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# MANIFESTATIONS CAUSED BY SALT AEROSOL ON SHOOTS AND BUDS OF STREET SIDE LIMES

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The aim of this work is to examine whether salt aerosol and the distance of tree planting have an impact on the development of shoots and buds of lime trees planted beside main communications arteries in Warsaw. Examined trees grew at different distances from the edge of the roadway (3 m, 10 m, 30 m). The level of the salinity was examined with the conductometry method, and the development of trees was measured by direct observation. Examinations showed that road salt in the form of saline spray, as well as the distance of planting from communications arteries have an impact on the normal development of trees and the amount of salt ions accumulated by them.

**Keywords:** Salt spray, deformation of tree crowns, salinity of shoots, salinity of buds, *Tilia* sp.

## Introduction

In recent years, there has been observed considerable increase the degradation of urban trees, in particular those planted close to roads. One of the main reasons for this is the increase in the amount of salt used in the chemical de-icing of streets. The early days of combating snow and ice chemically, in the winter of 1969/1970, 68.6 tons of mixture made up of 95% NaCl and 5% of $CaCl_2$ were used. By 1970 damage to the city's trees was already noticeable. Instructions were then prepared to specify how chemicals should be applied. Road salt it still being used, in spite of the fact that it destabilises the balance of the soil, and is clearly a cause of the death of trees (Czerwiński, 1978).

The intention of the regulations issued by the Polish Minister of the Environment from 2005 was that various substances could be used on the city's roads and squares, including chemicals, but in practice salt is used almost exclusively.

The use of salt can cause damage in various ways. A common phenomenon is the necrosis of the edges of leaves, evident as early as August. A second symptom is a delay in the growth of young shoots, followed by them quickly dying back and falling off (Bach and Pawłowska, 2007). It has also been observed that at the end of August there were considerably fewer leaves remaining compared to those evident in spring. A large proportion of leaves showed damage and fell, some of which were replaced by young leaves which showed peripheral damage through necrosis.

The deformations were also evident in the crowns of trees, in particular their central parts. In some up to 80–90% dying shoots were observed. Similar results were observed by researchers analyzing the health of limes at the Avenue of Our Lady in Częstochowa (Bach et al., 2007). These phenomena were without doubt as a result of an overdose of salt, not only in the soil (Ruge, 1978). Salinity seems to be one of the most serious causes of dieback and death in Polish street trees.

Much research, among others Dmuchowski and Badurek (2004), indicated that the application of Sodium Chloride affects the chemical make up of leaves, however that the reaction of plants can be variable (Breś, 2008). Marosz and Nowak (2008) stated that limes are particularly sensitive. Zimmerman and Jull (2006) claimed that the buds of limes are the most vulnerable to saline spray of three species tested. Salt acts not only through the roots. The salt distributed on the road or as saline solution, as a result of traffic, becomes spray and settles on the shoots and buds of trees. Pracz (1990), Cunningham et al. (2007) and Borowski and Pstrągowska (2010) wrote about this negative influence on the growth of trees.

The snowy and long winter of 2009/2010 meant that the streets of Warsaw were treated with salt many more times than in previous years. c. 72 million złoty (over 17 million euro) was spent, twice what was spent in 2006/2007. It was after that winter of 2009/2010 that we conducted our research.

The aim of this research was to show the scope and influence of salt in the form of spray on the development of two species of lime growing along main communication arteries of Warsaw.

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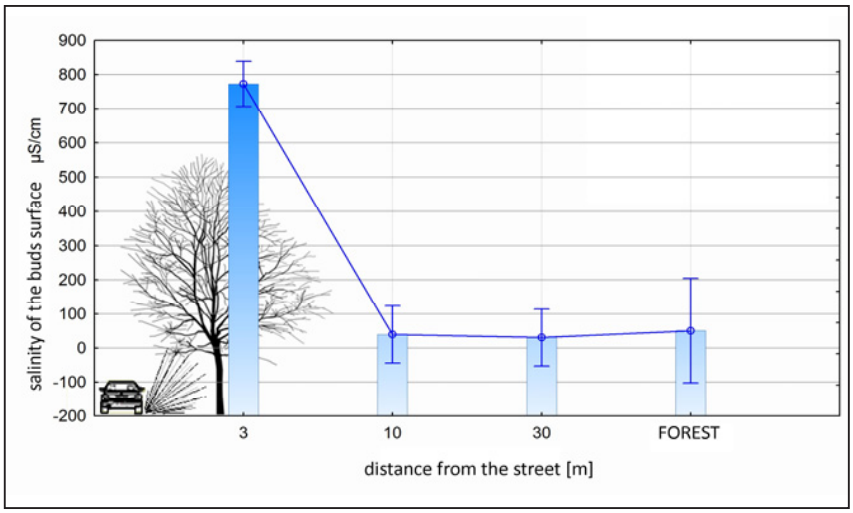


**Figure 1** Salinity on the surface of buds of lime trees at different distances from the street, and in the forest
Source: http://botany.cz/cs/cornus-mas/s

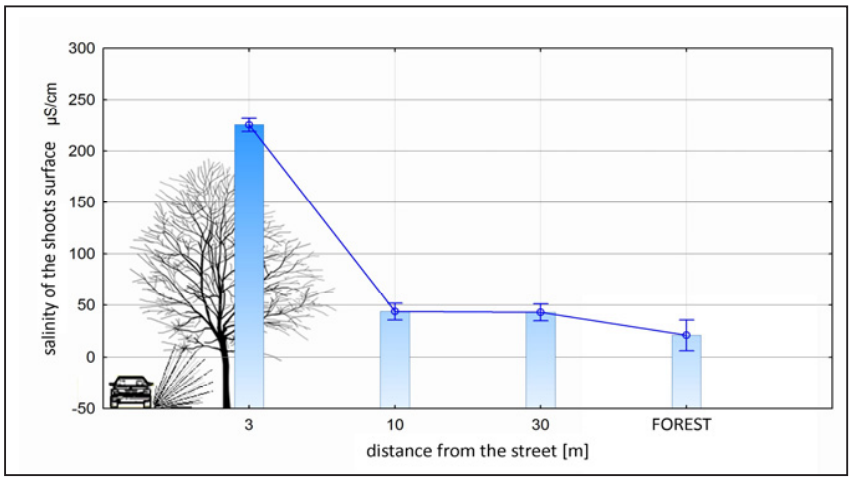


**Figure 2** Salinity on the surface of shoots of lime trees at different distances from the street, and in the forest
Source: http://botany.cz/cs/cornus-mas/s

## Material and methods

### Choice of trees

*Tilia cordata* and *T. platyphyllos* were chosen as the limes to be the subject of salt spray research along Władysław Sikorski and Żwirki and Wigury avenues as well as Jan III Sobieski street. These chosen arteries belong to amongst the busiest streets: 3116–3487 vehicles / hour, 1477–3791 vehicles / hour, 1133–1648 vehicles during evening rush hour (according to the Planning Office for the Development of Warsaw). By way of verification trees were assessed in the Kabaty Forest reserve in southern Warsaw, this is the largest forest reserve in the Mazowia Voivodship.

On all of these streets the distance between the roadway and the nearest row of trees was less than 3 m. On two of these streets material was used from trees growing 10 and 30 metres from the road. Shoots and buds were taken from both the road side of the tree and from the side farthest away from the road (that nearest the pavement). The samples were taken in spring at the time of bud break.

### The measurement of the level of salinity on the surface of buds and shoots

6 grams of buds were added to 40 ml of distilled water and mixed for 60 seconds, the shoots were submerged

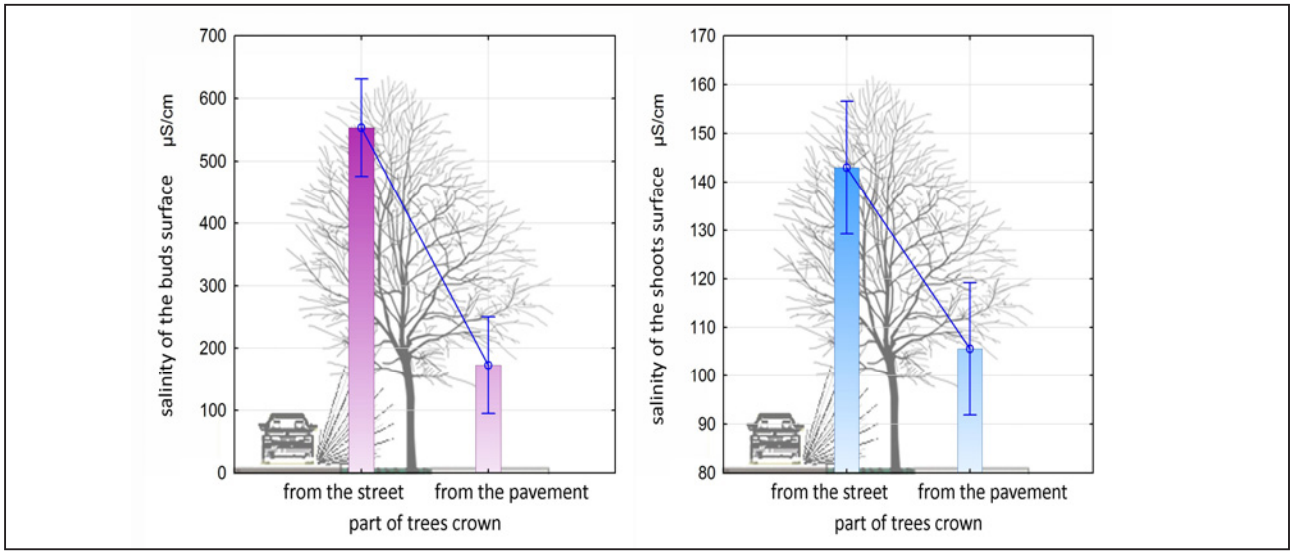


**Figure 3** Salinity on the surface of buds (left) and shoots in the crowns (right) of lime trees from the street and pavement
Source: http://botany.cz/cs/cornus-mas/s

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in distilled water so that they displaced 20 $cm^3$ of water. After 60 minutes the EC of the mixture was measured.

All of the trees were observed, anomalies were noted regarding their appearance and growth. Data were subjected to analysis of variance (ANOVA) procedures (STATISTICA v. 10). Mean separations were performed by pairwise Fisher-test comparisons at $p < 0.05$.

## Results and discussion

The average level of salinity on the surface of the lime buds was varied depending on the distance from the roadway. The salinity of the surface of the buds clearly reduced in relation to the distance from the street, and the difference (over 20 times) was statistically relevant between trees growing close to the street and the remainder (Fig. 1). The same represents the difference in salinity on the shoots surface, several times greater (Fig. 2). Regarding trees growing nearest the street, there was considerably greater salinity on buds and shoots on the roadside, than those on the opposite side, nearer the pavement (Fig. 3, table 1 and 2).

Previously recorded drying and dying of shoots and later appeared leaves and shoots from sleeping buds. New shoots were unnaturally extended and were bunched on the periphery of the crowns of trees. Many leaves appearing in spring, quickly began to turn yellow, and then died and fell. New leaves grew in their place in bunches.

The form of street limes differs considerably from those growing in the Kabaty Forest. Their crowns were irregular, frequently deformed on one side (Fig. 4). The density of the crowns was greater due to the presence of the previous year's and older shoots. The form of lime trees clearly differed in summer, depending on its location. Those limes growing by the street had leaves closer together and facing different directions (Fig. 5).

In urban planting, the most vulnerable to environmental factors are trees, and most often native tree species (Borowski, 2008). This is confirmed by our observations and research. In spring on the trees that we researched, salt crystals were clearly visible – the remains of winter street de-icing. Dead and dry branches, leaves and buds were clearly visible. This is confirmed by observations by Bach et al. (2007) and Borowski and Pstrągowska (2010). It was observed that there were many examples of deformed crowns on the street side, which clearly confirm that salt not only penetrates through soil, but also through saline spray, which was shown by Cunningham et al. (2007). Spray is blown about by air movements due to the traffic. This phenomenon

**Table 1** Salinity on the surface of buds of lime trees at different distances from the street, from both sides of trees (from the street and pavement), and in the forest

| Distance from the street in m | Side of trees | Salinity in µS/cm | Stat. error | -Stat. error. | +Stat. error | N | Homogeneous groups |
|---|---|---|---|---|---|---|---|
| **3** | from pavement | 349,625 | 76,2635 | 273,361 | 425,889 | 24 | b |
| **3** | from street | 1194,917 | 76,2635 | 1118,653 | 1271,180 | 24 | c |
| **10** | from pavement | 34,867 | 96,4666 | -61,600 | 131,333 | 15 | a |
| **10** | from street | 45,733 | 96,4666 | -50,733 | 142,200 | 15 | a |
| **30** | from pavement | 26,933 | 96,4666 | -69,533 | 123,400 | 15 | a |
| **30** | from street | 34,600 | 96,4666 | -61,867 | 131,067 | 15 | a |
| **Kabaty Forest** | | 51,089 | 124,5378 | -73,449 | 175,627 | 9 | a |

Source: http://botany.cz/cs/cornus-mas/s

**Table 2** Salinity on the surface of shoots of lime trees at different distances from the street, from both sides of trees (from the street and pavement), and in the forest

| Distance from the street in m | Side of trees | Salinity in µS/cm | Stat. error | -Stat. error. | +Stat. error | N | Homogeneous groups |
|---|---|---|---|---|---|---|---|
| **3** | from pavement | 186,6250 | 7,55038 | 179,0746 | 194,1754 | 24 | b |
| **3** | from street | 264,1250 | 7,55038 | 256,5746 | 271,6754 | 24 | c |
| **10** | from pavement | 41,6667 | 9,55057 | 32,1161 | 51,2172 | 15 | a |
| **10** | from street | 45,8000 | 9,55057 | 36,2494 | 55,3506 | 15 | a |
| **30** | from pavement | 39,7333 | 9,55057 | 30,1828 | 49,2839 | 15 | a |
| **30** | from street | 46,2667 | 9,55057 | 36,7161 | 55,8172 | 15 | a |
| **Kabaty Forest** | | 20,9222 | 12,32973 | 8,5925 | 33,2519 | 9 | a |

Source: http://botany.cz/cs/cornus-mas/s

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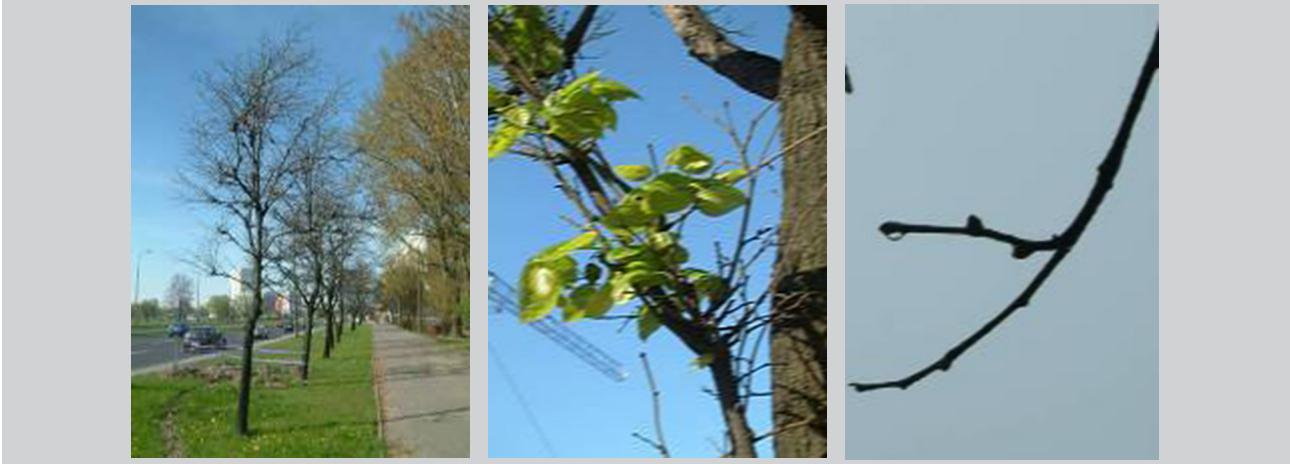

**Figure 4, 5, 6** Growth anomalies causing deformaties in the crowns of street limes (left). Leaves that have developed late, and dead shoots of street limes, is a typical symptom of salt damage (centre). In spring due to the solution that was present on buds and shoots of street trees, the salinity is extremely high (right)
Photo: J. Borowski

is considerably reduced as the distance from the street increases. Shoots and buds with salt deposits do not develop as they should and frequently die. Buds die during bud break, when young leaves make contact with dense NaCl solution (Fig. 6). The opinion of Zimmerman and Jull (2006) that buds are at their most vulnerable in March is confirmed. A similar phenomenon relates to fragile young shoots, which are covered with very thin and vulnerable bark. In this way we can confirm why there are so many dead buds and shoots in street trees, particularly after harsh and snowy winters.

## Conclusion

- The close proximity of main roads has a considerable impact on those parts of trees above the ground, which causes a changing in number of shoots in their crowns.
- The dying and deformation of buds and shoots of street limes is directly a consequence of saline spray.
- The high density of salt deposits causes the equilibrium of water in buds and leaves to be disturbed, leading to their death.
- After many years the effects of saline spray, mean that the crowns of street limes differ considerably from those growing in more natural environments.
- One should not plant species which are susceptible to saline spray (limes in particular) closer than 10m from the street.
- The amount of salt used should be limited in the de-icing of streets; otherwise we will loose a significant number of street trees.

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