therefore, the assessment of the suitability of established tree species in the central parts of Sofia has been carried out by the following groups of criteria:

- Criteria that are indicative of the suitability of the species regarding the climate change. Frost, heat, and drought resistances are the main ones that have been adopted in this direction;

- Criteria that are indicative of the suitability of the species regarding the typical streetscape conditions nowadays in the large urban areas and maintenance specifics of street trees. The rigor of tree species to soil, including pH values, salinity stability, wind resistance and post-prone reaction is at the basis of the assessment;

- Health condition. Based on the dependence between the resistance of the urban trees to pests and diseases and urban environment (Nomotny, 2013), their health status is perceived as an indicator of viability and adaptability to this environment. The results of the study are laid out in Table 1. Due to the combined impact of all environmental factors on the trees' condition and the real possibility of each of them being crucial in certain circumstances, the severity of the criteria is not given. However, for this study, a survey was made among 25 landscape architects to gain insight into their subjective opinion.

Using a 10-point system, they have assessed the importance of each of the 10 listed criteria when choosing trees for street landscaping. The most important criteria have the highest score, and the most unessential - the lowest. The most essential, according to them, is the correspondence between environmental requirements of species and environmental conditions of a streetscape. As a result of the collected and processed information on the suitability of the established species and varieties for street trees, the following most important points should be noted:

Acer platanoides 'Globosum', *Celtis australis* L., *Ginkgo biloba* L., *Platanus x acerifolia* Willd, *Robinia pseudoacacia* 'Umbraculifera' and *Tilia tomentosa* Moench., are most suitable for the first and second group of criteria. However, the first and the representative before last of this category are species for which the attack of aphids is typical under the conditions in Sofia. In the 2017 growth season, pests and diseases were not detected on *Celtis australis* L., *Ginkgo biloba* L., *Platanus x acerifolia* Willd. In *Tilia tomentosa* Moench, single individuals are affected by aphids. None of the listed taxons refers to the most commonly used ones.

With a certain reservation and consideration of their specific features and requirements, *Acer platanoides* L. (non-resistant to gas and sensitivity to soil compaction) can be used; *Betula pendula Roth*. (non-resistant to gas); *Fraxinus Americana* L. (demanding to soil richness); *Fraxinus excelsior* L. (soil-demanding, non-resistant to soil compaction), *Platanus occidentalis* L. (demanding to soil) and *Quercus rubra* L. (demanding to soil). Pests have been found on *Acer platanoides* L. and *Platanus occidentalis* L.

Although belonging to this group, some of the species, such as *Fraxinus excelsior* L, *Betula pendula* Roth, can be called "typical" for Sofia and they develop well. But perhaps this is also because they are applied for landscaping streets from the secondary street network.

Acer pseudoplatanus L., *Acer saccharrhinum* L., *Aesculus hippocastanum* L., *Ailanthus altissima* Swingle, *Gleditschia triacanthos* L., and *Tilia platyphyllos* Scop have been found to be unsuitable for street landscaping. In the worst condition are *Aesculus hippocastanum* L. trees. The Horse-chestnut is one of the most commonly used species. For nearly 20 years in Bulgaria, they have been subjected to attacks by the leaf miner *Cameraria ohridella* Deschka et Dimic. The biotic factors, combined with the increased intensity of anthropogenic pressure, and other negative ecological factors on the city streets, have exerted a negative synergistic impact on these trees (Pencheva, A., Anisimova, 2016).

CONCLUSIONS

As the first stage of a longer-term work on the problems of street landscaping in Sofia, the present study gives grounds for making few more important summaries and conclusions about its state in the central city parts:

- Thanks to purposeful plantings in the past, the streets in the discussed part of Sofia city still give the impression of an abundant greenery. Nearly 50% of the observed streets' total length is planted. A lot of tree-free streets can be considered as a real opportunity to create plantings in the future;

- Lack of regulatory requirements regarding the technologies for planting and maintaining street landscaping provide opportunities for construction activities and crown pruning to be not performed at the required professional level;

- The results of this research confirm the other studies about the unsatisfactory condition of *Aesculus hippocastanum* L. on Sofia city streets and also the opinion that the horse chestnut is not suitable for these purposes. With more targeted studies, this is likely to be the case for *Acer pseudoplatanus* L., and *Tilia platyphyllos* Scop;

- To make good conclusions in the future about the suitability of certain tree species for street landscaping it is necessary for a street tree monitoring system in Sofia to be created. The system would allow, along with purely theoretical judgments based on information from literary sources, that decisions on the use of one or other species also to be made by a long-term experience under the specific conditions.

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