

Reaction of street trees to adverse environmental conditions in the centre of Warsaw

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Abstract. The present study aimed at analysing the trees growing along the four main streets of Warsaw – Marszałkowska, Świętokrzyska, Jana Pawła II and Solidarności Avenues – in order to evaluate the condition of each of them. The observations made in 1973 and in 2007 revealed that in this time the trees passed from 1631 to 1014, which stands for 40.3% of the original number. The biggest loss was noted for species: *Sorbus aucuparia* L. (94%), *Acer pseudoplatanus* L. (83%), *Tilia cordata* Mill. (65%) and *Tilia* ‘Euchlora’ (62%). None of the species, that were growing in 1973, could have been more tolerant to the specific environmental conditions in the vicinity of the road. The observations made in September had shown that the most frequent average value of the leaf damage index was above 3. The growing of this index showed that as vegetation period was passing by the condition of the trees was getting worse. The comparison of the leaf damage index carried out in September showed that in 2007 the health condition in 2007 was slightly better than in 1973.

Key words: city environment, trees declining, de-icing.

1. Introduction

The greenery is one of the essential components of urban landscape in which trees play an important role in levelling ecological, scenic and health values of the city. Trees shape the local climate by influencing sunlight exposure, temperature, humidity, pollution levels as well as air exchange rates (Szczepanowska 2001; Kubiak & Księżniak 2005).

Trees complex reactions to natural and anthropogenic stressors often result in their exclusion from many regions of urban agglomerations (Bach et al. 2007). For the decades we have been observing the trees the declining was caused by gradual weakening of their vitality. This process usually affects mainly trees growing in the vicinity of the

roads. The drawbacks of the city environment, such as soil salinity (caused by de-icing of the roads), constant changes of city climate (elevated temperature, reduced air humidity), traffic (high levels of fumes and dust), limit the choice of the species and varieties of trees and shrubs that can be planted within the city (Szyprowski 2000).

Observing the existing trees, learning their history and assessing their adaptiveness should always precede the choice of the species of trees to plant in a city (Richards 1993).

The aim of this research was to value the sensitivity (vulnerability) of particular species of trees to the unfavourable conditions of growth and development in Warsaw’s street plantings.

2. Methodology

The research have been carried out along four main streets of Warsaw's centre: Marszałkowska and Świętokrzyska Streets and Jana Pawła II and Solidarności Avenues. The inventory of all the trees planted along those streets have been made. The trees were observed in 1973 and in 2007. The evaluation of the trees condition was made separately for each tree, in accordance with the trees condition table prepared by Duda et al. (1994). The leaf damage index was evaluated with a use of six-grade scale; where 0 – stands for leaves without a damage, while 5 stands for leaves with a significant damage (over 75% of the leaf's surface). The observations were made twice a year – in mid-July and in mid-September.

3. Results

The results of trees inventory are depicted in Figures 1 and 2 and presented in Table 1. In 1973, along the four streets indicated 1631 trees were growing, whilst in 2007 – only 1014. It means that the number of the trees decreased by 617, which stands for 38%. From 1973 to 2007 only 658 trees that were growing along those streets had survived, which stands for 41%. In this period 357 trees had been planted.

In Oakland from 1978 to 1984 about 60–70% of street trees withered away (Skalar & Ames 1985). According to Gilbertson and Brandshaw (1985) water stress (56%), acts of vandalism (18%), condensation of soil solution (9%) are the most common reasons of trees declining, while according to Patterson et al. (1980) the unfavourable soil conditions result in worsening trees condition. In Poland the main reason of street trees declining is, probably, the saline stress due to the de-icing streets and pathways by the use of salt (NaCl) (Czerwiński 1978; Chmielewski et al., 1999; Brogowski et al. 2000; Dmuchowski et al. 2001, 2005; Dmuchowski & Badurek 2001, 2003, 2004; Czerniawska-Kusza et al. 2004).

In Marszałkowska Street in 1973 766 trees had been growing whilst in 2007 only 476: the number of trees declined by 270, which stands 38%. In last 34 years 486 trees have withered away (70%). In that period 200 trees had been planted. In 1973 the dominating species was *Tilia* 'Euchlora' (66% of the trees) but during last 34 years 64% of these trees declined. The loss of other species trees was high too: *Tilia cordata* (65%), *Tilia x floribunda* A. Braun (60%), *Tilia platyphyllos* Scop. (58%), *Acer saccharinum* L. (90%). All Horse-chestnut trees survived (*Aesculus hippocastanum* L.) while all Norway Maples (*Acer platanoides* L.) withered away. After street modernisation in 2003 39 *Tilia tomentosa* 'Brabant' trees and 28 *Tilia platyphyllos*

trees were planted. During the extremely cold winter of 2003/2004 *Tilia tomentosa* 'Brabant' trees were severely damaged by frost (Dmuchowski 2004).

From among 366 trees growing in Jana Pawła II Avenue in 1973 only 162 had survived till 2007, which stands for 44%. During that period 35 trees had been planted, which resulted in a decrease of 169 (46%) in total number of trees. In 1973 the dominating species was *Acer saccharinum* (67%). About 49% of this species trees declined. The biggest loss was noted for *Sorbus aucuparia* (94%). The trees considered as less sensitive to the urban environment were planted, *Platanus x hispanica* Mill., oaks: *Quercus rubra* L. and *Quercus robur* L. (Łukaszewicz 1982; Bugała 1991; Marczewski 1996; Siewniak & Siewniak 2001; Appleton et al. 2002; Borowski & Latocha, 2006) and *Acer saccharinum* highly sensitive to the unfavourable growth condition, are not mentioned in the indices of trees recommended for urban greenery.

In Świętokrzyska Street 274 trees had been growing in 1973, whilst in 2007 only 181. The number of trees declined by 93 specimen (34%). In the last 34 years 486 trees have withered away (70%). From trees growing there in 1973 only 100 trees had survived till 2007, which stands for 37%. The dominating species was *Acer platanoides* (87%) and the loss for this species was noted as 61%. Trees of *Platanus x hispanica*, known as less sensitive to the conditions of urban environment, have been planted.

In Solidarności Avenue the smallest loss was noted. From 225 trees growing there in 1973 120 had survived till 2007, which stands for 53%. During that period 40 trees had been planted, which resulted in a decrease of 30% in total number of the trees within a period of 34 years. The dominating species was *Acer platanoides* (83%) and the loss for this species was noted as 52%.

The health condition of the trees growing along the four main streets of Warsaw is depicted in the charts (Fig. 3 and 4). This settlement includes only the trees that survived from 1973 to 2007. The first symptoms of the trees reaction to soil salinity are discolouration and necrosis of the leaves (Strogonov 1970). At the beginning of the vegetation period, in early spring, the changes appear on the top part of the edges of the leaf lamina. However, as a result of the increase in the chlorine and sodium concentrations in the leaves, the degree of leaf-damage also increases (Mak-dashi et al. 1988).

The health condition of the examined trees was exceptionally poor. The average value of the leaf damage index in the research carried out in September 1973 fluctuated from 1.7 (for *Tilia x floribunda*) to 4.6 (for *Tilia* 'Euchlora'). In 2007 the value of this index for *Tilia x floribunda* increased to 3.1. In 2007 the index in the research carried out in an analogous period of observation fluctuated from 2.5 (for *Acer pseudoplatanus*) to 4.0 (for *Sorbus aucuparia* and *Tilia* 'Euchlora'). The best health condition

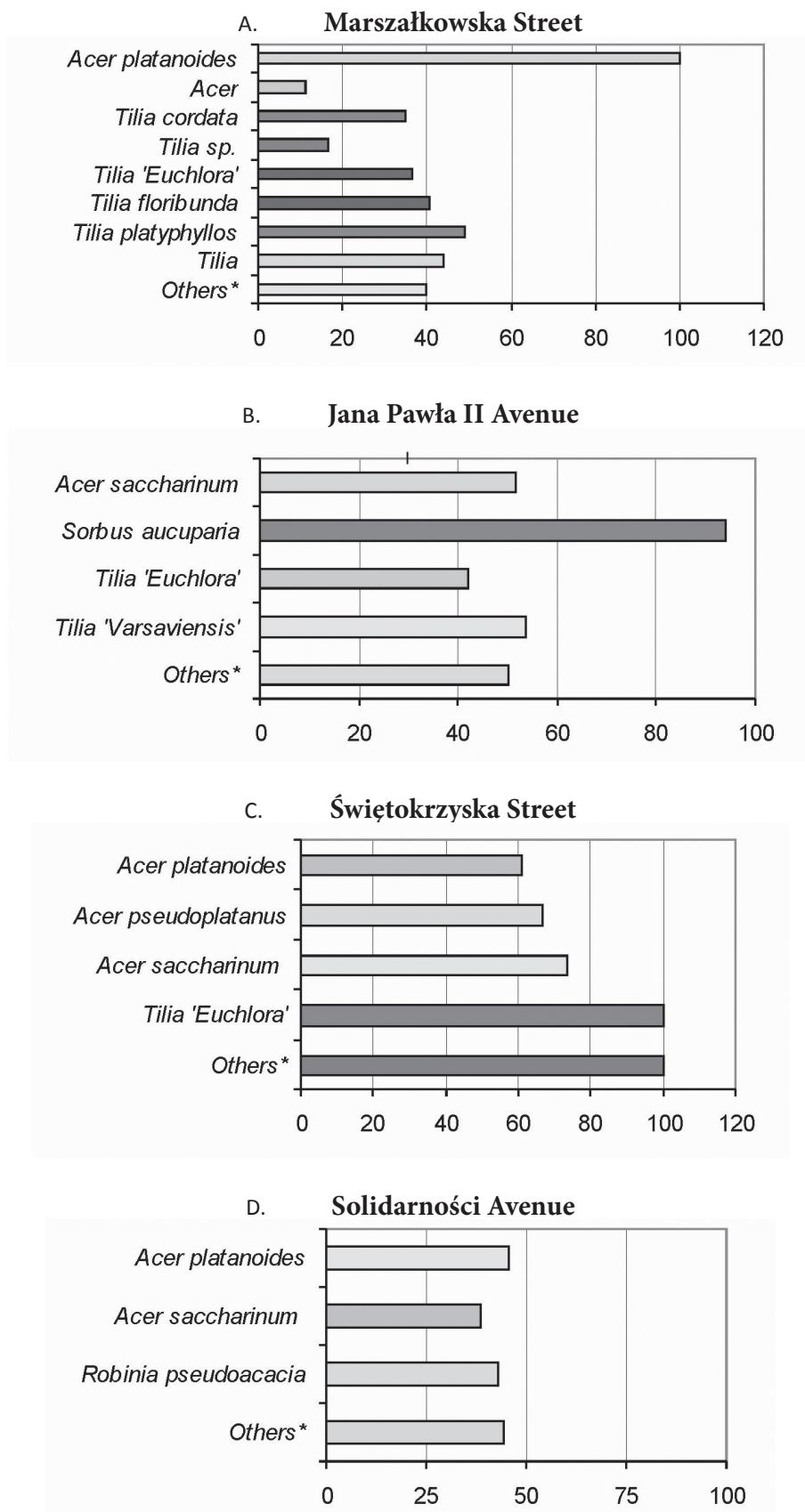


Figure 1. Percentages of each species of dead trees at the four major streets of Warsaw in the years 1973–2007

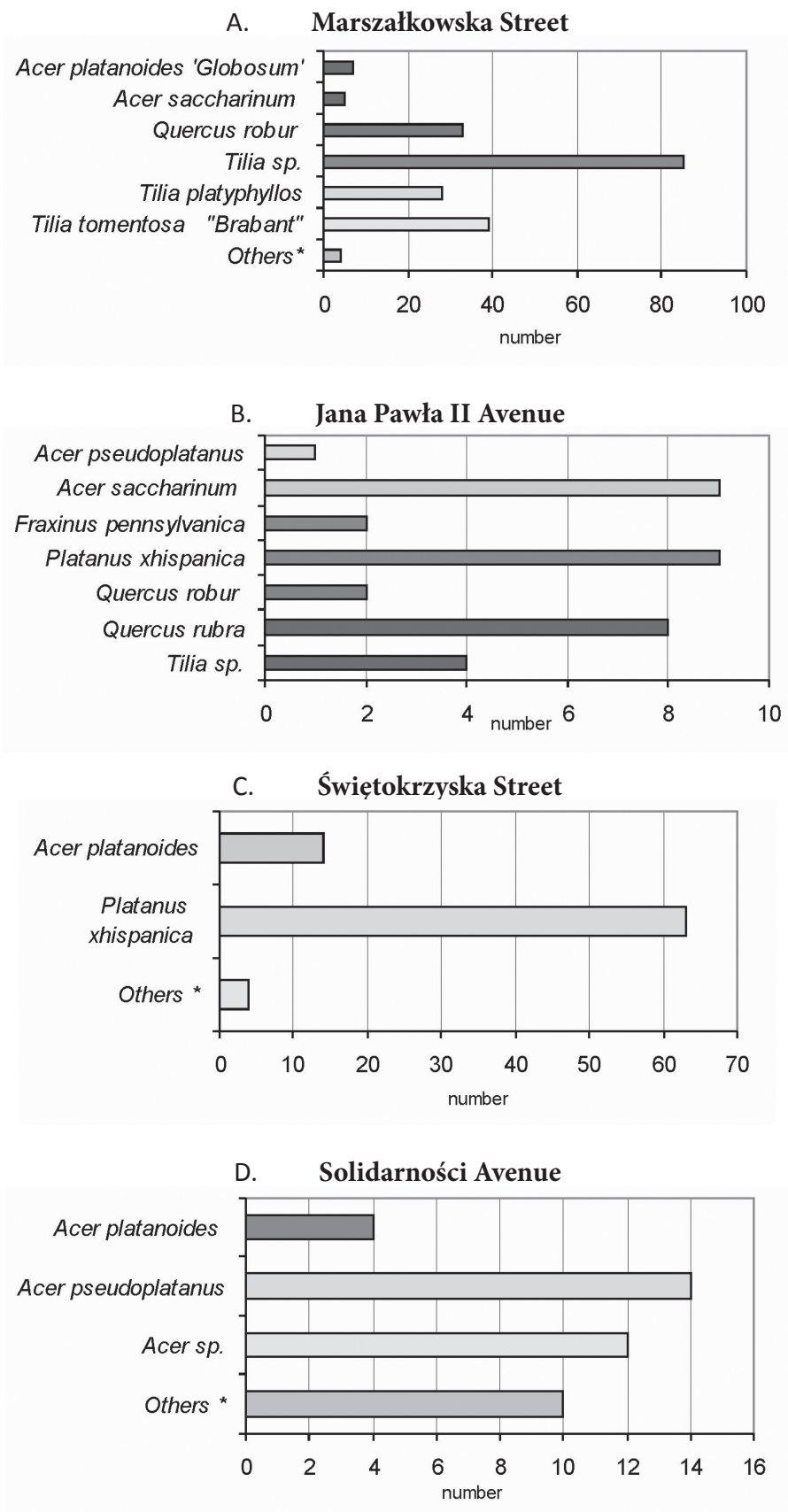
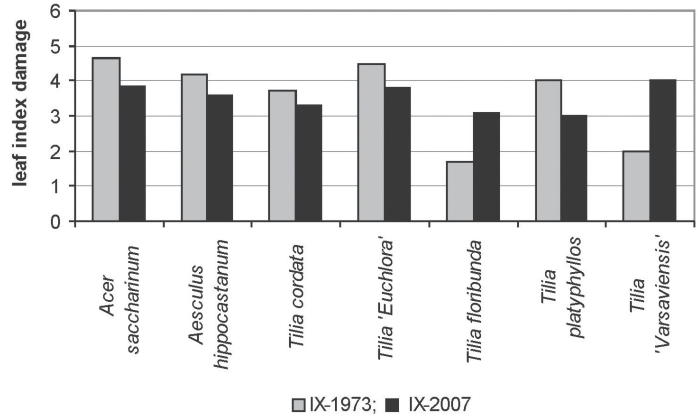
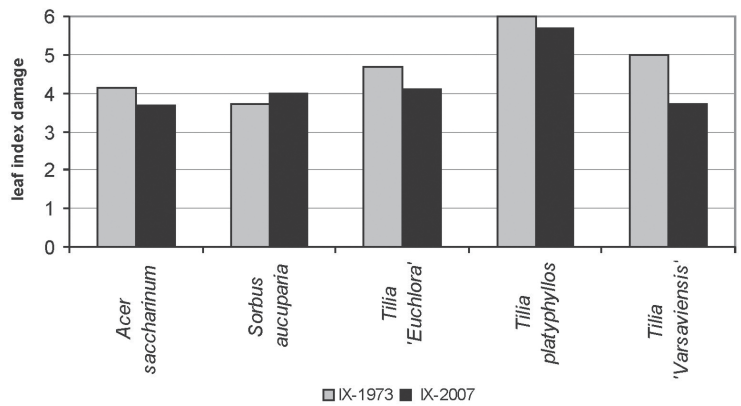


Figure 2. Number of trees in different taxons planted at the four main streets of Warsaw in the years 1973–2007

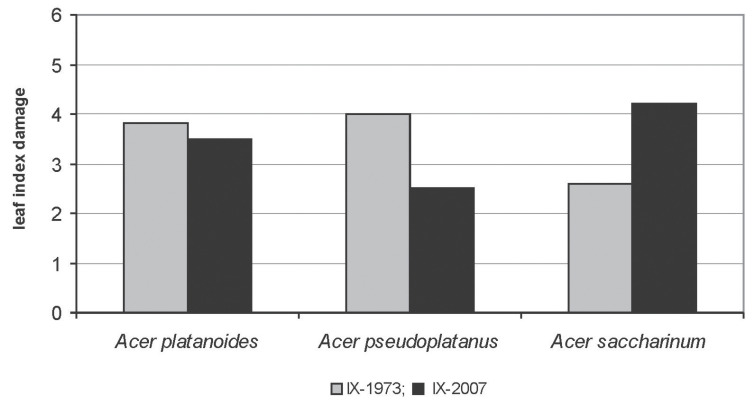
A. **Marszałkowska Street**



B. **Jana Pawła II Avenue**



C. **Świętokrzyska Street**



D. **Solidarności Avenue**

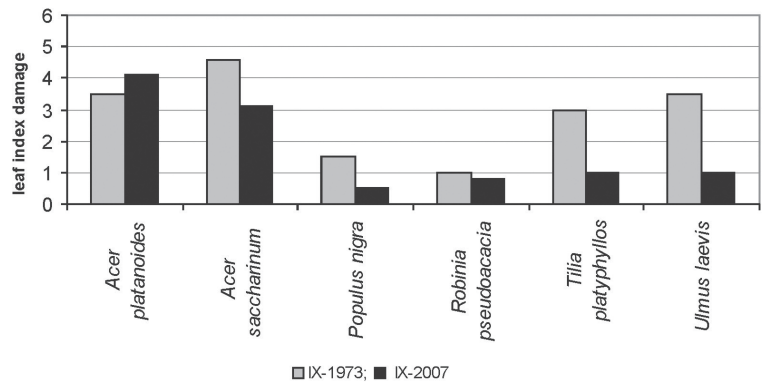


Figure 3. Comparison of health status of leaves (damage index) of trees from the main streets of Warsaw (the average for the species), the September 1973–2007 period of observation

Table 1. Summary results of the inventory of trees growing along the main streets of downtown of Warsaw in the years 1973 and 2007

| l.p. | Taxon | Year | | Growing from 1973 | | Cut off | Planted |
|------|---------------------------------------|------|------|-------------------|------|---------|---------|
| | | 1973 | 2007 | number | (%) | (%) | number |
| 1 | <i>Acer negundo</i> | 4 | 1 | 1 | | | |
| 2 | <i>Acer platanoides</i> | 431 | 205 | 191 | 44.3 | 55.7 | 14 |
| 3 | <i>Acer platanoides</i> (red variety) | 0 | 4 | | | | 4 |
| 4 | <i>Acer platanoides</i> ‘Globosum’ | 0 | 7 | | | | 7 |
| 5 | <i>Acer pseudoplatanus</i> | 12 | 17 | 2 | 16.6 | 83.4 | 15 |
| 6 | <i>Acer saccharinum</i> | 341 | 151 | 137 | 42.0 | 58.0 | 14 |
| 7 | <i>Acer</i> sp. | 0 | 13 | | | | 13 |
| 8 | <i>Aesculus hippocastanum</i> | 6 | 6 | 5 | 83.3 | 16.7 | 1 |
| 9 | <i>Catalpa speciosa</i> | 0 | 1 | | | | 1 |
| 10 | <i>Crataegus</i> sp. | 2 | 1 | | | | 1 |
| 11 | <i>Fraxinus americana</i> | 1 | 1 | 1 | | | |
| 12 | <i>Fraxinus exelsior</i> | 0 | 1 | | | | 1 |
| 13 | <i>Fraxinus pennsylvanica</i> | 0 | 2 | | | | 2 |
| 14 | <i>Platanus x hispanica</i> | 0 | 72 | | | | 72 |
| 15 | <i>Populus</i> sp. | 5 | 4 | 3 | | | 1 |
| 16 | <i>Prunus avium</i> | 1 | 0 | | | | |
| 17 | <i>Pyrus communis</i> | 0 | 2 | | | | 2 |
| 18 | <i>Quercus robur</i> | 0 | 35 | | | | 35 |
| 19 | <i>Quercus rubra</i> | 0 | 8 | | | | 8 |
| 19 | <i>Quercus</i> sp. | 5 | 1 | | | | 1 |
| 20 | <i>Robinia pseudoacacia</i> | 7 | 4 | 4 | 57.1 | 45.9 | |
| 21 | <i>Sorbus aria</i> | 0 | 1 | | | | 1 |
| 22 | <i>Sorbus aucuparia</i> | 51 | 4 | 3 | 5.9 | 94.1 | 1 |
| 23 | <i>Sorbus</i> sp. | 0 | 1 | | | | 1 |
| 24 | <i>Tilia cordata</i> | 20 | 7 | 7 | 35.0 | 65.0 | |
| 25 | <i>Tilia</i> ‘Euchlora’ | 565 | 215 | 215 | 38.0 | 62.0 | |
| 26 | <i>Tilia x floribunda</i> | 91 | 37 | 37 | 40.7 | 59.4 | |
| 27 | <i>Tilia platyphyllos</i> | 72 | 67 | 39 | 54.2 | 44.2 | 28 |
| 28 | <i>Tilia</i> ‘Stellata’ | 2 | 0 | | | | |
| 29 | <i>Tilia</i> sp. | 8 | 93 | 2 | 25.0 | 75.0 | 91 |
| 30 | <i>Tilia tomentosa</i> ‘Brabant’ | 0 | 39 | | | | 39 |
| 31 | <i>Tilia</i> ‘Varsaviensis’ | 20 | 9 | 9 | 45.0 | 55.0 | |
| 32 | <i>Tilia x europaea</i> | 0 | 1 | | | | 1 |
| 33 | <i>Ulmus glabra</i> | 0 | 1 | | | | 1 |
| 34 | <i>Ulmus laevis</i> | 2 | 2 | 2 | | | |
| | Total | 1631 | 1013 | 658 | 40.6 | 59.6 | 357 |

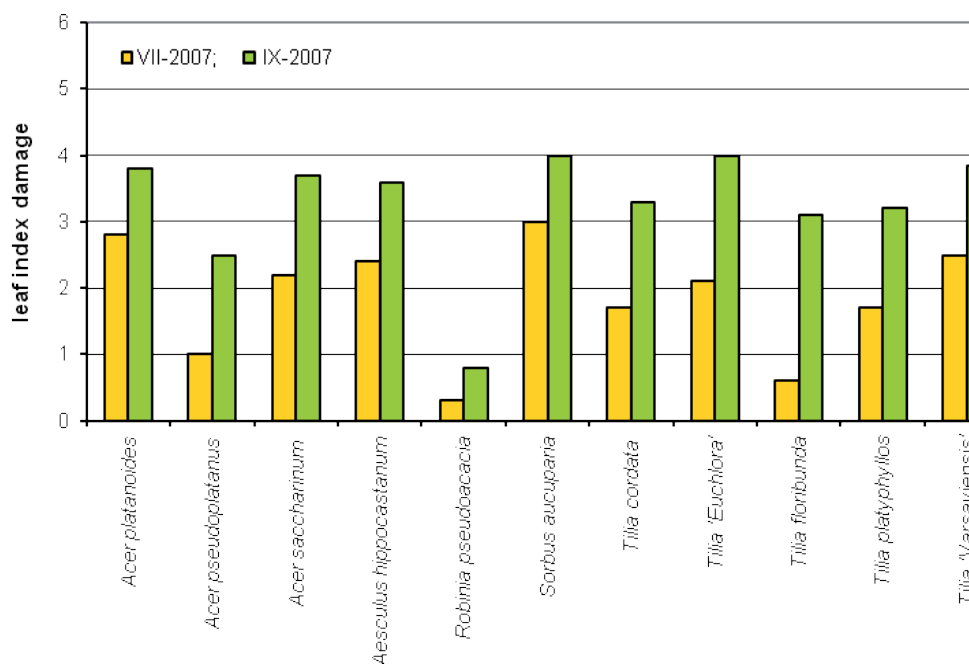


Figure 4. Comparison of health status of leaves (damage index) of trees from the main streets of Warsaw (average for the species) the July and September period of observation

of the leaves was noted for *Robinia pseudoacacia* L. The poorest health condition of the leaves was noted for *Tilia 'Euchlora'*. The leaf damage index value for both of them was 4.6 in 1973 and 4.0 in 2007. For these species the biggest loss (62%) was noted.

The comparison of the leaf-damage index measured in mid-September indicated that in 1973 the health condition of the observed trees was slightly worse than in 2007. This could be caused by the mild winters of those years. *Sorbus aucuparia* was the only species for which the leaf-damage index was higher in 2007. Also the biggest loss was noted for this particular species: 90% within 34 years reporting period.

The comparison of the leaf-damage index measured in mid-September and in mid-June shows significant worsening of the health condition of the trees as vegetation period is passing by. This phenomenon was noted for all of the observed species. *Platanus x hispanica* stood out from the new street plantings. Its health condition indicated that it is a species resistant to the specific climatic and soil conditions of the cities (Chmielewski & Molski 1986; Siewniak & Siewniak 2002; Borowski & Latocha 2006).

The inventory carried out in Warsaw had shown that the main streets are planted with the trees of the species sensitive to the urban stresses (specially soil salinity), such as Maples and Lime Trees. Consequently within 34 years more than 60% of the street trees had declined. Hence it is necessary to carry out the research on the growth and

development of trees in varied environmental conditions in order to adapt the composition of the species to the “difficult and demanding” city environment.

4. Conclusions

The following conclusions can be drawn based on the observations carried out within the framework of this study:

1. The number of the trees growing along the four main streets of Warsaw declined from 1631 trees in year 1973 to 1014 in 2007. Hence, the number of trees declined by 617, which stands for 38%. In the reporting period 357 trees had been planted and survived till 2007.

2. The biggest loss was noted for *Sorbus aucuparia* 94%, *Acer pseudoplatanus* 83%, *Tilia cordata* 65% and *Tilia 'Euchlora'* 62%. The smallest loss was noted for *Tilia platyphyllos*, but still it was estimated as 44%. None of the species, that were growing in 1973, stood out as more tolerant to the specific environmental conditions in the vicinity of the road in Warsaw.

3. The health condition of the leaves of the trees of most common species was poor. In mid-September observation the average value of the leaf-damage index exceeded 3. Trees of that health condition cannot perform none of their basic functions.

4. The comparison of the leaf-damage index measured in mid-September indicates that in 1973 the health condi-

tion of the observed trees was slightly worse than in 2007. This can be caused by the mild winters of those years.

5. The comparison of the leaf-damage index measured in mid-September and in mid-June shows significant worsening of the health condition of the trees as vegetation period is passing by. This phenomenon was noted for all the observed species.

6. *Platanus x hispanica* stood out from the new street plantings.

7. The poorest health condition of the leaves was noted for *Tilia* 'Euchlora', both in 1973 and in 2007. For this species the biggest loss (62%) was noted.

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