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The effect of salt stress on lime aphid abundance on Crimean linden (*Tilia* 'Euchlora') leaves

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ABSTRACT

Many authors claim that trees planted along streets are weaker because of environmental pollution, especially high soil salinity, which results in greater susceptibility to attacks by pathogens. The *Tilia* 'Euchlora' (Crimean linden) is described as one of the urban greenery species that is most prone to the effects of salinity. The aim of this research was to assess the influence of salt stress on the lime aphid abundance on the leaves of *Tilia* 'Euchlora'. The average number of aphids was lower for trees growing along the street and subjected to de-icing salt than in the controlled park area. It was strongly negatively correlated with the Na and Cl level in the leaves, whereas it was positively correlated with the content of N and P. The study showed that the aphids' abundance was most strongly influenced by the N and Cl content in the leaves (although in opposite ways). When the amount of nitrogen increased by 1.0% (from 2.0 to 3.0%), the abundance of aphids increased by 116%. An increase by 1.0% (from 1.0 to 2.0%) in the Cl content in the leaves resulted in a decrease in the abundance of aphids by 36%. The toxic Cl level (over 1%) was exceeded only in the leaves of trees growing along a busy street (79% of the examined individuals in this location), whereas it ranged from 0.23% to 0.40% for the trees from the park. There was concluded that aphids probably prefer trees with healthier leaves for their feeding, i.e. leaves of lower amount of Cl and Na, while with higher concentration of N.

1. Introduction

Trees are inseparable elements of the urban landscape; they provide a large number of positive aspects for urban ecosystems, including ecological, aesthetic, socio-cultural and pro-health benefits (Tyrvainen et al., 2005). Their condition as permanent plants seems to be crucial in urban areas. However, in the urban setting, they are exposed to different harmful factors that are typical for the urban environment. These factors, both abiotic and biotic, could cause important and adverse changes in the trees' structure and biological functions (Oleksyn et al., 2007; Sjöman and Nielsen, 2010; Koeser et al., 2013; Baczewska et al., 2014). Among the most common problems are de-icing impacts from the use of salts and damages caused by pests, especially sucking ones like *Aphididae* (Munck et al., 2010; Muñoz et al., 2014).

For people, ice and snow control is one of the most important issues during the winter. De-icing salts are used to maintain ice-free roadways and sidewalks. This is the reason for salt stress and the accompanying osmotic stress in plants, which may result in damages to their structure and function. The problem seems to be the most visible in cities, especially in the populations of street trees (Cekstere et al., 2008). The increased salinity also influences broadly defined soil properties and the associated microorganisms and disturbs mycorrhiza (Calvo-Polanco et al., 2008; Yi et al., 2008; Day et al., 2010). The trees planted along the cities' streets are subjected to salt stress often caused by NaCl.

Sodium chloride (NaCl) is one of the chemicals that are most often applied during de-icing. At least ninety percent of the total deposition of Na^+ and Cl^- in the soil occurs within 20 m of the road (Lundmark and Olofsson, 2007; Cunningham et al., 2008). An excessive uptake of salt ions affects the functioning of the cell membrane and cell metabolism by contributing to changes in cell membrane permeability, disturbing the ionic balance, reducing chlorophyll content and reducing enzyme activities. In this way, perturbations are caused in many physiological processes,

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including photosynthesis and respiration (Cekstere et al., 2008; Hussain et al., 2008; Chaves et al., 2009). This leads to the inhibition of growth and to injury of the foliage (marginal chlorosis and necrosis on mature leaves). As a consequence, diminished growth, premature decolourization of the leaves and leaf dropping, branch dieback, loss of plant vigour, and finally, death of the trees has been observed (Munns and Tester, 2008; Goodrich and Jacobi, 2012; Cekstere and Osvalde, 2013; Dmuchowski et al., 2013; Jimenez-Casas and Związek, 2014). The results of the research on the *T.* 'Euchlora' conducted by Baczewska et al. (2014) showed that the health status of the trees exposed to salt stress is associated primarily with the chlorine content in the leaves. According to Genc et al. (2015) both the high concentration of sodium and chlorine in the soil is harmful for plants, however the high content of the chlorine is more damaging for them.

The ecological range of the *Tilia* genus includes temperate, tropical and subtropical regions from dry to moist habitats; it can be found in Europe, Asia, Central America and Eastern North America (Muir, 1984). Crimean linden (*Tilia* 'Euchlora) was developed in the 19th century. It is grown in many countries of Central and Western Europe. *Tilia* 'Euchlora' is not recommended as an avenue tree because of its sensitivity to saline stress (Buschbom, 1968; Dmuchowski et al., 2011a, 2013). Research conducted in the centre of Warsaw by Dmuchowski et al. (2011b) showed that over a period of 34 years, more than half (59%) of the sidewalk trees died and these great losses include the *Tilia* 'Euchlora'(62%). Except that, the most considerable losses concerned: *Sorbus aucuparia* L. (94%), *Acer pseudoplatanus* L. (83%) and *Tilia cordata* Mill. (65%). The smallest loss was recorded for *Tilia platyphyllos* Scop. (44%).

The results obtained so far indicate that species differ in their response to unfavourable conditions of the urban environment (Dirr, 1976; Dmuchowski et al., 2013). Many species exposed to saline stress have much higher concentration of Cl^+ and Na^- ions in their leaves than controlled trees (Baczewska et al., 2014). However, the capacity of particular species to the accumulation of these elements varies widely which reflects different strategies implemented by species of dendroflora against soil salinity (Alaoui-Sosse et al., 1998; Dmuchowski et al., 2013). It is known that the leaves of the *Tilia* 'Euchlora' tend to accumulate considerable amount of Cl and Na, while *Quercus rubra* L., *Gleditsia triacanthos* L. and *Robinia pseudoacacia* L, accumulate a small amount of these elements in their leaves and are regarded as relatively resistant to soil salinity. Furthermore, there was stated that though *Platanus x hispanica* Mill and *Gingko biloba* L. accumulate a large amount of Cl, they are in the same time tolerant to salinity (Dmuchowski et al., 2013).

Aphids (*Homoptera*: *Aphididae*) ingest phloem sap from the plant through piercing-sucking mouthparts. They can be extremely successful in their colonization of the host because of the capacity for very fast population growth due to their cyclical parthenogenesis ability, which is an exception from the majority of insects that use sexual reproduction (Vereschagina and Gandrabur, 2014). As explained by Bennewicz et al. (2013), aphids are among the numerous species of insects that willingly colonize urban environments. It was also found that the sucking insect population, including aphids, is significantly greater on trees growing along the streets than on trees in parks or in suburban locations (Bennewicz et al., 2011; Lubiarz et al., 2011).

Aphids damage plants by removing assimilates and vectoring plant viruses. Aphid feeding induces various physical and biochemical defence responses involving structural changes, modification in resource allocation and some symptoms, like chlorosis, in the host plant (Zuparko and Dahlsten, 1995; Smith and Boyko, 2006; Will and van Bel, 2006). In addition, the individuals threatened by aphids also suffer a loss of decorative value (Ratajczak et al., 2011). The aphid-host plant relationship is a dynamic system that is not fully understood, but there has been a great deal of recent research, including molecular and genomic studies, which is trying to resolve many important issues (Will and van Bel, 2006; Blande et al., 2010; Smith et al., 2010).

Tilia species and cultivars are threatened by linden aphids *Eucallipterus tiliae* L. It is believed that the linden aphid feeds on only lindens (*Tilia* species) (Blackman and Eastop, 1994). The insect is common in the Palearctic region and is considered native to eastern Asia and probably Europe. It was denoted in Europe in 1758, in eastern North America in 1886 (in California in 1909), and then in New Zealand (Zuparko and Dahlsten, 1995). As stated, when examining 236 trees and shrubs taxa and cultivars, Ratajczak et al. (2011) determined that *Tilia* trees were not among the plants suffering the most (in regards to damage) from aphid feeding.

Many authors have claimed that trees planted along the streets are weaker because of environmental pollution, especially salinity, which results in greater susceptibility to attacks by pathogens (Bennewicz et al., 2011; Lubiarz et al., 2011; Wilkaniec et al., 2013). At the same time, *Tilia* 'Euchlora' is described as one of the urban greenery species that is the most prone to salinity (Buschbom, 1968; Dirr, 1976; Dmuchowski et al., 2011b, 2013). The negative effects of salt stress on the condition of trees have been previously confirmed, but there have not been any broader reports on the relationship between saline stress and aphid abundance to date. This paper describes the result of research regarding the influence of salinity on the abundance of lime aphids (*Eucallipterus tiliae* L.) on the leaves of *Tilia* 'Euchlora' growing in the city centre.

2. Materials and methods

2.1. Study area

The study was performed on trees belonging to one species, *Tilia* 'Euchlora', which is a sterile hybrid of *Tilia cordata* Mill. and *Tilia dasystyla* Steven.

The trees are located in the centre of Warsaw in the middle strip of Żwirki and Wigury Avenue (110 trees) (geographical coordinates: 52°12′27″N, 20°59′13″E) and in the controlled area (8 trees), which is located in the park (geographical coordinates: 52°12′15″N, 20°59′22″E) at a distance of approximately 150 m away and separated from the road by a dense strip of bushes and hedges. The Żwirki and Wigury Avenue is characterized by high intensity traffic, and it has been intensively salted during the winter for many years. Weather conditions, ie. humidity, temperature, sun exposure and also soil conditions (in exception of soil contamination by salt at the street) of both studied locations (street, park) was the same. All the trees planted along the street and in the control area (park) were at the same age and were derived from the same nursery plant.

2.2. Sampling

The abundance of lime aphids was estimated as the number of individuals per one leaf. Every effort was made to collect the leaves of the same generation, the same age and size of the leaf blade. The leaves harvested from the trees growing along the street and in the controlled area, were characterized by a similar magnitude. Counting of aphids was done *in situ*. The measurements were made four times in the year 2013 (specifically on the 5th and 18th of May and on the 1st and 8th of June). The average number of aphids per leaf was calculated based on observations of 40 randomly chosen leaves separately for each tree. They were cut off 10 per each side of the tree. Therefore, the aphids were counted for 4720 leaves. Each tree was treated as a statistical unit. Therefore the total number of the units was 118. The sample size from the middle strip of the road