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## THE IMPACT OF URBAN ENVIRONMENT ON THE PHENOLOGICAL PHASES OF CRIMEAN LINDEN (*Tilia* 'Euchlora')

### WPLYW ŚRODOWISKA MIEJSKIEGO NA PRZEBIEG FAZ FENOLOGICZNYCH LIP KRYMSKICH (*Tilia* 'Euchlora')

**Abstract:** Trees growing in urban areas are constantly exposed to the adverse conditions of the urban environment. The effect of increasing in concentration of pollutants is observed by systematic reduction in the number of trees in the streets and their poor health status, whose symptoms are discoloration and leaf necrosis occurring at the turn of May and June, and accelerated leaf fall. The subject of the study was the Crimean linden trees growing along the middle strip of Zwirki and Wigury Avenue. Control trees were growing in the park at the Cemetery of Soviet Soldiers. Phenological observations (concerning the development of the leaves) were carried out in years 2010-2011. Crimean linden trees are particularly sensitive to soil salinity. Phenological studies were complemented by visual assessment of the health status of trees. For this purpose, the degree of leaf damage was determined based on the six level scale, where "0" meant the healthy tree (no visible damage to the leaf blade). In 2011 from 128 trees - 83 trees rated as "healthy" (0-1 leaf damage index), 34 as "relatively healthy" (index of leaf damage 2-3) and 11 as "sick" (index of leaf damage 4-5). In the previous year 136 trees were observed: 60 rated as "healthy", 56 as "relatively healthy" and 20 trees were classified as "sick". For most of the surveyed trees of their health condition slightly improved. It was observed that with increasing degree of leaf damage slightly shortened the period of activity of the tested tree vegetation. There were no significant differences between the studied street trees in leaf development. Trees from the control area characterized by a longer growing season than street-trees.

**Keywords:** Crimean linden, urban trees, city environment, phenological stages

The city is a specific natural environment, transformed for the benefit of the dominance of technical elements. In the cities climatic, soil and water conditions affected by human activities have a significant impact on vegetation occurring there [1, 2]. Street trees planted in cities are exposed to unfavorable conditions for their growth and development. The factors limiting the growth and development of vegetation in cities are primarily: higher temperatures, low humidity, nutrients deficiency in the soil, high pH of the soil, limited soil volume, vandalism, mechanical damage and lack of maintenance [3-6]. The use of sodium chloride to deicing the roads in wintertime, as well as water deficiency result in a worsening condition of street trees and their withering away on a big scale [7-9]. An important factor is also the occurrence of pests with sucking mouthparts - mainly aphids and *tetranychus* [10].

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The course of the various phases of development (phenological phases) in urban trees is markedly different than in trees growing outside the cities [11]. Many studies have demonstrated that trees growing in extremely unfavorable conditions, *eg* street trees, have a much shorter growing season and less growth than their counterparts growing in park [1, 12-14]. Urban trees vegetation begin and comes to the end earlier [15]. Trees growing in the harsh urban conditions earlier reach maturity and faster get older. During the aging of the trees lose their adaptability to changing environmental conditions [1, 16, 17]. Also street trees have a much higher mortality rates than park trees [18-21]. The most vulnerable to the adverse effects of environmental stress are young trees. Life expectancy newly planted tree in urban conditions is no longer than 5 years [1]. Miller and Miller [22] found that the highest mortality is characterized by the newly planted trees and young (4-5 cm trunk circumference), within a year or two years after planting. The literature suggests that the life expectancy of trees in urban environment may be only 10 years [23, 24]. According to a study by Foster and Blaine [23] the life expectancy for linden is about 23 years.

The response of trees to stress factors can manifest itself in different ways, depending on their individual level of sensitivity and intensity, time and type of harmful effects. The reactions of trees to natural stress factors and those of anthropogenic origin are complicated and often lead to trees exclusion from many parts of urban areas [9,-10]. For many years we have seen a reduction of the number of trees in urban areas due to the progressive weakening of viability [20, 25]. This process mainly effects of street trees [26]. It is estimated that in 1971, more than 700,000 trees in Eastern Europe died [27]. In Liverpool from downtown trees planted in recent years, 39% stopped within five years [4]. Studies conducted in Warszawa by Dmuchowski et al [8] showed that within 34 years, more than half (59%) of trees along the main streets of the city center died. The greatest losses related species of trees: *Sorbus aucuparia* L. (94%), *Acer pseudoplatanus* L. (83%), *Tilia cordata* L. (65%) *Tilia* 'Euchlora' (62%). While the smallest losses showed *Tilia platyphyllos* L. (44%).

The aim of this research was the determination of the influence of urban environment on the health status of street trees - *Tilia* 'Euchlora' and their phenological development.

## Materials and methods

The study was performed on trees belonging to one species - the Crimean linden (*Tilia* 'Euchlora'), a sterile hybrid lime between *Tilia cordata* Mill. and *Tilia dasystyla* Steven. The species is known since the mid-nineteenth century and grown in many countries in Central and Western Europe. From the interwar period to the 70s of the last century it was often used for lining the roads, avenues, wide streets, as well as parks [28]. Currently none of street tree selection does not recommend the use of the Crimean limes for growing along the streets, due to the high sensitivity of this species to soil salinity.

The objects of research were planted in the middle strip of Zwirki and Wigury Avenue in Warszawa. Control areas was park in Cemetery of Soviet Soldiers located at the distance of 150 m from studied avenue. The leaves condition was evaluated in mid-July and mid-September using the six grade scale method of direct observation. In 2010 studies were

carried out on 136 trees and in 2011 it was 128 trees. Reducing the number of trees bring about their dieback.

Phenological observation method was based on the recording date of the beginning of beginning and duration of each phenological phases. In phenological studies we used a modified summary of the descriptions offered by many authors. Phenological observations were carried out from the beginning of vegetation until its completion. Due to the different intensity of trees development processes in urban areas studies were carried out at intervals of every 2-3 days throughout the growing season.

The various development stages of leaves were described in accordance with the following principles:

- *leaf buds start to open* - visible becomes green part of the leaf on the top of bud scale;
- *the beginning of leafage* - after mining out of the bud first leaves open and both halves of the upper surfaces of the leaf blade become visible;
- *the beginning of the staining of leaves* - 10% of the leaves are discolored;
- *the beginning of the leaves fall*- the tree dropped at least 10% of the leaves;
- *the end of the leaves fall* -all the leaves have fallen.

In order to compare the average length of the individual phases of phenological stages under different health conditions, univariate analysis of variance was applied. Multiple comparisons were made using the Tukey procedure. On the basis of the analysis mentioned above the groups of means were separated. For the analysis the significance level was assumed at  $\alpha = 0.05$  [29].

## Results and discussion

The health condition of trees from middle strip of Zwirki and Wigury Avenue (assessed by observing the degree of leaf damage) showed a large variation. The studies were conducted on more than 120 trees of Crimean linden in years 2010-2011. Despite the fact that the trees were growing in the same conditions (climate and habitat) and in the same distance from the roadway diverse response to environmental pressures has been observed. The health status of the surveyed trees, in the period from July to September, steadily deteriorated. In 2011 from 128 trees 83 trees were rated as "healthy" (0-1 leaf damage index), 34 as "relatively healthy" (index of leaf damage 2-3) and 11 as "sick" (index of leaf damage 4, trees with index of leaf damage noted as 5 - removed). In the previous year 136 trees were observed: 60 rated as "healthy", 56 as "relatively healthy" and 20 trees were classified as "sick". Increased leaf surface with characteristic necrosis were observed. Many studies have shown that main cause of leaf damage of urban trees is the adverse effects of the salt used for de-icing the streets in winter [4, 7-11]. The presence of chlorine in the leaves results in the initially invisible changes inside the plant cells, and with the increasing amounts of this ion, in morphological changes such as chlorosis visible on the leaf lamina. Research conducted in Warszawa on Crimean linden trees confirmed that even minor salinity of the soil can cause necrosis on the edges of leaves, and result in rapid withering and death of trees [7, 8, 10, 30].

Studies conducted in Warszawa by Dmuchowski et al [8, 9, 31] and Borowski [32] have shown a relationship between the degree of withering, and the conditions for growth. Relevant factors include: the type of land cover (lawn, paving, asphalt), the size of

uncovered area under the tree and the distance from the roadway. Street trees growing on the wide lawns are characterized by much better state of health than those growing on narrow lawns [5, 31-33]. In July the health status of studied trees was relatively better than the health status of trees growing on other streets in the center of Warszawa [8, 31]. This may be caused by relatively better growing conditions of the Zwirki and Wigury Avenue - a wide lawn of the Avenue creates more favorable conditions for trees development than concrete surfaces or narrow lawns, predominant along the street Warszawa. Changes on the leaves manifested by chlorotic and necrotic edges. Deformities and dieback part of the leaf blade was observed in early July. The comparison of tree health status recorded in July and in September (classifying trees into specific categories) revealed a general trend of significant decline in the percentage of trees categorized as 0 and 1 (leaves healthy or with minor damage) and increased share of trees in categories 3, 4, 5 with the duration of the growing season. This trend was confirmed by observations made on different species of trees [8, 9, 30]. Not only does it contribute to the deterioration of decorative qualities of the trees, but also, which is more important, it obstructs their biological functions [1].

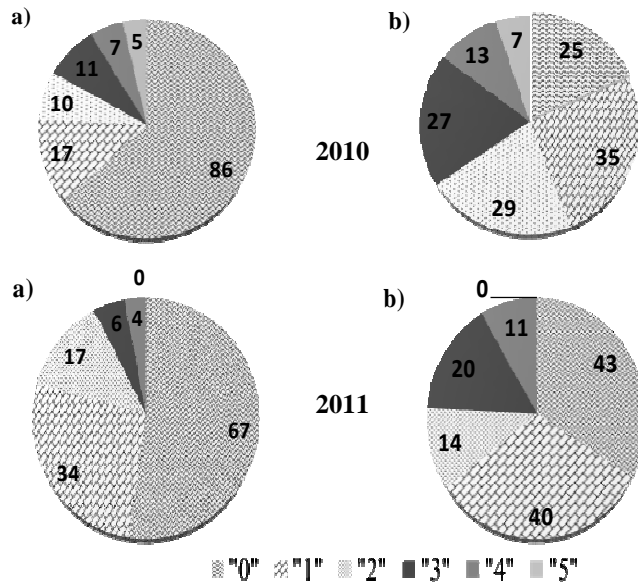


Fig. 1. The number of trees from individual health status categories based on the index of damage of the leaf blade, in two periods: a) July and b) September

Comparison of leaf state within two years of research (2010-2011) showed that in 2011 the trees were characterized by a relatively better condition both in July and in September. Probably the main reason for better state of health of studied trees were more favorable weather conditions observed in this year of the study. Summer in 2011 was rich in precipitation, while winter at the turn of 2010/2011 was characterized by a large snowfall and low temperatures. No damage was observed on the leaves of the trees from the control area (park at the Cemetery of Soviet Soldiers) throughout the growing season.

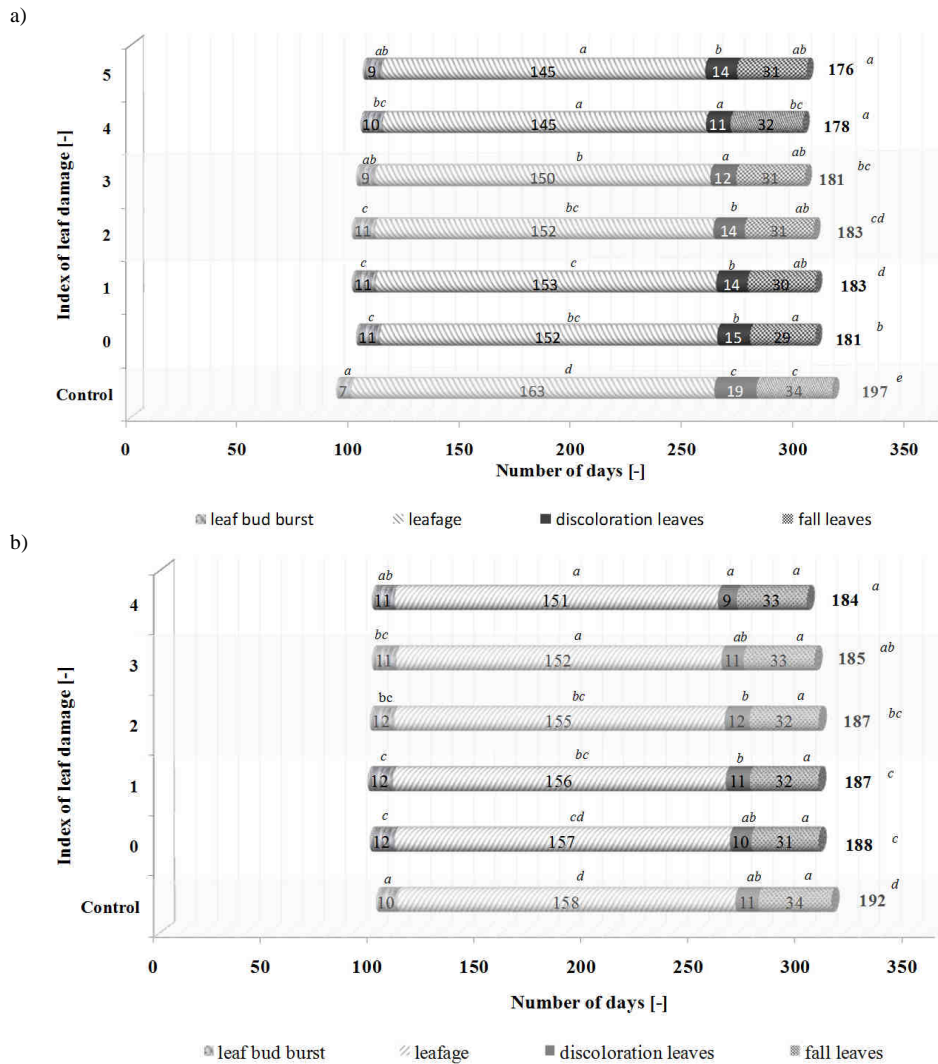


Fig. 2. The duration of the phases of development leaves of Crimean linden in: a) 2010 and b) 2011

On the basis of phenological studies we found slight differences in the time and duration of observed phases of the leaves of the trees with different health status. The phenological studies were conducted only in 2010 and 2011. This period was too short to draw definite conclusions concerning impact of the urban environment on the course of phenological phases of trees. This will be possible only after a longer period, at least a few years, of systematic research and comparison of the results with the thermal conditions prevailing during their pursuit.

Table 1

Weather conditions during the phenological observations

Year	The average monthly temperature [°C]*											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2010	-8.0	-1.9	3.9	9.5	13.6	17.8	21.9	19.7	12.4	6.1	5.8	-5.4
2011	-0.6	-3.8	3,3	11.1	14.4	19.0	18.1	18.9	15.1	8.5	3.0	2,6

Year	The average monthly rainfall [mm]*											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2010	25	37	24	39	116	87	92	143	89	3	109	34
2011	39	21	8	34	48	49	295	62	7	9	0	32

\*Data derived from statistical yearbook of Warszawa (2010-2012). The measurements refer to the meteorological station Warszawa - Okęcie, located approximately 3 km from the surveyed trees

The length of the vegetation activity best differentiates the influence of weather - climatic conditions and habitat on urban greenery. Street trees were characterized by a shorter growing season than trees growing in control area. The length of the active period of the vegetation shortened due to degree of leaf damage of studied trees. The biggest difference concerned the trees with no apparent damage of leaves and those with the highest degree of damage (an average of 5-9 days, depending on the year of observation). There was also interference in the course of individual phenological phases. In the case of discoloration phase, there were no clear and reproducible differences in both the date and duration of this phase. Similar results were obtained among others trees [12-14].

An interesting observation related to the control area in which the phase of leaf fall lasted longer than in street trees, regardless of the degree of damage to their leaves. This can be explained based on the specific light conditions, namely: a relatively large park trees shading the leaves that may have contributed to the earlier cut-off zone produce leaves. Low light intensity or change in intensity from high to low may cause premature cut off the leaves, buds and fruits [34]. Trees growing in the vicinity of lights, much later discolor leaves than the rest on the same tree (which are not exposed to direct light).

## Conclusions

1. There was a large variation in health condition of studied street trees. In July the trees showed less damage than in September. Share of trees with average and considerable damage of leaves between July and September has almost doubled.
2. The deterioration of the health condition of trees proceedings in the course of the growing season was observed. The influence of the state of health of trees on the length of the growing season has been shown- with the increase in the degree of damage of trees, vegetation activity period was shortened by a few days (5-9 days, depending on the year of observation).
3. No significant differences were observed in the duration of the various phases of development leaves. Significant differences found only between street trees and control group.

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## WPLYW ŚRODOWISKA MIEJSKIEGO NA PRZEBIEG FAZ FENOLOGICZNYCH LIP KRYMSKICH (*Tilia* 'Euchlora')

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**Abstrakt:** Drzewa rosnące na terenach miast są narażone na nieustanne oddziaływanie zespołu niekorzystnych warunków środowiska miejskiego. W wyniku wzrostu stężenia zanieczyszczeń obserwowane jest systematyczne zmniejszanie się liczby drzew rosnących przy ulicach oraz ich zły stan zdrowotny, którego objawem są między innymi przebarwienia i nekrozy liści, występujące już na przełomie maja i czerwca, oraz wcześniejsze opadanie liści. Przedmiotem przeprowadzonych badań były drzewa lipy krymskiej rosnące wzdłuż pasa międzyjezdniowego al. Żwirki i Wigury. Kontrole stanowiły drzewa rosnące w parku przy cmentarzu Żołnierzy Radzieckich. Obserwacje fenologiczne dotyczące rozwoju liści prowadzono w latach 2010-2011. Lipy krymskie są szczególnie wrażliwe na zasolenie gleb. Badania fenologiczne uzupełniono o wizualną ocenę stanu zdrowotnego drzew. W tym celu określano stopień uszkodzenia liści na podstawie sześciostopniowej skali, gdzie „0” oznaczało drzewo zdrowe (brak widocznych uszkodzeń blaszki liściowej). W 2011 r. na 128 drzew rosnących w pasie międzyjezdniowym al. Żwirki i Wigury (od ul. Banacha do wiaduktu kolejowego) 83 drzewa oceniono jako „zdrowe” (indeks uszkodzenia liści 0-1), 34 jako „względnie zdrowe” (indeks uszkodzenia liści 2-3) oraz 11 jako „chore” (indeks uszkodzenia liści 4-5). W poprzednim roku obserwacji na 136 obserwowanych drzew 60 oceniono jako „zdrowe”, 56 jako „względnie zdrowe” oraz 20 drzew sklasyfikowano jako „chore”. W przypadku większości badanych drzew ich stan zdrowotny poprawił się nieznacznie. Zaobserwowano, że wraz ze wzrostem stopnia uszkodzenia liści nieznacznie skracał się okres aktywności wegetacyjnej badanych drzew. Drzewa z terenu kontrolnego charakteryzowały się dłuższym okresem wegetacji niż przyuliczne. Nie stwierdzono istotnych różnic między badanymi drzewami w rozwoju liści.

**Słowa kluczowe:** lipa krymska, drzewa uliczne, środowisko miejskie, fazy fenologiczne