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HEALTH STATUS AND AESTHETIC EVALUATION OF HORSE CHESTNUT (*AESCULUS HIPPOCASTANUM* L.) ROADSIDE TREES IN SOFIA

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Abstract

The aim of this study was to assess the health status and the ornamental effect of horse chestnut trees used in landscaping of central Sofia streets.

Phytosanitary status assessment of trees was based on three groups of diagnostic criteria: leaf physiological and biotic problems; stem and roots injuries, and crown damages.

The results of this study suggest that horse chestnut specimens cultivated as roadside urban trees had not only reduced vitality, but also low ornamental qualities. At the end of the summer season, the resulting defoliation became rather depressing, preventing this highly regarded species to serve its ecological and ornamental purposes. The biological limitations make it unsuitable for the adverse urban environmental conditions common for street plantings. Improper pruning practices accelerates the processes of decay and reduces its longevity. A high percentage of trees had unbalanced crowns. Additionally, the available lower trunk cavities in 22% of investigated specimens make them potentially hazardous for people.

Key words: leaf diseases; *Cameraria ohridella*; stem and roots injuries; crown damages

INTRODUCTION

Due to its high ornamental qualities, the horse chestnut (*Aesculus hippocastanum* L.) is one of the most popular species used in the landscape design of parks, squares, streets and roadsides. It was introduced in Europe in 1557, when its seeds were imported from Turkey to Prague (Lack, 2002). Although the species is endemic to the Balkan Peninsula, its cultivation as an ornamental tree in Bulgaria began much later in 1891 (Trenchev et al., 2000). The large-scale cultivation of *A. hippocastanum* in the streets and boulevards of Sofia began in the middle of the last century and has made this species an emblematic tree for the city.

Horse chestnut is a large and tall tree which grows up to 30 m. It develops a dense crown and a large root system. Its age limit is 150 to 200 years. There are several natural habitats of the species. These include the mountains of Greece, Albania, FYR of Macedonia and Dervisha Managed Nature Reserve in Bulgaria (Avtzis et al., 2007; Dimitrov et al., 2012). *A. hippocastanum* is a mesophytic tree, growing in moist deciduous broad-leaved forests in warm temperate climates. It grows especially well at the bottom of shady ravines, on limestone bedrock, and on alluvial soils in association with hornbeam (*Carpinus betulus* L.). The species can also be found in mountain mixed forests up to 1600 m altitude (Kochev, Gorunova, 1972; Evstatieva, 2011).

Although the horse chestnut shows remarkable habitat adaptability, the unfavourable ecological conditions imposed by the urban activities strongly influence its development. In recent years, a significant number of researchers have discussed the considerable damage done to horse chestnut trees by traffic, improper tree maintenance, construction work, and intensive pruning (Poštenjak, Poštenjak, 2012; Papazov, 2007; Snieskiene et al., 2011). The species is very sensitive to soil quality. It is also highly susceptible to air pollution (Munkova, 2001), and is therefore recommended as a bioindicator of industrial and road traffic pollution in urban environments (Kurteva, Dimitrova, 2014).

One of the first *A. hippocastanum* health problems established in Bulgaria is leaf necrosis observed along busy boulevards in Sofia (Makedonska, 1972; Zheleva, 1972). Although not as significant, leaf damage was also caused by the fungus *Phyllosticta paviae* Desm. (with teleomorph: *Guignardia aesculi* (Peck) V. B. Stewart) (Zheleva, 1975). This fungal pathogen is currently causing serious problems in substantial parts of Europe, instigating premature defoliation (Pastirčáková et al., 2009; Snieskiene et al., 2011).

Since 1989 *A. hippocastanum* trees in Bulgaria have also been subjected to attacks by the leaf miner *Cameraria ohridella* Deschka et Dimic (Trenchev et al., 2000; Mirchev et al., 2013). The moth was first observed attacking ornamental horse chestnut trees in FYRMacedonia in the 1970s, and was described as a new species in 1986 (Kenis, 2014). Since its discovery, the leaf miner has experienced an explosive westward range expansion, progressively colonizing all of Central and Western Europe. Its origin has been a matter of debate, however, recent molecular studies suggest that *C. ohridella* probably originates from natural horse chestnut stands in FYRMacedonia, Albania and Greece and has moved to urban areas in the second half of the XX century (Lees et al., 2011; Valade et al., 2009).

The weakened condition of the infested horse chestnut trees makes them more susceptible to other diseases, which would not be harmful under usual circumstances (Oszmiański et al., 2014). Since 1999, a new pathogenic fungus of *Aesculus* spp. has been observed in Europe – the North American powdery mildew *Erysiphe flexuosa* (Peck) U. Braun & S. Takam (Zimmermannová-Pastiráková et al., 2002; Stoykov, Denchev, 2008). Another disease – stem bleeding cankers on horse chestnut trees, was first observed in the early 1970s and later on was proven to be associated with the bacterium *Pseudomonas syringae pathovar aesculi.* Disease symptoms include rusty-brown or black gummy liquid seeping from the bark, in addition to necrotic phloem (Schmidt et al., 2008).

The biotic factors, taken together with the increased intensity of anthropogenic pressures, and other negative ecological factors in the city streets, have exerted a negative synergistic impact on horse chestnut trees for several decades now (Jităreanu et al., 2010; Poštenjak, Poštenjak, 2012; Tyburska et al., 2013).

The **objective** of this study was to assess the health status and the ornamental effect of horse chestnut trees used in landscaping of central Sofia streets and boulevards.

MATERIALS AND METHODS

The survey was carried out mainly in 2016, but the article presents data collected between 2006 and 2015. The research samples included 500 horse chestnut trees used in

landscaping of central Sofia city streets. Of them 103 were analyzed in detail. They were located along 'St. Georgi Sofiyski' Str. (SGSS) and 'Patriarh Evtimiy' Blvd. (PEB). The indicated sites are characterized by heavy traffic and unfavourable growing conditions – high temperatures due to absorbed heat from the asphalt surfaces, limited space for crown and root system development, soil compaction, low soil and atmosphere humidity.

The age of the studied trees was determined after counting the tree rings of samples taken at chest height by a Pressler drill from 3 specimens of each street. The diameter at chest height and the distance of the stem from the roadway and the buildings were also measured.

Phytosanitary status assessment

It was based on three groups of diagnostic criteria: leaf diseases; stem and roots injuries, and crown damages.

The following leaf problems were studied: marginal leaf necrosis; chlorosis; Phyllosticta leaf blotch; powdery mildew and leaf miner damages. Infested leave samples were collected for further laboratory examination.

The development of leaf miner attacks was studied from 2006 to 2015. The degree of attack by leaf miners on the infested specimens was evaluated within a 5-grade scale, taking into account the percentage of mined leaves (Table 1).

Table 1. Horse chestnut degree of attack by leaf miner

No mines (0)	Weak attack (1)	Average attack (2)	Strong attack (3)	Very strong attack (4)
0%	1-25%	26-0%	51%-70%-	over 71%

The average degree of attack (in %) for each of the studied years was calculated applying the following formula (Snieskiene et al., 2011) :

$$R = \frac{\sum(n.k)}{NK} 100$$

where:

R – average degree of attack;

n – number of specimens affected to the same extent;

k – degree of attack (k ranges from 0 to 4);

N – number of examined specimens;

K – maximum degree of attack (K = 4).

In February 2016 each specimen of both studied locations was examined for visible stem and root problems as well as crown state problems. Stems and roots were examined for leaning stems, codominant stems, wounds and cracks on the bark and stem, decay in the lower trunks and cavities, fruiting bodies of a basidiomycete (basidiocarp), and bacterial bleeding canker. Crown states were analyzed for unbalanced crown configurations, decayed unsealed pruning cuts, broken branches, dieback of twigs or branches and epicormics (water) sprouts.

Ornamental effect evaluation

The complex ornamental effect of horse chestnut species was determined following Kotelova, Vinogradova's (1974) methodology. It can be expressed by the value of the following equation:

$$P = \Sigma aP/\Sigma P = (a1P1+a2P2+a3P3+a4P4+a5P5)/(P1+P2+P3+P4+P5)$$

where:

a1, a2, a3, a4, a5 – grade of the plant features (an=1÷5);

P1, P2, P3, P4, P5 – weighting coefficient for each of the plant characteristics (see below).

The ornamental plant characteristics have the following weight: architectonics of stem and crown – P1 = 4; leaves – P2 = 3; flowers and inflorescences – P3 =2; fruits – P4 = 2; stem and shoot colour and bark fracture – P5 = 1. The grade of the basic plant features depends on the age of the specimen and the studied period of the year.

The complex ornamental effect of the horse chestnut species is determined by a 5-point grading scale. The lowest grade signifies features that have no aesthetical value whereas the highest grade represents outstanding ornamental qualities in terms of structure, shape, size, colour, etc.

The seasonal dynamics of the horse chestnut ornamental performance were analyzed. A model tree (park specimen under natural conditions) was compared to the roadside urban specimens in this study.

RESULTS

Trees' age. Horse chestnut specimens in both study sites were evaluated to be 70-75 years of age, with an average diameter of 40.3 cm (min 31.2, max 53.2 cm). Given the species age limit and its reduction due to the adverse environmental conditions in the narrow street spaces, it was concluded that the surveyed trees have reached their optimum growth.

The distance between trees and roadway was up to 0.5 m, and the distance from them to the building facades was up to 3.5-3.6 m. The average distance between specimens was 6.6 m for PEB and 7.0 m for SGSS respectively.

According to the regulatory requirements for separation distance of ornamental woody plants from pipelines, facilities, and buildings (Regulation N1/03.10.1993) the minimum distance of street trees' stems to roadway edge is 2 m, and to the building facades is 3 m. On the other hand, the choice of species for street landscaping should be consistent with sidewalk width. According to the biology and habitus of *A. hippocastanum* (potential crown diameter of 10 m – by Gerhold, Porter, 2007), the species should be used on urban roadways (streets or boulevards) with a sidewalk width of over 5 m, as the recommended planting distance between specimens is 8-10 m.

Health status

The results from the analyses of leaves, obtained from the examination of the studied trees is shown in Fig. 1.

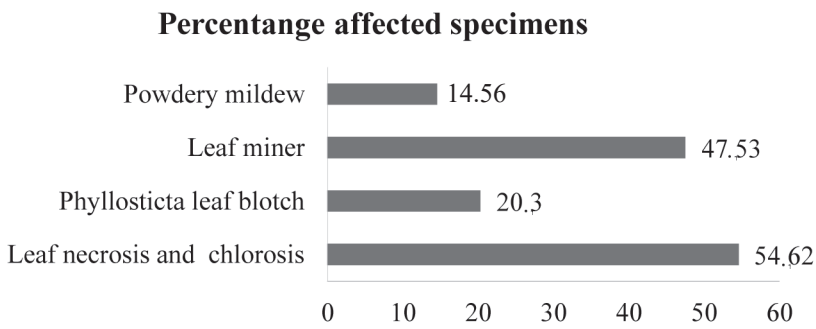

Fig. 1. Physiological and biotic problems of horse chestnut leaves

The most significant phytosanitary problems observed on horse chestnut leaves were the marginal leaf necrosis (scorch) accompanied by chlorosis (54.62% of the specimens were affected) (Fig. 2a,b). In 2016, these problems appeared in early spring (mid-May) on leaves located in the lower crown part of trees on the side facing the roadway (Fig. 2a). Although parts of the horse chestnut specimens (in the southern part of SSGS) are planted in a green belt, due to lack of shading from nearby buildings and heavy traffic, they were in the worst health condition. Even at the end of the last century, when attacks by *C. ohridella* were still limited in park areas, the leaves of street trees were turning brown and fell off prematurely in July (unpublished data).

Characteristically, there was a second growth of small leaves in July-August, while inflorescences tended to be small and under-developed. This phenomenon recurred by the beginning of autumn. The horse chestnut specimens on 'Maria Louisa' and 'Tsar Osvoboditel' Blvds. (most of which gradually declined in the 90s of the last century) had identical problems. The roadside trees along 'P. Slaveykov' Str. and 'Praga' Blvd. were in a similar condition, while the ones along 'Vitosha' Blvd. (except the part near 'Sv. Nedelya' Sq.) and 'Bulgaria' Blvd. were in significantly better conditions. This can be explained by their younger age and the lack of drastic pruning. Leaf necrosis was observed only in 11% of the specimens, although the leaves were affected to a much lesser extent.

Even though *E. flexuosa* and *Ph. paviae* are currently causing serious problems in Europe, their development on the examined horse chestnut specimens had relatively little impact. The percentage of leaves affected by powdery mildew was 14.56% and 20.3% by leaf blotch respectively.

C. ohridella has been appearing in Sofia street plantations since the beginning of the XXI century, and during the last ten years has developed dense populations (Fig. 3). In both study sites the highest percentage (63.7-87.2%) of foliar damage observed was during August in the time period between 2011 and 2015. The most affected trees were located in the southern part of SGSS, where leaf mines covered the entire surface of leaflets, and the trees had completely defoliated over many years. The trees in this part showed particularly severe symptoms of stress and decline (6.92% eventually completely dried out) (Fig. 4a). Even though the leaves containing overwintering pupae had been removed in the autumn (widely used control method) the attack resumed to the same extent by the following year.

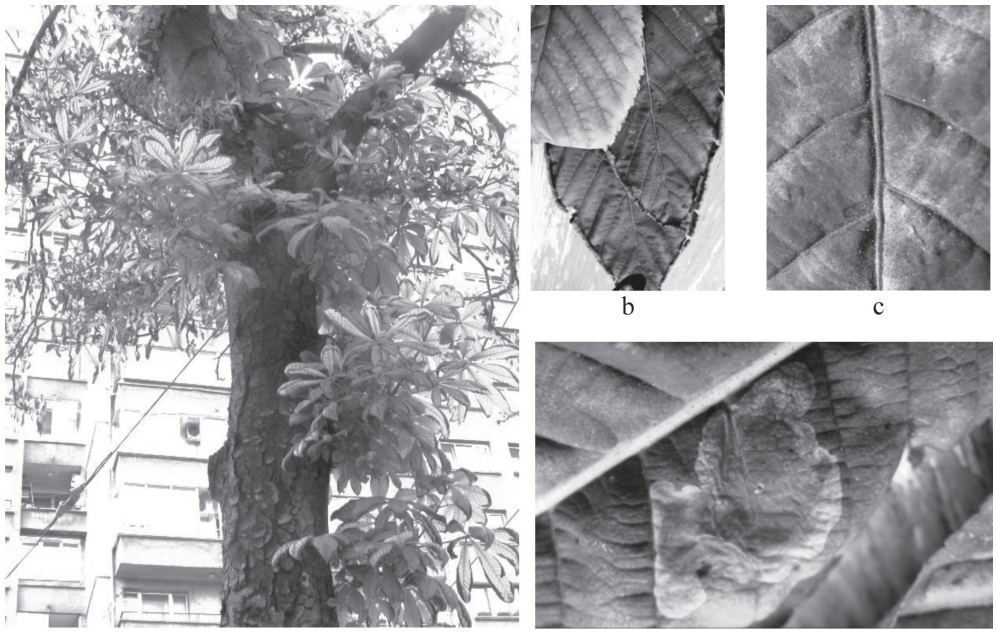

Fig. 2. Horse chestnut leaf problems: a, b – marginal leaf necrosis and chlorosis; c – powdery mildew *E. flexuosa*; d – leaf mine of *C. ohridella*

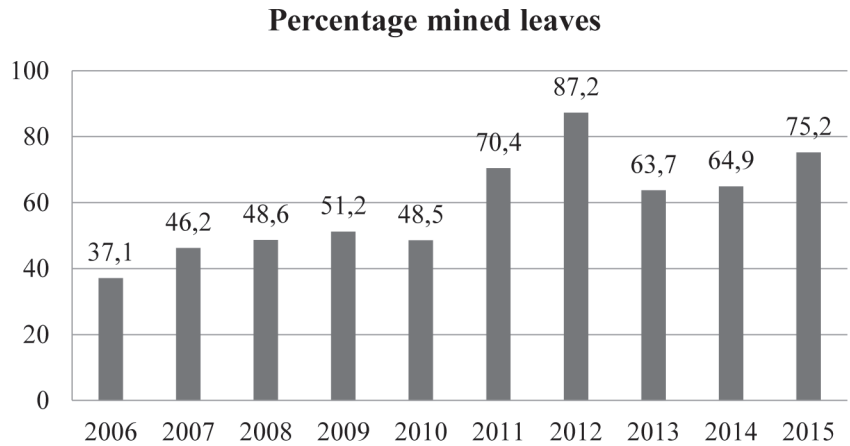

Fig. 3. The average degree of attack from *Cameraria ohridella* (in %) during the last ten years (2006 – 2015)

The results from trees' trunk and crown state examination are shown in Fig. 5 and 6.

The results from trunk state examination (Fig. 5) indicate that the majority of the sample specimens have substantial damage – bark wounds (55.46%) and cavities or decay in the lower trunk (21.85%) (Fig. 4d). In the current study fruiting bodies mainly of the species *Schizophyllum commune* Fr. (5.88%), and quite rarely of two others *Chondrostereum*

Fig. 4. Horse chestnut trunk and crown problems*:* a – dried out tree, located in the southern part of "St. Georgi Sofiyski" Street; b – symptoms of bleeding canker disease; c – decayed pruning cut; d – cavity in the lower trunk.

purpureum (Pers.) Pouzar and *Bjerkandera adusta* (Willd.) P. Karst, were identified. They were found on the bark of the branches or trunk of the most heavily damaged, declining, or dying specimens. Symptoms of bleeding canker disease (Fig. 4b) were identified in just a few of the specimens (1.68%); however, the causal agent has not been established.

Surface rooting was observed in 11.65% of the specimens. It provoked pavement lifting and had an adverse impact on the flow of water and soil nutrients. Additionally, surface rooting signified the specimens' starvation of oxygen due to soil compaction. Part of the studied specimens had leaning trunks (11.76%).

The lack of proper initial formative pruning at a young age (during the first 10 years) of the studied specimens led to the development of codominant stems in 30.25% of specimens instead of a balanced crown shape. The tension in the tangental plane between the two stems resulted in cracks. Additionally, moisture was retained for longer and thus provoked attacks by pathogens.

The majority of the studied specimens (68.87%) had long oval-shaped pruning cuts with a diameter of more than 15 to 20 cm, with developed rot, cracks and cavities in the boughs (Fig. 4c). As a response to improper pruning, excessive sprouting developed from epicormic buds in 23.53% of the specimens. The sprouts are a sign of low energy reserve. Additionally, some of the inspected trees were topped (5.04%), with a dieback of twigs and branches observed – 37.82%. As a result, a high percentage of trees had unbalanced crowns (82.53%).

Ornamental effect evaluation

The seasonal dynamics of the ornamental performance of the studied horse chestnut specimens compared to healthy park specimens is presented in Fig. 7.

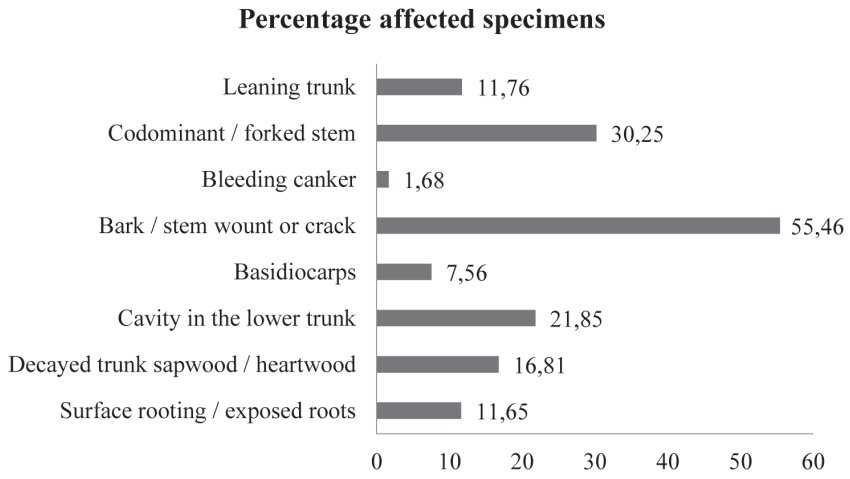

Fig. 5. Horse chestnut trunk and roots problems

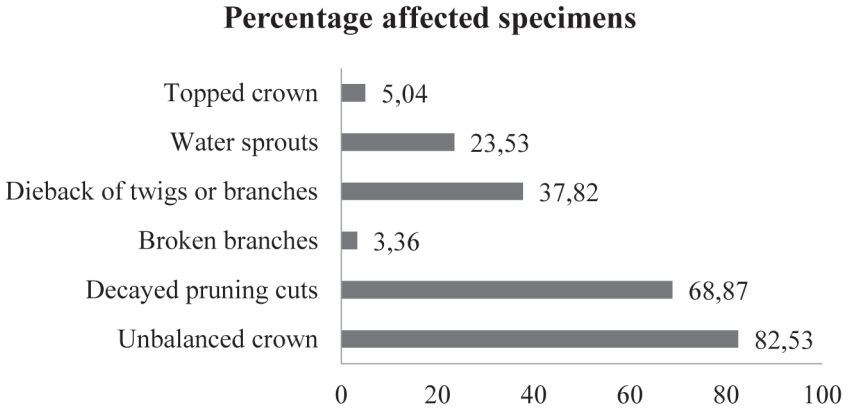

Fig. 6. Horse chestnut crown problems

The investigated species is deciduous and its ornamental effect in the winter months decreases. The habitus significantly differs from its natural one. The architectonics of *A. hippocastanum* stem and crown is the ornamental plant characteristics with the highest weighting coefficient, because of its year round effect. Improper pruning practices destroyed the specimens' crown frameworks, and these frameworks often were tipped and topped. Additionally, decay or cavities in the big pruning cuts or wounds, as well as died back branches were observed in the trees' crowns. There were also large wounds and cavities, mainly at the base of the trunks. Unsightly sprouts developed.

The maximum ornamental performance of horse chestnut species is achieved during the flowering period. Urban roadside horse chestnut specimens' foliage emerged later developing smaller and lighter leaves. Even in mid-May leaves' margins were dry. In July entire trees had autumn appearance. At the end of August and in September the majority of the specimens had completely withered leaves. During this period, leaves began to

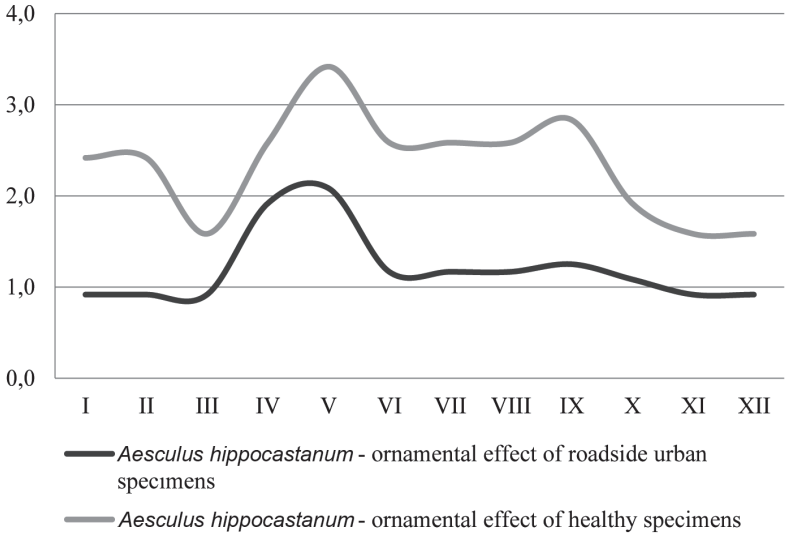

Fig. 7. Seasonal dynamics of horse chestnut ornamental performance: roadside urban specimens; park specimens

emerge again in some specimens. Observations suggested that the draught stress resulted in premature defoliation well before autumn. In addition, the leaf miner damaged the entire surface of the leaves, leading to their premature drying. All of these conditions affected the aesthetic value of the studied specimens. In comparison with the specimens grown under optimal conditions, whose complex performance evaluation has a value of 2.3; the value of the studied ones was 1.2.

DISCUSSION

The results from our current study, as part of long-standing observations, as well as other authors' findings suggest that leaf scorch and chlorosis are the most significant phytosanitary problem on horse chestnut (Makedonska, 1972; Zheleva, 1972; Papazov, 2007;). Similar damages were reported for the region of Prague (Smolák, 1963), as well as for Lithuania (Snieskiene et al., 2011). These physiological disorders are caused by unfavorable weather or soil conditions, or a combination of both. They are particularly common for horse chestnut specimens planted close to paved areas where the soil is often compacted and salinated. Studies of *A. hippocastanum* roadside trees (Jitareanu et al., 2010) indicate that salt stress leading to Na+ toxicity primarily affects stomatal closure. The photosynthesis is perturbed, the plant cannot feed itself, the existing reserves waste, and finally, the tree sears totally.

Recent findings indicate that the chronic *C. ohridella* attacks have similar impact as necrosis on the overall condition of horse chestnut trees. Their annual development drastically reduces the photosynthetic activity of specimens and leads to chlorosis and twigs dieback emergence. On the other hand, the reduced surface of the leaf lamina limits

the development of other foliar pathogens – powdery mildew and Phyllosticta leaf blotch. Their occurrence on street trees is significantly less in comparison to "King Boris" garden or other park areas as indicated in author's unpublished studies. In Poland the occurrence of spoting is also subdued according to spread of *C. ohridella* (Snieskiene et al., 2011).

Although the outbreaks of *C. ohridella* moth usually continue unabated, causing severe aesthetic damage to horse chestnut, studies in Italy showed that there is little to no impact on tree survival and tree growth in urban areas (Salleo et al., 2003). Similarly Mirchev et al., (2013) did not establish a relationship between the impacts of horse chestnut leaf miner and stem radial growth of specimens in the natural stand, located in the Dervisha Reserve. Furthermore, in Macedonia, trees still survive after 30 years of heavy outbreaks (Kanis, 2014). In contrast to this, in Germany *C. ohridella* is suspected to cause the decline of horse chestnut because defoliation induces a second flowering, decreasing frost hardness (Balder et al., 2004).

In regard to stem bleeding canker, the Gnienko et al. (2004) investigation showed similar damages on *A. hippocastanum* specimens in Varna in addition to the moth and leaf pathogens observed. Currently this bacterial pathogen has little impact on horse chestnut health status in Sofia.

Aesculus hippocastanum is a species susceptible to decay with structurally weak wood rating between non-durable to perishable (Smiley et al., 2007). It does not tolerate intense pruning well, especially pruning cuts with diameter larger than 10 cm. In order to maintain vitality and to prolong the tree's life, only small branches can be pruned. Therefore, it is most appropriate to plant the trees in places where pruning is unnecessary (Snieskiene et al., 2011). Over-pruning of mature trees creates an imbalance between the root system and the above ground part which affects specimens' nutrition, vitality and resistance.

The available trunk cavities in about 22% of specimens put them at risk of failure due to the fact that most were mature specimens (over 12-15 meters in height) with large skeletal unilaterally arranged limbs. According to the Beaufort scale, stronger winds (above 70 km/h) broke branches, knocked down whole trees or caused significant damage. For instance, the Hurricane that hit Sofia in July 2014 (wind speed 90 km/h) knocked down 40 trees in 2 hours. In another storm that hit Burgas in 2013 (wind speed 140 km/h) a horse chestnut tree fell down taking a man's life. The specimen was in apparently good condition but had asymmetrical crown and rot at the base of the stem caused by *Ganoderma* sp.

CONCLUSION

The investigation suggests that the overall health status of *A. hippocastanum* is significantly affected mainly by leaf necrosis and leaf miner *C. ohridella*, which established itself in the streets of Sofia by the early 2000s. Consequently, at the end of the summer season, the resulting defoliation became rather depressing, preventing this highly regarded species to serve its ecological, environmental and ornamental purposes. Due to the bad health status, the great part of horse chestnut specimens on 'St. Georgi Sofiyski' Street and "Patriarh Evtimiy" Boulevard had low ornamental performance.

The biological limitations of *A. hippocastanum* make the species unsuitable for the adverse urban environmental conditions common for street plantings. Improper pruning practices accelerate the processes of decay and reduce its longevity. A high percentage of trees had unbalanced crowns (82.53%) as well as cavities in the lower trunks. As a result, about 22% of investigated specimens are potentially hazardous for citizens.

After reconstruction of these streets is more appropriate to replace the specimens with hardy tree species, with an adequate size for the available growing space. There are already such landscaping practices examples in many European capitals such as Prague, Brussels and others.

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